Lower Miocene stable isotopes ($\delta^{18}O$, $\delta^{13}C$), biostratigraphy and environments in the Foz da Fonte and Penedo sections (Setúbal Peninsula, Portugal)

Isótopos estables, biostratigrafía, 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 micropaleontológico de dos secciones del Mioceno marino (Burdigaliense) de la cuenca inferior del Tajo (proximidades de Lisboa): Foz da Fonte y Penedo). Se presenta una biostratigrafía, y se interpretan paleoambientes a partir de las asociaciones de foraminiferos y ostracodos.
Las curvas isotópicas $\delta^{13}C$ y $\delta^{18}O$ presentan en ambas secciones fuertes oscilaciones, sobre todo en el contenido de $\delta^{13}C$ de Pectínidos (diferencias de 5δ).
Los datos de $\delta^{18}O$ realizados sobre Pectínidos sugieren un enfriamento a lo largo del Burdigaliense; no obstante la temperatura de las aguas debió de ser mas alta que la actual.
Se observan valores más altos de $\delta^{13}C$ 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, biostratigrafía, paleoambientes, Burdigaliense, Cuenca del Bajo Tajo, Península de Setúbal, Portugal*

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Introduction

Following a previous work concerning the analysis of stable isotope $\delta^{18}O$ and $\delta^{13}C$ (Antunes *et al.*, 1997a) new data are presented from two Lower Miocene sections (Foz da Fonte and Penedo) at Setúbal Peninsula distant about 1km 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 disconformity can be observed in the two sections binding BØ and B1 DS.

The isotopic analysis were carried out at "Servicio General de Analisis 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 biocalcarenites and marls. The lowermost beds include cobbles and pebbles of Cretaceous vulcanites 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 C5E since preliminary planktic foraminifera analysis

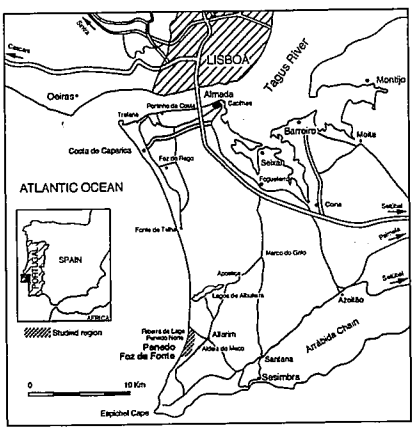

Fig.1 - Lisbon and Setúbal Peninsula region. Foz da Fonte and Penedo sections.

Fig.1 - Lisboa y Península de Setúbal. Mapa de situación de las secciones de Foz da Fonte y Penedo.

