

THE BASE OF THE JURASSIC SYSTEM IN WEST SOMERSET, SOUTH-WEST ENGLAND - NEW OBSERVATIONS ON THE SUCCESSION OF AMMONITE FAUNAS OF THE LOWEST HETTANGIAN STAGE

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The West Somerset coast includes the type locality of the index ammonite species of the first Subchronozone and Chronozone of a Standard Jurassic System, namely *Psiloceras planorbis* (J. Sowerby) of the Planorbis Subzone of the Planorbis Zone, and also includes a proposed Global Stratotype Section and Point (GSSP) for the base of the Jurassic System. The recent discovery of ammonite faunas below *Psiloceras planorbis*, including *Neophyllites* sp. and *Psiloceras erugatum* (Phillips), has facilitated a reappraisal of the nature of the earliest Hettangian faunas in western Europe, and the context of the proposed GSSP. The only known exposures in this region which show a complete succession of ammonite faunas at this level are here described. Within a re-defined Planorbis Subchronozone, the following biohorizons are recognized: *erugatum* Biohorizon, *imitans* Biohorizon, *antecedens* Biohorizon, *planorbis* Biohorizon, *sampsoni* Biohorizon and a *plicatum* Biohorizon.

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INTRODUCTION

Oppel (1856, p.24) first established a "Zone des Ammonites *planorbis*" as marking the base of a Jurassic System. His chosen zonal indicator species was based on a group of crushed ammonite specimens collected from shales near the base of the Lower Lias near Watchet on the West Somerset coast, as described by J. de C. Sowerby in 1824 (lectotype refigured by Dean, Donovan and Howarth, 1961, pl. 63, Fig. 1). The zone was subsequently included in a Hettangian Stage by Renevier (1864).

The Planorbis Zone was subdivided into two subzones by Trueman (1922) who first established a lower or Planorbis Subzone, the type locality effectively being the Glamorgan coast, South Wales (Donovan in Dean *et al.*, 1961, p. 443). In 1967, however, at the second Jurassic Colloquium in Luxembourg, a British proposal advocated that a type section for the base of the Planorbis "Subzone" and "Zone" and hence the Jurassic System, should be established on the West Somerset coast between Blue Anchor [ST 032 435] and Quantock's Head [ST 130 440] (George *et al.*, 1969, pp. 153-4, 159-6; Morton, 1971).

There has been much discussion as to where to draw the base of the system in the Triassic - Jurassic sequence so well exposed in this area (Page in Page *et al.*, 1994; Page 1994) but the use of a biostratigraphical criterion rather than a lithostratigraphical boundary has been generally preferred (Cope *et al.*, 1980; Warrington *et al.*, 1980, etc. - and is in fact a standard requirement under International Commission on Stratigraphy rules - see Remane *et al.* 1996). The first occurrence of *Psiloceras*, specifically *P. planorbis* (J. de C. Sowerby) in Bed 13 of Whittaker and Green (1983) (= Palmer, 1972, Bed A21) was taken as this marker, and on this basis, Warrington, Cope and Ivimey-Cook (1994) proposed the section in St. Audrie's Bay [ST 1020 4330], east of Watchet, as a candidate Global Stratotype Section and Point (GSSP) for the base of the Jurassic System. Following the discovery of two poorly preserved psiloceratid ammonites in Beds 8 and 9 in St. Audrie's Bay (Hodges, 1994), Warrington and Ivimey-Cook (1995, p. 15) adjusted the GSSP proposal to this lower level.

The exact nature of these earlier faunas, however, remained uncertain, as indeed did the interpretation of stratigraphically higher psiloceratid faunas. These ambiguities have made correlation of the

West Somerset faunas and the candidate GSSP problematic and even virtually impossible (Page, 1994; although Donovan in Warrington, 1995, p.16, considered this to be "a counsel of despair").

Recent re-examination of two sections on the coast east of Blue Anchor [ST 042 4381 and in Doniford Bay [c. ST 080 436], east of Watchet (Figure 1), has provided large new faunas which include over 50 specimens from the lowest levels first noted by Hodges (*loc. cit.*) (Bloos and Page, 1997). Although key characters such as sutures and whorl sections are generally not preserved, the dominantly crushed faunas consistently show variations in coiling and ornament of taxonomic importance, which thereby facilitate comparisons with material from elsewhere in Britain and Europe. These faunas are in the process of formal description but their occurrence and significance are summarised here.

