Lower Miocene stable isotopes (δ¹⁸O, δ¹³C), biostratigraphy and environments in the Foz da Fonte and Penedo sections (Setúbal Peninsula, Portugal)

Isótopos estables, bioestratigrafía, y paleoambientes del Mioceno inferior de las secciones de Foz da Fonte y Penedo (Península de Setúbal, Portugal)

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RESUMEN

Se estudia el contenido micropatofaunístico de dos secciones del Mioceno marino (Burdigaliano) de la cuenca inferior del Tajo (proximidades de Lisboa): Foz da Fonte y Penedo. Se presenta una bioestratigrafía, y se interpretan paleoambientes a partir de las asociaciones de foraminíferos y ostrácodos. Las curvas isotópicas δ¹³C y δ¹⁸O presentan en ambas secciones fuertes oscilaciones, sobre todo en el contenido de δ¹³C de Pectinídeos (diferencias de 58). Los datos de δ¹⁸O realizados sobre Pectinídeos sugieren un enfriamiento a lo largo del Burdigaliano; no obstante la temperatura de las aguas debió de ser más alta que la actual. Se observan valores más altos de δ¹³C en la sección de Penedo con respecto a la de Foz da Fonte, lo que está en acuerdo con la mayor distalidad de la primera.

Palabras clave: isótopos estables, bioestratigrafía, paleoambientes, Burdigaliano, Cuenca del Bajo Tajo, Península de Setúbal, Portugal

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Introduction

Following a previous work concerning the analysis of stable isotope δ¹⁸O and δ¹³C (Antunes et al., 1997a) new data are presented from two Lower Miocene sections (Foz da Fonte and Penedo) at Setúbal Peninsula distant about 1 km from each other (Fig. 1). The two sections are almost equivalent, Penedo section is slightly younger in age (Upper Burdigalian) and represents more distal facies. The stratigraphic and environmental frame are mainly based on data concerning foraminifera and ostracoda.

Two depositional sequences (DS) were characterised by Antunes et al., (1997b). An important regional unconformity can be observed in the two sections binding B0 and B1 DS.

The isotopic analysis were carried out at "Servicio General de Análisis de isótopos estables, Facultad de Ciencias, Universidad de Salamanca".

Stratigraphy

Foz da Fonte (Fig. 2)
The oldest Miocene sediment outcrops on the cliffs of Foz da Fonte beach (coordinates, sheet 464 - Sesimbra, scale 1:25 000: M - 106.975 Km, P - 165.625 Km).

Miocene deposits directly overlie Cretaceous limestones at a low angle unconformity. Sediments are mainly fossiliferous bioclastic limestones and marls. The lowermost beds include cobbles and pebbles of Cretaceous volcanites and limestones. In the lower part of the section, a sandy bed corresponds, probably, to a regressive event. The middle section presents detrital shallow facies and erosion surfaces. One of these is overlain by a remarkable oyster shells concentration. The upper part of the section shows a marly cyclic character.

Zbyszewski et al., (1965) and Zbyszewski (1967) described the section.

Sen et al., (1992) identified two magnetic normal polarity zones which were correlated with C6 and C5B since preliminary planktonic foraminifera analysis...
Fig. 2 - Foz da Fonte section and stable isotope data.

suggested correspondence with N5 to N7 Blow's zones.

Antunes et al., (1997b) indicate a 87Sr/86Sr age of about 20Ma to the lowest beds of this section.

Concerning biostratigraphy, G. altiaperatura occurs from near the base to the top of the section. Abundance and specific diversity of Globigerinoides allows correlation with N5 and N6 zones. Scarce Catapsydrax unicusus at high levels (samples 18, 19 and 23) prevents correlation with more modern zones.

In the lowest beds (FF1-FF4) ostracods Hemicyprideis helvetica and Pokornyella lusitana (typical Aquitanian species) occur for the last time. Upper beds contain typical Burdigalian forms (Nascimento, 1988).

Planktic foraminifera are abundant at the lower levels (FF3 and FF4) and the upper levels (FF17 to FF23). They are scarcer or absent in the middle section samples (FF5 to FF16).

Benthic foraminifera assemblages includes Amphistegina, Elphidium, Quinqueloculina, Asterigerina in the lower beds (FF1 to FF4) pointing out to an infralittoral environment. The greater depth may be reached at sample FF3 since planktic forms become more abundant and Cibicidoides, Caenis, Pleurostomella and Uvigerina are present in the benthic assemblage showing circalittoral influence. Ostracods assemblages are characteristic of infralittoral environments. The presence in samples FF1 to FF4 of the thermophile species Choristocoryx truncata and Pokornyella lusitana indicate warm waters. Towards the upper part of the section ostracod, associations point out to a decrease in water temperature.

Disconformities can be observed in the middle part of the section; variability of diversity and composition of benthic assemblages (FF7 to FF13), as well as the scarcity or absence of planktic forms suggest environmental instability (between the littoral and the infralittoral with little circalittoral influence).

Towards the upper beds, environmental conditions seem more stable corresponding to infralittoral with circalittoral influence as shown by the increase of planktic forms and greater diversity of benthic genera. The presence of Lenticulina, Cassidulina, Brizalina, rare Elphidium and Quinqueloculina suggests that circalittoral zone might be reached (probably at sample FF20). Ostracods indicate the infralittoral with circalittoral influence for samples FF17 to FF23.

