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Relative sea-level fluctuations and ecostratigraphy; applications to Middle/Upper Oxfordian fossil assemblages of east-central Algarve, Portugal

ABSTRACT: The replies of benthic-epibenthic marine macroinvertebrate assemblages to ecospace variations during the Middle/Upper Oxfordian (Plicatilis, Transversarium, Bifurcatus, and Bimammatum Zones) according to fluctuations in the faunal spectra are recorded from six analyzed sections in the east-central Algarve, southern Portugal. The general evolution of the ammonite record during the studied time interval, with a recognizable decrease during the Transversarium-Bifurcatus Zones, can be biased by the better development and better outcrop conditions of the Bimammatum Zone in the area. The other studied chronozones are comparatively worse known and correspond to a comparatively larger development of buildups and/or intervals of tectonic instability in the Algarve, specially during the Transversarium-Bifurcatus Zones. In the recorded ammonite assemblages, the lytoceratids are always accidental elements with less than 2% representation, and their record decreases significantly during the Bimammatum Zone. The general trend of decreasing in the phylloceratids is coherent with the reduction of the ecospace inherent to the sequential evolution proposed by MARQUES & *al.* (1991). On the contrary, the evolution of the phylloceratids does not offer a clear interpretation according to the sequential scheme recently proposed by PONSOT & VAIL (1991). Significant deviations in the record of some ammonite groups have been recognized in comparatively high-energy deposits and are related to taphonomic effects. In one case it has been interpreted as an evidence of the heterogeneity of ecologic parameters whose recognition is however difficult through facies analysis.

INTRODUCTION

The Upper Jurassic deposits of the Algarve, southern Portugal (Text-fig. 1), has long been known due to the presence of the famous ammonite fauna (CHOFFAT 1893; PRATSCH 1958; MARQUES 1983, 1985; MARQUES & OLÓRIZ 1989a, b, 1992; MARQUES & *al.* 1991, 1992; OLÓRIZ & *al.* 1991).

The geodynamic evolution in the Algarve during the Upper Jurassic determined the existence of a carbonate platform system to the west (onshore and land outcrops), also known as the "*Secteur Septentrional*" (MARQUES & OLÓRIZ 1989a). Detailed bio- and lithostratigraphic studies in the carbonate-terrigenous platform allowed to propose a model concerning the environmental evolution of the area (MARQUES & OLÓRIZ 1989a), and later to compare with the main traces of the sedimentary record in neighboring platforms (Prebetic and NW Africa). From these comparisons an integrated image resulted for the evolution of the South Iberian margin (MARQUES & *al.* 1991).

The analyses carried out on the Upper Jurassic materials in the east-central Algarve allowed to distinguish two "megasequences" (Callovian — uppermost lower/basal Upper Kimmeridgian and uppermost lower/basal Upper Kimmeridgian — Berriasian *p.p.*) dated by ammonites (MARQUES & OLÓRIZ 1989b). This stratigraphic framework was later interpreted in the context of the sequence stratigraphy model sensu HAQ & *al.* (1987, 1988), slightly modified by MARQUES & *al.* (1991).

Twelve discontinuites were individualized in the so-called "*cycle du Jurassique supérieur*" (MARQUES & OLÓRIZ 1989b, MARQUES & *al.* 1992), some of them were caused by interactions between tectonics and eustasy.

In the line of previous works (OLÓRIZ & *al.* 1988, 1991, 1992; MARQUES & OLÓRIZ 1989a, 1992; MARQUES & *al.* 1992) in this paper the authors analyze the eco-evolutive replies of marine macroinvertebrate assemblages, mainly ammonites and benthic faunas, to variations in the eco-sedimentary dynamics produced by relative sea-level changes.

The present example has to do with the Middle/Upper Oxfordian (Plicatilis, Transversarium, Bifurcatus and Bimammatum Zones), and was elaborated through counting of fossil material collected in sections studied in the carbonate-terrigenous platform above mentioned.

