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A PRELIMINARY ANALYSIS OF THE FORAMINIFERA FROM THE HETTANGIAN - SINEMURIAN BOUNDARY OF EAST QUANTOXHEAD, WEST SOMERSET

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The coastline of West Somerset has long been recognised as containing a classic example of Lower Lias (Lower Jurassic) geology consisting of alternating cycles of shale and limestone ('Blue Lias' facies). Recent investigations of the palynology, chemostratigraphy, magnetostratigraphy and ammonite successions have been undertaken to characterise the candidate basal Sinemurian Stage stratotype in the area around East Quantoxhead.

The present study has involved the preliminary investigation of the foraminifera across the Hettangian - Sinemurian boundary as part of the assessment of the potential of the section as a Global Stratotype Section and Point (GSSP).

35 samples of mudstone and shale were studied for microfossils in the >74 μm size-fraction from a 30 m section across the boundary. Ten samples proved fossiliferous with an abundant and diverse fauna of foraminifera.

The faunas are dominated by the *Lingulina tenera* Bornemann plexus group with associated nodosariids and a minor component of the *Frondicularia terquemi* Bornemann plexus group. The absence of foraminifera in the remaining samples could be a result of diagenesis associated with the formation of the limestones.

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INTRODUCTION

The Lower Jurassic of Northern Europe is dominated by relatively thick, complete sequences of argillaceous facies which are extensively developed on the north Somerset coast. Here, the Lower Jurassic is 203 m thick (Whittaker and Green, 1983) which when compared to equivalent zones in Dorset (47.6 m) and Glamorgan (119 m) shows considerable expansion (Palmer, 1972). This makes the Hettangian-Sinemurian boundary sequence, on the coast of west Somerset, near East Quantoxhead (Figure 1), some 5 times thicker than other comparable sequences. This marine sedimentary group comprises a sequence of alternating small scale limestone and shale rhythms (commonly known as Blue Lias facies), often containing finely laminated (bituminous) shales. A well-developed sequence of ammonite faunas and six successive and correlatable biohorizons have been recognised in the basal subzone of the Sinemurian by Page (1995) who proposed that this section was a potential global stratotype and point (GSSP) for the base of the Sinemurian Stage. The exclusive use of ammonites as correlative tools does not, however, fulfil the requirements of the International Commission on Stratigraphy (ICS), whose guidelines recommend that other methods, such as magnetostratigraphy and micropalaeontology are assessed (Salvador, 1994) before a formal proposal can be submitted to the International Subcommision on Jurassic Stratigraphy.

Consequently, this foraminiferal study was undertaken to aid in the assessment of the area for establishing an internationally recognised GSSP for the base of the Sinemurian Stage. Although planktonic foraminifera originated in the Triassic (?) or Early Jurassic, foraminifera were of predominantly of benthonic habit during the Lower Jurassic and show very consistent stratigraphic ranges throughout north west Europe (Copestake, 1985). Benthonic foraminifera are of great value in subdividing and correlating the Lower Jurassic with an obvious importance in situations where ammonites are not recovered.

PREVIOUS RESEARCH

The stratigraphy of the Lower Jurassic of the west Somerset coast was described by Palmer (1972) with a more recent re-description made by Whittaker and Green (1983) who proposed the biostratigraphic ammonite zonation scheme for the Hettangian - Sinemurian boundary sequence at East Quantoxhead in Figure 2. While the Stage is considered to be a unit of chronostratigraphic hierarchy, almost all Jurassic stages are defined in terms of their contained biozones (Cope *et al*., 1980, p3). Hence ammonite biozones can be considered tantamount to chronozones defined at their base and in accordance with guidelines on stratigraphic nomenclature (Salvador, 1984) this study uses the terms 'Zone' and 'Subzone' in this sense.

