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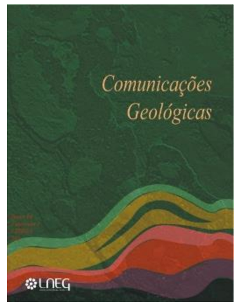
Palaeontological content and palaeodepositional interpretation of the Upper Jurassic Alcobaça Formation at Gralha beach (São Martinho do Porto, Portugal)



Conteúdo fossilífero e interpretação paleodeposicional da Formação Alcobaça (Jurássico Superior) na Praia da Gralha (São Martinho do Porto, Portugal)

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Abstract: This work aims to carry out a paleontological description of an outcropping Upper Jurassic 65 meters thick sedimentary succession at Gralha Beach, North of São Martinho do Porto in the Lusitanian Basin, that includes mainly reddish to yellowish fine-grained siliciclastics and some interbedded marly layers belonging to the Alcobaça Formation. Detailed facies classification and palaeontological analysis (Micropalaeontology and Ichnology), integrated with Petrography, Calcimetry and X-Ray Diffraction, showed a high-frequency cyclicity and pointed to a deposition in low to very - low energy shallow marine conditions, in a gently dipping, oligotrophic open lagoon linked to a muddy coastal wetland area. This is corroborated by the characteristics of microfossils (calcareous nannofossils, Foraminifera, Ostracoda and Charophyta), Bivalvia, Gastropoda and Echinoderma fragments, *Thalassinoides*, *Ophiomorpha* and *Rhizocorallium*.

Keywords: Shallow marine environment, Micropaleontology, Ichnology, Upper Jurassic, Lusitanian Basin.

Resumo: Este trabalho pretende realizar uma descrição paleontológica de uma sucessão sedimentar do Jurássico Superior da Bacia Lusitânica, com 65 metros de espessura, que aflora na Praia da Gralha (Norte de São Martinho do Porto). Esta pertence à Formação Alcobaça e inclui, principalmente, rochas siliciclásticas de grão fino e coloração avermelhada a amarelada, intercaladas com alguns níveis de argilito, margas e calcários. A integração da classificação das fácies e a análise paleontológica (Micropaleontologia e Icnologia) com petrografia, calcimetria e difração de Raio – X, demonstrou uma ciclicidade de alta frequência e aponta para uma deposição em condições de ambiente marinho raso de baixa a muito baixa energia, num meio de baixo pendor, oligotrófico, de laguna aberta, ligado com uma região costeira pantanosa. Esta interpretação é comprovada pelas características dos microfósseis (Nanofósseis calcários, Foraminifera, Ostracoda e Carofita), bivalves, gastrópodes e fragmentos de equinodermes, *Thalassinoides*, *Ophiomorpha* e *Rhizocorallium*.

Palavras-chave: Ambiente marinho raso, Micropaleontologia, Icnologia, Jurássico Superior, Bacia Lusitânica.

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1. Introduction

This work aims to make an integrated analysis of the outcropping sedimentary succession at Gralha Beach, North of São Martinho do Porto in the Lusitanian Basin. Lithofacies description and detailed analysis of paleontological samples enabled an accurate palaeodepositional interpretation. The integration of different data based on lithologies, microfossils and ichnofossils associations supports these findings, and their interpretation allows to characterise more properly this depositional system.

This article also shows how data from different kinds of stratigraphic, sedimentological and palaeontological analysis can be integrated to support a robust interpretation.

2. Location and geological setting

The studied zone is located at Gralha Beach (North of São Martinho do Porto) between the coordinates 39° 31' 23.74" N; 9° 8' 1.14" W and 39° 31' 37.05" N; 9° 7' 36.91" W in the Lusitanian Basin, Portugal. This basin, located on the western Iberian margin, experienced two rifting phases and is related to the North Atlantic opening during the Mesozoic (Tucholke *et al*., 2007).

The studied strata are of Kimmeridgian age (Late Jurassic) and belong to the Alcobaça Formation (Choffat, 1905, Marques *et al*., 1992), which is composed by alternating marls, sandstones, limestones and claystones, usually with brachiopods, bivalves (*e.g. Arcomytilus morrisi)* and echinoderms (Teixeira and Zbyszewski, 1968). Previous work in this region suggests a paleogeographic setting with progradation of a fan-delta distal zone towards an open lagoon (Bernardes, 1992), as well as a shallow carbonate platform punctuated by siliciclastic discharges (Rocha *et al*., 1996).

