A review of the ammonite faunas and standard zonation of the Hettangian and Lower Sinemurian succession (Lower Jurassic) of the east Devon coast (south west England)

K. N. Page

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The classical Jurassic sequence for which the coast of Dorset (south-west England) is famed, begins in East Devon. Faunal records for the lower part of the Hettangian (Planorbis and the lower part of the Liasicus chronozones) in this region are based solely on sections in the latter county and it is only from the higher part of the Lower Sinemurian (Semicostatum and Turneri chronozones) that records from Dorset become more important. The Planorbis and Liasicus chronozones of the early Hettangian yield characteristic *Psiloceras*, *Caloceras*, *Waehneroceras*, *Psilophyllites* and *Alsatites*. In the Angulata Chronozone, typical faunas of *Schlotheimia* spp. also include very rare forms with Mediterranean affinities such as *Angulaticeras* (*Charmasseiceras*) *marmoerum* (Wähner) and early Arietitinae (*Schreinbachites* Bloos). The overlying basal Sinemurian Conybeari Subchronozone (Bucklandi Chronozone) is relatively well developed with characteristic *Metophioceras*, *Vermiceras* and *A.* (*Charmasseiceras*) and although records from higher levels in the chronozone are less complete, good faunas of typical *Coroniceras* and *Arietites* have been recorded. The Semicostatum and Turneri chronozones are better known in Dorset, although equivalent strata are present in Devon, albeit not always well exposed within extensive landslip systems. Typical faunas from these levels include *Arnioceras*, *Paracoroniceras*, *Pararnioceras*, *Euagassiceras*, *Agassiceras*, *Caenisites*, *Microderoceras*, *Cymbites*, *Promicroceras* and early *Epophioceras*.

Department of Geological Sciences, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, U.K.
(E-mail: KevinP@bello-page.fsnet.co.uk).

Introduction

The Lyme Regis district has long been famed for its fossiliferous exposures of Lower Jurassic rocks. Exposures are present in coastal cliffs and foreshore, both to the east of the town, within Dorset, and to the west, mainly in Devon. Indeed, the classical Jurassic sequence for which the Dorset coast is famous, commences in Devon, and it is only in the latter county that the basal part of the sequence is seen, including the boundary with the underlying Triassic System.

The aim of this work is to provide an up-to-date review of this classic, earliest Jurassic sequence, with full revision of all recorded ammonite faunas and correlations, combined with new information from recent studies. As the succession west of Lyme Regis, towards Axmouth, is more completely accessible, research has been concentrated in this area, but as some lateral variation does exist in the sequence, additional faunas recorded from east of Lyme Regis are explicitly stated as such.

The former exposures lie almost entirely within the Axmouth to Lyme Regis Undercliffs National Nature Reserve (Figure 1). The reserve is protected for its geological and ecological features through the National Parks and Access to the Countryside Act 1949, the Wildlife and Countryside Act 1981, as amended by the Countryside and Rights of Way Act 2001, and the Conservation (Natural Habitats) Regulations, 1994 and advice regarding access and sampling protocols should be sought from English Nature, Devon Team, Renslade House, Bonhay Road, Exeter, Devon EX4 3AW, U.K.

Lithostratigraphy

Nomenclature and general characteristics of the sequence

Until recently there has been little standardised lithostratigraphical terminology for the Lias Group in Britain (cf. Getty in Cope *et al*., 1980), excepting a plethora of geographically restricted new names, generated by the British Geological Survey during remapping of areas in central and northern England. A review and rationalisation of this terminology for England and Wales has been proposed by Cox *et al.* (1999 - also available on http://www.bgs.ac.uk) and this scheme is largely followed here.

At a formational level, an essentially bipartite division has been adopted for Hettangian-Sinemurian deposits in England, with a lower or Blue Lias Formation and an upper Charmouth Mudstone Formation. The former is not readily separable into members in Devon and Dorset, although the latter has a well established subdivision, following Lang (in Lang *et al*., 1923, and Lang and Spath, 1926), with a lower, or Shales-with-Beef Member and an upper Black Ven Marls Member.

The Blue Lias Formation immediately overlies a distinct planar surface at the top of the Lilstock Formation of the Triassic Penarth Group, with well developed *Diplocraterion* burrows and, locally, desiccation cracks - the so-called "Sun Bed" (as recently redescribed by Wignall, 2001). The establishment of the well-known mudrock-limestone rhythms of the "Blue Lias" sequence, commences immediately above this level, although the first psiloceratid ammonites, indicating the base of the Jurassic System, are not recorded until Bed H25 of Lang (1924), around 2.5 m above the base of the formation.

Many of the limestones, especially in the higher part of the Blue Lias Formation sequence, were given names by quarrymen when the beds were worked along the foreshore for cement and building stone. These names were recorded by Lang (1924) and incorporated in his descriptions and some are utilised below. He also provides useful advice on recognising individual beds in the cliff and foreshore. Lang's bed numbers are also retained, including his use of the prefix "H" (= "Hettangian") for the lower part of the sequence.

There has been much discussion on the origin of the limestones, particulaly regarding a depositional versus diagenetic origin, going back to De la Beche (1839). As discussed by House (1985), Weedon (1986) and Weedon *et al.* (1999), this cyclicity is

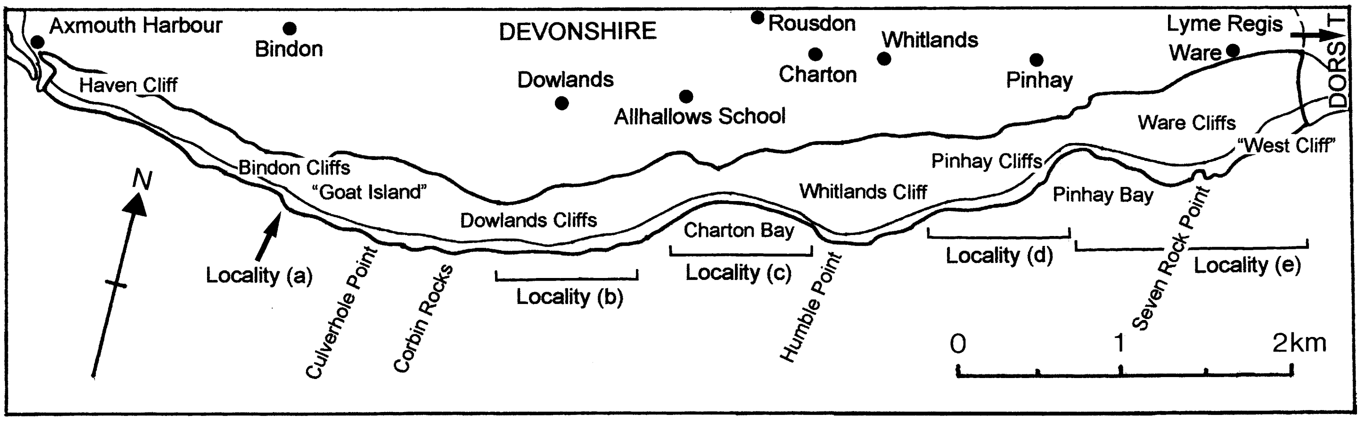

Figure 1. Axmouth to Lyme Regis Undercliffs National Nature Reserve, showing the location of the key sites mentioned in the text.

potentially linked to orbitally driven Milankovitch cycles. Further discussion and review of the sedimentology and general characters of the formation can be found in Hesselbo and Jenkyns (1995).

The overlying Shales-with-Beef Member (beds 54-76), of the Charmouth Mudstone Formation, is dominated by shales, frequently laminated, with very few limestones bands, but with several bands of calcareous, in some cases septarian, concretions. The "beef" are veins of diagenetic fibrous calcite, typically developed at well-defined stratigraphical levels. The base of the succeeding Black Ven Marls Member is poorly seen in the cliffs around Devonshire Head, and marks the establishment of marl-dominated sedimentation, again with few calcareous bands. The two members are described in detail by Lang *et al.* (1923) and Lang and Spath (1926) and reviewed by Hesselbo and Jenkyns (1995).