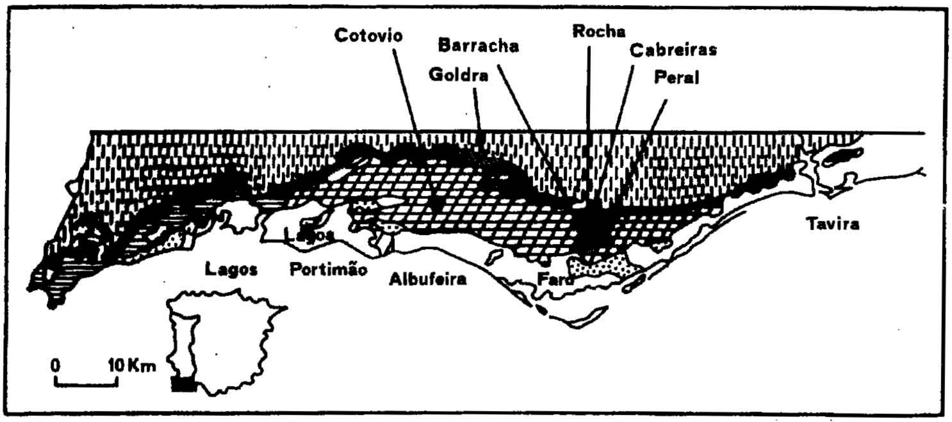
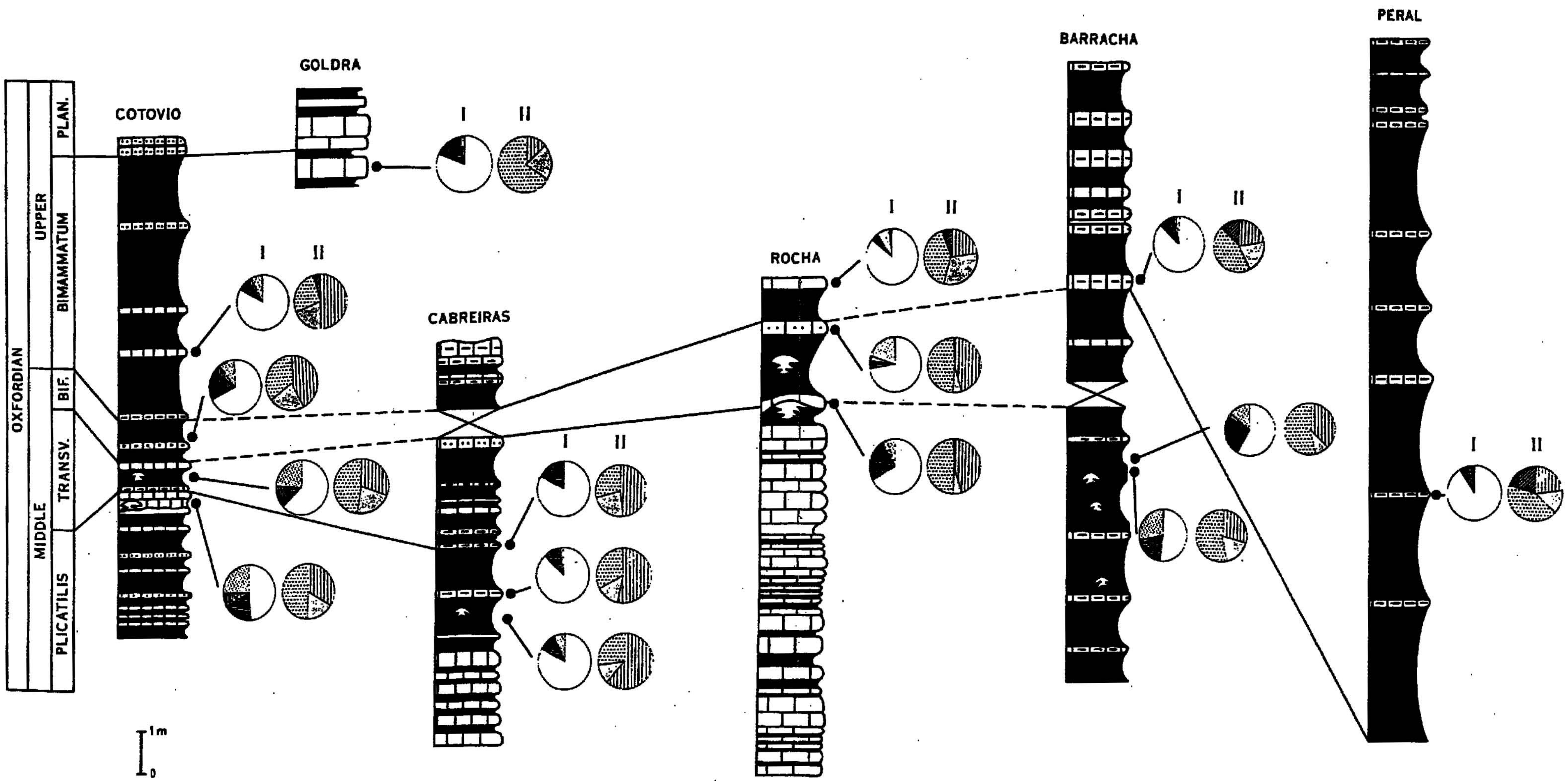


