Overview of microfossil assemblages and palaeoecological signatures in the Middle-Upper Jurassic transitional successions from the Lusitanian Basin, Portugal

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Key-words: Micropalaeontology; palaeoecology; facies; Middle-Upper Jurassic; Lusitanian Basin; Portugal.

Abstract: The successions across the Middle-Upper Jurassic disconformity in the Lusitanian Basin (Portugal), in particular those belonging to the Oxfordian Cabaços formation, have rich microfossil assemblages, comprising mainly ostracods and charophytes, but also benthic foraminifera, dasyclads, cyanobacteria, *Incertae-sedis* and palynomorphs. Recent detailed studies referring to many localities in the basin allowed a significant improvement of the systematical knowledge of different groups, in particular of the ostracods and charophytes, and the recognition of associations with palaeoecological significance, from the base upwards the sequences. The identified microfossil assemblages show variations in abundance and in diversity ranges, which seem to primarily relate to salinity ranges and changing frequency. Matching of the micropaleontological results with facies analysis, at a basinal scale, showed that the clearly linked regional palaeoecological signatures and evolution of palaeodepositional settings define two basic trends across the basin, one typical of the western successions and the other typical of the eastern successions.

An overview of the main data concerning ostracods, foraminifera, dasyclads and charophytes is presented, including palaeobiogeographical and biostratigraphical remarks. A brief mention to facies associations and their distribution over the basin is also made.

Palavras-chave: Micropaleontologia; paleoecologia; fácies; Jurássico Médio-Superior; Bacia Lusitânica; Portugal.

Resumo: As séries associadas à desconformidade Jurássico médio-Jurássico superior na Bacia Lusitânica (Portugal), em especial as da formação de Cabaços (Oxfordiano), contêm ricas associações de microfósseis. Estas são constituídas, especialmente, por ostracodos e carófitas, mas também por foraminíferos bentónicos, dascicladáceas, cianobactérias, *Incertae-sedis* e palinomorfos. Estudos pormenorizados recentes, abrangendo diversas zonas da bacia, permitiram melhorar significativamente os conhecimentos relativos à Sistemática dos diferentes grupos, em particular dos ostracodos e das carófitas, bem como reconhecer associações com significado paleoecológico, da base para o topo das sequências. As associações reconhecidas mostram variações na diversidade e na abundância relativa, as quais parecem estar relacionadas com o teor e a frequência de variação da salinidade e com o grau de exposição subaérea. A conjugação dos resultados micropaleontológicos com os da análise de fácies, à escala bacinal, demonstrou que a evolução dos paleoambientes e as assinaturas paleoecológicas regionais, claramente relacionadas, definem dois padrões, um característico da região oeste e outro da região leste da bacia.

Neste trabalho apresenta-se uma síntese dos principais resultados relativos a ostracodos, foraminíferos, dascicladáceas e carófitas e fazem-se considerações paleobiogeográficas e biostratigráficas. As associações de fácies e respectiva distribuição na bacia são também sucintamente referidas.

INTRODUCTION

The successions across the Middle-Upper Jurassic disconformity in the Lusitanian Basin (west-central Portugal), in particular those belonging to the Oxfordian Cabaços formation, have rich microfossil assemblages, comprising mainly ostracods and charophytes, but also benthic foraminifera, dasyclads, cyanobacteria, *Incertae-sedis* and palynomorphs.

The micropalaeontological record of such successions was either briefly or locally reported in previous studies, focused either on other main subjects, on specific areas of the basin or on systematic and palaeocological aspects of any particular group (RUGET-PERROT, 1961; RAMALHO, 1970, 1971a, b, 1981; HELMDACH, 1971, 1972; LEINFELDER, 1983; GRAMBAST-FESSARD & RAMALHO, 1985; CABRAL *et al.,* 1998, 1999, 2001; CARAPITO, 1998; PEREIRA *et al.,* 1998, 1999, in press; BARRÓN *et al.,* 1999; AZERÊDO *et al.,* 2000; COLIN *et al.,* 2000; MARTINS *et al.,* 2001; CABRAL & COLIN, 2002; PEREIRA, 2002; BARRÓN & AZERÊDO, in press).

In this paper, a first overview of the most significant Oxfordian micropalaeontological signatures at a wider,

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basinal scale is presented, coupled with more localized references to Middle Jurassic assemblages in order to complete the stratigraphical setting. This reappraisal is based on recent detailed studies referring to many localities in the basin (Fig. 1), undertaken within the scope of the research project PRAXIS XXI/PCNA/C/6/96 *"Passagem Jurássico Médio-Jurássico Superior na Bacia Lusitânica: caracterização paleoclimática, sedimentar e estratigráfica"* (AZERÊDO *et al.*, 2000). These studies focused both on micropalaeontology and on facies and palaeodepositional settings; a detailed description and interpretation of these, as well as a model for the events associated with the Middle-Upper Jurassic boundary in the Lusitanian Basin, within the scope of the Atlantic margin basins, is presented elsewhere (AZERÊDO *et al.*, in press). The micropalaeontological study did not cover loose specimens from Cabo Mondego, though field and petrographical data from this section was also considered in the broader work. Some foraminiferal and ostracod assemblages from the Callovian-Oxfordian of Cabo Mondego were mentioned by CARAPITO (1998).

The palynomorphs will not be addressed here, because the significant data basically refer to a single locality (Pedrógão) and a specific work on this palynological content is in publication (BARRÓN & AZERÊDO, in press).
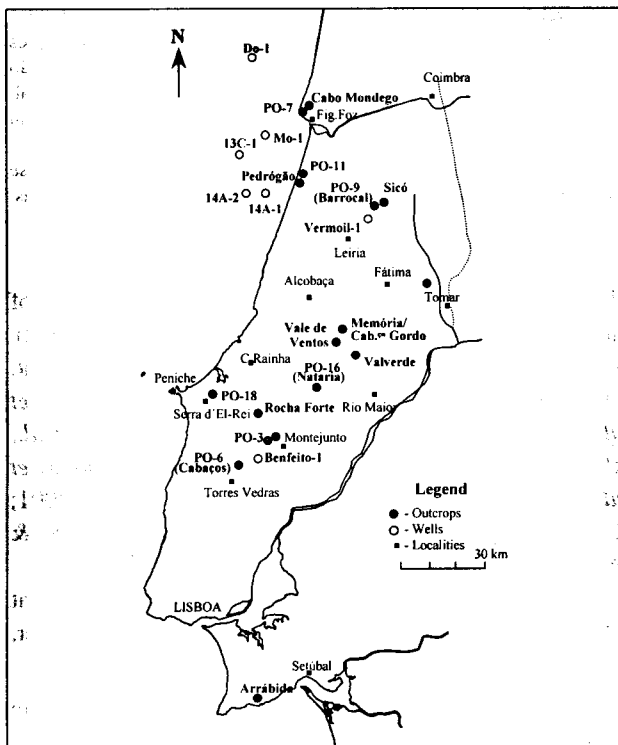

Fig. 1 – Location map, including the studied field sections and oil exploitation wells (Lusitanian Basin, W-Central Portugal).

STRATIGRAPHICAL SETTING

It is well known that, in the Lusitanian Basin, the Middle Jurassic is separated from the Upper Jurassic by a disconformable basinwide hiatus which, according to ammonite biostratigraphy (RUGET-PERROT, 1961; MOUTERDE *et al.*, 1979; ROCHA *et al.*, 1996), spans at least from the uppermost Callovian (Lamberti Zone is not recognized) to the end of the Lower Oxfordian (Mariae and Cordatum zones are not recognized). It is not possible to rule out the possibility that some of the undated deposits, which are not prone to have ammonites, may be of latest Callovian-Early Oxfordian age, though the same stratigraphical hiatus is recorded in many other Atlantic-margin basins (AZERÊDO *et al.*, 1998, 2000, and references therein). In places (namely at Serra dos Candeeiros) the disconformity is developed on Upper Bathonian limestones - dated by the foraminifera species *Meyendorffina bathonica* AUROUZE & BIZON, 1958 (AZERÊDO, 1993) – and may be associated with an angular unconformity. In the west and south of the basin (namely, at Cabo Mondego, Pedrógão, Serra d'El-Rei and Serra de Montejunto), the deposits immediately below the disconformity are dated as Upper Callovian, reaching the Athleta Zone only at Pedrógão (RUGET-PERROT, 1961; MOUTERDE *et al.*, 1979; ALMÉRAS *et al.*, 1991; ROCHA *et al.*, 1996).

The Middle Jurassic carbonate deposits immediately below the disconformity correspond either to shallow-marine facies (mostly to the east of the basin) or to open-marine facies (mostly to the west). The former represent what has been often informally named "Candeeiros formation", and the latter what has been informally named "Brenha formation"; however, these broad designations actually correspond to several lithostratigraphical units (see, for instance, the 1: 500 000 Carta Geológica de Portugal, SGP, 1992), but this issue will not be discussed here. The Upper Jurassic deposits above the discontinuity correspond to continental, transitional and restricted-marine facies and belong to the Cabaços formation (though often quoted as a Formation, it is not formally described), which basically corresponds to the originally named Cabaços Beds (*sensu* CHOFFAT, 1893a, b, followed by RUGET-PERROT 1961; RAMALHO, 1971a, b), sometimes also mentioned as Cabaços Limestones (MOUTERDE *et al.*, 1979). The Cabaços formation lacks good biostratigraphical markers but, over the whole of the basin, the lower to intermediate part of the successions are typified by the presence of the dasycladacean alga *Heteroporella lusitanica* (RAMALHO, 1970), which is attributed to the Middle Oxfordian in Portugal, because this species was also found in the Torres Vedras region (Cabaços), in levels

apparently equivalent to, or just below, those where a few ammonite findings (not precisely located) attributed to the Transversarium Zone had been recorded by P. Choffat (*vide* RUGET-PERROT, 1961; RAMALHO, 1970, 1971a, b). In other places, Middle Oxfordian, Plicatilis Zone (Serra de Montejunto - RUGET-PERROT, 1961; MOUTERDE *et al.,* 1979; ROCHA *et al.,* 1996) or Upper Oxfordian (RUGET-PERROT, 1961; FERREIRA, 1962) ammonites are documented from levels high above those containing *H. lusitanica,* which reinforces the validity of the age assigned to this species.

