

CALCAREOUS NANNOFOSSILS AND PALYNOMORPHS FROM PLIENSBACHIAN-TOARCIAN BOUNDARY IN LUSITANIAN BASIN, PORTUGAL

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ABSTRACT – The Pliensbachian/Toarcian boundary (Lower Jurassic) is well represented in the Lusitanian Basin (Portugal), mainly in Peniche area, where more than 450 m of marls and limestones are exposed. These deposits were chosen as a candidate for the Toarcian Global Stratotype Section and Point (GSSP). Calcareous nannofossil and palynomorph assemblages are described herein, with the aim to contribute to the GSSP definition. Marly samples were collected 3 m below and 15 m above this boundary and analyzed for calcareous nannofossils and palynomorphs. The main nannofossils observed were: *Biscutum finchii*, *B. grande*, *Calcivascularis jansae*, *Crepidolithus crassus*, *C. granulatus*, *C. impontus*, *Lotharingius hauffii*, *L. sigillatus*, *L. velatus*, *Schizosphaerella* spp. and *Tubirhabdus patulus*. This assemblage indicates that the Pliensbachian/Toarcian boundary in Peniche lies in the upper part of the NJ5b Subzone. *Schizosphaerella* and *Lotharingius* dominate the assemblage. The abundant occurrence of *C. jansae* and the common occurrence of *B. grande* indicate a strong Tethyan influence. The palynomorphs were, in general, fairly well-preserved with low diversity and common small forms. The residue is dominated by slightly carbonized woody organic material. *Corollina* (rimulates) dominates all samples and trilete spores form a significant component of the assemblage. Dinoflagellate cysts are common in the lower part of the section sampled. The relatively high percentage of rimulates indicates a hot climate. The abundance of organic residue in woody material indicates that a strong influx of continental debris invaded the carbonate platform during the Toarcian.

Key words: calcareous nannofossils, Palynology, Pliensbachian, Toarcian, Lusitanian Basin, Portugal.

RESUMO – O limite Pliensbaquiano/Toarciano (Jurássico inferior) está bem representado na bacia Lusitânica (Portugal), principalmente em Peniche, onde afloram mais de 450 m de margas e calcários. Os depósitos de Peniche foram escolhidos como um dos candidatos ao estabelecimento do GSSP do Toarciano. Visando contribuir para essa definição, são descritas aqui as assembléias de nanofósseis e de palinomorfos ocorrentes nesses depósitos. Análises de nanofósseis e de palinologia foram realizadas em amostras de margas coletadas 3 m abaixo e 15 m acima deste limite. Os principais nanofósseis observados foram: *Biscutum finchii*, *B. grande*, *Calcivascularis jansae*, *Crepidolithus crassus*, *C. granulatus*, *C. impontus*, *Lotharingius hauffii*, *L. sigillatus*, *L. velatus*, *Schizosphaerella* spp. e *Tubirhabdus patulus*. Esta assembléia, aliada ao aparente posicionamento das amostras acima da extinção de *Crucirhabdus primulus*, indica que o limite Pliensbaquiano-Toarciano estaria localizado na parte superior da subzona NJ5b. Os gêneros *Schizosphaerella* e *Lotharingius* dominam numericamente a assembléia, também caracterizada pela ocorrência abundante de *C. jansae* e comum de *B. grande*, indicadores de forte influência de águas do Tétis. A associação palinológica recuperada se apresenta, de modo geral, com baixo grau de preservação, pouco diversificada, com formas pequenas e domínio de matéria orgânica lenhosa, algo carbonizada. Predominam as formas rimuladas do gênero *Corollina*, sendo os esporos triletes um componente importante nas associações. Os dinoflagelados são comuns na porção mais inferior da seção. O relativo alto percentual dos rimulados indica um clima quente à época de deposição. O resíduo orgânico rico em material lenhoso indica um forte influxo de material continental, detrítico, invadindo a plataforma carbonática instalada, particularmente a partir do Toarciano.

Palavras-chave: nanofósseis calcários, Palinologia, Pliensbaquiano, Toarciano, bacia Lusitânica, Portugal.

INTRODUCTION

The high biostratigraphic potential of the Lower Jurassic calcareous nannofossils is well documented in Bown (1987), Bown *et al.* (1988), Kaenel *et al.* (1996), Bown & Cooper (1998), and Mattioli & Erba (1999). Their works were based on calcareous nannofossils recovered from many sections located in northwest Europe and the Mediterranean. The biohorizon succession and the calcareous nannofossil zones and subzones proposed for northwest Europe (Hettangian to Tithonian) and Italy and south of France (Hettangian to Callovian) were discussed by Bown & Cooper (1998) and Mattioli & Erba (1999), respectively.

As a part of a multidisciplinary work, data is also available on Pliensbachian to Aalenian calcareous nannofossil assemblages recovered from different sections along the western (Lusitanian Basin) and northeastern (Basque Cantabrian area and Iberian Range) margins of the Iberian Massif. In particular, the Pliensbachian/Toarcian calcareous nannofossil data set retrieved from the Basque-Cantabrian area (Perilli, 1999, 2000; Perilli & Comas-Rengifo, 2002) was discussed by Perilli *et al.* (2004). Previously studied by Hamilton (1977, 1979), Bown (1987) and Kaenel *et al.* (1996), the Toarcian calcareous nannofossils of the Lusitanian Basin have been investigated by Perilli & Duarte (2003), Duarte *et al.* (2004a) and Perilli & Duarte (2006). These works were focused on the Sinemurian/Pliensbachian and

Aalenian calcareous nannofossils recovered from sections in the Lusitanian Basin.

In comparison, very little work on the Lower Jurassic palynology of Portugal has been made so far: (i) a first palynofloral data set based on dinoflagellate cysts and spores and pollen grains encompassing the lower Mesozoic of Portugal (Doubinger *et al.*, 1970); (ii) an integrated study encompassing Triassic to Lower Jurassic miospores from Portugal (Adloff *et al.*, 1977); and (iii) outcrop samples from Late Sinemurian to Aalenian in age studied by Davies (1985), who subdivided the succession into seven miospore zones and an equal number of dinoflagellate cyst Oppel-zones, comparing them with the eastern Canada offshore zonation established by Bujak & Williams (1977).

In this paper, palynological and calcareous nannofossil assemblages are described and correlated in an attempt to integrate micropalaeontological data for the Pliensbachian/Toarcian boundary in the Peniche area. Furthermore, the results of this study give additional data to support and document the GSSP definition at Ponta do Trovão section, Peniche.

