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# HETTANGIAN TO SINEMURIAN (LOWER JURASSIC) SEA-LEVEL CHANGES AND PALAEOENVIRONMENTS: EVIDENCE FROM BENTHIC FORAMINIFERA AT EAST QUANTOXHEAD, WEST SOMERSET, U.K.

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The Hettangian to Sinemurian (Lower Jurassic) of the West Somerset coast, near East Quantoxhead, comprises an expanded fossiliferous sequence of alternations of thickly laminated mudstones, more homogenous mudstones and limestones.
During Hettangian times a broad shallow marine shelf sea was established over most of Britain and north-west Europe, colonised by a low (but gradually increasing) diversity foraminiferal fauna, related to the major transgressive pulse at the base of the Jurassic. Imposed upon this general trend of sea-level rise, with major pulses in the early Hettangian and early Sinemurian, were episodic falls of sea-level. While there is little facies evidence for a major sea-level drop around the end of the Hettangian at East Quantoxhead, it is notable that several index foraminifera become extinct at or near the top of the Hettangian Angulata Zone which is interpreted as evidence for a minor regression. Changes in foraminiferal assemblages from this Lower Jurassic section have been examined and are considered to be related to sea-level changes where transgressions mark the arrival of new species and subspecies (evolutionary appearances and/or migration) whereas regressions and times of lowered sea-level appear to equate to extinctions. Within these nodosariid-dominated foraminiferal populations, major variations in species and generic abundances are seen in taxa which are long ranging, suggesting controlling palaeoenvironmental factors. The predominance of the *Lingulina tenera* (Bornemann) plexus with associated *Lenticulina* and *Marginulina* species suggests inner to near shelf environments with periods of normal oxygen levels.

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## INTRODUCTION

Palaeoecological interpretations of Jurassic foraminiferal assemblages are frequently problematic owing to the lack of direct Recent analogues due to drastic changes which took place in the nature of benthic shelf assemblages during the Cretaceous and Tertiary (Copestake and Johnson, 1989). These changes resulted in the replacement of nodosariids, which were dominant in the Jurassic (Gordon, 1970), by other families of Rotaliina; it has been established that nodosariids in the modern day occupy a deeper water setting than

