

Upper Miocene planktonic foraminifera from Algarve. Chronostratigraphical implications

Paulo Legoinha

Work supported by the Project "Studies on Portuguese Paleontology (Post-Paleozoic)" (POCTI/CVT/36351/99-00)

Centro de Estudos Geológicos (FCT/MCT), Universidade Nova de Lisboa, Faculdade de Ciências e Tecnologia, Quinta da Torre, P-2825-114
Caparica, Portugal; pal@fct.unl.pt

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 $^{87}\text{Sr}/^{86}\text{Sr}$ 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; biostratigrafia; idades isotópicas; cronostratigrafia; Miocénico superior; Algarve (Portugal).

São apresentados novos dados acerca da biostratigrafia 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-eventos 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 biostratigráfica, mais fina, e datações $^{87}\text{Sr}/^{86}\text{Sr}$, 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 Cacela 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 spongoliths with diatoms, calcareous nannoplankton, foraminifera, ostracoda and fishes outcrop at Mem Moniz (Espongolitos 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 $^{87}\text{Sr}/^{86}\text{Sr}$ 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 (Sierra *et al.*, 1996).

Samples for foraminiferal study were disaggregated with a H_2O_2 solution, and washed in a 125 μm 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 Fábrika.

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 Fábrika, 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* Dollfus *et al.*, 1903-1904; *in* Choffat, 1950), Chavan *in* Bourcart & Zbyszewski (1940), Freneix (1957) and Brébion (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 paleontology, 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).

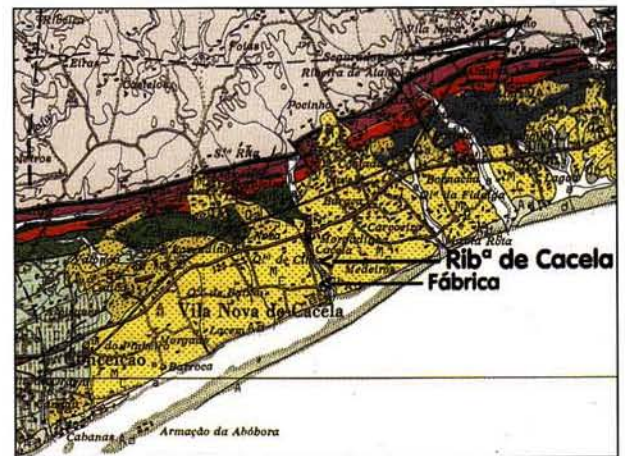


Fig. 1 - Cacela Formation (Geological Map of Algarve, 1:100000; Manuppella, 1992): Ribeira de Cacela and Fábrika outcrops.

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

Sierra (*in* Antunes *et al.*, 1990) identified abundant planktonic foraminifera at Fábrika, among others *Globigerinoides extremus*, *Globigerinoides seigliei* e *Neogloboquadrina acostaensis* (sinist.). The presence of the benthic *Spiroplectammia 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 Fábrika 2 (Fig. 2) gave additional important data.

Ribeira Cacela 2 yielded sinistral menardiform *Globorotalia*. In the Guadalquivir Basin, Sierra (1985) and Sierra *et al.* (1993) characterized a succession of bio-events. The first one is the sharp reduction of *Globorotalia menardii* group I (sinist.). 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* (Sierra *et al.*, 1993, p.143).

Fábrika 2 yielded a rich and diversified planktonic assemblage, that does not include keeled *Globorotalia*. This assemblage comprises (Antunes *et al.*, 1990): *Globigerina bulloides*, *Globigerina apertura*, *Globigerina druryi*, *Globigerinita glutinata*, *Globigerinoides bulloideus*, *Globigerinoides extremus*, *Globigerinoides seigliei*, *Globigerinoides immaturus*, *Orbulina universa*, *Orbulina suturalis*, *Globigerina quinqueloba*, *Globoquadrina globoşa*, *Globorotalia scitula*, *Neogloboquadrina acostaensis* (sinist.).

