Blue Anchor–Lilstock Coast, Somerset

[ST 033 436]–[ST 194 461]

Introduction

The Blue Anchor–Lilstock Coast GCR site stretches through almost continuous cliffs for 20 km along the coast between the eastern end of Blue Anchor Bay [ST 033 436] and Lilstock [ST 194 461] (Figure 2.17). The cliffs expose a section of between 160 m and 200 m of Lower Lias, which rests conformably on the Penarth Group (Upper Triassic). The succession is complicated by numerous faults, that repeat parts of the section, but the presence of distinctive marker bands allows correlation between fault blocks.

The series of sections provides an almost unbroken succession from the Penarth Group, through the Hettangian Stage and into the Lower Sinemurian Substage (Figure 2.18). It is developed largely in offshore facies of the Blue Lias Formation, characterized by alternating limestones and mudstones in varying proportions. The Blue Lias Formation succession here is the thickest succession in Britain other than that proven in the Mochras Borehole. The section is internationally significant for its exceptionally complete, and abundant, succession of ammonite faunas. Part of this site has been designated as Global Stratotype Section and Point (GSSP) for the base of the Sinemurian Stage, and part has been proposed as a potential GSSP for the base of the Hettangian Stage and of the Jurassic System.

The section is invaluable for comparison with correlative sections at other GCR sites in south Wales and those on the Dorset–Devon coast. The Blue Anchor–Lilstock Coast section has the advantage over these other sites in that the succession is substantially expanded, recording a virtually unbroken period of sedimentation, and fault-repetition of parts of the sequence provides access to greater volumes of any particular stratigraphical horizon than is possible at the other sites.

Horner (1816) was the first to refer to the Lias of the Somerset coast, but he considered that the numerous faults prevented accurate measurement of the succession. Furthermore, the faulting led him to believe that the red marls of the Mercia Mudstone Group (Upper Triassic) were interbedded with the Lias. A series of later papers (Dawkins, 1864; Etheridge, 1872; Bristow and Etheridge, 1873; Richardson, 1911) concentrated largely on the Penarth Group, with little more than passing mention of any parts of the succeeding Lias. Woodward (1893) was the first to provide a detailed account of the Lias, although he greatly under-estimated its thickness at about 50 m. He subdivided the Lias into five units and was the first to recognize that the Blue Lias Formation facies, of alternating limestones and mudstones, was interrupted by two thick mudstone developments. Later accounts by Arkell (1933) and Macfadyen (1970) were based largely on that of Woodward (1893) and it was to be almost 80 years before the first detailed stratigraphical description was published, by Palmer (1972). He established correlations between fault blocks and recognized seven major units. Each of these was assigned a formal name and accompanied by bed-by-bed descriptions of lithology and fauna.

Hamilton and Whittaker (1977) briefly described the Triassic and Jurassic succession between Blue Anchor and Watchet, and Whittaker and Green (1983) published a detailed description of the succession. This latter description was similar to that of Palmer (1972), but divided the succession into five, rather than seven, units that were not formally named. Bessa and Hesselbo (1997) published gamma-ray logs for the succession that they used to define 10 gamma-ray units, while Hesselbo *et al.* (2002) analysed carbon isotopes from the top of the Blue Anchor Formation (Upper Triassic) into the base of the Blue Lias Formation at St Audrie's Bay. Micropalaeontological elements of the succession have been described in papers dealing with foraminifera (Copestake and Johnson, 1989; Hylton, 1998), ostracods (Lord and Boomer, 1990), palynomorphs (Warrington, 1983, 1985; Warrington and Ivimey-Cook, 1990) and coccoliths (Hamilton, 1982). The reptilian vertebrate fauna has been summarized by Benton and Spencer (1995). Invertebrate macrofossils, other than ammonites, have been little investigated.

The ammonite faunas have formed the primary focus of attention on account of their biostratigraphical value (Ivimey-Cook and Donovan, 1983). Watchet is the type locality for the ammonite *Psiloceras planorbis,* the index species for the basal zone and subzone of the Jurassic System. Consequently Watchet and, more recently, St Audrie's Bay (Figure 2.19) have been proposed as stratotypes for the Triassic–Jurassic boundary, with the precise horizon being defined on the basis of lithostratigraphy (Whittaker, 1978; Hallam, 1990b,c), geochemistry (Hesselbo *et al.,* 2002) or biostratigraphy, in particular the first appearance of *Psiloceras,* including *P. planorbis* (Cope *et al.,* 1980a; Cope, 1990; Hodges, 1994; Page, 1994a; Page *et al.,* 1994; Warrington *et al.,* 1994; Bloos, 1997; Page and Bloos, 1998; Bloos and Page, 2000b). The Sinemurian part of the succession is of considerable importance for its ammonite faunas and has furnished data crucial to the establishment of a number of ammonite-correlated horizons within the Lower Sinemurian Substage (Page, 1992). A section at East Quantoxhead, some 4 km west of Lilstock, has been designated as the Global Stratotype Section and Point (GSSP) for the Hettangian–Sinemurian boundary (Figure 2.20) (Page, 1994b,c; Bloos and Page, 2000a, 2002; Page *et al.,* 2000).

