Upper Miocene planktonic foraminifera from Algarve.  
Chronostratigraphical implications

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Abstract

Key-words: Planktonic foraminifera; biostratigraphy; isotopic ages; chronostratigraphy; Upper Miocene; Algarve (Portugal).

New data on the planktonic foraminifera from the Upper Miocene Cacela Formation and Mem Moniz spongoliths are presented.

The coiling type of *Globorotalia menardii* from Cacela and Quelfes and the occurrence at Quelfes of *G. miotumida* allow correlation with the bio-events 1 to 3 (7,512 to 7,24 Ma; Sierro et al., 1993; 2001) that have been recognized in the Guadalquivir Basin (Spain). The presence of *Neogloboquadrina acostaensis* and *N. humerosa* at Mem Moniz points out to the Upper Miocene (Tortonian, upper N16, or even N17). Mem Moniz spongoliths are correlated with the Cacela Formation.

Some 87Sr/86Sr isotopic ages of mollusc or foraminifera shells don’t fit well with finer biostratigraphic record and present wide error margins.

Resumo

Palavras-chave: Foraminíferos planctónicos; bioestratigrafia; idades isotópicas; cronoostratigrafia; Miocénico superior; Algarve (Portugal).

São apresentados novos dados acerca da bioestratigrafia do Miocénico superior do Algarve (Formação de Cacela e espongolitos de Mem Moniz). Os foraminíferos planctónicos de Cacela e Quelfes, em especial o tipo de enrolamento de *Globorotalia gr. menardii* e a ocorrência de *Globorotalia miotumida* (em Quelfes) permitem correlações com os bio-evénitos 1 a 3 caracterizados na Bacia do Guadalquivir (7,512 to 7,24 Ma; Sierro et al., 1993; 2001). *Neogloboquadrina acostaensis* e *Neogloboquadrina humerosa* nos sedimentos de Mem Moniz permitem datá-los do Miocénico superior (Tortoniano, parte superior de N16 ou mesmo N17) e correlacioná-los com a Formação de Cacela.

Verifica-se desfasamento entre a informação bioestratigráfica, mais fina, e datações 87Sr/86Sr, que evidenciam grandes margens de erro.

Introduction

A comprehensive study of the chronostratigraphy of the Miocene of Portugal has been carried on. A synthesis on the Neogene of Algarve has been presented (Pais et al., 2002). The author has studied the Miocene planktonic foraminifera from the Lower Tagus Basin and Algarve (Legoinha, 2001). In this paper new data are presented on planktonic foraminifera from the Upper Miocene of Algarve, especially from Cacela Formation and Mem Moniz spongoliths.
The Caelela Formation (Antunes in Ribeiro et al., 1979) is exposed in eastern Algarve (Cacela, Quelfes). Basal levels are conglomerates and limestones with pebbles. Upwards, there are muddy or calcareous, often glauconite-rich sands. This Formation contacts by angular unconformity with the Triassic and by disconformity with the Lower to Middle Miocene, Lagos-Portimão Formation.

White spongioliths with diatoms, calcareous nanoplankton, foraminifera, ostracoda and fishes outcrop at Mem Moniz (Espoongolitos de Mem Moniz; Romariz et al., 1979). These deposits fill a tectonic depression. The concerned unit was ascribed to the Serravalian or Tortonian. However, several different age values had been proposed. Chronology can be settled now. Sediments like these are unknown elsewhere in Portugal.

The aims of this study are:

a) to review the published data concerning the planktonic biostratigraphy of Cacela, Quelfes and Mem Moniz;
b) to discuss new planktonic foraminifera data and 
\(^{87}\)Sr/\(^{86}\)Sr ages;
c) to improve the Upper Miocene chronostratigraphic knowledge of the Algarve;
d) to establish correlations with the bio-events defined in the Guadalquivir Basin (Sierrro et al., 1996).

Samples for foraminiferal study were disaggregated with a H\(_2\)O\(_2\) solution, and washed in a 125 \(\mu\)m sieve.

**Cacela**

**Location**

Outcrops near Cacela (Fig. 1). GPS coordinates: N 37° 09' 46", W 7° 32' 48.6". The upper part can be observed at the locality named Fábica.

