Miller's Nab to Blea Wyke, North Yorkshire

[NZ 968 027]–[NZ 989 014]

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Introduction

The cliffs and foreshore of the Miller's Nab to Blea Wyke GCR site, located below the village of Ravenscar, expose a Toarcian succession that is famous in Yorkshire and unique in Britain, being almost stratigraphically complete and in relatively expanded mudrock facies. The succession is the type locality for the higher subdivisions of the Whitby Mudstone Formation in the Cleveland Basin, namely the Peak Mudstone and Fox Cliff Slltstone members, and the Blea Wyke Sandstone Formation, comprising the Yellow Sandstone and Grey Sandstone members. The succession also has the most completely developed and expanded Lower–Upper Toarcian boundary sequence seen anywhere in Britain, and provides the only exposure in the basin where the Upper Toarcian succession is present beneath the unconformity at the base of the Middle Jurassic Dogger Formation. This Upper Toarcian succession is absent from sites elsewhere along the Yorkshire coast, and the thickness and lithostratigraphy of the Lower Toarcian succession also differs significantly from other Yorkshire coast sites, which has important implications for basin history. At Peak, on the south-east side of Robin Hood's Bay, the coastline is cut by a major fault that juxtaposes Toarcian strata to the south against Sinemurian strata to the north (Figure 6.6).

The cliffs here are high and the beach platform narrow and boulder strewn, these factors being a significant hindrance to investigation of the site (Dean, 1954; Rawson and Wright, 1995). Wright (1860b) was the first to describe the Upper Toarcian part of the section, followed by Hudleston (1874). The description by Tate and Blake (1876) was based largely on Wright's (1860b) account with only minor modification. Fox-Strangways (1892) described a section near Blea Wyke. Rastall (1905) and Herries (1906a) provided further descriptions of the section, while Buckman's (1915) account was largely a review of earlier work. Davies (in Evans and Stubblefield, 1929) was the first to identify the position of the Lower–Middle Jurassic boundary: this was followed by a description by Rastall and Hemingway (1939). These descriptions of the site show significant variations in thickness and reflect the difficulties inherent in measuring the section.

Arkell (1933) and Sylvester-Bradley (1953) described the site briefly. Dean (1954) provided a detailed description of the upper part of the Toarcian Alum Shale Member and Howarth (1962a) described the beds between the Grey Shale Member and the Peak Mudstone Member. Hemingway *et al.* (1969) referred to the succession, and Knox (1984) established a formalized lithostratigraphical framework for the upper part, in part based on the scheme of Powell (1984). This was correlated with the ammonite zonation of Dean (1954). Hesselbo and Jenkyns (1995) used the same biostratigraphical account. Rawson and Wright (1995) figured sections extending from the top of the Grey Shale Member to the base of the Peak Mudstone Member here. Doyle (1990–1992) described the complete succession, the only author to do so. He used the bed numbers of Howarth (1962a) for the lower part of the succession, but he re-numbered the higher beds found only at this site, making comparison with earlier descriptions difficult.

Descriptions of the faunas are included in works by Simpson (1855), Buckman (1909–1930), Howarth (1992) and Doyle (1990–1992). Riding (1984b) reviewed the palynology of the sequence using Knox's (1984) sections.

Description

At the northern end of the site at Peak Steel the Peak Fault has a downthrow to the east of about 150 m (Milsom and Rawson, 1989). The Staithes Sandstone Formation is exposed at low tide as a fault-bounded wedge on the north side of the Peak Fault. The oldest strata exposed on the south side of the fault are the top beds of the Cleveland Ironstone Formation, equivalent to beds 43–44 of the Hawsker Bottoms (Castlechamber to Maw Wyke GCR site) section. The Grey Shale Member is poorly exposed on the foreshore, with strata equivalent to beds 12–27 of other sites obscured by boulders. The lower part of the Mulgrave Shale Member, the Jet Rock, is exposed on the shore with higher strata present in the cliff. A low southerly dip brings progressively younger strata to shore level between Peak Steel and Blea Wyke. Much of the outcrop is obscured by beach deposits and cliff falls. At the southern end of the site, the Blea Wyke Sandstone Formation forms part of the headland of Blea Wyke.

The following account is a composite based on several accounts. Notes on the Grey Shale Member follow Howarth (1973), and descriptions of the Mulgrave Shale and Alum Shale members are from Howarth (1962a, 1992). Howarth (1962a, 1992) used roman numerals as bed numbers for this site (Figure 6.12)a,b to distinguish the succession from the Whitby section. Dean's (1954) notes for the Upper Toarcian succession have been incorporated into the lithostratigraphical framework established by Powell (1984) and Knox (1984) and his bed numbers have been used for all but the lowest five beds of the Upper Toarcian Substage.

