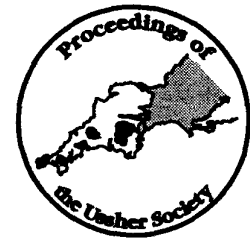


MICROPALAEONTOLOGICAL INVESTIGATIONS OF THE OXFORD CLAY – CORALLIAN SUCCESSION OF THE DORSET COAST.

M. J. OXFORD, M. B. HART & M. P. WATKINSON

Oxford, M.J., Hart, M.B., and Watkinson, M.P. 2000. Micropalaeontological investigations of the Oxford Clay — Corallian succession of the Dorset Coast. *Geoscience in south-west England*, **10**, 009-013



The Dorset Coast is internationally known for the near-continuous exposure of the Jurassic succession. The Oxford Clay-Corallian-Kimmeridge Clay sequence that is exposed between the Isle of Portland and Ringstead records the transition from deeper-water marine clays to shallow-water sands and oolitic shoals and back into deeper-water, near-stagnant, marine clays.

The preliminary data discussed here are part of an on-going study. This aims to assess the role of Foraminifera in the development of a sequence stratigraphical interpretation of continuous successions in Dorset and Normandy. In this report, faunas are described from the Nothe Grit and Red Cliff Formations in the lower part of the Corallian Group. This identifies, with more accuracy than has previously been the case, a Maximum Flooding Surface within the Red Cliff Formation.

M.J. Oxford, M.B.Hart, M.P.Watkinson,
Department of Geological Sciences, University of Plymouth, Drake Circus, Plymouth PL4 8AA

INTRODUCTION

The Middle-Upper Jurassic succession (Oxford Clay Formation, Corallian Group and Kimmeridge Clay Formation) is well exposed on the Dorset Coast (Figure 1) and has been intensively studied for over 100 years. The ammonite succession derived from these strata provides a reliable time-scale within which the use of a variety of fossil groups can be used to generate detailed palaeoenvironmental models. The classic ammonite zonation of the Jurassic (Cope *et al.*, 1980a, 1980b) was established in this area and it is rightly regarded as being of international importance (current proposals for a World Heritage Site). The lithostratigraphy of the succession has, only recently, been changed (Coe, 1992 and references therein) from the historical names to one of formations and members. The Corallian Group, the subject of this research, has been divided into six formations (Coe, 1992); the Nothe Grit, Red Cliff, Osmington Oolite, Trigonina clavellata Beds, Sandsfoot and Ringstead Formations. The Red Cliff Formation is further subdivided (Wright, 1986) into three members; the Preston Grit, Nothe Clay and Bencliff Grit Members. The present study aims to determine the detailed distribution of foraminifera in various parts of the Oxford Clay Formation — Corallian Group — Kimmeridge Clay Formation and to test previous sequence stratigraphic interpretations of this succession. Preliminary data investigate the relationship of the microfossils (primarily foraminifera) to the sequence stratigraphy of the Red Cliff Formation.

SEQUENCE STRATIGRAPHY

Sequence stratigraphy was developed in the 1970's and was based, initially, on the interpretation of seismic sections. Vail *et al.* (1977) further developed the original concept to interpret outcrop and borehole data and to directly relate the resulting stratigraphy to relative sea-level changes. Short term fluctuations lead to the formation of sequences, "genetically related packages of rock bounded by unconformities or their correlative conformities" (Van Wagoner *et al.* 1988). A sequence is divided into *systems tracts*, with three main tracts recognisable within a given sequence; the lowstand systems tract (LST), transgressive systems tract (TST) and highstand systems tract (HST).

Systems tracts assist in the understanding of the distribution of facies across the shelf and basins during given periods of the sea-level change as they are characterised by particular sedimentary, fossil, facies and seismic relationships. The boundaries between individual

systems tracts are indicated by key stratal surfaces. These represent significant, abrupt changes in relative sea-level (e.g., Maximum Flooding Surfaces (MFS)). The MFS separates the TST and the HST and is an important part of sequence stratigraphic interpretation.

Ever since the descriptions of the Jurassic succession of the Dorset Coast by Arkell (1933, 1956) geologists have been aware of the cyclical nature of the sedimentation. In the Corallian this concept was further extended by Wilson (1968a, b), Talbot (1973, 1974) and Sun (1989), all of whom describe repeated sedimentary cycles caused primarily by changes in sea level. Interpretations of the sequence stratigraphy of the Middle-Upper Jurassic of the Dorset Coast have been attempted by various workers (Wilson, 1991; Rioult *et al.*, 1991; Coe, 1992, 1995; Oliver, 1998; Newell, 2000) with differing — if not conflicting — results (Figure 2). Although all these workers are using terminology such as lowstand systems tract, transgressive systems tract and highstand systems tract, the "sequences" are on a smaller scale than the sequences of Van Wagoner *et al.* (1988) and others. In reality, what are being described as sequences on the Dorset Coast are probably parasequences (for which there is no separate nomenclature). It is hoped that, by integrating detailed micropalaeontological information with the sedimentology, it will allow the development of a more accurate sequence stratigraphic interpretation.

