Hock Cliff, Fretherne, Gloucestershire

[SO 725 093]

Potential GCR site

M.J. Simms

Introduction

Exposures of upper Hettangian and Lower Sinemurian strata occur at several localities along the tidal reaches of the River Severn between Gloucester and Sharpness. These include river cliffs at Maisemore [SO 818 216] (Richardson, 1906c), Fretherne [SO 725 093] (Richardson, 1908; Henderson, 1934) and Purton [SO 695 045] (Woodward, 1728; Weaver, 1824; Woodward, 1893) and foreshore exposures at Awre [SO 706 074] (Witton, 1830), Arlingham [SO 712 098] and Gatcombe [SO 685 057]. By far the most extensive of these is that at Hock Cliff near Fretherne, about 10 km south-west of Gloucester (Figure 4.1), a site that represents the best exposure in the Severn Basin of the Blue Lias Formation. It exposes limestone–mudstone rhythms that pass up into a sequence with more widely spaced limestones, transitional to the Charmouth Mudstone Formation. The site has yielded an exceptionally diverse macro- and microfauna, including the type specimens of several bivalve species and holothurian morphospecies, undescribed species of asteroid and ophiuroid, and two ammonite genera unique in the British Lias.

The earliest description of the site was by George Cumberland in 1822. Brodie (1853) gave a further short account; a fuller description, with coloured sections, was published by Lucy (1883). The site was mentioned briefly by Woodward (1893), who ascribed the strata to the Angulata, Bucklandi and possibly higher zones. Richardson (1908) provided the first detailed stratigraphical description, concluding from ammonite evidence that the strata could be assigned a 'marmorae-birchi' age (= Angulata to Turneri zones of the present system) or even a 'possible extension to megastomatos-obtusi' (= Laqueus to Obtusum subzones). However, he stated subsequently (Richardson, 1910a) that 'the topmost limestones of marmorea hemera are just visible at low tide and are succeeded by nodule-lined clays of rotiformis–gmuendensis and possibly later hemerae' (= topmost Angulata Zone to Lyra Subzone). In a short note on the section Trueman (1922a) stated that 'it appears from recent observations that no beds lower than the bucklandi zone are present'. Henderson (1934) gave a more detailed account of the fauna although her stratigraphical section was essentially the same as that of Richardson (1908). Other accounts have been concerned solely with aspects of the fossil fauna. Ager (1954) figured material of two rhynchonellid species from here and Simms (1989) described crinoid material from the site. Gilliland (1992) gave a summary graphic log of the succession and figured numerous holothurian spicules, including several new species based on material from the site.

Description

The Lower Lias exposed at Hock Cliff extends for almost 1 km along the shore of the Severn Estuary a few hundred metres to the south-west of the village of Fretherne (Figure 4.3). At low tide a more than 17 m-thick succession of mudstones with subordinate limestone bands is exposed in the cliff and foreshore (Figure 4.4) and (Figure 4.5), with the lowest limestone forming a ledge extending more than 100 m into the river. A minor anticlinal fold occurs in the middle part of the section, and a small but conspicuous asymmetric anticline is present towards the eastern end of the cliff. Slight flexuring occurs at the extreme western end, but the strata in the western half of the cliff are almost horizontal. East of the central anticline they dip gently east so that the highest part of the succession is present only towards the eastern end. The section reproduced here is based on measurements made in 1999 and 2002 and observations made on numerous visits since 1976. Equivalent bed numbers used by Richardson (1908) are included in parentheses; these are the same as those used subsequently by Henderson (1934).