Chronostratigraphical framework

"Standard zonations" and chronostratigraphy

As discussed at length elsewhere (e.g. Callomon, 1985a, b; Page, 1995a, in press), Jurassic standard ammonite zones are chronozones and NOT biozones as incorrectly implied by authors such as Whittaker *et al.* (1991). To minimise this risk of confusion and to emphasise the true nature of the units being used, all standard zones in this paper are therefore quoted explicitly as "chronozone" or "subchronozone". Standard subzones are now subdivided into even finer, high resolution units, often known collectively as "horizons" (Callomon, 1985a, b; Page, 1995a). The latter include the "Horizons" of French authors, which are typically used as subdivisions of subchronozones (and as such were termed "zonules" by Phelps, 1985) and "biohorizons", which represent discrete beds with a distinctive and correlatively useful fauna. In the Sinemurian, the use of biohorizons in particular, permits the recognition of stratigraphical "events" at a possible resolution of as little as 120,000 years (Callomon, 1985b; Page, 1995a). As well as establishing a high-resolution time scale, the use of biohorizons to characterise a sequence of faunas or events at a basin or regional scale assists the stabilisation of stratigraphical nomenclature at the level of subchronozone and chronozone throughout a single faunal province. As these units are formally defined, they are quoted as, for example, *Psiloceras erugatum* Biohorizon, or simply *erugatum* Biohorizon.

Hettangian zonation and the base of the Jurassic system

The base of the Jurassic system is drawn at the base of the Planorbis [ammonoid] Chronozone following Oppel (1856-1858), the chronozone, as conventionally interpreted, marking the first occurrence of ammonites in North West Europe, after the re-establishment of fully marine conditions towards the end of the Triassic Period. Recent work by Bloos and Page (1997, 2000a) and (Page and Bloos, 1998) has demonstrated that the lowest of these faunas is characterised by *Psiloceras erugatum* (Phillips), marking an *erugatum* Biohorizon.

The standard zonal framework for the Hettangian of the North-West European Province (sensu Page, 1995b), is based on the scheme of Donovan in Dean *et al.* (1961) as modified by Bloos (1983) and reviewed by Mouterde and Corna (1997). The included biohorizons follow Page (in press) after Page (1995a, b), Page and Bloos (1998) and Bloos and Page (2000a).

Sinemurian zonation

As historically one of the best known exposures of the Hettangian-Sinemurian boundary in Britain, sections on either side of Lyme Regis have inevitably been important to discussions of the definition of the stage boundary, including a proposal as a stratotype (Donovan in Morton, 1971). The subsequent discovery of expanded and stratigraphically more complete sections at this level on the West Somerset coast (Page, 1992, 1995b), however, led to the latter's formal designation as the Global Stratotype Section and Point (GSSP) for the boundary (Page *et al.*, 2000; Page, 2001; Bloos and Page, 2002). The base of the Sinemurian Stage is taken at the first occurrence of abundant arietitid ammonites, including *Vermiceras quantoxense* Bloos & Page, characterising a *quantoxense* Biohorizon at the base of the Conybeari Subchronzone of the Bucklandi Chronozone.

The North-West European Province scheme for the Sinemurian of Donovan in Dean *et al.* (1961) remains in use, with only minor changes as senior synonyms of zonal indices are recognised (Getty in Cope *et al.*, 1980; Page, 1992, in press; Mouterde and Corna, 1997). Page (in press) reviews the current biohorizonal framework for the stage, based on Page (1992, 1995a, b) and Bloos and Page (2000b).

Distribution of key exposures

The occurrence of outcrops of Jurassic rocks as far west into Devon as Culverhole Point was noted by de la Beche (1822, p. 42) and the first measured section of the Blue Lias in the district was provided by the same author in 1826 (p. 26; also 1839, p. 223) at Seven Rock Point (see below). Further notable accounts include Wright (1860, pp. 401-2; 1878, pp. 38-9), Woodward (1893, also in Woodward and Ussher, 1906, 1911) but the most completely described sections remain those of W.D. Lang (in Lang *et al.*, 1923, 1924, in Lang and Spath, 1926). Hesselbo and Jenkyns (1995, figs 8 and 9), provide a recent diagrammatic section with explanatory notes, although bed by bed details are not included. The most well known section in Devon is that between Pinhay Bay and Lyme Regis itself, but several other significant localities are also present, as listed below:

(a) Culverhole Point, west [SY 273893]. The top of the Triassic sequence, including the Lilstock Formation at the top of the Penarth Group (Rhaetian) is well exposed in the cliff and landslipped masses, although the overlying Blue Lias Formation, does not appear to be visible *in situ* at present, being concealed

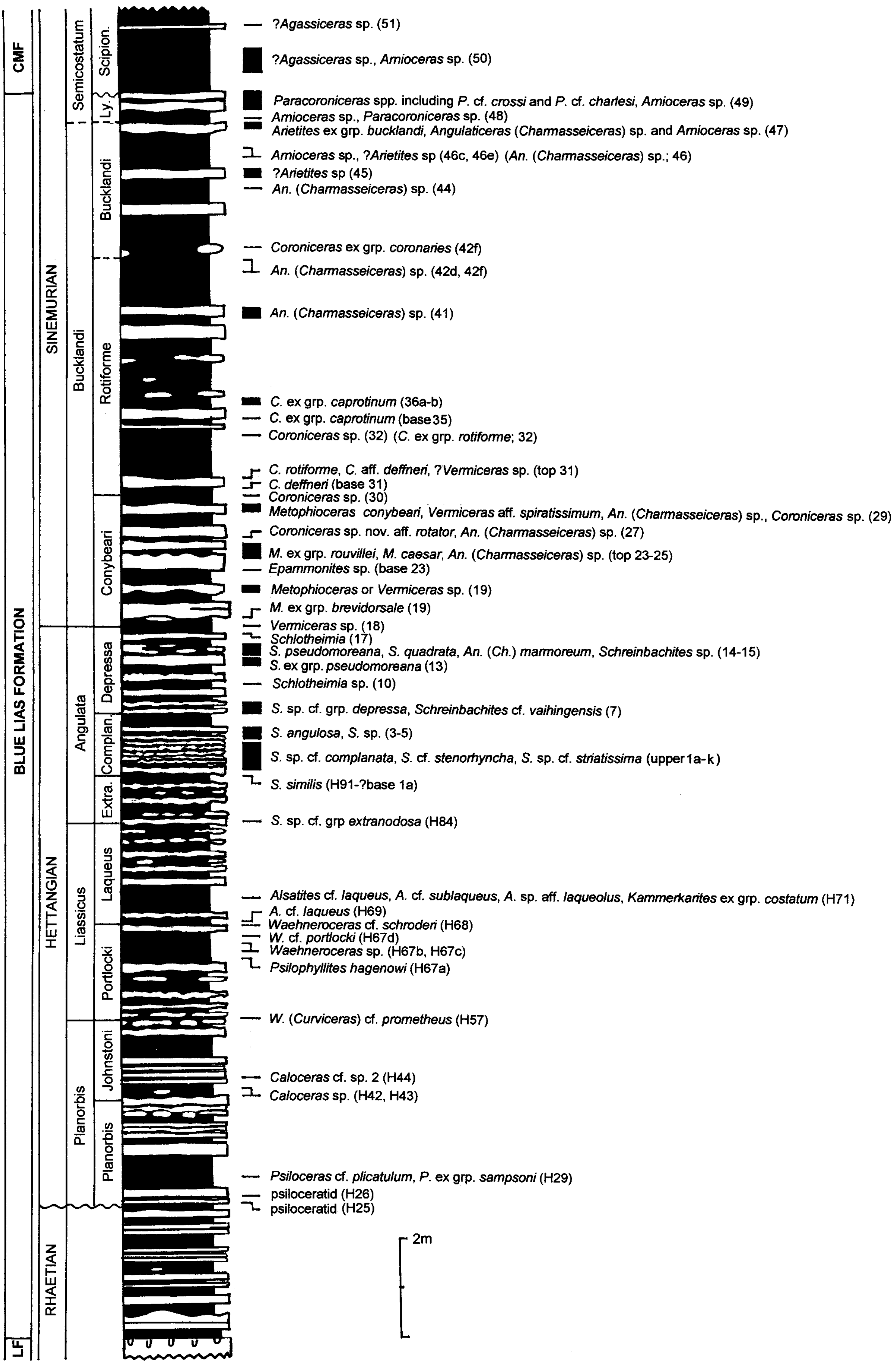

Figure 2. *The sequence of ammonite faunas in the Blue Lias Formation of the East Devon coast. The provenance of taxa in brackets are not specified by Lang (1924), and could include records from Dorset. Bed numbers follow Lang (1924). Abbreviations as follows: LF= Lilstock Formation, CMF= Shales-with-Beef Member, Charmouth Mudstone Formation, Scipion. = Scipionianum, Ly. = Lyra, Semicostat. = Semicostatum, Complan. = Complanata, Extra. = Extranodosa.*

Figure 3. *The Triassic-Jurassic boundary in the large landslipped block on the west side of Charton Bay. Note the pale coloured Lilstock Formation ("White Lias") below - the Jurassic begins with the first ammonites, recorded immediately below the 11th limestone of the succeeding Blue Lias Formation (see text).*

Figure 4. *The Hettangian–Sinemurian boundary on the west side of Seven Rock Point, East Devon, in Blue Lias Formation facies. Hammer is 40 cm long and rests on Bed 16 at the level of the last* Schlotheimia; *the top of hammer shaft touches Bed 19 with* Metophioceras *ex grp.* brevidorsale *(see text).*

beneath the western part of landslips. However, loose blocks are present on the shore.

