

ALICANTINA, A NEW EOCENE PLANKTONIC FORAMINIFERAL GENUS FOR THE LOZANOI GROUP

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ABSTRACT

The *lozanoi* group appeared in the early Eocene and includes two taxa, *Globigerina prolata* Bolli, 1957, characterized by a globigerinid test, and *Globigerina lozanoi* Colom, 1954, which is distinguished by having 5–6 globular chambers in the final whorl that tend to increase the height of the coiling axis to a medium-high trochospire and an intraumbilical aperture that tends to extend extraumbilically. The two species both possess a non-spinose, irregularly cancellate wall texture (*dutertrei*-type) very similar to the praemuricate-type typical of the Paleocene genus *Praemurica* Olsson et al., 1992. However, the stratigraphic gap and the lack of intermediate morphotypes between the two groups suggest that the *lozanoi* group evolved independently from a different ancestor. Therefore, *Alicantina* n. gen. is here proposed to accommodate the species *lozanoi* and *prolata*, the ancestor of which is presently unknown.

INTRODUCTION

Planktonic foraminifera are an extremely diverse group of marine, unicellular shell-bearing protozoa that produce calcareous tests (CaCO₃). As a consequence, they are probably the most extensively used tool for biostratigraphic studies and paleoecological investigations. The main distinguishing feature of the Paleogene planktonic foraminifera is the distinctive structure of the spinose and non-spinose walls, as exhaustively described in the taxonomic atlases by Olsson et al. (1999) and Pearson et al. (2006).

Pertinent to this paper is the non-spinose wall texture that occurs in the Paleogene genera *Praemurica* Olsson et al., 1992, *Igorina* Davidzon, 1976, *Morozovella* McGowran, 1968 (in Luterbacher, 1964), *Acarinina* Subbotina, 1953, and *Pearsonites* Soldan et al., 2014. Three genera, *Morozovella* McGowran, 1968 (in Luterbacher, 1964), *Acarinina* Subbotina, 1953, and *Pearsonites* Soldan et al., 2014, are characterized by walls that are covered by variably developed conical muricae. In contrast, the walls of the other genera mentioned above, besides the absence of spines, are distinguished by being covered by subparallel ridges and with growth of pustules on the entire test (Olsson et al., 2006; Soldan et al., 2011). In particular, *Praemurica* is characterized by an irregularly cancellate wall texture (namely praemuricate-type in Paleocene forms) that is very similar to the wall texture observed in the extant foraminifera included in *Neoglobobulimina* (the *dutertrei*-type cancellate).

Berggren et al. (2006a) demonstrated that the non-spinose, irregularly-cancellate wall texture reoccurs in globigerinid forms appearing in the lowermost Eocene and represented by morphotypes originally described as *Globigerina lozanoi*

Colom, 1954. According to Berggren et al., such morphotypes are characterized by 4–5 chambers in the final whorl early in its stratigraphic range, and by 5–6 globular chambers and a relatively high spire later in its range. Berggren et al. (2006a) tentatively assigned the taxon *lozanoi* to the genus *Praemurica*?, but admitted that this taxonomic assignment was temporary until the phylogenetic affinity of these forms could be established. In fact, the origin and ancestor of the species *lozanoi* is uncertain because the genus *Praemurica* became extinct in the early Paleocene, resulting in a stratigraphic gap between the extinction of the genus and the origination of *lozanoi* (Olsson et al., 1999).

The purpose of this study is to establish the taxonomic status of the species *lozanoi*, and to discuss and clarify the origin of this group based on taxonomic analysis and detailed study of the wall structures of new specimens from different localities.

MATERIALS AND METHODS

This study was performed on samples from Eocene sediments at four Ocean Drilling Program (ODP) holes, namely Leg 198 Hole 1209A and Hole 1210A (Shatsky Rise, north-western Pacific Ocean), Leg 143 Hole 865B (Allison Guyot, Central Pacific Ocean), and Leg 115 Hole 707C (Seychelles Bank-Saya de Malha Bank, western Indian Ocean), and from the drill-core Tanzania Drilling Project (TDP) 3 recovered in southeastern Tanzania (Pearson et al., 2004; Fig. 1, Table 1).