	Thickness (m)
29: Mudstone, yellowish-weathered (Bed 1).	0.45

28: Yellow Limestone. Limestone, grey, shelly, weathering yellow (Bed 2). *Arietites bucklandi, Coroniceras lyra, Arnioceras ceratitoides. Cuneirhynchia oxynoti* abundant, *Cenoceras* sp., *Plagiostoma giganteum, Gryphaea arcuata, Chlamys.*	0.15
27c: Mudstone, grey- to yellow-weathered.	*c.* 1.2
27b: Paper shale, dark grey-brown, well laminated. Fish debris.	0.22
27a: Mudstone, grey, shaly.	0.45
26: Limestone, impersistent, grey, earthy.	0.20
25e: Mudstone, grey, shaly.	1.50
25d: Mudstone, dark grey, shelly.	0.40
25c: Mudstone, grey, shaly, passing downwards into;	0.30
25b: Shale, dark grey, passing downwards into;	0.10
25a: Mudstone, grey, shaly.	0.10
24: Limestone, impersistent.	0.12
23: Mudstone, grey, shaly, with pyritized burrows.	0.65
22: Limestone, fairly persistent.	0.15
21c: Mudstone, grey, shaly.	1.80
21b: Shale, dark grey.	0.08
21a: Mudstone, blue-grey, with occasional limestone lenticles.	0.65
20: Limestone, persistent (Bed 10). In places with an abundant benthic fauna including *Gryphaea, Plagiostoma, Antiquilima, Chlamys, Oxytoma, Isocrinus* and *Miocidaris.*	0.20
19c: Mudstone, grey, shaly, with burrow mottling towards top. Spines of *Miocidaris lobatum* abundant at base.	0.60
19b: Mudstone, dark grey, shaly.	0.10
19a: Mudstone, grey, shaly, with burrow mottling towards base. *Hybodus* tooth. Pyritized *Arnioceras* sp. common throughout beds 19a–c.	0.65
18: Limestone, persistent (Bed 12). *Eucoroniceras sinemuriense.*	0.16
17d: Clay, dark grey, shaly. Pyritized multi-costate *Coroniceras.*	0.11
17c: Clay, grey, shaly, with occasional shelly limestone lenses.	0.36
17b: Limestone, impersistent, lenticular. Fossiliferous on upper surface.	0.12
17a: Clay, grey, shaly. *Charmasseiceras cbarmassei.*	0.72
16: Limestone, persistent (Bed 14).	0.20
15: Mudstone, grey, with occasional shelly limestone lenticles (Bed 15). *Charmasseiceras charmassei. Piarorhynchia juvensis* abundant throughout. *Gryphaea arcuata* abundant 0.3 m below top, commonly as intact specimens. *Zeilleria* sp..	0.60
14: Limestone, fairly persistent (Bed 16). *Cenoceras striatus.*	0.12
13c: Mudstone, grey, shaly, with abundant, dark, burrow mottling. *Charmasseiceras charmassei,* abundant *Piarorhynchia juvensis,* occasional bio-eroded *Gryphaea* valves, *Pleurotomaria anglica, Oxytoma inequivalvis, Camptonectes* sp., *Isocrinus psilonoti.*	0.72

13b: Shale, dark grey, very well-laminated. Many pyritized burrows.	0.05
13a: Mudstone, blue-grey. *Oxytoma inequivalvis, intact Gryphaea arcuata* and plesiosaur rib.	0.35
12: Limestone, rather constant, tabular (Bed 18). Abundant *Gryphaea arcuata Cenoceras striatus.*	0.12
11: Mudstone, blue-grey, darker and more shaly in top 0.12 m. Abundant shell debris and darker *Diplocraterion* burrows. *Charmasseiceras charmassei.*	0.36
10: Limestone, rather impersistent (more so than beds 6 or 8). *Charmasseiceras charmassei.*	0.08
9c: Mudstone, blue-grey, shaly, darker towards base and with paler burrow mottling. Worn ichthyosaur vertebra and bio-eroded *Gryphaea.* Passes down into;	0.28
9b: Shale, dark grey, very well-laminated, with conspicuous jointing and forming prominent break in shale slope. *Charmasseiceras charmassei.* Passes down into;	0.08
9a: Mudstone, blue-grey, becoming darker towards top. Burrow mottling in upper part and abundant dark *Diplocraterion* burrows in the lower part. *Gryphaea arcuata.*	0.22
8: Limestone, rather impersistent and forming irregular lenticular masses.	0.12
7e: Mudstone, fairly dark-grey, very shaly. *Gryphaea* common and commonly highly bio-eroded.	0.09
7d: Shale, dark-grey, well laminated.	0.05
Mudstone, blue-grey, shaly. *Gryphaea* common and commonly highly bio-eroded.	0.08
7b: Mudstone, dark grey, shaly. Forms conspicuous break on shore.	0.04
7a: Mudstone, blue-grey, shaly. *Charmasseiceras, Gryphaea* common, sometimes bio-eroded.	0.30
6: Limestone, rather impersistent and forming irregular lenticular masses (Bed 20). Driftwood.	0.12
Shale, fairly dark-grey. *Charmasseiceras, Gryphaea* common.	0.15
Shale, dark grey, well laminated, forming break on shore.	0.03
5a: Mudstone, blue-grey, shaly, with occasional limestone lenticles and nodules. Crinoid and echinoid debris common, particularly in limestone lenticles. Pyritized and crushed 0.3 m-diameter *Coroniceras* cf. *rotiforme.*	0.30
4: Limestone (Bed 22).	0.10
3c: Mudstone, blue-grey, shaly.	0.25
3b: Shale, dark grey, very well-laminated, particularly in upper part. *Coroniceras ? rotiforme, Vermiceras scylla.*	0.10
3a: Mudstone, blue-grey, shaly. Crinoid and echinoid debris common in shelly patches.	0.22
2: Limestone, grey, persistent, forming conspicuous wide ledge at northern end of cliff at low tide (Bed 24). Upper 0.05 m bluish and rather softer and contains common *Vermiceras scylla.*	0.25

