Boulby Quarries, Redcar and Cleveland

[NZ 735 200]–[NZ 757 194]

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Introduction

The Boulby Quarries GCR site, also known as 'Boulby and Loftus Alum Shale Quarries', comprises a series of large pits excavated into the highest cliffs in England, which rise to 215 m above sea level. The quarries and the cliffs below expose a virtually complete, but largely inaccessible, succession through the Redcar Mudstone, Staithes Sandstone, Cleveland Ironstone and Whitby Mudstone formations, thereby providing an almost unbroken sequence through the Pliensbachian and Toarcian stages in the Cleveland Basin. The term Alum Rock' was coined at this site by Young (1817) in reference to the whole Lower Jurassic succession exposed on Boulby Cliff, but the name has subsequently been refined to Alum Shale Member', representing just part of the (Toarcian) 'Whitby Mudstone Formation. The Toarcian sequence in the alum shale quarries is now weathered and overgrown in places (Figure 6.18). The Lower Jurassic succession is capped by the Middle Jurassic (Aalenian–Bajocian) Dogger Formation and Ravenscar Group.

During their working life the quarries were an important source of marine reptiles, including plesiosaurs, ichthyosaurs and a single pterosaur (Benton and Taylor, 1984; Benton and Spencer, 1995). The first record of vertebrate remains from the area, was that of a plesiosaur vertebra from Loftus Quarry (Young and Bird, 1828). Most of this fauna is likely to have been collected prior to closure of the Loftus quarries in 1863, two years after the Boulby works had ceased operating (Fox-Strangways, 1892). The Alum Shale Member in particular has been a rich source of marine reptiles, while the Pliensbachian succession below has yielded some of the only intact asteroids known from the Yorkshire Lias.

Despite the remarkable nature of the exposure at Boulby Quarries, little has been published on the stratigraphy of the quarries or of the main cliff commonly known in early accounts as 'Rockcliff', for well over a century. Hence only general comparison can be made with better-known exposures, particularly that at the Staithes to Port Mulgrave GCR site only a few kilometres farther east along the coast. The most complete and detailed section yet published of the site, and still the most useful today, was by Hunton (1836). His graphic depiction of the section exposed in the cliff enables the main modern lithostratigraphical units to be recognized (Figure 6.19). His account also documented the stratigraphical distribution of the main fossils present and a separate list of taxa and their occurrence. The site was mentioned by Phillips (1829, 1835, 1875) and Herries (1906a,b), who also provided sketches of the cliff face and its stratigraphy. Wright (1862–1880) reproduced part of Hunton's (1836) description, from the 'Lower Lias Shales' to the 'Jet Rock', but added little additional information. Rastall (1905) discussed the site briefly in connection with the relationship of the Middle Jurassic beds to the Lias beneath. The area is also included in the descriptions of the Yorkshire Lias of Tate and Blake (1876) Taken together these accounts formed the basis for the brief description provided by Fox-Strangways (1892). Other than the lists of fossils published by Hunton (1836) and Phillips (1829, 1835, 1875), only two taxonomic groups have been investigated in any detail here. The reptile fauna from the Toarcian strata has been described and much discussed over the past 150 years in publications by Carte and Bailey (1863), Seeley (1865), Tate and Blake (1876), Newton (1888), Watson (1911), Melmore (1930), Wellnhofer (1978), Benton and Taylor (1984), Taylor (1992), Benton and Spencer (1995). Wright (1862–1880) described and figured two species of asteroid from here.

Description

The cliff and quarries form a vertical exposure through most of the Pliensbachian to Toarcian succession of North Yorkshire and Cleveland (Figure 6.19). Phillips (1829, 1835, 1875) and Herries (1906a) showed that the site lies on the axis of a broad gentle anticline that stretches from east of Staithes westwards to Skinningrove Bay. Phillips (1829, 1835, 1875) noted that this stretch of cliffs is unbroken by faults and stated that it was possible to measure almost every bed and collect its contained fauna, except from the inaccessible middle part of the Middle Lias.