It is also worth mentioning that, over the whole of the basin, the lituolid foraminifera *Alveosepta jaccardi* (SCHRODT, 1894) and/or *Pseudocyclammina parvula* HOTTINGER, 1967 always appear in the more marine influenced facies which gradually succeed, or laterally replace, the restricted lagoonal facies with *H. lusitanica. A. jaccardi* has been placed in the Middle Oxfordian-Kimmeridgian, and *P. parvula* in the Upper Oxfordian-Tithonian (HOTTINGER, 1967; RAMALHO, 1971a, 1981, 1985; LEINFELDER, 1983; LEINFELDER *et al.,* 1988). However, according to our recent data (see below), *P. parvula* may also be locally found in the Middle Oxfordian.

The Middle-Upper Jurassic disconformity is coincident with the tectonic record of compressional movements in the Portuguese Mesozoic Basins (TERRINHA, 1998) and with eustatic short regressive events, according to most published global sea-level curves for the Jurassic, which indicate a late or latest Callovian to early Oxfordian slightly decreased sea-level rise (HAQ *et al.,* 1987, 1988; HARDENBOL *et al.,* 1998), prominent (HALLAM, 1988), or incipient (NORRIS & HALLAM, 1995) sea-level fall, followed by a rapid sea-level rise. The discussion of the possible role of global and regional processes related to this major discontinuity is beyond the scope of this paper, but the reader may refer to AZERÊDO *et al.* (in press) and references therein.

MAIN FACIES TYPES AND TYPICAL SUCCESSIONS

FACIES TYPES

Most of the data dealt with in this paper refer to deposits attributed to the Oxfordian Cabaços formation, as the Middle Jurassic formations were not the main subject of the research project. On the other hand, an updated facies analysis approach is made elsewhere (AZERÊDO *et al.,* in press), thus only a brief report of the main facies types recognized in the studied formations is made here. The study was mainly based on original field sections coupled with formerly existing material from C. P. P. sections, and also used a few borehole material (Petrogal and Shell wells) - Fig. 1. The preexisting material is deposited at the IGM (Lisbon). The key to symbols used in the lithostratigraphical columns is presented in Fig. 2.
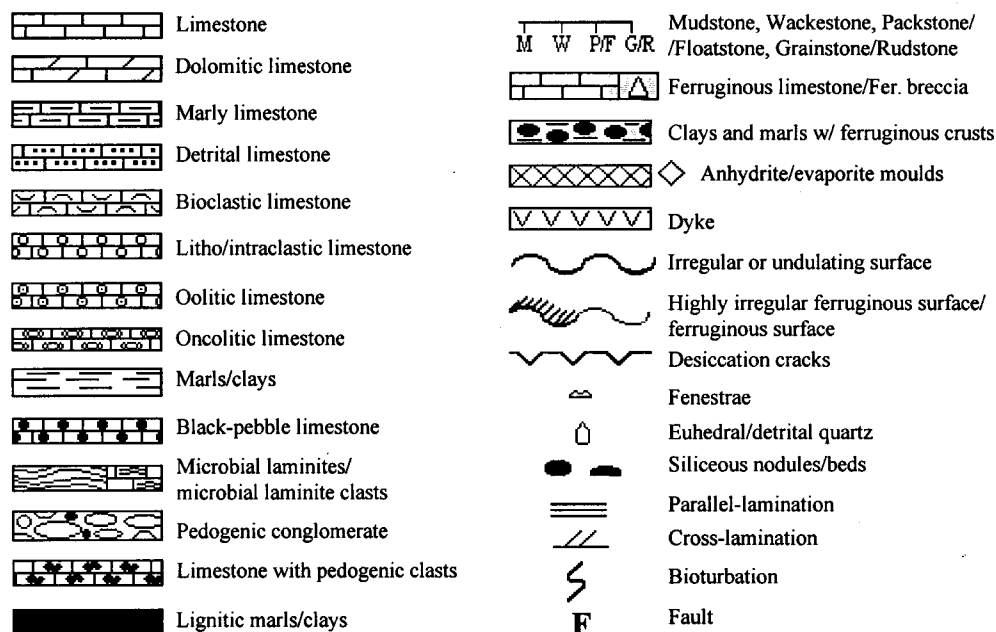
	Limestone
	Dolomitic limestone
	Marly limestone
	Detrital limestone
	Bioclastic limestone
	Litho/intraclastic limestone
	Oolitic limestone
	Oncolitic limestone
	Marls/clays
	Black-pebble limestone
	Microbial laminites/ microbial laminite clasts
	Pedogenic conglomerate
	Limestone with pedogenic clasts
	Lignitic marls/clays

M W P/F G/R	Mudstone, Wackestone, Packstone/ /Floatstone, Grainstone/Rudstone
	Ferruginous limestone/Fer. breccia
	Clays and marls w/ ferruginous crusts
◇	Anhydrite/evaporite moulds
V V V V V	Dyke
	Irregular or undulating surface
	Highly irregular ferruginous surface/ ferruginous surface
	Desiccation cracks
	Fenestrae
	Euhedral/detrital quartz
	Siliceous nodules/beds
	Parallel-lamination
	Cross-lamination
	Bioturbation
F	Fault

Fig. 2 – Symbols used in the lithostratigraphical columns throughout the paper.

The "Brenha-type" successions are composed of often bioturbated, fossiliferous marls and limestones, with normal-marine fauna (ammonites, brachiopods, corals, bivalves, echinoderms, hyaline-walled foraminifera, ostracods, palynomorphs). In the studied successions, it is present immediately below the discontinuity at Pedrógão (Fig. 3), Serra de Montejunto and Benfeito-1 well (Fig. 4); and below the "Candeeiros-type" sandbody, which is then capped by the discontinuity, at Cabo Mondego (WRIGHT, 1985; AZERÊDO et al., in press). These topmost "Brenha-facies" sediments are of Late Callovian age (cf. RUGET-PERROT, 1961; MOUTERDE et al., 1979; ALMÉRAS et al., 1991).

With regards to the studied sections/boreholes, the "Candeeiros-type" successions immediately below the discontinuity (Figs. 4 and 5) are represented by skeletal, oolitic and intraclastic grainstones and packstones (Arrábida, Rocha-Forte, PO-18/Serra d'El-Rei, Vermoil-1, PO-9/Barrocal/Pombal, Cabo Mondego) and by oncolitic, peloidal and fenestral mudstones to wacke-packstones (PO-6/Cabaços, Rocha-Forte, PO-16/Nataria, Valverde, Vale de Ventos, Memória/Cabeço Gordo, PO-9/Barrocal/Pombal). These facies types may be intercalated with each other, range in age from Bathonian to Callovian and show rich assemblages of large, imperforate-walled benthic foraminifera, calcareous algae, porostromates and other shallow-marine benthos (AZERÊDO, 1993, 1999; AZERÊDO et al., 2000).

The Cabaços formation, whose typical thickness ranges from 40-50 m to 100-150 m (locally 200 m?), is composed of pedogenic limestones, ferruginous or lignitic marls/clays, lacustrine, restricted lagoonal and marginal-marine to shallow-marine marls and limestones, and, locally, oyster-coral rich mudstones and deltaic sandstones (see also RAMALHO, 1971a; WILSON, 1979; WRIGHT, 1985; WRIGHT & WILSON, 1987; AZERÊDO et al., 1998, in press). Recently, AZERÊDO et al. (in press) defined six facies associations within the Cabaços formation and documented their basinal distribution, as follows (see also Figs. 3 to 5):

- Erosional palaeosurfaces and ferruginous deposits facies association (Arrábida, Montejunto, Serra dos Candeeiros, Pedrógão, Cabo Mondego).

- Pedogenic and black-pebble limestone-conglomerate facies association (Arrábida, Serra d'El-Rei, Rocha--Forte/Montejunto, Cabaços, Serra dos Candeeiros, Pedrógão).

- Heterolithic oyster-coral sandstone-limestone facies association (Cabo Mondego).

- Sandstone-lignite facies association (Cabo Mondego).

- Medium/thick-bedded non-marine limestone-marl-lignite facies association (at all the localities studied, with a minor expression in the Montejunto/Rocha-Forte region).

- Thin-bedded fossiliferous marly limestone-microbial laminite-evaporite facies association (at all the localities studied). In particular, this facies association includes marginal marine deposits, the restricted lagoonal Heteroporella lusitanica beds and more marine-influenced intercalations, as echinoid/brachiopod-bearing limestones (for instance at Pedrógão) and, probably, the ammonite levels at Torres Vedras.

TYPICAL SUCCESSIONS

A synthetic mention to the typical vertical arrangement of the main facies types recognized in the studied successions is made below, with simplified logs of the field sections most relevant to this paper.

In the west of the basin, the sediments just below the disconformity usually correspond to the open-marine "Brenha facies", except for Cabo Mondego as mentioned (see WRIGHT, 1985; AZERÊDO et al., in press). At Pedrógão (Fig. 3), the topmost levels of that formation are lignitic marls and limestones containing both marine and a few reworked, non-marine microfossils. The presumed stratigraphical boundary between the Callovian and the Oxfordian may correspond, according to AZERÊDO et al. (in press), to a 0.5 m thick couplet of two reddish ferruginous and charophytic limestone beds (Pl. I/1), separated by a highly irregular ferruginized surface.