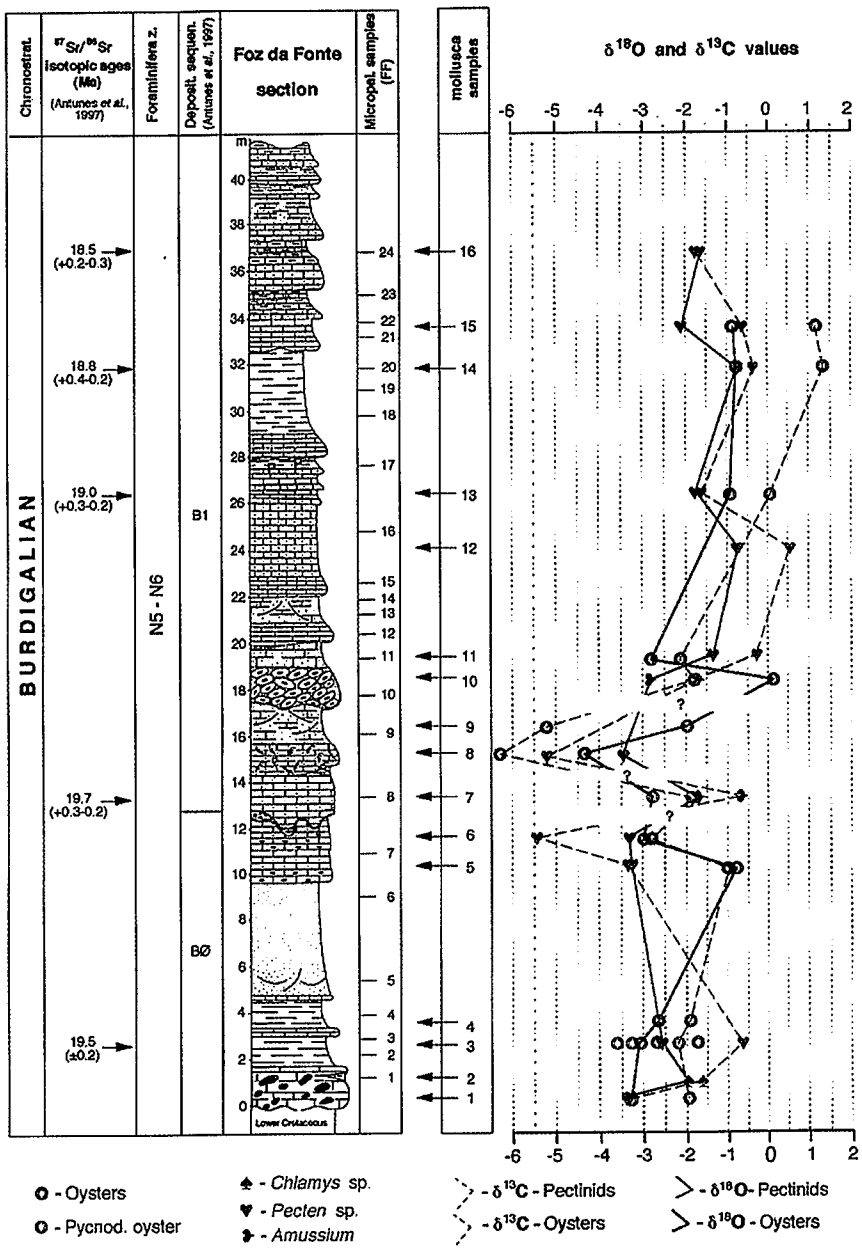

Fig.2 - Foz da Fonte section and stable isotope data.

Fig.2 - Sección de Foz da Fonte y datos isotópicos de C y O.

suggests correspondance with N5 to N7 BLOW's zones.

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

Concerning biostratigraphy, *G. altiaperturus* 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 unicavus* 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 lusitanica* (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, Cancris, Pleurostomella* and *Uvigerina* are present in the benthic assemblage showing circalittoral influence. Ostracod assemblages are characteristic of infralittoral environments. The presence in samples FF1 to FF4 of the thermophile species *Cnestocythere truncata* and *Pokornyella lusitanica* 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, environment 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 been 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 464-Sesimbra, scale 1:25 000: M - 107,400 Km, P - 166,575 Km).

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

Zbyszewski *et al.*, (1965) correlated this section with the Lower Helvetian.

Samples PS6/94 to Pen6 yielded planktic foraminifera; *Catapsydrax unicavus* and *Globigerinoides altiaperturus* allowing correlation to N5-N6 zones (Lower Burdigalian). In the upper beds *Praeorbulina* cf. *transitoria* occurs and *Globigerinoides triloba* becomes more frequent; *Catapsydrax unicavus* was not found; the association may be correlated with N7 (Upper Burdigalian).

Among Ostracoda there are *Ruggieria (R.) micheliniana* and *C. (Cytherelloidea) 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.

Palynomorphs are scarce. Dinoflagellates predominate over spores and pollens. *Operculodinium centrocarpum* and

Spiniferites pseudofurcatus suggest warm waters. At Pen8 and Pen9 samples, *Impagidinium* indicates open sea environments. The spores are rare; bisaccate pollens predominate 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 infralittoral environment.

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

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 shallowing 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 $\delta^{13}C$ and 0.30‰ for $\delta^{18}O$ 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 $\delta^{13}C$ content which may attain 5δ (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 $\delta^{13}C$ values are observed at Penedo in agreement with its more distal situation. An increase in $\delta^{18}O$ would be expected but it is not very clearly expressed.

A similar behaviour of all isotopic curves near the BØ-B1 sequence boundary (Antunes *et al.*, 1997b) can be observed in both sections: a drop in $\delta^{13}C$ content (less in $\delta^{18}O$ 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).