GEOLOGICAL SETTING

The Lusitanian Basin (Figure 1) is located on the western margin of the Iberian Plate (Portugal), and is a marginal ocean basin which formed in the Triassic. Its orientation is NE-SW and it is approximately 300 km in length and 150 km wide,

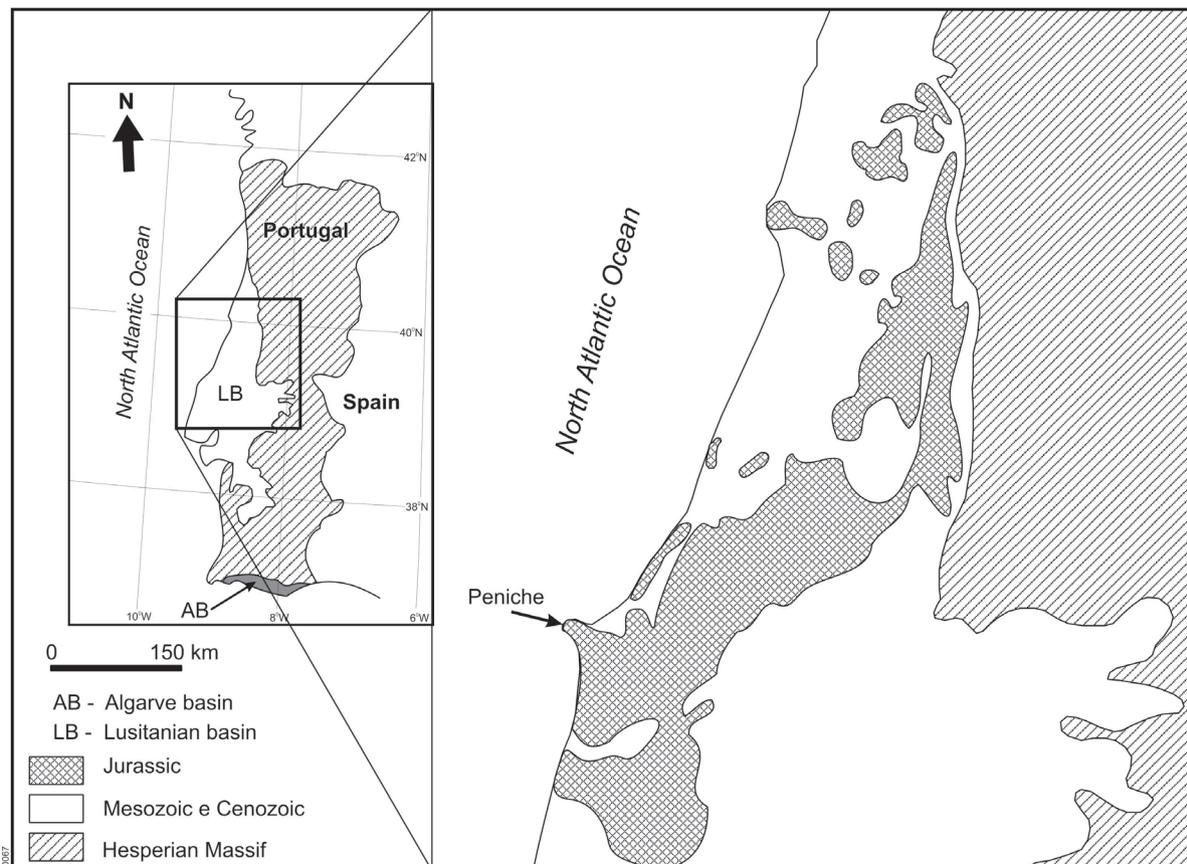
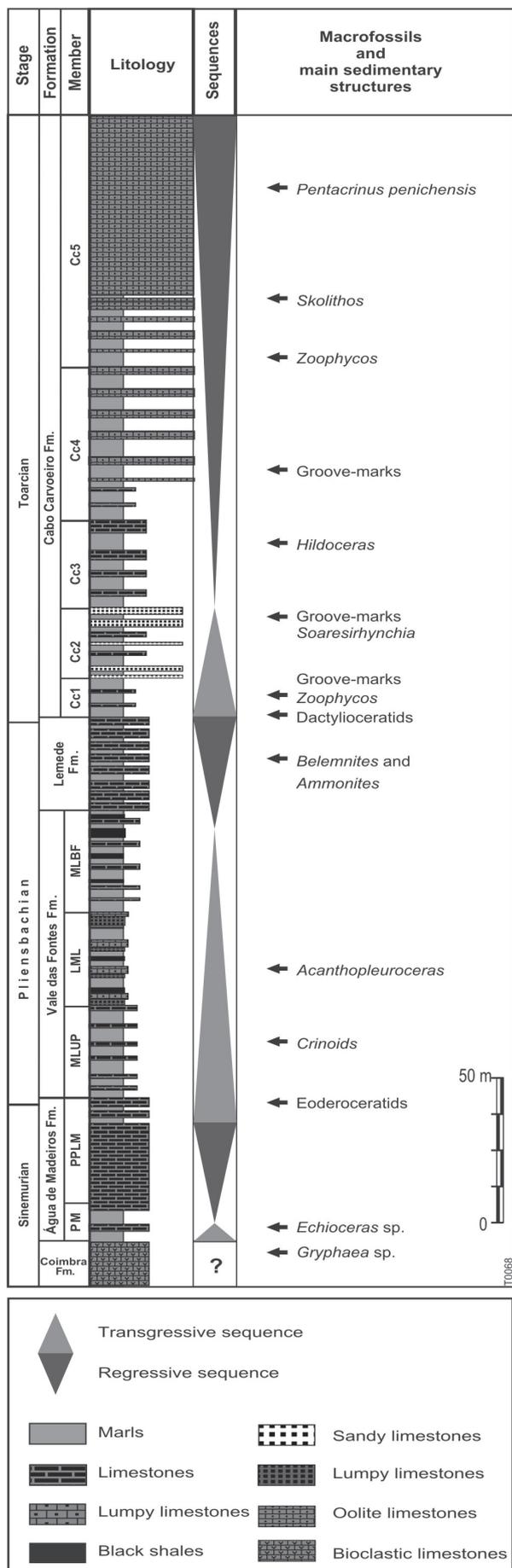


Figure 1. Location map of the study area.



including the offshore area, with a maximum thickness of 5 km. The sedimentary rocks range from Upper Triassic to Upper Cretaceous, and are mainly of Jurassic age, overlain by Tertiary. The Lower Jurassic is particularly well represented in the Lusitanian Basin, especially in the Peniche region, where outcrops of carbonate rocks more than 450 m thick are between Sinemurian and Toarcian in age (Mouterde, 1955; Wright & Wilson, 1984; Duarte, 1995, 2003, 2004; Duarte *et al.* 2004b). These carbonate rocks correspond to the Coimbra, Água de Madeiros, Vale das Fontes, Lemede and Cabo Carvoeiro formations (Duarte & Soares, 2002) (Figure 2).