Above the discontinuity surface, the successions are typically composed of non-marine limestones, marls and lignites, with desiccation cracks, ferruginous surfaces capping some beds, some detrital or authigenic quartz, abundant ostracods and charophytes, gastropods, bivalves, plant remains (including diverse palynomorphs) and rarer reptile teeth. Locally (Cabo Mondego), oyster-coral sandstones and sandy limestones are found above the disconformity. Further upwards, the non-marine units (locally pedogenic) are interbedded with restricted-marine fossiliferous (ostracods, charophytes, gastropods, bivalves, serpulids, dasyclads, agglutinate-walled foraminifera, including lituolids, low-diversity spore assemblage, including planktonic protozoans) and bioturbated marly limestones and limestones (including the *H. lusitanica* beds); microbial laminites, evaporites, pedogenic conglomerates and minor bioclastic or oolitic-intraclastic pack-
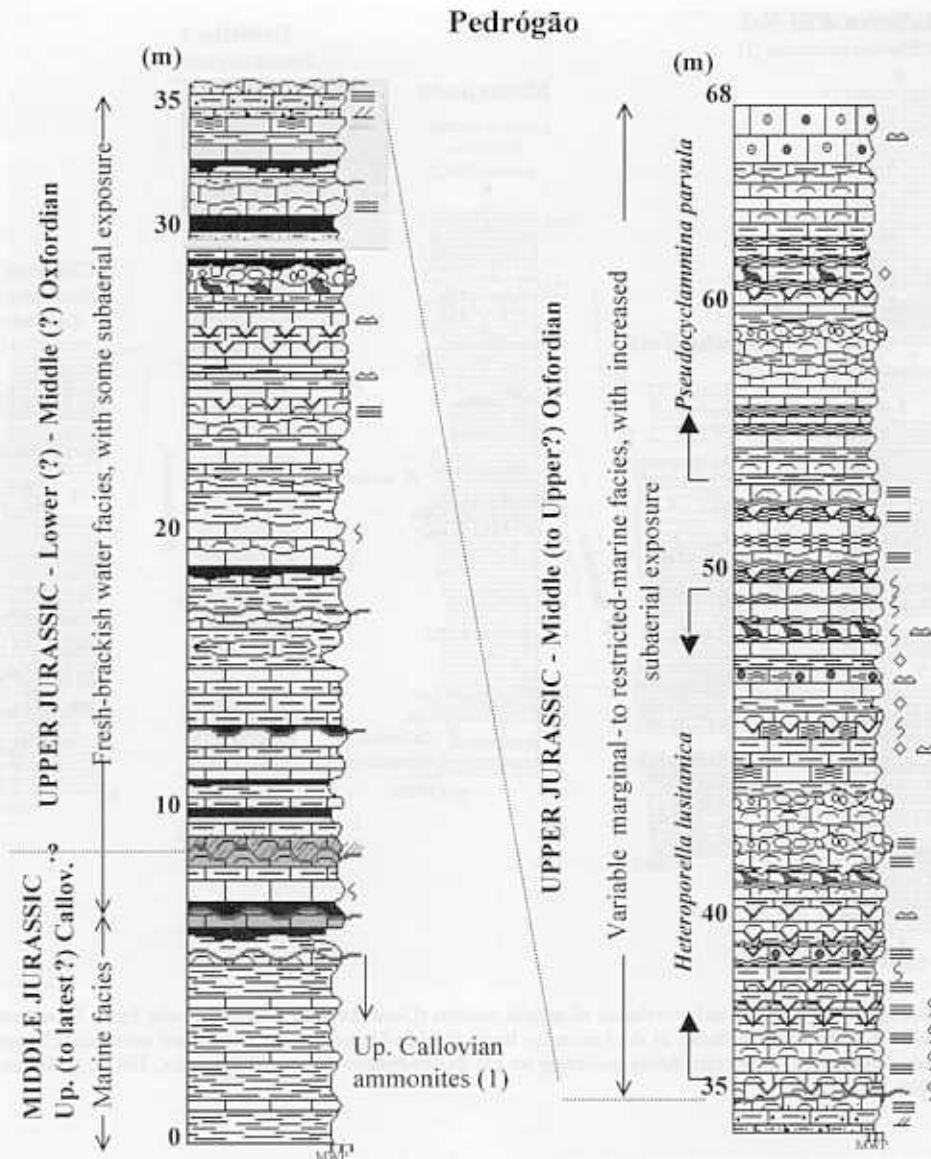
Pedrógão

Fig. 3 – Synthetic lithostratigraphical column for the Middle-Upper Jurassic transitional succession at Pedrógão (W-Lusitanian Basin, Portugal), mainly focusing on the Oxfordian Cabaços formation. 1) Ammonite dating according to RUGET-PERROT (1961).

grainstones (event deposits) occur also. Towards the top, microbial laminites and evaporites are more common, often associated with ostracod coquinas (see below; Pl. I/2).

Most of the lithofacies composing the western successions are recognized offshore as well, namely in the wells 13C-1, 14A-1, 14A-2, MO-1 and DO-1 (offshore between Cabo Mondego and Pedrógão, approximately – Fig. 1).

In the east and to the south of the basin (Figs. 4 and 5), the "Candeeiros facies" shallow-water limestones or, locally, more distal "Brenha facies" (as at Montejunto), are truncated by the disconformity. The erosional palaeo-surfaces and associated ferruginous marls/clays with iron

crusts are overlain by pedogenic limestones/conglomerates, lignites, marls, black-pebble/oncoidal and ferruginous limestones, locally dolomitized or with detrital quartz. These deposits are rich in ostracods and charophytes, less abundant but common porostromates (locally forming centimetric "tufts" and cyanoids – MARTINS *et al.*, 2001), including *Girvanella* sp., abundant gastropods and bivalves, and lack marine organisms. This succession passes gradually upwards into bioclastic/fossiliferous and locally bioturbated marly limestones and limestones (including the *H. lusitanica* beds), in places fenestral and intercalated with microbial laminites.
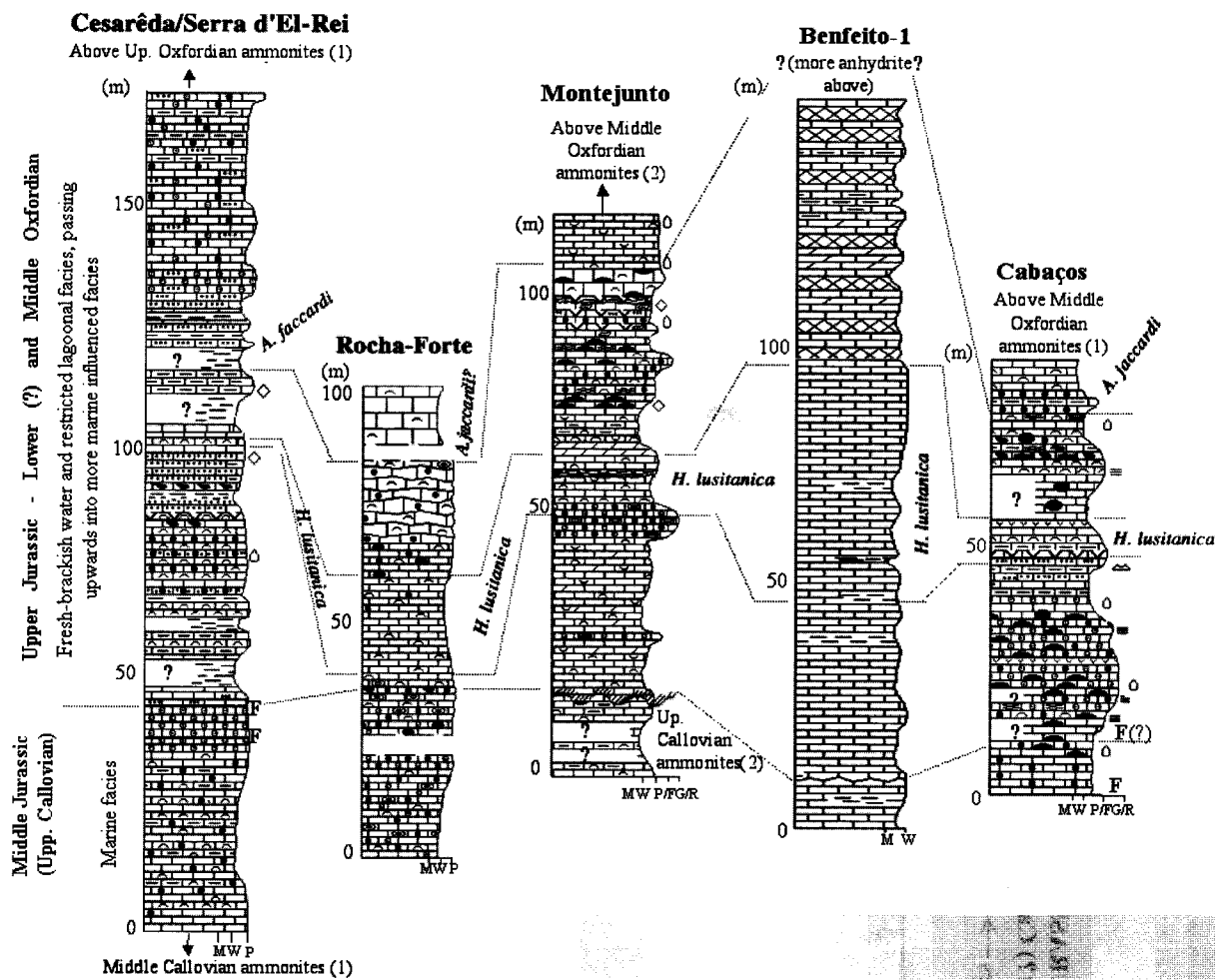
Fig. 4 – Synthetic lithostratigraphical columns and correlation of several sections (Cesarêda/Serra d'El-Rei, Rocha-Forte, Montejunto, Cabaços) and a borehole (Benfeito-1) in the south/southeast of the Lusitanian Basin (Middle-Upper Jurassic transitional successions, mainly focusing on the Oxfordian Cabaços formation). Ammonite dating according to: (1) RUGET-PERROT, 1961 and FERREIRA, 1962; (2) RUGET-PERROT, 1961 and ROCHA *et al.*, 1996.

MICROPALAEONTOLOGICAL SIGNATURES AT A BASINAL-SCALE

This section presents the broad, basinwide, palaeoecological trends recognized in the identified microfossil assemblages, particularly from the Cabaços formation (though a brief mention to the assemblages of the immediately underlying deposits is made). At the same time, the occurrence of the most important species is highlighted, within a palaeobiogeographical framework.