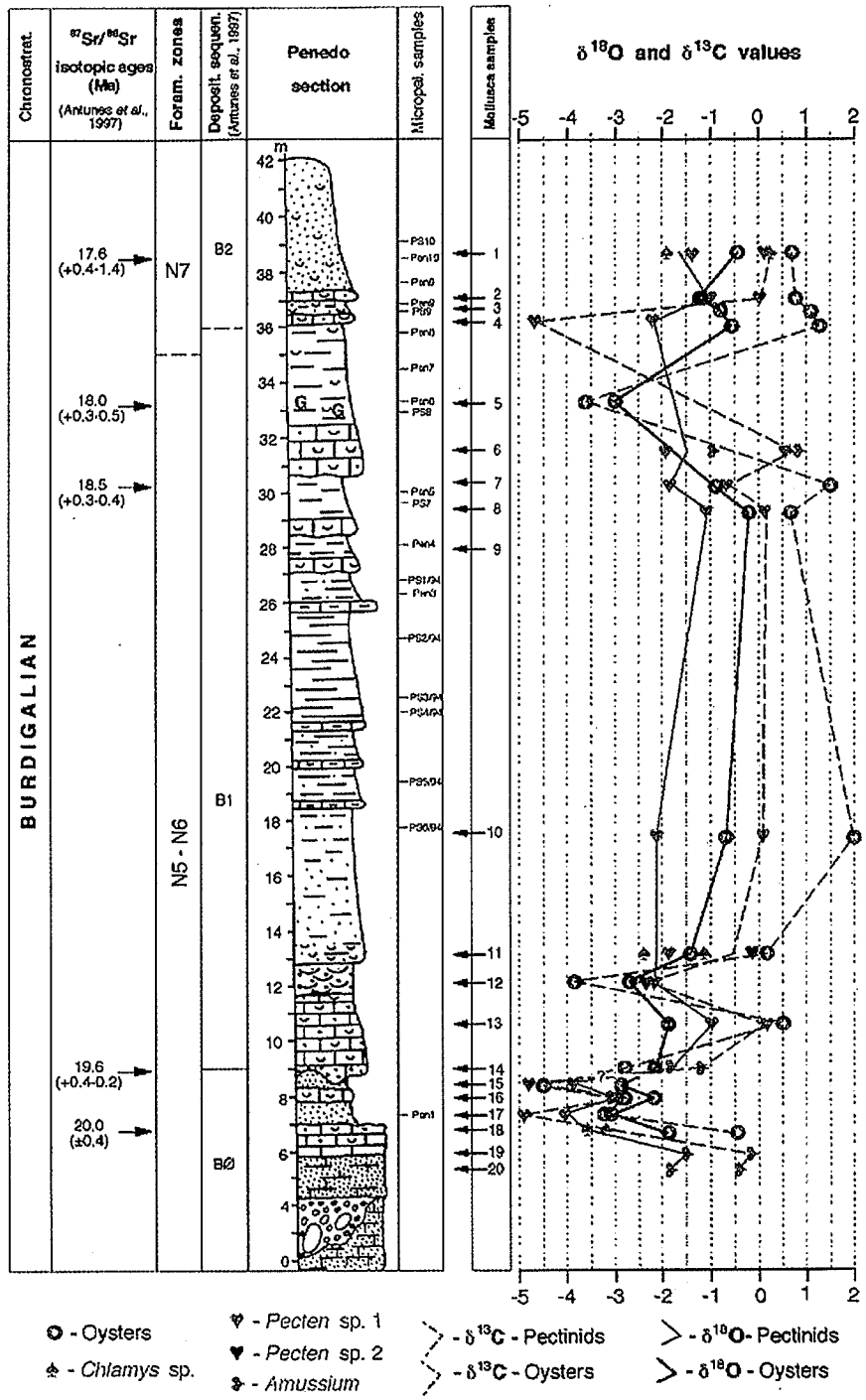

Fig. 3 - Penedo section and stable isotope data.

Fig. 3 - Sección de Penedo y datos isotópicos de C y O.

During the Burdigalian, a $\delta^{18}O$ 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 $\delta^{18}O$ 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 $\delta^{13}C$ while the oysters show a $\delta^{13}C$ rise; this can be related to resedimentation as at Penedo Norte and Ribeira da Lage sections (Antunes *et al.*, 1997a).

The $\delta^{13}C$ values from Foz da Fonte and Penedo are much lower than those from