During the Pliensbachian and early Toarcian, deposition in the Lusitanian Basin was controlled by homoclinal ramp dipping towards the northwest (Duarte, 1997). In Peniche area, with the exception of the Lower Sinemurian and Upper Toarcian, the whole section is well constrained by high resolution ammonite biostratigraphy. The Pliensbachian-Toarcian boundary is represented by a limestone-marl succession, consisting of the uppermost part of the Lemede Formation and the lowermost part of Cabo Carvoeiro Formation (Figure 3). The former is composed by centimetric-thick marl/decimetric-thick bioturbated limestone alternations, very rich in belemnites, ammonites, bivalves and brachiopods. The base of the Cabo Carvoeiro Formation is dominated by greyish marls and marly limestones, very rich in tiny brachiopods, belemnites, ammonites and *Zoophycos*.

The Peniche section was recently proposed as the main candidate for the Toarcian Global Stratotype Section and Point (GSSP) (Elmi *et al.*, 1996, 2005; Elmi, 2006; Duarte *et al.*, 2004b). The Pliensbachian/Toarcian boundary is defined based on ammonite biostratigraphy, coinciding with the boundary between the *Spinatum* (Upper Pliensbachian) and *Polymorphum* (Lower Toarcian; *Polymorphum* = *Tenuicostatum*; Ogg, 2004) biozones (Elmi *et al.* 1997).

SAMPLES AND METHODS

Twelve marl samples were collected for calcareous nannofossil analysis 3 m below and 7 m above the Pliensbachian/Toarcian Stage Boundary at Ponta do Trovão (Peniche). The slides were prepared in the Petrobras Research Center (CENPES/BPA) laboratories, using the Petrobras standard methodology (Antunes, 1997; Oliveira, 1997). The slides were scanned using a Zeiss Axioplan 2 imaging microscope, at 1600X magnification; 500 fields of view were examined for each slide. The relative abundance for each species and total relative abundance estimates for each sample (Figure 4) were based on the scheme presented by Concheryo & Wise Jr. (2001). Estimates of preservation were based on the classification of Roth & Thierstein (1972). The nannofossil

Figure 2. Schematic stratigraphy of the Peniche section (Duarte *et al.*, 2004b). **Abbreviations:** PM, Polvoeira Member; PPLM, Praia da Pedra Lisa Member; MLUP, Marls and Limestones with *Uptonia* and *Pentacrinus* Member; LML, Lumpy Marls and Limestones Member; MLBF, Marls and Limestones with Bituminous Shales Member; Cc, Cabo Carvoeiro Members 1 to 5.