	Thickness (m)
AALENIAN STAGE (part)	
Dogger Formation	
? Opalinum Zone	
Terebratula Bed: Sandstone, hard, sideritic, with abundant phosphatic pebbles, derived from the Toarcian Stage below; with abundant *Lobotyris trilineata, with Gresslya, Blgonia,* crinoidal and woody debris. Belemnites, in part at least derived from below include *Acrocoelites pyramidalis, A. vulgaris, A. levidensis, A. subtricissus, Brevibelus breviformis* and *Megateuthis rhenana.*	
UPPER TOARCIAN SUBSTAGE	
Blea Wyke Sandstone Formation	
Yellow Sandstone Member	
Pseudoradiosa Zone, ?Levesquei–Pseudoradiosa subzones	
82 (= Bed 81 of Doyle): Sandstones, massive, yellow, fine grained, with scattered impersistent ferruginous layers; bivalves and brachiopods present, including *Homeoeorhynchia cynocephala, H. acuta, Lobotyris* aff. *trilineata, Gresslya* sp., *Gervillia tortuosa, G. lata, Modiolus* sp., *Oxytoma inaequivalvis, Pinna cuneata* and *Thigonia striata,* also *Megateuthis rhenana.* Ammonites reported by Dean include *Dumortieria* spp. (*D. moorei, D. lata, D.* aff. *munda* and *D.* cf. *penexigua*). Top surface of unit burrowed, with *Skolithos.*	8 (26 ft)
Grey Sandstone Member	
?Dispansum Zone	
81 (= Bed 80 of Doyle): Sandstone, grey, massive, with very uneven upper surface. Scattered ferruginous concretions, especially near top. *Homeoeorhynchia cynocephala, H. acuta, Serpula deplexa, S. ?compressa, Oxytoma inaequivalvis, Aulacothyris, Acrocoelites vulgaris, Simpsonibelus expansus, S. dorsalis, Brevibelus bremformis* and *Megateuthis glaber.*	1.7 (5 ft 6 in.)

79–80 (= beds 78–79? of Doyle): Sandstone, grey, massive, forming part of the headland of Blea Wyke Point. Ferruginous hard band at base contains *Phylseogrammoceras dispansum, Hudlestonia affinis, Lingula beani, S. deplexa* and *O. inaequivalvis.* Upper 0.15 m is also ferruginous and rich in fossils, including *S. deplexa, S. ?compressa, Discinisca reflexa, Dentalium elongatum, Eryma birdi* and many belemnites (from beds 78–79 of Doyle, these include *Acrocoelites pyramidalis, A. levidensis, A. subtricissus, Simpsonibelus dorsalis* and *Megateuthis rhenana*).	2 (6 ft 6 in.)
70–78 (= beds 58–77? of Doyle): Siltstone (?), grey, sandy, with ferruginous bands, and some concretions. Belemnites frequent, mainly in upper part, including *Acrocodites pyramidalis*, *A. vulgaris*, *A. levidensis*, *A. tricissus*, *Simpsonibelus expansus*, *S. dorsalis*, *S. lentus* near base; *Brevibelus breviformis, B.* cf. *gingensis* and *Megateuthis rhenana* near top. *Lingula beani* and *Serpula deplexa* present.	6.3 (20 ft 6 in.)
Whitby Mudstone Formation	
Fox Cliff Siltstone Member	
68–69: Shale, grey, sandy, ferruginous above, with *Lingula beani, Discinisca reflexa* and *Eryma birds.*	0.5 (1 ft 8 in.)
63–67: Shales, grey, sandy, with bands of sandy ferruginous nodules. *PhIyseogrammoceras dispansum,* belemnites common (although no named species seem to be recorded by Doyle, 1990), *Lingula beani* first appears and *Discinisca reflexa* also present.	2.5 (8 ft 1 in.)
Thouarsense Zone, ?Fallaciosum Subzone	
59–62: Shales, typically micaceous and sandy, with two continuous bands of hard sideritic mudstone.	3.85 (12 ft 6 in.)
58: Grey micaceous shales with *Pseudogrammoceras latescens* and many belemnites (probably close to beds 31–37 of Doyle) including *Acrocoelites inaequistriatus, S. expansus* and *S. lentus.*	5.2 (17 ft)
Striatulum and *Fascigerum subzones*	
57: Ferruginous concretionary band, fossils abundant in places including *Pseudolioceras boulbiense, Grammoceras* sp. (recorded by Dean as *G.* cf. *striatulum*), *Pseudogrammoceras* (aff. *doertense* and ?aff *audax* in Dean), *Ostrea subauricularis, Pseudomytiloides* sp., *Camptonectes* sp., *Pecten disciformis. Oxytoma substriata* and *Venus tenuis.*	0.23 (9 in.)
Peak Mudstone Member	
56: Shale, grey, micaceous, with belemnites.	4.15 (13 ft 6 in.)
55: Sideritic nodule band. Ammonites include *Pseudolioceras boulbiense, Grammoceras striatulum, G.* cf. *tbouarsense* and *Lytoceras* sp. bivalves abundant, including *Oxytoma substriata, Ostrea* sp., *Pecten disciformis, Pseudomytiloides* sp., *Venus tenuis, Actaeon?* sp., *Camptonectes* sp., and *Protocardia* sp..	0.15 (6 *in.*)