Samples were processed for foraminifera using standard procedures (Petrizzo et al., 2005). Subsequently, the residues were examined under a stereomicroscope. To perform the taxonomic study, several specimens of the *lozanoi* plexus were analyzed with a Scanning Electron Microscope (SEM) to observe the morphological characters of the shells and the details of wall ornamentation. The preservation of planktonic foraminifera was very good and, although shells were slightly recrystallized, the wall structures and test ornamentation remain clearly visible. In addition, following the same procedure by Soldan et al. (2014), several specimens of the *lozanoi* group were dissected using a surgical knife for detailed study of internal wall structure and pore shape. Figured specimens are deposited in the Micropaleontological Collection, Università degli Studi di Milano, Dipartimento di Scienze della Terra “A. Desio,” Italy.

THE TAXONOMIC STATUS OF *GLOBIGERINA LOZANOI* COLOM, 1954

Colom (1954) described medium-high spired, smooth-walled specimens with 4–6 globular chambers as *Globigerina lozanoi* from the Alicante province, southeastern Spain. He illustrated his species with drawings of numerous syntype

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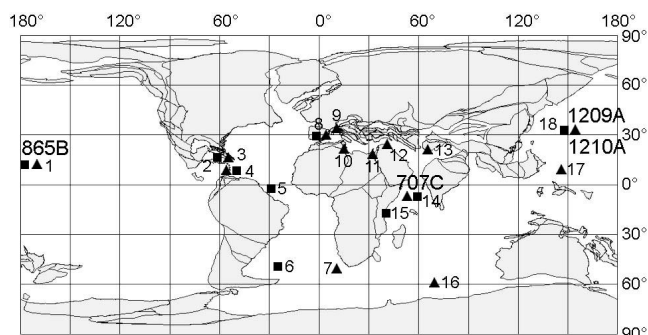


FIGURE 1. Location map of ODP Sites 865 (Allison Guyot, equatorial Pacific Ocean), 1209A and 1210A (Shatsky Rise, northwestern Pacific Ocean), 707C (Seychelles Bank-Saya de Malha Bank, western Indian Ocean), and some of the localities (1 to 18) where specimens of *Alicantina prolata* (triangle) and *A. lozanoi* (square) have been previously identified. 1. Shipboard Scientific Party, Leg 143 (1993), this study; 2 and 3. Jamaica & Cuba, Colom (1954), Blow (1979), Toumarkine (1983); 4. Trinidad, Bolli (1957a, b); 5. Leg 154, Ceara Rise, Pearson & Chaisson (1997); 6. Subantarctic Transect, Nocchi et al. (1991); 7. Site 361, west of Cape Town, Toumarkine (1978); 8. Alicante, type locality, Colom (1954); 9. Northern Italy, Cita et al. (1968); 10. Tunisia, Salaj (1980); 11. Egypt, Said (1960), Blow (1979); 12. Siria, *fide* Krasheninnikov & Hoskins (1973); 13. Sulaiman Range (Pakistan), Warraich & Natori (1997); 14. Indian Ocean, Premoli Silva & Spezzaferri (1990), this study; 15. Tanzania, Pearson et al. (2004), this study; 16. Site 738, Kerguelen Plateau, Lu & Keller (1993); 17. Ita Mai Tay Guyot, Krasheninnikov & Hoskins (1973); 18. Shatsky Rise, Petrizzo et al. (2005), this study. Middle Eocene paleogeographic reconstruction from Schettino & Scotese (2005) (<http://www.serg.unicam.it/Reconstructions.htm>).

specimens, but did not designate any as a holotype. Later, Blow (1979) selected a morphotype with 6 chambers in the final whorl as a lectotype corresponding to specimen no. 45 among Colom's 48 original drawings (Fig. 2.1).

