Marine Micropaleontology, 9 (1985): 525—535
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

THE REPLACEMENT OF THE "*GLOBOROTALIA MENARDII*" GROUP BY THE *GLOBOROTALIA MIOTUMIDA* GROUP: AN AID TO RECOGNIZING THE TORTONIAN-MESSINIAN BOUNDARY IN THE MEDITERRANEAN AND ADJACENT ATLANTIC

FRANCISCO J. SIERRO

Department of Paleontology, University of Salamanca, 37008 Salamanca (Spain)

(Received July 2, 1984; in revised form accepted June 3, 1985)

Abstract

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 adjacent Atlantic. Mar. Micropaleontol., 9: 525—535.

Different authors working in the Mediterranean area have reported a distinctive change in the assemblages of keeled globorotaliids coinciding with the FAD of *Globorotalia conomiozea* Kennett. This change which has now been observed in the Guadalquivir basin consists of the abrupt disappearance of the "*Globorotalia menardii*" group, which is then replaced by the *Globorotalia miotumida* group.

This event has been found in a number of areas of the Atlantic Ocean and it is proposed that it can be used to recognize the Tortonian—Messinian boundary in this realm where *G. conomiozea* occurs only sporadically.

Introduction

Globorotalia menardii (Parker, Jones and Brady) is frequently found in the Mediterranean Miocene but it has not been found in rocks younger than the Messinian evaporitic event. The systematic confusion concerning this species and other similar keeled globorotaliids makes them difficult to study, impeding proper research of the evolution and development of this group of species, generally referred to as menardiform globorotaliids.

Globorotalia menardii described by D'Orbigny from specimens collected in Italy, poses serious taxonomic problems which have already been discussed by many workers (e.g., Banner and Blow, 1960; Bizon and Bizon, 1970; Stainforth et al., 1975; Serrano, 1979) and I use the name in an informal way. I think that the name *G. menardii* has been used for very different species and consequently I prefer to use the name of the group to include a series of populations related to each other, whose central types are included in *Globorotalia cultrata* s.l., *Globorotalia plesiotumida* and *Globorotalia merotumida*.

The *Globorotalia miotumida* group (*G. miotumida* Jenkins and *G. conomiozea* Kennett) was described in the Pacific. In the Mediterranean this group has very frequently been cited under the name of *Globorotalia dalii* Perconig—*Globorotalia mediterranea* Catalano and Sprovieri; however, strong controversy exists concerning the reason for their occurrence in this area; its appearance is related to a true evolutionary appearance or to immigration from the Pacific.

0377-8398/85/$03.30

The study of these two groups and their relationships in the Guadalquivir basin (Southern Spain) is of great interest for demonstrating the interactions between the Atlantic and Mediterranean realms, since it has long been known that the Guadalquivir basin and the Southern Riff depression (North of Morocco) are probably the passages which communicated the two domains during the Upper Miocene times.

Research area

The present study was carried out on samples collected from several sections of the western Guadalquivir basin (Sevilla and Huelva provinces) (Fig. 1). In general the Neogene filling of the basin can be split into three units which represent a complete sedimentary cycle: unit I is detritic and transgressive over the Paleozoic basement of the Iberian Meseta. It consists of a basal conglomerate of about 1 m thick, formed by large blocks derived from Paleozoic rocks, overlain by sandy or calcarenitic layers of varying thickness, usually topped by glauconite-rich sands. Unit 2 is composed of up to 1000 m thick grey-blue clays and minor silts with sandy intercalations. The Upper Neogene marine unit, unit 3, consists of about 10—40 m of yellowish, fine-grained sands to silts with abundant macrofauna, particularly bivalves, gastropods, scaphopods, fish remains, cirripeds, etc. The transition between units 2 and 3 is generally marked by a layer of glauconitic sandy silts. Younger continental deposits are also found.

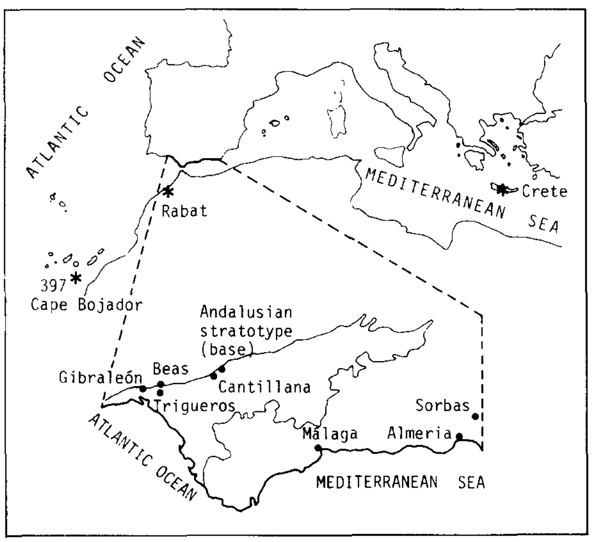


Fig. 1. Location map of the Guadalquivir basin and other places cited in the text.

Despite the remarkable lithological monotony of unit 2, major changes in planktonic foraminiferal assemblages (specially the keeled globorotaliids) are recorded. These changes are assumed to have a regional significance.