Variabilis Zone, ?Illustris–Vitiosa subzones to Thouarsense Zone, Bingmanni Subzone	
54: Shale, grey, micaceous, with abundant belemnites (probably equivalent to Bed 19 of Doyle) with *Acrocoelites tricissus, Simpsonibelus expansus, S. dorsalis* and *S. lentus.*	2.5 (8 ft)
53 (= Bed 18 of Doyle?): Mudstone, sideritic, with uncrushed body chambers, and occasionally parts of other whorls, of large *Podagrosites/Denckmannia* (aff. *bodei* in Dean). *Ostrea subauricularis, Camptonectes, Acrocoelites levidensis, A. tricissus, A. inaequistriatus, Simpsonibelus lentus* also present.	0.08 (3 *in.*)
49–52: Shales, silty and micaceous, with several nodular bands and large *Haugia* sp. (crushed); *Trigonia literata* and *Oxytoma substriata* present. Belemnites include *Acrocoelites levidensis, A. tricissus, A. subtricissus, A. inaequistriatus, Simpsonibelus expansus, S. dorsalis, S. lentus, Dactyloteuthis* cf. *venticosa, Brevibelus breviformis, Megateuthis rhenana, M. glaber* and *M.? longisulcata* (probably close to beds 15–17 of Doyle). Probable horizon of *c.* 0.5 m length of articulated icthyosaur vertebrae (K.N. Page, unpublished observation, 1985).	2.4 (7 ft 9 *in.*)
?Variabilis Subzone	
48: Shales, grey, silty and micaceous with *Trigonia literata, Haugia variablis* (according to Dean), *Pelecoceras* sp. and *Phyllohylloceras heterophyllum.*	0.9 (3 ft)
45–47: Shale with nodule bands at top and bottom; *Haugia* (large and fragmentary). 0.8 (2 ft 7 in.)	
44b: Shale, grey, ?micaceous; Dean reported large *Haugia* (fragmentary), *Pseudolioceras whitbiense, Pigonia literata* and *Gresslya donaciformis* from an undivided Bed	44. 0.3
Alum Shale Member	
Cement Shale Beds	
43–44a: Shale, grey with band of large flattened nodules at base. Dean reported large *Haugia* (fragmentary), *Pseudolioceras whitbiense, Trigonia literata* and *Gresslya donaciformis* from an undivided Bed 44. Beds 43–48 of Dean (1954) probably equates to beds 5–13 of Doyle (1990–1992) with *Acrocoelites vulgaris, A. tricissus, A. inaequistriatus, Simpsonibelus expansus,* S.1.6 (6 ft 4 in. for 43–44b) *dorsalis, S. lentus, Dactyloteuthis* cf. *venticosa, Megateuthis rhenana, M. glaber* and *M.? longisulcata.*	
42: Shales with occasional nodules. Dean reported *Lytoceras cornucopia* and *Haugia* spp. (reported as *H. beani* and *H. illustris,* although these identifications may need revising).	0.8 (2 ft 6 in.)
39–41: Shale, grey, with nodule bands; *Dacromya ovum* last appears at this level, *Gresslya* and *Oxytoma substriata* also present.	0.8 (2 ft 6 in.)
lviii (= Bed 38 of Dean): Shale. *Haugia* sp., *Catacoeloceras dumortieri, Phylloceras heterophyllum.*	0.9 (3 ft)

lvii (= Bed 37 of Dean): Band of calcareous nodules in grey shale. *Oxytoma substriata* and *Trigonia literata first* appear at this level.	0.08 (3 in.)
liv–lvi: Shale with band of flat nodules or red limestone. *Catacoeloceras dumortieri, C. crassum, Pseudolioceras boulbiense, Phylloceras heterophyllum,* and *Acrocoelites levidensis.* This corresponds to at least part of the Navis Zonule (= Horizon) of Elmi *et al.* (1997).	1.9 (6 ft 1 in.)
LOWER TOARCIAN SUBSTAGE	
Bifrons Zone, Crassum Subzone	
xlviii–liii: Shale with bands of calcareous nodules. *Catacoeloceras crassum, Hildoceras semipolitum, Dacromya ovum, Trigonia literata, Gresslya donaciformis, Acrocoelites levidensis, A. subtricissus, A. wrighti, A. inaequistriatus, Simpsonibelus dorsalis, Dactyloteuthis* cf. *venticosa, Megateuthis rhenana* and *M. glaber.* This corresponds to part of the *crassumsemipolitum* Biohorizon.	2.5 (8 ft 1 in.)
xlv–xlvii: Shale with double row of large concretions at base and band of small nodules at top. *Catacoeloceras crassum, Hildoceras bifrons, Dacromya ovum, Trigonia literata, Gresslya donaciformis.* Corresponds to part of the *crassumsemipolitum* Biohorizon.	1.3 (4 ft 1 in.)
Fibulatum Subzone	
xlii–xliv: Shale with many calcareous concretions. *Porpoceras* ex grp. *vortex, Hildoceras bifrons* and occasional *Pseudolioceras lythense* and *Harpoceras subplanatum. Dacromya ovum, Gresslya donaciformis, Acrocoelites pyramidalis, A. vulgaris, A. levidensis, A. tricissus, A. subtricissus, A. wrighti, Simpsonibelus expansus, S. dorsalis* and *Dactyloteuthis crossotela.* The *vortex* Biohorizon extends down to the base of Bed xliv, around 1 m below the top.	3.1 (10 ft 1 in.)
xxxiii–xli (= Whitby Beds 65–71 of Howarth 1962a): Shale with bands of nodules and a 0.15 m-thick cementstone band at base; *Hildoceras* ex grp. *bifrons, Pseudolloceras lythense, Acrocoelites pyramidalis, A. vulgaris, A. levidensis, A. tricissus, A. subtricissus, A. inaequistriatus, Simpsonibelus expansus, S. dorsalis, S. lentus, Dactyloteuthis* cf. *venticosa, D. crossetela, Megateuthis rhenana, M. glaber* and *M? longisulcata, Dacromya ovum, Gresslya, Pseudomytiloides* and pentacrinitid ossicles (in lower part).	4.6 (15 ft)
Main Alum Shale Beds	
xxxii: Shale with many nodules; *Hildoceras ex* grp. *bifrons, Pseudolloceras lythense, Acrocoelites vulgaris, A. tricissus, A. inaequistriatus, Simpsonibelus expansus, S. dorsalis, S. lentus* and *Dacromya ovum.*	2.0 (6 ft 6 in.)
xxxi: Band of large calcareous concretions in shale. *Peronoceras subarmatum, Zugodactylites braunianus, Z. thompsoni, Hildoceras* ex grp. *bifrons* and occasional *Pseudolioceras lythense.* This corresponds to the *braunianus* Biohorizon.	0.15 (6 in.)