Fig. 1. Geologic setting of the studied sections (*black circles*), and location of the area in Southern Portugal

Indicated are: Paleozoic deposits (*vertical broken lines*), Triassic (*black*), Jurassic carbonate platform systems (*horizontal ruling*); east-central Algarve Basin is in crossed framework, Cretaceous (*stippled*) and Cenozoic (*blank*)

Adopted from: MARQUES & OLÓRIZ (1992)

Selected sections with the main facies types, chronostratigraphy, correlations, and faunal spectra



LEGEND TO TEXT-FIGS 2 AND 3

- MARLS
- LIMESTONES
- SANDY LIMESTONES/MARLY LIMESTONES
- SPONGE BUILDUPS
- LACK OF OBSERVATIONS (Only in Text-fig. 2)

MACROINVERTEBRATE ASSEMBLAGE SPECTRA (TYPE I)

- AMMONITES
- BELEMNITES
- BIVALVES
- BRACHIOPODS
- GASTROPODS

AMMONITE ASSEMBLAGE SPECTRA (TYPE II)

- PHYLLOCERATIDAE+LYTOCERATIDAE
- HAPLOCERATACEAE
- PERISPHINCTIDAE
- ASPIDOCERATIDAE

STRATIGRAPHIC FRAMEWORK

In the sequential organization proposed for the "*Secteur Septentrional*" of MARQUES & OLÓRIZ (1989b), the interval studied in the "Calcarios Margosos e Margas do Peral" Fm. (MARQUES 1983) is a part of a 2nd order sequence of "Megasequence *MI*" located between discontinuites *D2* and *D6*. The materials of this major sequence belong to a part of cycle *4.3* and the initial part of cycle *4.4* of the *LZA-4* supercycle of HAQ & *al.* (1987, 1988), VAIL & *al.* (1987), and VAN WAGONER & *al.* (1988), corresponding to the development of a Transgressive System Tract and a High Stand System Tract from the Plicatilis Zone *p.p.* to the Bifurcatus/Bimammatum Zone boundary, and to a Shelf Margin Wedge System Tract for the Bimammatum Zone (MARQUES & *al.* 1991). Thus, the studied interval corresponds with the major depositional sequences *OX II* and *OX III p.p.* between discontinuites *DIII* and *dVII* in MARQUES & *al.* (1991).

A tectonic pulse was individualized at the Transversarium/Bifurcatus Zone boundary. Associated to it are significant erosions recorded by the presence of coarse siliciclastic materials ("Grés do Cotovio" of MARQUES 1983) observed in the whole region between Albufeira and Peral. The internal organization of the beds suggest that gravitational transport processes operated throughout escarpments, possibly individualized by block movements, in some cases revealing channel infilling. The trace of this event was identified as the tectonically induced *D4* unconformity in MARQUES & OLÓRIZ (1989b) which biostratigraphically corresponds to the Transgressive Surface of cycle *4.3* (HAQ & *al.* 1987, 1988; *cf. also* MARQUES & *al.* 1991). This uncorformity was recently observed in the Rocha region where it is related to horizons containing reworked and fragmented faunal remains (MARQUES & *al.* 1992). A change in facies with the increasing and thickening of marly levels was recognized within the upper part of the studied interval (Bimammatum Zone), determinig the decline for sponge buildups development. This sedimentary shift seems to be related to the sequence boundary between cycles *4.3* and *4.4* (*DVI* of MARQUES & *al.* 1991).

