Lower Jurassic rocks between Staithes and Port Mulgrave - an excursion

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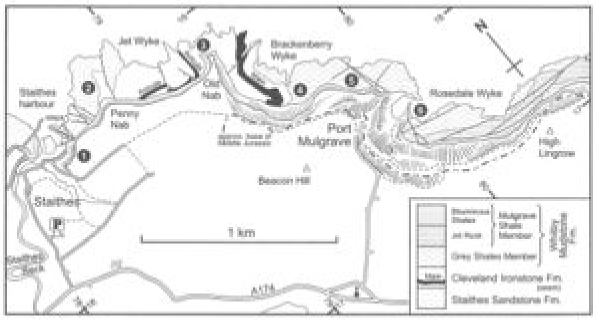

Figure 16.1 Geological map of the foreshore between Staithes and Port c.,3 Mu[grave (modified from Rawson in Rawson & Wright, 1992).

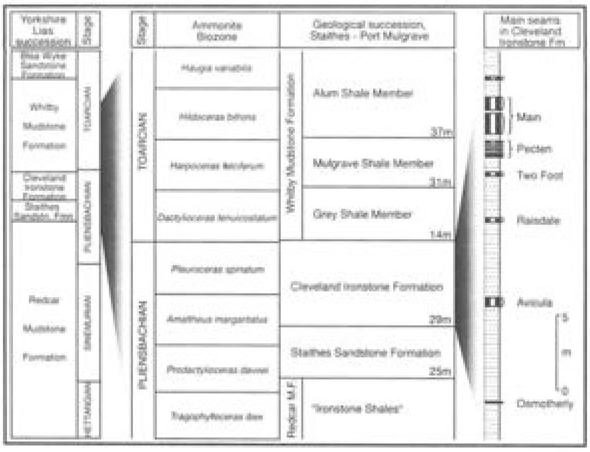

Figure 16.2 Lower Jurassic (Lias Group) succession in Yorkshire, with details for the Staithes–Port Mulgrave area.

Figure 16.3 Cleveland Ironstone Formation in Jet Wyke, looking west. The Avicula Seam forms the bedding surface in the foreground; higher seams can be identified in the cliff. Photo: C. Scrutton.

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Purpose

To examine a gently **dipping** coastal sequence of mid Lias (early Jurassic) rocks, from the Staithes Sandstone Formation through the overlying Cleveland Ironstone Formation and the succeeding Grey Shale, Mulgrave Shale and Alum Shale Members of the Whitby Mudstone Formation. The succession is rich in fossils, principally **ammonites, bivalves, belemnites** and **trace fossils**. The Cleveland Ironstone Formation, Mulgrave Shale and Alum Shale have all been exploited historically.

Logistics

This section was compiled in 2006 when the printed guidebook was published. Before visiting this site please ensure you have up-to-date contact and access information.

In Staithes, cars and buses can park in the car park, 300 m on the right from the junction with the A174 [NZ 781 184] (Figure 16.1). It is not advisable, and for coaches not permitted, to drive down the hill closer to Staithes harbour. At Port Mulgrave [NZ 797 177], there is limited parking for cars at the top of the cliff. Coaches are prohibited from the short road between the A174 and the coast, but can park in a layby immediately north of the junction on the A174. The distance along the foreshore from Staithes to Port Mulgrave is no more than 2.5 km but may occupy 3–4 hrs, depending on time spent in observations. A cliff-top footpath links Port Mulgrave and Staithes for a return journey on foot. The section is suitable for large parties.

Note: The section is tide dependent. ***The traverse should be started approximately 2½ hours before low tide and care taken to leave the foreshore 3 hours before high tide***. The foreshore may be slippery in parts and involves one or two scrambles over boulders. The cliffs are high and minor falls frequent so ***safety helmets should be worn***.

Staithes is an **S.S.S.I.** so hammering of the outcrop is prohibited.

Maps

O.S. 1:50 000 Sheet 94 Whitby; O.S. 1:63 360 Tourist Map of the North York Moors; B.G.S. 1:50 000 Sheet 34 Guisborough.