1: Mudstone, grey, fossiliferous, exposed only at northernmost end of foreshore during low tides (Bed 25). *Vermiceras scylla, Gryphaea arcuata, Camptonectes* sp., *Isocrinus psilonoti, Miocidaris* spines.	0.45 (seen)

Earlier accounts of the section (Richardson, 1908; Henderson, 1934) generally lacked detail, distinguishing only mudstones from limestones, but it is clear that the mudstones show significant facies variations. Nine persistent limestone bands can be recognized in the cliff and foreshore. A further six, although impersistent, are sufficiently well-developed to be easily traced along the cliff section, but other isolated limestone lenticles occur sporadically at any level, commonly associated with fossil debris. The lower part of the succession (beds 1 to 14) shows a fairly distinct rhythmicity closely comparable with that considered typical of the Blue Lias Formation by Hallam (1964a), with thin, dark, commonly pyritic, well-laminated shale units occurring towards the middle of the paler, bioturbated mudstones that separate the limestones. Above Bed 14 these rhythms are indistinct or absent and the limestone bands are, in general, more widely spaced. The abundance of *Gryphaea* in Bed 12 and towards the top of Bed 15 render these useful marker horizons for both the eastern and western parts of the cliff. The yellow-weathering shelly limestone of Bed 28 is particularly conspicuous as fallen blocks towards the eastern end of the section, although it may be difficult to locate in *situ.*

Other than Bed 28, which contains fairly abundant brachiopods, bivalves, ammonites and echinoderm debris, the limestone bands are, in general, rather poorly fossiliferous. With the exception of ammonites, large specimens of the nautilus *Cenoceras,* and *Gryphaea,* fossils are largely confined to localized patches on the upper surface of the limestones and commonly are associated with these large cephalopods or with large pieces of driftwood. Within the mudstones benthic macrofossils also tend to be concentrated at certain horizons or in localized patches. For example, the brachiopod *Piarorhynchia fuvensis* is abundant throughout Bed 15 whereas spines of the echinoid *Miocidaris lobatum* are abundant at the base of Bed 19c. The richest accumulations tend to be associated with shelly and crinoidal limestone lenses that have a flat top and irregular base. Although much of the fossil material is broken and disarticulated, intact crinoids and ophiuroids have been found on the upper surface of some of these lenses. The thin, dark, well-laminated mudstone units in the lower part of the succession have yielded only ammonites, although vertical pyritized burrow-fills are common in Bed 13b. The other mudstones show varying degrees of bioturbation, with darker mudstones showing less disruption of lamination than paler units. Distinct *Chondrites* and *Diplocraterion* burrows are visible at several levels.

Most of the beds have only a limited foreshore outcrop and fossil material can be difficult to find in *situ in* the cliff. Nonetheless an exceptionally rich and diverse macrofauna has been recovered, primarily from loose material on the shore. Ammonites are common but often rather poorly preserved, immature and of poorly understood arietitid taxa. *Charmasseiceras charmassei* is not uncommon in the lower part of the section, while various small arietitids and *Arnioceras* dominate the upper part of the section. Large specimens of both *Arietites bucklandi* and *Coroniceras lyra* have been recovered from Bed 28, which also commonly contains *Arnioceras ceratitoides* (Spath, 1956). A large specimen of *Coroniceras* cf. *vercingetorix* was also figured from here by Wright (1878–1886) (as *Arietites bisulcatus;* see Donovan, 1954). More than 30 specimens of the Tethyan micromorph *Canavarites,* together with a few of the closely related genus *Pseudotropites,* have been found towards the eastern end of this site and appear confined to the upper part of the section. As such they represent unique records of these genera in the British Lower Jurassic sequence.

Bivalves are a common, and often conspicuous, element of the fauna with many typical Blue Lias Formation taxa represented. The site has long been known for the occurrence of numerous large examples of *Gryphaea arcuata* with both valves articulated, and articulated examples at all stages of growth are common. Indeed, this is the type locality for the subspecies *Gryphaea arcuata incurva* (Sowerby, 1815), one of the best known of British Lower Jurassic fossils; the holotype was re-figured by Hallam (1968b) and material from here has been used in investigations of the evolution of this genus (Hallam, 1968b; Johnson, 1993; Jones and Gould, 1999). The holotype of *Antiquilima antiquata* (Sowerby, 1815) was also from here, as were three nominal species of *Cardinia — C. cuneata, C. ovalis* and *C. imbricata* — described by Stutchbury (1842) and re-figured by Palmer (1975).