xxx: Shale with few nodules. *Peronoceras fibulatum, P. perarmatum, Hildoceras* ex grp. *bifrons, Pseudolioceras lythense, Phylloceras heterophyllum, Acrocoelites pyramidalis, A. vulgaris, A. tricissus, A. subtricissus, A. inaequistriatus, Simpsonibelus expansus, S. dorsalis* and *S. lentus.*	2.15 (7 ft)
xxix: Shale with many small nodules. *Peronoceras turriculatum* common, also *P. fibulatum* and *P. subarmatum, Dacromya ovum, Gressyla donaciformis* and *Simpsonibelus expansus.* This corresponds to the *turriculatum* Biohorizon.	0.9 (3 ft)
Commune Subzone	
xxvii–xxviii: Shale with scattered nodules. *Dactylioceras athleticum* common, with rare *Hildoceras* cf. *lusitanicum, Dacromya ovum* and *Simpsonibelus expansus.* Corresponds to the *athleticum* Biohorizon.	1.4 (4 ft 6 in.)
xxvi: Shale with occasional nodules. *Dactylioceras praepositum, Hildoceras* ex grps *lusitanicum* or *sublevisoni* and *Acrocoelites vulgaris.*	1.28 (4 ft 3 in.)
xviii–xxv: Shale with several bands of nodules, including a level with large concretions at top and many small nodules between (Bed xxv). *Dactylioceras commune* common and occasional *D. temperatum, with D. praepositum* and *D. crassiusculum* only recorded in Bed 30 (*V. Hildoceras* ex grp. *sublevisoni* and *Phylloceras heterophyllum* also present. Dean recorded *Frechiella subcarinata* in Bed xxi (his Bed 7) and *Frechiella* sp. in Bed xviii (Bed 4). *Dacromya ovum first* appears in Bed xxii. Belemnites in Bed xxiv include *Acrocoelites vulgaris, A. subtricissus, A. inaequistriatus, Simpsonibelus expansus* and *S. dorsalis.* Corresponds to at least part of the *commune* Biohorizon.	12.6 (40 ft 11 in.)
Hard Shale Beds	
xvi–xvii: Shale with band of large flat nodules at top. *Parapassaloteuthis robusta, Acrocoelites subtenuis* and *Simpsoniteuthis dorsalis.*	4 (13 ft)
Mulgrave Shale Member	
xv: Ovatum Bed (= Bed 48 at Whitby): Double row of red-weathering large concretions with some pyritic masses, *Ovaticeras ovatum, Dactylioceras* sp., *Phylloceras heterophyllum.* Corresponds to the *ovatum* Biohorizon. 0.35 (1 ft 2 in.)	
Bituminous Shales	
Serpentinum Zone, Falciferum Subzone	
xii–xiv: Shale, grey, bituminous, with a band of red-weathering sideritic mudstone. *Dactylioceras* sp. and belemnites; *Parapassaloteuthis robusta, P. polita, Acrocoelites subtenuis, A. pyramidalis* (at top only), *A. vulgaris, A. subtricissus, A. inaequistriatus, Simpsonibelus dorsalis, Youngibelus tubularis* and *Y. simpsoni* (*latter* two only near base).	13.7 (44 ft 7 in.)

xi: **Peak Stones**: Large lenticular concretions, typically around 1.5 m diameter but sometimes larger, in grey shale with occasional *Harpoceras* ex grp. *falciferum.* They cap conspicuous pedestals of shale on the foreshore below Ravenscar and were termed the 'fairy tables' by Bairstow and Hemingway (1961).	0.22 (9 in.)
viii–x: Shale, grey, bituminous, with scattered row of pyrite-skinned concretions with *Pseudomytiloides* just above the middle (= Bed 42 at Whitby). *Harpoceras* ex grp. *falciferum, Dactylioceras* spp. (including *D. gracile*) and rare *Phylloceras heterophyllum* and *Lytoceras* sp. present, though all typically crushed. *Hildaites* sp. present in lowest	1.5 m. 9.7 (31 ft 6 in.)
Jet Rock	
Exaratum Subzone	
vi–vii: Shale, grey with many flat concretions, capped by a level with occasional lenticular concretions, no more than 1.2 m in diameter; these are the Millstones (= Bed 40) of sections to the north-west. *Harpoceras elegans* present with *Phylloceras heterophyllum* and *Acrocoelites trisulcolosus.* Corresponds to the *elegans* Biohorizon.	2.6 (8 ft 6 in.)
v: Shale, grey with paler calcareous laminations weathers to form a small step on the scar.	0.22 (9 in.)
iv: Shale, grey, with numerous small calcareous concretions and occasional large Whalestones (= Bed 35 of sections to the north-west) up to 1.5 m long and 0.6 m thick, with some jet; *Harpoceras exaratum, Hildaites* sp. and *Elegantuliceras* sp. present. Corresponds to the *exaratum* Biohorizon.	0.9 (3 ft)
iii: Shale, grey with paler calcareous laminations. Weathers to form a small step on the scar.	0.3 (1 ft)
ii: Shale, grey with many small calcareous concretions. *Elegantuliceras elegantulum,* crushed, especially near base. Corresponds to the *elegantulum* Biohorizon.	1.85 (6 ft)
i: Shale, grey, with rare concretions.	2.45 (8 ft)
Grey Shale Member	
Tenuicostatum Zone, Semicelatum Subzone	
28–32: Grey shale with occasional bands of calcareous nodules, well exposed below the base of the Jet Rock; *Dactylioceras semicelatum* present. According to Howarth (1973), beds 28 and 30 were similar in lithology and thickness to the same levels farther north (e.g. Castlechamber to Maw Wyke and Staithes to Port Mulgrave GCR sites).	No overall thickness recorded
Tenuicostatum Zone, Tenuicostatum, Clevelandicum and *Paltus* (part) *subzones*	
12–27: Obscured by boulders.	No overall thickness recorded.
Tenuicostatum Zone, Paltus Subzone (part)	