OSTRACODS

This is the most abundant microfossil group in the studied formations, being represented by a high number of indivi-

duals in most facies types (Pl. II/1-14 and Pl. III/1-8). The identified faunas show different diversity ranges, which seem primarily related to salinity variations (see below). Several associations with palaeoecological significance have been recognized in different sections of the basin (CABRAL *et al.*, 1998, 1999, 2001). Subsequent matching of those assemblages showed them to distinguish two basic trends across the basin, one typical of the western successions and the other typical of the eastern successions, though intermediate situations occur. Systematical study is only possible on loose specimens, therefore it covers those sections/boreholes from which loose sediment samples could be obtained (except for Cabo Mondego): Pedrógão, Vermoil-1, Vale de Ventos, Valverde and Memória/Cabeço Gordo (from the latter, only rare identifiable loose specimens were obtained).

Callovian

The ostracod faunas are completely different from those of the Oxfordian, as could be expected, since the former are mostly normal-marine faunas and the latter are dominated by non-marine ostracods. The Callovian marine faunas were identified in fossiliferous marls from the lowermost part of the Pedrógão section (Fig. 3); rarer and poorly preserved specimens were also found in residues from Vermoil-1. This fauna mainly comprises: *Cytherella* cf. *fullonica* JONES & SHERBORN, 1888, *sensu* METTE, 1995; *Cytherella* cf. *index* OERTLI, 1959, *sensu* METTE, 1995; *Cytherelloidea* cf. *C.* aff. *jugosa* (JONES, 1884) in METTE, 1995; *Patellacythere* n. sp. 1, *Bythoceratina (Praebythoceratina)* n. sp. 1, *Procytheridea* cf. *gublerae* BIZON, 1958, *Polycope* n. sp. 1, *Neurocythere (Neurocythere)* cf. *composita* (WIENHOLZ, 1967), *Praeschuleridea* aff. *subtrigona magna* BATE, 1964, *Virgulacytheridea* aff. *sherifensis* OERTLI & DÉPÊCHE, 1987 and *Rutlandella* n. sp. 1. At Pedrógão, this marine assemblage was referred to in the association-1 of CABRAL *et al.* (1998).

Towards the top of the Callovian deposits, a few non-marine species also occur, as *Theriosynoecum fluxans spiculata* (HELMDACH, 1972), *T. levis* (HELMDACH, 1972) and *Darwinula* n. sp. 2.

Oxfordian

The study of material from different sections over the basin has allowed the identification of twelve genera and twenty-two species, including at least 2 new genera (described in COLIN *et al.,* 2000 and CABRAL & COLIN, 2002), and 16 new species (of which, 6 were already described - COLIN *et al.,* 2000 and CABRAL & COLIN, 2002). Several ostracod associations may be distinguished, coupled with other palaeontological and sedimentological data, either from the base upwards the successions or between the western (typically Pedrógão) and the eastern (typically Vale de Ventos) successions AZERÊDO & CABRAL, in press. Most of this Oxfordian fauna is limnic (*sensu* CARBONEL *et al.,* 1988).

In the west of the basin (Pedrógão, Fig. 3; and Vermoil-1), most of the levels attributed to the Oxfordian Cabaços formation display abundant ostracod assemblages, in which diversity and dominant components are clearly different and compare well with other micropalaeontological and sedimentary features (CABRAL *et al.,* 1998; BARRÓN *et al.,* 1999; AZERÊDO *et al.,* 2000). The lowermost Oxfordian deposits contain very abundant fresh-brackish water ostracods, but the diversity is lower than in the Callovian marine assemblages: *Theriosynoecum* gr. *wyomingense* (BRANSON, 1935), *T. fluxans fluxans* (HELMDACH, 1972), *T. fluxans spiculata* (HELMDACH,

1972), *T. levis* (HELMDACH, 1972), *Darwinula* n. sp. 1 and *D.* n. sp. 2, *Sinuocythere pedrogaensis* CABRAL & COLIN, 2000, Ind. Gen. n. sp. O-16, Ind. Gen. n. sp. 1 and *Klieana* n. sp. 1. Towards the middle part of the successions (Fig. 3), characterized by intercalations of the previous lithologies with the lagoonal deposits with *Heteroporella* and a few foraminifera, the euryhaline *S. pedrogaensis* becomes dominant relative to the other species. This group of species defined the associations 2 of the Pedrógão section in CABRAL *et al.* (1998) and 2 and 3 of the same section in BARRÓN *et al.* (1999), interpreted as having developed from a fresh-brackish water setting into a variable, hyposaline to hypersaline environment.

Further upwards, the increasing presence of desiccation surfaces, evaporites, pedogenic conglomerates and microbial laminites and the foraminifera genera *Pseudocyclammina/Alveosepta* (see below) is accompanied by a marked change in the ostracod population: it shows the highest number of individuals, diversity decreases, *Theriosynoecum* disappears, *S. pedrogaensis* dominates and is associated with *Galliaecytheridea* n. sp. 1 (marine species, only found in the west of the basin), *Schuleridea* sp. (only at Vermoil-1), *Klieana* n. sp. 2 and *Darwinula* n. spp.. Towards the top, almost exclusively *S. pedrogaensis* occurs, commonly in monospecific coquinas (ostracodites), usually within microbial laminites. These two types of assemblage cover the associations 3 and 4 in CABRAL *et al.* (1998) and 4 and 5 in BARRÓN *et al.* (1999), corresponding to a marginal-marine, frequently subaerially exposed setting.

In the east of the basin (Vale de Ventos, Valverde and Memória/Cabeço Gordo, Serra dos Candeeiros; Fig. 5) the clearly continental deposits in the lower part of the Upper Jurassic successions display limnic ostracod populations of variable abundance and diversity. In the deposits immediately above the disconformity, with marked subaerial exposure, the mainly freshwater family Candonidae may be the dominant ostracod fauna (at Vale de Ventos), namely *Septacandona ramalhoi* CABRAL & COLIN, 2002, *S. azeredae* CABRAL & COLIN, 2002, *S. multicostulata* CABRAL & COLIN, 2002 and *Candona ? parvissima* CABRAL & COLIN, 2002. Other species present are *Sinuocythere candeeirosensis* CABRAL & COLIN, 2000, *Klieana* n. sp. 1, *Darwinula* n. sp. 3, *D.* n. sp. 1 and *D.* n. sp. 2 (both rare and only at Vale de Ventos) and rare *Theriosynoecum* spp. This assemblage corresponds to the associations-1 of Vale de Ventos and Valverde in CABRAL *et al.* (1999, 2001), interpreted as representing a very shallow, freshwater (?) setting. At Memória/Cabeço Gordo section, the identifiable individuals are rare, but Candonidae *(S. ramalhoi, S. azeredae, C.? parvissima), Darwinula* n. sp. 3, *S. candeeirosensis, Theriosynoecum*
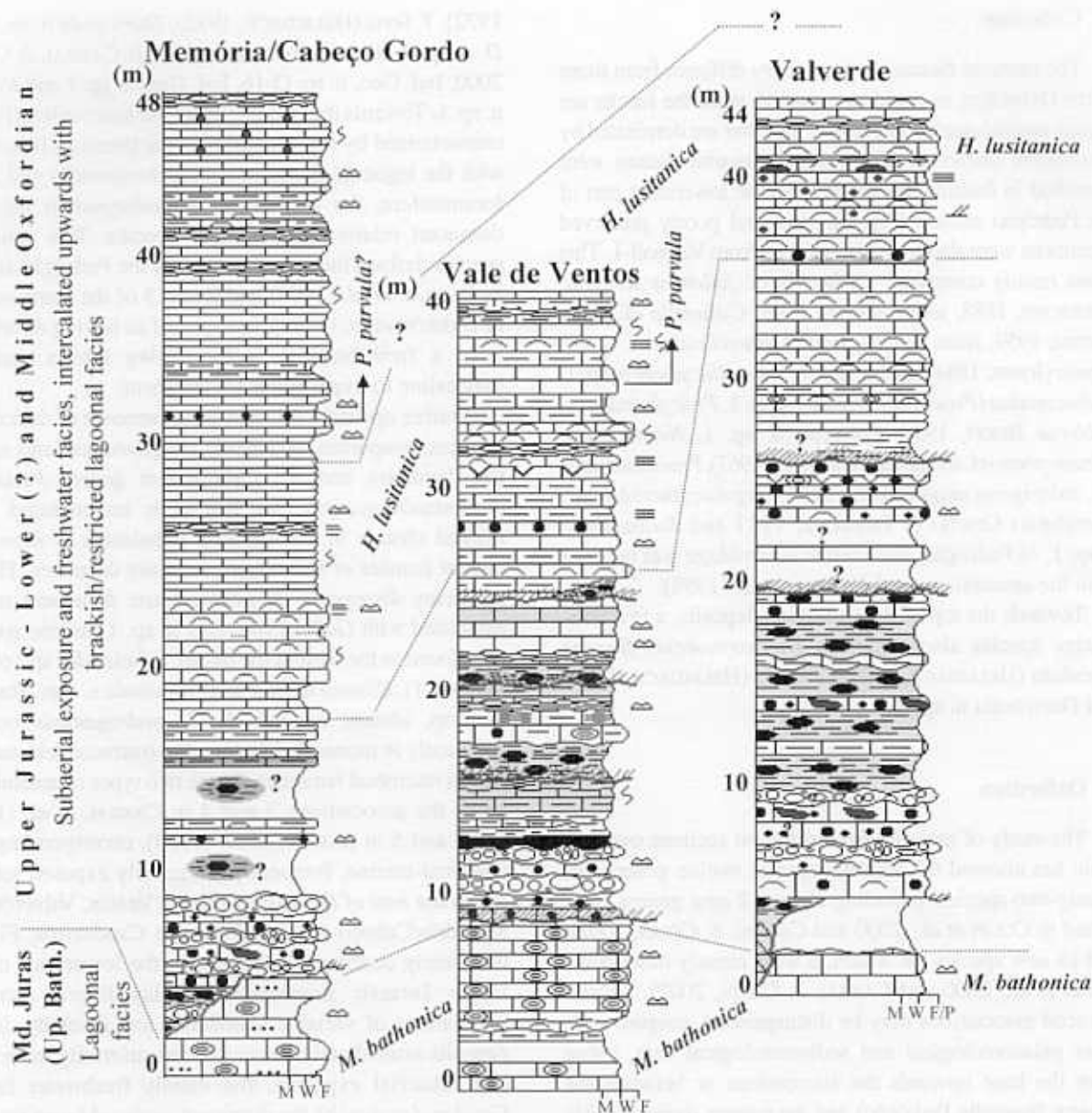
Fig. 5 – Synthetic lithostratigraphical columns and correlation of Memória/Cabeço Gordo, Vale de Ventos and Valverde sections (Serra dos Candeeiros, E-Portugal); Middle-Upper Jurassic transitional successions, mainly focusing on the Oxfordian Cabaços formation.

fluxans spiculata, Ind. Gen. n. sp. O-16, *Timiriasevia* sp. and Ind. Gen. n. sp. M-1 have been recognized in pedogenic levels above the disconformity, equivalent to the basal ones of Vale de Ventos and Valverde sections.