About 45 m (150 ft) of shales and siltstones of the upper part of the Ironstone Shale Member of the Redcar Mudstone Formation are exposed on the foreshore and in the lower part of the cliff. Towards the base, grey shales with bands of concretionary iron-rich (?sideritic) carbonate nodules contain ammonite faunas, in part pyritized, indicating at least three of the four subzones of the Jamesoni Zone; taxa include *Polymorphites* (Polymorphus Subzone), *Platypleuroceras* (Brevispina Subzone) and *Uptonia* (Jamesoni Subzone). It is unlikely that any lower strata are represented, although because of the lack of any other detailed studies north of Staithes, this cannot be ruled out entirely. Higher parts of this member were described by Hunton (1836) including an upward transition to the Staithes Sandstone Formation. At the top of the Redcar Mudstone Formation, shell beds with *Aegoceras maculatum* may have been the source of some of the specimens of the ophiuroid *Palaeocoma milleri* as noted by Tate and Blake (1876); similar occurrences are known from this level at Cowbar Nab, west of Staithes (Herries, 1906a,b; M.J. Simms, unpublished observations).

The largely inaccessible 80–90 m-high cliff exposes the full thickness of the Staithes Sandstone and Cleveland Ironstone formations, which Hunton (1836) estimated as 160 ft (50 m) thick (Figure 6.20). Of this, 77 ft (24.5 m) can be assigned to the Staithes Sandstone Formation, and 83 ft (25.5 m) to the Cleveland Ironstone Formation. Fox-Strangways (1892) recorded a section through part of the Cleveland Ironstone Formation, including the Main Seam ironstone, in the old road below the Alum Works but this presumably is now lost owing to cliff erosion. Hunton (1836) and Wright (1862–1880) listed elements of the invertebrate macrofauna, particularly bivalves and brachiopods, from parts of the sequence. *Rhynchonelloidea lineata* (= *Terebratula trilineata*) was described as 'very abundant' in the upper part of the Cleveland Ironstone Formation, an observation confirmed by Ager (1956–1967). Ammonites include *Aegoceras capricornus* in the Staithes Sandstone Formation, presumably near its base, and *Amaltheus stokesi* (*Ammonites clevelandicus*) and *Amaltheus subnodosus* (*Ammonites vittatus*) from the lower part of the Cleveland Ironstone Formation. Wright (1862–1880) described and figured intact examples, from Staithes Sandstone Formation lithologies, of the asteroids *Archastropecten bastingiae* and *Uraster carinatus,* and the ophiuroids *Palaeocoma milleri* and *Ophioderma carinata*, the latter probably a junior synonym of *P. milleri* (Hess, 1960).

The top of the Cleveland Ironstone Formation forms a broad shell', behind which a further cliff rises to the summit (Figure 6.18) and exposes the entire Whitby Mudstone Formation, some 72 m (235 ft) thick (Hunton, 1836). The alum shale quarries are excavated into the upper part of this cliff. The thicknesses cited by Hunton (1836) are approximate but the boundaries of the main lithostratigraphical units can be recognized from his description. The Grey Shale Member is about 9 m (30 ft) thick and was described as 'hard compact shale, very sandy; a few small nodules. Very barren in fossils'. Fox-Strangways (1892) also noted that it was seen in Boulby Cliff. Above lies the Jet Rock, 6 m (20 ft) thick, which from Hunton's (1836) description of 'many pyritous nodules, very much flattened' can be readily correlated with the lower part of the Mulgrave Shale Member. Fox-Strangways (1892) mentioned that the Jet Rock had been worked for jet here, and that a small ledge had been excavated in the cliff at this level between the Boulby Alum Works and the west end of Loftus Alum Works. From the Jet Rock and the lower part of the Bituminous Shales Hunton (1836) recorded *Harpoceras exaratum, H. falciferum* (= *Ammonites mulgravius*)*, Elegantuliceras elegantulum, Ovaticeras ovatum, Pseudolioceras lythense* (= *Ammonites concavus*)*, Phylloceras heterophyllum* and a small lytoceratid that he identified as '*Ammonites fimbriatus*'. He also noted remains of *Ichthyosaurus, Plesiosaurus* and the crocodilian *Pelagosaurus brongniarti* (= *Teleosaurus chapmanni*)*,* preserved 'generally in pyritous nodules', and the fish *Lepidotes gigas* which he described as being 'rarely met with elsewhere'. The bivalve *Pseudomytiloides dubius* was found throughout what is considered here to represent the Mulgrave Shale Member.