The "*G. menardii*" group, which is very abundant in unit 1 and the lower part of unit 2, disappears suddenly and is replaced by the *G. miotumida* group. This change has been observed in all the sections studied along the northern edge of the basin where the lower part of unit 2 crops out, as for example in the Gibraleón, Beas and Trigueros sections, which will be described below, or Cantillana and the lower part of the Andalusian stratotype (Arroyo Galapagar) sections, that are at present under study.

It is not the author's goal to discuss the biostratigraphy of the Neogene in the Guadalquivir basin, which has been analyzed elsewhere (Sierro, 1984), but to provide a schematic picture of the major events observed. These events are the following: (1) The disappearance of sinistral forms of the "*G. menardii*" group, located approximately at the transition between unit 1 and unit 2, though this event is not found in the sections to be discussed below. (2) The appearance of abundant dextral forms, after a short interval in which the group is almost absent (in this interval the keeled globorotaliids are replaced by the *Globorotalia scitula* group). (3) Replacement of the "*G. menardii*" group by sinistral forms of *G. miotumida*; the study of this event is the aim of this paper. (4) A shift in the coiling direction of the

Turborotalia acostaensis group. (5) The abrupt disappearance of the *G. miotumida* group. (6) The FAD of *Globorotalia margaritae* s.s. Bolli and Bermudez. (The short period between the disappearance of the *G. miotumida* group and this event is characterized by a renewed abundance of the *G. scitula* group and particularly by the presumed ancestors of *G. margaritae*.) (7) The FAD of *Globorotalia puncticulata* Deshayes in unit 3.

The Gibraleón section

This section is located next to Gibraleón at a clay quarry on the road to Trigueros (province of Huelva). The succession begins with a 2 m thick layer of glauconitic sands in which the transition between unit 1 and unit 2 occurs, overlain by some 15 m of unstratified grey yellowish clays with a carbonate content ranging between 10 and 30%.

Planktonic Foraminifera consistently predominate over benthonic forms in the clay layers, with percentages ranging between 60 and 80%. The most remarkable feature of this section is the prominent disappearance of representatives of the "*G. menardii*" group (*G. cultrata* s.l., *G. merotumida* and *G. plesiotumida*) between samples GB.6 and GB.7. The "*G. menardii*" group is relatively abundant in the lower part of the section, sometimes exceeding 10% of the overall planktonic Foraminifera (>149 μm fractions) but they are abruptly replaced by *Globorotalia miotumida*, which is not found below sample GB.7. *Globorotalia miotumida* is abundant from sample GB.7 upwards, reaching values up to 20%. Accompanying *G. miotumida* there are specimens which are transitional between this species and *Globorotalia conomiozea*, and, very sporadically, some typical individuals of *G. conomiozea*. In samples GB.1 and GB.2 one specimen of *G. conomiozea* was found prior to the abundant appearance of the group.

Note also that this change involves a shift in coiling direction, since the "*G. menardii*" group is predominantly dextral, whereas the *G. miotumida* group is sinistral.