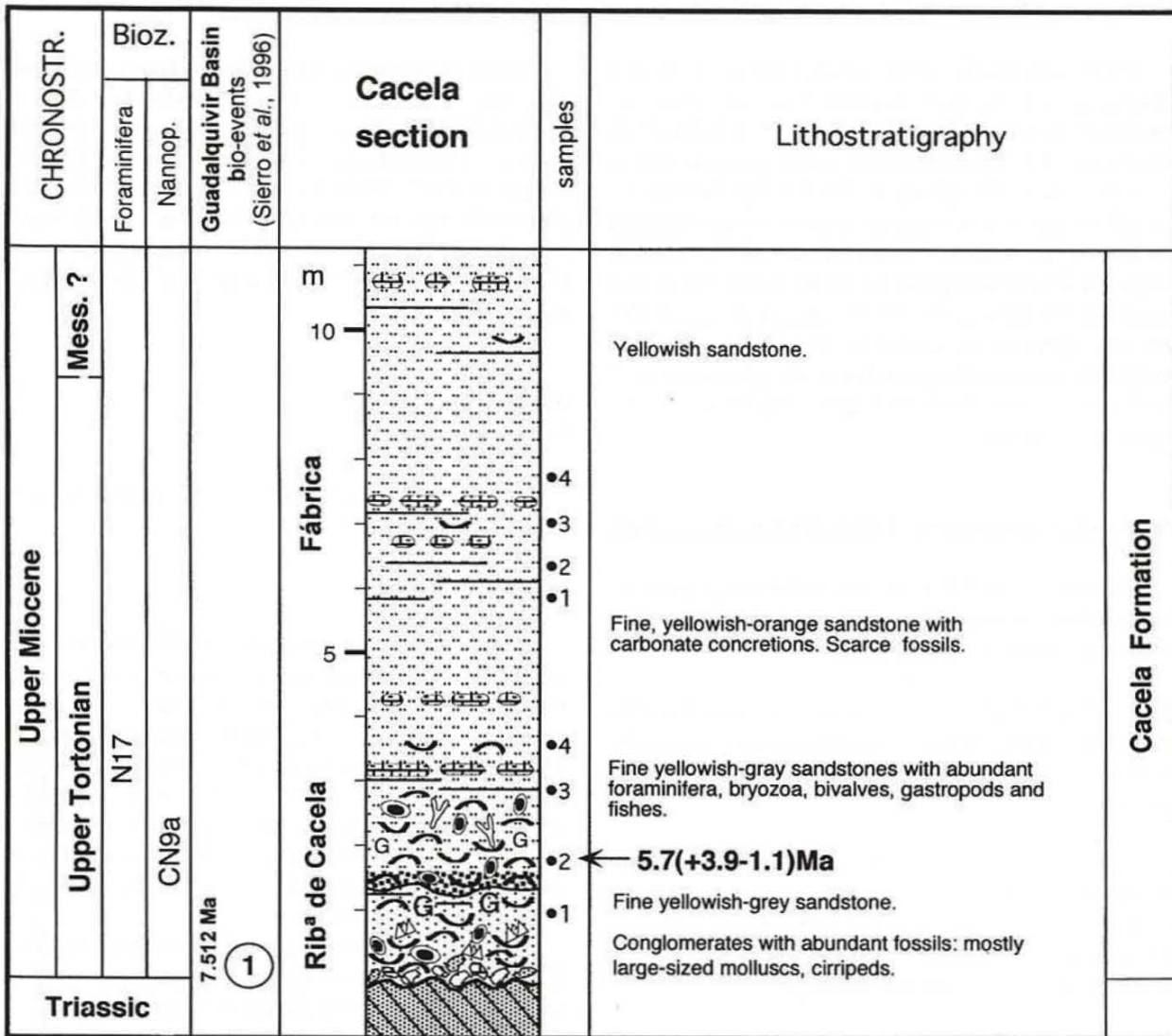


Fig. 2 - Cacela section: chronostratigraphic framework; correlation with bioevents from the Guadalquivir Basin and ⁸⁷Sr/⁸⁶Sr ages.

Cacela 2 and Fábrika 2 age is between that of the events 1 and 2 of the Guadalquivir Basin (respectively 7,512 and 7,35Ma astronomic ages; Sierro *et al.*, 2001).

Isotopic ages

⁸⁷Sr/⁸⁶Sr 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".

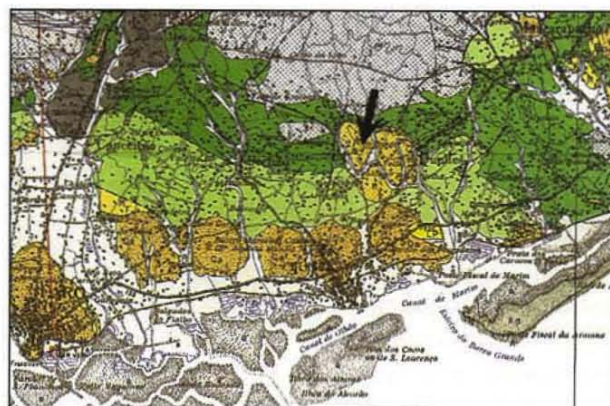


Fig. 3 - Quelfes (Geological Map of Algarve, 1:100 000; Manuppella, 1992): the arrow points out to the location of the studied outcrops.