Geological background

During the Lower Jurassic, the Staithes area was part of the Cleveland (or Yorkshire) Basin, bounded by land to the north and at times to the west, by the Market Weighton Block to the south, and passing offshore into the **fault**-bounded Sole Pit Trough. Shelf seas covered the area to depths of up to 100–200 m. The Lias Group is a sequence of dominantly mud-grade sediments reaching about 420 m thickness in North Yorkshire (Figure 16.2). The Staithes Sandstone Formation, of Pliensbachian age, lies at the top of a shallowing and coarsening upwards sequence. Deepening seas above led to a return of fine-grained sediments, but the shales of the Cleveland Ironstone Formation are punctuated by a series of ironstone bands, each formed at the top of a small-scale shallowing upward cycle. Renewed **transgression** close to the Pliensbachian–Toarcian boundary initiated the Whitby Mudstone Formation, including the distinctive, hydrocarbon-rich Mulgrave Shale Member and the widely worked Alum Shale Member. A final shallowing event led to an influx of sandy material forming the Blea Wyke Sandstone Formation capping the Lias, but over most of the region these younger sediments are missing and the Middle Jurassic rests directly on the Alum Shale Member at Port Mulgrave. The cause of sedimentary cyclicity in the Lias is probably a combination of global sea level rise and fall and local earth movements. The best-known evidence for the latter is the **unconformity** of about 25 m amplitude below the Main Seam of the Cleveland Ironstone Formation that causes it to **overstep** lower units to the south down to a level below the Avicula Seam.

Ammonites are variably common more or less throughout the sequence, which is thus well dated. Both trace and body fossils are richly represented at various levels, with bivalves the dominant invertebrates.

Three units in this sequence are of former economic importance. The Cleveland Ironstone Formation was worked in the 19th and 20th centuries, sporadically on the foreshore between Staithes and Port Mulgrave where the seams are thin, but extensively inland in the Cleveland Hills where the Main Seam reaches 3.8 m thick. The last mine closed in 1964. The ore was the original raw material for the local iron and steel industry. Within the background sequence of dark grey shales, the ironstones are scattered, orangey-brown weathering beds composed principally of **siderite** and **chamosite** and variably **oolitic**. Their method of formation has been controversial. Current opinion is that they formed in shallow marine inshore waters, at times of very slow sedimentation. Large amounts of iron, derived from **lateritic** weathering of a landmass in the area of the Pennines, were periodically introduced by river systems transporting ferric oxides and hydroxides as a colloidal suspension, or absorbed on the surface of organic material, or as oxide films on clay minerals. Siderite and chamosite were probably formed under reducing conditions by early **diagenetic** processes, with the iron salts replacing and displacing freshly deposited sediments below the sediment-water interface.

Scattered masses of a tough, shiny, dense black material called jet, occurring in the Mulgrave Shale Member, formed the basis of local manufacture of personal and domestic ornaments, particularly in the second half of the 19th century. Jet was formed from logs of araucarian wood transported into the sea, which became waterlogged and then sank to the reducing sea floor. Diagenetic alteration and compression under these conditions produced this unusual result. The shales of the Mulgrave Formation are rich in hydrocarbons and are an example of an oil source rock. Laboratory distillation yields 54–86 litres per ton of sulphurous oil (Hemingway *in* Rayner & Hemingway, 1974).

The Alum Shale Member was extensively worked for alum, a mordant (fixing agent) in the dyeing industry, from the early 17th to mid-19th century. The shale was burnt for a year or more in huge heaps (up to 30 m diameter and 15 m high) over beds of brushwood. **Pyrite** in the shale was oxidized to form iron and aluminium sulphates, which were extracted by steeping in tanks of water. Potash alum was produced by adding ashes produced by burning seaweed, and later ammonium alum was made by adding urine. On evaporation, the alum crystallized before the impurities (mainly salts of iron), which could then be pumped off. The precise moment at which to stop heating for the maximum yield of alum was determined by floating an egg in the liquor as a hydrometer!