3. Methodology

Sixty-five meters of sedimentary succession exposed in outcrop were described using a 1:40 vertical scale, with regard to the lithology, sedimentary structures, facies associations, and ichnofossils. Forty-four samples were collected for micropaleontological analysis (Ostracoda, Foraminifera and Charophyta counted in total number per sample; calcareous nannofossils in total number per microscope column). The bioturbation index according to Bann *et al.* (2008) was also used for the ichnological content.

4. Results

4.1. Lithologies and lithofacies

Twelve different lithofacies were recognised based on lithology, grain size and sedimentary structures: Sh (horizontal to low angle lamination sandstones), St (trough cross-stratification sandstones), Ss (swaley/hummocky sandstones), Sw (wave ripples sandstones), Sm (massive sandstones), Sc (convolute bedding sandstones), H (heterolytic facies), Fsm (massive claystones), FsD (massive claystones with mud-cracks), P (palaeosols), Mrl (marls) and Wack (wackestones). The predominance of fine-grained lithofacies (claystones and marls) is remarkable all over the succession.

4.2. Microfossils content

Microfossils content is higher in carbonate than in fine-grained clastic facies.

Around 70% of all collected samples for a micropaleontological study contain calcareous nannofossils, all of them belonging to the *Watznaueria* group. The most abundant species are *W. manivitiae* Bukry, 1973, followed by *W. barnesiae* Black *in* Black and Barnes, 1959, *W. ovata* Bukry, 1969, and *W. britannica* Stradner, 1963.

Benthonic foraminifers appear in wackestones and fine – grained siliciclastics with a single occurrence in each one. However, their preservation does not allow a precise identification of genus and species.

Around 30% of all the collected samples contain ostracods, which were mostly identifiable, in spite of the poor preservation. Some significant forms, including *Mantelliana* sp., *Theriosynoecum helmdachi* Sohn, 1982, *Darwinula* sp., *Theriosynoecum* spp., *Sinuocythere* sp., *Damonella* sp., *Cetacella*, *Timiriasevia guimarotensis* Schudack *et al.*, 1998, *Fabanella* sp. and *Stenestroemia* sp. were identified.

Finally, around 20% of all the collected samples contain charophytes, with a distribution similar to the ostracods. However, due to weathering it was not possible to identify any genus nor species.

4.3. Ichnology and Bioturbation Index

The presence of bioturbation is frequent all over the studied interval, mostly of ichnogenera *Thalassinoides*, followed by *Ophiomorpha* and also *Rhizocorallium*, with Bioturbation Index between 1 and 4 according to Bann *et al*. (2008). Their occurrence is related mainly to sandy facies, but they also occur in claystones with bioturbation index 1 and 2. All over the succession, Bioturbation Index 2 is the most abundant.

5. Discussion

A vertical log with the described results is shown in Figure 1. The interval between 0 and 30 meters shows the most significant occurrence of marl, wackestone, Charophyta, Ostracoda, and nannofossil content. Foraminifera and Echinoderma fragments appear at the base of the succession. Above 30 meters the presence of paleosols is remarkable.

The predominance of fine-grained lithofacies (claystones and marls) indicates deposition in a low to very low-energy setting (Bridge, 2006) with wave-action during the deposition of sandstones (Reineck and Singh, 1980) corroborated by wave ripples and swaley/hummocky in some sandstone's layers.

The presence of *Watznaueria* group all over the studied interval, through the species *W. manivitiae*, Bukry, 1973, *W. barnesiae*, Black in Black and Barnes, 1959, and *W. britannica*, Stradner, 1963, point for oligotrophic conditions in warm waters (Ovechkina *et al.*, 2019; Giraud *et al.*, 2006; Erba, 1992). Both calcareous nannofossils, echinoderms fragments and foraminifers suggest deposition in a shallow-marine environment. In addition, the presence of *Thalassinoides*, *Ophiomorpha* and *Rhizocorallium* (*Skolithos* and *Cruziana* ichnofacies) are in line with this conclusion because these ichnogenera are usually related with shoreface and sublittoral contexts (MacEachern *et al.*, 2010).

The presence of Ostracoda and Charophyta suggests a transport and deposition together with sediments coming from restricted source areas to the marine environment.

The remarkable presence of abundant paleosol layers towards to the top suggests that sedimentation was frequently interrupted by significant episodes of subaerial exposure caused by relative sea – level oscillations.

All the evidences point for a deposition in a gently dipping, low to very – low energy, oligotrophic open lagoon located nearby a muddy coastal wetland area with significant episodes of subaerial exposure. The occurrence of low-energy lagoonal carbonate deposition reinforces this interpretation (Barros, 2020).