The faulting exposed in the cliffs and foreshore within the GCR site has been investigated by Chadwick (1986), Miliorizos and Ruffell (1998) and Peacock and Sanderson (1999) with respect to the development of the Bristol Channel and Central Somerset basins. Peacock and Sanderson (1999) proposed that the present southern margin of the Bristol Channel Basin is bounded by the North Quantocks Fault, with a downthrow of at least 1 km. As evidence they cited the striking change in relief between the Palaeozoic uplands of the Quantock Hills and the low Mesozoic plain to the north, the southward dip of the Mesozoic strata that developed as a rollover or reverse drag into a large northward-dipping fault just to the south, the high density of faulting on the coast nearby, and the complete lack of marginal facies anywhere in the exposed Mesozoic succession. They also suggested the existence of a second fault to the west, the North Exmoor Fault, developed on a similar scale and offset by several kilometres to the north along the Watchet–Cothelstone–Hatch Fault System. The existence of the North Quantocks Fault implies that the Blue Anchor–Lilstock Coast GCR site lies entirely within the south-eastern part of the Bristol Channel Basin, whereas defining the boundary between this and the Central Somerset Basin places only the westernmost part of the site within the Bristol Channel Basin.

The most recent general account of the stratigraphy of the sections within the GCR site, summarizing much of the earlier work, is that by Warrington and Ivimey-Cook (1995).

Description

Palmer (1972) and Whittaker and Green (1983) have provided detailed descriptions of the Lower Jurassic succession exposed within the GCR site. Their accounts are broadly in agreement, although correlation of individual beds can be difficult. The bed numbers used here are those of Whittaker and Green (1983). Their logs also differ in minor respects from other published logs of the basal Lias (Hodges, 1994; Page and Bloos, 1998: Bloos and Page, 2000a) and of the Hettangian–Sinemurian boundary (Bloos and Page, 2000b, 2002; Page *et al.,* 2000; Page, 2002). In places the section is disrupted by faulting, both normal and reverse, and Peacock and Sanderson (1999) noted that the complexity of deformation is greater in the Lilstock area than in the Kilve–Watchet area. Among the largest of the faults are the Doniford Bay Fault [ST 0840 43630], which throws down Semicostatum Zone strata to the south against red and grey mudstones of the Mercia Mudstone Group, and the Blue Ben Fault [ST 202 4376], which brings Bucklandi Zone strata against red mudstones of the Mercia Mudstone Group. The Watchet Fault, a major transcurrent fault (Whittaker, 1972a) intercepts the coast about 1 km west of Watchet and is outside the GCR site.

The base of the Lias Group was taken by Whittaker (1978; Whittaker and Green, 1983) at the base of a fissile mudstone that rests on a hard, grey, calcareous mudstone, up to nearly 1 m thick, which separates it from the pale limestone of the Sun Bed beneath. The Sun Bed itself is a marker band that can be traced throughout southern England. Palmer (1972) placed the base of the Lias immediately above the Sun Bed.

The lowest part of the Lias succession is exposed at several points along the coast, including Doniford Bay and Lilstock Bay, but it can be examined most easily in the cliff at St Audrie's Bay (Figure 2.19). This section has been proposed as the Global Stratotype Section and Point GSSP) for the base of the Jurassic System (Warrington *et al.,* 1994) although, as noted by Bloos and Page (2000a), the ammonite sequence is actually better in Doniford Bay. Some 5 m of mudstones and rather nodular limestones at the base of the Lias are devoid of ammonites but contain a moderately diverse bivalve fauna. *Liostrea hisingeri,* a characteristic species of the basal Lias, occurs in some abundance at certain levels. The ammonite *Psiloceras, taken* as marking the base of the Jurassic System, has been found as low as Bed 8 (Figure 2.18) and (Figure 2.19) (Hodges, 1994), while Page and Bloos (1998) have identified a fauna of weakly ribbed *Psiloceras,* including *P. erugatum* (Bloos and Page, 2000a) and *Neophyllites,* below the typical smooth forms of *Psiloceras in* the lower part of the Planorbis Subzone. Unequivocal *Psiloceras planorbis* is abundant in beds 13 to 19. Bed 24 comprises 2 m or more of indurated laminated mudstone in which crushed iridescent specimens of *Psiloceras* ex. grp. *planorbis* are abundant; it is from Bed 24, or possibly beds 14 or 18, at either Doniford Bay or west of Watchet, that the lectotype of this species probably was obtained. The Planorbis Subzone is about 4.5 m thick at St Audrie's Bay and extends up to the base of Bed 25, a limestone band in which the appearance of *Caloceras* sp. marks the base of the Joluistoni Subzone. The latter comprises 3.4 m of limestones and mudstones. Hard laminated mudstones contain *Caloceras johnstoni* (in Bed 36) and *C. intermedium* (in Bed 37). Specimens of *Caloceras* from Doniford Bay, near Watchet, are iridescent, suggesting that this may be the source of the type of *C. johnstoni* described by J. de C. Sowerby (1824). The potential threat to these horizons from commercial exploitation has been discussed by Webber (2001). The base of the succeeding Liasicus Zone is indicated by the appearance of *Waehneroceras sensu lato* in Bed 43, with *Laqueoceras* appearing around Bed 67 to indicate the boundary between the Portlocki Subzone and the succeeding Laqueus Subzone. The Liasicus Zone is about 28 m thick and, particularly in its lower part up to about Bed 69, is dominated by mudstones with only subordinate limestones. The base of the Angulata Zone is taken at the appearance of *Schlotheimia* cf. *amblygonia* in Bed 80 and extends up to Bed 145 through some 40 m of mudstones and nodular limestones. The bases of the Complanata Subzone and the Depressa Subzone have been placed at the bases of beds 95 and 134 respectively by Bloos and Page (2000b). The ammonite faunas across the Hettangian–Sinemurian boundary have been documented in considerable detail (Page, 1994b,c, 2001; Bloos and Page, 2000b, 2002; Page *et al.,* 2000). Within a 27 m-thick sequence, from the upper Complanata to lower Rotiforme subzones, 15 distinct ammonite biohorizons have been recognized (Bloos and Page, 2002). From the Complanata into the Depressa subzones there is marked reduction in species diversity of *Schlotheimia,* the characteristic Angulata Zone genus. *Schlotheimia pseudomoreana is* present virtually throughout the Depressa Subzone but around the middle of the paper shale unit of Bed 145 the genus is abruptly replaced by an arietitid fauna dominated by species of *Vermiceras, V. quantoxense, V. palmeri* and *V. elegans,* from the basal Sinemurian Stage in the vicinity of the GSSP at Limekiln Steps, East Quantoxhead.