This account is based in part on Hemingway *(in* Hemingway *et al.,* 1968; Rayner & Hemingway, 1974) and Rawson *(in* Rawson & Wright, 1992).

Excursion details

The bus park at Staithes is on the edge of a 60 m marine wave-cut platform. The Boulby headland 3.5 km to the west is pitted by alum, jet and ironstone workings and capped by the massive delta-top sandstones of the Middle Jurassic Saltwick Formation. Immediately inland from it can be seen the headgear of the Boulby potash mine, which extracts potassium salts from a level in the Permian at about

oo m depth. The road to the harbour descends the deep, post-glacial gorge cut by Staithes Beck in the ferruginous, fine- to medium-grained sandstones and siltstones of the Staithes Formation.

Locality 1 [NZ 784 188]

Within the harbour, the Staithes Formation is well exposed in the cliff-foot ledges to the east. Note the cyclic development of the beds clearly defined by the sedimentary structures. Each unit has a sharp, erosive base, with shelly channel-floor lag deposits, overlain by sands showing planar and some hummocky **cross-stratification**, with parallel and ripple lamination above. Increasing numbers of trace fossils progressively destroy the depositional fabric towards the finer-grained top of each unit. The sequence reflects the activity of intermittent, shallow-water storm events eroding the tops of previous cycles and depositing each unit under a waning current. The muddy bed tops were colonized by burrowing organisms, including bivalves such as *Protocardia*, during the intervals between major storms. Fossils are common, including *Protocardia truncata, Oxytoma inequivalvis*, the **scaphopod** *Dentalium giganteum* and belemnites. Ammonites are not common but evidence for the *Prodactylioceras davoei* and succeeding *Amaltheus margaritatus* **Biozones** has been established within the formation.

Cross the inner end of the east pier of the harbour, now fortified by large blocks of a Scandinavian **gneiss**, onto the foreshore flats. In the cliff, the transition upwards into the shaley Cleveland Ironstone Formation can be seen. One-third of the distance to the headland, faulting is clear in the cliff, displacing the prominent ironstone bands near the top of the face. Bedding plane surfaces on the foreshore exibit excellent interference ripples at one point and many accumulations of fossils. As well as mixed assemblages, almost monospecific shell **coquinas** of *Protocardia* can be found, whilst elsewhere, this shallow-burrowing bivalve can be seen *in situ* in its burrow. Clusters of belemnite guards demonstrate current alignment. Fragments and even substantial trunks of wood may also be found. Clusters of fossils often act as loci for the formation of sideritic **concretions**, giving the rock a dark, reddish-brown colour.

Locality 2 [NZ 788 189]

At the first headland, Penny Nab, scattered ironstone concretions occur in shales a few metres from the cliff at the base of the Cleveland Ironstone Formation. With the change in **lithology**, there is a reduction in **benthonic** fauna and an increase in **pelagic** fauna, principally belemnites and ammonites. It is possible to find species of the ammonite *Amaltheus* around here. Some of the ironstone concretions contain a rich fauna of bivalves with **brachiopods** and small ammonites. Immediately beyond the headland, there is an excellent view to the southeast, across the wide wave-cut platform of Jet Wyke. The Cleveland Ironstone Formation is superbly exposed in the cliffs and on the foreshore, with the ironstone bands standing out as thin, more resistant, orangey-brown units. The succession of bands, from the Avicula Seam to the Main Seam, can be readily identified in the cliff section (Figure 16.2, Figure 16.3).

Cross Jet Wyke towards the next headland of Old Nab. On the traverse, scattered ammonites and belemnites can be found in the shales. The effects of the minor faults which cut the succession can best be seen where they displace the ironstones, whose detailed character can be examined in several places, preferably on the foreshore well away from the base of the cliffs. The Avicula Seam, for example, which is repeated on the foreshore by the faulting, shows an irregular top, with specimens of *Oxytoma cygnipes* (formerly *Avicula)* and other bivalves, burrows formed by *Protocardia,* and a **conglomeratic** base. The rock is a fine-grained sideritic mudstone, containing pale green ooliths of chamosite which are best seen on fresher surfaces.