Brachiopods are fairly common, particularly at two horizons; with *Piarorhynchia juvensis* abundant in the mudstones of Bed 15 and *Cuneirhynchia oxynoti* in the uppermost limestone, Bed 28. Ager (1956–1967) used material from this site to obtain serial sections of both species. The terebratulid *Zeilleria perforata* has been recorded occasionally, from Bed 18 (Richardson, 1908) and from Bed 15. Davidson (1851–1852, 1876–1878) described a new species of inarticulate brachiopod, *Discinisca* (= *Orbicula*) *townshendi* from here although initially he incorrectly attributed it to the Oxford Clay of southern England. With a diameter of 42 mm and height of 16 mm this was the largest species known to him.

The echinoderm fauna recorded from this site is the most diverse in the British Lias from such a limited stratigraphical interval, with three species of crinoid (Simms, 1989), at least three species of echinoid, three species of asteroid, two species of ophiuroid and at least six holothurian sclerite morphospecies (Gilliland, 1992). Two of the holothurian sclerite morpho-species were based on material from here, while undescribed species of an asteroid, *Terminaster,* and an ophiuroid, *Ophiocantha, are* the earliest known representatives of the family Zoroasteridae and suborder Laemophiurinae respectively (Simms *et al.,* 1993). Most of the echinoderm material is disarticulated, with columnals of *Isocrinus psilonoti* and plates and spines of *Miocidaris lobatum* being by far the dominant component of this fauna, but examples of all but the holothurians have also been found articulated, sometimes preserved in the finest detail (Figure 4.6). The site is of key importance for understanding the evolution of the *Isocrinus* clade, having yielded material transitional between *Isocrinus psilonoti* and *Isocrinus tuberculatus* (Simms, 1988).

Other more occasional elements of the macro-fauna include encrusting bryozoa (Richardson, 1908), the solitary coral *Montlivaltia hairnet,* decapod crustacea and the belemnite *Nannobelus acutus.* A rich fauna of small pyritic gastropods and bivalves remains to be investigated. The vertebrate fauna is known only from fragmentary remains since little in-situ material has been found. Isolated bones and teeth of ichthyosaurs and, less frequently, plesiosaurs are not uncommon; most are from rather small individuals, with vertebral centra rarely exceeding 5 cm in diameter. The most frequently found fish remains are the teeth of *Acrodus,* but fragmentary remains of several other typical Lower Jurassic genera have also been found. Of these the most significant are a fin spine and part of a head spine of the early chimaeroid *Metopacanthus granulatus.*

A rich and diverse microfauna is present and has formed a topic of discussion from some of the earliest publications pertaining to this site (Brodie, 1853), though much of this early work needs to be re-interpreted in terms of modern taxonomy. Both Richardson (1908) and Henderson (1934) gave lists of species of foraminifera from several of the mudstone units; this was one of many GCR sites investigated by Copestake (1989). Gilliland (1992) also reported very high yields of holothurian spicules from some mudstones at this site.

Interpretation

Correlation between the section recorded here and those published by Richardson (1908) and Henderson (1934) is straightforward for parts of the succession but less clear for others. In the lower part of the section there is a good match from beds 1 to 7 of this account, correlating with beds 25 to 19 of Richardson (1908). However, more than 1 m of strata above this, corresponding to beds 8 to 11 of this account, is unrepresented in the earlier descriptions. Presumably this was due to an oversight by Richardson, an error unfortunately perpetuated by Henderson (1934) who appears merely to have transcribed Richardson's bed thicknesses without actually re-measuring the section. Beds 12 to 22 of the section here correlate fairly well with beds 18 to 8 of Richardson (1908), based on his description and photograph of the western end of the cliff. The highly distinctive limestone of Bed 28 here obviously correlates with Richardson's Bed 2, but it has proven impossible to resolve his description of beds 3 to 7 with beds 23 to 27 of the present section.

