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FORAMINIFERAL CHARACTERISATION OF MID-UPPER JURASSIC SEQUENCES IN THE WESSEX BASIN (UNITED KINGDOM)

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Abstract. The use of foraminifera in the characterisation of sequences (systems tracts, maximum flooding surfaces, etc.) has developed over the last decade. Much of this work has been based in the Cenozoic successions of the Gulf of Mexico, although there is a growing application of such data in the Middle East and the North Sea Basin. The easiest surface to characterise has been the maximum flooding surface with its high diversity and high(er) abundance faunas; the characterisation of individual systems tracts has been less successful.

Using the well-known mid-Upper Jurassic successions of the Dorset coastal sections, we have investigated a number of high resolution (para)sequences for their foraminiferal content. Using data of foraminiferal diversity and standing crops from a range of modern substrates we have investigated the potential faunas available after deposition, taphonomy, compaction, groundwater dissolution and modern weathering. By understanding the processes involved we have identified the key foraminiferal features of typical mid-Upper Jurassic sequences and indicated how this work may help in the correlation of successions in North Dorset and Normandy.

Riassunto. L'uso dei foraminiferi nella caratterizzazione delle sequenze (system tracts, superfici di massimo allagamento, ecc.) si è sviluppato durante l'ultimo decennio. La maggior parte di questo lavoro è basata sulle successioni cenozoiche del Golfo del Messico, sebbene ci sia una crescente applicazione di tali dati nei bacini del Medio Oriente e del Mare del Nord. La superficie più facile da caratterizzare è stata la superficie di massimo allagamento, con alta diversità e alte abbondanze faunistiche; la caratterizzazione dei singoli systems tracts ha avuto meno successo.

Usando le ben note successioni costiere del Dorset della parte centrale del Giurassico superiore si è indagato il contenuto in foraminiferi di un certo numero di (para)sequenze ad alta risoluzione. Usando i dati sulla diversità e produttività fissa dei foraminiferi da una gamma di substrati moderni, si sono investigate le faune potenziali disponibili dopo la deposizione, la tafonomia, la compattazione, la dissoluzione delle acque circolanti e l'alterazione meteorica moderna. Capendo i processi coinvolti, è stato possibile identificare le chiavi caratteristiche dei foraminiferi delle tipiche sequenze della parte centrale del Giurassico superiore, indicando come questo lavoro possa essere d'aiuto nella correlazione delle successioni nel Dorset settentrionale ed in Normandia.

Introduction

Sequence stratigraphy developed in the 1970s and was based, initially, on the interpretation of seismic profiles. Vail et al. (1977) expanded these initial concepts to include both borehole and outcrop data and closely related the resulting stratigraphy to sea level changes. Short-term fluctuations in sea level were shown to generate "sequences" or "genetically related strata bounded by unconformities or their correlative conformities" (Van Wagoner et al. 1988, p. 39). Sequences soon developed a nomenclature, with the three main sub-divisions being represented (in ascending order) by the Lowstand Systems Tract (LST), Transgressive Systems Tract (TST) and Highstand Systems Tract (HST). The Maximum Flooding Surface (MFS) is an important part of sequence stratigraphic interpretation and separates the TST and the HST. In some successions (see below) the 'surface' cannot be located precisely and we have adopted the concept of a Zone of Maximum Flooding following the work of Montanez & Osleger (1993), Strasser et al. (1994, 1999) and Oliver (1998). This "Exxon Model" of a sequence must not be confused with the "Galloway Model", which uses the MFS as they key to sequence identification (Galloway 1989a,b; Reading 1996, pp. 25-26, fig.2.10), and the "Einsele Model" which is based on the recognition of transgressive/regressive cycles (Einsele & Bayer 1991).

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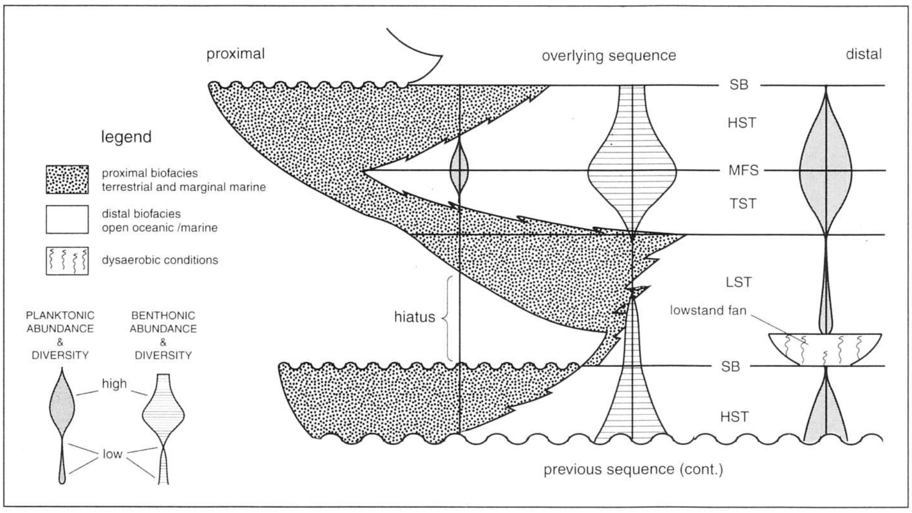


Fig. 1 - The "Exxon model" of a sequence (based on Emery & Myers 1996, fig. 6.14a) and the hypothetical distribution of benthonic and planktonic foraminifera. The planktonic foraminifera are most abundant (and diverse) in the region of the MFS with deeper-water morphotypes being found in more distal regions while only surface-water morphotypes are to be found in more proximal environments. The abundance (and diversity) of benthonic foraminifera mirrors that of the planktonic fauna, although benthonic taxa are found in a much wider range of proximal environments. SB = Sequence Boundary; LST = Lowstand Systems Tract; TST = Transgressive Systems Tract; MFS = Maximum Flooding Surface; HST = Highstand Systems Tract.

The "Exxon Model" is used by Emery & Myers (1996) in their description of how palaeontology and biostratigraphy contribute to sequence stratigraphy (Fig. 1). Emery & Myers (op. cit., pp. 101, 104, fig. 6.14) describe how the MFS can be identified by the abundance and diversity of benthonic foraminifera. It also coincides with the most landward distribution of diverse, open marine, plankton. This approach has been used effectively in younger rocks, most notably in the Cenozoic of the Gulf of Mexico (Shaffer 1987, 1990; Armentrout 1987, 1991; Armentrout & Clement 1990; Armentrout et al. 1990, 1999; Pacht et al. 1990; Vail & Wornardt 1990; Van der Zwan & Brugman 1999). More recently, a number of authors have extended this approach to the interpretation of Mesozoic successions (Olsson 1988; Cubaynes et al. 1990; Simmons et al. 1991; Powell 1992; Hart 1997, 2000; Henderson 1997; Henderson & Hart 2000; Oxford et al. 2000; Sharland et al. 2001) with varying degrees of success. In their work on the Jurassic to Lower Cretaceous successions of the North Sea Basin, Partington et al. (1993) used the distinctive assemblages associated with the maximum flooding events to generate a biostratigraphical framework for correlation. One of the problems associated with more ancient successions is the loss of diagnostic taxa or even complete faunas as a result of taphonomy, burial and other diagenetic processes. In this account we report on our research into the preservation and identification of microfaunas within Jurassic sequences.