Locality 3 [NZ 794 188]

The ironstones are best seen at Old Nab, where richly fossiliferous surfaces can be examined on the cliff-foot ledges which extend round into Brackenberry Wyke. Among the bivalves *Pseudopecten equivalvis* reaches large size, occurring together with *Oxytoma cygnipes, Pleuromya costata, Pholadomya* and *Protocardia,* the brachiopod *Tetrarhynchia tetrahedra,* and rare pleuroceratid and amaltheid ammonites. Fossil wood can be found and more rarely vertebrate remains. On Old Nab itself, where the Main Seam has been mined by pillar and stall workings, the trace fossil *Rhizocorallium,* excavated by crustaceans, is widespread on the stall floors, exposed by marine erosion. It consists of horizontal parallel tubes with striated walls, occasionally with the terminal U-bend visible. On the intervening pillars, thin branching tubes of the trace fossil *Chondrites* are common. The shale backfill of an old **adit** can be seen at one point. In Brackenberry Wyke beyond Old Nab, the Main Seam has been extensively quarried and mined, the material having been carried to Port Mulgrave for shipping by a cliff-foot tramway. ***The old adits are extremely dangerous.***

Locality 4 [NZ 795 182]

The base of the Grey Shale Member crosses onto the foreshore about two-thirds of the distance across Brackenberry Wyke to the next headland. In the lower part, the pale grey-weathering shales contain six rows of reddish-brown-weathering sideritic concretions. Higher calcareous nodules, often found loose on the foreshore here, yield *Dactylioceras tenuicostatum,* belemnite guards and contain crystals of **sphalerite**. Pyrite is common in the shales.

At the southeastern end of Brackenberry Wyke, fallen blocks of medium to coarse-grained deltaic sandstones of the Middle Jurassic Saltwick Formation, which form the top of the cliffs, obscure the cliff face and block the foreshore. Scramble over the blocks with care.

Locality 5 [NZ 798 180]

Immediately beyond the obstruction, isolated blocks of Saltwick Formation on the foreshore are perched on shale pedestals which the blocks have protected from erosion. These are the Sheep Stones. At the level of the cliff foot, the Grey Shale Member, with common *Dactylioceras* spp., passes up transitionally into the Mulgrave Shale Member. This latter is a sequence of dark to black, laminated pyritic shales rich in hydrocarbons. Freshly broken rock smells strongly of oil. Calcareous concretions, some pyrite-skinned, are common and may contain ammonites such as *Harpoceras falciferum,* with rare specimens having oil in their chambers. Flattened specimens *of Harpoceras,* often pyritized, are abundant in the shales, together with the pelagic bivalves *Pseudomytiloides dubius* and *Bositra radiata.* Note the lack of any benthonic fauna, indicating reducing conditions at the sea floor. Signs of excavations for jet can be seen. Adits, **which are extremely dangerous**, were usually roofed by a thin bed of limestone concretions, the 'Top Jet Dogger'. Rare masses of jet occur in the 3 m of beds below this level. Small faults bring the Grey Shale Member up to cliff-foot level again just before Port Mulgrave.

Locality 6 [NZ 799 177]

The harbour at Port Mulgrave was built for shipping ironstone, principally from mines 3.5 km to the west. For the last 1.5 km, the tramline entered an inclined tunnel to reach the harbour at shore level; the bricked-up exit can be seen in the cliff at the back of the bay. The piers were severely damaged in the storm surge of 1953. The Alum Shale Member is exposed in the cliffs above Rosedale Wyke just beyond Port Mulgrave. A detour may be made to the southeastern part of Rosedale Wyke where the Top Jet Dogger reaches shore level and beyond which, the upper part of the Mulgrave Shale Member may be examined. The cliff-top can be gained at Port Mulgrave by a steep path immediately behind the harbour.

Glossary

Bibliography

At all times follow: Countryside code and Code of conduct for geological field work

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- Discussion

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