Emery & Myers (1996), in a discussion of the distribution of (principally) microfossils within sequences provide an interesting model (*op. cit.*, 1996, fig. 6.14) which can be tested using the successions of the Dorset coast. Their figure, quoted above, uses the distribution of planktonic microfossils to identify the maximum flooding surface (MFS) along with an associated peak in faunal diversity. The majority of the previous works on the microfossil distribution in sequences has been done in the younger levels of the succession (mainly Cenozoic of the Gulf of Mexico). In these, mainly sub-surface, successions the numbers of Foraminifera in any assemblage reportedly vary both in absolute numbers and diversity (see 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) within each of the identified sequences. More recently Olsson (1988), Cubaynes *et al.* (1990), Simmons *et al.* (1991), Powell (1992), Partington *et al.* (1993), Hart (1997), Henderson (1998) and Henderson & Hart (2000) have extended this approach into the Mesozoic successions of the Atlantic Coastal Plain of the USA and North-West Europe. In all cases the various authors have been using a combination of diversity variations, planktonic: benthonic ratios and

other faunal events to characterise their sequence stratigraphic model interpretations.

THE MIDDLE-UPPER JURASSIC SUCCESSION

The Nothe Grit Formation represents the base of the succession (Figure 2). This is characterised by a fine-grained, fairly well-sorted sand which is pervasively bioturbated (Wright, 1986). It is interpreted as having been formed in a shallow shelf sea environment (Coe, 1995). The Red Cliff Formation consists (in ascending order) of the Preston Grit, Nothe Clay and Bencliff Grit Members. The Preston Grit, despite comprising one massive bed, is split into two distinct parts; a lower, soft, argillaceous fine-grained sand and an upper medium-grained, shelly, calcareous sandstone.

The Nothe Clay Member consists of a grey mudstone with eight beds of limestone (Coe, 1995). The macrofauna is abundant, with bivalves, brachiopods, gastropods and echinoderm fragments all being recorded. The Bencliff Grit Member is, according to Allen & Underhill (1989), composed of an heterolithic sandstone and mudstone facies, with the sandstone forming 85-90% of the Member. Various interpretations of the unusual bedforms have been made (Allen & Underhill, 1989; Coe, 1992; Oliver, 1998), with storm dominated shoreface being the generally accepted interpretation of the environment. These two formations have been selected for a this study of the foraminiferal distribution within a sequence stratigraphical framework. This can be correlated (Henderson & Hart, 2000) with the successions in North Dorset that have recently been described by Henderson (1998).

METHODOLOGY

For this investigation close-sampling of the succession, with each sample located against an accurate sedimentological log within identified lithostratigraphic units, was undertaken. Samples were taken from freshly exposed rock surfaces from which any signs of weathering have been removed. Sample locations are reinstated to the best of our ability after samples were collected. Samples are split in the laboratory and a reserve sub-sample retained for reference.

In this preliminary investigation the Nothe Grit Formation, Preston Grit Member, Nothe Clay Member and the Bencliff Grit Member were sampled as indicated in Figure 3. The samples were divided into a reserve sample, with the remained being processed using the solvent

method described in Brasier (1980). Once washed on a 63µm sieve the residue was dried at a low temperature and then stored prior to investigation. The samples were picked for foraminifera, although holothurian sclerites and ostracods have also been separated and identified. A minimum of 300 specimens of foraminifera were picked from the > 250µm grain size fraction, with the smaller size fractions only being inspected for smaller, largely juvenile, specimens. A selection of the smaller individuals was picked from each of the samples.

Sampling is, to some extent, biased by the lithology, with the clay-rich parts of the formation yielding diverse, well-preserved individuals. The full range of lithologies has, however, been collected. Diverse faunas are commonly associated with levels of maximum flooding although other factors, such as preservation, must also be taken into account. The diversity of the fauna is plotted in Figure 3, while Table 1 includes data on the distribution of key genera in the succession.

DISTRIBUTION OF THE FAUNA

Van Wagoner *et al.* (1988) suggest that there is a close relationship between the MFS and the water depth in a basin. Many of the faunal changes are, therefore, related to the water depth available to the fauna, with "deeper water" taxa being located adjacent to, or at, the MFS. This is particularly true in the case of planktonic taxa (see Emery & Myers, 1996, fig. 6.14) although benthonic taxa are also sensitive to water depth changes, particularly those on the shelf.