The first appearance of *Vermiceras quantoxense, V. palmeri* and *Metophioceras* occurs 0.9 m above the base of Bed 145, and this is taken as the base of the Bucklandi Zone and the Sinemurian Stage (Bloos and Page, 2002). Bessa and Hesselbo (1997) also placed one of their gamma-ray unit boundaries at the Hettangian–Sinemurian boundary on the basis of a marked increase in uranium concentration. Elsewhere in Britain and north-west Europe species of *Schlotheimia* are not found with *Vermiceras* and *Metophioceras* but, uniquely, they do occur together in the upper part of Bed 145 at this site. There is a rapid turnover of arietid faunas in the Conybeari Subzone enabling recognition of nine distinct ammonite biohorizons (Page, 2001; Bloos and Page, 2002). The lowest two of these have not been recognized elsewhere in northwest Europe and it is suspected that at most localities, including the Pinhay Bay to Fault Corner GCR site, they are represented by a hiatus. The Bucklandi Zone extends up to Bed 244, some 80 m higher in the succession and consists predominantly of mudstone, in part fissile and bituminous, with limestones, some of them laminated, at frequent intervals. Page (pers. comm.) has assigned beds 145 (upper) to 164 to the Conybeari Subzone (14.2 m thick) and beds 165 to 202 to the Rotiforme Subzone (32.6 m thick), though this differs by up to almost 9 m from the intervals cited by Whittaker and Green (1983) and reproduced in (Figure 2.18). Page (pers. comm.) assigned beds 203–?244 to the Bucklandi Zone (about 41 m thick). The remainder of the succession, about 50 m thick up to Bed 257, is mudstone dominated with only a few, mostly nodular, beds of limestone. Page (1992) assigned this part of the succession to the Lyra Subzone, recognizing three distinct ammonite horizons within this part of the succession at Doniford Bay. There is no conclusive evidence for higher subzones despite the supposed record of *Agassiceras* from a fault-bounded block at East Quantoxhead (Ivimey-Cook and Donovan, 1983). This has been re-determined as a *Coroniceras* sp. cf. *kridion* (K.N. Page, pers. comm.). The completeness of the succession has led to the recognition of a series of ammonite-correlated biohorizons. Page (1992) cited locations within the GCR site as stratotypes for 13 of these, but more are added as the ammonite stratigraphy is refined.

Fossils other than ammonites have been relatively little investigated. Palmer (1972) recorded a few of the more conspicuous taxa, notably bivalves and the trace fossil *Diplocraterion,* while Warrington and Ivimey-Cook (1995) provided lists of some of the more characteristic taxa. The macrofauna of the Planorbis Zone is dominated by a few species of bivalve, notably *Liostrea, Camptonectes, Protocardia* and *Pteromya.* The echinoids *Diademopsis* and *Eodiadema bechei* are also present and, rather remarkably in such a facies, occasional small pyritized colonies of the coral *Heterastraea* in the laminated mudstones of Bed 24. Fragmentary, or more rarely articulated, skeletons of ichthyosaurs and fish have been found in the Planorbis Zone and include an embryo within a large well-preserved ichthyosaur skeleton (Deeming *et al.,* 1993).