(b) Dowlands foreshore [SY 285893–c.293894]. A small periclinal structure on the foreshore below Dowlands Cliffs, shows a section in the Blue Lias Formation at the level of beds 41 to 53 of Lang (1924), although slightly thinner and varying in detail from the same interval immediately west of Lyme Regis – faunas including *Coroniceras*, *Arietites*, ?*Arnioceras* and *Charmasseiceras* indicate the Rotiforme and Bucklandi subchronozones of the Bucklandi Chronozone, Bed 47 in particular being well exposed. This is the western-most *in situ* exposure of Jurassic rocks at beach level and certainly that referred to by most earlier workers as "Culverhole" (e.g. Woodward and Ussher, 1906, 1911; although some of the exposures recorded by De la Beche (1822, 1826) could be concealed beneath a major landslip of 1839). Eastwards from the Blue Lias exposures, towards Charton Bay, isolated blocks/ outcrops of Sinemurian rocks are caught up amongst landslipped Cretaceous chalk and "Upper Greensand" on the foreshore, at least three small sections being visible. Faunas present indicate the following subchronozones: Sauzeanum (level of Bed 70 in western outcrop), ?Brooki (level uncertain, in central outcrop) and Birchi (level of Bed 76 in eastern outcrop) (further details are included in relevant sections below). In addition there also appears to be evidence of the early Obtusum Chronozone (Obtusum Subchronozone) amongst loose material.

(c) Charton Bay [SY 297899]. Cliff exposures in the Blue Anchor Formation are overlain by the Penarth Group, although the latter, especially the Lilstock Formation ("White Lias" auctt.) is seen mainly in degraded undercliff exposures to the east, frequently much disturbed by landslips. The Blue Lias Formation is also present, mainly seen as landslipped debris, although also as small outcrops. Most significantly, the Lilstock Formation-Blue Lias Formation and the Triassic-Jurassic boundary are very well exposed in large slipped blocks at beach level, to the west of the Blue Anchor Formation cliff (Figure 3). The section ranges up to at least the lower Liasicus Chronozone. Palaeontological observations elsewhere in Charton Bay include evidence of the Portlocki Subchronozone (including *Psilophyllites hagenowi* (Dunker) from the "North side of the road from Rousdon to the shore at Humble Point"; Lang collection, NHM, London (NHM), C55427-31) and levels as high as the early Bucklandi Chronozone in loose blocks (including ?*Metophioceras* sp.).

(d) Pinhay Cliffs and foreshore [c. SY 312901-318907]. The Blue Lias Formation emerges on the foreshore, towards the west of this area, from below the toe of landslips. The shore includes the contact with the underlying Lilstock Formation, albeit somewhat difficult to study due to extensive marine growth and scattered boulders, and ranges up to at least the higher part of the Conybeari Subzone, including Bed 29. On the west side of Pinhay Bay, the first high cliffs in Blue Lias Formation appear, ranging from at least the Angulata Chronozone upwards, although the Planorbis Chronozone may also be present, at least on the foreshore (Lang collection (NHM), includes *Psiloceras* sp., from Bed H29, "West of Pinney Gorge": C55465).

(e) Pinhay Bay to Devonshire Head [SY 318908-332914]. In

the middle of Pinhay Bay the Lilstock Formation is faulted into position in the lower part of the cliff, and also traceable on the foreshore to the east. This exposure is well known and has been recently redescribed by Wignall (2001). Eastwards from Pinhay Bay, and around Seven Rock Point to Lyme Regis, is the most complete and well known Blue Lias Formation section in the district, exposed both in the cliff and on the foreshore, and described in most accounts of the district (e.g. De la Beche, 1826, 1839; Woodward, 1893, in Woodward and Ussher, 1906, 1911; Lang, 1924; Hesselbo and Jenkyns, 1995; Figure 2). The sequence begins in Pinhay Bay, immediately above the Lilstock Formation exposure in the cliff, where the Planorbis Chronozone is accessible, with care, just above beach level. Gradually higher levels reach shore level towards Seven Rock Point, including the Hettangian-Sinemurian boundary (Figure 4) and ultimately the Bucklandi Subchronozone (Bucklandi Chronozone). The point is developed around an anticlinal structure, and the succession is repeated on its eastern side, where the Hettangian-Sinemurian exposure is once again crossed, although no levels below Angulata Chronozone are exposed east of the point (as mapped in detail by Lang, 1924).

The cliffs immediately below the Devon-Dorset county boundary, at Devonshire Head (an area variably known as West Cliff or Monmouth Beach) usually show, depending on beach level, the upper part of the Conybeari Subchronozone at beach level and an excellent, albeit difficult of access, section through the remainder of the Blue Lias Formation above. Crucially, higher in the cliff, a complete section through the Shales-with-Beef Member is present (Semicosatum to Birchi chronozones), as referred to by Lang *et al.* (1923). The highest levels clearly seen *in-situ* here, include the Birchi Nodular and Birchi Tabular beds and traces of the overlying basal Black Ven Marls Member (Birchi Subchronozone). The Birchi Tabular Bed contributes to the development of a conspicuous platform in the undercliff at this point.

The succession of ammonite faunas in the Jurassic of the east Devon coast

The sections on the Devon coast, west of Lyme Regis, form one of the most important and famous British geological sites and have been important to the development of Jurassic studies not only in Britain but also internationally. Unfortunately, however, due to the area's close proximity to Lyme Regis and Charmouth, the centre of an international trading network in palaeontological heritage, there is now an intense attrition of the available resource and obtaining new material for research from certain levels is consequently very difficult. The results presented here represent, therefore, the cumulative results of many years of sampling by the author combined with early records by Lang and more recent contributions from other sources. Significantly, Lang continued to collect in the Blue Lias of the district long after the publication of his 1924 paper, generating a steady supply of specimens to the Natural History Museum (NHM) in London until at least the 1950's and these results are incorporated below. The composite sequence of these faunas is shown on Figure 2.

The location of cited specimens is as follows: NHM = W.D. Lang collection (unless otherwise stated), Natural History Museum, London; SMC = author's collection, Sedgwick Museum, Cambridge; BCM = author's coll., Bristol City Museum and Art Gallery; NMW = M. Foster collection, National Museum of Wales, Cardiff. Earlier correlations of the Jurassic sequence of the district include Palmer (1972) and Getty in Cope *et al.* (1980) and the later revision by Page (1992).

Hettangian Stage

Planorbis Chronozone, Planorbis Subchronozone. The earliest known psiloceratids are from Bed H25 of Lang (1924). Specimens from foreshore exposures on the west side of Seven Rock Point, include small crushed and poorly preserved forms, associated with a horizon of burrows filled with greyish white marl, around 2-5 cm below the base of Bed H26. As umbilical nodes or plications are not present, the specimens are not referable to *Psiloceras erugatum*; they are also too evolute for typical *S. planorbis* and much smaller than mature *P. sampsoni*. Assignment to *Neophyllites* is consequently most likely, although not confirmable as no sutures, spiral grooves or sharp umbilical walls (cf. Bloos and Page, 2000a) are discernable in the available material. Unfortunately, Lang's oyster xenomorph from the same level (1924, p. 184) does not appear to survive in the NHM collections.

Psiloceratids are also present in Bed H26, including on the lower surface, as recorded by Lang (1924). Lang's specimens do not seem to be present in the NHM, but specimens seen on the lower surface in Pinhay Bay (Locality e) and Charton Bay (Locality c; Figure 1) are small and evolute and may well also be *Neophyllites*. If this determination is correct, beds H25-H26 broadly correlate with the *imitans* and *antecedens* biohorizons of Page and Bloos (1998) and Bloos and Page (2000a).

From the available evidence in Pinhay and Charton bays, the base of the Jurassic System remains placed with some uncertainty within Bed H25. The apparent absence of the basal Jurassic *erugatum* fauna/biohorizon, however, may be genuine, and the burrowed horizon below the first ammonites may well be a small non-sequence. Circumstantial evidence for such a gap is provided by the first occurrence of the bivalve *Plagiostoma* in Bed 24 – this genus typically first occurs in the Blue Lias sequence, some distance below the first ammonites (Hodges, 1994), but in East Devon only around 0.2 m intervenes between these two first records.