THE STUDIED SECTIONS

The six selected sections (Moinho do Cotovio, Goldra, Cabreiras, Rocha, Barracha, and Peral — *see* Text-figs 1-2) on which the faunal spectra were made have already been described in detail in other papers (MARQUES 1983, MARQUES & *al.* 1992). All of them belong to the "Calcários Margosos e Margas do Peral" Fm. which was previously defined for the Upper Jurassic, Middle Oxfordian/uppermost Lower Kimmeridgian, in east-central Algarve (MARQUES 1983, MARQUES & OLÓRIZ 1992). In the Peral Fm., gray compact micritic limestones (mudstones-wackstones) alternating with marly levels characterize deeper areas of the basin where cephalopods were dominant, whereas reefal and parareefal buildups developed in shallower areas of the platform.

A predominantly carbonate sedimentation, with the presence of sponge buildups, took place during the Plicatilis-Transversarium interval (Text-fig. 2). Reefal and parareefal macroinvertebrate assemblages are represented by bryozoans, corals, echinoderms, gastropods, bivalves, brachiopods, belemnites and ammonites. At times (Moinho do Cotovio section), sponges reach 40 cm in size. In surrounding marly levels recorded is the presence of fragmented macrofauna and of plant remains. In depressed areas macrofaunal assemblages are comparatively depleted in benthos.

The Bifurcatus Chron corresponds to one of tectonic instability throughout the whole basin. This is revealed by the presence of a siliciclastic input with abundant quartz grains, sometimes of large size. In the studied sections, this depositional event has only been recognized in the Moinho do Cotovio, and in few other places (nearby areas to Cotovio and Rocha). Where recognized, the Bifurcatus Zone is dominated by marly sedimentation with macrofauna composed of gastropods, bivalves, brachiopods, belemnites and ammonites, and by the presence of small sponge buildups.

As previously commented, the Bimammatum Zone corresponds well with both the increase in siliciclastic inflows and thickness, which are related with a higher sedimentation rate. Significant is the presence of condensed horizons within this chronozone in the outcrops at Peral and Goldra. The recorded macrofaunal assemblages are composed of gastropods, bivalves, belemnites and ammonites.

FAUNAL ASSEMBLAGES

The macroinvertebrate assemblages and particularly the ammonites, correspond to the Submediterranean type (MARQUES 1983). The ammonite distribution recorded in the Peral Fm. was described by MARQUES (1983) whilst the first faunal spectra for the Middle Oxfordian correlated with the Long Term eustatic curve for supercycle *LZA-4* were presented by OLÓRIZ & *al.* (1991).

At the moment, the quantification of about 2000 ammonites, together with other invertebrates (belemnites, brachiopods, bivalves, gastropods, and echinoderms) collected in the studied sections of Middle/Late Oxfordian age in the east-central Algarve Basin allows to obtain the faunal spectra (Text-fig. 2), the sample size of which ranges between 130 and 350 specimens.

The ammonites were gathered through a bed-by-bed sampling in the selected outcrops of the Peral Fm. There, limestone beds are mainly fine-grained, and without evidences of sedimentary structures or traces of current activity. In general, the fossil remains have been preserved as internal casts and no preferential orientation was found other than that practically in coincidence with the bedding planes, exception made for the smaller size ammonites and/or some broken specimens. On the ammonite shells, or on the internal casts, epizoans are present, but they are not frequent. As interpreted by OLÓRIZ & *al.* (1991), the extremely scarce record of aptychi is a sign of limited transport of the ammonites before their fall to the sea-floor. In consequence, the possibility for a short post-mortem drift of the ammonite shells towards the shoreline is supposed.

Among a total amount of about 3000 macroinvertebrate remains selected are 30 faunal spectra (6 from the Plicatilis Zone, 10 from the Transversarium Zone, 4 from the Bifurcatus Zone, and 10 from the Bimammatum Zone) which were obtained from samples standardized in size, being 50 specimens the minimal size. At a whole, it is significant the qualitative uniformity of the macroinvertebrate assemblages (type *I* spectra in Text-fig. 2). There are only minor changes in the faunal components with the persistent presence of cephalopods (ammonites and belemnites) followed by brachiopods (locally absent in the known assemblage of the Transversarium Zone in the Cabreiras section and also in that from the Bimammatum Zone in the Goldra section) and bivalves (missing component in the known record of the Plicatilis Zone in the Cabreiras section and also locally in those belonging to the Transversarium and Bimammatum Zones). Other faunal components as echinoderms and gastropods have been more restrictly recorded in the Plicatilis-Transversarium, and Bifurcatus-Bimammatum Zones, respectively.