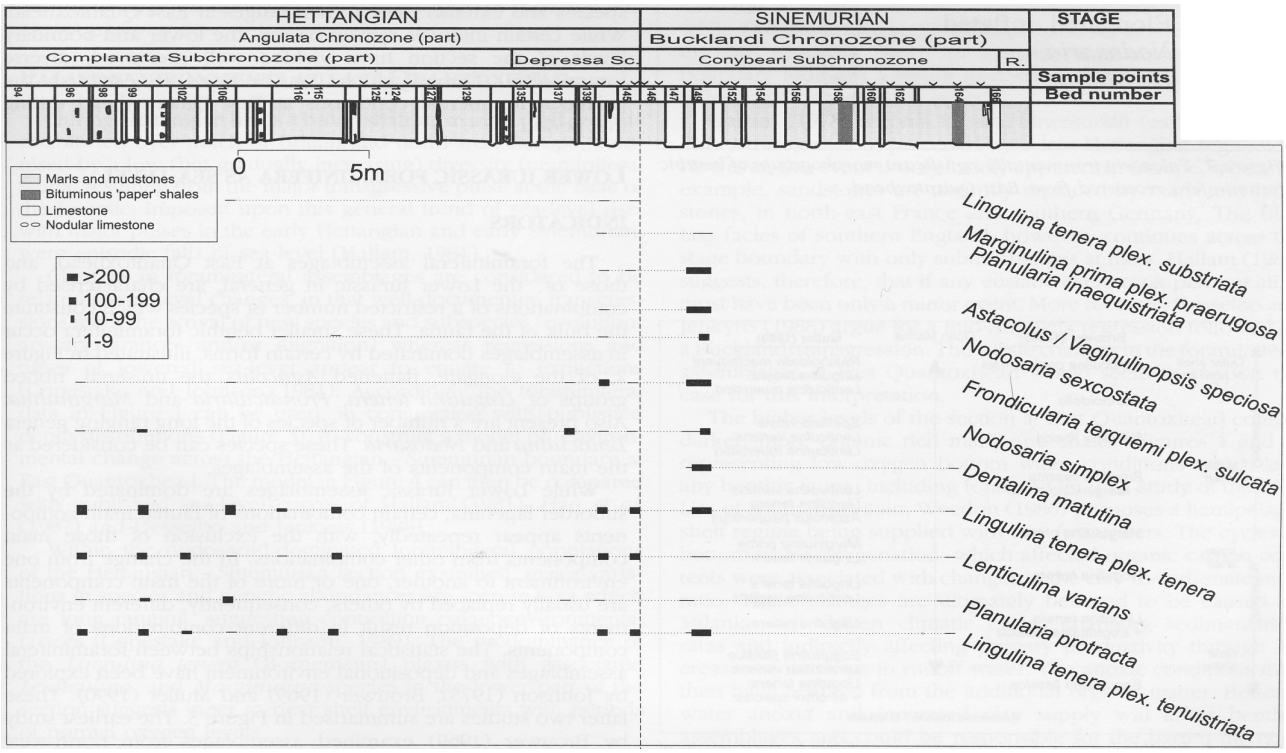


***Figure 1.*** *Distribution of foraminiferal index species at East Quantoxhead. Hettangian/Sinemurian succession after Page et al. (in press).*

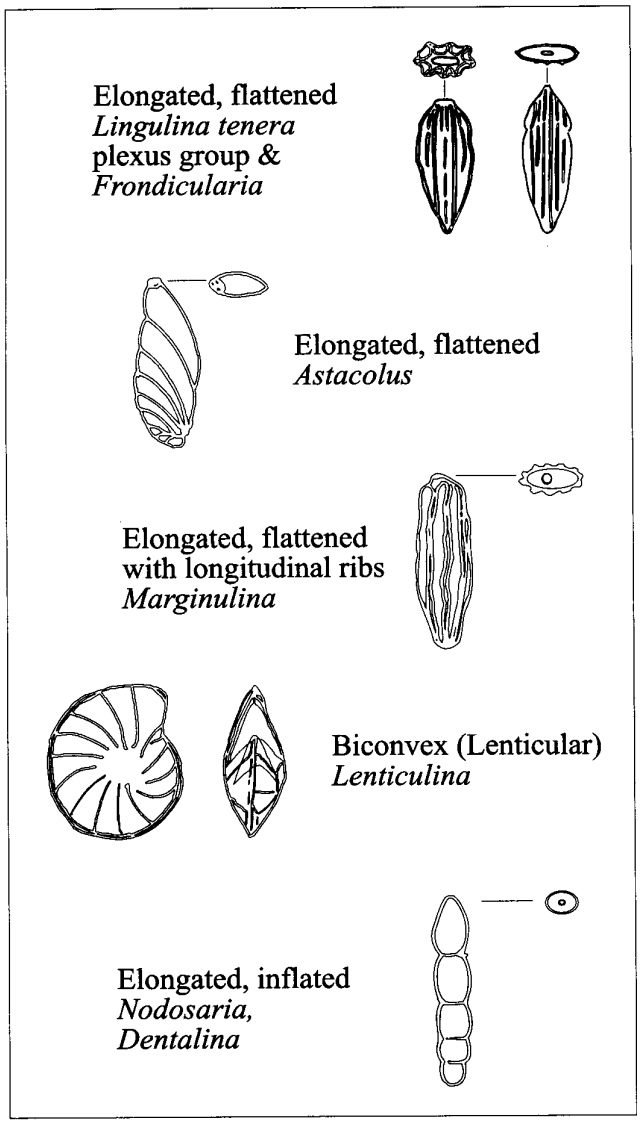


***Figure 2.*** *Palaeoenvironmentally significant morphogroups of benthic foraminifera recovered from East Quantoxhead.*