The foraminifera of the Lower Jurassic of the United Kingdom have been extensively researched, a comprehensive review of which is contained in Copestake and Johnson (1989). Hettangian-Sinemurian faunas of the Mochras Borehole in North Wales, were described by Copestake (1978) from the thickest Lower Jurassic sequence in the United Kingdom. Although there is no published research on the foraminifera of the Hettangian-Sinemurian of the north Somerset coast, Copestake and Johnson (1989) list the ranges of seven species known from the Hettangian of St. Audries Slip and Watchet compiled from unpublished data.

MATERIALS AND METHODS

A total of 35 samples of shale and mudstone were taken at the levels shown in Figure 3 from the section near East Quantoxhead [ST 137 443] with an emphasis placed on the boundary shale. Samples labelled EQH were provided by K. N. Page and those labelled QTX were collected by the author. Samples from the limestone beds were

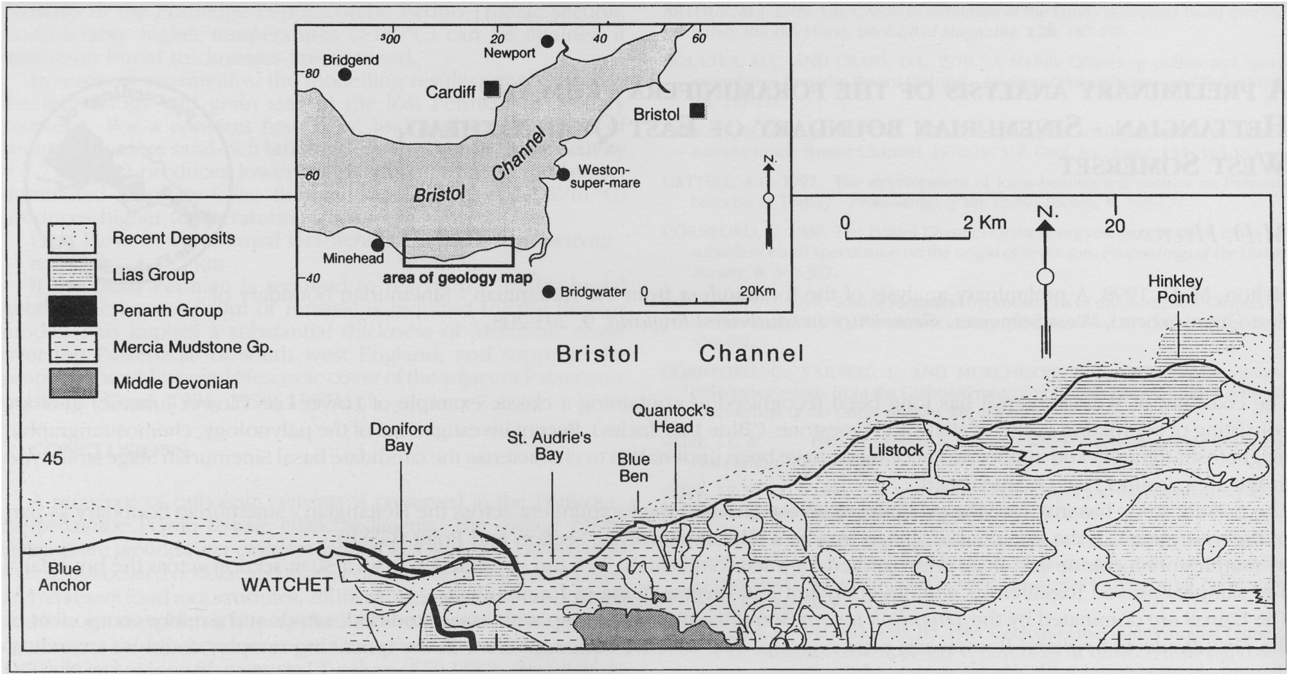

Figure 1: Location map and local geology of the Lower Jurassic, Hettangian - Sinemurian, coastal section at East Quantoxhead (after Warrington and Ivimey-Cook, 1995)

not included in this study as the recognition of nodosariid foraminifera in thin-section is problematic.