The macrofauna of the Liasicus Zone is more diverse than that of the Planorbis Zone, with a range of bivalve taxa (*Camptonectes, Gervillia, Lucina, Liostrea, Modiolus, Plagiostoma* and *Pseudolimea*) including the lowest *Gryphaea* (*Gryphaea* cf. *obliquata*) in this area. The macrofauna of the Angulata Zone, although relatively sparse, includes an increasing abundance of *Gryphaea arcuata* and the brachiopod *Calcirhynchia calcaria.* The lower part of the Bucklandi Zone also has a sparse fauna, but the fauna of the upper part (Bucklandi Subzone) is locally abundant and diverse. It indudes epifaunal and shallow infaunal bivalves together with rhynchonellid and terebratulid brachiopods, gastropods, serpulids and vertebrate remains.

Warrington and Ivimey-Cook (1995) summarized much of the micropalaeontological work that has been undertaken within the GCR site. Warrington (1983, 1985) found the Lower Jurassic spore, pollen and dinoflagellate cyst assemblages to be less diverse than those of the underlying Penarth Group, and to be dominated by conifer pollen such as *Classopolis.* The stratigraphical range of seven species of foraminifera at Watchet and St Audrie's Bay were listed by Copestake and Johnson (1989), but there are no published accounts of foraminifera from the GCR site except that of Hylton (1998), who examined foraminiferal assemblages across the Hettangian–Sinemurian boundary at East Quantoxhead. Of 35 sampled levels from the upper Angulata Zone to the Rotiforme Subzone (beds 135–170), Hylton (1998) found that most were barren and only 10, mostly in the Hettangian part of the succession, yielded foraminifera together with ostracods, echinoderm debris and microgastropods. These confirmed a microfaunal change across the Hettangian–Sinemurian boundary; *Lingulina tenera* plex. *substriata* are confined to the uppermost Angulata Zone while *Planularia inaequistriata* and the *Frondicularia terquemi* plexus group make their first appearance above the boundary. The ostracod fauna was investigated by Lord and Boomer (1990) for the latest Triassic and Hettangian successions at Watchet and St Audrie's Bay. The considerable stratigraphical overlap observed in some taxa prevented some of the ostracod subzonal boundaries being defined.

The mudstones within the succession vary in their colour, carbonate and organic content, and in the extent of bioturbation. Medium-to dark-grey, mostly non-fissile to only poorly fissile, blocky and calcareous mudstones are dominant but dark, brownish-grey, well-laminated bituminous mudstones are a major component of some parts of the succession with some individual shale units exceeding 1 m in thickness. The mudstones, other than the laminated bituminous units, usually contain evidence of benthic activity, either as body fossils or as bioturbation and burrow mottling. The limestones are mostly of two types. The more common are dark blue-grey, hard, compact and rather homogeneous, often grading downwards into calcareous mudstone. Most are laterally persistent but they may be lenticular or nodular, particularly in mudstone-dominated parts of the succession. Fossils are commonly associated with the boundaries of these limestones. The second type of limestone is fine grained or porcellanous, sometimes laminated; a few have a strikingly sharp junction with underlying mudstones.

Fossil preservation varies through the succession. Three-dimensional preservation is common in many of the limestone beds while all but the more robust fossils typically are flattened in the intervening mudstones. Original aragonitic shell material is common in the more organic-rich mudstones and is seen perhaps most spectacularly in the iridescent ammonites from the laminated mudstones of the Planorbis Zone. Pyrite is relatively uncommon as a preserving medium and silica is unknown.

Interpretation

The lithostratigraphy and ammonite biostratigraphy of the succession is now largely established, though some uncertainties still exist. Although the lithostratigraphies of Palmer (1972) and Whittaker and Green (1983) are broadly in agreement, direct correlation of individual beds can be difficult. There is a discrepancy between the measured thicknesses for part of the Bucklandi Zone, where Whittaker and Green (1983) recorded 45.9 m for beds 165–224 and

Palmer (1972) recorded only 30.9 m for the equivalent beds (his beds D1–E15). This may partly account for the different total thicknesses that they record; 178.9 m for Palmer (1972) against 203 m for Whittaker and Green (1983). Uncertainty also surrounds the stratigraphical continuity between the succession up to Bed 224 and that above (beds 225–257; about 70 m in total) since no continuous section exposes this interval.

There have been various interpretations of the position of the Triassic–Jurassic boundary at St Audrie's Bay. Hallam (1990b,c) placed the boundary at the top of the Langport Member of the Penarth Group, while Hesselbo *et al.* (2002) suggested a position a little lower, within the Cotham Member. Others have taken the boundary within the Blue Lias Formation, at the first appearance of *Psiloceras* (Cope, 1990; Warrington *et al.,* 1994; Page and Bloos, 1998; Benton *et al.,* 2002). Intensive searching in the basal Lias by Hodges (1994) and others (Page and Bloos, 1998; Bloos and Page, 2000a) renders it unlikely that the range of *Psiloceras* will be extended significantly lower at this GCR site. Recent work has also resolved the positions of several zonal and subzonal boundaries higher in the succession, although biostratigraphical interpretation of the upper part of the succession has long proved problematic. Woodward (1893) implied that the Turneri Zone might be present, but this has been ascribed to a misidentification of *Arnioceras bodleyi* (Whittaker and Green, 1983). Palmer (1972) assigned beds 229–253 to the Scipionianum Subzone and beds 254–257 tentatively to the Sauzeanum Subzone. Warrington and Ivimey-Cook (1995) followed Palmer (1972) in this respect, though conceding that the presence of these two subzones was largely unproven. Page (1992) has suggested that recognition at this GCR site of subzones higher than the Lyra Subzone is based on mis-identifications.