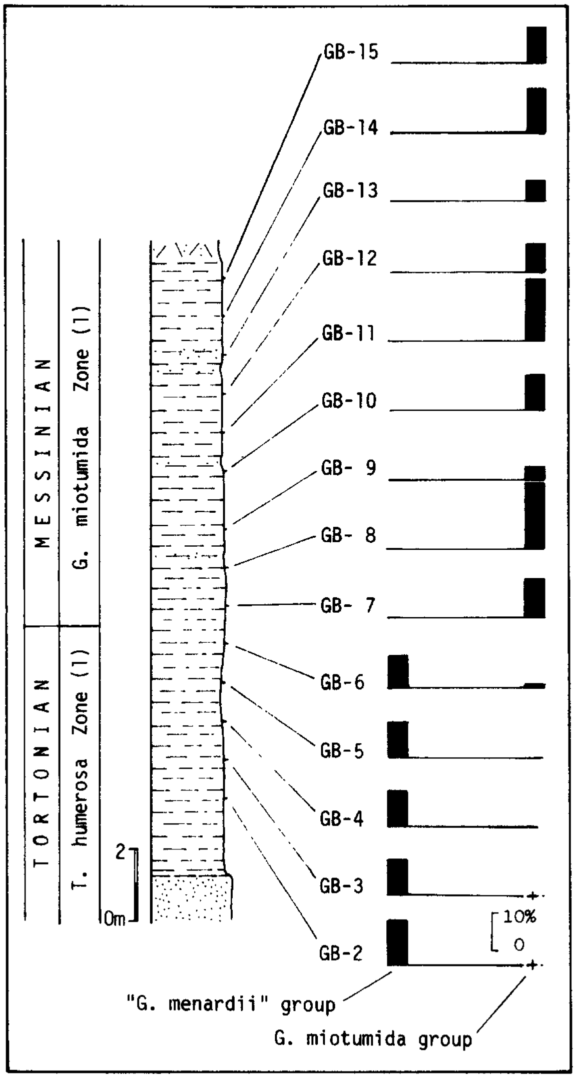
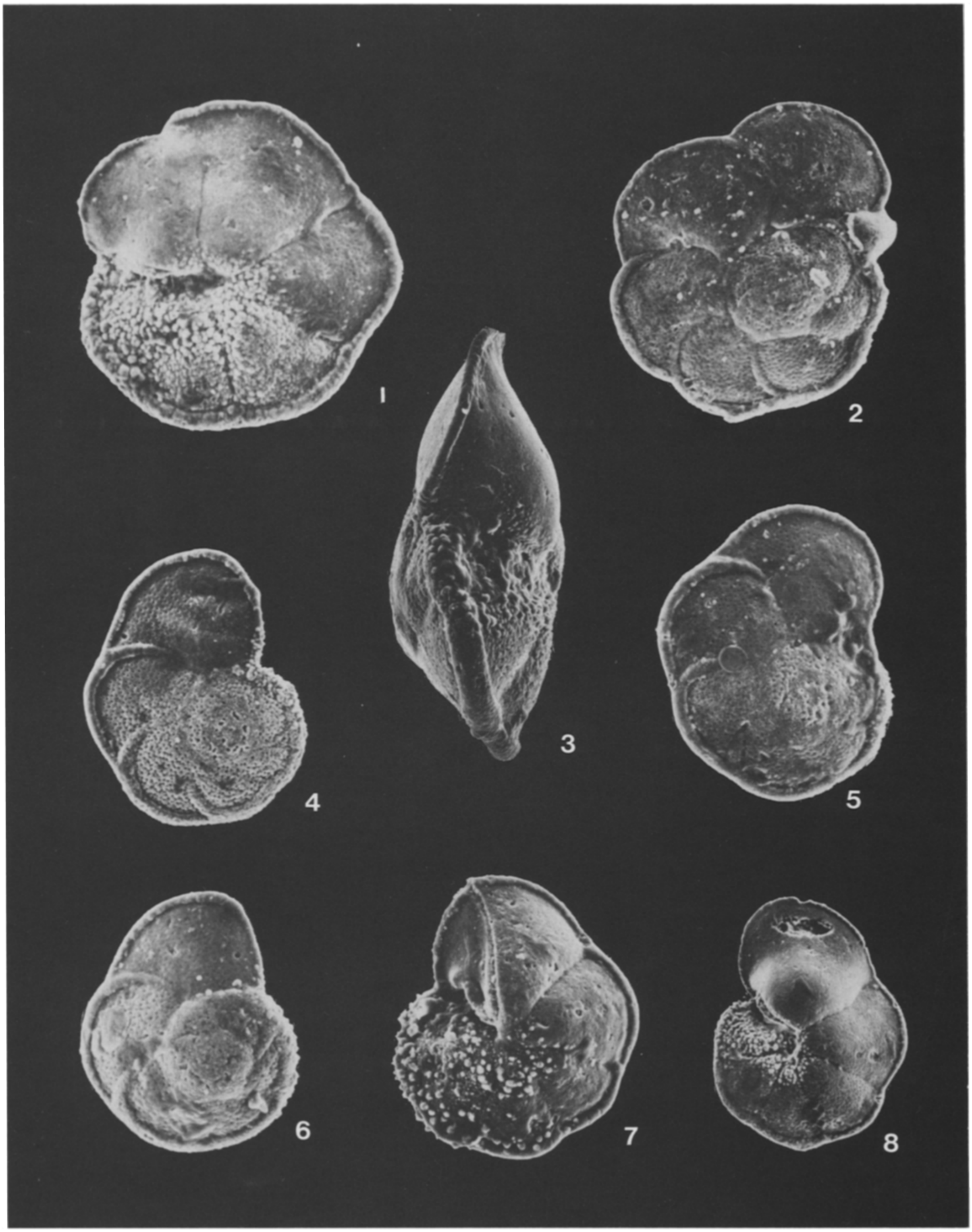


Fig. 2. Distribution and relative abundance of the "*G. menardii*" and *G. miotumida* groups in the Gibraleón section. (*1*) = After Sierro (1984).