LOCALITIES

(a) *St. Audrie's Bay*. The Rhaetian (Penarth Group and basal Lias Group) to Hettangian (Lias Group) sequence is well exposed in the cliffs on the east side of St Audrie's Bay and on the foreshore around the headland at [ST 102 433]. The sequence has been described by Whittaker and Green (1983) and Warrington and Ivimey-Cook (1990) and again by Warrington *et al.* (1994) as part of the formal proposal of the candidate GSSP.

Although the overall lithostratigraphical sequence of the area is probably best displayed here, in contrast to neighbouring sections the preservation of the ammonite faunas is relatively poor. Most specimens from the shales of the Planorbis Subzone have no preserved shell material and a brown periostracal stain is usually all that remains. Whether this is due to local tectonically-induced low grade metamorphism or to original taphonomic factors is unclear.

The site is important as having yielded the first indications of pre-*planorbis* ammonite fauna's on the Somerset coast (Hodges, 1994). The specimens were recorded initially as "*P. cf. planorbis*" from Bed 8 and "*P. planorbis*" from Bed 9 (Hodges, *op. cit.*, p. 841), but ?*Psiloceras* sp. indet would be more appropriate. Ammonites, primarily *Psiloceras planorbis*, first occur in abundance in Bed 13 and this very obvious event had influenced most earlier workers, leading to the suggestion that it was "... unlikely, in view of the long history of

the study of this section, that *Psiloceras* will be found to occur lower" (Warrington *et al.*, 1994, p. 196).

All specimens studied so far from Beds 13 to 15 are consistent with *P. planorbis* (J. de C. Sowerby), a form with a relatively narrow umbilicus (as characterised in the type area of the species nearer Watchet itself, see below). An indistinguishable fauna also occurs in Beds 17 to 19. Bed 24, although not sampled in detail at St. Audrie's, contains *P. ex grp. planorbis* in its lowest 0.5 m or so, but bluntly ribbed *P. ex grp. plicatulum* (Quenstedt) are present at least in the upper part of the Bed ("Plicatulum Subzone", see below). The first *Caloceras* sp. with strong, blunt ribs (Johnstoni Subzone) is recorded in the limestone Bed 25 (= "*Caloceras* sp. or spp.1" in Page, 1994, Fig. 1). Limestones below Bed 24 in the sequence have yielded only very poorly preserved indeterminate ammonites.

(b) *Doniford Bay*. The foreshore north of the Watchet fault in the western part of Doniford Bay, shows good exposures of the Rhaetian-Hettangian transition at around [ST 080 436]. The sequence has been described by Whittaker and Green (1983) and is broadly similar to that in St. Audrie's Bay. Importantly, however, the ammonite faunas are better preserved, with *Psiloceras* in shale from beds 13 to 24 having iridescent aragonitic shells (albeit still in a crushed condition). Ammonites in limestone beds are still infrequent, however, and again, not well preserved.

Following Hodges' discovery of ammonites in beds below Bed 13 in St. Audrie's Bay, a detailed re-examination of similar levels in Doniford Bay was made by one of us (KNP) in 1994. Bed 8 at Doniford Bay was also found to yield ammonites and a further search by both authors and J. Radley (formerly of the City of Bristol Museum) and H.C. Ivimey - Cook (formerly of the British Geological Survey) in 1995 led to the recovery of further partially crushed specimens.

One of the greatest problems in studying the early ammonites of the Somerset coast has been the absence of whorl cross sections and visible sutures on the dominantly crushed shells - both characters are essential for psiloceratid taxonomic studies (cf. Page *et al.*, 1994; Page, 1994). Remarkably, however, one of the specimens from Bed 8 in Doniford Bay showed a simple but typical *Psiloceras* suture, similar to that known from well preserved *P. psilonotum* from southern Germany (Bloos and Page, 1997). Two specimens also display blunt primary ribbing unlike anything known in assemblages of *P. planorbis* from higher levels, and have relatively open umbilici.

The occurrence of ribbed psiloceratid ammonites below smooth forms has never before been clearly demonstrated from surface exposures in Europe. Donovan in Poole and Whiteman (1966), however, recorded ribbed "*Psiloceras planorbis erugatum*

(Phillips)" below smooth "*P. planorbis*" from the Wilkesley Borehole in Cheshire (north-west England). These records have been largely overlooked in subsequent work, but re-examination of specimens in the British Geological Survey collections (Keyworth) has confirmed the determination by comparison with the type and effective topotypes of the former species (known previously only from loose blocks washed up on the shore of Robin Hood's Bay, North Yorkshire, presumably *ex glacial drift*; Bloos and Page, 1997). A distinctive feature of *P. erugatum* is the presence of "bead-like ribs on the innermost whorls" (Donovan, 1966), typically followed by blunt ribbing. The duration of the ribbed stage is very variable and occasional specimens are virtually smooth. This latter character is matched by the specimens from Bed 8, but the noded nucleus is not well preserved in the available material.