Hunton (1836) noted the lowest level worked for alum (Figure 6.19) but this may not correspond to the base of the Alum Shale Member as currently defined, which probably lies a little higher. The ferruginous nodules in the Alum Shale Member here may be similar to the nodular siderite horizons described by Howarth (1962a) from the Hard Shale Beds and Main Alum Shale Beds. Hunton's (1836) description of the succeeding 25 ft (7.7 m), as the 'Hard or Cementstone Seam' with 'numerous calcareous nodules, exclusively manufactured into Roman cement', clearly corresponds to the lower part of the Cement Shale Beds towards the top of the Alum Shale Member, as does the remaining 10 ft (3 m) of 'shale' beneath the unconformity at the base of the local Middle Jurassic succession.

The alum workings removed an enormous volume of rock and the vertebrate remains were so numerous that one of the walks at Boulby House was edged with saurian vertebrae (Fox-Strangways, 1892). Tate and Blake (1876) suggested that the vertebrate fauna came primarily from their zone of A. *communis,* suggesting the early Bifrons Zone (= Main Alum

Shale Beds), a view supported by Benton and Spencer (1995) based on observations of matrix adhering to specimens. The Cement Shale Beds have also been suggested as a source for some (Taylor, 1992). Benton and Spencer (1995) noted that the holotypes of the plesiosaur *Eretmosaurus macropterus,* the pliosaur *Rhomaleosaurus zetlandicus,* the ichthyosaur *Ichthyosaurus crassimanus* and the only pterosaur known from the Toarcian Stage of Britain, *Parasicephalus purdoni* came from this locality. The ichthyosaur *Temnodontosaurus platyodon* was recorded by Simpson (1884): this species and *Ichthyosaurus communis* were noted by Hunton (1836), but without indicating the level within the Whitby Mudstone Formation that they occurred. The bivalve *Nuculana ovum* was stated by Hunton (1836) as very abundant in the Cement Shale Beds and present throughout much of the Alum Shale Member. He commented that the species was used to indicate which part of the shale succession was suitable for alum extraction. Among the fauna cited from the Alum Shale Member were *Dactylioceras commune, Hildoceras bifrons* (*Ammonites walcotti*)*, Frechiella subcarinata, Catacoeloceras crassum, Peronoceras fibulatum, P. subarmatum, Pseudolioceras lythense, Ps. boulbiense, Nodicoeloceras crassoides* (= *Ammonites annulatus*)*, Phylloceras heterophyllum* and '*Ammonites fimbriatus*' Other elements include *Cenoceras astacoides,* belemnites and the inarticulate brachiopod *Discinisca reflexa.*

The upper part of the Cement Shale Beds and the Peak Mudstone Member are missing at this site beneath the unconformity at the base of the Middle Jurassic Dogger Formation. Rastall (1905) indicated that there was palaeorelief on the unconformity of perhaps as much as 50 ft (15 m). Fox-Strangways (1892) recorded around 1.4 m (4 ft 6 in.) of ironstone and ferruginous shale above the unconformity, perhaps representing the Murchisonae Shale, a key marker horizon of proven Aalenian (Murchisonae Zone) age which is seen only here on the Cleveland–Yorkshire coast. This in turn is succeeded by the Hayburn Formation of the Ravenscar Group, with some 25 m of massive sandstone and subordinate shale forming the top part of the upper cliff (Figure 6.18).

Interpretation

The succession at the Boulby Quarries GCR site is similar to that at the Staithes to Port Mulgrave GCR site. Bed-by-bed correlation is possible for parts of the succession (Figure 6.19). The ironstones of the Cleveland Ironstone Formation are thicker here than east of Staithes, a reflection of the north-westerly thickening towards Eston (Young *et al.,* 1990a) (Figure 6.11).