Some of each sample was retained unprocessed as a safeguard against contamination during processing and the possible need for a sample check. Around 200 grams of material was processed using standard disaggregation techniques. The samples were manually broken down into fragments of around 5-10 mm in diameter, dried at 60°C in an oven for 12 hours and then soaked in white spirit for a further 8 hours. The white spirit was then decanted off and the sample soaked in distilled water for around 8 hours.

While many of the samples were quite argillaceous, the more indurated samples did not disaggregate using this method only. If breakdown was not complete at this point the sample was dried again in the oven before using a second technique. This involved boiling the sample in a solution of washing soda (Na_2CO_3) for one hour, after which time some of the fine clays were in suspension. The suspension was poured through a 74 µm sieve so that the finer material was washed away, The residue was then reboiled in washing soda solution until there was no further noticeable breakdown.

The residue from both techniques was finally washed in a 74 µm sieve, dried in an oven and then weighed. The residues were examined under a binocular microscope and at least 300 individuals from each sample were picked, where possible, to obtain a representative assemblage of the species present (Dennison and Hay, 1967).

Chronostratigraphy			Bed no. of base	Lithological Unit
Stage	Zone	Subzone		Bed no.
Sinemurian	Bucklandi	Rotiforme	162	147
		Conybeari	146	146
Hettangian	Angulata	*not delimited*	80	

Figure 2: Chronostratigraphic division of the Hettangian -Sinemurian sequence at East Quantoxhead, bed numbers after Whittaker and Green (1983).

A Scanning Electron Microscope (SEM) was used to inspect the microfossils at higher magnifications. A well preserved individual of each species was selected and mounted on a carbon tab covered plain stub. The stubs were then coated with gold and examined using a JEOL JSM-5200 SEM at 25kv.

RESULTS

The majority of the residues proved to be barren of any microfauna with ten samples containing foraminifera. The fossiliferous samples, however, did have an abundant and diverse foraminiferal fauna. Also present were ostracods, echinoid spines and micro-gastropods.

The taxonomic problems of Lower Jurassic foraminifera are well documented (Barnard, 1950; Copestake, 1978; Copestake and Johnson, 1989) because of differing species concepts employed by authors, owing partly to considerable morphological variation. Barnard (1950) and Adams (1957) first applied the plexus concept to Jurassic foraminifera as an approach to the problem of intraspecific variation. Copestake (1978) defines the species plexus as a single, variable, polytypic species which is evolving and has thus produced distinct subspecies, in addition to many variants, during the course of its development. As progressive evolution in the Lower Jurassic is shown by a number of species and in particular by the *Lingulina tenera* Bornemann plexus, the value of short ranged morphological variants is enhanced by recognition of their place as subspecies (chronosubspecies) within the evolving plexus. The species and subspecies names used here, therefore, are those considered to have consistent stratigraphic ranges and differentiation (Copestake and Johnson, 1989). Table 1 illustrates the distribution of selected index species which are the most relevant to the present study and published foraminiferal biozonation schemes for the Lower Jurassic (Copestake, 1985; Copestake and Johnson, 1989).

Taxonomic notes on selected species

The following list contains the species figured from the East Quantoxhead section in the present paper (Plate 1). The species names used here are given together with the original name where it differs and a reference to a recent publication where the species is illustrated. Remarks on their taxonomy, abundance and distribution are also given.

Astacolus/Vaginulinopsis speciosa (Terquem) = *Cristellaria speciosa* Terquem, 1858. (Plate 1, Figure 1).

Figured by Copestake (1978), pl. 23, figs. 5-9.

Remarks: A common species in the Lower Jurassic, occurring throughout north-western Europe from the base of the Hettangian Angulata Zone to the Pliensbachian Margaritatus Zone (Copestake, 1978).

Dentalina matutina (d'Orbigny) = *Dentalina primaeva* d'Orbigny, 1849. (Plate 1, Figure 2).

Figured by Copestake and Johnson (1989), pl. 6.2.2, fig. 10.