**Geological setting**

Conglomerates and fine yellowish-gray sandstones outcrop at Ribeira de Cacela, corresponding to the basal levels of the Cacela Formation, Lower member. At Fábica, there are fine yellowish-orange sands intercalated with levels of carbonate concretions, the upper member of the same Formation (Antunes et al., 1981).

Cacela yielded the richest and best preserved Miocene mollusk fauna in Portugal. This fauna was described by Pereira da Costa (1866; 1867), Cotter (1879; in Dolfius et al., 1903-1904; in Choffat, 1950), Chavan in Bourcart & Zbyszewski (1940), Freneix (1957) and Brebion (1957).

In the last 30 years, a systematic study of the Algarve's Neogene have been carried on by researchers of the Centro de Estudos Geológicos, often in collaboration with foreign colleagues. The knowledge on palontology, stratigraphy and chronology has been improved (essential data concerning Cacela, Antunes et al., 1981; Antunes et al., 1990, 1997; González-Delgado et al., 1995; Pais et al. 2000; González-Delgado & Civis, 2000; Civis et al., 2000).

![Fig. 1 - Cacela Formation (Geological Map of Algarve, 1:100000; Manuppella, 1992): Ribeira de Cacela and Fábica outcrops.](image)

Bizon (in Antunes et al., 1981) found Globigerinoides extremus, Globorotalia aff. conomiozea, Globorotalia pseudoomiocenica, Globorotalia menardii, Globorotalia acostensis (sinist.) and Globorotalia humerosa (sinist.) that indicate the top of N16 or, probably, N17.

Sierrro (in Antunes et al., 1990) identified abundant planktonic foraminifera at Fábica, among others Globigerinoides extremus, Globigerinoides seigliei e Neogloboquadrina acostaensis (sinist.). The presence of the benthic Spiroplectammina carinata, which disappears in the basal Messinian, was remarked. The foraminiferal assemblage points out to the Upper Tortonian.

According to Nascimento (in Antunes et al., 1981), the Ostracoda indicate a Messinian age.

**Planktonic Foraminifera and biostratigraphic analysis**

The samples Ribeira Cacela 2 and Fábica 2 (Fig. 2) gave additional important data.

Ribeira Cacela 2 yielded sinistral menardiform Globorotalia. In the Guadalquivir Basin, Sierrro (1985) and Sierrro et al. (1993) characterized a succession of bio-events. The first one is the sharp reduction of Globorotalia menardii group I (sinist.) and the second one is marked by the appearance of Globorotalia menardii group II (dext.). Between these events, the temperate waters of North Atlantic and Mediterranean were almost deprived of keeled Globorotalia (Sierrro et al., 1993, p.143).

Fábica 2 yielded a rich and diversified planktonic assemblage, that does not include keeled Globorotalia. This assemblage comprises (Antunes et al., 1990): Globigerina bulloides, Globigerina aperture, Globigerina druryi, Globigerinita glutinata, Globigerinoides bulloides, Globigerinoides extremus, Globigerinoides seigliei, Globigerinoides immaturus, Orbulina universa, Orbulina suturealis, Globigerina quinqueloba, Globoquadrina globosa, Globorotalia scitula, Neogloboquadrina acostaensis (sinist.).
Cacela 2 and Fábrica 2 age is between that of the events 1 and 2 of the Guadalquivir Basin (respectively 7,512 and 7,35 Ma astronomic ages; Sierro et al., 2001).

Isotopic ages

$^{87}$Sr/$^{86}$Sr age of a bivalve mollusc gave 5.7 (+3.9 -1.1) Ma. This age seems too young in comparison with biostratigraphic data. Furthermore the margin of error is very wide. This could suggest that the calibration curve is not well established for this span of time.

**Quelfes**

**Location**

Samples were collected at some outcrops near Quelfes (Fig.3). GPS coordinates: N 37° 03' 18.3"; W 7° 49' 52.6".

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**Fig. 2 - Cacela section: chronostratigraphic framework; correlation with bioevents from the Guadalquivir Basin and $^{87}$Sr/$^{86}$Sr ages.**

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**Fig. 3 - Quelfes (Geological Map of Algarve, 1:100 000; Manuppella, 1992): the arrow points out to the location of the studied outcrops.**
Geological setting

Sands and marly silts, often with bioturbation structures, are exposed. A glauconite-rich level was recognised in the upper part. Basal beds are conglomeratic limestones with siliceous pebbles and limestone boulders.