Passing upwards in the eastern series, the ostracod fauna is increasingly abundant and diversified. The "more-freshwater" ostracods (*Candonidae* and *Darwinula*) are drastically reduced (the *Candonidae* are even absent at Vale de Ventos). On the other hand, the genus *Theriosynoecum*, with different species, becomes abundant (e. g. *T. fluxans spiculata, T.* gr. *wyomingense* and *T.*

levis), in association with *S. candeeirosensis* and, at Valverde, *Klieana* n. sp. 2 and *K.* n. sp. 4. This assemblage corresponds to the associations-2 of Vale de Ventos and Valverde in CABRAL *et al.* (1999, 2001), interpreted as representing a very shallow, freshwater-oligohaline, lacustrine-palustrine (?) setting.

A third type of assemblage is also recognized at Vale de Ventos, towards the upper part of the succession, marked by the gradual transition from the lacustrine facies into the slightly more-marine influenced facies (locally fenestral and intercalated with microbial laminites), with

dasyclads and agglutinated foraminifera (see below), typical of restricted lagoonal settings. This assemblage is very rich in *S. candeeirosensis* and in *Klieana* n. sp. 3, increasingly abundant towards the top, with rarer occurrences of the genera *Darwinula* and *Theriosynoecum*.

Palaeobiogeographical and palaeoecological remarks

Both the Callovian marine and the Oxfordian limnic ostracod faunas recognized in the Lusitanian Basin are, at the generic level, broadly similar to the faunas described from deposits of equivalent or close age, in the Atlantic and Tethyan marginal basins (BODERGAT, 1997; COLIN, 1997). Also worth mentioning concerning both palaeoecology and palaeobiogeography, is the good representation of the *Candonidae*, namely a new genus with three new species. This is interesting because there are very few data on the *Cypridacea* (superfamily that includes the *Candonidae*) during the Oxfordian and even during all the Jurassic (see COLIN, 1997; CABRAL & COLIN, 2002). During this period, the assemblages of limnic ostracods were clearly dominated by genera from other superfamilies, namely *Cytheracea (Theriosynoecum, Timiriasevia)* and *Darwinulacea (Darwinula)*. This fact is also recorded in Portugal, particularly in the western part of the Lusitanian Basin (HELMDACH, 1971, 1972; CABRAL *et al.*, 1998; SCHUDACK, 2000).

FORAMINIFERA

This group is much less common in the Cabaços formation than the ostracods and charophytes, though locally relatively abundant populations may be found. However, the occurrence of some species have a regional significance, concerning palaeoecological and biostratigraphical aspects. A brief reference to the typical foraminiferal population of the Middle Jurassic deposits just below the disconformity is also made.

Upper Bathonian-Callovian

As stated, the topmost Middle Jurassic below the disconformity is mostly of shallow-marine (inner-mid ramp) facies to the east, and of open-marine (outer ramp) facies to the west of the basin, though in places (particularly to the south of the basin; Fig. 4) intermediate situations occur or both types of facies interfinger with each other.

The shallow-marine limestones deposits ("Candeeiros-facies") bear rich assemblages of complex, large benthic foraminifera, associated with calcareous algae, porostromates and other organisms (see AZERÊDO, 1993, 1999; MARTINS *et al.*, 2001). At Nataria, Memória/Cabeço Gordo, Vale de Ventos and Valverde sections (Fig. 5), the presence of *Meyendorffina bathonica* AUROUZE & BIZON, 1958, indicates a late Bathonian age for the last Middle Jurassic preserved deposits, while at most other locations a Callovian age is usually admitted for these limestones. Other common species in the uppermost Middle Jurassic of the studied sections are *Chablaisia chablaisensis* (SEPTFONTAINE, 1977), *Pseudocyclammina maynci* HOTTINGER, 1967, *Praekurnubia crusei* REDMOND, 1964, *Mesoendothyra croatica* GUSIC, 1969, *Nautiloculina oolithica* MOHLER, 1938, *Trocholina* spp. and *Valvulina lugeoni* SEPTFONTAINE, 1977.

The open, normal-marine sediments ("Brenha-facies") comprise mostly the hyaline-walled *Nodosariidae*, as could be expected, but other small benthic foraminifera occur *(Epistominidae, Textulariidae, Milioliidae)*. This assemblage is associated with marine ostracods, marine-influenced palynofacies and normal-marine macrofauna. Identifiable loose specimens were obtained only from Pedrógão, and their study is not yet completed. However, preliminary results show that the populations are clearly dominated by *Lenticulina* spp. (several morphogenera, *sensu* RUGET, 1985), as documented for the European Jurassic in general (e. g. RUGET & NICOLLIN, 1997): *Lenticulina* sp. mg. *tricarinella* (REUSS, 1863), *L.* gr. *polonica, Lenticulina* sp., *Citharina* sp., *Spirillina* sp., *Frondicularia* sp. and *Vaginulina* sp. were identified. At Pedrógão (Fig. 3), the topmost marine Callovian beds comprise corals, oysters, brachiopod clusters and ferruginous surfaces, overlain by levels bearing mixed marine and non-marine, probably reworked, ostracods and charophytes, plant remains and detrital quartz (AZERÊDO *et al.*, in press). Thus, it clearly reflects a rapid shallowing, interpreted as related to a forced regression, for which evidence from other locations in the basin also exists (AZERÊDO *et al.*, in press). Within those levels, the presence of simple agglutinated foraminifera and *Milioliidae* is more common, though never abundant. *Ammobaculites* sp., *Reophax* sp., small *Textulariidae* and *Verneuilinidae* are present.

Oxfordian

In this case, the foraminifera are always studied in limestone thin-sections, so it covers material from all of the field sections and boreholes. The most significant

foraminifera species within the Cabaços formation belong to the *Lituolidae*, and have been well documented in previous works (RAMALHO, 1971a, b, 1981; LEINFELDER, 1983; AZERÊDO *et al.*, 1998, 2000).

In the more continentally influenced facies, rich in charophytes and fresh-brackish water ostracods, there are no foraminifera. These begin to appear further upwards in the successions, in the transitional deposits corresponding to brackish/restricted lagoonal settings, always with abundant ostracods and charophytes but also with *Heteroporella lusitanica* (Pl. IV/1). However, these first assemblages are not rich, neither in number of individuals neither as regards to diversity: *Pseudocyclammina* sp., *Kurnubia palastiniensis* HENSON, 1948, *Verneuilinidae*, small *Textulariidae*.

Towards the top of the successions, as said, less restricted, more marine influenced facies interfingers with, and gradually overlies, the lagoonal/marginal-marine facies all over the basin. In these deposits, in which *Heteroporella* only occurs very rarely in the lowermost levels, the foraminifera are more common, even locally abundant (though the populations are never as numerous as compared to the other microfossil groups referred to here), and their diversity increases. This assemblage comprises (Pl. IV/2-4): common *Verneuilinidae*, locally abundant *Alveosepta jaccardi* (SCHRODT, 1894), *Pseudocyclammina parvula* HOTTINGER, 1967 and *P. maynci* HOTTINGER, 1967, rarer *P.* sp., *Ammobaculites* sp., *Reophax* sp., *Kurnubia palastiniensis*, *Valvulina* sp., *Nautiloculina oolithica* MOHLER, 1948, *N.* sp., *Placopsilina* sp., *Conicospirillina basiliensis* MOHLER, 1938, *Glomospira* sp., small *Textulariidae* and very rare *Milioliidae*. These deposits also contain ostracods, *Lenticulina* sp. and other hyaline-walled foraminifera, frequent bivalves, gastropods and echinoids, rarer crinoids, corals and brachiopods, porostromates, *Aeolissacus* sp., *Koskinobullina socialis* CHERCHI & SCHROEDER, 1979, etc.

The higher abundance of individuals of the genera *Pseudocyclammina* and/or *Alveosepta* in some levels is locally associated with a predominant orientation of the tests, which may indicate that these tests were transported by a sporadic current and suddenly redeposited altogether (event deposits). The preferred orientation could have also resulted from lateral advection of constant currents, though in this case more frequent effects of such process should be expected. The fact that the same deposits exhibit fenestral structures and bridge-like cements indicates a partially subaerial exposed original sediment; these levels are recorded, for instance, at PO-9/Barrocal (Pl. IV/4) and Memória/Cabeço Gordo.

The most significant species are *Alveosepta jaccardi* (Pl. IV/2) and *Pseudocyclammina parvula* (Pl. IV/3); see

below. These lituolids were also identified in material from the offshore wells 13C-1, 14A-2 (Pedrógão/Vieira de Leiria) and MO-1 (Cabo Mondego/Figueira da Foz).