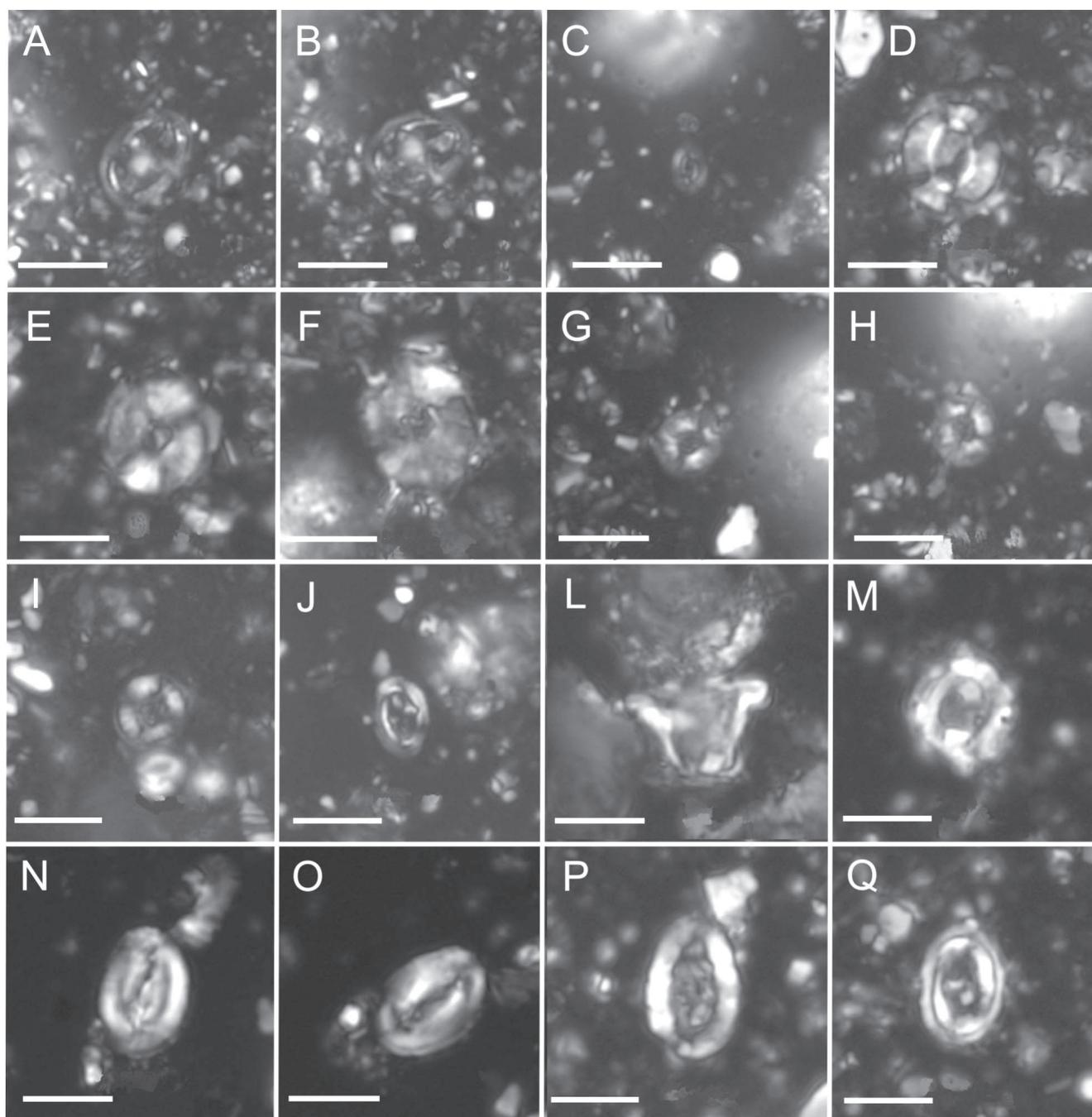


Figure 5. Calcareous nannofossil species observed in the studied interval (cross polarized light). **A-B**, *Axopodorhabdus atavus* (same specimen, **A** at 0°, **B** at 45°); **C**, *Biscutum dubium*; **D**, *Biscutum grande*; **E-F**, *Biscutum finchii* (different specimens); **G-I**, *Biscutum novum* (**G-H**, same specimen, **G** at 0°, **H** at 45°; **I**, different specimen); **J**, *Bussonius prinsii*; **L-M**, *Calyculus* sp. (different specimens, **L**, side view; **M**, top view); **N-O**, *Crepidolithus crassus* (same specimen, **N** at 0°, **O** at 45°); **P**, *Crepidolithus granulatus*; **Q**, *Crepidolithus impontus*. Scale bar = 5 μ m.

photos were obtained with a Zeiss AxioCam MRc digital camera using the Axionvision 4 software.

Thirteen samples were examined for palynological content. The samples were processed using conventional techniques (e.g. Phipps & Playford, 1984; Wood *et al.*, 1996) for the retrieval and concentration of palynomorphs. Roughly 30–40 g of sample were broken into pea-sized fragments, which were immersed for ca. 2 hours in hydrochloric acid (32%), and then in hydrofluoric acid (ca. 40%) for 22 hours for the dissolution of

carbonates and silicates respectively. The resultant residue was then oxidized for 10 minutes with concentrated nitric acid. Any remaining mineral matter was removed by means of heavy-liquid separation (zinc chloride, S.G. 1.95–2.00), and a few drops of the definitive residue were mounted on glass slides as permanent strew mounts in a polyester resin (“Entellan”). Optical microscopy was performed using Nikon and Zeiss Axioplan microscopes; the latter was utilized for photomicrography (with Kodak T-Max 100 35-mm film).

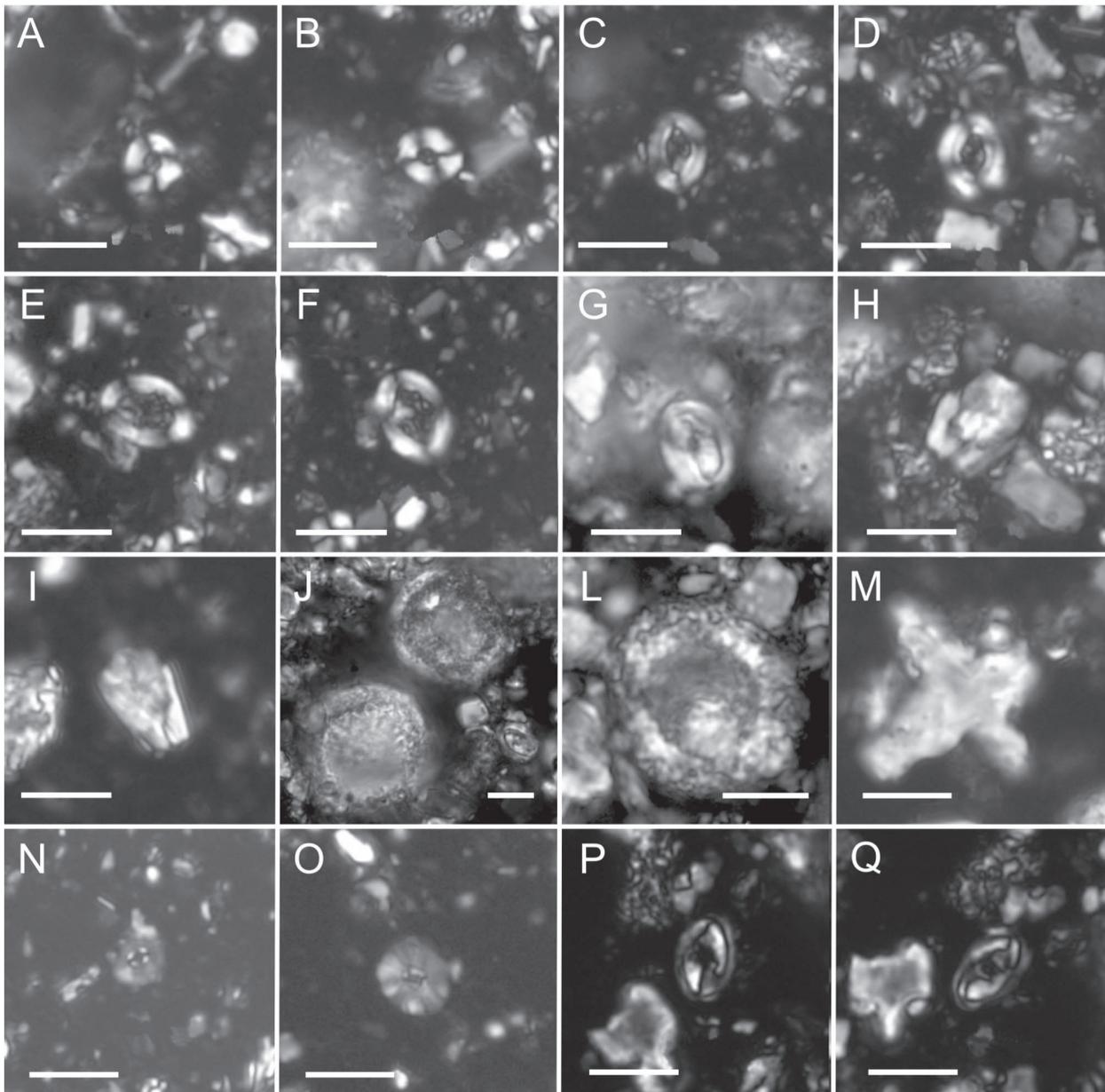


Figure 6. Calcareous nanofossil species observed in the studied interval (cross polarized light). **A-B**, *Lotharingius hauffii* (different specimens); **C-D**, *Lotharingius sigillatus* (different specimens); **E-F**, *Lotharingius* aff. *L. velatus* (same specimen, **E** at 0°, **F** at 45°); **G**, *Mitrolithus elegans*; **H-I**, *Calcivascularis jansae* (different specimens); **J-L**, *Schizosphaerella* sp. (different specimens); **M**, *Orthogonoides hamiltoniae*; **N**, *Similiscutum orbiculus*; **O**, *Similiscutum cruciulus*; **P-Q**, *Tubirhabdus patulus* (same specimen, **P** at 0°, **Q** at 45°). Scale bar = 5 μ m.