These deposits belong to the Cacela Formation. Neogloboquadrina acostaensis (sinist. predominance), Globigerinoides extremus and some keeled Globorotalia (dext. predominance) point out to the Upper Tortonian. Sierro (in Antunes et al., 1990) stressed the possibility that the upper levels could be Messinian in age. In comparison with Guadalquivir Basin, the age of concerned deposits is sometime between events 2 and 3 (Sierro, 1985; Sierro et al., 1993).

Planktonic Foraminifera and biostratigraphic analysis

Samples Q2 and Q4 are the richest in planktonic foraminifers, while Q3 is the less rich (Fig.4). The following species were identified:

Q1 — Dentoglobigerina altispira, Globigerinoides bulloideus, Globigerinoides conglobatus, Globigerinoides extremus, Neogloboquadrina humerosa, Orbolina universa.

Q2 — Dentoglobigerina altispira, Globigerina bulloides, Globigerina praeccalida, Globigerinoides bullioideus, Globigerinoides conglobatus, Globigerinoides extremus, Globigerinoides seigliei, Neogloboquadrina humerosa, Orbolina sutilalis, Orbolina universa.

Q3 — Globigerinoides bulloideus, Globigerinoides seigliei, Orbolina sutilalis, Orbolina universa.

Q4 — Globigerina bulloides, Globigerina concina, Globigerinoides bullioideus, Globigerinoides elongatus, Globigerinoides extremus, Globigerinoides seigliei, Globorotalia gr. menardii (dext.), Globorotalia miotumida, Neogloboquadrina acostaensis, Neogloboquadrina humerosa, Orbolina universa.

Q5 — Globigerina bulloides, Globigerina druryi, Globigerinoides bullioideus, Globigerinoides trilobus, Globorotalia conomiozea, Orbolina sutilalis, Orbolina universa.

Biostratigraphic interpretation is shown (Fig.4). In the lower part, N. humerosa e G. conglobatus indicate the Upper Tortonian (probably N17). In the upper part G. miotumida and G. conomiozea point out to the Messinian (N17). Globorotalia gr. menardii (dext.) is still present in the Q4 sample. This suggests that the concerned levels may be correlated to the event 3 of the Guadalquivir Basin, marked by the replacement of the G. menardii group by the G. miotumida group (Sierro et al., 1993).

Isotopic ages

Shells of molluscs from different levels were dated 

$^{87}Sr/^{86}Sr: 5.3 (+4.3, -0.7) Ma, 5.2 (+4.4, -1.1) Ma, 5.2 (+4.4, -0.6) Ma. These ages seem too much younger than the expected age 7 (+1-1) Ma as established by Berggren et al. (1995) for N17. Let us recall that K/Ar glauconite age for two samples from Luz de Tavira (correlative of Quefles) is 6.88 ±0.4 Ma and 7.03 ±0.4 Ma (Antunes et al., 1986). Age of event 3 is 7,24 Ma (Sierro et al., 2001).

Mem Moniz

Location

Outcrops at Mem Moniz (Fig. 5) that border the national road EN395.

Geological setting

Withish sediments with some teleostean fish remnants (bones and scales) and high abundance of microfossils (spore skeletal elements, diatoms, calcareous nannofossils, planktonic foraminifera and ostracods). The lower contact is an angular unconformity over Cretaceous units (Romariz et al., 1979; Antunes et al., 1981). The stratigraphic position has been object of controversy. Sediments like these are unknown elsewhere in Portugal. In Spain, similar sediments are known to overlie the Guadalquivir olistostrome.

Prates (in Romariz et al., 1979) ascribed the Mem Moniz deposits to the Upper Burdigalian or Lower Langhian (N8 or N9) on planktonic foraminifera. According to Bizon (in Antunes et al., 1981), Globorotalia acostaensis (sinistral) points out to a Tortonian, N16 age.