Diversity increases in the region of the MFS can be due to at least three main controls although others also exist:

1. In clay-rich successions the sedimentation rate is usually slow and a unit volume of sediment will represent a longer period of time (= more annual reproduction cycles of the standing crop). In sand-rich successions deposition is (probably) faster and the length of time represented by the fauna is much less.
2. In sand-rich successions percolating groundwater can remove some elements of the fauna (e.g., the aragonitic taxa) through dissolution and, in extreme cases, much of the calcareous assemblage may be destroyed.
3. In clay and sand successions the different energy levels represented by the environments may influence the fauna. In high energy environments, that are typically characterised by the deposition of coarse sands, the microfauna can be preferentially winnowed.

Distribution of Foraminiferal Genera in the Nothe Grit and Redcliff Formation

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
<i>Ammobaculites</i> sp.																															
<i>Haplophragmoides</i> sp.																															
<i>Textularia</i> sp.																															
<i>Trochammina</i> sp.																															
<i>Lenticulina</i> sp.																															
<i>Citharina</i> sp.																															
<i>Dentalina</i> sp.																															
<i>Nodosaria</i> sp.																															
<i>Planularia</i> sp.																															
<i>Vaginulina</i> sp.																															
<i>Nubeculina bigoti</i> Cushman																															
<i>Lagena</i> sp.																															
<i>Epistomina</i> sp.																															
<i>Eoguttulina</i> sp.																															
<i>Pseudonodosaria</i> sp.																															
<i>Triplasia</i> sp.																															
<i>Marginulina</i> sp.																															
<i>Lingulina</i> sp.																															
<i>Frolicularia</i> sp.																															
<i>Ophthalmidium</i> sp.																															
<i>Suboidellina</i> sp.																															
<i>Ramulina</i> sp.																															
<i>Trocholina</i> sp.																															
<i>Tristix</i> sp.																															

Table 1. Distribution of foraminiferal genera in the Nothe Grit and Redcliff Formations. The sample locations are indicated in Figure 3. In one case, *Nubeculina bigoti* Cushman, a species is used as this is the only species recorded within the genus in this investigation.