The use of a Plicatulum "Horizon" (effectively a "zonule") for the higher part of the Planorbis Subchronozone follows Corna and Mouterde (1997) and is equivalent to the Plicatulum Subchronozone" of Hillebrandt (1990). The former usage is retained here but including a *plicatulum* Biohorizon, following Bloos and Page (2000a) and Page (in press). Lang (1924, p. 183) recorded a typical fauna of this interval around 0.18 m above the base of Bed H29, including *P.* cf. *plicatulum* (Quenstedt) and *P.* ex grp. *sampsoni* (Portlock) and this level is therefore taken to mark the base of the unit. The former specimen has not been found, but the latter is a typical relatively large (95 mm diameter) and evolute form (NHM C25639).

Johnstoni Subchronozone. *Caloceras* faunas are currently poorly characterised in East Devon, the lowest seen to date include relatively strongly ribbed forms embedded in the top of Bed H42 on the west side of Seven Rock Point. Beds H43 and the top surface of H44 also yield *Caloceras*. The former was compared to "*C. belcheri* (Portlock)" by Spath (1924, p. 191- NHM C25638), but is small and not clearly determinable, but the latter is comparable to *Caloceras* sp. 2 of the biohorizon of the same name (Page, 1994), a form with straighter, sharper and closer ribs than *C. johnstoni*, but not as closely ribbed as *C. intermedium* (Portlock), with which it was originally compared (Spath, 1924, including NHM C55406-7 and C25634).

The affinities of the forms of beds H42 and H43 are unclear, but do not appear to represent the *Caloceras* sp. 1 Biohorizon - it is therefore likely that the base of the subchronozone lies at a lower level, between beds H30 and H41 of Lang.

Later, post 1924, collections by Lang include *Caloceras* from higher levels, specifically H53 and H54. The former includes a close ribbed fragment comparable to true *C. intermedium* (NHM C55409; C55408 is a coarser nucleus from the same level), apparently proving the *intermedium* Biohorizon at the top of the subchronozone. The specimen reported to be from Bed H54, NHM C55410, however, is stronger ribbed and shows greater morphological affinities to *C. johnstoni* itself. If the bed number is not incorrectly recorded, it must therefore represent an unusually coarse variant of *C. intermedium*.

Spath noted better preserved *Caloceras* spp. in NHM collections (pre-Lang), reported to be from quarries at Uplyme - or at least more readily extractable specimens from partially weathered exposures (Spath, 1924). Most significantly, these specimens include the holotypes of "*C.*" *giganteum* Spath (p. 192; NHM

C26287) and *C. wrighti* (p. 192, figured by Wright, 1878, pl. 19, figs 1-2). The former is not a *Caloceras*, however, it is a large (septate to c. 260 mm), evolute *Waehneroceras* s.l. macroconch from the Liasicus Chronozone, a form apparently unknown on the coast.

Liasicus Chronozone, Portlocki Subchronozone. In East Devon, the lowest *Waehneroceras* s.l. is recorded by Lang (1924, p. 183) in Bed H57 and although fragmentary, shows sharp curved ribbing typical of *W.* (*Curviceras*) cf. *prometheus*, suggesting the *prometheus* Biohorizon at the base of the Portlocki Subchronozone (including NHM C25633).

A good fauna of the higher part of the Portlocki Subchronozone is known from Bed H67, probably including representatives of several biohorizons. From around 0.05 m to at least 0.15 m above the top of Bed H66, a dark shale with very thin seams of "beef" yields common crushed *Psilophyllites hagenowi* (Dunker) (=H67a, part) indicating the *hagenowi* Biohorizon (including the specimen figured by Spath, 1924, pl.18, fig. 1a, = NHM C25423; also NHM C25423 and C25622-25631).

Poorly characterised schlotheimiids including "*Waehneroceras*. sp. cf. *iapetus*" (NHM C25621) and "W. sp." (not seen) are recorded from beds H67b and H67c respectively, although these cannot be readily assigned to a named biohorizon. Bed H67d, however, (i.e. the topmost 0.13 m of H67), yields frequent *Waehneroceras* s.l., including specimens with slightly prorsiradiate ribbing referable to *W.* cf. *portlocki* (Wright) and larger (?macroconch) forms comparable to "*W. portlocki* morphotype *extracostatum* (Wähner)" of Guérin-Franiatte (1990, e.g. Pl. 11, fig. 2, = "*W.* cf. *megastoma* (Wähner)" of Spath, 1924, p. 195) (NHM C55411, C5616-7, C25619-20 and BCM 96-2-4), a species of *Kammerkarites*. The top surface of Bed H68 on the west side of Seven Rock Point shows common embedded *Waehneroceras* cf. *schroderi* Lange, distinguishable from *W. portlocki* by a more radial ribbing style (possibly including BCM 96-2-7). This fauna was missed by Lang (1924), but is represented by a single specimen donated to the NHM in 1945 (C55433). Assignment of these two levels to, respectively, the cf. *stricklandi* and *schroderi* biohorizons of Page (in press) is clear.

Spath (1924, pp. 195-196, including fig. 13a, NHM collection), discusses a pyritic specimen of "*W. iapetus*" "said to be from [west of] Lyme" although he appears to have been sceptical that the locality given was accurate. He was certainly correct, as no trace of pyritic ammonites is evident in the various levels known to yield Liasicus Chronozone ammonites on the coast and the specimen is almost certainly from Barrow-on-Soar, Leicestershire, as Spath seems to have suspected.

Laqueus Subchronozone. Bed H69 yields the lowest *Alsatites* cf. *laqueus* (Quenstedt) (including NHM C25614-5), indicating the *laqueus* Biohorizon at the base of the Liasicus Chronozone (Lang, 1924, p. 182). As Bed H71 also yields crushed *A.* ex grp. *laqueus*, including *A.* cf. *laqueus* and *A.* cf. *sublaqueus* (including NHM C55412-5), it is included in the same biohorizon, but occasionally specimens have slightly stronger ribbing and recall the younger *A. laqueolus* (= *A.* sp. aff. *laqueolus* on Figure 2, including NHM C55613 and possibly C5541-5). *Kammerkarites* [= *Waehneroceras* s.l.] spp. are also frequent in Bed H71, and include K. ["*Saxoceras*"] ex grp. *costatum* (Lange) and coarsely ribbed *Schlotheimia*-like forms (Lang, 1924; Page, 1995b, fig. 2, after G. Bloos, pers. comm. 1994; BCM 96-2-5, also NHM C55417-21).

Uncrushed typical *Alsatites laqueolus* is, however, present in the district, indicating the succeeding *laqueolus* Biohorizon (= laqueolus "Horizon"/Zonule of Mouterde and Corna, 1997), but the specimen recorded by Spath is from inland at Uplyme and from an uncertain horizon (1924, p. 201; NHM).

Angulata Chronozone, Extranodosa Subchronozone. The base of the Angulata Chronozone is drawn at the first occurrence of *Schlotheimia* sp. in Bed H84 (Lang collection, 1949, NHM C55436; quoted by Callomon and Cope, 1995, p. 50, as "Spath MS"). The sole specimen is a septate fragment of a relatively evolute macroconch with strong ventral ribbing (septate to at least 140 mm). Traces of the venter of the inner whorls are consistent with *S.* ex grp *extranodosa*, as figured by Lange (1951), but more material is needed to confirm this identification. Contrary to Smith (1989), as quoted by Hesselbo and Jenkyns (1995, p. 113), there is therefore no compelling evidence of a significant non-sequence at the base of the Angulata Chronozone.

Complanata Subchronozone. The stratotype of the *similis* Biohorizon of Page (1995b, p. 477), which was taken to mark the base of the Complanata Subchronozone by Page (1995b, after Palmer, 1972), is Bed H91 on the west side of Seven Rock Point. This is also the type locality and horizon of the index species itself, *Schlotheimia similis* Spath, as described and figured by Spath (1924, p. 197, pl. 18, figs 2a, b; NHM 5609). Although crushed shells are occasionally visible on bedding surfaces of the dark shales at this level, specimens are also preserved partially uncrushed as limestone internal moulds in the upper part of the bed. Macroconch fragments, similar to the holotype, are commonest with a characteristic compressed trigonal section, although a distinctive coarse-ribbed microconch is also present (BCM 96-2-6; 08-763, 764, 765, 766, 2067, 2068). Some specimens show a general resemblance to *S. polyeides* Lange (e.g. BCM 08-763).