Remarks: First appears in the Hettangian, upper Angulata Zone, ranging as high as the Pliensbachian, Margaritatus Zone in Britain and up to the top Spinatum Zone in mainland Europe (Copestake and Johnson, 1989).

Frondicularia terquemi plex. *sulcata* Bornemann = *Frondicularia sulcata* Bornemann, 1854. (Plate 1, Figure 3).

Figured by Copestake and Johnson (1989), pl. 6.2.3, fig. 8.

Remarks: Members of this plexus group are diagnostic of the Lower Jurassic. Most of the forms found at East Quantoxhead have a large test and ten ribs, corresponding to Form C of Barnard (1957) which

Plate 1: 1) Astacolus/Vaginulinopsis speciosa *(Terquem), QTX10, 2)* Dentalina matutina *(d'Orbigny), QTX10, 3)* Frondicularia terquemi *plex.* sulcata *Borneman, QTX10, 4)* Lenticulina varians *(Bornemann), EQH24, 5)* Lingulina teneraplex. substriata *(Nørvang), EQH10,* 6) Lingulina tenera plex. tenera *Bornemann, EQH22,* 7) Lingulina tenera *plex*. tenuistriata *(Nørvang), EQH22, 8)* Marginulina prima *plex*. praerugosa *Nørvang, EQH10,* 9) Nodosaria sexcostata *Terquem, EQH24, 10)* Nodosaria simplex *(Terquem), EQH23, 11)* Planularia inaequistriata *(Terquem), EQH8, 12)* Planularia protracta *(Bornemann), EQH22.*

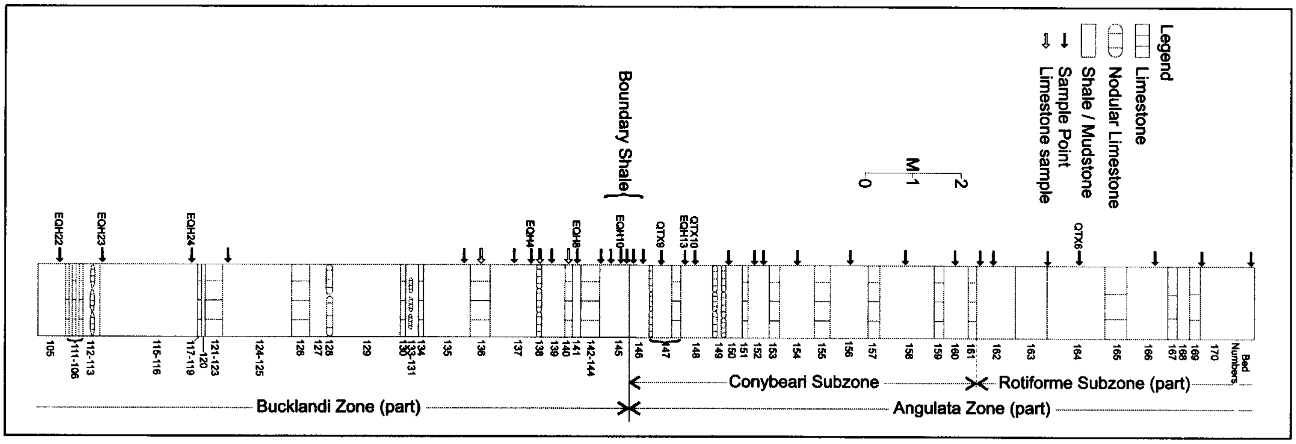

Figure 3: Hettangian - Sinemurian boundary sequence at East Quantoxhead, showing location of samples studied (Log by author, bed numbers after Whittaker and Green, 1983). Samples containing foraminifera are identified. Biostratigraphy as for Figure 2.

ranges from the Hettangian, Angulata Zone to the Pliensbachian Spinatum Zone (Copestake and Johnson, 1989).

Lenticulina varians (Bornemann) plexus group = *Cristellaria varians* Bornemann, 1854. (Plate 1, Figure 4).