Mid-Upper Jurassic of the Dorset Coast

The dominantly siliciclastic succession of the Dorset Coast has been the subject of a number of investigations many of which have directly, or indirectly, related the sedimentary succession to changes in sea level (Arkell 1933, 1956; Wilson 1968a,b; Talbot 1973, 1974; Brookfield 1973a,b, 1978; Fürsich 1975; Sun 1989, 1990a,b; Rioult et al. 1991; Coe 1992, 1995; Oliver 1998; Newell 2000; Henderson & Hart 2000; Oxford et al. 2000).

In many of these interpretations (Fig. 2) of the sequence stratigraphy there are different, if not conflicting, conclusions especially between Wilson (1991), Rioult et al. (1991), Coe (1992, 1995), Oliver (1998) and Newell (2000). In attempting to resolve some of these differences, and to explore the use of foraminifera in the recognition of Jurassic sequences, Oxford et al. (2000) used a part of the succession for a pilot investigation. The Nothe Grit Formation and the Redcliff Formation are well exposed on the Dorset Coast between Weymouth and Ringstead (Fig. 3). In this succession 96 samples were collected and prepared using the solvent method of Brasier (1980). All samples were washed on a 63 μm sieve, dried gently and stored ready for investigation. A minimum of 300 foraminifera were picked from the 500-250 μm size fraction with counts of the other size fractions (250-125 μm and 125-63 μm) also being recorded for further analysis (not presented here). Fig. 4 records the results of this preliminary investigation with the percentage of dry sediment retained on the 63 μm sieve plotted alongside the generic diversity recorded in each sample.

The most clay-rich samples are located in the Nothe Clay Member (samples between O1 and O6) and it is these same samples that record the highest levels of generic (and specific) diversity. This would appear to be the "zone of maximum flooding" recorded by Oliver (1998) and would clearly show up as a gamma-ray peak on a wireline log. Unfortunately planktonic foraminifera are not recorded at this level in the UK Jurassic succession and one cannot fully test all the features of the Emery & Myers (1996, fig.

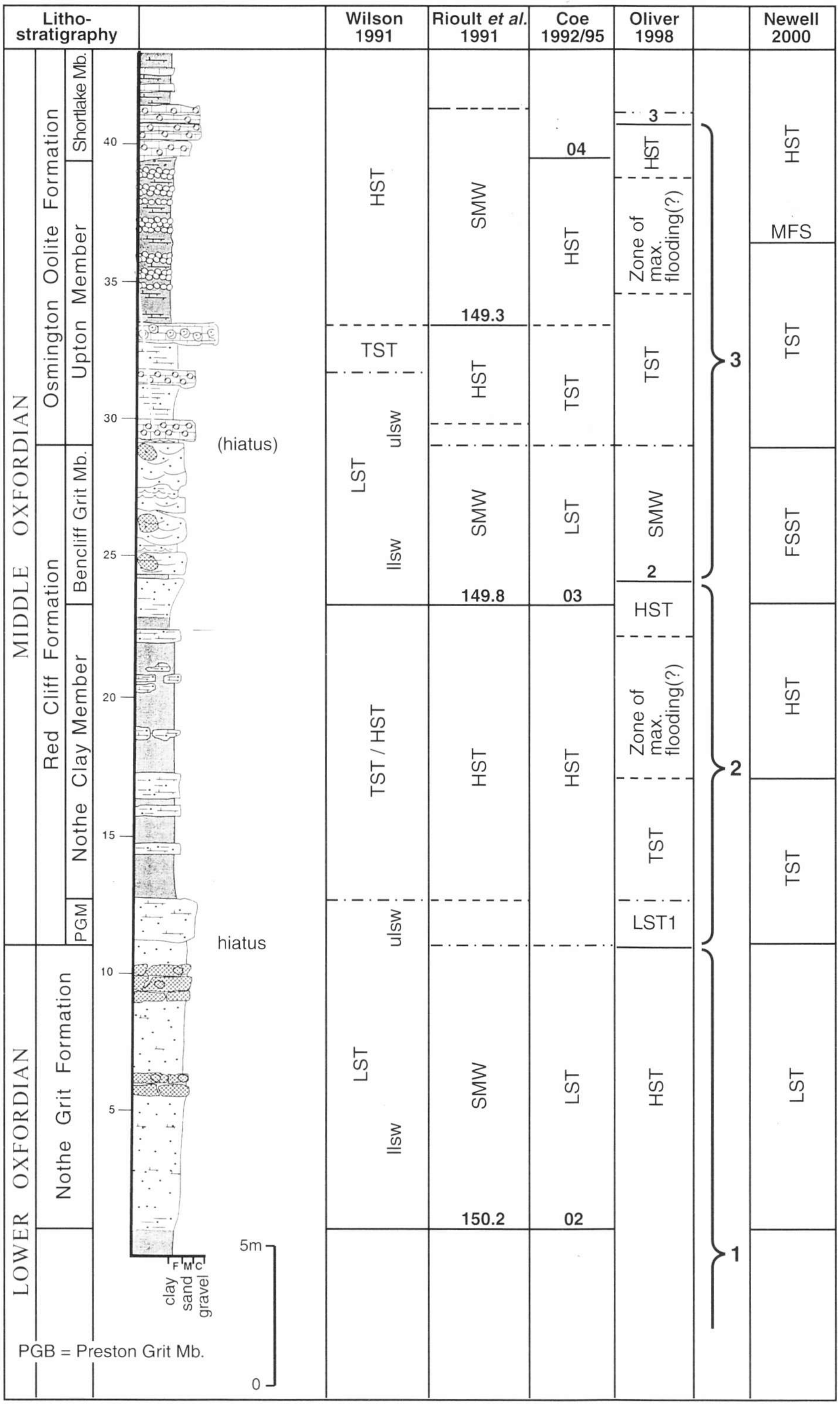


Fig. 2 - The Jurassic succession of the Weymouth to Ringstead Bay section (see Fig. 3) with the major lithostratigraphical units identified. The various sequence stratigraphical interpretations are also indicated. Additional terms include: llsw = lower lowstand wedge; ulsw = upper lowstand wedge; SMW = Shelf Margin Wedge; FSST = Falling Stage Systems Tract. O2/O3/O4 are the unconformities identified by Coe (1995). The radiometric dates (in millions years) are the ages assigned to Sequence Boundaries by Rioult et al. (1991).