Inner whorls of macroconchs are also distinctive, with relatively fine ribbing and noticeably relatively involute coiling – as such they include specimens compared by Spath (1924) to the later species "*S. striatissima* (Quenstedt)" (e.g. NHM C55437 from Seven Rock Point). Lang's collection also includes a superb selection of post-1924 specimens of typical *S. similis* macroconchs from Church Cliffs, north-east of Lyme Regis, which characterise the species considerably better than the holotype (e.g. NHM C40568, C55446-7, C55450-2). Although levels from Bed H91 upwards east of Lyme Regis are clearly represented in Lang's collections in the NHM, the exact provenance of faunas from these beds is generally not stated by Lang (1924) or Spath (1924) and records therefore include a mixture of Devon and Dorset faunas.

S. ex grp *similis* may also be present on the base of Bed 1a (e.g. BCM 08-768 and possibly 96-2-13), but higher levels in Bed 1 (probably even in Bed 1a) yields a new fauna, where it is well exposed on the foreshore on the west side of Seven Rock Point. *S.* sp. cf. *complanata* von Koenen, is present in Bed 1i (BCM 96-2-11), but the bulk of the macroconchs have more persistent, relatively sharp, close ribbing, often to at least 120 mm, and are therefore comparable to true *S. striatissima*, a form characteristic of the higher part of the Complanata Subchronozone in West Somerset and Germany (Bloos and Page, 2000b). Macroconch whorl sections are less compressed than *similis* and include specimens resembling *S. stenorhyncha* (Lange). Again, the bulk of Lang's material from this level was collected post-1924 from north east of Lyme Regis (including C40324-6, C55410, C55433, C55453-9, C56461-2, C55464 from beds 1a-1k). Additional material from Devon includes BCM 96-2-15. Beds 3-5 yield occasional *Schlotheimia* which may have close affinities with those of Bed 1 below but are not yet well characterised, although include *S. angulosa* Lange – a form typical of the Complanata Subchronozone (BCM 08-770) – and NHM C25600 a fragmentary schlotheimiid from the same level.

Beds 1-3 formed the stratotype of the original cf. *complanata* Biohorizon of Page (1995b, p. 447), but the known fauna is not the same as that of the *complanata* Biohorizon of Bloos and Page (2000b) and Page (in press) which was based on sections in West Somerset. It is possible, however, that both the *complanata* and succeeding *striatissima* biohorizons are represented in Bed 1 near Lyme Regis, but further comparisons between the Complanata Subchronozone sequence in East Devon/West Dorset and the expanded sections in West Somerset described by Bloos and Page (2000b) is not yet possible, especially as recovered specimens in the former area are dominated by macroconchs and in the latter area by microconchs.

Figure 5. *Large* Arietites *sp. in loose block, presumed ex Bed 47 ("Glass Bottle") in Pinhay Bay (Bucklandi Subchronozone and Chronozone) (Hammer scale = 40 cm)*

Depressa Subchronozone. Bed 7 (Lang's "Lower Skulls") yields a third schlotheimiid fauna, retained in the Complanata Subchronozone by Page (1995b) and assigned to a "*Schlotheimia* sp. 1 Biohorizon" (now superseded by the biohorizonal sequence of Page, in press, based on the West Somerest coast sections described in Bloos and Page, 2000b). Although presently poorly characterised, the fauna on Seven Rock Point includes very large *Schlotheimia* macroconchs, 45 cm + in diameter, and inner whorls, at least some of which have relatively coarse secondary ribs on relatively evolute inner whorls (include NHM 55470-1 BCM 95-12-27, 96-2-13, 96-2-15). Specimens of this group from Bed 7c (NHM C55472) at Church Cliffs, Lyme Regis and from the "North side of Bourdon [=Rousdon] Beach Road, Devon". This fauna includes forms close to *S. princeps* (Buckman) and *S. depressa* and would therefore indicate the lower part of the Depressa Subchronozone. Significantly, a specimen of the rare early arietitid *Schreinbachites* cf. *vaihingensis* Bloos has also been recovered from this level (Page, 1995a, p. 447; author's collection). The latter species also occurs in the upper part of the Complanata Subchronozone in southern Germany (Bloos, 1994). The specimen of *S.* sp. aff. *depressa* (Quenstedt) recorded by Spath (1924, NHM C6114) is, unfortunately, not recorded. The fauna of Bed 7 is here taken to characterise a cf. *depressa* Biohorizon nov.

Bed 13 has yielded few ammonites, but includes a fragment from Seven Rock Point (NHM C55492) comparable to *S.* ex grp *pseudomoreana* Spath of Beds 14-15 (Lang's "Upper Skulls"). The rich faunas of beds 14 and 15 of the Lyme Regis district are dominated by macro- and microconchs of *S.* ex grp. *pseudomoreana* and were assigned to the upper part of the Depressa Subzone by Bloos and Page (2000b). This fauna characterises the *pseudomoreana* Biohorizon of Page (1995b, p. 447), exposures on either side of Seven Rock Point syncline being the defined stratotype for this unit (the fauna from here including NHM C40261-2, C40307, C55493-6; BCM 08-775, 776, 779, 780,782, 784, 787-789, 842 and 95-12-26). The same fauna is also well developed north-east of Lyme Regis (including NHM C25584, C25596, C25599, C40259-60, C41504-6, C41510-14, C55465-9), although the "Lyme Regis" holotype of *S. pseudomoreana* Spath (1924, p. 197), as unreliably figured by Wright (1878-1884, pl. 17, fig. 1 only; NHM C2227) is not precisely localised as also are some of Lang's other specimens (e.g. NHM C25585-95, C25597-8, C55473-5).

Macroconchs are generally relatively compressed, but less so than in forms of the Complanata Subchronozone and tend to be slightly more involute. Microconchs, from beds 14 and 15, include specimens broadly comparable to *S. polyeides* Lange and *S. postangulata* (Page, 1995b, p. 447, including BCM 08-782), although not morphologically identical. Typical specimens, almost certainly from the same level figured by Wright (1878, pl. 14, figs 3-6), include the holotype of *S. quadrata* Spath (pl. 17, figs 3, 4; Spath, 1924, p. 198) - a characteristic form with a sub-quadrate section and relatively fine wiry ribbing. Occasional coarsely ribbed micoconchs with a higher whorl section show some similarities to *S. princeps* Buckman (including NHM C25589 and C55496) and others show some resemblance to *S. lymense* Spath (1924, p. 189; e.g. NHM C55473-4, C55494), a species based on a microconch from the Lyme Regis district figured by Wright (1878) from an unrecorded level.

Notable very rare elements of the *pseudomoreana* Biohorizon fauna include specimens of Tethyan species, including *Schreinbachites* sp. (author's collection and NHM C25596) and, very significantly, a single *Angulaticeras* (*Charmasseiceras*) *marmoreum* (Wähner) (BCM) - the latter is the indicator species of the Marmorea Chronozone at the top of the Hettangian in Mediterranean Province areas (Bloos, 1983).

The highest *Schlotheimia* specimens recorded ***in-situ*** in East Devon are small poorly preserved and indeterminate fragments from the top surface of Bed 17 (Page, 1992, p. 136, 1995b, p. 407) (Figure 4).

Sinemurian Stage- Lower Sinemurian Substage

Bucklandi Chronozone, Conybeari Subchronozone. The lowest Sinemurian ammonites known from East Devon and West Dorset are very poorly preserved traces of small, crushed arietitids in Bed 18 (basal Bed 18d of Lang, 1924), only around 0.25 m above the last *Schlotheimia* seen, on the top surface of Bed 17. It is tempting to assign this fauna to the basal Sinemurian *quantoxense* Biohorizon (= *rougemonti* Biohorizon of Page, 1992, 1995b), as fully described in West Somerset by Bloos and Page (2000b), but specimens are too poorly preserved to confirm their identity. Large *Metophioceras* ex grp. *brevidorsale* (Quenstedt) (= *M. longidomus* (Quenstedt) in Page, 1992, p. 136) recovered from concretions on the base of Bed 19, around Seven Rock Point (SMC, possibly also NMW), were previously believed to be the first of the Sinemurian in the district (Palmer, 1972; Page, 1992). This fauna is typical of the basal Sinemurian throughout much of north-west Europe and has been provisionally assigned to the *conybearoides* Biohorizon of Bloos and Page (2000b) and Page *et al*. (2000) (equivalent to the *longidomus* "Horizon" of Page (1992) and the *Metophioceras* sp. 2 Biohorizon of Page (1995b) (Figure 4).