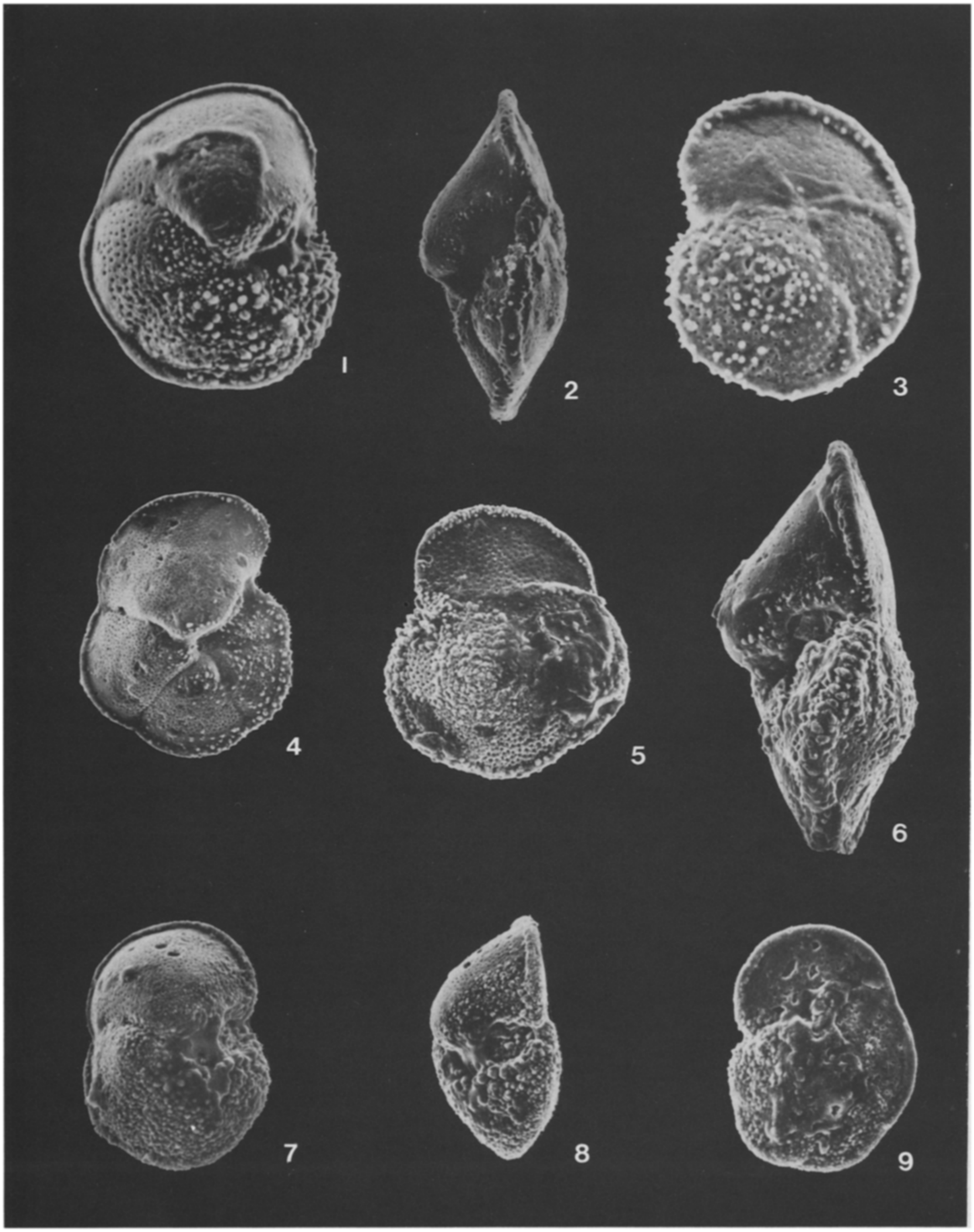
Coinciding with this horizon, variations in the calcareous nannoplankton take place (J.A. Flores, personal communication, 1984); however, the remaining planktonic Foraminifera are scarcely altered and there are no visible changes of lithology, carbonate and mud contents.

PLATE I



(For explanation see p. 530)

PLATE II



(For explanation see p. 530)

PLATE I (see p. 528)

("*G. Menardii*" Group)

1—3. *Globorotalia cultrata* s.l. (Brady), section Beas, BE-4, × 140. 4—5. *Globorotalia plesiotumida* Banner and Blow, × 140: 4 = Andalusian type section, basal part; 5 = section Beas, BE-2. 6—7. *Globorotalia merotumida*, section Beas, BE-2, × 230. 8. Specimen transitional between *Globorotalia plesiotumida* and *Globorotalia cultrata* s.l., section Beas, BE-2, × 80.

PLATE II (See p. 529)

(*G. miotumida* Group)

1—6. *Globorotalia miotumida* Jenkins: 1 = section Trigueros, TR-1, × 225; 2—6 = section Beas, BE-4, 2 (× 150), 3,6 (× 200), 4,5 (× 110). 7—9. *Globorotalia conomiozea* Kennett, section Gibraleón, GB-8, × 200.

The Beas section

The lithology of this section is similar to that of Gibraleón: basal thin transgressive calcarenite lying unconformably over the Paleozoic rocks, 2 m of glauconitic sands and 7 m of clays. The passage from unit 1 to unit 2 occurs within the glauconitic sands.

In the clay unit, planktonic Foraminifera predominate over the benthonic, the ratio varying between 60 and 80%, except in the lower levels where both groups are represented equally.

The assemblages of planktonic Foraminifera are generally similar to those of Gibraleón and the same change of keeled globorotaliids occurs, that is, the "*G. menardii*" group is replaced by the *G. miotumida* group. However, in this section, the replacement takes place more gradually between samples BE-3 and BE-5 such that in BE-3 both groups coexist, with a predominance of the former group, while the situation is the reverse in BE-4. At the top of the section (BE-5) the "*G. menardii*" group disappears altogether. Similar to the situation at Gibraleón, some changes in the assemblages of calcareous nannoplankton have been noted (J.A. Flores, personal communication, 1984).