6.14) predictions. The genera recorded in this part of the succession are indicated in Fig. 5. The pattern is not clear, but samples O3 and O4 appear to be close to the zone of 'maximum flooding' and a number of important genera (*Ophthalmidium*, *Nubeculina*, *Vaginulina*, *Frondicularia*, *Citharina*, *Lingulina* and *Epistomina*) are restricted to this interval. The miliolids (with a porcellanous wall) and the epistominids (with an aragonitic wall) point to a preservational control of the fauna that characterises this interval.

Interpretation of the fauna

The faunas we record from geological samples are the product of:

- the initial fauna;
- post-mortem taphonomy;
- diagenesis and compaction;
- changes during burial and "geological time";
- modern weathering and exhumation (if not collected from the sub-surface);
- errors introduced during sampling, processing and analysis.

Work on modern-day faunas and their relationship with the substrate are important in helping to understand the death assemblages preserved in the geological record. In a recent survey of the foraminifera of Plymouth Sound (Fig. 6), Castignetti (1997) sampled a series of siliciclastic locations at monthly intervals over a yearly cycle and was able to determine the standing crop of all taxa from a wide range of environments. Fig. 7 shows the total annual production and the total annual diversity for these sites, all but one of which were located within Plymouth Sound. The most diverse and productive fauna is at Location 9 (mud) with the lowest values recorded at Location 11 (sand waves). The controls on the fauna are complex (and the subject of a further publication by the authors) but it is clear that in the nutrient-rich clays there is an abundant, di-

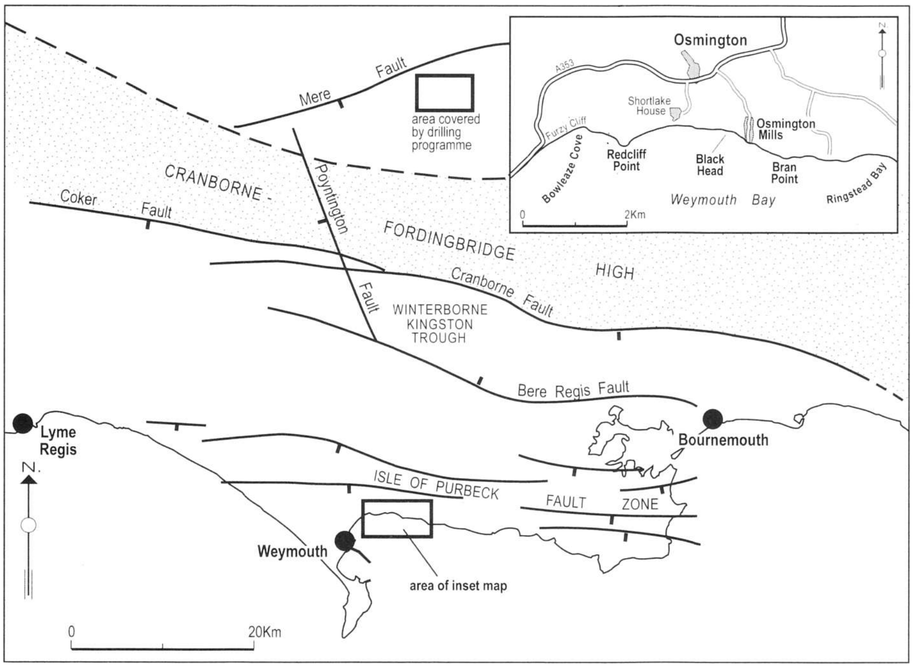


Fig. 3 - Outline structural map of Dorset showing the locations mentioned in the text. The area of North Dorset indicated in the box marks the location of the 5 boreholes used by Henderson (1997) and Henderson & Hart (2000).

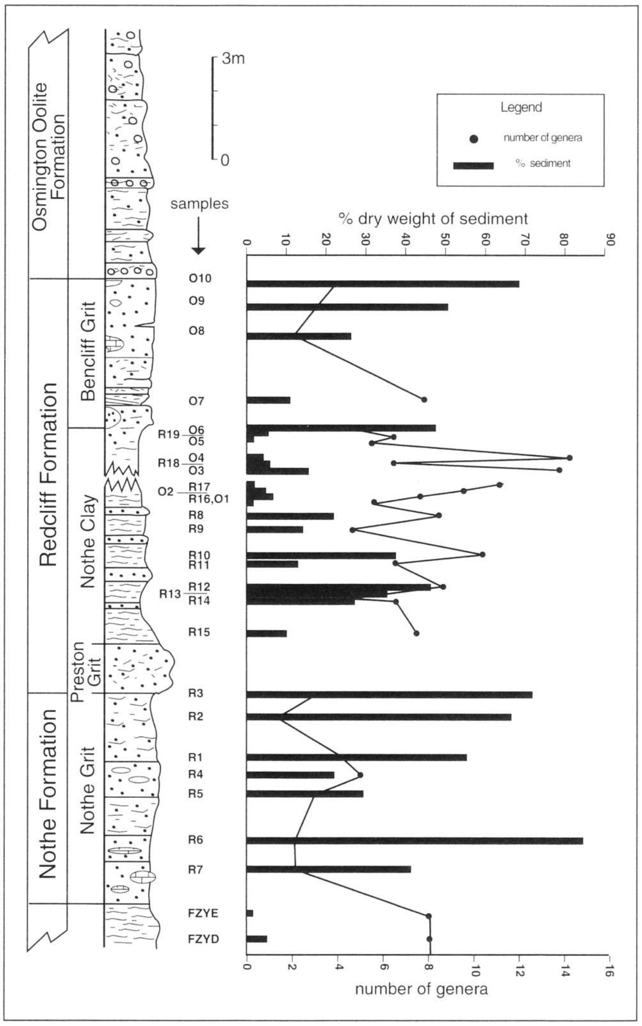


Fig. 4 - Sample locations within the Nothe Grit Formation, Preston Grit Member, Nothe Clay Member and the Bencliff Grit Member. Plotted against these samples are the percentages of dry sediment (by weight) retained on the 63μm sieve and the generic diversity.

verse fauna with the nutrient-poor sands supporting only a poor, in-situ, living fauna.