Opposite to that alluded as an uniform faunal composition, the record of macroinvertebrates other than ammonites shows quantitative fluctuations affecting to different groups, as well as in benthic as in epibenthic or nectonic faunas. But some considerations are pertinent before to interpret the obtained data. Thus, to take into account the climax for reefal and/or tectonic activities during the Transversarium-Bifurcatus Zones is significant. Another limiting factor is recognized as difficulties to obtain faunal spectra more or less continuously through a particular section. This was only possible in the Cotovio section where faunal spectra from all the standard chronozones were controlled. Therefore, the authors selected suitable information in stratigraphic order from different sections. In fact, sampling limitations and/or defective preservation determined the information considerably.

The coupled record of decreasing ammonites and increasing other macroinvertebrates is a fact which could be an artificial compensation effect methodologically induced, at least at times. However, the presented data show selective fluctuations in belemnites and brachiopods during opposite trends in ammonites which occur within the Transversarium-Bifurcatus Zones. The increase in ammonites together with an impoverished record of other macroinvertebrates was detected in the Bimammatum Zone where siliciclastic inputs raised, but it will be commented below.

As a whole the record of ammonite assemblages may be comparatively impoverished, at least locally, during the Transversarium and Bifurcatus Zones with possibilities to be detected also at the top of the Plicatilis Zone. It is to consider this as probably related to increasing reefal activity and/or tectonic instability, and erosional processes. It must be noted that the similarity in ammonite frequency in the upper Plicatilis and the Bimammatum Zones could be not real, but related to the better outcrop conditions for sampling in the latter.

It is worth to mention the constancy of components in the ammonite assemblages (type *II* spectra in Text-fig. 2), with only minor fluctuations affecting to the presence/absence of lytoceratids and aspidoceratids. Thus, diversity at the subfamily/family level seems to be only slightly affected by hypothetical fluctuations in the ecospace volume. It is also significant the scanty, near-to-absence, record of lytoceratids ($\leqslant 2\%$), while in phylloceratids *Sowerbyceras* is dominant and *Phylloceras* very rare. The analysis of the relative composition within ammonite spectra shows, with some exceptions, a general trend to the decrease in phylloceratids+lytoceratids when the opposite for perisphinctids is recorded. The haploceratids (Oppeliidae+ +Glochiceratidae) are the third component among the collected ammonites with locally (Rocha section) a minimal record in the Bifurcatus Zone which is difficult to interpret. Thus, in the Bifurcatus Zone, there are comparatively great fluctuations in the haploceratids record, and these are likely related with taphonomic noise. At present, very characteristic seems to be the near-to- -absence in "aspidoceratids" (Peltoceratinae, Euaspidoceratinae, Epipeltoceratinae) which only reach a comparatively significant representation with the Euaspidoceratinae, but not with the Epipeltoceratinae, from the lower Bimammatum Zone.

ECOSTRATIGRAPHIC INTERPRETATION

Paleogeography, facies analysis and faunal assemblages allow to interpret the existence of a shelf environment in which a relative homogenization of sea-floor depositional conditions started during the increase in siliciclastic inputs at the beginning of the Bimammatum Zone. This is coincident with