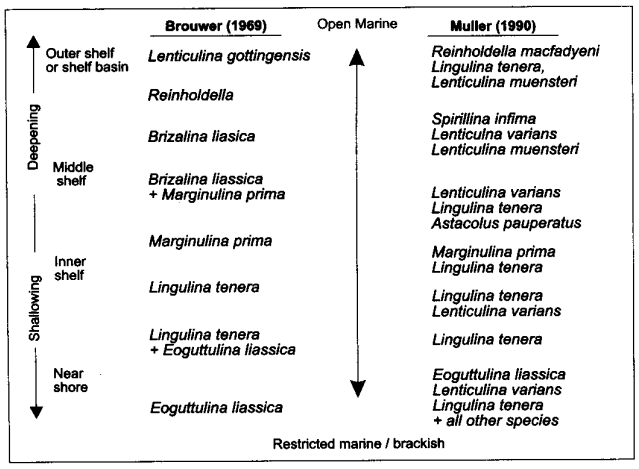


***Figure 3.*** *Benthic foraminiferal assemblages as Early Jurassic sea-level indicators.*

in the Jurassic (Johnson, 1976). It is necessary, therefore, to establish environmental data on individual Lower Jurassic fossil species so that finer and more accurate palaeoecological analyses can be made.

The sedimentology, palaeontology and palaeogeography of the Lower Jurassic of southern Britain is well documented (e.g. Sellwood, 1972; Hallam, 1987; Warrington and Ivimey-Cook, 1995) and the exposure at East Quantoxhead presents an excellent opportunity to establish ecological data on individual Lower Jurassic foraminiferal species. This study expands upon the investigation of the correlation potential of foraminiferal faunas by Hylton (1998) as a contribution to the proposal of the section as a candidate "Global Stratotype Section and Point" for the base of the Sinemurian Stage (Page *et al. in press).* As a result of this proposal the section at East Quantoxhead has been assessed for its macrofossil, microfossil, geochemical and magnetostratigraphical global correlation potential. More recently Hart and Hylton (this volume) have investigated the stratigraphical distribution of the ostracod fauna.

## MATERIAL AND METHODS

The coastal exposures of the Hettangian - Sinemurian succession can be easily accessed from the village of East Quantoxhead on the West Somerset Coast. The typical marine sedimentary facies at this locality is an alternating limestone/shale sequence known as the Blue Lias Formation (Palmer, 1972). Comprehensive descriptions of the location, stratigraphy, macro- and microfossil groups of the succession can be found in Hart and Hylton (this volume); Hylton (1998); Page (1992, 1995) and Page *et al. (in press).*

A total of 50 samples from the cliff and wave-cut platform have been collected from the levels marked on Figure 1. 200 gm of material from each sample was dissagragated using the techniques detailed in Hylton (1998). The foraminiferal fauna obtained was picked according to the methodology of this initial study and follows the same taxonomy.

Figure 1 lists the ranges of 11 stratigraphically useful index species and extends their known ranges at East Quantoxhead. While certain intervals remain barren, the lower and boundary levels of the section have yielded well preserved, diverse foraminiferal faunas which can be used to establish the palaeoenvironmental conditions at East Quantoxhead during this period.

## LOWER JURASSIC FORAMINIFERA AS SEA-LEVEL INDICATORS

The foraminiferal assemblages at East Quantoxhead, and those of the Lower Jurassic in general, are characterised by combinations of a restricted number of species which constitute the bulk of the fauna. These smaller benthic foraminifera occur in assemblages dominated by certain forms, illustrated in Figure 2, of the elongate, flattened *Astacolus,* the uniserial, ribbed groups of *Lingulina tenera, Frondicularia* and *Marginulina.* Also present are a number of species of the long ranging genera *Lenticulina* and *Nodosaria.* These species can be considered as the main components of the assemblages.

While Lower Jurassic assemblages are dominated by the suborder lagenina, certain combinations of faunal main components appear repeatedly, with the exclusion of those main components from other combinations. In the change from one environment to another, one or more of the main components are usually replaced by others, consequently, different environments of deposition result in different combinations of main components. The statistical relationships between foraminiferal assemblages and depositional environment have been explored by Johnson (1975), Brouwer (1969) and Muller (1990). These latter two studies are summarised in Figure 3. The earliest study by Brouwer (1969) examined assemblages from north-west Europe while more recently Muller (1990) used statistical analysis of foraminiferal assemblages from the U.K. Lower Jurassic to