Spath (1924) noted a fauna in loose blocks, which included closely ribbed forms, similar to *M. brevidorsale*, to which he assigned the name *M. gracile* Spath (1924, p. 203) – it is conceivable that these forms are also from Bed 19, and they certainly recall specimens of the poorly characterised *Metophioceras* sp. 1 Biohorizon on the West Somerset coast (Page, 1995b; Bloos and Page, 2000b). If this assumption is correct, it is possible that Bed 19 may include faunas of both the *Metophioceras* sp. 1 and the *conybearoides* biohorizons, although further confirmation is required.

A poorly characterised arietitid, probably assignable to *Metophioceras* or *Vermiceras* was noted by Lang in Bed 21 (1924, p. 180) but a cast of a sharp-ribbed small form from the lower surface of Bed 23 (NHM C25585) is highly suggestive of *Epammonites*, and would therefore suggest the presence of the *rotarius* Biohorizon.

The top surface of Bed 23, however, yields the next stratigraphically diagnostic fauna, which is best characterised in Bed 24 (Bed 24c) and probably also Bed 25, and includes *M.* ex grp. *rouvillei* (Reynès) (including NHM C25582 and C25580; SMC 94-4-A (from a loose block at Seven Rock Point) and 96-2-7(A) from *in-situ* below Pinhay Cliffs), *M. caesar* (Reynès) (including NHM C25581 and C55477) and *Angulaticeras* (*Charmasseiceras*) sp. Specimens form this level were recorded by Lang (1924, p. 180) and Spath (1924, p. 203) as including "*M.* sp. cf. *janus* Spath", and were therefore assigned to a *janus* Biohorizon by Page (1992, p. 136), and later to the *rotarius* Biohorizon (1995b) – re-examination of Lang's collections, however, confirms that the assemblage is typical of the *rouvillei*

Biohorizon, although some of the *M.* ex grp. *rouvillei* from Bed 24c (e.g. NHM C25582 and C25580) have a greater tendency to develop backward sloping (rursiradiate) *janus*-style ribbing than specimens from an equivalent level on the West Somerset coast.

The base of Bed 27 has yielded the very early coroniceratid, *Coroniceras* sp. nov. aff. *rotator* (Reynes) sensu Page (1992), on the east side of Seven Rock Point (authors collection, SMC) and forms the stratotype for the *rotator* Biohorizon of Page (1992, p. 136 – as "cf. *rotator* Horizon"; Page, 1995b, p. 448). Very significantly, this genus is characteristic of the Rotiforme Subchronozone above, but its first occurrence in south west England actually predates the index fossil of the earlier Conybeari Subchronozone, *Metophioceras conybeari* (J. Sowerby). Large *Angulaticeras* (*Charmasseiceras*) are also present at this level.

M. conybeari is abundant in the upper part of Bed 29 (the "Top Tape" of Lang, 1924) which forms spectacular and readily recognisable surfaces on either side of the syncline that forms Seven Rock Point, covered with traces of large ammonites up to at least 40 cm in diameter (including SMC 08-811, 835, 837, 839, 94-4-16 to 20, 96-2-8; also NHM C40494, C55476, C55478). Associated are much rarer *Vermiceras* aff. *spiratissimum* (Quenstedt) sensu Page (1992) (authors collection, SMC) and *Angulaticeras* (*Charmasseiceras*) sp. – a single small *Coroniceras* sp. has also now been recovered. Spath (1924) recognised other "undescribed" forms at this level (1924, p. 203), although most are likely to be simply varients of *M. conybeari*. This bed at Seven Rock Point forms the stratotype for the *conybeari* Biohorizon of Page (1992, 1995b). Specimens from the same bed below Pinhay Cliffs include SMC 91-6-5, 96-2-3.

Rotiforme Subchronozone. A small evolute *Coroniceras* sp. from Bed 30, recorded as "*C.* cf. *schloenbachi* (Reynes)" by Lang (1924, p. 179; NHM C25579) is consistent with forms of the *silvestrei* Biohorizon at the base of the Rotiforme Subchronozone on the West Somerset coast (sensu Bloos and Page, in press). The occurrence of giant *Coroniceras deffneri* (Oppel) on the base of Bed 31 (including SMC and NMW1529), on the east side of Seven Rock Point indicates the succeeding *deffneri* Biohorizon and this level in Westcliff was designated as the stratotype for the biohorizon by Page (1992, p. 137).

The top surface of Bed 31, however, contains a different fauna, including strong ribbed *C. rotiforme* (J. de C. Sowerby) (including SMC94-4-12) and was therefore assigned to the *rotiforme* Biohorizon by Page (1992). Additional material from the junction of beds 31 and 32 in Lang's collection, and therefore possibly from north east of Lyme Regis, includes forms with straighter and weaker ribs than typical *C. rotiforme*, and more akin to *C. deffneri* (including NHM C55479 and C55481) and a third specimen is more evolute and *Vermiceras*-like (NHM C55480). As typical coarsely ribbed *C. rotiforme* is also recorded in Bed 32 (NHM C25577), north-east of Lyme Regis, it would appear that the top surface of Bed 31 yields a fauna intermediate between the *deffneri* and *rotiforme* biohorizons.

Higher levels in the subchronozone are less well known in the Lyme Regis district, although *Coroniceras* sp. is recorded in Bed 32n (NHM C25578), and a specimen from the base of Bed 35, shows some similarities to *C.* ex grp. *caprotinum* (d'Orbigny) (SMC 08-2334, from Westcliff) although other specimens from the same bed are less diagnostic (e.g. NHM C25576, SMC 92-2-17). Bed 36, probably 36a-b, has yielded a fauna (recorded by Lang, 1924) which includes a fragment of a large *Coroniceras* sp. consistent with *C.* ex grp. *caprotinum* sensu Guerin-Franiatte non d'Orbigny (NHM C25570) and coroniceratid nuclei consistent with the same species (but recorded by Lang as "*Arnioceratoides*"; 1924, p. 178; NHM C25571-5). Together the fauna of beds 35-36b represent a level which is likely to include the *caprotinum* Biohorizon of Page (1992). A diverse selection of *Coroniceras* spp. in the M. Foster collection (NMW) appear to provide evidence of further faunas, although *in-situ* confirmation is required.

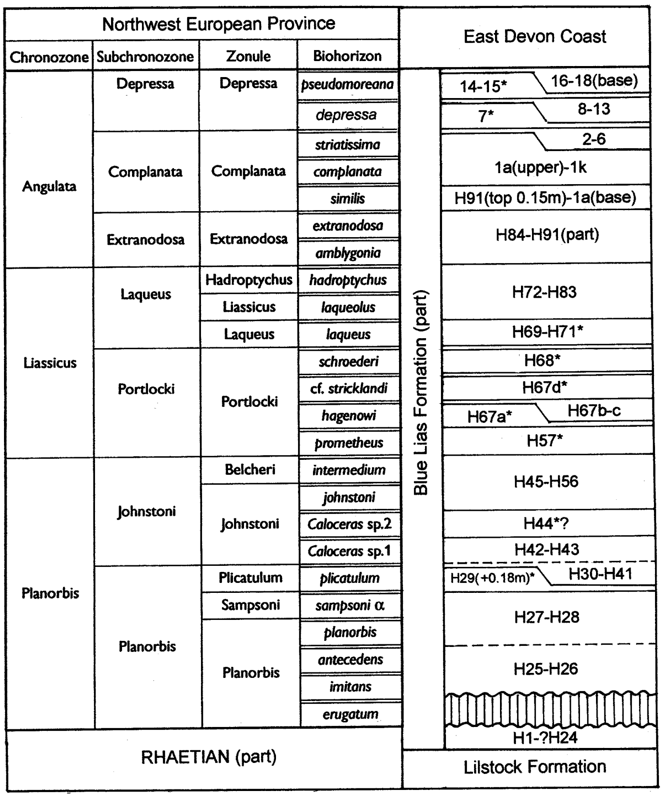

Figure 6. *Correlation of the Hettangian succession of the East Devon coast. Zonules are used in the sense of subdivisions of subchronozones; biohorozonal sequence follows Page (in press). Dotted lines indicated uncertainty, verticle hatching indicates non-sequence and asterix (*) indicates confirmed presence of biohorizon.*

Bucklandi Subchronozone. Bed 42, probable Bed 42f, near Seven Rock Point, has yielded a single large, relatively evolute coroniceratid (SMC), showing some affinities to *Coroniceras* ex grp. *coronaries* of the early Bucklandi Subchronozone.