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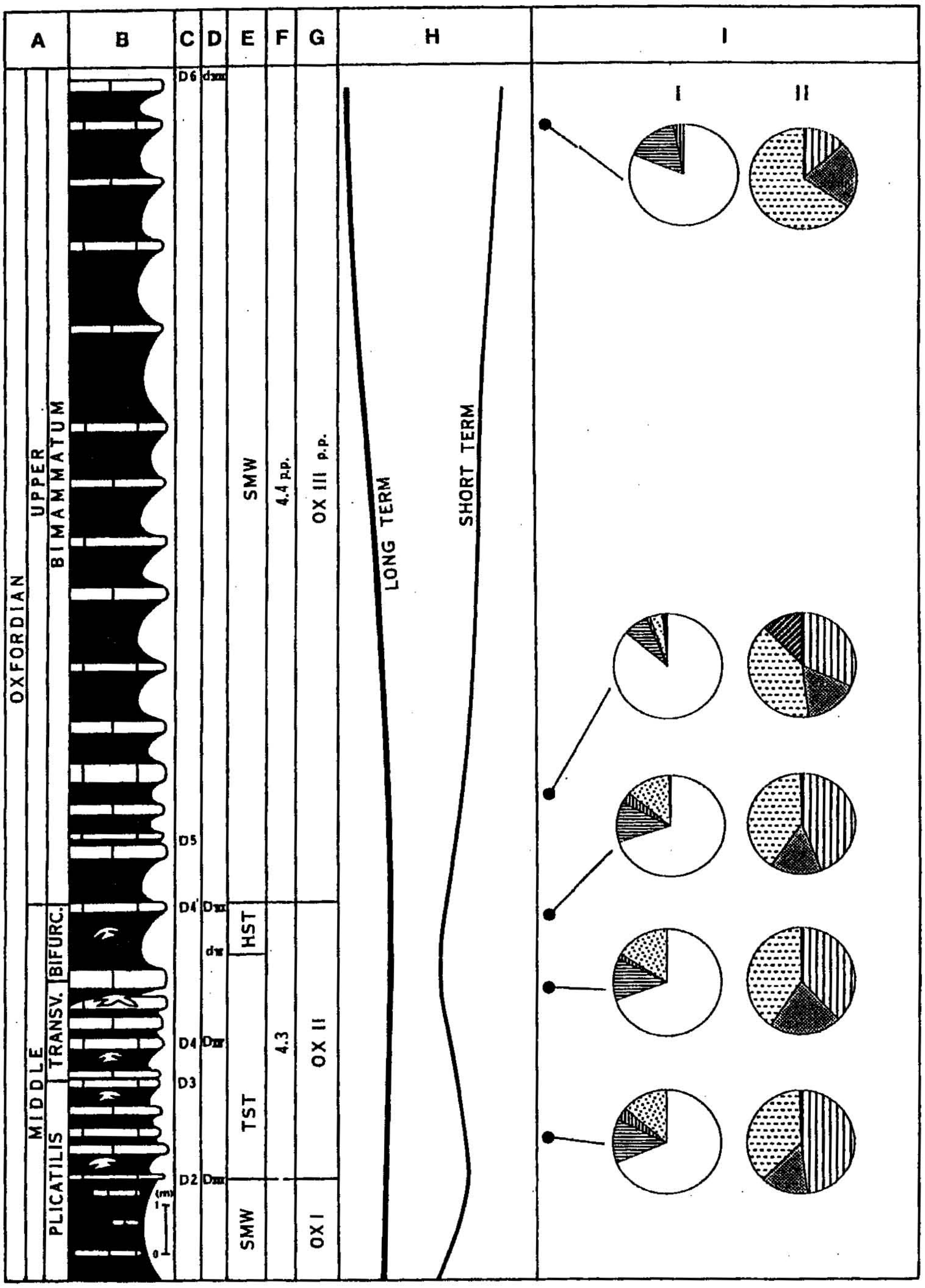
Fig. 3

Synthetic profile with the *Sequence Stratigraphy* and selected averaged faunal spectra for ecostratigraphic interpretation; legend as for Text-fig. 2

A — Chronostratigraphy, B — Synthetic profile for the studied interval, C and D — Discontinuities, E — System tracts, F — *3rd* order cycles, G — Major depositional sequences, H — Eustatic sea-level curves, I — Selected averaged faunal spectra

C, D, E and *G* from MARQUES & OLÓRIZ (1989b) and MARQUES & *al.* (1991, 1992); *F* and *H* from HAQ & *al.* (1987, 1988) a significant fall in the record of benthic macroinvertebrates, and therefore it is considered to be related with, or better induced by, the environmental shift which resulted in the change of lithofacies. In such a situation not only the



dominant suspension-feeding benthos (mainly brachiopods) was affected, but also belemnites impoverished. On the contrary, the amount of ammonite remains makes possible to interpret this group as a more tolerant one (MARQUES & *al.* 1992) which adapted this environmental change through internal fluctuations in the relative composition of their assemblages. Thus, the authors consider as significant the near-to-general decrease in the tolerant phylloceratid *Sowerbyceras* and the absence in the previously scarce lytoceratids. The record known from the Cotovio sections is comparatively unusual with scarce but present lytoceratids during all the studied Oxfordian sequence. Even so, when compared the record of the lower Bimammatum ammonite assemblages from the Cotovio section with those from the uppermost Bimammatum at Goldra it is evident the increasing impoverishment in phylloceratids and lytoceratids as should be expected.