The microfaunal biostratigraphy of the succession is poorly documented. The foraminiferal succession conforms to the zonal scheme proposed by Copestake (1989), and Hylton (1998) has shown its importance for defining the Hettangian–Sinemurian boundary, which is particularly significant for the proposed designation of the East Quantoxhead section as the Global Stratotype Section and Point (GSSP) for this boundary. Dinoflagellate cysts, coccoliths and ostracods from this site provide only a crude biostratigraphy compared with ammonites. Stratigraphical overlap of the ostracod subzonal index fossils within the *Ogmoconchella aspinata* Biozone on the west Somerset coast prevented Lord and Boomer (1990) from identifying subzonal boundaries and cast doubt on the wider validity of Lower Jurassic ostracod subzones.

The thick, often mudstone-dominated, Hettangian and Lower Sinemurian sequence of this GCR site is comparable with the predominantly argillaceous succession beneath the Bristol Channel (Lloyd *et al.,* 1973). Whittaker and Green (1983, p. 98) noted similarities between Lower Lias successions in the Bristol Channel and Central Somerset basins, and Miliorizos and Ruffell (1998) considered the former to be an offshore continuation of the latter. A significant component of the more than five-fold increase in thickness of the Lias exposed at this GCR site, compared with the correlative succession at the Dorset GCR site, occurs in the mudstones suggesting that rapid subsidence in the Central Somerset Basin during early Jurassic times favoured the accumulation of fine clastic material. The offshore Blue Lias Formation facies of the south Wales succession, as seen at the Lavernock to St Mary's Well Bay and Pant y Slade to Witches Point GCR sites (see Chapter 3), shows a broad similarity to this GCR site in terms of large-scale lithostratigraphical units. Hence the major mudstone development in the Liasicus Zone, the 'St Audrie's Shales' of Palmer (1972), can be correlated with the Lavernock Shale Member of south Wales. This can be traced to successions farther afield, notably the Saltford Shale Member of the Bristol region (Donovan, 1956) and beds H55-H72 of the Dorset coast (Lang, 1924). This widely traceable mudstone development has been ascribed to a sea-level rise of at least regional extent (Hallam, 1981). Smith (1989) correlated presumed Milankovitch cycles between the Somerset coast, the nearby Burton Row Borehole [ST 3356 5208], and the Dorset coast, and found evidence for a hiatus in the Angulata Zone of Dorset that was absent in Somerset. Similarly, Bessa and Hesselbo (1997) inferred a stratigraphical gap at the Planorbis–Liasicus zone boundary in the Somerset coast succession on the basis of comparison between spectral gamma-ray data from St Audrie's Bay and the correlative section at St Mary's Well Bay in south Wales. However, the remarkably complete ammonite succession indicates virtually continuous sedimentation through the Hettangian and Sinemurian stages in this region and casts doubt on the existence of these inferred hiatuses (K.N. Page, pers. comm.). The nature of the much-studied Hettangian–Sinemurian boundary lends support to the view that sedimentation was not interrupted for any significant length of time. The actual boundary occurs within a paper shale unit rather than at a lithological boundary and there is a unique coexistence of the diagnostic ammonite groups for the upper Hettangian and lower Sinemurian stages. Whittaker (1978) attempted direct correlation of individual beds at the base of the Blue Lias Formation between Somerset and south Wales, demonstrating that Richardson's (1911) correlation of the Watchet Beds of Somerset with silty marls above the White Lias at Lavernock was incorrect. Whittaker and Green (1983) also noted the presence of laminated limestones in the Johnstoni Subzone at roughly the same level as similar limestones in Dorset and south Wales (Hallam, 1960a, 1964a), and Palmer (1972) correlated Bed 147 (his Bed C101) with the Calcaria Bed near the base of the Conybeari Sub-zone in the Keynsham area (Donovan, 1956). Page (1992) has made correlations of individual sedimentary units between Somerset, Bristol (the Keynsham area) and the Devon–Dorset coast on the basis of their characteristic ammonite faunas.