Beds 45-47 yield a fauna of large *Arietites* spp., as already suggested by early records, and quoted by Lang (1924, p. 177) but recently spectacularly confirmed by M. Foster (NMW, including 0129, 0241, 249, 0312, 0717, 1029, 1519, 1533, 1540, 1543, 1541, 1544, 1545 and 1547 from between Whitlands shore and Devonshire Head). Forms close to *A.* cf. *bucklandi* and *A.* cf. *quadratum* are present, although currently, no clear sequence of species can be determined. The presence of *Arnioceras* sp. in beds 46c (probably including NHM C2556-61) and 46e (including NHM C25546-55 and possibly also C25543-5), however, as recorded by Lang (1924, p. 177), suggests a level at around that of the *isis* and *scunthorpense* biohorizons of Page (1992, pp. 138-139). A few fragments from these levels could conceivably include the inner whorls of *Arietites* as they have an *Epammonites*-style of ribbing.

Angulaticeras (*Charmasseiceras*) sp. or spp. is also recorded in beds 41, 42d (including NHM C25568-9), 42f, 44 (including NHM C25562-6) and 46 (including NHM C25540-2) by Lang (1924), mainly as fragmentary small specimens, and compared to *Ch.* ex grp. *charmassei* by Spath (1924, p. 199). A specimen of this group from "Lyme Regis" was figured by Wright (1880, pl. 20, figs 1-3). The large loose "*Schlotheimia* allied to *grenoughi*" observed by Spath (1924, p. 198) west of Lyme Regis, are also likely to be mainly Conybeari-Bucklandi Chronozone *A.* (*Charmasseiceras*) and not Hettangian as he then believed. Further examples of *A.* (*Charmasseiceras*) sp. from these levels are also present in the Foster collection (e.g. NMW 1562 and 1570).

The top of the subchronozone includes Bed 47 (= "Glass Bottle" of Lang, 1924), as "large *C. bucklandi*" is noted by the Geological Survey at this level (Lang, 1924, p. 177) – this fauna would include at least some of the large *Arietites* seen welded into or onto the surface of large blocks on the shore around Seven Rock Point and eastwards (e.g. Figure 5), recorded by Spath (1924, p. 203) as "*Coroniceras* [= *Arietites*] of the *bucklandi-solarium-pingue* groups". Bed 47 is well exposed within the Dowlands foreshore pericline, where further *Arietites* spp. are common, welded into the top surface of the bed. Typical specimens include *Epammonites*-like inner whorls (including SMC 92-2-14). *Angulaticeras* (*Charmasseiceras*) and *Arnioceras* are also present.

Spath noted fragmentary specimens, probably from the upper part of Bed 47 or Bed 48, comparable to *Arietites meridionalis* and *Coroniceras* of the *bisulcatus-multicostatum* group (1924, p. 204), suggesting that levels including the *multicostatum* Biohorizon, at the top of the Bucklandi Subchronozone may also be represented. The presence of the latter biohorizon somewhere in the sequence is confirmed by a fragment of *C. multicostatum* collected loose below Westcliff (SMC 92-2-11). Spath's ?*Paracoroniceras* sp. (NHM C25539) (1924, p. 177) is, however, a fragment of an indeterminate large *Arietites* or *Coroniceras*.

Semicostatum Chronozone, Lyra Subchronozone. Beds 48 to 49 around Lyme Regis yields remnants of a Lyra Subzone fauna characterised by *Paracoroniceras* spp. and *Arnioceras* spp. (including "*A.* aff. *geometricus* (Oppel)" and "*A. ceratitoides* (Quenstedt)" in Bed 48) (Lang, 1924, p. 177). The former include *P.* cf. *crossi* (Wright) (NMW 0067) and forms resembling

Chronozone	Sub-chronozone	Zonule	Biohorizon	Formation	Member	East Devon Coast
Turneri	Birchi	Bordoti	31: *cf. bordoti*	Charmouth Mudstone Formation (part)	BVMM	80-81j \ 81k-81n
		Turneri	30: *subturneri*			76b* \ 77-79
			29: *birchi*		Shales-with-Beef Member	75a(upper)* \ 75b-76
			28: *pseudobonnardi*			75a (lower)*
			27: *obtusiformis*			74r* \ 74s-74w
	Brooki	Brooki	26: *hartmanni*			74e-f* \ 74g-74q
			25: *brooki*			74c-d*
			24: *sulcifer*			73* \ 74a-74b
Semicostatum	Sauzeanum	Sauzeanum	23: *cf. semicostatum*			71-72*
			22: *alcinoeiforme*			70c* \ 70d-70h
			21: *Euagassiceras*			64-69* \ 70a-70b
			20: *cf. resupinatim*			56* \ 57-64
	Scipionianum	Nodulatum	19: *pseudokridion*			53* \ 54-55
		Scipionianum	18: *acuticarinatum*			50-52
	Lyra	Alcinoe	17b: *alcinoe*			
		Crossi	17a: *Paracoroniceras sp*	Blue Lias Formation (part)		49
			16: *bodleyi*			
		Charlesi	15b: *cf. charlesi*			
		Lyra	15a: *lyra*			48
Bucklandi	Bucklandi	Bisulcatus	14: *multicostatum*			
		Isis	13: *cf. scunthorpense*			46-47
			12: *isis*			
			11: aff. *isis*			
		Coronaries	10: *scylla*			?42f-45
	Rotiforme	Schloenbachi	9: *kridion*			36c-42e
		Hyatti	8: *caprotinum*			35-36b
			7b: aff. *rotiforme*			32-34
			7a: *rotiforme*			
			6: *cf. defneri*			31(base)* \ 31(top)
	Conybeari	Conybeari	5c: *silvestrei*			30(upper)*?
			5b: *conybeari*			29* \ 30(lower)
		Rotarium	5a: *elegans*			27(top –0.28m)
			4: *rotator*			27(base)
			3b: *rouvillei*			23(top)-25* \ 26
			3a: *rotarius*			23(base)
		'Latisulcatum'	2b: *conybearoides*			20-22
			2a: *Metophioceras* sp.B			19
			1: *quantoxense*			18(from +0.25m)

Figure 7. *Correlation of the Sinemurian succession of the East Devon coast. Zonules are used in the sense of subdivisions of subchronozones; biohorozonal sequence follows Page (in press). Doted lines indicated uncertainty, verticle hatching indicates non-sequence and asterix (*) indicates confirmed presence of biohorizon. BVMM= Black Ven Marls Member.*

P. cf. *charlesi* (Donovan) (NMW 0041) amongst material collected by M. Foster from Devonshire Head, presumably all ex Bed 49 (probably also NMW 1435, 0046, 0969 and 0978), suggesting that the Crossi Zonule, at least, is represented at this level.

There are indications of other levels in the Lyra Subchronozone in beds 48-49, including further *Paracoroniceras* species and possible late arietitids, although there may be some mixing with Bucklandi Chronozone taxa faunas from below. There is clear evidence of sedimentological condensation at this level, including glauconite, limestone intraclasts and phosphate nodules in Bed 49, which may even be locally absent (= "Grey Ledge" of Lang, 1924; Hallam, 1960; Hesselbo and Jenkyns, 1995, p. 113). Nevertheless, the current picture of the ammonite sequence of beds 47-49 is somewhat cryptic and further *in situ* sampling is therefore needed.

Scipionianum Subchronozone. Scipionianum Subchronozone faunas are crushed and poorly preserved on the Devon-Dorset coast and Lang (1924) did not specify whether his faunas were collected in Devon or Dorset. Indications in the text, however, suggest that his material may have come primarily from the foreshore below Black Ven, east of Lyme Regis, where sampling would be easier and safer.

The base of the subchronozone in the district is placed at the base of Bed 50, where ?*Agassiceras* is first recorded, associated with abundant *Arnioceras* (including *A.* cf. *obliquecostatum* Zieten and *A.* cf. *nodulosum* (J. Buckman) according to Spath, 1924, p. 206). *Agassiceras colesi* (J. Buckman) is first recorded in Bed 52a and ranges up to 52f, and "*Euagassiceras* spp." including *E. striaries* (Quenstedt), is first recorded in bed 52d (Lang, 1924; Spath, 1924, p. 208). *Arnioceras* is generally abundant throughout (full details can be found in the cited sources). According to Corna *et al.* (1997, p. 11), *E. striaries* is typical of the upper part of the Scipionianum Subchronozone in France, specifically within a Nodulatum "Horizon".

Although these faunas are not explicitly recorded in Devon, they will be present in the cliffs west of Lyme Regis and visible in fallen blocks. The fauna of Table Ledge (Bed 53), however, marking the top of the subchronozone, is frequently seen in fallen blocks in the latter area, and includes *Arnioceras pseudokridion* Spath, a species based on type material from east of Lyme Regis (Spath, 1924, p. 207, pl.18, figs 4a,b), indicating the *pseudokridion* Biohorizon in the upper part of the Scipionianum Subchronozone (Page, 1992).