The authors interpret this scenario (*see* Text-fig. 3) and the alluded eco-sedimentary dynamics within the proposal of Sequence Stratigraphy pattern offered by MARQUES & *al.* (1991) for the South Iberian Margin during the Oxfordian, slightly modifying the global scenario of HAQ & *al.* (1987, 1988). The general deterioration of the environment for macroinvertebrates during the Bimammatum Chron seems to be a fact which may be related to the evolution of a Shelf Margin Wedge System Tract. In such a situation, progradational deposits and increasing sea-level fall determined regressions and progressive ecospace reductions. The unexpected decrease in benthic macroinvertebrates in sites which became more and more proximal must be induced by deterioration of life conditions close to the sea-floors when siliciclastic inflows persistently arrived. Coherent with diminishing shelf ecospace are the above mentioned trends in the record of ammonite assemblages.

Earlier in the analyzed Middle Oxfordian (Plicatilis *p.p.*, Transversarium, and Bifurcatus Zones), a high presence of phylloceratids and the persistence of perisphinctids is generally recorded, always being these two groups clearly dominant within the ammonite assemblages. In the cases of discontinuous record of lytoceratids, their very scarce presence was precisely found in the Plicatilis *p.p.* and the Transversarium Zones. All these data coincide well with the higher relative sea-level during the studied part of the Middle Oxfordian as proposed by MARQUES & *al.* (1991). According to these authors, deposits belonging to the analyzed part of the Middle Oxfordian in the South Iberian Margin should correspond with the eco-sedimentary system insert in developing Transgressive System Tract and High Stand System Tract. A lesser rate in siliciclastic inflows together with possibilities for buildup activity complete well the obtained information from ammonite assemblages within the environmental evolution here proposed.

The recorded maintenance in phylloceratids within the identified Bifurcatus Zone could be interpreted as caused by relatively minor ecological changes during the main phases of the connection with open seas, which should be related to the uppermost Transgressive System Tract and lowermost High Stand System Tract of cycle *4.3* as proposed by MARQUES & *al.* (1991).

The record of haploceratids is difficult to interpret since this group shows a very uniform record in all the Cotovio sections with the only exception at Rocha (minimal record taphonomically biased?). Even so, the known record of haploceratids seems to have compensating relations with phylloceratids during the above considered ecospace fluctuations.

The interpretations of those components in the ammonite assemblages, which are near-the-minimum to be represented (2%), were regarded very hypothetical and therefore should not be taken into account, exception made for their characterization as fortuitous components.

Finally, it is worth to mention the existing difficulties to relate the commented fluctuations in the macroinvertebrate assemblages, and lithofacies, with new proposals for *3rd* order eustatic cycles made up by PONSOT & VAIL (1991). Especially, the proliferation of Middle Oxfordian *3rd* order sequences is very difficult to recognize by the means of both the facies analysis (*see* LEINFELDER & WILSON 1992, for the Arruda Sub-Basin of the Lusitanian Basin, Portugal) and ecostratigraphic procedures.

CONCLUSIONS

Ecostratigraphic interpretations of Middle/Upper Oxfordian macroinvertebrate assemblages from epicontinental areas in the Algarve in southern Portugal improve the possibilities to identify Sequence Stratigraphy proposals. In the studied sections major fluctuations in ammonite assemblages correspond well with ecospace reductions during development of the Shelf Margin Wedge System Tract.

The phylloceratids appear to be more sensitive to identify ecospace fluctuations than the lytoceratids which, even with a very scarce record, give also a reliable information.

Benthic faunas are useful in ecostratigraphic interpretations, not only when compared with ammonites but also as showing fluctuations coherent with depositional dynamics in the context of sequence stratigraphy models.

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