Figured by Copestake and Johnson (1989), pl. 6.2.4, fig. 3.

Remarks: This species is common throughout the Lower Jurassic, ranging from the Rhaetian - Oxfordian, first appearing in Britain in the Liascus Zone (Copestake and Johnson, 1989).

Lingulina tenera plex. *substriata* (Nørvang) = *Geinitzinita tenera substriata* Nørvang, 1957. (Plate 1, Figure 5).

Figured by Copestake and Johnson (1989), p1. 6.2.4, fig.12.

Remarks: Distinguished from other members of the *Lingulina tenera* plexus group by its keel, sulcus and irregular ribbing, this form is a valuable index species for the Hettangian ranging from the base of this stage to just into the basal Sinemurian Bucklandi Zone in Britain (Copestake and Johnson, 1989).

Lingulina tenera plex. *tenera* Bornemann = *Lingulina tenera* Bornemann, 1854. (Plate 1, Figure 6).

Figured by Copestake and Johnson (1989), pl. 6.2.4, fig 9.

Remarks: This member of the *L. tenera* plexus group is distinguished by having two main ribs, a keel and an absence of interstitial ribs or striae. There was a high degree of variability in size among the individuals seen. Main range Rhaetian - Toarcian with a distinct acme in Britain in the Hettangian, upper Angulata Zone (Copestake and Johnson, 1989).

Lingulina tenera plex. *tenuistriata* (Nørvang) = *Geinitzina tenera* subsp. *tenuistriata* Nørvang, 1957. (Plate 1, Figure 7).

Figured by Copestake and Johnson (1989), pl. 6.2.4, fig. 10.

Remarks: A long ranging form, abundant in the Lower Jurassic. British range from Rhaetian to Upper Toarcian, most abundant in the Lower Sinemurian, Bucklandi-Semicostatum Zones (Copestake and Johnson, 1989).

Marginulina prima praerugosa Nørvang, 1957. (Plate 1, Figure 8).

Figured by Copestake and Johnson (1989), pl. 6.2.5, fig. 5.

Remarks: British range between the Hettangian, uppermost Liasicus Zone to the basal Toarcian, Tenuicostatum Zone, being most consistent and widespread in the Sinemurian (Copestake and Johnson, 1989).

Nodosaria sexcostata Terquem, 1858. (Plate 1, Figure 9).

Figured by Riegraf (1985), pl. 7, figs.19-22.

Remarks: This species has a recorded European range from the Hettangian to the Lower Toarcian. British range is from the Hettangian to the Upper Pliensbachian (Copestake, 1978).

Nodosaria simplex (Terquem) = *Dentalina simplex* Terquem, 1858. (Plate **1,** Figure 10).

Figured by Riegraf (1985), pl. 7, fig. 1.

Remarks: Occurring at most levels at East Quantoxhead, this species has a long north western European range between the Hettangian and the Toarcian (Copestake, 1978).

Planularia inaequistriata (Terquem) = *Marginulina inaequistriata* Terquem, 1863. (Plate 1, Figure 11).

Figured by Copestake and Johnson (1989), pl. 6.2.5, fig. 16.

Remarks: This species is restricted to the uppermost Hettangian - Upper Sinemurian, with its optimum development during the Lower Sinemurian. First appears at the base of the Hettangian, Liasicus Zone in Britain with typical forms disappearing in the Upper Sinemurian, Obtusum Zone. With a wide European distribution (also reported from Alaska) and a short stratigraphic range, it is a useful index fossil (Copestake, 1978).

Planularia protracta (Bornemann) = *Cristellaria protracta* Bornemann, 1854. (Plate 1, Figure 12).

Figured by Barnard (1950), p. 376, fig. 8h.

Remarks: Although a geographically wide ranging form during the Jurassic, occurring between the Rhaetian and the Bathonian (Copestake and Johnson, 1989), this species is characteristic of the faunas through the section at East Quantoxhead.