The age range of the succession exposed at Hock Cliff is now well-constrained, although further work is needed to refine the ammonite sequence within these limits. *Vermiceras scylla* occurs in beds 1, 2 and 3b, and poorly preserved *Coroniceras* cf. *rotiforme* in Bed 5a, establishing that the lowest 1.5 m of the succession lies within the Rotiforme Subzone. *Coroniceras lyra* in Bed 28 demonstrates that at least the top 0.6 m of the section can be assigned to the Lyra Subzone (Page, 1992). The remainder, more than 14 m, is assumed to lie entirely within the Bucklandi Subzone. Although the succession here is obviously less condensed than the well-documented type succession of the Blue Lias Formation in the Keynsham area, near Bristol, where the combined Bucklandi and Semicostatum zones may be only 6 m thick and packed with ammonites (Donovan, 1956), the occurrence at Hock Cliff of *Arietites bucklandi* and *Coroniceras lyra in the* same limestone, Bed 28, is unique in the British Lias. Further work on the ammonite faunas at this site may help to identify some of the biohorizons within the Bucklandi Subzone described by Page (1992); the highest of these is known to be present from the occurrence here of *Coroniceras vercingetorix.* The presence at this site of the Tethyan micromorphs *Canavarites* and *Pseudotropites* is unique for the British Isles: it may relate to the widely observed eustatic sea-level rise in early Sinemurian times (Hallam, 1978, 1981; Hesselbo and Jenkyns, 1998) allowing dispersal of these southern taxa into the region. Their apparent absence from other well-documented sites of this age in southern Britain may reflect preservation or collection failure.

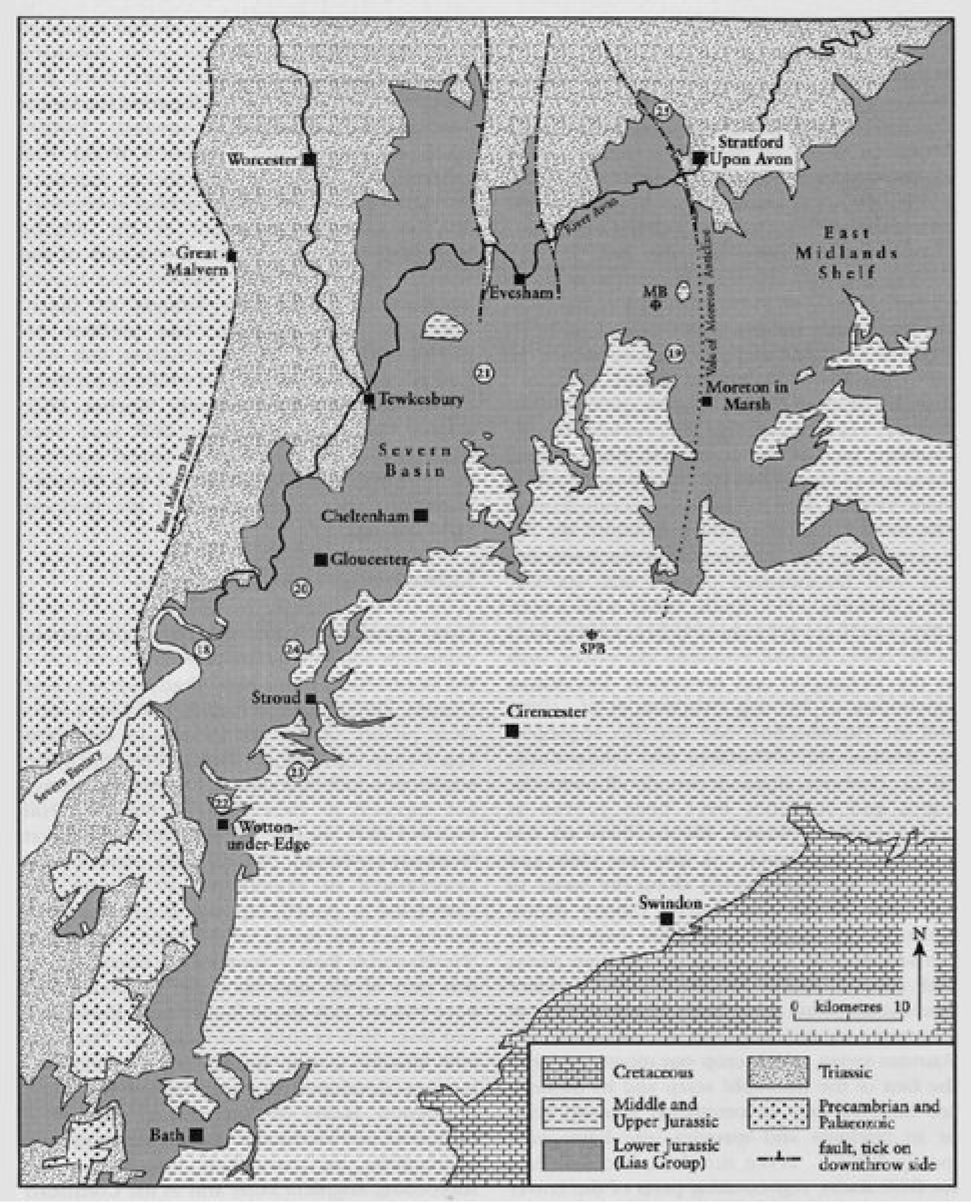
At more than 14 m, the Bucklandi Subzone here is substantially thicker than on the Dorset coast or in the Bristol district (Donovan and Kellaway, 1984), though less than a fifth of that on the north Somerset coast and only about half of that in the Stowell Park Borehole (Spath, 1956). This suggests that during early Sinemurian times Hock Cliff lay in a less actively subsiding graben or half-graben within the Severn Basin, perhaps reflecting its position less than 4 km from the western margin of the basin (Figure 4.1).