It is evident that the faunas in the clay-rich environments (Fig. 8) will be further enhanced by the slow rate of sedimentation (= several yearly standing crops in an average micropalaeontological sample) compared to the dilution effect of the higher rates of sedimentation in the more sand-rich environments. Compaction will further accentuate this situation with clays often being subjected to ~50% reduction. This is often detected by the presence of compressed agglutinated foraminifera where the flexible chitinous inner lining of the test has allowed an inward collapse of the chambers (Henderson, pers. comm.). This is particularly seen in genera such as *Trochammina, Haplophragmoides, Ammobaculites* and *Reophax.*

In recent years a number of investigations of the preservation potential of foraminifera have been undertaken by Murray (1989), Boltovskoy & Totah (1992), Alve & Murray (1995) and Murray & Alve (2000). It is particularly noted by Alve & Murray (1995) and Murray & Alve (2000) that high diversity agglutinated assemblages can be derived from high diversity assemblages apparently dominated by calcareous taxa through the selective dissolution of the calcareous component over time. This will particularly effect the aragonitic taxa and, in the Jurassic and Cretaceous, the epistominids will often only be found in the dense, clay-rich parts of the succession that have acted as aquacludes (Fig. 8). In Jurassic sequences, therefore, the aragonitic fauna of epistominids and planktonic foraminifera (Oxford et al. 2002) are the most likely indicators of maximum flooding surfaces or "zones".

In samples collected at outcrop, even the best preserved faunas can still be removed by modern processes. A sure sign of this will be the presence of selenite (gypsum)

sample codes	FD	FE	R7	R6	R5	R4	R1	R2	R3	R15	R14	R13	R12	R11	R10	R9	R8	R16	O1	O2	R17	O3	R18	O4	O5	R19	O6	O7	O8	O9	O10
Ammobaculites spp.	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨	▨	▨		▨		
Haplophragmoides spp.		▨	▨	▨	▨	▨	▨																			▨					
Textularia spp.	▨	▨								▨			▨		▨						▨			▨	▨			▨		▨	
Trochammina spp.										▨								▨		▨	▨	▨		▨	▨	▨	▨	▨			
Lenticulina spp.	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Citharina spp.						▨					▨	▨	▨				▨	▨				▨		▨		▨					
Dentalina spp.	▨	▨								▨				▨	▨		▨		▨		▨	▨	▨	▨							
Nodosaria spp.									▨									▨	▨		▨	▨	▨	▨		▨	▨				▨
Planularia spp.		▨					▨								▨				▨			▨		▨			▨	▨			
Vaginulina spp.	▨																▨		▨	▨	▨	▨		▨							
Nubeculina bigoti Cushman										▨	▨		▨	▨	▨	▨							▨								
Lagena spp.	▨										▨				▨					▨	▨	▨		▨		▨		▨			
Epistomina spp.	▨	▨								▨		▨		▨	▨	▨	▨	▨					▨	▨							
Eoguttulina spp.	▨					▨									▨		▨			▨		▨		▨	▨			▨		▨	
Pseudonodosaria spp.														▨																	
Triplasia spp.																								▨							
Marginulina spp.													▨																		
Lingulina spp.													▨							▨	▨	▨		▨							
Frodicularia spp.		▨									▨				▨		▨		▨	▨		▨		▨				▨			
Opthalmidium spp.										▨	▨	▨	▨	▨	▨	▨	▨		▨	▨		▨	▨	▨				▨			▨
Suboidellina spp.																				▨											
Ramulina spp.																					▨										
Trocholina spp.													▨								▨	▨			▨		▨				▨
Tristix spp.																					▨										

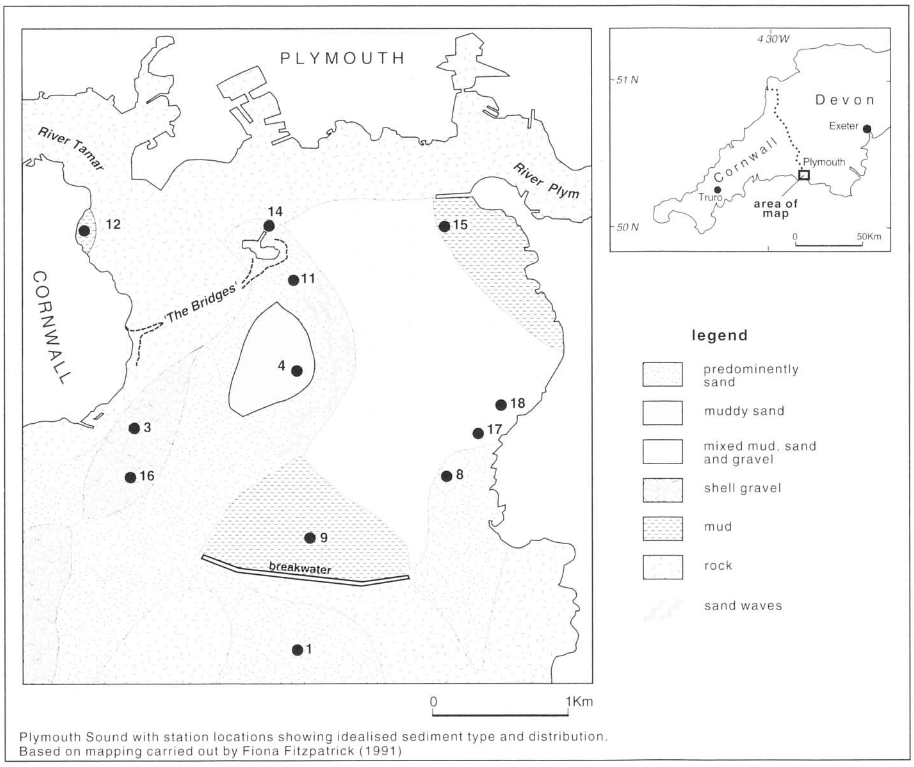
Fig. 5 - Distribution of foraminifera in the Nothe Grit and Redcliff Formations. *Nubeculina bigoti* Cushman is identified as this is the only species recorded within that genus in this succession.

crystals on bedding and fracture surfaces, or processed residues containing an abundance of such crystals.

The dense, impermeable clays will, therefore, contain the most abundant and diverse faunas from deposition, through compaction, to preservation in an aquaclude. These dense clays should also record the highest levels of gamma-rays in wireline logs and be readily identified as a zone of maximum flooding by both palaeontologists and sedimentologists.

The Oxfordian succession of the Dorset Coast

Using the form of analysis shown in Fig. 4, the complete Oxfordian succession of the Dorset Coast



Plymouth Sound with station locations showing idealised sediment type and distribution.
Based on mapping carried out by Fiona Fitzpatrick (1991)

Fig. 6 - Sediment distribution map of Plymouth Sound and the location of the sampling sites used in the monthly analysis (1994-1996) of the benthonic foraminifera (after Castignetti et al. 2000).