3–11: Shale, grey with red-weathering sideritic concretions exposed near Mean Low Water. Beds 3 and 5 were well exposed and similar in lithology and thickness to the same levels farther north (e.g. Castlechamber to Maw Wyke and Staithes to Port Mulgrave GCR sites). No overall thickness recorded. Bed 3 elsewhere yields the lowest typical Toarcian fauna in the region, e.g. at Hawsker Bottoms (Normanby Style Batts–Miller's Nab GCR site) and at Kettleness.	
UPPER PLIENSBACHIAN SUBSTAGE	
Spinatum Zone, Hawskerense Subzone	
1–2: Shale, grey exposed near Mean Low Water. Basal shales of Grey Shale Member probably also present as Cleveland Ironstone Formation is present below (e.g. equivalent to beds 43–44 at Hawsker Bottoms, see Normanby Style Batts–Miller's Nab GCR site report).	No overall thickness recorded
Cleveland Ironstone Formation	
Kettleness Member	
Seen below near Mean Low Water (Howarth, 1973).	

The Toarcian Whitby Mudstone Formation contains relatively few marker beds. Beds of sideritic or calcitic nodules, and a few more continuous beds occur throughout the succession from the Grey Shale Member to the lower part of the Fox Cliff Siltstone Member, but most are inconspicuous. The distinctive nodule bands in the Mulgrave Shale Member at the Castlechamber to Maw Wyke and Staithes to Port Mulgrave GCR sites are mostly absent here, with only the Whalestones and the Millstones recognizable, though more poorly developed than farther north (Howarth, 1962a). An additional band of large, circular, flattened nodules, the Peak Stones (Figure 6.13) is present and forms a conspicuous feature on the shore where, perched on pillars of shale, they form the 'Fairy Tables' of Bairstow and Hemingway (1961). The Ovatum Bed at the top of the member also is well exposed but, between there and the base of the Dogger Formation there are only two or three ferruginous bands in the Peak Mudstone and Fox Cliff Siltstone members that form useful markers. Phosphatic nodules occur in abundance at some levels in the Peak Mudstone Member, and continue up into the Fox Cliff Siltstone Member. Chamositic day and ooliths first appear near the base of the latter member. Knox (1984) identified five sedimentary cycles in the Upper Toarcian succession at Ravenscar. The first comprises the Peak Mudstone Member, its base marked by a sharp upward increase in silt and mica content, followed by a slow upward decrease in grain size. Cycles two and three, also fining upwards, are developed in the Fox Cliff Siltstone Member. An increase in grain size at the base of the Grey Sandstone Member is followed by a (fourth) upward-coarsening cycle. The fifth cycle, represented by the Yellow Sandstone Member, is also upward-coarsening.

The fauna of the Toarcian succession is abundant and diverse at some levels. The ammonite assemblages from the lower part of the succession have been described by Howarth (1962a, 1973, 1992), and those for the upper part by Dean (1954). This was the type locality for the zonal index fossil *Grammoceras striatulum* (J. de C. Sowerby, 1812–1846; Buckman, 1887–1907), presumably from the Peak Mudstone Member but now apparently lost (Dean *et al.,* 1961); for the holotype of *Lytoceras cornucopia* (Young and Bird, 1822), from the Alum Shale Member or Peak Mudstone Member at Ravenscar; and for the holotypes of Simpson's (1855, 1884) *Pseudolioceras simplex* (= *P. boulbiense*) and *Pseudolioceras leptophyllus* (= *P. lythense*), re-figured by Howarth (1962b). The last specimen was considered by Howarth (1962b) to originate from the Grey Sandstone Member at Peak Steel (beds 79–81 of Dean, 1954) and it remains the youngest record of *Pseudolioceras lythense* (Howarth, 1992). The holotype of *Pseudolioceras boulbiense* was thought to be from the Striatulum Subzone here (Howarth, 1992). Several hildoceratid species from the site were figured by Howarth (1992). Doyle (1990–1992) figured numerous specimens from here, including the lectotypes of *Odontobelus levidensis, Megateuthis rhenana* and *M. glaber,* and other material was used by Doyle (1985) to argue for the existence of sexual dimorphism in the belemnite genus *Youngibelus.* Doyle and Macdonald (1993) described a 'condensation and predation concentration' type of 'Belemnite Battlefield' from the Ovatum Bed (Bed xv), with abundant aligned specimens of *Acrocoelites vulgaris* and *A. subtenuis* associated with belemnite hooklets and ichthyosaur vertebrae. The types of the crustacea *Glypbaea prestwichi* and *Eryma birdi* were described and figured from the Blea Wyke Sandstone Formation by