The succession at Hock Cliff appears to record the upward transition from facies typical of the Blue Lias Formation to those more typical of the Charmouth Mudstone Formation. The pattern of limestone–mudstone rhythmicity described by Hallam (1964a) becomes increasingly indistinct above Bed 14 while the limestone bands become more widely spaced. These changes probably reflect an interplay between several factors, such as climate, sea level and basin subsidence rates. The ubiquity of the transition to Charmouth Mudstone Formation facies suggests exogenic control, such as climate or sea-level change; Hesselbo and Jenkyns (1998) suggest a sharp rise in sea level from the late Bucklandi Zone to the early Semicostatum Zone. However, since the formational boundary appears to be diachronous, for instance occurring earlier here in the Severn Basin than on the Dorset coast in the Wessex Basin, endogenic factors, in the form of differences in basin subsidence rates or sediment supply, must also be significant. The succession at Hock Cliff shows that sedimentation rates were not constant in this part of the Severn Basin. Reduction or cessation of sedimentation for brief periods is indicated by burrowed horizons within several of the mudstone units and by the severely bio-eroded *Gryphaea* in beds 7, 9 and 13. Irregular shallow scours up to 1–2 m across and 0.15 m deep are not uncommon, typically now occupied by flat-topped shelly and crinoidal limestone lenticles. Concentrations of intact *Miocidaris* tests (Figure 4.6) or articulated crinoid or ophiuroid remains are sometimes associated with these scour infills, either at their base or top. They are classic obrution deposits (Seilacher *et al.,* 1985) and testify to sudden influxes of fine-grained sediment, perhaps generated by storm activity. Hallam (1968b) noted a much higher proportion of specimens of *Gryphaea* with the valves articulated than was typical of other sites. This appears to hold true for all growth stages of this bivalve, suggesting sedimentation rates often were sufficiently high to prevent the valves disarticulating. Benthic oxygen levels also experienced significant variation, from the thin, dark, finely laminated mudstones deposited under anoxic conditions to the paler, bioturbated mudstones with a locally abundant benthic fauna, deposited in well-oxygenated conditions.