Foz da Fonte samples	$\delta^{13}C$ (PDB)	$\delta^{18}O$ (PDB)	Penedo samples	$\delta^{13}C$ (PDB)	$\delta^{18}O$ (PDB)
1 OS	-1,933	-3,331	1-CH	0,491	-1 897
1 PEC	-3,317	-3,391	1-PEC	0,335	-1 490
2 CH	-1,595	-1,987	1-OS	0,690	-0,452
3 OS	-1,733	-2,656	2-PEC	-0,076	-1 023
3 PEC	-0,678	-2,560	2-OS	0,809	-1 253
3 PYC-F	-2,249	-3,278	3-OS	1 213	-0,770
3 PYC-V5	-3,046	-3,550	4-PEC	-4 668	-2 283
4 OS	-1,965	-2,558	4-OS	1 388	-0,558
5 OS	-0,967	-0,873	5-OS	-3 624	-2 940
5 PEC	-3,330	-3,237	6-AM	0,920	-1 096
6 OS	-2,819	-2,934	6-PEC	0,573	-1 961
6 PEC	-5,393	-3,291	7-PEC	-0,687	-1 915
7 AM	-0,652	-1,626	7-OS	1 558	-0,860
7 PYC	-1,951	-2,875	8-PEC	0,182	-1 153
8 OS	-6,236	-4,317	8-OS	0,636	-0,284
8 PEC	-5,135	-3,493	10-PEC	0,038	-2 105
9 OS	-5,100	-1,903	10-OS	2 075	-0,615
10 AM	-1,831	-2,814	11-CH	-1 183	-2 452
10 OS	-1,850	0,249	11-PEC-2	-0,115	-1 914
11 OS	-2,159	-2,844	11-OS	0,118	-1 448
11 PEC	-0,263	-1,375	12-PEC-2	-2 397	-2 319
12 PEC	0,698	-0,787	12-OS	-3 829	-2 269
13 OS	0,122	-0,969	13-PEC	0,111	-0,993
13 PEC	-1,656	-1,783	13-OS	0,525	-1 764
14 OS	1,390	-0,775	14-AM	-1 228	-1 891
14 PEC	-0,336	-0,747	14-OS	-2 811	-2 231
15 OS	1,119	-0,831	15-PEC	-4 872	-3 807
15 PEC	-0,633	-2,098	15-OS	-4 541	-2 771
16 PEC	-1,694	-1,680	16-AM	-2 898	-3 113
			16-OS	-2 732	-2 261
			17-PEC	-4 989	-4 041
			17-OS	-3 355	-3 133
			18-CH	-3 271	-3 592
			18-OS	-0,477	-1 710
			19-AM	-0,127	-1 561
			20-AM	-0,460	-1 960

Table 1.- Isotopic values for Foz da Fonte and Penedo sections. (OS - oyster, PEC - Pecten; AM- Amusium; CH- *Chlamys*; PYC - Pycnodont oyster)

Table 1.- Valores isotópicos para las secciones de Foz de Fonte y Penedo.

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

Conclusions

Biostratigraphy, palaeoecology, chronostratigraphy and isotopic data have improved our knowledge of Lower Miocene units from the western litoral area of the southern limb of Albufeira sincline.

The Foz da Fonte and Penedo sections yielded faunas that indicate N5-N6 (Burdigalian) although uppermost Penedo levels can reach N7. The paleoenvironments correspond to infralittoral, or circalittoral near infralittoral.

The isotopic curves present strong oscillations in both sections, mainly in respect to Pectinid $\delta^{13}C$ content which may attain 5δ. There is no covariation of δC and δO.

Striking variations of the isotopic values, mainly in $\delta^{13}C$, were observed near the depositional sequence boundaries.

During the Burdigalian there is a $\delta^{18}O$ increase tendency (water cooling). However, water temperatures were higher than today. A temperature maximum seems to have been attained about 19.6Ma (Lower Burdigalian).

$\delta^{13}C$ 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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References

Antunes, M.T., Civis, J., González-Delgado, J.A., Legoinha, P., Nascimento, A. and Pais, J. (1997a): *Geogaceta*, 21: 21-24.

Antunes, M.T., Elderfield, H., Legoinha, P. and Pais, J. (1997b): *Second Congress R.C.A.N.S.* Salamanca (Spain) October 1997, Abstracts: 25-27.

Antunes, M. T., Pais, J. and Legoinha, P. (1992): *Ciências da Terra (UNL)*, Número Especial II, Lisboa: 29-35.

Antunes, M.T., Legoinha, P., Nascimento, A. and Pais, J. (1995): *Mus. Lab. Min. geol. Univ. Porto*, Memória 4: 19-23.

Antunes, M.T., Legoinha, P., Nascimento, A. and Pais, J. (1996): *Géologie de la France*, 4: 1-16.

Berggren, W. A., Kent, D. V. Aubry, M.-P. and Hardenbol, J. (1995): *SEPM Special Publication* 54, 386 p.

Legoinha, P., (1993): *Dissertação de Provas de Aptidão Pedagógica e Capacidade Científica*, FCT/UNL, 78p.

Nascimento, A. (1988): *Dissertação de Doutoramento*, Univ. Nova de Lisboa, 305 p.

Sen, S., Antunes, M. T., Pais, J. and Legoinha, P. (1992): *Ciências da Terra (UNL)*, 11: 173-184.

Zbyszewski, G. (1967): *Com. Serv. Geol.Portugal*, Lisboa, LI: 37-148.

Zbyszewski, G., Veiga-Ferreira, O., Manuppella, G. and Assunção, C. (1965): *Carta geológica de Portugal na escala 1/50 000. Notícia explicativa da folha 38-B, Setúbal.* Serv. Geol. Portugal, Lisboa.