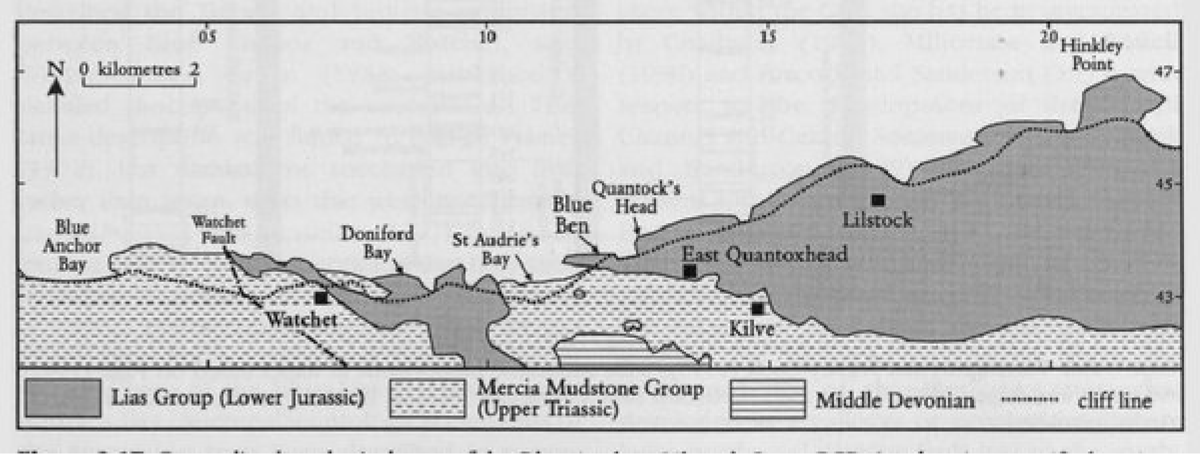
Many of the individual beds and groups of beds can be traced throughout this GCR site and can be correlated with the succession in the Burton Row Borehole (Ivimey-Cook and Donovan, 1983). This reveals an eastward thinning of the succession from the St Audrie's Bay and Watchet area to Blue Ben, particularly in the Angulata Zone and Conybeari Subzone, but also to some extent in the Planorbis Zone (Bloos and Page, 2000a). All of the principal limestone beds are present throughout the section, but some of those at Blue Ben have irregular junctions and the intervening shales have thinned markedly, perhaps indicating minor hiatuses. The Blue Ben section lies less than 1 km from outcrops of Devonian rock, and Whittaker and Green (1983) ascribed the eastward thinning of the Lias to differential subsidence near the basin margin. Whittaker (1973, 1975) also found evidence for a northwards thickening of the Lias away from the basin margin and toward an elongate ESE-trending basin. In this respect Bloos and Page (2002) noted that the succession exposed on the south Wales coast is approximately twice as thick as at this GCR site. Many of the faults that now cut the coastal sections probably relate to Tertiary basin inversion. However, two major faults that mark the northern edge of the Quantock and Exmoor hills have recently been identified as basin-bounding normal faults, with throws of perhaps more than 1000 m during the Mesozoic Era (Peacock and Sanderson, 1999). The Watchet–Cothelstone–Hatch Fault System, which intersects the coast near Watchet (Whittaker, 1972a) shows evidence of movement during early Jurassic times (Miliorizos and Ruffell, 1998). The greater structural complexity of the Lilstock area compared with the Kilve–Watchet section of coast has been attributed to the location of the latter within a stress shadow associated with a relay ramp represented by this fault system (Peacock and Sanderson, 1999).

Ivimey-Cook and Donovan (1983) noted an increase in the thicknesses of individual ammonite zones in passing up through the succession. In the Hettangian Stage the Planorbis Zone is about 8 m thick, the Liasicus Zone is about 27 m thick, and the Angulata Zone is about 40 m thick. This trend appears to continue into the Sinemurian Stage, where the combined Conybeari and Rotiforme subzones are about 50 m thick and the thickness of the combined Bucklandi and Lyra subzones may exceed 75 m. If the assumption of Torrens (in Cope *et al.,* 1980a) is correct, that ammonite zones are of similar duration (0.5–1 Ma), then the subsidence rates in this area, between the Mendip and Exmoor highs, increased from Hettangian into early Sinemurian times. Confirmation of this comes from comparison with correlative successions in other basins in southern England (Table 2.1). The Planorbis Zone is thin in most areas, but succeeding zones show a fairly consistent thickness within each succession (Dorset coast: 4–6 m; Severn Basin: *c.* 18 m; Mochras Borehole: 60–80 m; south Wales: *c.* 30 m). These variations in thickness reflect different rates of subsidence in each of the basins but the Central Somerset Basin appears to be unusual in that the subsidence rate increased progressively through Hettangian and early Sinemurian times rather than maintaining a fairly constant subsidence rate, at least for the Hettangian Age, as is seen in the other basins. The dominance of mudstones through much of the succession at this GCR site testifies to rapid subsidence and generally low-energy conditions with little erosion. The ammonite faunas documented by Page (1992, 1994b; Page and Bloos, 1998; Bloos and Page, 2000a,b, 2002) also indicate that the succession here is more complete than elsewhere in southern Britain. This pattern of deposition contrasts with that of the Radstock Shelf. There the Planorbis and Liasicus zones usually are present, but the Angulata and Bucldandi zones are absent or represented only by derived fossils in the basal bed of the overlying Sinemurian strata (Donovan and Kellaway, 1984).