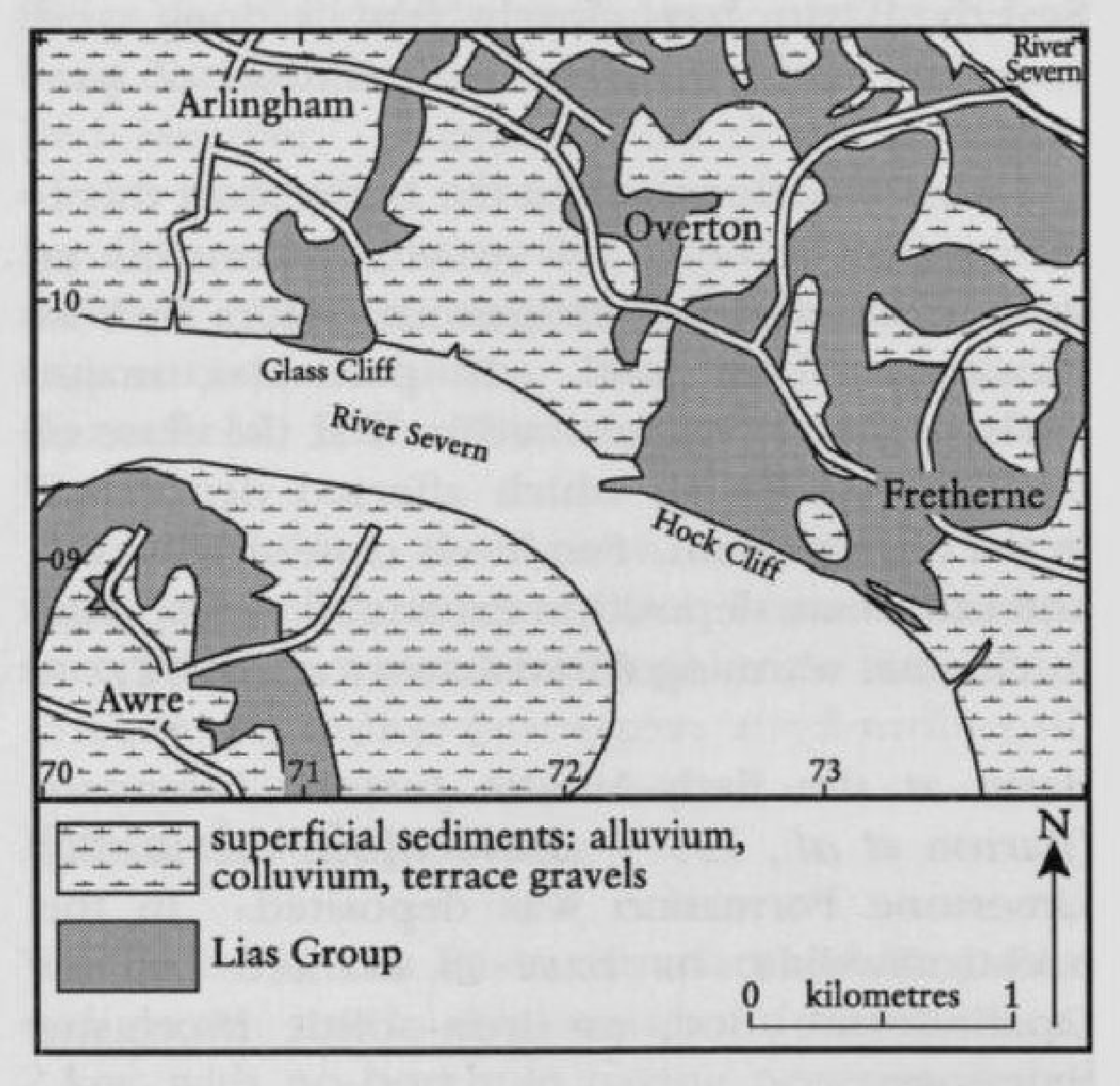
Conclusions

The exposure at Hock Cliff represents the finest (Lower Sinemurian) Blue Lias Formation and basal Charmouth Mudstone Formation section in the Severn Basin. It differs substantially in thickness from correlative strata on the Dorset coast, north Somerset coast and the Bristol–Bath area, thereby providing information on regional differences in subsidence rates and palaeoenvironments between three adjacent depositional basins and their margins. The unusually rich fauna from this site provides critical information on the palaeoecology, evolution and migration of several fossil groups.

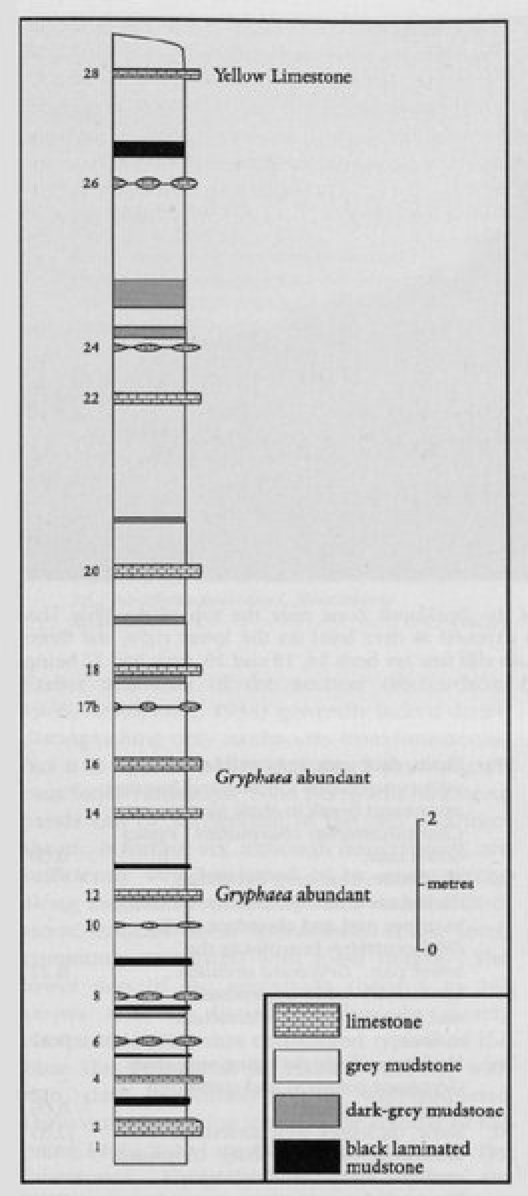
References



(Figure 4.1) Generalized geology of the Severn Basin and western edge of the East Midlands Shelf. Only the main basin-bounding faults are indicated. Numbers correspond to the locations of the GCR sites: 18 — Hock Cliff; 19 — Blockley Station Quarry; 20 — Robin's Wood Hill Quarry; 21 — Alderton Hill Quarry; 22 — Wotton Hill; 23 — Coaley Wood; 24 — Haresfield Hill; 25 — Newnham (Wilmcote) Quarry (Chapter 5); MB — Mickleton Borehole; SPB — Stowell Park Borehole.