6. Conclusion

This work demonstrates how an integrated analysis in an outcropping sedimentary succession provides more information to interpret the paleodepositional setting. This work also contributes to characterize more properly the Alcobaça Formation and its depositional conditions in the Praia da Gralha.

The co-occurrence of calcareous nannofossils and other marine taxa and ichnofossils, together with carbonate and mixed lithofacies point for a low to very - low energy, gently dipping shallow – marine palaeodepositional environment. The remarkable presence of abundant paleosol levels indicates significant episodes of subaerial exposure.

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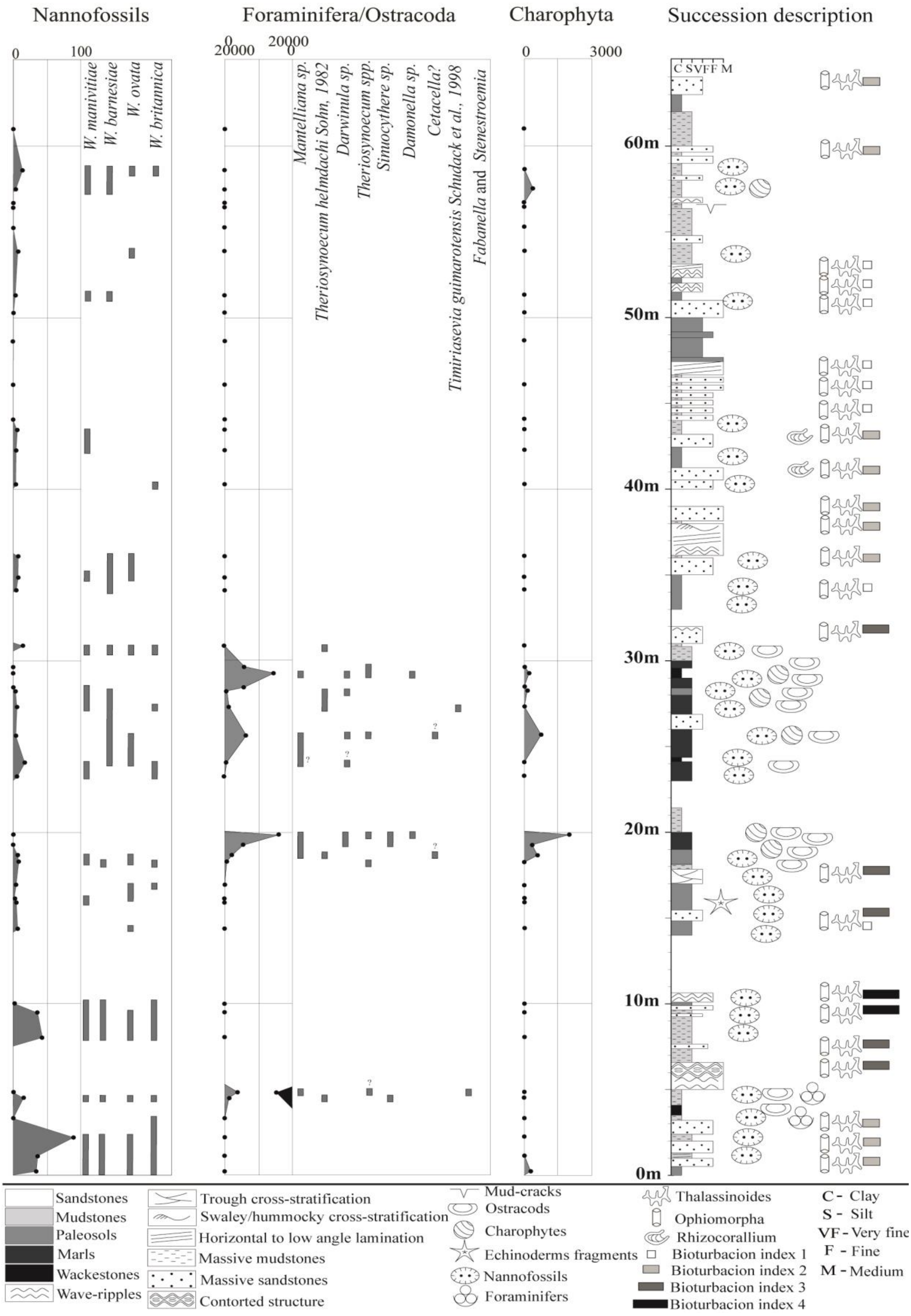

Figure 1. Integration of all data from the applied methods. Nannofossils and ostracods species and genus are indicated in each rectangle

Figura 1. Integração de todos os dados dos métodos aplicados. As espécies e gêneros de nanofósseis e ostracodes estão indicados em cada retângulo.

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