Palaeobiogeographical and biostratigraphical remarks

The Jurassic assemblages dominated by simple agglutinated forms like *Ammobaculites* spp., small textularids and verneuilinids, have been usually assigned to restricted-marine facies, to shallow brackish settings or to marginal-marine and pro-deltaic settings, with direct terrigenous influence (NAGY & JOHANSEN, 1991). Genera like *Reophax/Subreophax* and *Ammobaculites*, observed in the Recent and in the Ancient, are considered endobenthic organisms typical of moderate water depth, showing non-calcareous, simple tests and whose elongated morphotypes are prone to rapidly colonize the substrate under oligotrophic conditions (KUHNT & KAMINSKI, 1993). Thus, the occurrence of these type of assemblage in the topmost Callovian from Pedrógão is in accordance with evidence mentioned above for shallowing and influx of nearby coastal sediment (oysters, reworked non-marine ostracods and charophytes, plant remains, detrital quartz), later followed by the onsetting of a paralic depositional setting in the early Oxfordian.

The lituolids, which are large benthic foraminifera with imperforate walls and usually complex inner structures, are common in the Jurassic shallow-marine, mainly carbonate-platform environments of the peri-Atlantic and peri-Tethyan realms, being increasingly abundant and diversified from the Lower into the Middle and Upper Jurassic (HOTTINGER, 1967; RAMALHO, 1971a, 1981, 1985; SEPTFONTAINE, 1981; PÉLISSIÉ *et al.*, 1984; BASSOULLET *et al.*, 1985; SEPTFONTAINE *et al.*, 1991; BASSOULLET, 1997). The lineage *Pseudocyclammina/Alveosepta* has also adapted well to shallow marine settings with terrigenous influx (e. g. BASSOULLET *et al.*, 1985; BASSOULLET, 1997).

As regards to the two most significant species in the Cabaços formation, *Alveosepta jaccardi* has been widely reported in the Tethyan domain, namely from: Portugal, both in the Lusitanian and Algarve basins (RAMALHO, 1971a, b, 1981, 1985; LEINFELDER, 1983; LEINFELDER *et al.*, 1988), Spain (BASSOULLET *et al.*, 1985), France (PÉLISSIÉ *et al.*, 1984; BASSOULLET *et al.*, 1985; BASSOULLET, 1997), Morocco (HOTTINGER, 1967; SEPTFONTAINE, 1981; BASSOULLET *et al.*, 1985; PEYBERNÈS *et al.*, 1987), the Italian-Dinaride region (BASSOULLET *et al.*, 1985), Israel (DERIN & REISS, 1966) and Turkey (TASLI, 1993); by Late Jurassic it also reached the American margins (BASSOULLET *et al.*, 1985; BASSOULLET, 1997). *Pseudocyclammina*

parvula is basically known from Portugal and Morocco (HOTTINGER, 1967; RAMALHO, 1971a, 1985), but was also cited in Turkey (TASLI, 1993). *A. jaccardi* is known from the Middle Oxfordian to the Upper Kimmeridgian; *P. parvula* or gr. *parvula* is generally reported from the Upper Oxfordian to the Kimmeridgian, but we have locally found it (Vale de Ventos; Fig. 5) in levels still attributable to the Middle Oxfordian on the basis of *H. lusitanica,* and in Algarve it reaches the Tithonian (RAMALHO, 1985).

Kurnubia palastiniensis ranges in age from the Oxfordian to the Tithonian (RAMALHO, 1971a; SEPTFONTAINE, 1988) and the other identified species have wider stratigraphical ranges.

DASYCLADACEANS

Apart from a few occurrences of *Salpingoporella* sp. and unidentified dasyclad fragments in the Upper Bathonian lagoonal limestones just below the disconformity at Serra dos Candeeiros (AZERÊDO, 1993), this group of algae is solely represented by one species, *Heteroporella lusitanica* (Pl. IV/1), in the successions here concerned with. However, as previously mentioned, this alga has a major importance as regards to the Cabaços formation, as it represents the best biostratigraphical constraint for this unit, as shown in the logs of Figs. 3-5. *H. lusitanica* was recognized in all of the studied localities, except in Barrocal/Pombal (PO-9) and in Vermoil-1 well. In the offshore wells, it was found in 14A-2 (Pedrógão/Vieira de Leiria).

The fact that *H. lusitanica* occurs in very restricted, locally brackish lagoonal sediments, implies that this species has an higher level of tolerance for salinity variations than usually accepted for dasyclads. However, it must be noted that in those sediments it is rarely abundant, whereas in the deposits from less restricted (though always very shallow) settings, with more frequent marine incursions, it is much more abundant, even forming coquinas as at Pedrógão (AZERÊDO *et al.,* 1998, 2000). These coquinas are associated with concentrations of thick-shelled bivalves and with serpulid bioherms on bedding surfaces; whether these represent condensation or simply accumulation horizons is still an open question. A concentration of *Heteroporella* stems in thin-section had also been previously recognized by M. Ramalho, in samples from a small limestone outcrop in Ota region mentioned by LEINFELDER *et al.* (1988), but not directly studied by us.

Heteroporella lusitanica was never found in the Algarve Basin (RAMALHO, 1985).

CHAROPHYTES

As mentioned, the charophyte algae are, next to ostracods, the most typical fossil group in the Cabaços formation, being represented by several species, abundant number of gyrogonites and less abundant stems, over the whole of the basin (Pl. I/1, 2; Pl. III/9-17).

Though present either in marls or limestones, in similarity to ostracods the systematic identification of charophytes demands loose specimens of gyrogonites. Therefore, the taxonomic study covered the same four field sections from which marly beds could be sampled (Pedrógão, Vale de Ventos, Memória and Valverde). The specimens in residues from Vermoil-1 borehole are still under study, but current data point out to assemblages similar to those from Pedrógão and Memória/Cabeço Gordo sections. The main results of the detailed systematic study are the subject of a Master's thesis, recently presented (PEREIRA, 2002) and of a thematic paper (PEREIRA *et al.,* in press). Preliminary data had been presented in PEREIRA *et al.* (1998, 1999).

The abundance of charophyte specimens in the sampled sediment and the well-known high intraspecific diversity of the gyrogonites led us to try a twofold approach, integrating both morphological analysis and comparative populational analysis. These studies revealed the presence of several *Porocharaceae* species, some previously recognized in Portugal, as *Porochara raskyae* (MÄDLER) SHAIKIN, 1976, *P. minima* (MÄDLER) SHAIKIN, 1976, *P. fusca* MÄDLER, 1955, *P. sulcata* GRAMBAST-FESSARD, 1985 and *P. kimmeridgensis* MÄDLER, 1955, but others unknown, as *Auerbachichara* cf. *saidakovskyi* KISELEVSKY & SAIDAKOVSKY, 1967, and a new species (*Porochara* n. sp. 1). In addition, some specimens were left in open nomenclature (*Porochara* sp. and an Ind. Gen.) and one species of *Characeae* was also identified (*Aclistochara longiformis* WANG & YANG, 1983).

In the typically freshwater facies, the charophyte assemblages are richer, both in abundance and diversity, with gyrogonites and stems occurring together. The main species are *Porochara raskyae, P. minima, P. sulcata, P.* n. sp. 1, *P. fusca, Auerbachichara saidakovskyi, Aclistochara longiformis* and Ind. Gen.. However, the brackish lagoonal and marginal-marine facies also bear significant assemblages of these algae, showing lower diversity and higher number of gyrogonites relative to stem remains. These assemblages are dominated by *Porochara kimmeridgensis,* locally associated with *P. fusca.*

Two particular features recognized in the studied successions are worth mentioning: one is the fact that the charophyte remains often form coquinas, either on bed

tops or as stratified laminae within microbial laminites, very much in common with the ostracodites, including (at Pedrógão) in layers intercalated with evaporite-bearing limestones. This recalls the examples of co-occurrence of charophytes and evaporites in modern deposits from coastal saline lakes of Australia (BURNE *et al.*, 1980). Another interesting fact is the already mentioned charophytic ferruginous limestone truncated by a discontinuous palaeosurface draped by charophyte stems (mostly) and gyrogonites (Fig. 3; Pl. I/1), assigned to the Middle-Upper Jurassic boundary at Pedrógão (AZERÊDO *et al.*, 2000, in press). Other examples of particularly high numbers of stem remains were observed in thin-sections, namely from Pedrógão, Cabo Mondego, Valverde, Vale de Ventos, Memória/Cabeço Gordo and Montejunto limestones.

CONCLUSIONS

The successions across the Middle-Upper Jurassic disconformity in the Lusitanian Basin, in particular those belonging to the Oxfordian Cabaços formation, have rich microfossil assemblages, comprising mainly ostracods and charophytes, but also benthic foraminifera, dasyclads, cyanobacteria, *Incertae-sedis* and palynomorphs.

Recent detailed studies referring to many localities in the basin allowed a significant improvement of the systematic knowledge of different groups, in particular of the ostracods and charophytes: within the former, 12 genera (including at least 2 new) and 22 species (16 new) were identified; within the latter, 9 species (including a new one) and 4 genera were recognized.

The identified microfossil assemblages show variations in diversity and in abundance ranges which seem to primarily relate to salinity ranges and changing frequency, and to degree of subaerial exposure, defining associations with palaeoecological significance from the base upwards the successions. The combined interpretation of micropaleontological and sedimentary data allows the regional palaeoecological signatures to be clearly linked to palaeodepositional settings. Matching of the results at a basinal scale showed two basic trends across the basin, one typical of the eastern successions and the other typical of the western successions:

– In the west of the basin, open-marine deposits and fossil assemblages of the Callovian beneath the disconformity are succeeded by Oxfordian sediments and assemblages sucessively defining a fresh-brackish water setting, a highly variable, hyposaline to hypersaline setting, including restricted-marine incursions, and marginal-marine, frequently exposed settings.

– In the east of the basin, inner-marine deposits and assemblages of late Bathonian-Callovian age below the disconformity are succeeded by Oxfordian deposits and assemblages sucessively suggesting erosion, very shallow, dominant freshwater conditions with marked subaerial exposure, freshwater-oligohaline lacustrine setting gradually interfingered with, and overlain by, restricted lagoonal, more marine influenced environment.

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PLATES

PLATE I

Fig. 1 – Photomicrograph of the ferruginous charophytic limestone (charophyte stem coquina) featuring the presumed Middle-Upper Jurassic boundary at Pedrógão; Lower (?) Oxfordian. X36.