The lower part of Bed 9 in Doniford Bay has also yielded a few psiloceratid ammonites, but although no distinctive characters are visible, the relatively evolute coiling of one specimen recalls *Neophyllites* (see below). The upper part of the same bed has also yielded poorly determinable psiloceratids which resemble *P. planorbis* in possessing relatively narrow umbilici. Beds 13 to 15 and 17 to 19 yield abundant crushed, but otherwise well preserved, iridescent aragonite-shelled psiloceratids - again with relatively narrow umbilici typical of *P. planorbis* s.s.. Indeed, it is likely that the lectotype of the species came from one of these levels here or further west, between Watchet and Blue Anchor. Macroconchs and microconchs appear to be distinguishable, the former reaching 50-60 mm in diameter, the latter around 20-30 mm. A few specimens, however, show slightly different features. In Bed 14 around 10% of the fauna have traces of weak plications on the inner whorls and very occasionally on nuclei, but no *erugatum*-like nodes have been observed. In Bed 18, around 6% show weak plications, but as the sample size is relatively small (around 30 specimens), this difference might not be significant. There is no reason to believe that most of these plicate specimens are no more than variants of *P. planorbis*. A single plicate specimen from Bed 18, however, is noticeably more evolute and is therefore more problematic.

A single specimen from Bed 18, although superficially similar to the rest of the fauna, shows a number of spiral grooves (or rills) on its outer whorl at a diameter of around 35 mm. This character is typical of some specimens of *Neophyllites* known from Germany and is the first indication of this genus in situ in Britain. *Neophyllites* is primarily distinguished from *Psiloceras* by its simplified suture and more angular umbilical edge. The former cannot be seen in the Somerset specimens and the latter is difficult to observe in crushed specimens. It is possible, therefore, that some of the other specimens from beds 13 to 19 which have been referred to *P. planorbis* could also include *Neophyllites*. In the Wilkesley borehole, *Neophyllites* is common above *P. erugatum* but below *P. planorbis* (BGS collections). This sequence is not yet clearly demonstrable in West Somerset, as ammonites are uncommon and generally poorly preserved in the higher part of Bed 9 and up to Bed 12, below the first typical *P. planorbis*.

The lowest 0.6 m of Beds 23 to 24 also yields *P. ex grp. planorbis*, but from around 0.6 m to 1.0 m above the base of Bed 23, larger and more evolute *Psiloceras* are present, maturing at around 70-75 mm diameter. These latter forms are referred to *P. sampsoni* (Portlock), a possible senior synonym of *P. psilonotum* (Quenstedt). About 1.2 m above the base of Bed 23, a narrow horizon, around 0.10 to 0.20 m thick, yielded abundant typical *P. ex grp. plicatulum* (Quenstedt), with strong blunt plications to at least 50-55 mm diameter on macroconchs (which mature at up to 70mm diameter). Remarkably, around 0.55 m higher, *P. ex grp. sampsoni* once more dominates. *P. ex grp. plicatulum* persists and appears to dominate the fauna of the uppermost part of Bed 24. The sequence at these levels is, however, unclear due to disruption of the outcrop by minor faulting and damage to the exposures by intensive and unregulated fossil collecting. The base of the succeeding Johnstoni Subchronozone is not so clearly recognisable as at St. Audrie's Bay, again due to faulting, although *Caloceras* is recorded from Beds 36 and 37 (Whittaker and Green, 1983).