DISCUSSION

The results of this preliminary study provide some valuable data on the nature of the foraminiferal fauna at East Quantoxhead. The predominance of calcareous foraminifera and especially the *Lingulina tenera* plexus group is typical of Lower Jurassic sequences in Northern Europe and the United Kingdom. The assemblages also comprise useful index species and other forms diagnostic of the Lower Jurassic and the Hettangian - Sinemurian in particular. The first and last appearances of *Lingulina tenera* plex. *substriata* are restricted to the top of the Hettangian Angulata zone and are therefore useful for correlating the base of the Sinemurian (Copestake and Johnson, 1989). The consistent appearance of *Planularia inaequistriata* and the *Frondicularia terquemi* plexus group above the boundary at East Quantoxhead is also a characteristic of the basal Sinemurian zones. Copestake and Johnson (1984) also include the important index species *Lingulina tenera* plex. *substriata*, *Planularia inaequistriata* and *Dentalina matutina* in their benthic foraminiferal zonation scheme. This scheme, of international applicability for both southern and northern hemispheres, covers Britain and seventeen other countries and regions throughout the world.

The absence of foraminifera, or indeed any microfauna, from the majority of samples studied could be associated with secondary

Species / Sample ID	*Astacolus / Vaginulinopsis speciosa*	*Dentalina matutina*	*Frondicularia terquemi plex. sulcata*	*Lenticulina varians*	*Lingulina tenera plex substriata*	*Lingulina tenera plex tenera*	*Lingulina tenera plea tenuistriata*	*Marginulina prima plea praerugosa*	*Nodosaria sexcostata*	*Nodosaria simplex*	*Planularia inaequistriata*	*Planularia protracta*	*Bed Number T(Top), M(Mid), B(Base), after Whittaker and Green (1913)*
QTX1	-	-	-	-	-	-	-	-	-	-	-	-	T170
QTX2	-	-	-	-	-	-	-	-	-	-	-	-	B170
QTX3	-	-	-	-	-	-	-	-	-	-	-	-	T166
QTX6	**-**	**?**	**-**	**R**	**-**	**R**	**R**	**-**	**-**	**-**	**-**	**R**	**M164**
QTX5	-	-	-	-	-	-	-	-	-	-	-	-	B164
QTX4	-	-	-	-	-	-	-	-	-	-	-	-	M162
EQH21	-	-	-	-	-	-	-	-	-	-	-	-	B162
EQH20	-	-	-	-	-	-	-	-	-	-	-	-	M160
EQH19	-	-	-	-	-	-	-	-	-	-	-	-	M158
EQH18	-	-	-	-	-	-	-	-	-	-	-	-	M156
EQH17	-	-	-	-	-	-	-	-	-	-	-	-	M154
EQH16	-	-	-	-	-	-	-	-	-	-	-	-	T152
EQH15	-	-	-	-	-	-	-	-	-	-	-	-	M152
EQH14	-	-	-	-	-	-	-	-	-	-	-	-	B150
QTX10	**P**	**P**	**P**	**R**	**-**	**P**	**P**	**R**	**P**	**P**	**P**	**-**	**M148**
EQH13	**P**	**P**	**P**	**R**	**-**	**P**	**P**	**-**	**-**	**-**	**P**	**R**	**B148**
QTX9	**P**	**R**	**P**	**-**	**-**	**R**	**R**	**-**	**-**	**R**	**P**	**?**	**M147**
EQH12	-	-	-	-	-	-	-	-	-	-	-	-	T146
EQH11	-	-	-	-	-	-	-	-	-	-	-	-	B146
QTX8	-	-	-	-	-	-	-	-	-	-	-	-	T145
EQH10	**-**	**-**	**R**	**P**	**R**	**P**	**P**	**-**	**-**	**?**	**R**	**R**	**T145**
QTX7	-	-	-	-	-	-	-	-	-	-	-	-	M145
EQH9	-	-	-	-	-	-	-	-	-	-	-	-	B145
EQH8	**R**	**-**	**P**	**P**	**?**	**P**	**P**	**R**	**R**	**?**	**R**	**R**	**M141**
EQH7						Limestone - not processed							M140
EQH6	-	-	-	-	-	-	-	-	-	-	-	-	M139
EQH5						Limestone - not processed							M138
EQH4	**-**	**-**	**R**	**R**	**-**	**-**	**-**	**-**	**-**	**P**	**-**	**-**	**T137**
EQH3	-	-	-	-	-	-	-	-	-	-	-	-	M37
EQH2						Limestone - not processed							M136
EQH1	-	-	-	-	-	-	-	-	-	-	-	-	T135
EQH25	-	-	-	-	-	-	-	-	-	-	-	-	B124
EQH24	**-**	**-**	**-**	**P**	**-**	**P**	**P**	**-**	**R**	**-**	**-**	**-**	**T116**
EQH23	**-**	**-**	**-**	**R**	**-**	**C**	**P**	**-**	**R**	**-**	**-**	**-**	**B115**
EQH22	**-**	**-**	**R**	**R**	**?**	**A**	**R**	**-**	**R**	**R**	**-**	**P**	**T106**