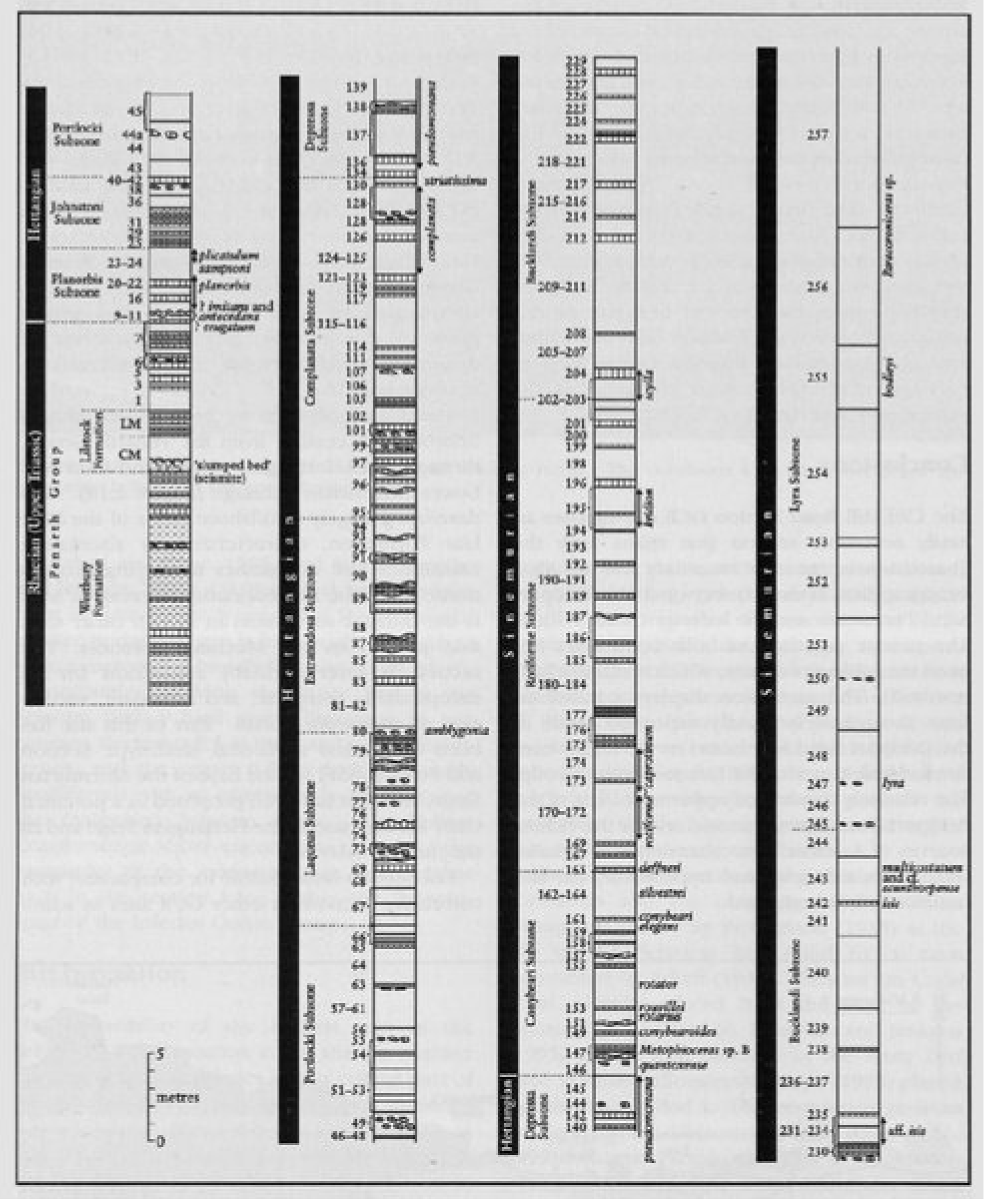
Conclusions

The Blue Anchor–Lilstock Coast GCR site exposes a greater thickness of Hettangian and Lower Sinemurian strata than is seen in any other correlative section in an onshore basin in Britain. Its basinal setting provides a valuable contrast with the basin-margin succession exposed on the southern flanks of the Mendip High and along the south Wales coast. The succession contains an exceptionally full, and well-documented, sequence of ammonite faunas that have served as the basis not only for further subdivision of the established ammonite zonal scheme but also for designation of the Global Stratotype Section and Point (GSSP) for the base of the Sinemurian Stage, and a proposal for similar status for the base of the Hettangian Stage and the Jurassic System. This is a site of clear international significance for Lower Jurassic chronostratigraphy.