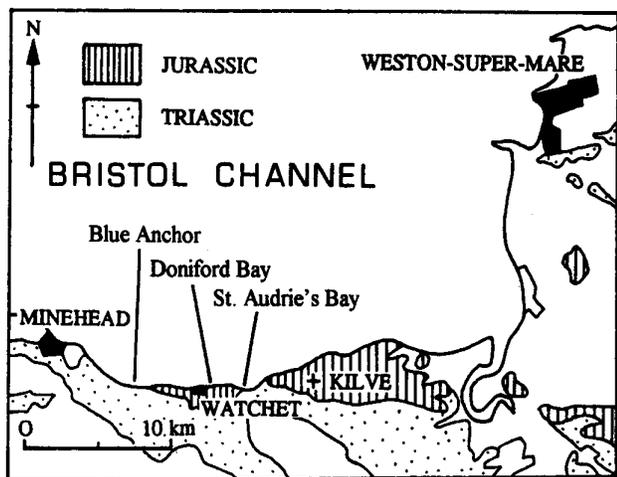


Figure 1. Simplified geological map of the West Somerset coast (after Whittaker and Green, 1983) showing the location of key Triassic-Jurassic boundary sequences mentioned in the text.

(c) *Blue Anchor*. The cliffs and foreshore east of Blue Anchor [from around ST 042 438] to near Watchet [c. ST 068 437] show a number of small and highly faulted outcrops of the Rhaetian - Hettangian transition. The sequence here has not been described in detail but is comparable to sections further east. Bed 8 is recognisable but has not yet yielded any ammonites. Bed 9, however, includes around 5 - 10 cm above its base, a silty calcareous band with common crushed and partially crushed ammonites and bivalves, the former often retaining a brownish calcitic shell. Around 20 - 25% of the recovered fauna has plications and therefore superficially resembles *P. erugatum*, but nodes are not visible on the few nuclei preserved. A few specimens also have a relatively sharp umbilical edge, suggesting *Neophyllites*, but no sutures are visible. As some German *Neophyllites* have plications, the identity of this fauna requires further investigation. Nevertheless, specimens from the Wilkesley borehole indicate that a few *P. erugatum* persist into levels dominated by *Neophyllites*.

Beds 13 to 15 and levels apparently equivalent to Beds 17 to 24 (basal part) yield typical *P. ex grp. planorbis*, as at Doniford, but often with relatively white aragonite shells. *Neophyllites* is also present, as indicated by a few specimens in similar preservation in old collections, which possess typical spiral grooves and are labelled "west of Watchet". One specimen, in the collections of the Natural History Museum in London (C 79568), is recorded as coming from "four inches above the upper surface of two six-inch cementstone bands separated by about 40 inches of grey marl". This record suggests Bed 18. Higher levels are present but faulting makes accurate sampling difficult.

STRATIGRAPHICAL REVISION OF THE PLANORBIS ZONE

The new faunas obtained from the West Somerset coast have resolved some of the uncertainties concerning the succession of earliest Jurassic-type ammonite faunas in Europe (cf. Bloos, 1984). The coastal exposures can now be considered to form a valuable reference section for British faunas otherwise known mainly from loose blocks *ex glacial drift* or from boreholes. This sequence of faunas can form the basis of a refined zonation for the basal Hettangian, as follows:

PLANORBIS CHRONOZONE. Index: *Psiloceras planorbis* (J. de C. Sowerby, 1824). Author: Oppel (1856).

(a) Planorbis Subchronozone. Index: as chronozone. Author: Trueman (1922). Type locality: Glamorgan, South Wales. Stratotype: Proposed by Warrington *et al.* (1994) and revised by Warrington and Ivimey-Cook (1995); base of Bed 8, St Audries Bay, West Somerset. Correlating fauna: Dominated by smooth-whorled psiloceratids including *P. planorbis*, *P. sampsoni* (Portlock) and *Neophyllites* spp. (*sensu* Lange, 1941). The basal part of the Subchronozone is characterised by the early ribbed form *P. erugatum* (Phillips) and higher parts include *P. ex grp. plicatulum* (Quenstedt). Comments: The Planorbis Subchronozone as used here includes the Plicatulum Subzone of Hillebrandt (1984, 1990) and Page (1995) (see below).

The following biohorizons are recognised in a restricted Planorbis Subchronozone in Britain:

(i) *erugatum* Biohorizon. Index: *Psiloceras erugatum* (Phillips 1829). Author: Buckman (1921) as an *erugatum* Hemera. Type locality: Robin Hood's Bay, North Yorkshire (but no *in situ* record). Proposed stratotype (provisional): Wilkesley Borehole, Cheshire; levels 487' (148.4 m) to 485' 6" (147.95 m). Correlating fauna: *P. erugatum* with characteristic noded nuclei and typically bluntly ribbed later whorls. No other taxa are recorded. Comments: As no surface exposures of these levels are presently recorded in Cheshire (e.g. in