Fig. 2 – Photomicrograph of an ostracodite, also showing a charophyte gyrogonite (top-centre of the picture) and textularid foraminifera (one clearly visible towards the right). Middle Oxfordian, Pedrógão section. X49.
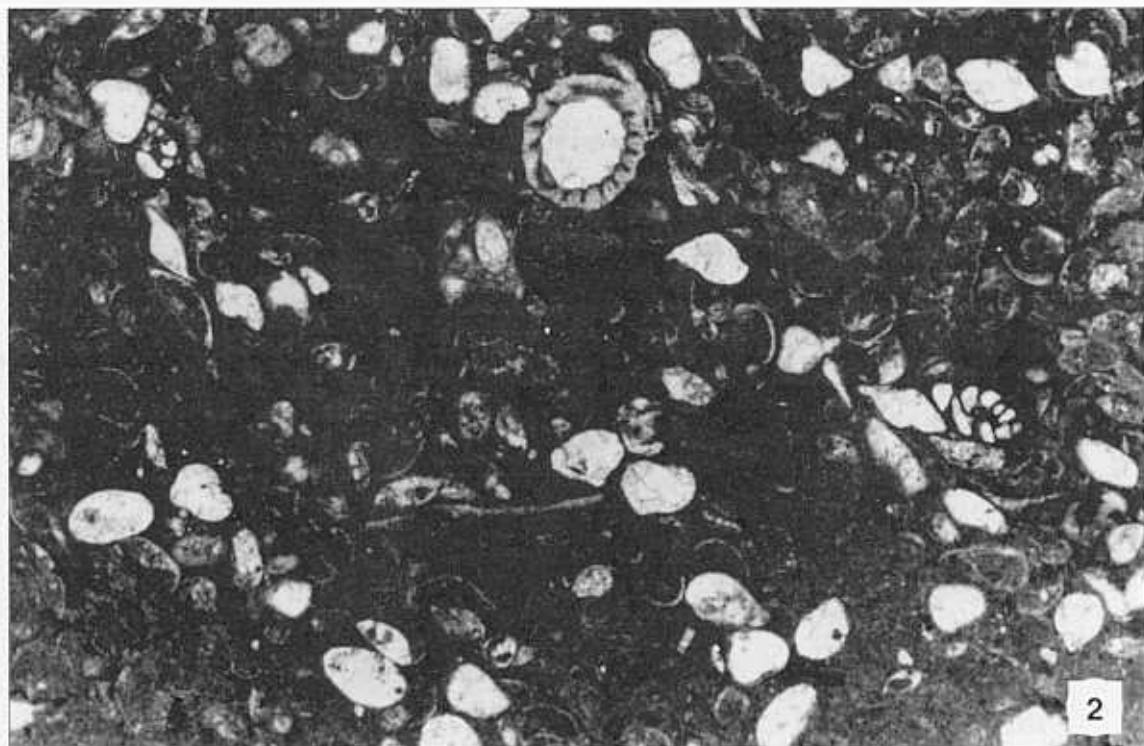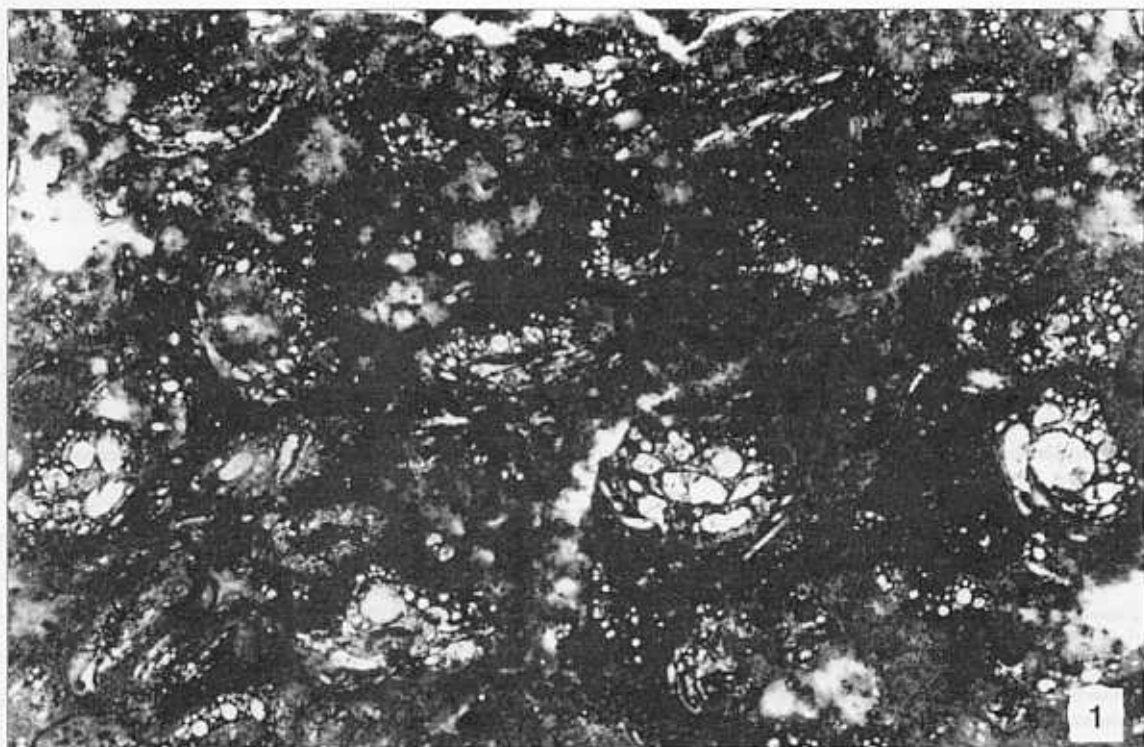
Pl. I

PLATE II

Fig. 1 – *Theriosynoecum* gr. *wyomingense* (BRANSON, 1935): example from the Lower (?) to Middle Oxfordian of Valverde section, female left valve, lateral view, X50.

Fig. 2 – *Theriosynoecum fluxans spiculata* (HELMDACH, 1972): example from the Lower (?) to Middle Oxfordian of Pedrógão section; female left valve, lateral view, X50.

Fig. 3 – *Theriosynoecum fluxans fluxans* (HELMDACH, 1972): example from the Lower (?) to Middle Oxfordian of Pedrógão section; male carapace, right view, X50.

Fig. 4 – *Theriosynoecum levis* (HELMDACH, 1972): example from the Lower (?) to Middle Oxfordian of Pedrógão section; right valve, lateral view, X50.

Fig. 5 – *Sinuocythere pedrogaensis* CABRAL & COLIN, 2000: example from the Middle to Upper (?) Oxfordian of Pedrógão section; female carapace, right view, X75.

Fig. 6 – *Sinuocythere candeeirosensis* CABRAL & COLIN, 2000: example from the Lower (?) to Middle Oxfordian of Vale de Ventos section; female carapace, right view, X75.

Fig. 7 – *Timiriasevia* sp.: example from the Lower (?) to Middle Oxfordian of Memória section; carapace, left view, X75.

Fig. 8 – *Klieana* n. sp. 1: example from the Lower (?) to Middle Oxfordian of Vale de Ventos section; female left valve, lateral view, X75.

Fig. 9 – *Klieana* n. sp. 2: example from the Lower (?) to Middle Oxfordian of Valverde section; female left valve, lateral view, X75.

Fig. 10 – *Klieana* n. sp. 3: example from the Middle Oxfordian of Vale de Ventos section; male? carapace, left view, X75.

Fig. 11 – *Klieana* n. sp. 4: example from the Lower (?) to Middle Oxfordian of Valverde section; male? carapace, left view, X75.

Fig. 12 – Ind. Gen. n. sp. O-16: example from the Lower (?) to Middle Oxfordian of Pedrógão section; female? left valve, lateral view, X75.

Fig. 13 – *Galliaecytheridea* n. sp. 1: example from the Middle Oxfordian of Pedrógão section; male? carapace, left view, X75.

Fig. 14 – Ind. Gen. n. sp. 1: example from the Lower (?) to Middle Oxfordian of Pedrógão section; carapace, left view, X50.

The Scanning Electron Microscope photographs were taken in the Centro de Biologia Ambiental (Faculdade de Ciências da Universidade de Lisboa) by Drs. Mónica Martins and Telmo Nunes.
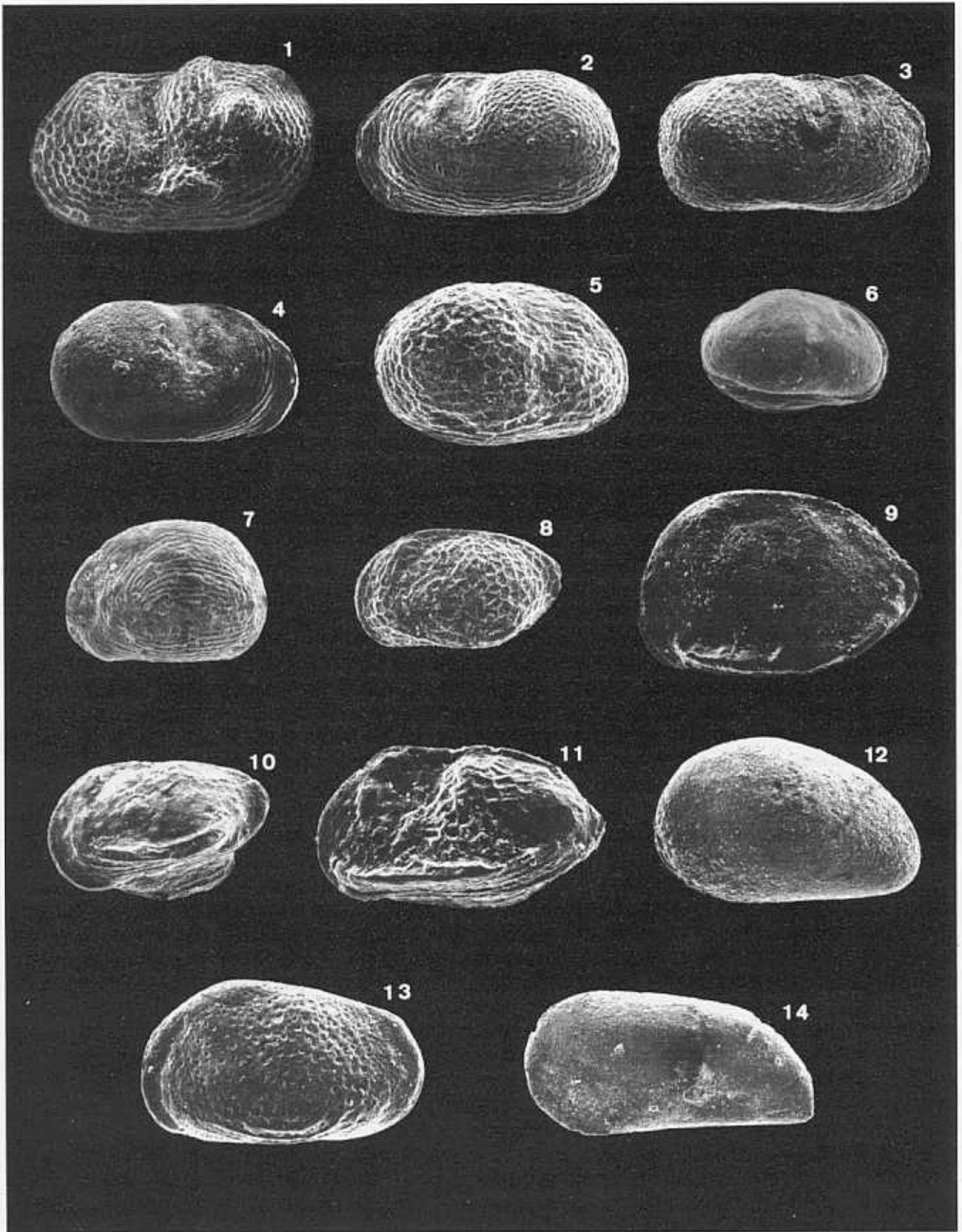
Pl. II