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 Cacula 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*, *Orbulina universa*.

Q2 — *Dentoglobigerina altispira*, *Globigerina bulloides*, *Globigerina praecalida*, *Globigerinoides bulloideus*, *Globigerinoides conglobatus*, *Globigerinoides extremus*, *Globigerinoides seigliei*, *Neogloboquadrina humerosa*, *Orbulina suturalis*, *Orbulina universa*.

Q3 — *Globigerinoides bulloideus*, *Globigerinoides seigliei*, *Orbulina suturalis*, *Orbulina universa*.

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

Q5 — *Globigerina bulloides*, *Globigerina druryi*, *Globigerinoides bulloideus*, *Globigerinoides trilobus*, *Globorotalia conomiozea*, *Orbulina suturalis*, *Orbulina 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 $^{87}\text{Sr}/^{86}\text{Sr}$: 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 Quelfes) 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 (sponge 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).

$^{87}\text{Sr}/^{86}\text{Sr}$ 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 angustiumbilitata*, *Globigerina bulloides*, *Globigerina concina*, *Globigerina druryi*, *Globigerina falconensis*,

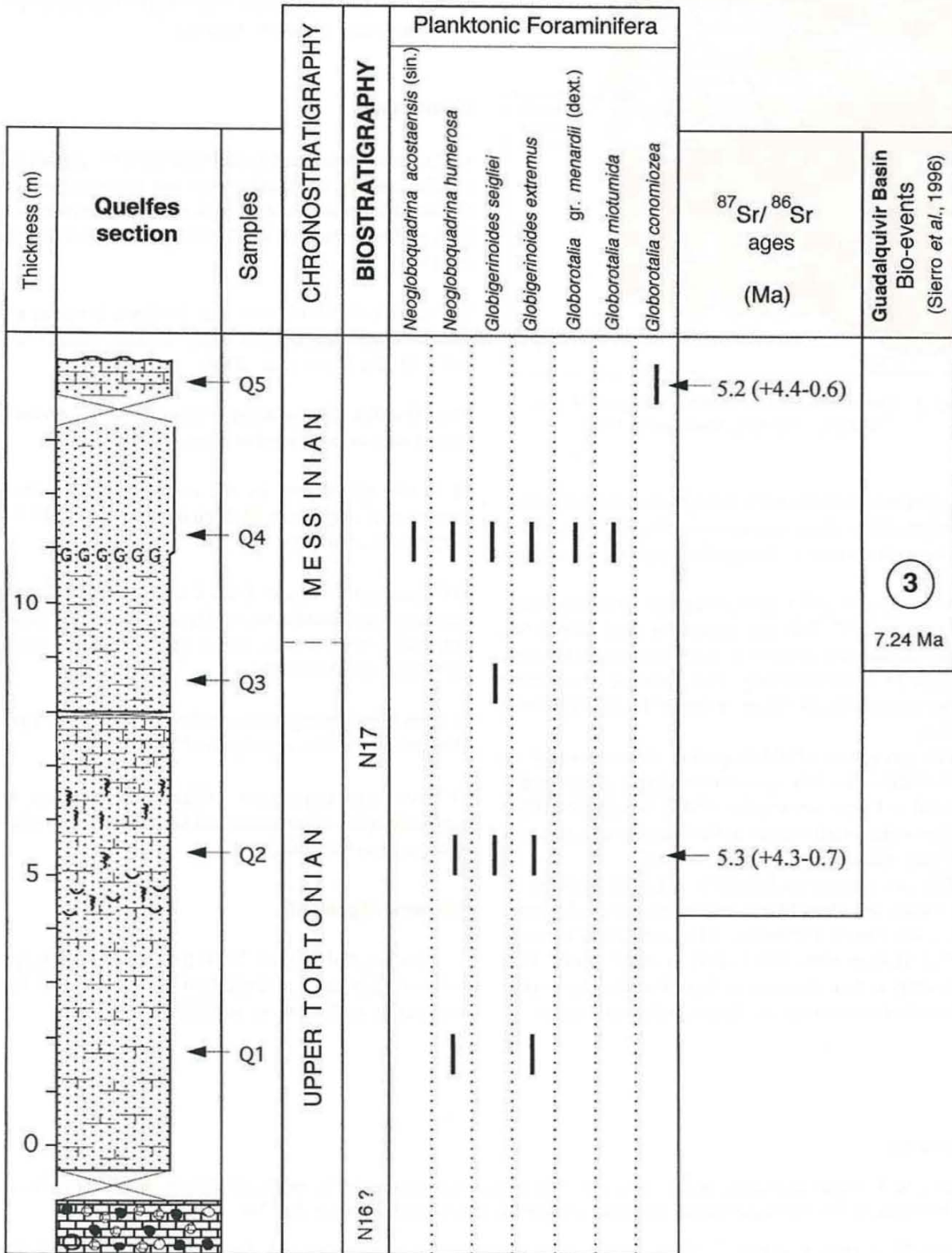


Fig. 4 - Chronostratigraphic framework of the Quelfes section; occurrence of planktonic markers, correlation with bioevents from the Guadalquivir Basin, and ⁸⁷Sr/⁸⁶Sr ages.

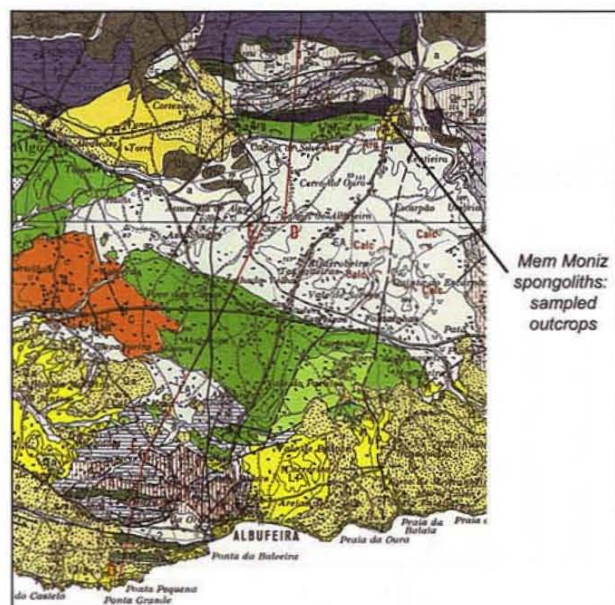


Fig. 5 - Spongoliths at Mem Moniz (Geological Map of Algarve, 1:100 000; Manuppella, 1992).

Globigerinella aequilateralis, *Globigerinoides bulloideus*, *Globoquadrina baroemoenensis*, *Neogloboquadrina acostaensis* (sinist.), *Neogloboquadrina humerosa* (sinist.).