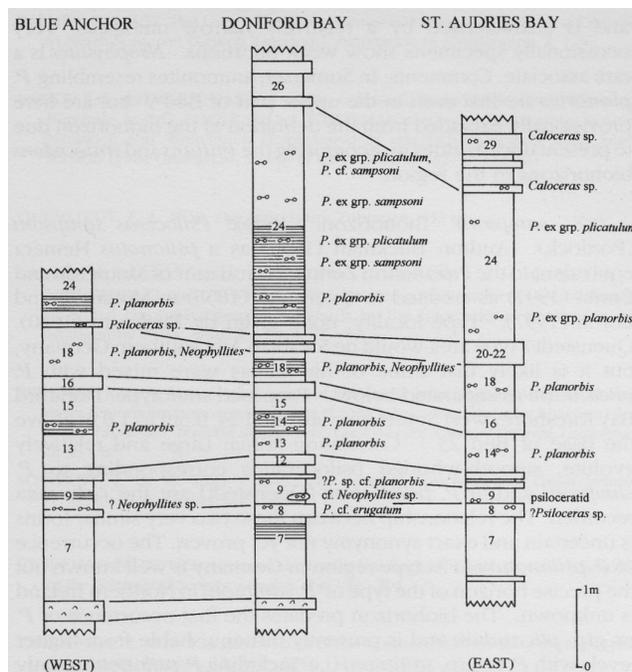


Figure 2. Diagrammatic representation and correlation of the Triassic-Jurassic boundary sequences described in the text and their faunas.

Poole and Whiteman, 1966), the stratotype is provisionally established in the borehole sequence.

(ii) *imitans* Biohorizon nov. Index: *Neophyllites imitans* Lange (1941). Type locality and provisional stratotype: Wilkesley Borehole, Cheshire, levels 478' 10" (145.95 m) to 472' 2" (143.9 m). Correlating fauna: *N. imitans* is common and characteristic, and dominates assemblages. The species has a narrower umbilicus than that of the later *N. antecedens* and there is no accentuated umbilical edge or spiral grooves. Very rare *P. erugatum* may also be present in the lowest part of the biohorizon. Comments: The stratotype is provisional as no surface exposures are recorded (see above). Levels 485' 6" to 478' 10", separating the *erugatum* and *imitans* biohorizons, have not yielded any ammonites.

(iii) *antecedens* Biohorizon. Index: *Neophyllites antecedens* (Lange, 1931). Author: Lange (1941) as an *antecedens* Zone, here restricted to exclude faunas dominated by *N. imitans*. Type locality: Drove, Germany. Provisional stratotype: Wilkesley Borehole, Cheshire, levels 471' 6" (143.7 m) to 453' 9" (138.3 m). Correlating fauna: *N. antecedens* is dominant and distinguished from *N. imitans* by its relatively wide umbilicus. Spiral grooves on outer whorl's only appear towards the top of the Biohorizon (above 465' 3"). *Psiloceras ex grp. planorbis* may also be present at higher levels. Comments: The *imitans* and *antecedens* biohorizons are distinguished on the basis of the relative frequency of the two related species. The separation, or polarisation, of *Neophyllites* faunas towards *N. imitans* or *N. antecedens* is also recognisable in southern Germany, indicating that the two biohorizons are potentially recognisable in that region. The *imitans* and *antecedens* biohorizons would be represented by parts of Beds 9 to 12 on the West Somerset coast, but due to the preservational style and rarity of ammonites at the higher levels they are not yet clearly distinguishable.

(iv) *planorbis* Biohorizon. Index: As zone. Author: Buckman (1930, p. 37) as a *planorbis* Hemera. Type locality: Watchet district, West Somerset. Proposed stratotype: Doniford Bay foreshore, West Somerset coast, Bed 13 to around 0.6 m above the base of beds 23/24. Correlating fauna: *P. planorbis* is abundant and is characterized by a

relatively narrow umbilicus. Very occasionally specimens show weak plications. *Neophyllites* is a rare associate. Comments: In Somerset, ammonites resembling *P. planorbis* are first seen in the upper part of Bed 9 but are here provisionally excluded from the definition of the biohorizon due to present uncertainties in recognising the *imitans* and *antecedens* biohorizons in the region.