The Trigueros section

This section is south of Beas and shows younger sediments consisting of clay in the lower part, interlayered clay and silt in the middle part and sandy silts towards the top. The assemblage of keeled globorotaliids is completely dominated by the *G. miotumida* group (Fig. 3); on the other hand the *Turborotalia acostaensis* group exhibits a coiling shift from sinistral to dextral in the upper part of the section.

The Tortonian—Messinian boundary

The Tortonian—Messinian boundary (sensu D'Onofrio et al., 1975) is marked in the Mediterranean by the appearance of new species of *Globorotalia*, characterized by a strong ventral convexity, such as *G. conomiozea* Kennett, *G. mediterranea* Catalano and Sprovieri, *G. saphoae* Bizon and Bizon, etc. According to various authors, some of these species are autochthonous in the Mediterranean and their occurrence is a good marker of the Messinian in this realm.

In the Atlantic, these species appear only sporadically and often they are not found at all. In these cases the boundary must be

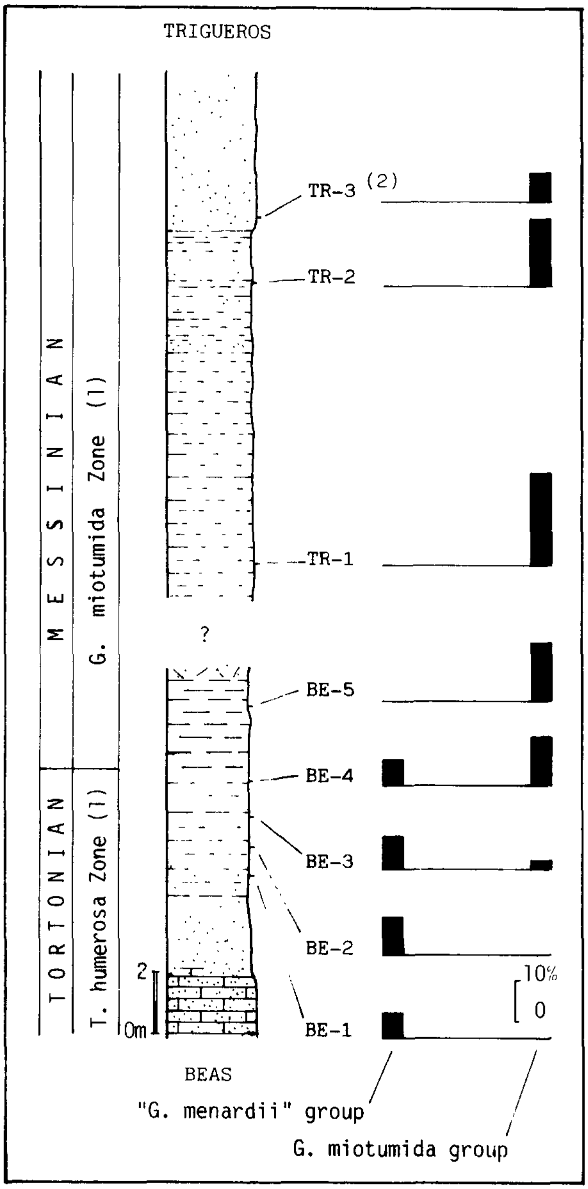


Fig. 3. Distribution and relative abundance of the *G. miotumida* and "*G. menardii*" groups in the Beas and Trigueros sections. (*1*) = After Sierro (1984). (*2*) = In this horizon the coiling of the *T. acostaensis* group shifts from sinistral to dextral.

defined on the basis of other criteria, specially the calcareous nannoplankton, as for example the FAD of *Amaurolithus delicatus* (Gartner and Bukry), which approximately coincides with the FAD of *G. conomiozea* in the Mediterranean realm.

Zachariasse (1975) was the first to report that together with *G. conomiozea*, a new species, *Globorotalia dalii* (= *G. miotumida* in this paper), occurs in the Miocene of Crete (Greece) and other areas of the Mediterranean. Thus the base of Zachariasse's *G. conomiozea* zone is defined either by the appearance of the zonal marker or by the presence of *Globorotalia dalii*. Both species seem to mutually exclude each other and either one or the other is present, according to the area considered. He also reported that *G. dalii* or *G. conomiozea* succeed *G. menardii* form 5 (dextral coiled specimens). This change has also been observed in the Capodarso section (Messinian stratotype), though here the "*G. menardii*" group is represented by *G. menardii* form 4 (sinistral coiled specimens).

Zachariasse (1979a, b) considered *G. miotumida* and *G. conomiozea* to be two extreme morphotypes of a single evolutionary cline with different geographical distributions due to environmental control. In an exhaustive study carried out in the Pothamida section (Crete), Zachariasse reported a vertical replacement of *G. menardii* form 5 by *G. miotumida*, and this remarkable faunal change coincides with the FAD of *G. conomiozea*; Zachariasse (op. cit.) wondered if this abrupt change in the keeled globorotaliids is the result of a major change in the environmental conditions of the Mediterranean or a immigration from the Atlantic Ocean.