PLATE III

Fig. 1 – *Darwinula* n. sp. 1: example from the Lower (?) to Middle Oxfordian of Pedrógão section; carapace, right view, X50.

Fig. 2 – *Darwinula* n. sp. 2: example from the Lower (?) to Middle Oxfordian of Pedrógão section; carapace, right view, X50.

Fig. 3 – *Darwinula* n. sp. 3: example from the Lower (?) to Middle Oxfordian of Valverde section; carapace, right view, X75.

Fig. 4 – *Candona ? parvissima* CABRAL & COLIN, 2002: example from the Lower (?) to Middle Oxfordian of Valverde section; male carapace, right view, X100.

Fig. 5 – *Septacandona multicostulata* CABRAL & COLIN, 2002: example from the Lower (?) to Middle Oxfordian of Vale de Ventos section, carapace, left view, X100.

Fig. 6 – *Septacandona ramalhoi* CABRAL & COLIN, 2002: example from the Lower (?) to Middle Oxfordian of Vale de Ventos section; carapace, right view, X75.

Fig. 7 – *Septacandona azeredae* CABRAL & COLIN, 2002: example from the Lower (?) to Middle Oxfordian of Vale de Ventos section; carapace, right view, X75.

Fig. 8 – Ind. Gen. n. sp. M-1: example from the Lower (?) to Middle Oxfordian of Memória section; carapace, right view, X50.

Fig. 9 – *Porochara* n. sp. 1: example from the Lower (?) to Middle Oxfordian of Pedrógão section; gyrogonite lateral view, X50.

Fig. 10 – *Porochara kimmeridgensis* MÄDLER, 1955: example from the Middle Oxfordian of Pedrógão section; gyrogonite lateral view, X50.

Fig. 11 – *Porochara raskyae* (MÄDLER) SHAIKIN, 1976: example from the Lower (?) to Middle Oxfordian of Vale de Ventos section; gyrogonite lateral view, X50.

Fig. 12 – *Porochara minima* (MÄDLER) SHAIKIN, 1976: example from the Lower (?) to Middle Oxfordian of Vale de Ventos section; gyrogonite lateral view, X50.

Fig. 13 – *Porochara sulcata* GRAMBAST-FESSARD, 1985: example from the Lower (?) to Middle Oxfordian of Pedrógão section; gyrogonite lateral view, X40.

Fig. 14 – *Porochara* n. sp. 1: example from the Lower (?) to Middle Oxfordian of Pedrógão section; gyrogonite lateral view, X50.

Fig. 15 – *Auerbachichara* cf. *saidakovskyi* KISELEVSKY & SAIDAKOVSKY, 1967: example from the Middle Oxfordian of Vale de Ventos section; gyrogonite lateral view, X50.

Fig. 16 – *Aclistochara longiformis* WANG & YANG, 1983: example from the Lower (?) to Middle Oxfordian of Pedrógão section; gyrogonite lateral view, X50.

Fig. 17 – *Porochara fusca* MÄDLER, 1955: example from the Middle Oxfordian of Pedrógão section; gyrogonite lateral view, X50.

The Scanning Electron Microscope photographs were taken in the Centro de Biologia Ambiental (Faculdade de Ciências da Universidade de Lisboa) by Drs. Mónica Martins and Telmo Nunes.
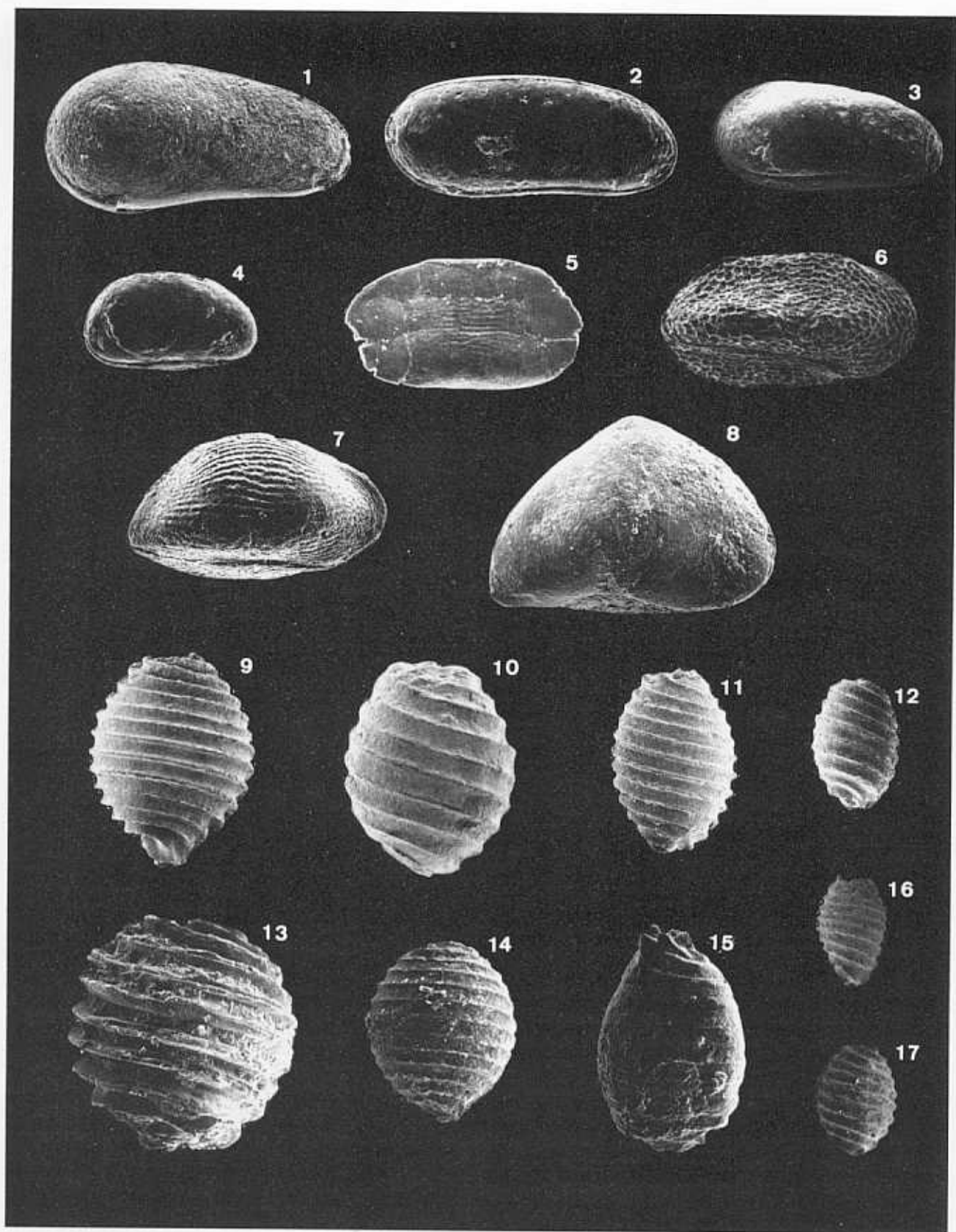
Pl. III

PLATE IV

Fig. 1 – *Heteroporella lusitanica* (RAMALHO, 1970): example from the Middle Oxfordian of Pedrógão section (wackestone, with ostracods); axial to tangential, oblique and transversal sections are seen; note the clave-shaped branches (arrow), X47.

Fig. 2 – *Alveosepta jaccardi* (SCHRODT, 1894): example from the Middle Oxfordian of Vale de Ventos section (fenestral wackestone); axial section, X42.

Fig. 3 – *Pseudocyclammina parvula* HOTTINGER, 1967: example from the Middle to Upper (?) Oxfordian of PO-9/Barrocal/Pombal (packstone-grainstone with pyrite); equatorial section, X42.

Fig. 4 – General thin-section view of a *Pseudocyclammina* spp.-rich, bio-intraclastic packstone with fenestral structures and vadose cements (arrows at examples), interpreted as an event (probably storm) deposit (note predominant orientation of foraminiferal tests). Middle to Upper (?) Oxfordian, PO-9/Barrocal/Pombal section, X16.

Pl. IV