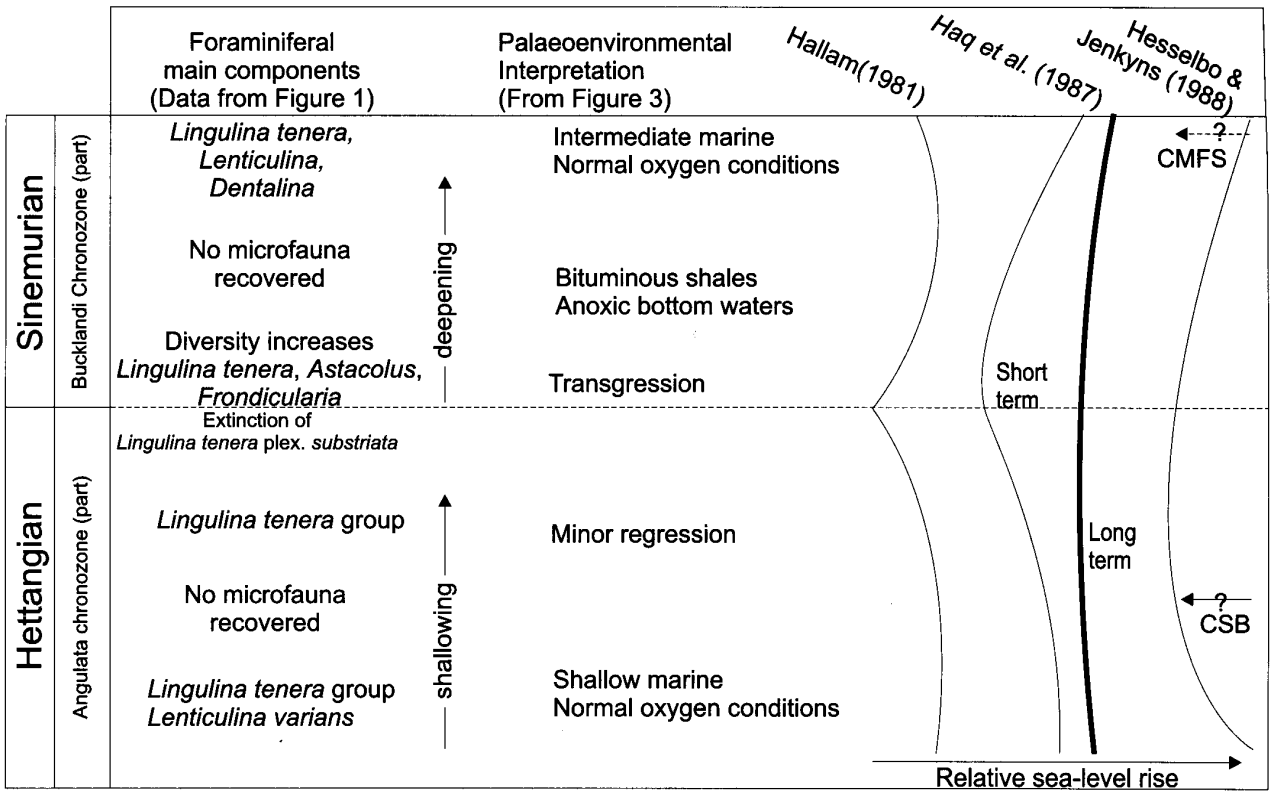


***Figure 4.*** *Interpretation of eustatic events and palaeoenvironments from foraminiferal evidence at East Quantoxhead. CMFS - Candidate maximum flooding surface, CSB - Candidate sequence boundary (after Hesselbo and Jenkyns, 1988).*

propose biofacies' groups and hence a depth distribution model. Put simply, it seems that the deeper shelf environments were dominated by *Lenticulina,* intermediate depths by the *Marginulina prima* group and shallower depths by the *Lingulina tenera* group.

## PALAEOENVIRONMENTS AT EAST QUANTOXHEAD

During Hettangian times a broad shallow marine shelf sea was established over much of Britain and north-west Europe, colonised by a low (but gradually increasing) diversity foraminiferal fauna, resulting from the major transgressive pulse at the base of the Jurassic. Imposed upon this general trend of sea-level rise, with major pulses in the early Hettangian and early Sinemurian, were episodic falls of sea-level (Hallam, 1981).