As pointed out by Zachariasse (1979a, b) the Atlantic influence in the evolution of foraminiferal plankton in the Mediterranean during the Upper Miocene is obvious. In this sense, it is significant that the changes in the assemblages of keeled globorotaliids described by Zachariasse (1975) in Crete have been observed in the Guadalquivir basin, in the South Riff depression of Morocco, and other places of the Atlantic and Mediterranean realms. The sudden replacement of the "*G. menardii*" group by that of *G. miotumida* takes place in both areas between the horizons of coiling shift from sinistral to dextral of the "*G. menardii*" and *T. acostaensis* groups. For this correlation, I assume that the specimens with a low ventral convexity and dextral coiling, included here in the "*G. menardii*" group, are approximately equivalent to *G. menardii* form 5.

Some authors seem to have found a similar horizon across the Mediterranean. In Southern Spain, Gonzalez Donoso and Serrano (1977) studied the planktonic Foraminifera of the Chozas and Turre formations in the Sorbas basin (province of Almería) where, in spite of the discontinuity of the sampling due to the presence of calcarenites, they report a coiling shift from sinistral to dextral in the "*G. menardii*" group followed by a generalized appearance of the *G. dalii—G. mediterranea* group (equivalent to the *G. miotumida—G. conomiozea* group in this paper). According to these authors, the change of assemblages coincides with the Tortonian—Messinian boundary. Thus a succession of events similar to that found in the Guadalquivir basin, in Morocco and in Crete seems to have taken place in Almería too.

In the area of Málaga (South Spain), Carrasco et al. (1977) have studied samples from two borings in the mouth of the Velez River. They report a clayey sequence unconformably overlying the Paleozoic basement. Numerous keeled dextral globorotaliids are found in most of the succession. However, towards the top *G. mediterranea* and specimens of transition between it and *G. dalii* (sinistral coiling) become abundant. These authors correlate the appearance of this group with the Tortonian—Messinian boundary.

In Italy, D'Onofrio et al. (1975) report an abundance of *G. cultrata* in the top of the zone of *G. acostaensis* (Tortonian), though they also point out the existence of rich populations of *G. miotumida* in the basal part of the zone of *G. conomiozea* (Messinian).

According to these data it seems evident that the replacement is a generalized feature throughout the Mediterranean realm, coinciding with the FAD of *G. conomiozea*. However, what about the Atlantic domain?

Feinberg and Lorenz (1970) were the first (prior to the above-mentioned authors) to recognize a similar event in the Atlantic realm at the Bou-Regreg area close to Rabat (Morocco). They defined a horizon characterized by the disappearance of *G. miocenica* s.l. and *G. menardii*; (="*G. menardii*" group); this horizon separates the biozone of *G. miocenica* s.l. from the biozone of *G. dalii—G. dutertrei*, which is characterized by an abundance of *G. dalii* (= *G. miotumida*).

In the same region, Bossio et al. (1976) report a succession of events that completely coincides with the one found in the Guadalquivir basin and in other parts of the Mediterranean realm. The keeled globorotaliids of the *G. cultrata* group are very common at the base and "elles deviennent tout à coup rares et sporadiques", whereas *G. miotumida*, which is rare at lower levels, "elle devient tout à coup fréquente en concomitance avec le soudain appauvrissement de *G.* gr. *cultrata*" (Bossio et al., 1976). It is important to note that, according to Bossio et al. (1976), this horizon coincides with the FAD of *G. conomiozea* in that region, postdates the shift in the coiling direction of the "*G. menardii*" group and is prior to the coiling change in the *T. acostaensis* group.

Salvatorini and Cita (1979) working at Cape Bojador D.S.D.P. site 397, observed an interval in which *G. miotumida* is extremely abundant, but they did not refer to the relationship between this species and *G. cultrata*. They considered its base to be immediately prior to the FAD of *Amaurolithus delicatus*, which for Mazzei et al. (1979) constitutes the Tortonian—Messinian boundary in this site. Does this interval coincide with the one observed in Morocco, the Guadalquivir basin and other areas of the Mediterranean?

According to the references just mentioned, a rapid change in the assemblages of keeled globorotaliids of the Mediterranean and adjacent Atlantic took place coincident with the FAD of *G. conomiozea* but the reason for the abrupt appearance of the *G. miotumida* group in the NE Atlantic and in the Mediterranean is unknown. Nevertheless, the replacement of the tropical and subtropical "*G. menardii*" group by that of *G. miotumida* seems to be significant, suggesting a slight cooling of sea waters as pointed out by Feinberg and Lorenz (1970), Van der Zwaan (1979) and Zachariasse and Spaak (1983).

The origin of the *G. conomiozea* group (*G. miotumida* group in this paper) has given rise to considerable controversy between those authors who place its autochthonous origin in the Mediterranean and those who consider it to be an immigrant form from the Pacific.

According to Zachariasse's (1979a) review, "*G. menardii* forms 4 and 5 belong to a group of ecophenotypes with the genetic potential to attain the morphology of *G. conomiozea*".

Poore (1981) mentions an aspect which might be of interest for understanding the relationships between both groups of keeled globorotaliids. He found a complete intergradation between the representatives of the *G. menardii* group and the plexus of *G. conomiozea* towards the top of D.S.D.P. sites 410 and 334 (N. Atlantic), coinciding approximately with the FAD of *Amaurolithus primus* (Bukry and Percival) which in turn predates the FAD of *G. conomiozea* in the Mediterranean.