N. acostaensis and *N. humerosa* point out to uppermost N16 or even N17. This age should be older than 6 Ma (Upper Messinian), as the *N. acostaensis* coiling direction changed to dextral coiling. The absence of carinate *Globorotalia* do not allow a better biostratigraphic accuracy.

The presence of *Globigerina druryi* could be problematic. The last appearance datum is generally regarded as Upper Serravallian (N14), but Sierro (1984) has shown that it still occurs in the Guadalquivir Basin in the Upper Miocene and Lower Pliocene.

This assemblage undoubtedly is Upper Miocene in age. Hence the Mem Moniz sediments are of the some age as the Cacela Formation. The correlation between Quelfes (lower part) and Cacela is most likely. This chronology is near the same as that of similar deposits in peri-mediterranean area, i.e. Spain, Italy and Argelia.

References

- Antunes, M. T.; Bizon, G.; Nascimento, A. & Pais, J. (1981) - Nouvelles données sur la datation des dépôts miocènes de l'Algarve (Portugal), et l'évolution géologique regionale. *Ciências da Terra (UNL)*, Lisboa, 6: 153-168.
- Antunes, M. T.; Odin, G. & Pais, J. (1986) - Âges K/Ar de glauconies des environs de Luz de Tavira, Algarve. *Ciências da Terra (UNL)*, Lisboa, 8: 22-30.
- Antunes, M. T.; Civis, J.; Dabrio, C. J.; Sierro, F. J.; González-Delgado, J. A.; Flores, J. A.; Pais, J. & Valle, M. (1990) - El Neogeno del Algarve (Portugal) y de la cuenca del Guadalquivir (España). *Actas de Paleontología, Universidad de Salamanca*, 68: 65-73.
- Antunes, M. T.; Elderfield, H.; Legoinha, P., & Pais, J. (1997) - *The Neogene of Algarve in Field Trip Guide - Excursion 2 / The Guadalquivir Basin and Algarve (Spain, Portugal)*. II Congress R.C.A.N.S., Spain.