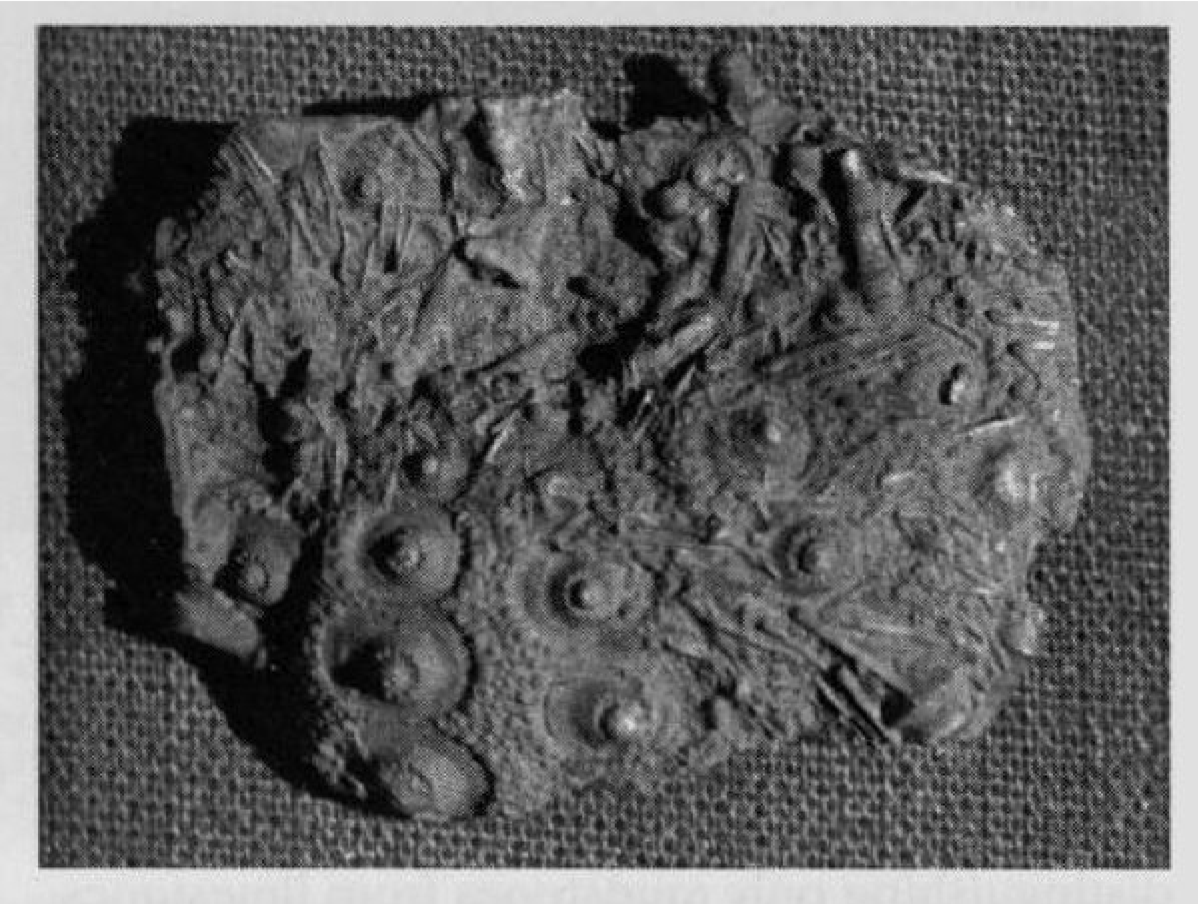


(Figure 4.3) Geology and location map for the Hock Cliff GCR site.



(Figure 4.4) Simplified graphic log of the succession exposed at Hock Cliff, Fretherne.

(Figure 4.5) Alternating mudstones and limestones of the Bucklandi Zone near the top of the Blue Lias Formation at Hock Cliff, looking eastwards. Bed 2 is exposed at river level on the lower right; the three conspicuous limestone bands in the lower half of the main cliff face are beds 16, 18 and 20, with Bed 22 being the fainter band about 2 m higher. (Photo: M.J. Simms.)



(Figure 4.6) Intact test (32 mm across) of the echinoid Miocidaris lobatum, from the lower part of the Bucklandi Subzone at Hock Cliff. Isolated plates and spines of this species are one of the most common elements of the exceptionally rich and diverse echinoderm fauna at this site. (Photo: M.J. Simms.)