Penedo (Fig. 3)
The outcrop is exposed at the praia das Bicas cliff (coordinates: sheet 4644, Sesimbra, scale 1:25 000: M - 107,400 Km. P - 166,575 Km).

Basal beds, including f ciliferous biocalcareous and sandstones with sedimentary discontinuities, are the same as recognised in the middle part of Foz da Fonte section.

Zbyzekewski et al., (1965) correlated this section with the Lower Helvetician.

Samples PS69/4-26 yielded planktic foraminifera Catapsydrax unicusus and Globigerinoides altiaperura allowing correlation to N5-N6 zones (Lower Burdigalian). In the upper beds Praearbula cf. transitoria occurs and Globigerinoides triloba becomes more frequent; Catapsydrax unicusus was not found; the association may be correlated with N7 (Upper Burdigalian).

Among Ostracoda there are Ruggieria (R.) michelini and C. (Cytherelolida) jonesiana which are not known later than the Lower Tagus basin Burdigalian. Typical aquitanian forms do not occur. The associations are characteristic of sublittoral environments.

Polynymorphs are scarce. Dinoflagellates predominate over spores and pollens. Operculodinium centrocarpum and
Spiniferites pseudofuscatus suggest warm waters. At Pen8 and Pen9 samples, Impagidinium indicates open sea environments. The spores are rare; bisaccate pollen predominates suggesting weakly continental influence.

The lowest sample (Pen1) shows little diversity of the genera Ammonia, Elphidium, Cibicides, and Asterigerina besides the absence of planktic forams indicate an infraaltlal environment.

Diversity of benthic genera from Pen2 to Pen7 assemblages, varies, gradually decreasing to the latter. There are abundant individuals of Nodosarida, Ammonia, Cibicidoides, Nonion, Lenticulina, Uvigerina as well as Cancriis and Operculina in some levels. The planktic forams are abundant (very abundant in Pen5). The environment seems to be the circalittoral near the infracltal.

Reduction of genera toward Pen7, relative change in the composition of Pen7 benthic assemblage and the absence of foraminifera in Pen8 are interpreted as the result of shallowning or increasing environmental stress.

In the top of the section, samples Pen9 and Pen10 show great diversity of benthic genera and abundant planktic forams. The environment suggested is, again, the circalittoral.

C and O Isotope analysis

Sample preparation method is briefly described in Antunes et al., (1997a). Isotopic values are plotted in Table I. Error is 0.13% for δ13C and 0.30‰ for δ18O in Penedo samples and, respectively, 0.03% and 0.11‰ for Foz da Fonte section.

The isotopic curves present in both sections show strong oscillations, mainly in respect to Pectinid δ18O content which may attain 5‰ (samples PS4-PS5 of Penedo section and samples FF7 and FF8 of Foz da Fonte section). These oscillations are in accordance with local sea level fluctuations as indicated by ostracoda and benthic foraminifera and sedimentation features.

Higher δ18O values are observed at Penedo in agreement with its more distal situation. An increase in δ18O would be expected but it is not very clearly expressed.

A similar behaviour of all isotopic curves near the B0-B1 sequence boundary (Antunes et al., 1997b) can be observed in both sections: a drop in δ13C content (less in δ18O content) just before the sequence boundary, and a rise followed by another strong isotopic drop above it (samples 12 from Penedo and 8 from Foz da Fonte).

During the Burdigalian, a δ18O increase is registered, mainly concerning the Pectinids from Foz da Fonte; this can be related with a waters cooling to the top of the section. Although taking into account the isotopic signal of Penedo section the water temperature, should be higher than today. Extant Chlamys varia specimens from Algarve region present δ18O values of about 1.13‰ heavier than any studied Pectinids. A maximum of temperature seems to be attained around 19.6Ma (Lower Burdigalian).

There is not a covariation of C and O in the studied samples. Some anomalous isotopic values between Pectinids and Oysters are registered. The most striking is in sample PS4 where the pectinids indicate a strong fall in δ13C while the oysters show a δ18C rise; this can be related to reedimentation as at Penedo Norte and Ribelm da Lage sections (Antunes et al., 1997a).

The δ18O values from Foz da Fonte and Penedo are much lower than those from
Table 1.- Isotopic values for Foz da Fonte and Penedo sections. (OS - oyster; PEC - Pecten; AM - Amusium; CH - Chlamys; PVC - Pycnodont oyster)

Table 1.- Valores isotópicos para as secções de Foz da Fonte e Penedo.

Middle Miocene sections of Penedo Norte and Ribeira da Lage (Antunes et al., 1997a).

Conclusions

Biostratigraphy, palaeoecology, chronostatigraphy and isotopic data have improved our knowledge of Lower Miocene units from the western littoral area of the southern limb of Albufeira sillcline.

The Foz da Fonte and Penedo sections yielded faunas that indicate NS-N6 (Burdigalian) although uppermost Penedo levels can reach N7. The paleoenvironments correspond to infralittoral, oculittoral near infralittoral.

The isotopic curves present strong oscillations in both sections, mainly in respect to Pectinid δ13C content which may attain 58. There is no covariation of δ18O and δ13C.

Striking variations of the isotopic values, mainly in δ18O, were observed near the depositional sequence boundaries.

During the Burdigalian there is a δ18O increase tendency (water cooling). However, water temperatures were higher than today. A temperature maximum seems to have been attained about 19,6Ma (Lower Burdigalian).

δ13C values from Foz da Fonte and Penedo are much lower than those from Middle Miocene to Lower Tortonian sections (Antunes et al., 1997a).

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