MICROPALEONTOLOGICAL DATA

Calcareous nanofossil assemblages

All the samples yielded common to abundant assemblages that were moderately to well-preserved. Thirteen genera and 18 species (Figures 4 to 6) were identified. The genus *Schizosphaerella*, along with *Lotharingius hauffii* and *Calcivascularis jansae*, dominate the assemblages, which is also characterized by the continuous presence of *Biscutum finchii*, *B. grande*, *Crepidolithus crassus*, *C. granulatus*, *Lotharingius* aff. *L. velatus* and *Tubirhabdus patulus*. *Biscutum dubium*, *B. novum*, *Bussonius prinsii*, *Calyculus*

spp., *Mitrolithus elegans*, *Orthogonoides hamiltoniae*, *Similiscutum cruciulus*, and *Similiscutum orbiculus* are sporadically present and range in abundance from very rare to few. A few specimens of *Axopodorhabdus atavus* have been identified from one sample (P5T). Present from the bottom of the succession, the relative abundance of *Crepidolithus impontus* and *Lotharingius sigillatus* increase upwards, in particular that of *L. sigillatus*.

Palynological assemblages

A rich, poorly-preserved palynoflora were extracted from the Upper Pliensbachian/Lower Toarcian deposits of the

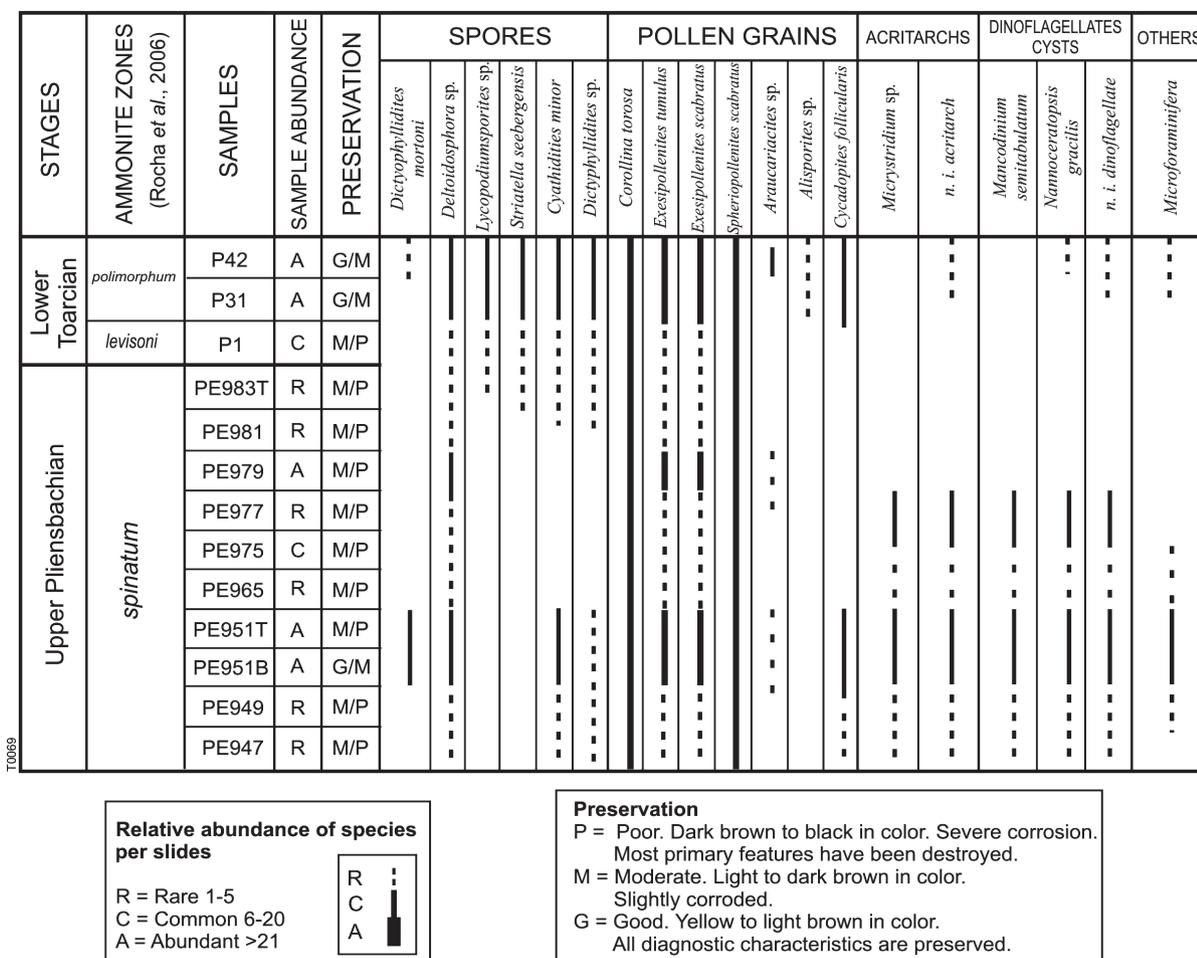


Figure 7. Distribution of palynomorphs in the studied section.

Lusitanian Basin in the Peniche area. Some of these samples are either barren or contain badly preserved palynomorphs. From the productive samples, 30 species of spores, pollen grains, dinoflagellate cysts, acritarchs, and organic microforaminifer inner walls (foraminifer linings) were identified (Figures 7 and 8). Terrestrial palynomorphs (spores and pollen grains) dominate the assemblage; also the presence of the dinoflagellate cysts is significant, mainly at the lower part of the section (corresponding to the Upper Pliensbachian). The most common spores belong to the *Dictyophyllidites*, and *Deltoidospora* genera, and the pollen grains are dominated by *Corollina torosa*, *Spheripollenites scabratus*, *Exesipollenites scabratus*, and others small inaperturate pollen grains. Additionally, dinoflagellate cysts related to the *Mancodinium* and *Nannoceratopsis* genera are important assemblage elements, and are better represented semi-quantitatively in the lower portion of the section studied.

The palynoflora is characterized by moderate preservation in the lower part of the section and by higher proportions of marine elements when compared with the upper part (Lower Toarcian). However, the palynoflora is better preserved and the terrestrial influence is stronger, in the upper part of the section, as evidenced by increased abundance of

Exesipollenites, and *Spheripollenites* pollen grains.