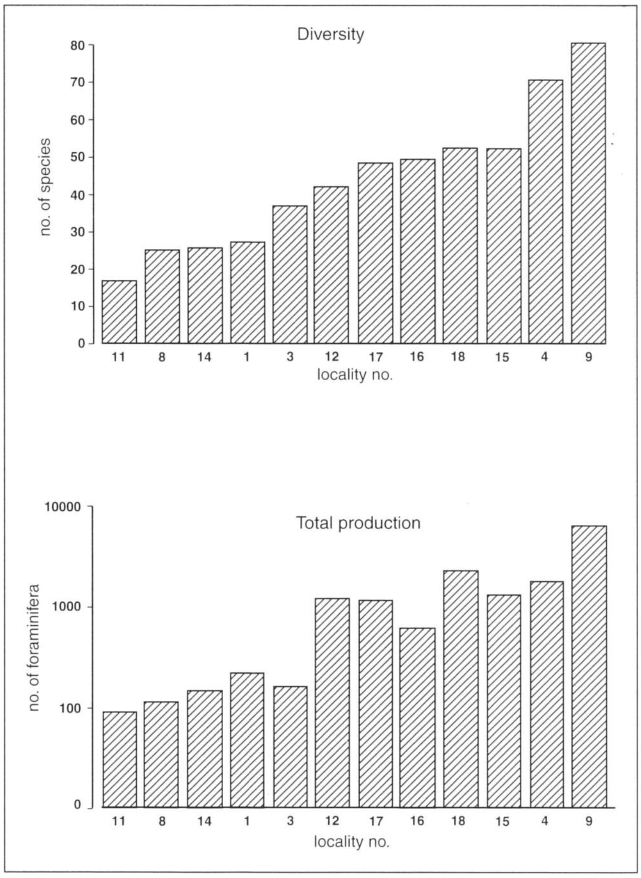


Fig. 7 - Plots of annual specific diversity and annual total production for the sites indicated in Fig. 6 (after Castignetti 1997).

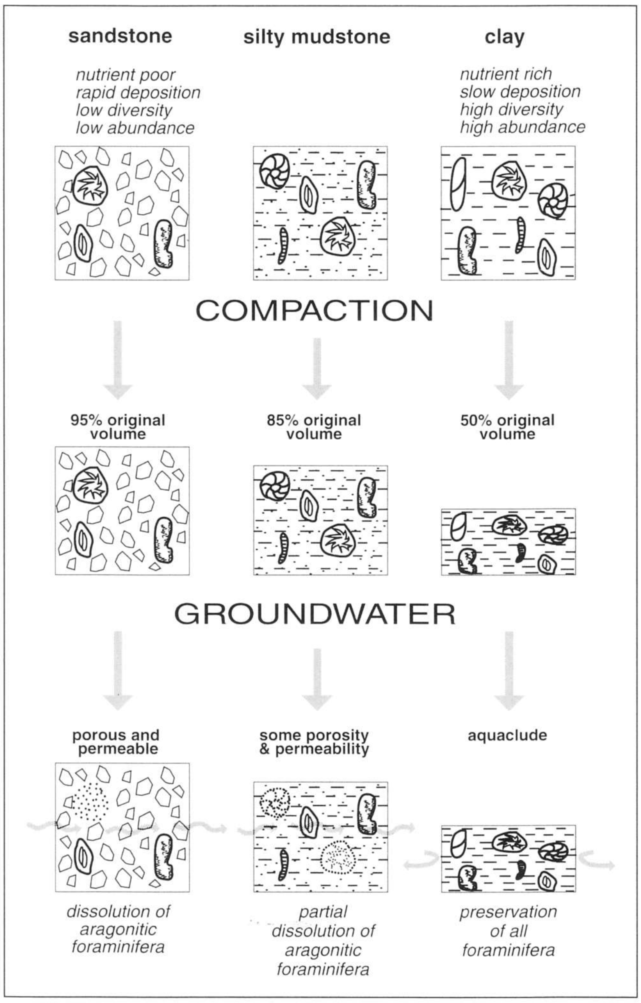


Fig. 8 - Theoretical model for the history of a "sample" from deposition to final collection, showing the effects of taphonomy, compaction and dissolution by groundwater flow.

(Weymouth to Ringstead) has been analysed (Fig. 9). The 'cycle' shown in Fig. 4 can be seen in the middle of this diagram, picked out by a number of diversity peaks (around sample OSM3). These pick out the zone of maximum flooding described above. This is within the upper part of the Nothe Clay Member of the Redcliff Formation. Lower in the succession, below sample FZ3, there are reduced percentages of sediment retained on the 63μm sieve and moderate levels of foraminiferal diversity. This is typical of the upper part of the Oxford Clay Formation (Mariae Zone). It is the Mariae Zone, on the shores of the Fleet west of Weymouth (Fig. 3), that has yielded planktonic foraminifera (Oxford et al. 2002) and these assemblages are coeval with the occurrence of planktonic foraminifera in the Marnes de Villers Formation on the Normandy Coast (Samson et al., 1992; Oxford et al. 2002, fig. 2). In North Dorset (Fig. 3) Henderson & Hart (2000, fig. 3) have identified several floods of epistominids at this level which probably records the same maximum flooding event.

Above the Nothe Clay 'cycle' (Figs 4, 9) there is a marked drop in diversity and an increase in sediment retained on the 63μm sieve. This appears to indicate a significant break (= sequence boundary) within the lower part of the Bencliff Grit Member and, although the exact position of this is disputed by the various workers who have studied this succession (Fig. 2), all show this event at about this level. In the overlying Upton Member of the Osmington Oolite Formation (around sample BH1 on Fig. 9) we record a major diversity peak. Above this level there are four more diversity peaks in descending order of magnitude until, at about the level of sample R2 there appears to be a major sequence boundary before the onset of the major cycle at the base of the Kimmeridge Clay Formation. If all the diversity peaks between the top of the Oxford Clay Formation and the base of the Kimmeridge Clay Formation are considered, it is possible to detect a large 'cycle' with a peak at about the level of the mid-Upton member. Is this a 3rd Order sequence in the Van Wagoner et al. (1988) terminology? If this is the case, then the regularly spaced minor peaks would be 4th Order sequences (or parasequences). In both North Dorset and Normandy our work has detected comparable diversity fluctuations with floods of diverse assemblages (with epistominids) at regular intervals (see Henderson & Hart 2000).