Some aspects of the biostratigraphy of the site are still unresolved. Hunton (1836) correctly cited *Amaltheus subnodosus* (= *Ammonites vittatus*) as occurring in the Osmortherley Seam (Bed 26 of Howarth, 1955) at the base of the Subnodosus Subzone. However, his notes imply that he found *Amaltheus stokesi* (= *Ammonites clevelandicus*)*,* indicative of the Stokesi Subzone, in beds equivalent to beds 29 to 38 of the Penny Nab Member at Staithes (Howarth, 1955), whereas these beds actually lie within the succeeding Subnodosus and Gibbosus subzones. *Pseudolioceras lythense* was said to occur in the Mulgrave Shale Member, corresponding to the Serpentinum Zone, but this species is known to be restricted to the succeeding Commune Subzone (Howarth, 1992). Hunton (1836) cited *Pseudolioceras boulbiense* from the Alum Shale Member at this site but this species is confined to the Cement Shale Beds, and higher parts of the Toarcian succession not preserved at Boulby Quarries. Simpson (1855) described a large slab from the Jet Rock, containing some 80 specimens of *Cleviceras exaratum* and the holotype and paratype of *Phylloceras easingtonense* (= *P. heterophyllum*)*, the* latter being re-figured by Howarth (1962b).

Some elements of the Pliensbachian and Toarcian fauna listed by Hunton (1836) cannot now be interpreted, Including most of the belemnites and certain of the ammonites and brachiopods. His identification of *Lytoceras* ('*Ammonites*') *fimbriatum* from the Mulgrave Shale and Alum Shale members is questionable because this is a Pliensbachian species. The Mulgrave Shale Member specimen may represent *Trachylytoceras nitidum,* a small species with periodic raised annular ribs rather like those of *Lytoceras fimbriatum* (Howarth, 1962a), while the Alum Shale Member record may refer to *Lytoceras cornucopia,* said to occur sporadically in the Bituminous Shales and in the Alum Shale Member (Howarth, 1962a). Among the vertebrates, records of the ichthyosaurs *Temnodontosaurus platyodon* and *Ichthyosaurus communis* (Hunton, 1836; Simpson, 1884) need to be confirmed since these are characteristically Hettangian and Sinemurian taxa.

This site was an important source of intact echinoderms, from the Upper Pliensbachian sequence, and marine reptiles, from the Toarcian Stage, during the 19th century. The preservation of the echinoderms is typical of obrution deposits