In the sections of the Guadalquivir basin, as in the case of Crete, there is a clear morphological discontinuity between the "*G. menardii*" group (dextral forms) and that of *G. miotumida*. However, specimens close to *G. miotumida* are also found at the lower parts of the Cantillana and Arroyo Galapagar sections where they coexist with the sinistral forms of the "*G. menardii*" group.

According to all the previous data it is difficult to delineate the origin of the *G. miotumida* in the Mediterranean and adjacent Atlantic realms, because very little is known about the *G. miotumida* group during the long time in which the populations of the "*G. menardii*" group dominated. However, I assume that the appearance of the *G. miotumida* group can serve to recognize the Tortonian—Messinian boundary both in the Mediterranean and in the adjacent Atlantic.

Langereis, Zachariasse and Zijderveld (1984) place this horizon towards the middle of chronozone 5, with an absolute age of 5.6 my. They consider that the difference of 0.4 my between the FAD of *G. conomiozea* in the Mediterranean and New Zealand is a result of the different nature of the event in these two realms: evolutionary in New Zealand and migratory in the Mediterranean.

Finally, it is important to note that this event can help to solve the much discussed correlation between the Andalusian and Messinian Stratotypes. Sierro et al. (in preparation) found that the appearance of the *G. miotumida* group is some meters above the Tortonian—Andalusian boundary as established by Perconig (1974).

Conclusions

Several faunal changes mainly in planktonic foraminiferal assemblages took place in the Mediterranean realm during the late Miocene. One of these changes is the appearance of several species close to *G. conomiozea* (Zachariasse, 1979a, b) which succeed *G. menardii* in Crete and other places such as the Messinian Stratotype. Other workers have found a similar change both in Mediterranean and Atlantic realms. This change also coincides with the FAD of *G. conomiozea*.

In this paper a horizon in which the "*G. menardii*" group (dextral coiled specimens) is replaced by the *G. miotumida* group, is documented in several sections of the Guadalquivir basin. This horizon postdates the coiling shift of the "*G. menardii*" group and predates a coiling change in the *T. acostaensis* group. It is suggested here that this replacement horizon can be used to recognize the Tortonian—Messinian boundary in those Atlantic areas that are related to the Mediterranean realm and where *G. conomiozea* occurs only sporadically. This event is easily recognized for there is a sharp morphologic discontinuity and a coiling difference between the "*G. menardii*" group (dextral) and that of *G. miotumida* (sinistral).

The evolutionary history of the group of *G. miotumida* remains obscure because it is not represented in the Mediterranean and adjacent Atlantic realms during the long time in which the "*G. menardii*" group dominated. It is suggested here that the appearance of the *G. miotumida* group in the Guadalquivir basin and the Mediterranean is the result of an invasion that probably coincided with a slight cooling of the sea waters.

As this horizon has also been found in the Arroyo Galapagar section (Andalusian type section), a valid correlation between the Andalusian and Messinian stratotypes can be drawn (Fig. 4): the horizon marking the base of the Messinian is placed some meters above the base of the Andalusian as defined by Perconig (1974).

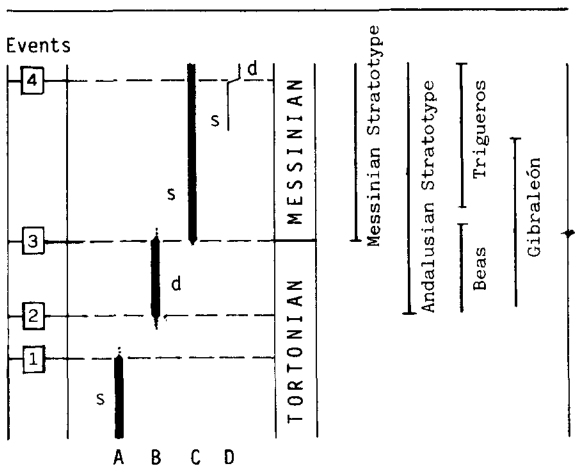


Fig. 4. Inferred relationships among the Andalusian and Messinian stratotypes, the sections studied and the events cited in this paper. *A* = "*G. menardii*" group (sinistral coiled specimens). *B* = "*G. menardii*" group (dextral coiled specimens). *C* = *G. miotumida* group. *D* = *T. Acostaensis* group. *s* = sinistral. *d* = dextral.

Acknowledgements

This paper represents the conclusions of the author's Ph.D. research carried out under the directions of Drs. Civis, University of Salamanca and Drs. de Porta, University of Barcelona, who are kindly acknowledged.

References

Banner, F.T. and Blow, W., 1960. Some primary Types of species belonging to the superfamily Globigerinacea. Contrib. Cushman Found. Foraminiferal Res., 11: 1—41.

Bizon, G. and Bizon, J.J., 1970. Observations sur l'évolution de *Globorotalia menardii* dans le Miocène moyen et supérieur d'Espagne méridionale. In: Proc. IInd. Plankton Conf. Roma 1970, 1: 85—89.