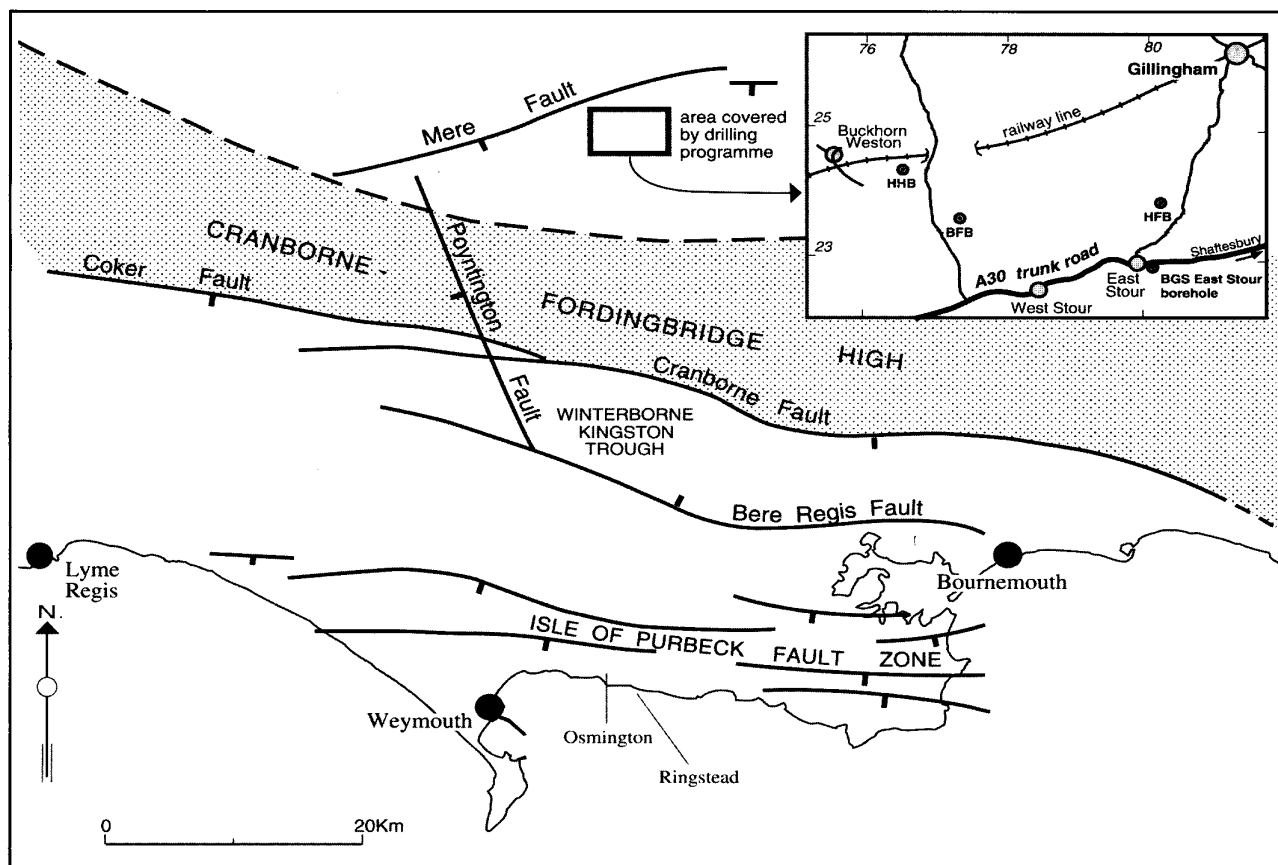


Figure 1. Outline geological map of the Dorset area showing the locations mentioned in the text and the area studied by Henderson (1998) and Henderson & Hart (2000).

Figure 3 shows the relationship between the percentage of dried sample retained on the 63 μ m sieve and the diversity. Where samples have a higher 'sand' content (e.g., R4, R7, etc.) there is low foraminiferal diversity while samples with a low 'sand' content (i.e., a clay or clay/silt lithology) have higher foraminiferal diversity (e.g., 09, 03, etc.). The MFS of any siliciclastic sequence is usually to be found in the clay-rich part of the succession and, in subsurface work, is usually identified by a gamma-ray spike on the electric logs. Oliver (1998) identified the Nothe Clay Member as a zone of maximum flooding (Figure 2) as he was unable to identify the precise 'surface', although Rioult *et al.* (1991) and Coe (1992, 1995) used the omission surface above, and below, the Preston Grit Member as the MFS. Our data appear to indicate that samples 03 or 04, near the top of the Nothe Clay Member, represent the MFS. The asymmetry of the diversity graph is suggestive of a rapid shallowing into the overlying Bencliff Grit Member. This may indicate the presence of a type-1 sequence boundary at that level.

Table 1 shows the distribution of genera (and one species) in the samples identified in Figure 3. In the clay-rich samples the MFS can be seen located between 02 and 04. As well as being the samples with higher diversity a number of key genera (*Ophthalmidium*, *Nubeculina*, *Vaginulina*, *Fronidularia*, *Citharina*, *Lingulina* and *Epsitomina*) are restricted to this interval. These are usually recognised as more open marine, although *Ophthalmidium* and *Nubeculina* (with a porcellanous wall structure) and *Epistomina* (with an aragonitic wall) probably indicate a preservational control; these taxa are rarely found in sandy lithologies. *Ophthalmidium* is also found in the clay-rich part of the succession (Henderson, 1997; Henderson & Hart, 2000). Table 1 also indicates that *Haplophragmoides* is present in the clay-rich part of the succession that may represent the MFS while *Trochammina*, a closely related taxon, is absent.

There is no apparent reasoning for this, as this palaeoenvironmental relationship has not previously been described.

IDENTIFICATION OF SEQUENCES

The identification of sequence boundaries and systems tracts in the Dorset succession has been debated intensely in the years following the publication of the terminology (Van Wagoner *et al.*, 1988). Sequences are bounded by unconformities (or their correlative conformities) and it follows from this that sequence boundaries might be recognised by missing biozones and/or marked facies changes. Figure 2 shows the various interpretations of the Upper Oxford Clay Formation and the Corallian Group succession exposed on the Dorset Coast between Wyke Regis and Ringstead. The foraminiferal data presented here (Figure 3; Table 1) indicate an MFS in the upper part of the Nothe Clay Member. This does not support the findings of Rioult *et al.* (1991) or Coe (1992, 1995). It falls within the "zone of maximum flooding(?)" postulated by Oliver (1998) and lies just above that indicated by Newell (2000). The data in Table 1 provide the basis for further work on the detailed distribution of the fauna. This will be done at the species level (unlike the generic data used in this account) to enable an accurate correlation with the work of Henderson (1998) in North Dorset.