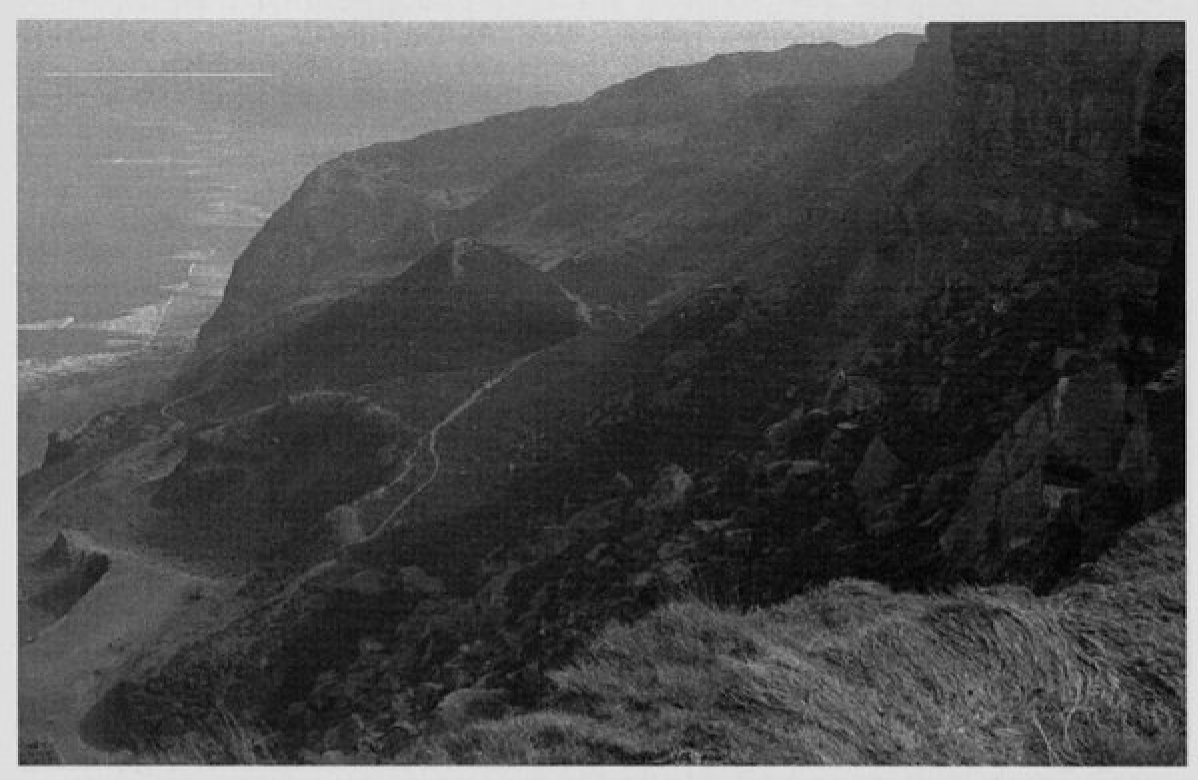
(Seilacher *et al.,* 1985) and suggests a similar general palaeoenvironment to that of the Staithes Sandstone Formation at its type locality, with frequent storm re-suspension of sediment bringing about the burial and death of many elements of the benthos. However, although ophiuroids have been found at Staithes (M J. Simms, unpublished observations) at a level comparable to that at which they are recorded here by Wright (1862–1880), asteroids have not been reported from the former site though this may reflect collection failure.

The Toarcian vertebrate remains have received more attention than other elements of the fauna at this site, though there is little documentation of the stratigraphical levels from which they were obtained. Early records suggest that more specimens were found in the Loftus Alum Quarries than at Boulby Quarries (Tate and Blake, 1876; Fox-Strangways, 1892). However, this could reflect collector bias rather than a genuine difference in distribution, particularly if all of the bones from Boulby were used to line pathways rather than ending up in collections! Benton and Spencer (1995) noted that the Loftus quarries appeared to have yielded a reptile fauna distinct from those from sites around Whitby. Only six specimens from the Boulby–Loftus area can now be positively traced but it is likely that a greater variety of taxa was collected. The preservation of these animals in laminated, organic-rich, mudstones is typical of stagnation deposits (Seilacher *et al.,* 1985). Taylor's (1992) investigation of a large plesiosaur skeleton, *Rhomaleosaurus zetlandicus,* suggested that it had drifted and decayed before sinking to the sea floor. He found no evidence for postmortem scavenging but the decay of soft tissues continued on the sea floor and, in early diagenesis, probably caused the growth of pyritous nodules around the axial skeleton.