Sierro (in Antunes et al., 1990) stressed that the predominance of Globigerina bulloides in association with Neogloboquadrina acostaensis, Globigerinoides bulloideus, Globigerina druryi, Globigerina quinqueloba and Globigerinita glutinata indicates at least N16. These sediments were ascribed to the Middle Serravallian (CN5a) on calcareous nannoplankton (Cachão, 1995).

$^{87}Sr/^{86}Sr age on planktic foraminifera was obtained: 12.5 (+0.7-1.7) Ma, Upper to Middle Serravallian (Antunes et al., 1997).

Planktonic Foraminifera and biostratigraphic analysis

Four samples were studied. The planktonic foraminifera frequency decreases from the lower to the middle part of the succession. They are more abundant again in the upper part. Foraminifera are well preserved but are smaller than usual.

The following species were identified: Globigerina angustiambilicata, Globigerina bulloides, Globigerina concina, Globigerina druryi, Globigerina falconensis,
### Fig. 4 - Chronostratigraphic framework of the Quelfes section; occurrence of planktonic markers, correlation with bioevents from the Guadalquivir Basin, and $^{87}$Sr/$^{86}$Sr ages.

<table>
<thead>
<tr>
<th>Thickness (m)</th>
<th>Quelfes section</th>
<th>Samples</th>
<th>CHRONOSTRATIGRAPHY</th>
<th>BIOSTRATIGRAPHY</th>
<th>Planktonic Foraminifera</th>
<th>$^{87}$Sr/$^{86}$Sr ages (Ma)</th>
<th>Guadalquivir Basin Bio-events (Siervo et al., 1996)</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>Q5</td>
<td>MESSINIAN</td>
<td>N17</td>
<td>Planktonic Foraminifera</td>
<td>5.2 (+4.4-0.6)</td>
<td>7.24 Ma</td>
</tr>
<tr>
<td>5</td>
<td>Q4</td>
<td>MESSINIAN</td>
<td>N17</td>
<td>Planktonic Foraminifera</td>
<td>5.3 (+4.3-0.7)</td>
<td>7.24 Ma</td>
<td></td>
</tr>
</tbody>
</table>
Isotopic ages

The $^{87}$Sr/$^{86}$Sr planktonic foraminifera shell age is seemingly too old — 12.5 (±0.7-1.7) Ma (Middle to Upper Serravallian). This age is not supported by biostratigraphic information and should be rejected.

Conclusions

1) Planktonic foraminifera and especially the coiling type of Globorotalia menardii group and the occurrence of Globorotalia miotumida at Quelfes allow correlation with the 1 to 3 bio-events in the Guadalquivir Basin (Sierro et al., 1993).

2) Cacela and Fábrica may thus be dated from the time span between Guadalquivir basin’s events 1 and 2 (7.512 and 7.35 Ma; Sierro et al. 2001).

3) At Quelfes, Globorotalia miotumida and G. menardii (dext.) may be correlated to event 3 (7.24 Ma).

4) In the upper part of the outcrop, Globorotalia conomiozea suggests a Messinian age (FAD 7.12 Ma; Berggren et al., 1995).

5) Glaucinite K/Ar ages from Luz de Tavira sediments, that can be correlated to those of Quelfes, yielded 6.88±0.4 Ma and 7.03±0.4 Ma; these ages fit well with the planktonic biostratigraphy.

6) Mem Moniz spongoliths can be ascribed to the Upper Miocene, Tortonian, upper part of N16 or N17.

7) There are important differences between the biostratigraphic information and the Sr$^{86}$/Sr$^{87}$ ages whose error margins are quite broad.

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References


Plate 1

Planktonic foraminifera. Scale, 100 μm.

Fig. 1 – Globorotalia miotumida Jenkins, 1960; Quelfes section.
Fig. 2 – Globorotalia gr. menardii (Parker, Jones & Brady, 1865); Quelfes section.
Fig. 3, 6 – Neogloboquadrina humerosa (Takayanagi & Saito, 1962); Mem Moniz section.
Fig. 4, 5 – Neogloboquadrina acostaensis (Blow, 1959); Mem Moniz section.
Fig. 7, 8 – Globorotalia (G) conomiozea Kennett, 1966; Quelfes section.
Fig. 9, 10 – Globigerinoides extremus Bolli, 1965; Quelfes section.