Table 1: Sample distribution of selected foraminiferal species at East Quantoxhead. Key to occurrences: A = Abundant (>200 individuals), C = Common (100-199 individuals), P = Present (1099 individuals), R = Rare (1-9 individuals), 7 = Possible occurrence, ? = Not present. Samples listed in stratigraphic order, see Figure 3 for locations.

diagenetic enhancement of the limestones (Copestake and Johnson, 1989). Alternatively, the barren intervals could be a result of faunal poverty or dilution caused by an increase in the level of sediment deposition in the area or the development of basin stagnation. Finely laminated shales are indicative of sea-bed anoxia during sea-level rise (Hallam and Bradshaw, 1979) and rarely contain benthic foraminifera. Corresponding to Biofacies 1 of Wignall and Hallam (1991), discrete, thin beds indicate permanently anoxic bottom waters that may have occupied a large proportion of the water column and possibly precluded nektobenthic ammonites. The absence of ammonites at certain levels has also been noted by K. N. Page (pers. comm. 1998). Although these have yet to be correlated with the foraminiferal data it does suggest stagnation of the basin at certain periods.

Upper Hettangian samples (EQH22, 23 and 24) contain a diverse foraminiferal fauna suggesting normal oxygen levels while the boundary samples (QTX10, EQH13, QTX9) show an increase in diversity and abundance. Sample QTX6, however, indicates a return to very low diversity and abundances with smaller individuals. A tendency towards small size is seen in anaerobic assemblages (Bernhard, 1986), where a small test maximises relative surface area. Flattened morphologies, such as those seen in *Frondicularia, Planularia* and some *Lenticulina* species also predominate in low-oxygen deposits (Bernhard, 1986). While the reason for this is not known it can be seen that these morphologies would reduce the rate of sinking into soft oxygen poor sediments or maximise oxygen uptake (Hendrix, 1958).

CONCLUSIONS AND IMPLICATIONS OF THIS STUDY FOR THE PROPOSED GSSP

The guidelines of the International Commission on Stratigraphy (ICS) recommend that a GSSP should be correlatable on a world-wide scale using a variety of techniques including chemostratigraphy, macro- and microfossils (Salvador, 1994). The foraminiferal species discussed here are those considered to be the most important for zonation and correlation purposes in the British and north west European Lower Jurassic (Copestake and Johnson, 1989). Accordingly this study has shown that the foraminifera from East Quantoxhead could provide a useful tool for correlation of the proposed GSSP with other sections.

Additionally, this work recognises that while the base of the Sinemurian is recognisable on foraminiferal criteria and that the faunal assemblages are characteristic on either side of the boundary, further work is needed to complete and correlate the foraminiferal faunas at East Quantoxhead with published foraminiferal biozonation schemes (e.g. Copestake, 1985; Copestake and Johnson, 1989).

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