The recovered palynoflora is dominated by gymnosperm pollen grains, in particular *Corollina torosa* (the most abundant species), together with *Spheripollenites* and *Exesipollenites* (Figure 7). Also represented are small, smooth and apiculate trilete spores (*Dictyophyllidites*, *Deltoidospora*, and *Cyathidites*), together with dinoflagellate cysts (*Mancodinium* and *Nannoceratopsis*). Other marine microplankton (acritarchs and microforaminifers lining) are common, although they do not occur in all samples. Bisaccate and monosulcate pollen grains are rare components of the assemblage.

Palynological evidence also indicates a strong continental influence on the depositional environment testified by the almost exclusively and continual presence of woody organic material in the residue.

REMARKS

The Upper Pliensbachian/Lower Toarcian portion of the biostratigraphic scheme proposed by Bown & Cooper (1998) and Mattioli & Erba (1999) and the zonal markers utilized to define their calcareous nannofossil zone and subzone boundaries can be observed in Figure 9. They

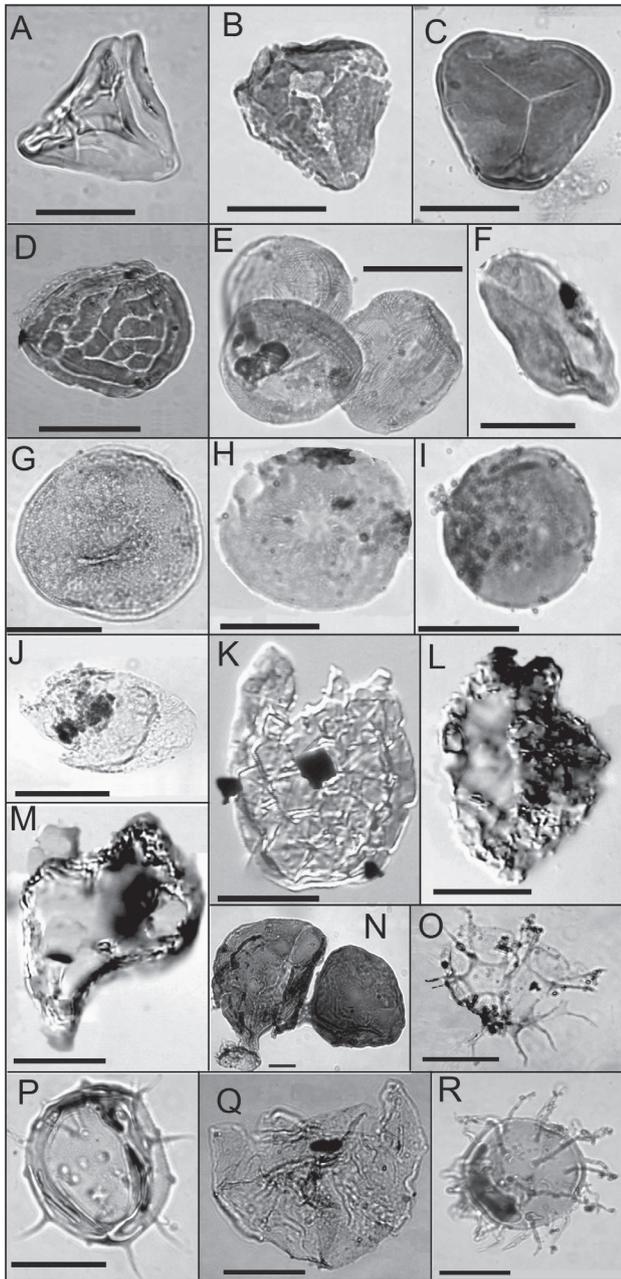


Figure 8. Terrestrial (A-J) and marine (K-R) palynomorphs in the studied section. **A**, *Dictyophyllidites mortonii*; **B**, *Deltoidospora* sp.; **C**, *Cyathidites minor*; **D**, *Striatella seebergensis*; **E**, *Corollina torosa*; **F**, *Cycadopites follicularis*; **G**, *Exesipollenites tumulus*; **H**, *Exesipollenites scabratus*; **I**, *Spheripollenites scabratus*; **J**, *Alisporites* spp.; **K**, *Mancodinium semitabulatum*; **L**, *Nannoceratopsis gracilis*; **M**, *Nannoceratopsis gracilis*; **N**, microfossil; **O**, Dinoflagellate n. id.; **P**, *Microhystridium* sp.; **Q**, Dinoflagellate n. id.; **R**, Acritarch n. id. Scale bar = 15 μ m.

are correlated with the biohorizons and calcareous nanofossil zones recognized in the Basque-Cantabrian area by Perilli *et al.* (2004), calibrated in respect of the ammonite subzones. In Northwest of Europe and Italy and south of France, the Pliensbachian/Toarcian Boundary lies within the *Lotharingius hauffii* Zone and more specifically within the NJ5b *Crepidolithus impontus* Subzone of Bown & Cooper (1998) and coinciding with the NJT5a *Biscutum finchii*/NJT5b *Lotharingius sigillatus* Subzone boundary

of Mattioli & Erba (1999). In the Basque-Cantabrian area, the successive First Common Occurrence (FCO) of *Lotharingius hauffii* and the Last Common Occurrence (LCO) of *Calcivascularis jansae* allow the division of the NJ5 *Lotharingius hauffii* Zone into three portions, and the Pliensbachian/Toarcian Stage Boundary is positioned between the FCO of *Lotharingius hauffii* and the LCO of *Calcivascularis jansae*. Since the FCO of *L. hauffii* roughly approaches the NJ5a/NJ5b Subzone boundary of Bown & Cooper (1998), the Pliensbachian/Toarcian Stage Boundary lies within the NJ5b Subzone, in the Basque-Cantabrian area.

The presence of *Crepidolithus impontus* and the absence of *Carinolitus superbus*, places the Pliensbachian/Toarcian Boundary, exposed in the reference section of Peniche, in the NJ5b Subzone. With respect to the scheme proposed by Mattioli & Erba (1999) it lies within the NJT5b *Lotharingius sigillatus* Subzone, because *Lotharingius sigillatus* is present from the bottom of the interval sampled. However, in the Basque-Cantabrian area the first specimen of *Lotharingius sigillatus* is present from the *spinatum* ammonite zone.

The common and continuous presence of *Calcivascularis jansae*, along with the presence of *B. grande*, support a Tethyan affinity for the calcareous nanofossil assemblages recovered from the Pliensbachian/Toarcian transition sampled at Peniche. In particular, *Calcivascularis jansae* is the most striking Tethyan marker (Bown, 1987; Bown & Cooper, 1998).