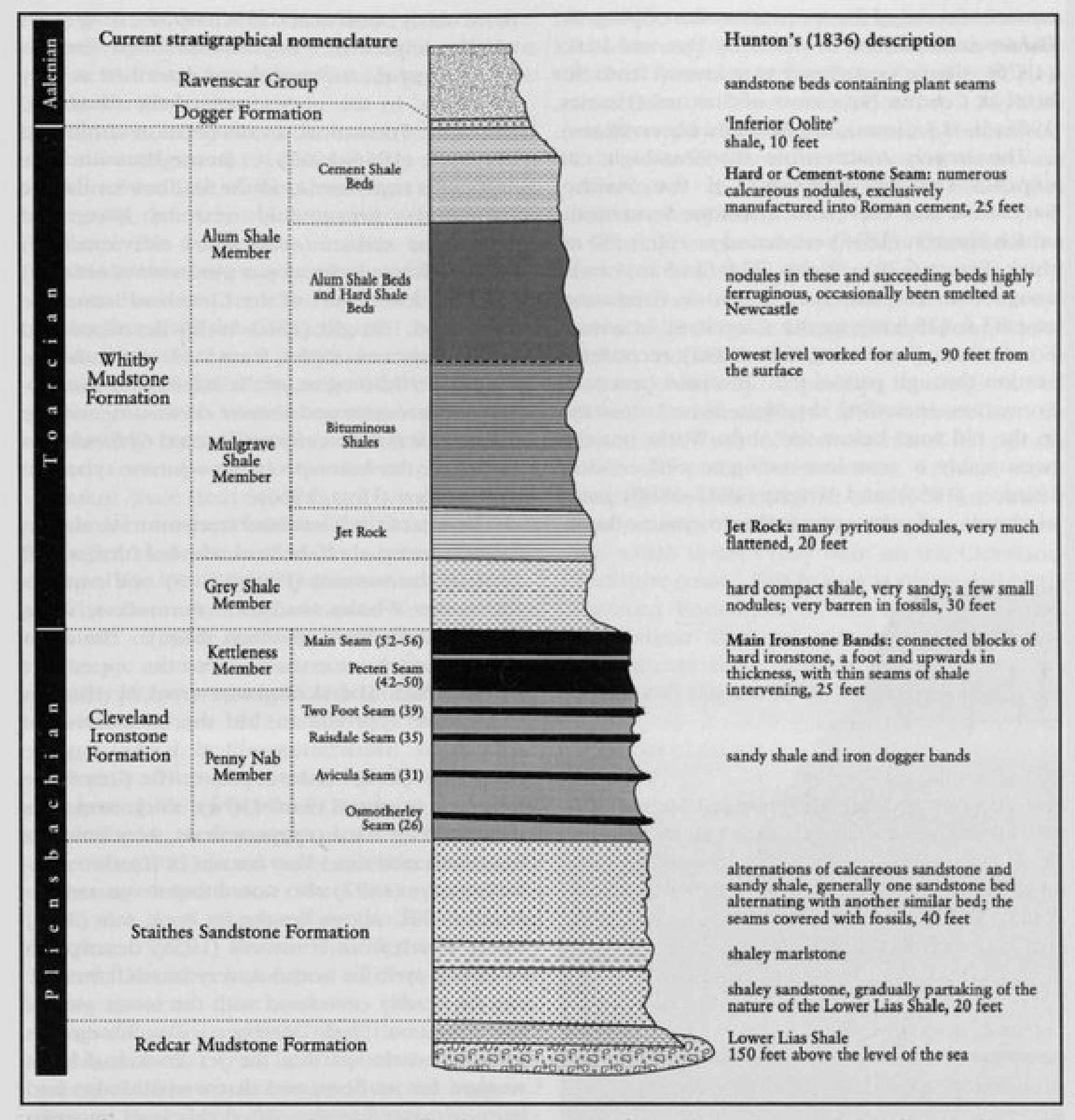
Conclusions

The Boulby and Loftus alum quarries, and the cliffs and foreshore below, constitute the thickest vertical exposure of the Lower Jurassic Series in Britain, representing levels from the Lower Pliensbachian Substage up to the Aalenian Stage, and including the base of the Redcar Mudstone Formation and the Staithes Sandstone, Cleveland Ironstone and Whitby Mudstone formations. Despite the main description of the site having been published more than 160 years ago, all of the main lithostratigraphical units were recognized. Hunton's (1836) attempt at an ammonite biostratigraphy of the section is one of the earliest known; its wider significance has perhaps been overlooked on account of his premature death. The stratigraphy of the site has been little studied since that time and has great potential for further investigation. The site has yielded important faunas of Toarcian reptiles, including plesiosaurs, ichthyosaurs and a pterosaur, and of Upper Pliensbachian asterozoan echinoderms. The Toarcian reptile fauna appears distinct from those known from correlative sections farther south. More precise data on thicknesses or facies of individual sedimentary units will prove invaluable in understanding regional patterns within the Lower Jurassic succession of the Cleveland Basin.