Woods (1925–1931), and disarticulated remains of the crinoid *Cbariocrinus wuerttembergicus,* abundant in the Grey Sandstone Member, were figured by Simms (1989). Examples of commensalism between the bivalve *Dacromya ovum* and the encrusting brachiopod *Discinisca reflexa* were described from the Alum Shale Member here (Watson, 1982). A list of 77 nominal species from the upper part of the succession, above the Mulgrave Shale Member, was included by Dean (1954) in his descriptive section. Few vertebrates have been recovered from this site: Dean (1954) reported a 'specimen of *Ichthyosaurus …* the bones relatively undisturbed' from shales about 3 m above the Ovatum Bed (Bed xv). Ichthyosaur vertebrae were also reported from the Ovatum Bed (Doyle and Macdonald, 1993), and an articulated series of ichthyosaur vertebrae was found in beds 49–52 of the Peak Mudstone Member (K.N. Page, unpublished observation, 1985). Broadhurst and Duffy (1970) and Benton and Spencer (1995) reported a skeleton of the plesiosaur *Macroplata longirostris* from the Bifrons Zone (beds xv–liii) between Peak and Blea Wyke. In addition to the ammonites and belemnites, other taxa provide stratigraphical markers within the section, and were recognized as such in the earliest descriptions. The upper part of the Grey Sandstone Member is sufficiently rich in serpulids to have been termed the 'Serpula Beds' in most accounts from Wright (1860b) to Dean (1954). The brachiopod *Lingula beani* is common in the 'Lingula Beds' in the lower part of this member. The Blea Wyke Sandstone Formation contains a richer and more diverse benthic fauna than lower parts of the Toarcian succession. Unequivocally benthic elements are absent from the Mulgrave Shale Member and lowest part of the Alum Shale Member, but diversity gradually increases upwards. The Alum Shale Member benthos is virtually confined to a few species of bivalve, notably *Dacromya ovum* (beds 7–41), *Gressyla donaciformis* (beds 12–44) and *Trigonia literata* (beds 32–50) (Dean, 1954). In the slider beds of the Peak Mudstone and Fox Cliff Siltstone members these are joined by an increasingly diverse bivalve fauna, and in the Blea Wyke Sandstone Formation by several species of brachiopod.

Interpretation

It has long been appreciated by geologists that the succession to the south-east of the Peak Fault shows significant differences, and in particular is substantially more complete than, the correlative sections farther along the coast to the northwest. Early observers (Wright, 1860b; Hudleston, 1874; Tate and Blake, 1876; Fox-Strangways, 1892; Rastall, 1905; Buckman, 1915) differed in their placement of the Lower–Middle Jurassic boundary in the succession close to the village of Ravenscar. These ranged from a level within the Peak Mudstone Member (Fox-Strangways, 1892) to one well above the base of the Dogger Formation (Rastall, 1905). The position of the Toarcian–Aalenian boundary is now well-established here, on the basis of the ammonite assemblages, and lies immediately below the Terebratula Bed at the base of the Dogger Formation.

Lithological correlations between the succession here and at other sites to the north-west, such as those at Whitby and Port Mulgrave (the Whitby to Saltwick and Staithes to Port Mulgrave GCR sites), become increasingly uncertain upwards. Howarth (1973) considered the Grey Shale Member succession here to be sufficiently similar to that to the north-west for the same bed numbers to be applicable. In contrast, the Mulgrave Shale and Alum Shale members are sufficiently different to require different numbering schemes (Howarth, 1962a). Howarth (1962a) showed that although the thickness of the Mulgrave Shale Member was similar on both sides of the Peak Fault, the Alum Shale Member was significantly thicker on the east side of the fault at Ravenscar. Knox (1984) showed that the Upper Toarcian succession between Blea Wyke and Peak Steel also showed significant thinning to the north-west.

The Upper Toarcian part of the succession is of especial interest at the Miller's Nab to Blea Wyke GCR site, because equivalent strata have been removed by pre-Dogger erosion in more northerly sections. All descriptions of the Upper Toarcian Substage at Ravenscar published over the last two decades (Knox, 1984; Howarth, 1992; Hesselbo and Jenkyns, 1995) have used the ammonite zonation established by Dean *et al.* (1961). This has been recently refined by work in France, Germany and Spain, notably by Elmi *et al.* (1997), and their scheme is provisionally applied here although some of the specimens will need to be re-examined. For example, a fauna with *Catacoeloceras dumortieri,* considered by Howarth (1962b, 1992) to be from the latest Lower Toarcian succession, would be interpreted as indicative of the basal Upper Toarcian sequence by Elmi *et al.* (1997) on the basis of the associated ammonites. Further collecting is needed. This illustrates the importance of the site as the most completely developed and expanded Lower–Upper Toarcian boundary sequence known in Britain is exposed at this site. Cox (1990) considered that the sections here could provide reference sections for the Bifrons, Variabilis, Thouarsense and Levesquei zones, as defined in Dean *et al.,* (1961).

A hiatus exists at the top of the sequence and cuts out the Aalensis Zone at the top of the Toarcian Stage. *Leioceras* aff. *opaliniforme* is recorded from the middle of the Dogger Formation at Ravenscar by Cope *et al.* (1980b) and hence the base of the formation here is presumed to be of basal Aalenian, Opalinum Subzone, age.

Knox (1984) attributed the discontinuous, but apparently cyclic, grain-size changes in the Upper Toarcian succession to a single underlying shallowing trend culminating in the intensely bioturbated sands at the top of the Yellow Sandstone Member. Brief episodes of epeirogenic uplift were superimposed on this coarsening-upwards trend. These are cycles which were linked to stages in the development of the North Sea dome. Knox (1984) noted that the incoming of chamositic ooliths and clay in the upper part of the Whitby Mudstone Formation, was associated with an influx of coarser sediment. He suggested that this material was swept into the area from lagoonal areas bordering the western margin of the Cleveland Basin. Hemingway's (1974) observation of chamosite enrichment at similar stratigraphical levels in the Rosedale area, some 30 km to the west of Ravenscar, lends support to this hypothesis. The overall upward grain-size increase from the Alum Shale Member to the Blea Wyke Formation is accompanied by a change from calcitic to sideritic concretions (Hallam, 19671)), and a changing and increasingly diverse benthic fauna (Dean, 1954). However, despite the upward shallowing indicated by these changes there is no evidence of littoral or restricted marine facies. Ammonites and brachiopods are present throughout and indicate that fully marine conditions prevailed throughout the Whitby Mudstone and Blea Wyke Sandstone formations and into the Dogger Formation (Knox, 1984).