Bossio, A., El-Bied Rakich, K., Giannelli, L., Mazzei, R., Russo, A. and Salvatorini, G., 1976. Correlation de quelques sections stratigraphiques du Mio-Pliocène de la zone atlantique du Maroc avec les stratotypes du Bassin Méditerranéen sur la base des Foraminifères planctoniques, nannoplancton calcaire et ostracodes. Atti. Soc. Toscana Sci. Nat. Mem., 83: 121—137.

Carrasco, F., Gonzalez Donoso, J.M., Linares, D., Rodriquez, P. and Serrano, F., 1977. Sobre la presencia de materiales del Mioceno superior en la desembocadura del rio Vélez (provincia de Málaga). Seminario sobre el Messiniense, 3: 17—19 (Résumenes de las comunicaciones).

D'Onofrio, S., Giannelli, L., Iaccarino, S., Morlotti, E., Romeo, M., Salvatorini, G., Sampo, M. and Sprovieri, R., 1975. Planktonic Foraminifera of the Upper Miocene from some Italian sections and the problem of the Lower Boundary of the Messinian. Boll. Soc. Paleontol. Ital., 14 (2): 177—196.

Feinberg, H. and Lorenz, H.G., 1970. Nouvelles données stratigraphiques sur le Miocène supérieur et le Pliocène de Maroc Nord-Occidental. Notes Serv. Geol. Maroc., 30 (225): 21—26.

Gonzalez Donoso, J.M. and Serrano, F., 1977. Bio y cronoestratigrafia de los materiales pre-evaporíticos de Sorbas (provincia de Almería). Seminario sobre el Messiniense, 3, excursión, 2 (Sorbas): 69—76.

Langereis, C.G., Zachariasse, W.J. and Zijderveld, D.A., 1984. Late Miocene magnetobiostratigraphy of Crete. Mar. Micropaleontol., 8 (4): 261—268.

Mazzei, R., Raffi, I., Rio, O., Hamilton, N. and Cita, M.B., 1979. Calibration of late Neogene calcareous plankton datum planes with the paleomagnetic record of site 397 and correlation with Moroccan and Mediterranean sections. In: U. Von Rad, W.B.F. Ryan et al. (Editors), Initial Reports of the Deep Sea Drilling Project, 47. U.S. Government Printing Office, Washington, D.C., pp. 375—389.

Perconig, E., 1974. Etat actuel de nos connaissances sur l'étage Andalousien. Vième Congr. Néogène Méditerranéen, Lyon, 1971. Mem. B.R.G.M., 78 (2): 659—662.

Poore, R.Z., 1981. Late Miocene biogeography and paleoclimatology of the central North Atlantic. Mar. Micropaleontol., 6 (5—6): 599—616.

Salvatorini, G. and Cita, M.B., 1979. Miocene foraminiferal stratigraphy, D.S.D.P. site 397 (Cape Bojador, North Atlantic). In: U. Von Rad, W.B.F. Ryan et al. (Editors), Initial Reports of the Deep Sea Drilling Project, 47. U.S. Government Printing Office, Washington, D.C., pp. 317—375.

Serrano, F., 1979. Los foraminíferos planctónicos del Miocene superior de la cuenca de Ronda y su comparación con los de otras áreas de las Cordilleras Béticas. Thesis, Univ. Málaga, pp. 9—272.

Sierro, F.J., 1984. Foraminíferos planctónicos y bioestratigrafía del Mioceno superior-Plioceno del borde occidental de la Cuenca del Guadalquivir (SO de España). Ediciones Universidad de Salamanca, pp. 7—34 (Resumen de Tesis Doctoral).

Stainforth, R.M., Lamb, J.L., Luterbacher, H.P., Beard J.H. and Jeffords, R.M., 1975. Cenozoic planktonic foraminiferal zonation and characteristics of index forms. Univ. Kans. Paleontol. Contrib. Artic., 62: 13—162.

Van der Zwaan, G.J., 1979. Late Miocene changes in foraminiferal associations from Crete and Sicily. VIIth Congr. Mediterranean Neogene, Atenas, 1979. Ann. Geol. Pays Hell., tome hors serie, 3: 1313—1320.

Zachariasse, W.J., 1975. Planktonic foraminiferal biostratigraphy of the Late Neogene of Crete (Greece). Utrecht Micropaleontol. Bull., 11: 1—171.

Zachariasse, W.J., 1979a. The origin of *Globorotalia conomiozea* in the Mediterranean and the value of its entry level in biostratigraphic correlations. VIIth Congr. Mediterranean Neogene, Atenas, 1979. Ann. Geol. Pays Hell., tome hors serie, 3: 1281—1292.

Zachariasse, W.J., 1979b. Planktonic foraminifera from section Pothamida 1: taxonomic and phyletic aspects of keeled Globorotaliids and some paleoenvironmental estimates. Utrecht Micropaleontol. Bull., 21: 129—166.

Zachariasse, W.J. and Spaak, P., 1983. Middle Miocene to Pliocene paleoenvironmental reconstruction of the Mediterranean and adjacent Atlantic Ocean: planktonic foraminiferal record of Southern Italy. Utrecht Micropaleontol. Bull., 30: 91—110.