Isotopic ages

The $^{87}\text{Sr}/^{86}\text{Sr}$ 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 Fábrika 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) Glauconite 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 $\text{Sr}^{86}/\text{Sr}^{87}$ ages whose error margins are quite broad.

Acknowledgements

I am grateful to Prof. M. Telles Antunes for helpful review of this paper. I thank Prof. João Pais for aid and cooperation on field work and SEM photography.

- Berggren, W. A.; Kent, D. V.; Aubry, M.-P. & Hardenbol, J. (1995) - Geochronology, time scales and global stratigraphic correlation. *SEPM, Special Publication*, 54: 386 p.
- Cachão, M. (1995) - *Utilização de nanofósseis calcários em biostratigrafia, paleoceanografia e paleoecologia. Aplicações ao Neogénico do Algarve (Portugal) e do Mediterrâneo Ocidental (ODP 653) e à problemática de Coccolithus pelagicus*. Dissertação de Doutoramento, Universidade de Lisboa, 356 p.
- Civis, J.; Pais, J.; González-Delgado, J. A. & Legoinha, P. (2000) - Síntesis paleontológica del Tortonense superior de Cacela (Algarve, Portugal). *I Congreso Ibérico de Paleontología/XVI Jornadas de la Sociedad Española de Paleontología - Livro de Resumos*: 10-11.
- Dollfus, G.; Cotter, J. C. B. & Gomes, J. P. (1903-1904)- Mollusques tertiaires du Portugal. Planches de Céphalopodes, Gastéropodes et Pélécypodes laissées par F.A. Pereira da Costa accompagnées d'une explication sommaire et d'une esquisse géologique. *Mem. Comm. Serv. Geol. Portugal*, Lisboa: 48 p.
- González-Delgado, J. A. & Civis, J. (2000).- Ciclicidad estacional en perfiles de isótopos estables de C y O del bivalvo *Megacardita jouanneti* del Tortonense superior de Cacela (Algarve, Portugal) y Arroyo Trujillo (Sevilla, España). *Ciências da Terra (UNL)*, Lisboa, 14: 297-302.
- Legoinha, P. (2001) - *Biostratigrafia de Foraminíferos do Miocénico de Portugal (Baixo Tejo e Algarve)*. Dissertação de doutoramento, Universidade Nova de Lisboa, 241 p., 24 est.
- Manuppella, G. (Coord.) (1992) - Carta Geológica da região do Algarve, folha ocidental, na escala 1:100 000. *Serviços Geológicos de Portugal*.
- Pais, J.; Legoinha, P.; Elderfield, H.; Sousa, L. & Estevens, M. (2000) - The Neogene of Algarve. *Ciências da Terra (UNL)*, Lisboa, 14: 277-288.
- Pereira da Costa, F. A. (1866) - Molluscos fósseis/gasterópodes dos depósitos terciários de Portugal. *Comissão Geológica de Portugal*. 1º Caderno, 116 p.
- Pereira da Costa, F. A. (1867) - Molluscos fósseis/gasterópodes dos depósitos terciários de Portugal. *Comissão Geológica de Portugal*. 2º Caderno: 117-252.
- Ribeiro, A.; Antunes, M. T.; Ferreira, M. P.; Rocha, R.; Soares, A. F.; Zbyszewski, G.; Moitinho de Almeida, F.; Carvalho, D. & Monteiro, J. H. (1979) - Introduction à la Géologie générale du Portugal. *Serv. Geol. de Portugal*, Lisboa: 114 p.
- Romariz, C.; Correia, F. & Prates, S. (1979) - Contributions to the geology of Algarve, Portugal. III - Un nouveaux [sic] facies du Miocène. *Bol. Mus. Lab. Min. Geol. Fac. Ciênc. Lisboa*, 16 (1): 265-271.
- Sierro, F. J. (1985) - The replacement of the *Globorotalia menardii* group by the *Globorotalia miotumida* group: an aid to recognizing the Tortonian-Messinian boundary in the Mediterranean and the adjacent Atlantic. *Marine Micropaleontology*, 9: 525-535.
- Sierro, F. J.; Flores, J. A.; Civis, J.; González-Delgado, J. A. & Francés, G. (1993) - Late Miocene globorotaliid event-stratigraphy and biogeography in the NE-Atlantic and Mediterranean. *Marine Micropaleontology*, 21: 143-168.
- Sierro, F. J.; Hilgen, F. J.; Krijgsman, W. & Flores, J. A. (2001) - The Abad composite (SE Spain): a Messinian reference section for the Mediterranean and the APTS. *Paleogeography, Paleoclimatology, Paleocology*, 168: 141-169.

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.

PLATE 1