Palynostratigraphic biozonation schemes for the European Lower Jurassic interval are profuse (*e.g.* Davey & Riley, 1978; Morbey, 1978; Wille & Gocht, 1979; Bjaerke, 1980; Woollam & Riding, 1983; Davies, 1983, 1985; Riding, 1984a, 1984b; Williams & Bujak, 1985; Feist-Burkhardt & Wille, 1992; Riding & Ioannides, 1996; Bucefallo-Palliani & Riding, 1997, 2003; Koppelhus & Hansen, 2003; Poulsen & Riding, 2003). Most of them are based on dinoflagellate cysts due to their abundance in the Jurassic marine deposits of Europe. In consequence, there are fewer published schemes based exclusively on spores and pollen grains, or utilizing a combination of these groups.

The palynoflora here identified are characterized by the dominance of relatively long-ranging species; hence, it was not possible to fit it into any biozone scheme available. However, some considerations could be drawn based on some species and their relative abundance.

The most conspicuous component of the palynoflora is the presence in almost all productive samples of *Nannoceratopsis gracilis* which, ranges from the late Pliensbachian to Bajocian (see compiled range charts in Bucefallo-Palliani & Riding, 2003). This specie has its inception in late Pliensbachian biozones of some palynological European schemes (*e.g.* Feist-Burkhardt & Wille, 1992; Bucefallo-Palliani & Riding, 2000; Poulsen, 1996). Davies (1985) correlated the first occurrence of *N. gracilis* to the *Luehndea* sp. A biozone of his dinoflagellate cyst scheme. He considered this palynozone to encompass

| | | BASQUE-CANTABRIAN AREA (Perilli et al., 2004) | | | | NW EUROPE (Bown & Cooper, 1998) | | | | ITALY/S FRANCE (Mattioli & Erba, 1999) | | | | | | | | | | | | | | |
|--------------|-------------|---|--------------|-------------------------|--------------|---------------------------------|--------------|-------------------------|--------------|--|--------------|-------------------------|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|---------------|--------------|--------------|---------------|
| Stage | Substage | Ammonites | | Calcareous Nannofossils | | Ammonites | | Calcareous Nannofossils | | Ammonites | | Calcareous Nannofossils | | Substage | Stage | | | | | | | | | |
| | | Zones | Subzones | Zones | Bioevents | Zones | Zones | Subzs. | Bioevents | Zones | Zones | Subzs. | Bioevents | | | | | | | | | | | |
| Toarcian | Lower | Bifrons | Semipolitum | NJ7 | D. striatus | J.D. striatus | Bifrons | NJ7 | D. striatus | J.D. striatus | Bifrons | NJ7 | D. striatus | NJ7a | Toarcian | Lower | | | | | | | | |
| | | | Falciferum | | | | | | | | | | | | | | NJ6 | C. superbus | Falciferum | C. superbus | Serpentinus | NJT6 | C. superbus | J.D. striatus |
| | | | Strangewaysi | | | | | | | | | | | | | | NJ5 | L. hauffii | C. superbus | C. superbus | Tenuicostatum | NJ5 | L. hauffii | NJ5b |
| | Semicelatum | NJ4 | S. cruciulus | Margaritatus | NJ4 | S. cruciulus | Margaritatus | NJ4 | S. cruciulus | NJ4b | J.L. hauffii | B. finchii | | | | | | | | | | | | |
| | Mirabile | | | | | | | | | | | | Stokesi | Monestieri | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii |
| | Spinatum | Margaritatus | Stokesi | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | | | | | | | | | | | | |
| Margaritatus | Stokesi | | | | | | | | | | | | Monestieri | J.L. hauffii | J.L. hauffii | J.L. hauffii | |
| Stokesi | | Monestieri | Monestieri | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | J.L. hauffii | | | | | | | | | | | | J.L. hauffii |

J or L - first occurrence Γ - Last occurrence LCO - Last common occurrence FCO - First common occurrence Subzs. - Subzones

Figure 9. Calcareous nannofossil zonal correlation between Basque Cantabrian area, Northwest Europe and Italy and South France (modified from Perilli et al., 2004).

the *Spinatum* and *Tenuicostatum* ammonite zones, and is indicative of uppermost Pliensbachian to lower Toarcian sediments. Furthermore Van Helden (1977) and Riding et al. (1999), report that *N. gracilis* has a wide geographical distribution in the Northern Hemisphere. The occurrence of *Mancodinium semitabulatum*, is considered as ranging from Pliensbachian to Bajocian (Bucefallo-Palliani & Riding, 2003), having its inception in the Early Pliensbachian palynozonal schemes of Europe (Feist-Burkhardt & Wille, 1992; Poulsen, 1996).

With respect to the miospores, strong correlation exists between the assemblage identified here and assemblage zones defined for the Early Jurassic sediments (e.g. Davies, 1985; Koppelhus & Dam, 2003), where biozones characterized by abundance or acmes of *Corollina torosa*, and *Spheripollenites scabratus* are defined and the late Pliensbachian/early Toarcian age ascribed.

Subsequently, besides the non definition of a specific palynozone, the assemblage here identified is in accordance with the attributed age recognized by the nannofossil and ammonite methods.

Regarding the palaeoenvironment, the palynoflora suggests the prevalence of warm climatic conditions during deposition, evidenced by the high content of *Corollina torosa*, pollen grains produced by the xerophytic (drought-resistant) and thermophytic Cheirolepidaceae, which are considered to reflect warm and arid conditions (Vakhrameev, 1982, 1991). In addition, the presence of dinoflagellates cysts, organisms that currently form a major part of the ocean plankton (Armstrong & Brasier, 2005) together with pollen grains and terrestrial macerals confirms that it occurred in a marine relatively shallow and nearshore environment with a large input of terrigenous material (Hergreen et al., 2000); and that this terrestrial influence increase upward in the section.

FINAL CONSIDERATIONS

The calcareous nannofossil and palynomorph results obtained throughout the Pliensbachian/Toarcian boundary, in the Ponta do Trovão area in Peniche, allow several interpretations regarding the micropaleontological assemblages, biostratigraphy, geological ages, palaeoenvironment and Tethys influence, summarized in the Figure 10. The studied calcareous nannofossil assemblages are abundant, diversified and well preserved, allowing relative abundance estimation and revealing that *Schizosphaerella* spp., *Lotharingius hauffii* and *Calxivascularis jansae* dominate the assemblages. *Crepidolithus impontus* and *Lotharingius sigillatus* are rare at the base of studied section increasing in abundance upwards. In contrast, the palynology assemblage is poor, low diversified and badly preserved, dominated by gymnosperms (Cupressaceae, Taxodiaceae and Taxaceae) with low frequency of spores and dinoflagellate cysts, with rare bissacate pollen grains.