The apparent absence of forms typical of the early Scipionianum Subchronozone, including *Arnioceras acuticarinatum* and *Agassiceras scipionianum* itself - respectively a biohorizonal index in Page (1992) and a zonule index in Corna *et al.* (1997), suggests that the non-sequence at the top of Bed 49 also includes the basal part of the subchronozone above, as already suspected by Spath (1924).

Sauzeanum Subchronozone. As for the Scipionianum Subchronozone, the faunas of the Sauzeanum Subchronozone recorded by Lang *et al.* (1923) are likely to have been collected primarily from the foreshore below Black Ven, which therefore effectively include the stratotypes of the cf. *resupinatum* and *Euagassiceras* biohorizons of Page (1992). Occasionally elements of these faunas are mainly seen in fallen blocks of shale from beds 54-72, west of Lyme Regis, and include typical *Euagassiceras* spp. (e.g. SMC 95-12-17) and *Arnioceras* spp. In addition, occasional blocks of limestone crowded with uncrushed *Arnioceras* spp., but also including rare *Euagassiceras*, are frequently seen on the beach on the east side of Pinhay Bay (SMC 95-12-11 to 13, 95-12-16). This fauna is likely to have come from a level between beds 54 and 69 of Lang *et al.* (1923), although biohorizonal assignment is currently unclear, as those authors do not record a bed of this character *in situ* east of Lyme Regis.

In contrast, the *alcinoeforme* Biohorizon of Page (1992, p. 141) is well developed in East Devon, the best faunas having been obtained from small sections, possible landslipped, on the shore below Dowlands cliffs, in the western outcrop of the

Shales-with-Beef Member. The fauna is dominated by large *Pararnioceras alcinoeforme* Spath, typically preserved as internal moulds partly embedded in limestone nodules. The type of this species, named by Spath (in Lang *et al*., 1923, p. 73; Lang, 1924, p. 208) almost certainly came from Black Ven foreshore. *Arnioceras* is also present at this level, which corresponds to Bed 70c of Lang *et al.* (1923) - the "*Pararnioceras alcinoë* Bed". A large *Euagassiceras* sp. from the same locality, may have come from a level just above the "*alcinoë* Bed".

Blocks and fragments of limestone nodules in this area include abundant dimorphic *Arnioceras* ex grp. *semicostatum* (Young and Bird), and are also seen from time to time west of Lyme Regis, below West Cliff. The fauna suggests a level close to the cf. *semicostatum* Biohorizon of Page (1992) equivalent to beds 71-72 of Lang *et al.* (1923).

Turneri Chronozone, Brooki Subchronozone. Lang *et al.* (1923) described in detail the sequence of faunas in the Brooki Subchronozone of the West Dorset coast, east of Lyme Regis, which formed the basis for the sequence of biohorizons proposed by Page (1992). Elements of these faunas are to be expected in fallen blocks on the beach west of Lyme Regis, originating from beds 73-74q. *Caenisites* spp. from the central Shales-with-Beef Member outcrop on Dowlands foreshore, may be from the Brooki Subchronozone, although further information on the succession of species at this level elsewhere is needed to clarify correlations – certainly no *Microderoceras* or *Promicroceras*, thereby proving higher levels, have been seen to date in this exposure.

Birchi Subchronozone. The lowest horizon of the Birchi Subchronozone, the *obtusiformis* Biohorizon, is likely to be present in Bed 74r of Lang *et al.* (1923) in the cliffs west of Lyme Regis, although the typical fauna is not yet explicitly recorded. In contrast, however, higher parts of the subchronozone are well known in East Devon, both in fallen blocks and, in one instance at least, *in situ*.

The Birchi Nodular Bed of Lang *et al.* (1923) (= Bed 75a), yields two distinctive faunas in septarian concretion preservation in East Devon and West Dorset, as discussed by Page (1992, p. 142-143). The presumed lowest fauna is only recorded in East Devon, *in situ* in West Cliff, and in loose blocks on the beach below. The assemblage is dominated by abundant evolute *Epophioceras pseudobonnardi* (Spath), a very early ancestor of the Echioceratidae of the Upper Sinemurian. Associated are common *Cymbites* sp. and *Microderoceras* cf. *gigas* Buckman (1928, pl. 762 A, B) non Quenstedt. The lower part of Bed 75a in Westcliff is the defined stratotype for this biohorizon (Page, 1992; the fauna including SMC 95-12-18; 08-833, 834, 840, "690" and probably also NMW 1555).

The higher fauna is best developed in West Dorset, but is occasionally recovered form loose concretions in Devon, even as far west as Dowlands foreshore (eastern Shales-with-Beef Member outcrop). This fauna is characterised by typical *M. birchi* (J. Sowerby), with associated small smooth microconch forms. *Cymbites* is also present. Notably, *Epophioceras* appears to be completely absent, although very rare *Caenisites* do occasionally occur, at least in Dorset. This fauna characterises a *birchi* Biohorizon (Page, 1992, p. 143). Elements of this fauna from Westcliff, include SMC 95-12-15 and probably also 94-4-2.

Bed 76a, the Birchi Tabular Bed, is prominent in the cliff west of Lyme Regis, straddling the Devon-Dorset county boundary below Devonshire Head, and may be expected to yield early *Promicroceras*, as in West Dorset. Fragments of concretions with abundant *P. capricornoides* (Quenstedt), presumed to be from immediately above the Birchi Tabular Bed and thereby corresponding to a level close to the *subturneri* Biohorizon of Page (1992, p. 143, in Bed 76 of Lang and Spath, 1926) are occasionally found loose on the beach in this area. The same biohorizon is also confirmed on Dowlands foreshore, in the eastern foreshore outcrop, by loose *Caenisites subturneri* Spath, again associated with *P. capricornoides*.

Body chambers of microconch *Caenisites* ex grp. *turneri* (J. Sowerby), partially enclosed in small nodules, are found from time to time on the beach below Westcliff - although clearly from the Turneri Chronozone, from what level in the sequence is currently unknown.

Upper Sinemurian Substage

Obtusum Chronozone, Obtusum Subchronozone (part). There is very little evidence of Obtusum Chronozone faunas in East Devon, although fragmentary early *Asteroceras* have occasionally been recovered loose on the beach, below Dowlands cliffs. No younger ammonite faunas are recorded on the East Devon coast.

Comparison with other areas and concluding remarks

The East Devon coast displays a superbly exposed early Jurassic succession, from the basal Hettangian to close to the top of the Lower Sinemurian. Slightly higher levels, up to at least the early Obtusum Subchronozone, the lowest part of the Upper Sinemurian, are also present beneath a Cretaceous unconformity, but only seen as loose blocks at beach level.

The area provides stratotypes (type sections) for the *similis* and *pseudomoreana* biohorizons of the Complanata and Depressa subchronozones, respectively, of the Angulata Chronozone of the latest Hettangian. The cf. *complanata* and *Schlotheimia* sp. 1 biohorizons, as defined by Page (1995b) in East Devon are, however, superceded by divisions established through the work of Bloos and Page (2000b) on the thicker and stratigraphically more complete sections of the West Somerset coast. Similarly, most of the biohorizons of the Conybeari Subchronozone and all the biohorizons of the Rotiforme Subchronozone, with the exception of the *rotator* and *conybeari* biohorizons of the former, are now best interpreted based on expanded sections in the latter area, as described by Bloos and Page (2000b).

Similarly, at lower and higher levels in the Planorbis to early Semicostatum chronozone sequence, West Somerset sections provide more detailed biostratigraphical evidence, and are therefore more suitable for defining stratotypes for chronostratigraphical units at various scales. Nevertheless, the Devon-Dorset sections, having played a much greater role in the early development of geology as a science, are of much greater significance as a source of type specimens of key species, and their correct interpretation therefore remains crucial to any taxonomic study of the ammonite faunas of the interval.

At higher levels in the Semicostatum Chronozone and the overlying Turneri Chronozones, although the fauna is dominantly not well preserved, the area remains one of the most stratigraphically complete in Britain. Elsewhere exposure tends to be very poor or incomplete (e.g. Redcar in Cleveland and Robin Hoods Bay, North Yorkshire) or faunal sequences are incomplete (isles of Skye and Raasay, Scotland) – continued importance for biostratigraphical studies is therefore ensured. The Birchi Subchronozone is, however, better developed in this district than anywhere else in Britain, and the Devon coast provides a stratotype for the *pseudobonnardi* Biohorizon. The Obtusum Chronozone, and higher levels in the Sinemurian are only well seen to the east, in Dorset. Figures 6 and 7 summarise the correlation of the observed sequence of faunas in East Devon.

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