(v) *sampsoni* Biohorizon. Index: *Psiloceras sampsoni* (Portlock). Author: Buckman (1930) as a *psilonotus* Hemera equivalent to the *Psilonotum* Zonule / "Horizon" of Mouterde and Coma (1991) as credited to Quenstedt (1858) in Mouterde and Coma (1997). Type locality: none given by Buckman (1930). Quenstedt's type area would be Swabian Alb, southern Germany, but it is likely that some of his faunas were mixed with *P. plicatum* as separated below. Proposed stratotype: Doniford Bay foreshore, West Somerset coast, Bed 24, 0.6m to 1.0 m above the base of Bed 23. Correlating fauna: Large and relatively evolute, smooth-whorled psiloceratids corresponding to *P. sampsoni* and/or *P. psilonotum* (Quenstedt) are the only taxa recorded. The relationship between these two very similar forms is uncertain and exact synonymy not yet proven. The occurrence of *P. psilonotum* in its type region in Germany is well known but the precise horizon of the type of *P. sampsoni* in Northern Ireland is unknown. The biohorizon predates the first occurrence of *P. ex grp. plicatum* and is presently distinguishable from higher levels with *P. ex grp. sampsoni* (i.e. including *P. psilonotum*) only on that basis.

(vi) *plicatum* Biohorizon. Index: *Psiloceras plicatum* (Quenstedt). Author: Buckman (1930) as a *plicatus* Hemera. Used by Elmi and Mouterde (1965) as a "Horizon" (zonule *sensu* Page, 1995). First used as a subzone by Hillebrandt (1984, 1990) and subsequently by Page (1994). Use as zonule retained by Mouterde and Corna (1997). Type locality: none given by Buckman; Ardèche (Elmi and Mouterde, 1965). Proposed Stratotype: Doniford Bay foreshore, West Somerset coast, Bed 24, 1.2 to 2.6 m above the base of Bed 23. Comments: The higher part of a conventional Planorbis "Subzone" is not yet well characterised on the Somerset coast. Nevertheless, three potentially correlatable faunas may be present. The lower fauna, from 1.2 to 1.3 m above the base of Beds 23/24 is almost exclusively composed of strongly plicate *P. ex grp. plicatum*. At slightly higher levels, smooth *P. ex grp. sampsoni*, is again common. *Psiloceras ex grp. plicatum* persists and once more dominates assemblages in the uppermost part of Bed 24. The precise identity of these younger plicate *Psiloceras* on the West Somerset coast is ambiguous as the crushed condition does not presently allow the separation of true *P. plicatum* from the similar *P. bristoviense* (Donovan); both are therefore provisionally grouped here within *P. ex grp. plicatum* and the West Somerset coast faunas united in a single *plicatum* Biohorizon. The status of a *plicatum* Biohorizon as a potentially subdivisible unit requires further investigation. Hillebrandt (1984, 1990) and Page (1995) chose to raise its status to that of a subzone although other authors (e.g. Mouterde and Corna 1997) preferred to retain it as a "Horizon" (= zonule *sensu* Page, 1995, i.e. equivalent to a sub-subzone). The mixing of plicate *plicatum* / *bristoviense* and smooth *sampsoni* / *psilonotum* observed in Britain and Germany means that separation of a Planorbis from a Plicatum subchronozone could be difficult where faunas representing levels at which the former is rare and the latter dominant are developed. Should it be possible to morphologically, and therefore taxonomically, separate the two *P. ex grp. plicatum* faunas and/or the higher *P. ex grp. sampsoni* fauna from the lower, full biohorizonal and possibly even subchronozonal status could be established.

(b) *Johnstoni* Subchronozone. Index: *Caloceras johnstoni* (J. de C. Sowerby). Author: Stoddard (1868, see Donovan in Dean *et al.*, 1961). Comments: The West Somerset coast includes the type locality of the subzonal index and at least three biohorizons may be potentially recognisable (see Page 1994). Good faunas of the subzone are also known from the Glamorgan coast (*pers. obs.* by authors). Further

work is needed, however, before these two regions can be accurately correlated and a formal sequence of biohorizons is not, therefore, proposed here.

As described by Bloos and Page (1997), work in progress aims to establish accurate correlations between the faunas described above and sections known elsewhere in Europe and further afield, for instance in south and north America (e.g. as proposed as candidate GSSPs by Hillebrandt, 1997 and Guex *et al.*, 1997 respectively). In the meantime, however, the new information available from West Somerset and Cheshire, establishes the nature and sequence of the basal Jurassic ammonite faunas of North West Europe and provides an important basis for international correlation of the candidate GSSP for the base of the Jurassic System proposed by Warrington *et al.* (1994).

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