Regarding biostratigraphy and age, the calcareous nannofossils present good definition. Bown & Cooper (1998) defined the NJ5b Subzone as an interval between the FO of *Crepidolithus impontus* to the FO of *Carinolithus superbus*. As the former is present and the latter is absent, the analyzed interval places in the NJ5b *Crepidolithus impontus* Subzone. With respect to the scheme proposed by Mattioli & Erba (1999), all the samples analyzed for calcareous nannofossils lie within the NJT5b *Lotharingius sigillatus* Subzone. Using the Perilli et al. (2004) scheme the studied section corresponds to the NJ5 Zone. Ogg (2004), using the von Salis (1998) compilation, placed the Pliensbachian/Toarcian boundary into the NJ5b, as is indicated herein. Besides, this author indicated an absolute age of 183.0 ± 1.5 Ma to this Stage Boundary. Nevertheless, it is not possible to fit the palynoflora into any biozone scheme because it is dominated by long-ranging species.

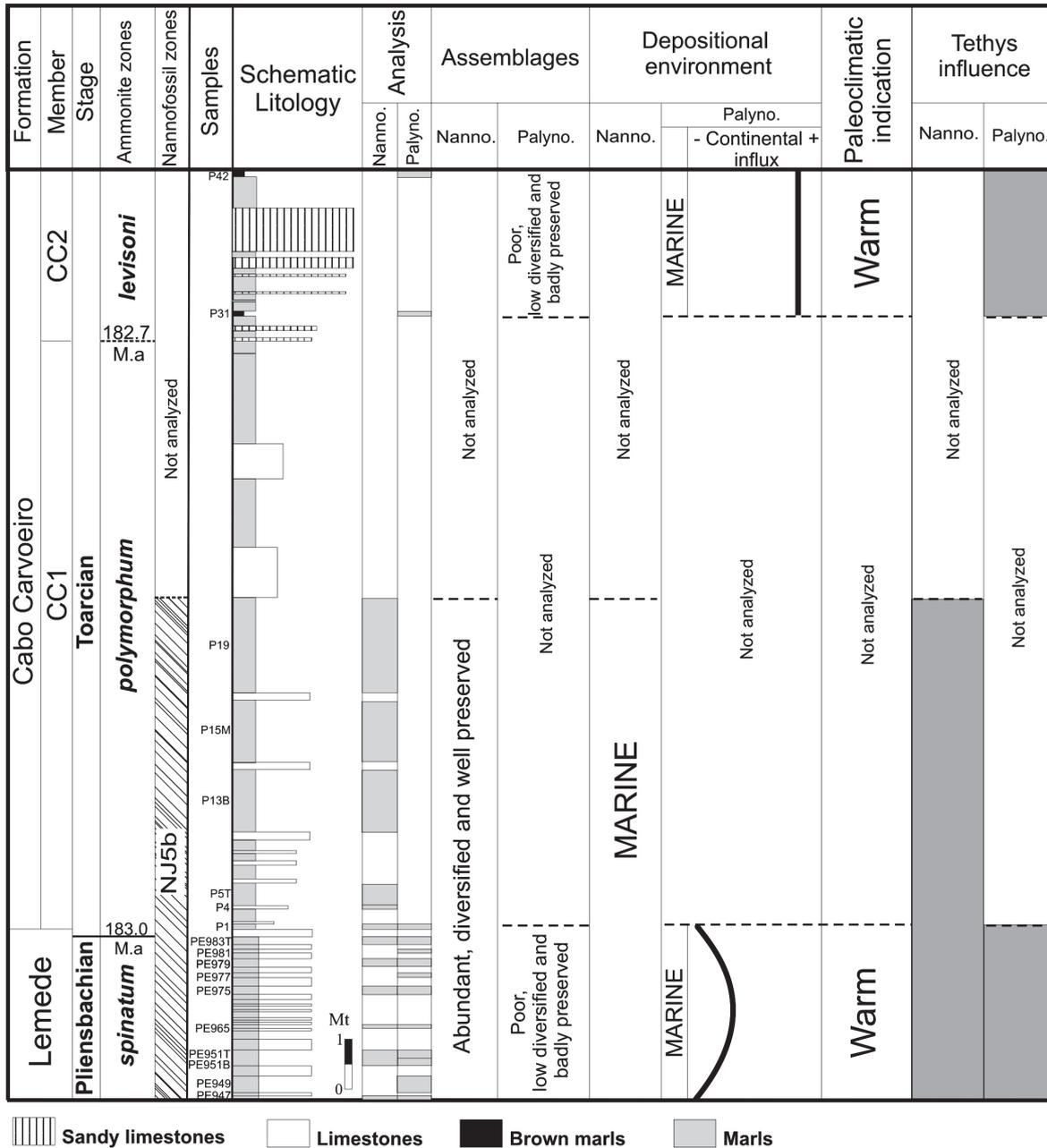


Figure 10. Calcareous nannofossil and palynomorph data integration. Ammonite zones from Rocha *et al.* (1996); calcareous nannofossil zones based on Bown & Cooper (1998) scheme; lithostratigraphy from Duarte *et al.* (2004b) and absolute ages from Ogg (2004). **Abbreviations:** **nanno**, calcareous nannofossils; **palyno**, palynomorphs.

Based on the calcareous nannofossil and, chiefly, palynological analysis, it is possible to suggest that the depositional environment was predominately marine, with gradual increasing of continental influence upward to the studied section top. These conclusions are supported by the augment of the terrestrial debris and the spores and pollen grains content towards the top of the section. In addition, the domination of rimulates and inaperturate pollen grains suggest the prevalence of warm climatic conditions during the Pliensbachian/Toarcian boundary.

Furthermore, the Tethyan influence can be demonstrated by the presence of some Tethyan marker fossils recovered

from the Pliensbachian-Toarcian transition sampled at Peniche. According to Bown & Cooper (1998), the Lower Jurassic nannofloras from western Tethys are characterized by the abundant occurrence of *Calxivascularis jansae* and other endemic forms, included *Biscutum grande*. In Peniche, *C. jansae* is abundant in all samples and *Biscutum grande* is frequent in some samples, mainly in the Toarcian, supporting a Tethyan affinity for the calcareous nannofossil assemblages. In the palynomorph assemblages Tethyan influence is indicated by the presence of *Mancodinium semitabulatum* and *Nannoceratopsis gracilis* (Bucefallo-Palliani & Riding, 2003).

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