CONCLUSIONS

This preliminary study has described the distribution of foraminifera in the Nothe Grit and Redcliff Formations. Interpretation of this distribution has allowed a more accurate placing of a maximum flooding surface than has hitherto been the case. As this work progresses it is hoped that further information on the distribution and preservation of the fauna within the sequences exposed on this part

- COPE, J.C.W., DUFF, K.L., PARSONS, C.F., TORRENS, H.S., WIMBLEDON, W.A. & WRIGHT, J.K. 1980b. A correlation of Jurassic rocks in the British Isles, Part 2: Middle and Upper Jurassic. *Geological Society of London, Special Report*, **15**, 109pp.
- CUBAYNES, R., REY, J., RUGET, C., COURTINA, B. & BODEGAT, A.M. 1990. Relations between systems tracts and micropalaeontological assemblages on a Toarcian carbonate shelf (Quercy, southwest France). *Bulletin, Société Géologique de France*, **8**, 989-993.
- EMERY, D. & MYERS, K. J. 1996. *Sequence Stratigraphy*, Blackwell Science, Oxford, 297pp.
- HART, M.B. 1997. The application of micropalaeontology to sequence stratigraphy; an example from the chalk of south-west England. *Proceedings of the Ussher Society*, **9**, 158-163.
- HENDERSON, A.S. 1998. *The palaeoecology and biostratigraphy of the Foraminifera from the Oxfordian of North Dorset*. Unpublished PhD Thesis, University of Plymouth.
- HENDERSON, A.S. & HART, M.B. 2000. The distribution of Foraminifera in the Oxfordian sequences of North Dorset, U.K. *GeoResearch Forum*, **6**, 311-320.
- NEWELL, A.J. 2000. Fault activity and sedimentation in a marine rift basin (Upper Jurassic, Wessex Basin, UK) *Journal of the Geological Society, London*, **157**, 83-92.
- OLIVER, G.M. 1998. *High resolution sequence stratigraphy and diagenesis of mixed carbonate/siliciclastic successions*. Unpublished PhD 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 changes: an integrated approach*, Special Publication of the Society of Economic Paleontologists and Mineralogists, **42**, 289-298.
- PACHT, JA., 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 Societies, Transactions*, **40**, 1-18.
- 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, Geological Society of London, Vol.1, 371-386.
- POWELL, A.J. 1992. Making the most of microfossils. *Geoscientist*, **2**, 12-16.
- RIOULT, M., DUGUE, O., JAN DU CHENE, 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). *Bulletin, Centres Recherches Explor.-Prod. Elf Aquitaine*, **15**, 101-194.
- SHAFFER, B.L. 1987. The potential of calcareous nanofossils 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.
- SHAFFER, B.L. 1990. The nature and significance of condensed sections in Gulf Coast late Neogene stratigraphy. *Gulf Coast Association of Geological Societies, Transactions*, **40**, 186-195.
- SIMMONS, M.D., WILLIAMS, C.L. & HART, M.B. 1991. Sea level changes across the Albian-Cenomanian boundary in south-west England. *Proceedings of the Ussher Society*, **7**, 408-412.
- SUN, S.Q. 1989. A new interpretation of the Corallian (Upper Jurassic) cycles of the Dorset coast, Southern England. *Geological Journal*, **24**, 139-158.
- TALBOT, M.R. 1973. Major sedimentary cycles in the Corallian beds (Oxfordian) of southern England. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **14**, 293-317.
- TALBOT, M.R. 1974. Ironstones in the Upper Oxfordian of southern England. *Sedimentology*, **21**, 433-450.
- 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. (Ed.), *Seismic stratigraphy- applications to hydrocarbon exploration*, American Association of Petroleum Geologists, Memoir **26**, 49-62.
- 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.
- VAN DERZWAN, 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*, Geological Society Special Publication, **152**, 291-301.
- 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., HASTINGS, B.S., KENDALL, C.G.St. C., POSAMENTIER, H.W., ROSS, CA. & VANWAGONER, J.C. (Eds), *Sea-level changes: an integrated approach*, Society of Economic Paleontologists and Mineralogists, Memoir **42**, 39-45.
- WILSON, R.C.L. 1968a. Carbonate facies variation within the Osmington Oolite Series in Southern England. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **4**, 89-123.
- WILSON, R.C.L. 1968b. Upper Oxfordian palaeogeography of Southern England. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **4**, 5-28.
- WILSON, R.C.L. 1991. Sequence Stratigraphy, an Introduction. *Geoscientist*, **1**, 13-23.
- WRIGHT, J.K. 1986. A new look at the stratigraphy, sedimentology and ammonite fauna of the Corallian Group (Oxfordian) of south Dorset. *Proceedings of the Geologists' Association*, **97**, 1-21.