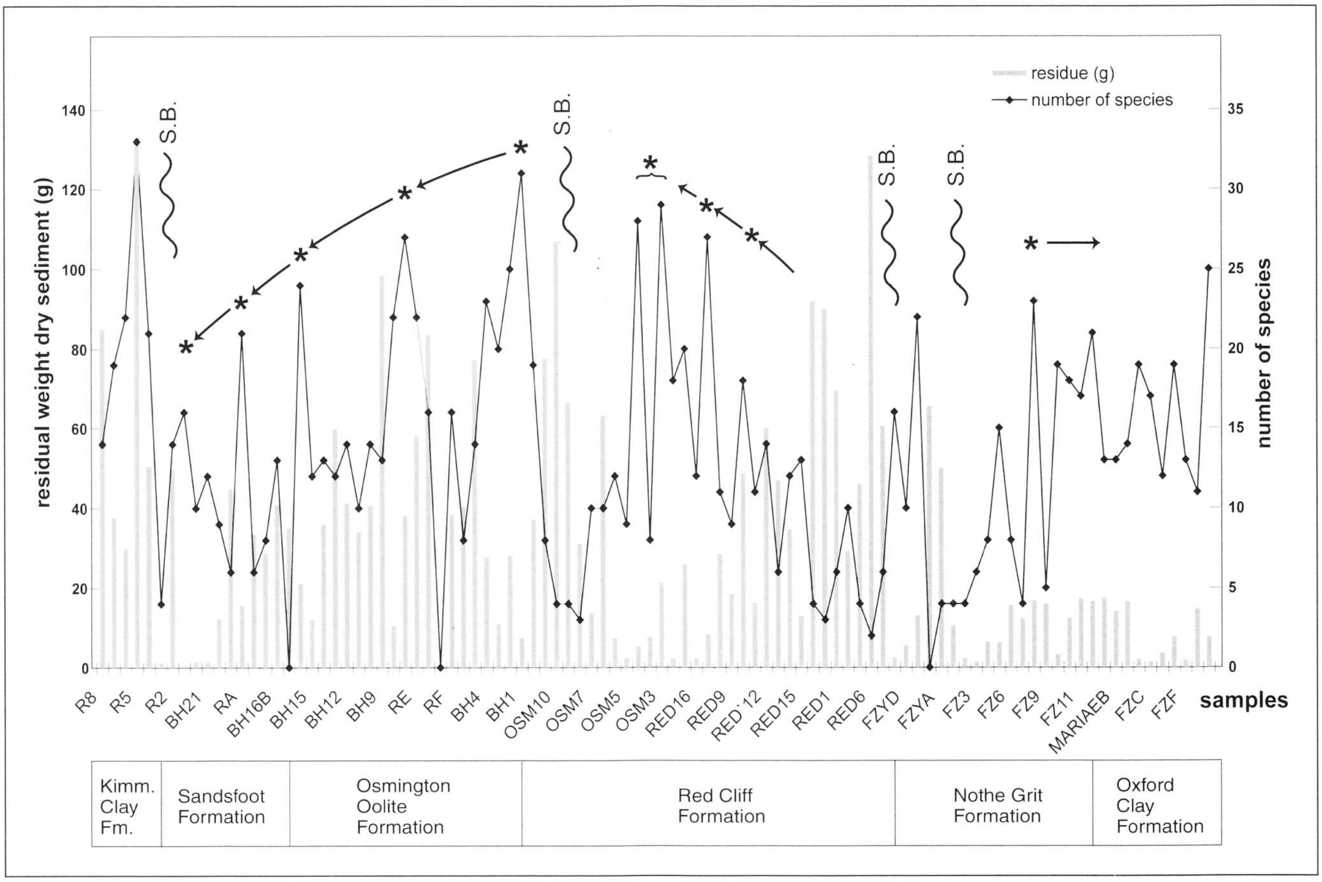


Fig. 9 - Analysis of the Oxfordian succession of the Dorset Coast following the methodology used in Figure 4. Locations of potential Maximum Flooding Surfaces (or Zones) are indicated by an asterisk; some of these are sequences while others may be parasequences. Potential sequence boundaries are indicated by the 'wavy' lines and initials SB. The sample codes are as follows:
FZ / FZY ~ Furzy Cliff [Upper Oxford Clay - Nothe Grit Formation]
RED ~ Redcliff [Nothe Grit Formation - Nothe Clay Member]
OSM ~ Osmington [Nothe Clay Member - Osmington Oolite Formation]
BH ~ Black Head [Osmington Oolite and Sandsfoot Formations]
R ~ Ringstead Bay [Sandsfoot Formation and base of Kimmeridge Clay Formation]

Only an outline assessment of our results have been presented here as there is clearly a great deal of detailed information to process on all the faunas we have recovered in our samples. This work is in hand, including that based on the material available from North Dorset and Normandy.

Summary

Using data from the analysis of foraminifera living in modern siliciclastic environments we have developed a model for the categorization of Jurassic assemblages and their interpretation in a sequence stratigraphic context. Preliminary work comparing the Dorset Coast with North Dorset and Normandy indicate that the foraminifera can provide significant assistance in the development of correlations based on sequence stratigraphy. Maximum flooding events in the Jurassic appear to be identified by high diversity assemblages in which epistominids are a significant component. Planktonic foraminifera (which at this stratigraphic level may also have been aragonitic) have also been shown to occur at maximum flooding surfaces within the mid-Upper Jurassic (Oxford et al. 2002; Hart et al. 2002).

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REFERENCES

Alve, E. & Murray, J.W. (1995) – Experiments to determine the origin and palaeoenvironmental significance of agglutinated foraminiferal assemblages. In: Kaminski, M.A., Geroch, S. & Gasinski, M.A. (eds), Proceedings of the Fourth International Workshop on Agglutinated Foraminifera, *Grzybowski Foundation Spec. Public.*, 3: 1-11, Krakow.

Arkell, W. J. (1933) – The Jurassic System in Britain. 125 pp., Oxford University Press, Oxford.

Arkell, W. J. (1956) – Jurassic Geology of the World. 65 pp., Oliver & Boyd, London.

Armentrout, J. M. (1987) – Integration of biostratigraphy and seismic stratigraphy: Pliocene – Pleistocene, Gulf of Mexico. In: Gulf Coast Section, Society of Economic Paleontologists and Mineralogists, Eighth Annual Research Conference: 6-14, Houston.

Armentrout, J. M. (1991) – Paleontologic constraints on depositional modelling; examples of integration of biostratigraphy and seismic stratigraphy, Gulf of Mexico. In: Weimer, P. & Link, M. H. (eds), Seismic facies and sedimentary processes of submarine fans and turbidite systems: 137-170, Springer-Verlag, Berlin.

Armentrout, J. M. & Clement, J. F. (1990) – Biostratigraphic correlation of depositional cycles: a case study in High Island-Galveston-East Breaks areas, offshore Texas. In: Gulf Coast Section, Society of Economic Paleontologists and Mineralogists, Eleventh Annual research Conference: 21-51, Houston.

Armentrout, J. M., Echols, R. C. & Lee, T. D. (1990) – Patterns of foraminiferal abundance and diversity: implications for sequence stratigraphic analysis. In: Gulf Coast Section, Society of Economic Paleontologists and Mineralogists, Eleventh Annual Research Conference: 53-58, Houston.