Changes in foraminiferal assemblages are considered to be related to sea-level changes, in that well-documented transgressions mark the arrival of new species and subspecies (evolutionary appearances and/or migration) whereas regressions and times of lowered sea-level appear to equate to extinctions (Copestake and Johnson, 1981). Accordingly the foraminiferal data in Figure 1 can be used, in conjunction with published depth distributions (Figure 3), to construct a model of environmental change across the Hettangian - Sinemurian boundary at East Quantoxhead. The model in Figure 4 can then be compared with published sea-level curves of Hallam (1981), Haq *et al.* (1987) and Hesselbo and Jenkyns (1988).

Within the nodosariid-dominated foraminiferal populations of the Hettangian - Sinemurian section examined, major variations in species and generic abundances are seen in taxa which are long ranging, suggesting controlling palaeoenvironmental factors (Copestake and Johnson, 1989). The predominance of the *Lingulina tenera* (Bornemann) plexus with associated *Lenticulina* and *Marginulina* species in the lower part of the section suggests inner to near shelf environments with periods of normal oxygen levels.

Towards the boundary, there is a noticeable decline in abundances and diversity, eventually resulting in the extinction of *Lingulina tenera* plex. *substriata.* Indicative of a regressive phase, Copestake and Johnson (1989) also report that several index foraminifera become extinct at or near the top of the Angulata Zone at many European localities *(Lingulina tenera collenoti, L. tenera substriata, Frondicularia terquemi* subsp. A) while *Dentalina langi* both appeared and became extinct within the late Angulata Zone. An increase in diversity across the boundary indicates a return to deeper, oxygenated conditions, reflecting a transgressive event.

Hallam (1978) records a basal Sinemurian (early Bucklandi Zone) transgression, preceded by a late Hettangian regression. However, this event is only locally apparent in Europe, where for example, sandstones are abruptly replaced by marls and limestones, in north-east France and southern Germany. The Blue Lias facies of southern England, however, continues across the stage boundary with only subtle changes at most. Hallam (1981) suggests, therefore, that if any eustatic event took place at all, it must have been only a minor event. More recently, Hesselbo and Jenkyns (1988) argue for a mid-Angulata regression followed by a Bucklandi transgression. The subtle changes in the foraminiferal assemblages at East Quantoxhead would seem /to support the case for this interpretation.

The higher levels of the section at East Quantoxhead contain darker, more organic rich marls and shales (Figures 1 and 4) representing low-oxygen bottom water conditions which lack any benthic fauna, including foraminifera. In a study of the Blue Lias of southern Britain, Weedon (1986) proposes a hemipelagic shelf regime being supplied with clay from rivers. The cycles in bottom-water oxygenation, which affected organic carbon contents were associated with changes in the clay-to-carbonate mud ratio. These changes are ultimately believed to be caused by Milankovitch driven climatic cycles changing sedimentation rates and indirectly affecting primary productivity through increases of nutrients in runoff water. The anoxic conditions may then have resulted from the additional organic matter. Bottom-water anoxia and increased clay supply will affect benthic assemblages and could be responsible for the barren intervals seen in the foraminiferal and ostracod faunas (Hart and Hylton, this volume).

## CONCLUSIONS

The ranges of identified foraminiferal taxa at East Quantoxhead have been extended and provide further data to assist in the definition of the base of the Sinemurian stage. This data can be used to interpret the palaeoenvironmental conditions at East Quantoxhead during this interval of the Lower Jurassic.

While there is little facies evidence for a major sea-level drop around the end of the Hettangian at East Quantoxhead interpretation of foraminiferal assemblages provide evidence for a minor regression. Following this regression at the end of the Hettangian a transgressive event coincides with the deposition of organic-rich mudstones associated with the periodic development of low-oxygen bottom waters. It is also notable, from other studies, that several index foraminifera become extinct at or near the top of the Hettangian Angulata Zone.

The changes in foraminiferal assemblages are considered to reflect sea-level changes where transgressions mark the arrival of new species whereas regressions and times of lowered sea-level appear to equate to extinctions. Interpreted palaeoenvironmental ranges of Lower Jurassic foraminiferal species however still remain broad, varying between the inner and outer shelf and further work to establish environmental parameters of these species is required.

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