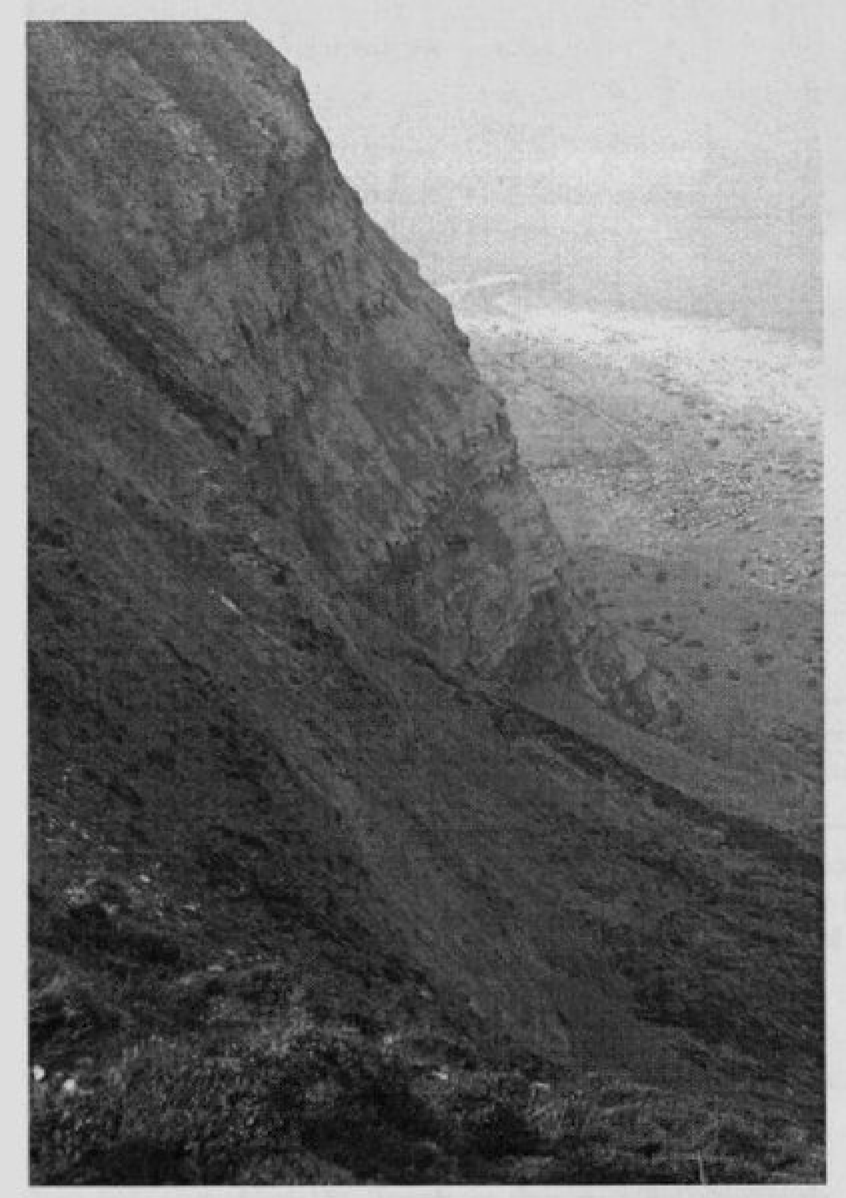
References



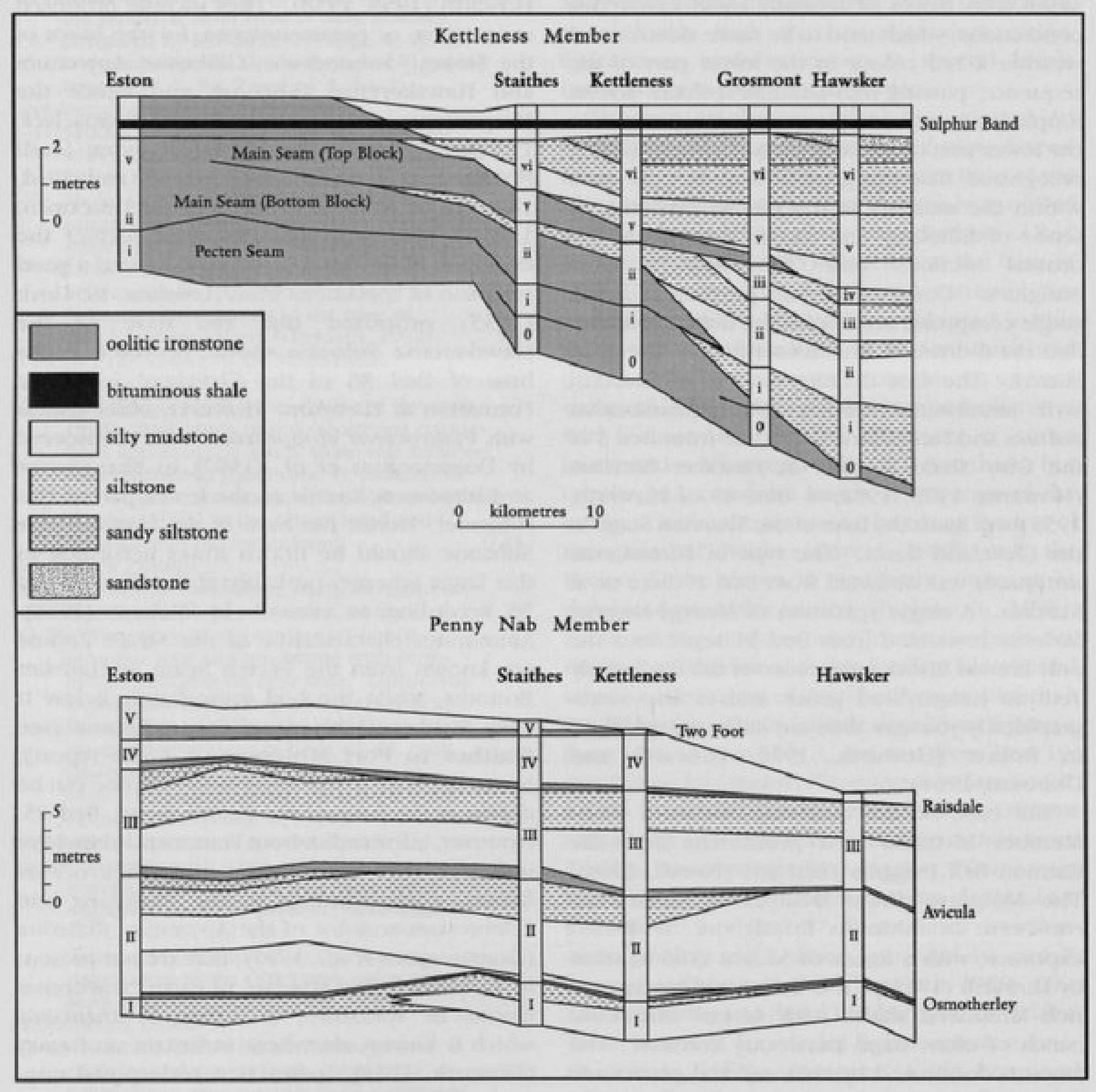
(Figure 6.18) The long-abandoned alum shale workings on Boulby Cliff, with the Middle Jurassic sandstones of the Dogger Formation rising behind them. (Photo: K.N. Page.)



(Figure 6.19) Sketch section of Boulby Cliff. After Hunton (1836). Bed numbers are those of Howarth (1955) for the Staithes section. Hunton's original lithological notes are on the right-hand side of the column; the modern interpretation of the lithostratigraphy is on the left.



(Figure 6.20) The Pliensbachian succession on the lower face of Boulby Cliff viewed from the abandoned alum workings. The ironstone bands of the Cleveland Ironstone Formation are visible in the upper part of the face. Foreshore reefs are formed by the upper beds of the Redcar Mudstone Formation, Ironstone Shale Member. (Photo: K.N. Page.)



(Figure 6.11) Lateral variation in the Cleveland Ironstone Formation along NW–SE transects between Eston and Hawsker. Datum for the Kettleness Member is the Sulphur Band; datum for the Penny Nab Member is the base of the Two Foot Seam. Roman numerals indicate the cycles of Howard (1985). After Young et al. (1990a).