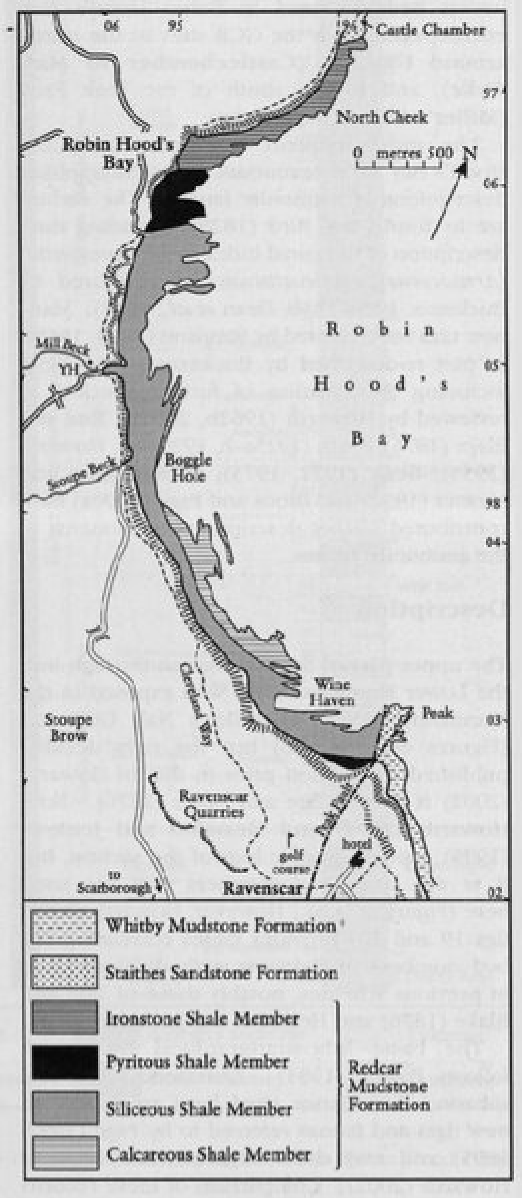
It is unclear whether Upper Toarcian sediments similar to those at the Miller's Nab to Blea Wyke GCR site were once present throughout the Cleveland Basin. Knox (1984) considered it unlikely that a continuous and uniform spread of such sediments had existed. At Ravenscar the succession thins from south-east to north-west, and there are rapid thickness and facies changes in the late Toarcian successions preserved in several inland sub-basins (Hemingway, 1974). The absence of derived phosphate nodules in the Blea Wyke Sandstone Formation was taken by Knox (1984) as evidence that there was little, if any, erosion of older sediments. Alexander (1986) considered that fault activity started during the Toarcian Stage and was responsible for the thick Middle Jurassic sands in the Peak Trough area. Milsom and Rawson (1989) and Rawson and Wright (1995) considered that Upper Toarcian sediments were preserved in small troughs.

The Toarcian succession at this GCR site is strikingly different from those in the Wessex Basin both on the Dorset coast and at the Hurcott Lane Cutting and Babylon Hill GCR sites. In the Wessex Basin, the Beacon Limestone Formation, rarely more than 2–3 m thick but encompassing seven ammonite zones, is overlain by the Bridport Sand Formation which spans only two ammonite zones but is 70 m thick. Farther north, in the Severn Basin, the Lower Toarcian sequence is typically developed in more expanded mudstone facies, reaching a thickness of almost 100 m north of Cheltenham (Whittaker and Ivimey-Cook, 1972), but the Upper Toarcian sequence is mostly in a condensed sand or carbonate facies only a few metres thick as, for instance, at the Wotton Hill GCR site. Toarcian successions on the East Midlands Shelf and in the Hebrides Basin are far from complete and the only other succession comparable with that at Ravenscar is the extraordinarily thick sequence seen in the Mochras Borehole. At nearly 262 m thick it is more than twice as thick as that at Ravenscar, comprising a rather monotonous series of mudstones with subordinate limestones and nodule bands (Woodland, 1971). The Mochras succession shows no evidence of an overall coarsening-upwards sequence comparable with that in passing from the Alum Shale Member to the Yellow Sandstone Member at Ravenscar.