Armentrout, J. M., Fearn, B., Rodgers, K., Root, S., Lyle, W. D., Herrick, D. C., Bloch, R. B., Snedden, J. W. & Nwanko, B. (1999) – High-resolution sequence biostratigraphy of a lowstand prograding delta wedge: Oso Field (late Miocene), Nigeria. In: Jones, R.W. & Simmons, M. D. (eds), Biostratigraphy in Production and Development Geology, *Geol. Soc., Spec. Public.*, 152: 259-290, London.

Boltovskoy, E. & Totah, V. I. (1992) – Preservation index and preservation potential of some foraminiferal species. *J. Foraminiferal Res.*, 22: 267-273, Washington.

Brasier, M. (1980) – Microfossils, 193 pp. George Allen & Unwin, London.

Brookfield, M. E. (1973a) – Palaeogeography of the Upper Oxfordian and Lower Kimmeridgian (Jurassic) in Britain. *Palaeog., Palaeocl., Palaeoecol.*, 14: 137-167, Amsterdam.

Brookfield, M. E. (1973b) – The palaeoenvironment of the Abbotsbury Ironstone (Upper Jurassic) of Dorset. *Palaeontology*, 16: 261-274, Oxford.

Brookfield, M. E. (1978) – The lithostratigraphy of the upper Oxfordian and lower Kimmeridgian Beds of South Dorset. *Proc. Geologists' Ass.*, 89: 1-32, London.

Castignetti, P. (1997) – Population dynamics and facies association of Recent foraminifera from a nearshore marginal marine environment: Plymouth Sound. Unpublished Ph.D. Thesis, University of Plymouth [2 volumes], Plymouth.

Castignetti, P., Hart, M. B. & Manley, C.J. (2000) – *Technitella* (Norman, 1878) from Plymouth Sound, South Devon, U. K. In: Hart, M. B., Kaminski, M. A. & Smart, C. W. (eds), Proceedings of the Fifth International Workshop on Agglutinated Foraminifera, *Grzybowski Foundation Spec. Public.*, 7: 81-88, Krakow.

Coe, A. L. (1992) – The Oxfordian and Portlandian. In: Coe, A. L., Hesselbo, S. P., Parkinson, D. N. & Jenkyns, H. C. (eds), Sequence Stratigraphy of the Dorset Jurassic, a field guide. Sequence Stratigraphy of European Basins, *CNRS-IFP*: 37-81, Dijon.

Coe, A.L. (1995) – A comparison of the Oxfordian successions of Dorset, Oxfordshire, and Yorkshire. In: Taylor, P. D. (ed.), Field Geology of the British Jurassic, *Geol. Soc. London*: 151-172, London.

Cubaynes, R., Rey, J., Ruget, C., Courtinat, B. & Bodegat, A. M. (1990) – Relations between systems tracts and micropalaeontological assemblages on a Toarcian carbonate shelf (Quercy, southwest France). *Bull. Soc. Géol. France*, 8: 989-993, Paris.

Einsle, G. & Bayer, U. (1991) – Asymmetry in transgressive-regressive cycles in shallow seas and passive continental margin settings. In: Einsle, G., Ricken, W. & Seilacher, A. (eds), Cycles and Events in Stratigraphy: 660-681, Springer-Verlag, Berlin.

Emery, D. & Myers, K. J. (1996) – Sequence Stratigraphy, 297 pp., Blackwell Science, Oxford,.

Fitzpatrick, F. (1991) – Studies of sediments in a tidal environment. Unpublished PhD Thesis, Polytechnic South West, (now University of Plymouth), Plymouth.

Fürsich, F. T. (1975) – Trace fossils as environmental indicators in the Corallian of England and Normandy. *Lethaia*, 8: 151-172, Oslo.

Galloway, W. E. (1989a) – Genetic stratigraphic sequences in basin analysis. 1: Architecture and genesis of flooding surface bounded depositional units. *Bull. AAPG*, 73: 125-142, Tulsa.

Galloway, W. E. (1989b) – Genetic stratigraphic sequences in basin analysis. ll: Application to northwest Gulf of Mexico Cenozoic basin. *Bull. AAPG*, 73: 143-154, Tulsa.

Hart, M. B. (1997) – The application of micropalaeontology to sequence stratigraphy: an example from the chalk of southwest England. *Proc. Ussher Society*, 9: 158-163, Crediton.

Hart, M. B. (2000) – Foraminifera, sequence stratigraphy and regional correlation; an example from the uppermost Albian of Southern England. *Revue Micropal.*, 43: 27-45, Paris.

Hart, M. B., Oxford, M. J. & Hudson, W. (2002) – The early evolution and palaeobiogeography of Mesozoic planktonic foraminifera. In: Crame, J. A. & Owen, A. W. (eds), Palaeobiogeography and Biodiversity Change: the Ordovician and Mesozoic-Cenozoic Radiations, *Geol. Soc., Spec. Publ.*, 194: 115-126, London.

Henderson, A. S. (1997) – The palaeoecology and biostratigraphy of the Foraminifera from the Oxfordian of North Dorset. Unpublished Ph.D. Thesis, University of Plymouth.

Henderson, A. S. & Hart, M. B. (2000) – The distribution of Foraminiferida in the Oxfordian sequences of north Dorset. *GeoResearch Forum*, 6: 311-320, Zürich.

Montanez, I. P. & Osleger, D. A. (1993) – Parasequence stacking patterns, third-order accommodation events, and sequence stratigraphy of Middle to Upper Cambrian platform carbonates, Bonanza King Formation, southern Great Basin. In: Loucks, R. G. & Sarg, J. F. (eds), Carbonate sequence stratigraphy: Recent developments and applications. *AAPG*, Memoir, 57: 305-326, Tulsa.

Murray, J. W. (1989) – Syndepositional dissolution of calcareous foraminifera in modern shallow-water sediments. *Marine Micropal.,* 15: 117-121, Amsterdam.

Murray, J. W. & Alve, E. (2000) – Do calcareous dominated shelf foraminiferal assemblages leave worthwhile ecological information after their dissolution? In: Hart, M. B., Kaminski, M. A. & Smart, C. W. (eds), Proceedings of the Fifth International Workshop on Agglutinated Foraminifera, *Grzybowski Found. Spec. Pub.,* 7: 311-331, Krakow.

Newell, A. J., (2000) – Fault activity and sedimentation in a marine rift basin (Upper Jurassic, Wessex Basin, UK). *Journ. Geol. Soc.,* 157: 83-92, London.

Oliver, G. M. (1998) – High resolution sequence stratigraphy and diagenesis of mixed carbonate/siliciclastic successions. Unpublished Ph.D. Thesis, University of Plymouth.

Olsson, R. K. (1988) – Foraminiferal modelling of sea-level change in the Late Cretaceous of New Jersey. In: Wilgus, C. K. et al. (eds), Sea-level change: an integrated approach, *SEPM Spec. Public.,* 42: 289-298, Tulsa.