References

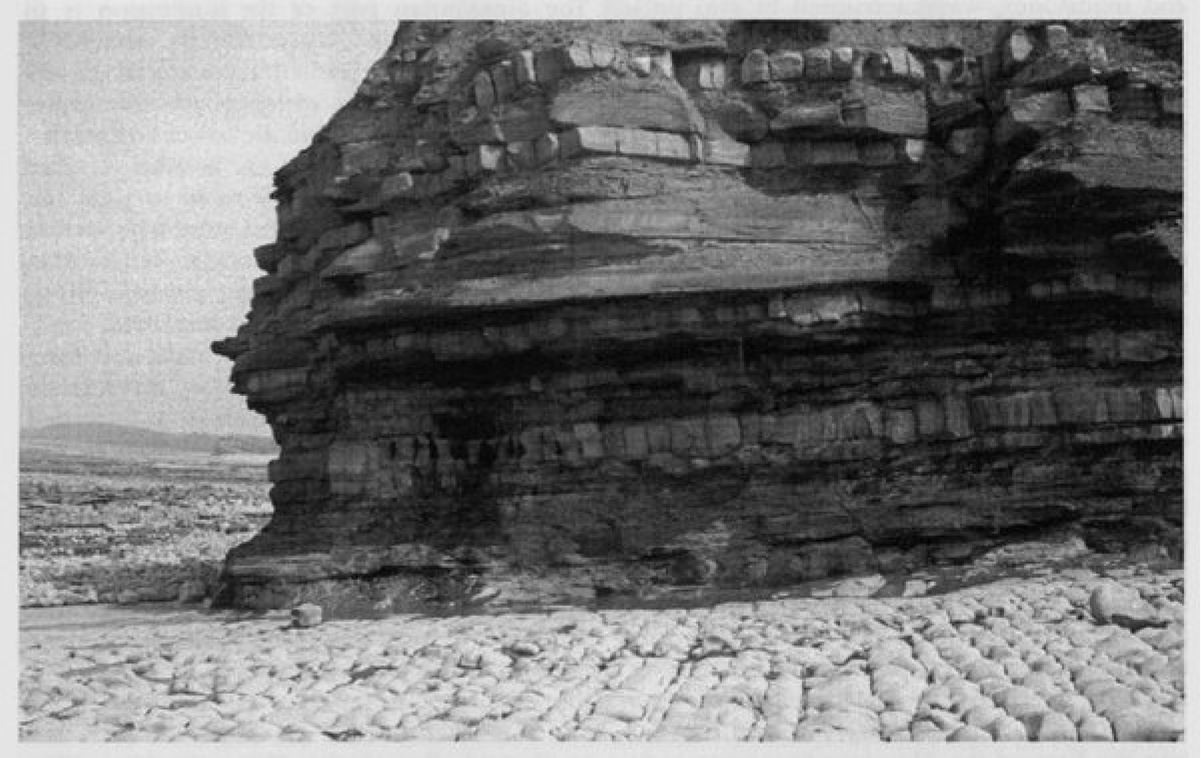


(Figure 2.17) Generalized geological map of the Blue Anchor–Lilstock Coast GCR site showing specific locations mentioned in the text.

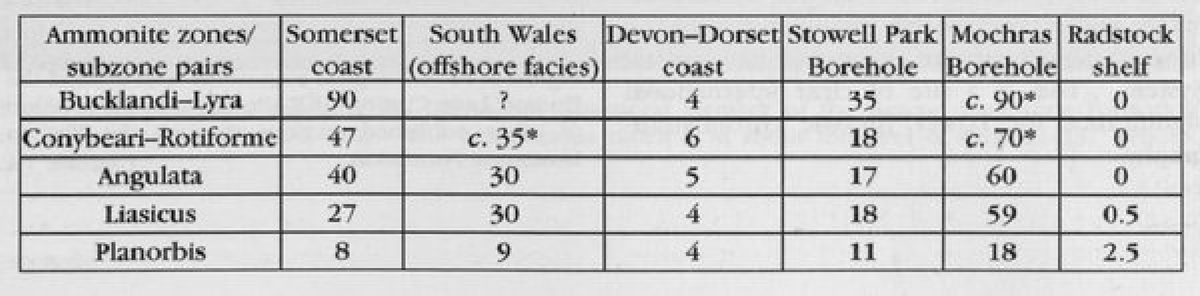


(Figure 2.18) Composite log of the Penarth Group and Lias Group succession exposed on the north Somerset coast. After Warrington and Ivimey-Cook (1995); with ammonite biohorizons in italics based on Page (1992) and Bloos and Page (2000a,b). In the Lias Group only limestones (vertical hatching) and mudstones (blank) are distinguished.

(Figure 2.19) The basal Lias Group and candidate Global Stratotype Section and Point (GSSP) for the base of the Hettangian Stage and Jurassic System at St Audrie's Bay, Somerset. The lowest level at which Psiloceras has been found is in Bed 8, visible immediately above the person's head. (Photo: M.J. Simms.)



(Figure 2.20) Limekiln Steps, East Quantoxhead, west of Kilve, the Global Stratotype Section and Point (GSSP) for the base of the Sinemurian Stage. The limestone platform at the foot of the cliff is the top of Bed 144 and the Hettangian–Sinemurian boundary lies in the thick shale unit at the base of the cliff (beds 145–146). (Photo: M.J. Simms.)



Ammonite zones/ subzone pairs	Somerset coast	South Wales (offshore facies)	Devon–Dorset coast	Stowell Park Borehole	Mochras Borehole	Radstock shelf
Bucklandi–Lyra	90	?	4	35	*c.* 90*	0
Conybeari–Rotiforme	47	*c.* 35*	6	18	*c.* 70*	0
Angulata	40	30	5	17	60	0
Liasicus	27	30	4	18	59	0.5
Planorbis	8	9	4	11	18	2.5

(Table 2.1) Table of approximate zone/subzone-pair thicknesses for the Hettangian and basal Sinemurian stages at six different locations. (= figures estimated from total zone thickness.) Data from Cope et al. (1980a), Warrington and Ivimey-Cook (1995) and Page (1992, unpublished Geological Society Correlation Guide).*