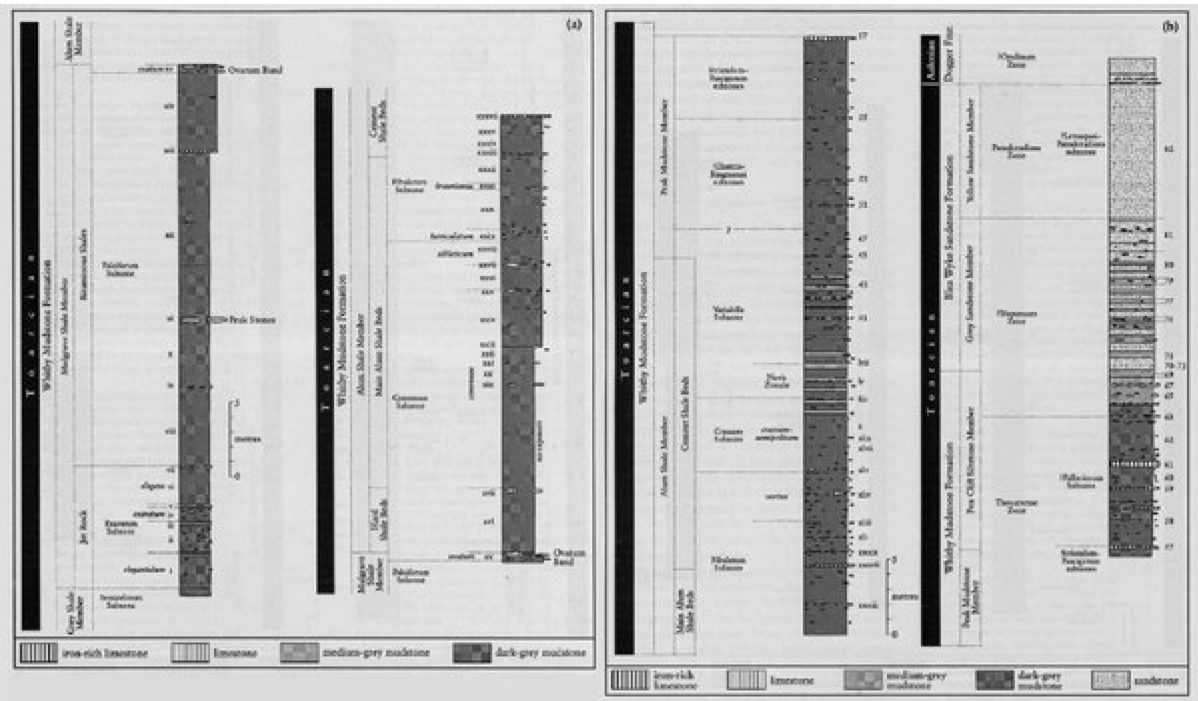
Conclusions

The Toarcian succession at Ravenscar represents the most complete and expanded section of this part of the Lower Jurassic sequence exposed anywhere in Britain. It provides the only substantial evidence for late Toarcian events in the Cleveland Basin and is the type locality for the two uppermost members of the Whitby Mudstone Formation, and for the Blea Wyke Sandstone Formation and its two constituent members. As such it is likely to form a cornerstone of any future work on this much neglected subdivision of the Jurassic System in Britain. It contrasts strikingly with the truncated Toarcian sections seen farther north in the Cleveland Basin, where only the Lower Toarcian sequence is preserved beneath the unconformity at the base of the Dogger Formation.

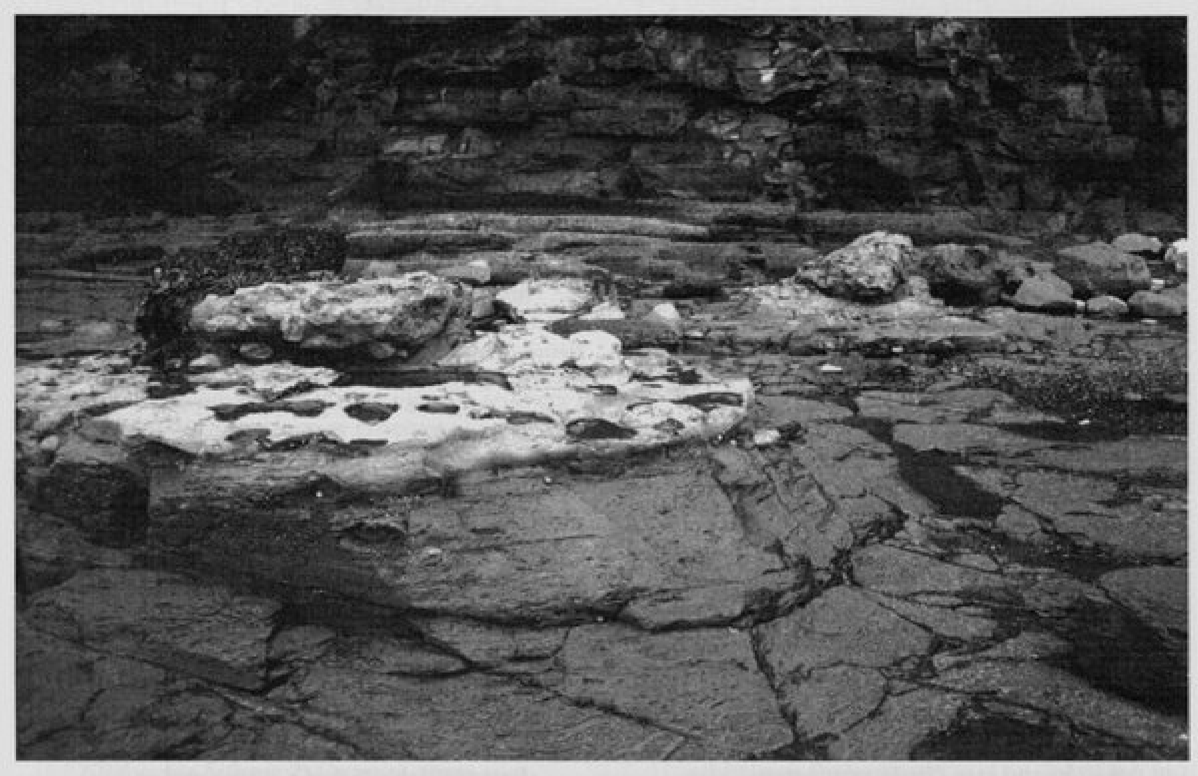
References



(Figure 6.6) Outcrop map of Lower Jurassic strata on the foreshore around Robin Hood's Bay. After Rawson and Wright (1992).



(Figure 6.12) a. The Lower Toarcian succession exposed at Blea Wyke. Based on Hesselbo and Jenkyns (1995) and Howarth (1962a). b. The Lower and Upper Toarcian succession exposed at Blea Wyke. Based on Hesselbo and Jenkyns (1995) and Howarth (1962a).



(Figure 6.13) Concretions of the Peak Stones at least 1.5 m in diameter (Bed xi of Howarth, 1962a) in the Bituminous Shales of the Mulgrave Shale Member (Falciferum Subzone), on the shore below Ravenscar Hotel. (Photo: K.N. Page.)