Oxford, M. J., Hart, M. B. & Watkinson, M. P. (2000) – Micropalaeontological investigations of the Oxford Clay – Corallian succession of the Dorset Coast. *Geoscience in south-west England,* 10: 9-13, Crediton.

Oxford, M. J., Gregory, F. J., Hart, M. B., Henderson, A. S., Simmons, M. D. & Watkinson, M. P. (2002) – Jurassic planktonic foraminifera from the United Kingdom. *Terra Nova,* 14: 205-209, Oxford.

Pacht, J. A., Bowen, B. E., Beard, J. H. & Shaffer, B. L. (1990) – Sequence stratigraphy of Plio-Pleistocene depositional facies in the offshore Louisiana south additions. *Gulf Coast Association of Geological Society, Transactions,* 40: 1-18, Houston.

Partington, M. A., Copestake, P., Mitchener, B. C. & Underhill, J. R. (1993) – Biostratigraphic calibration of genetic sequences in the Jurassic-lowermost Cretaceous (Hettangian to Ryazanian) of the North Sea and adjacent areas. In: Parker, J. R. (ed.), Petroleum Geology of Northwest Europe, Proceedings of the 4th Conference, *Geol. Soc. London*, 1: 371-386, London.

Powell, A. J. (1992) – Making the most of microfossils. *Geoscientist,* 2: 12-16, London.

Reading, H. G. (1996) – Sedimentary Environments: Processes, Facies and Stratigraphy. 230 pp., [3rd Edition], Blackwell Science, Oxford.

Rioult, M., Dugué, O., Jan du Chêne, R., Ponsot, C., Fily, G., Moron, J. M. & Vail, P. R. (1991) – Outcrop sequence stratigraphy of the Anglo-Paris Basin, Middle to Upper Jurassic (Normandy, Maine, Dorset). *Bull., Centres Rech. Explor.-Prod. Elf Aquitaine,* 15: 101-194, Boussens.

Samson, Y., Janin, M.-C. & Bignot, G. (1992) – Les globobuligerines (Foraminifères Planctoniques) de l'Oxfordien Inférieur de Villers-sur-Mer (Calvados, France) dans leur gisement. *Rev. Paléobiologie*, 11: 409-431, Geneva.

Shaffer, B. L. (1987) – The potential of calcareous nannofossils for recognising Plio-Pleistocene climatic cycles and sequence boundaries on the shelf. Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists, Eighth Annual Research Conference: 142-145, Houston.

Shaffer, B. L. (1990) – The nature and significance of condensed sections in Gulf Coast late Neogene stratigraphy. *Gulf Coast Ass. Geol. Soc., Trans.,* 40: 186-195.

Sharland, P. R., Archer, R., Casey, D. M., Davies, R. B., Hall, S. H., Heward, A. P., Horbury, A. D. & Simmons, M. D. (2001) – Arabian Plate Sequence Stratigraphy, *GeoArabia Spec. Publ.,* 2, Gulf PetroLink, Bahrain.

Simmons, M. D., Williams, C. L. & Hart, M. B. (1991) – Sea level changes across the Albian-Cenomanian boundary in southwest England. *Proc. Ussher Society,* 7: 408-412, Crediton.

Strasser, A., Pittet, B. & Pasquier, J.-B. (1994) – Multiplication of maximum-flooding surfaces, sequence boundaries, and transgressive surfaces as a response to high-frequency sea-level fluctuations. 14th International Sedimentological Congress, Abstracts:70-72, Rio de Janeiro.

Strasser, A., Pittet, B., Hillgärtner, H. & Pasquier, J.-B. (1999) – Depositional sequences in shallow carbonate-dominated sedimentary systems: concepts for a high-resolution analysis. *Sedimentary Geology,* 128: 201-221, Amsterdam.

Sun, S. Q. (1989) – A new interpretation of the Corallian (Upper Jurassic) cycles of the Dorset coast, Southern England. *Geol. Journ.,* 24: 139-158, Chichester.

Sun, S. Q. (1990a) – Discussion of swaley cross-stratification produced by unidirectional flows, Bencliff Grit (Upper Jurassic), Dorset, UK. *J. Geol. Society,* 147: 396-400, London.

Sun, S. Q. (1990b) – Facies-related diagenesis in a cyclic shallow marine sequence, the Corallian group (Upper Jurassic) of the Dorset Coast, Southern England. *Journ. Sedim. Petrol.,* 60: 42-52, Tulsa.

Talbot, M. R. (1973) – Major sedimentary cycles in the Corallian beds (Oxfordian) of southern England. *Palaeog., Palaeocl., Palaeoecol.,* 14: 293-317, Amsterdam.

Talbot, M. R. (1974) – Ironstones in the Upper Oxfordian of southern England. *Sedimentology,* 21: 433-450, Oxford.

Vail, P. R. & Wornardt, W. W. (1990) – Well-log seismic stratigraphy: an integrated tool for the 1990's. In: Sequence Stratigraphy as an Exploration Tool: concepts and practices in the Gulf Coast, Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists, Eleventh Annual Research Conference: 379-397, Houston.

Vail, P. R., Mitchum, R. M., Todd, R. G., Widmier, J. M., Thompson, S., Sangree, J. B., Bubb, J. N. & Hatleid, W. G. (1977) – Seismic stratigraphy and global changes in sea-level. In: Payton, C. E. et al. (eds), Seismic stratigraphy – applications to hydrocarbon exploration. *AAPG*, Memoir 26: 49-62, Tulsa.

Van der Zwan, C. J. & Brugman, W. A. (1999) – Biosignals from the EA Field, Nigeria. In: Jones, R.W. & Simmons, M.D. (eds), Biostratigraphy in production and development geology, *Geol. Soc. Spec. Publ.,* 152: 291-301, London.

Van Wagoner, J. C., Posamentier, H. W., Mitchum, R. M., Vail, P. R., Sarg, J. F., Loutit, T. S. & Hardenbol, J. (1988) – An overview of the fundamentals of sequence stratigraphy and key definitions. In: Wilgus, C. K. et al. (eds), Sea-level changes: an integrated approach, *SEPM*, Mem. 42: 39-45, Tulsa.

Wilson, R. C. L. (1968a) - Upper Oxfordian palaeogeography of Southern England. *Palaeog., Palaeocl., Palaeoecol.,* 4: 5-28, Amsterdam.

Wilson, R. C. L. (1968b) - Carbonate facies variation within the Osmington Oolite Series in Southern England, *Palaeog., Palaeocl., Palaeoecol.,* 4: 89-123, Amsterdam.

Wilson, R. C. L. (1991) - Sequence Stratigraphy, an introduction. *Geoscientist*, 1: 13-23, London.