For several years, the species *lozanoi* was included in *Globigerina* and only occasionally in *Subbotina* (i.e., Nocchi et al., 1991; Warraich & Nishi, 2003) due to the presence of globular chambers associated with a supposedly smooth wall surface, which were used as the dominant taxonomical criteria. Berggren et al.'s (2006a) investigation of the *lozanoi* wall structure opened the yet unresolved question of which genus *lozanoi* should be assigned.

After the death of Colom in 1993, the scientific community did not know the location for the repository of Colom's type material, the study of which could have solved some taxonomic problems that have arisen. Recently, thanks to Usera & Alberola (2009), it is now known that Colom's collection is deposited at the Museo de Ciencias Naturales de Söller, Mallorca (Spain). These authors, in revising the Paleogene foraminifera described by Colom (1954), provided new color illustrations of planktonic foraminifera of Colom's original slides (Fig. 2.2) and of some single specimens of *Globigerina lozanoi* (Fig. 2.3) and *Globigerina aspensis* Colom, 1954, taken with a digital camera. In addition, they presented SEM images of two specimens each for both of Colom's species *lozanoi* and *aspensis*.

Colom's slide CN12688, curated by Usera & Alberola (2009), contained only 30 specimens instead of 45 as drawn by Colom (1954, pl. 2). The random orientation of the specimens on both Colom's original plate and the actual suite slide prevented Usera & Alberola (2009), and us as well, from recognizing the lectotype selected by Blow (1979), which must be considered as lost. On the other hand, Usera & Alberola selected the specimen in umbilical view in line 3, no. 4 as the neotype of *lozanoi* (inappropriately calling it a 'holotype'). The Scientific Director of the Museo de Ciencias Naturales de Söller, Mallorca (Spain), Dr. Guillem Mateu Vincens, took SEM images at the Palma de Mallorca University

TABLE 1. List of the studied samples. References: 1. Bralower et al. (2002); 2. Petrizzo et al. (2005); 3. Premoli Silva & Spezzaferri (1990); 4. Shipboard Scientific Party (1993); 5. Pearson et al. (2004); 6. Wade et al. (2011).

	Leg	Hole	Samples (core, section, cm)	6. Zone	Taxa
1	198	1210A	2H-CC	PT1b	<i>Neoglobobquadrina</i>
2	198	1209A	24H-5, 26-28	P3a	<i>Praemurica</i>
			24H-5, 127-129	P3a	<i>Praemurica</i>
3	115	707C	13R-1, 20-23	E7	<i>lozanoi</i> group
			13R-1, 50-53	E7	<i>lozanoi</i> group
4	143	865B	8H-01, 130-132	E8	<i>lozanoi</i> group
			8H-02, 130-132	E8	<i>lozanoi</i> group/ <i>Acarinina</i>
			8H-03, 130-132	E8	<i>lozanoi</i> group
			8H-06, 112-114	E8	<i>lozanoi</i> group
			9H-01, 130-132	E7	<i>lozanoi</i> group
			9H-03, 50-52	E7	<i>lozanoi</i> group
			9H-03, 130-132	E7	<i>lozanoi</i> group
			9H-05, 20-22	E7	<i>lozanoi</i> group
			10H-01, 130-132	E5	<i>lozanoi</i> group
			10H-02, 130-132	E5	<i>lozanoi</i> group
			10H-03, 130-132	E5	<i>lozanoi</i> group
			10H-04, 130-132	E4	<i>lozanoi</i> group/ <i>Parasubbotina</i>
			10H-05, 117-119	E4	<i>lozanoi</i> group/ <i>Parasubbotina</i>
			11H-02, 130-132	E4	<i>lozanoi</i> group/ <i>Parasubbotina</i>
			11H-03, 130-132	E4	<i>lozanoi</i> group/ <i>Parasubbotina</i>
			14H-04, 47-49	P4a	<i>Parasubbotina</i>
			14H-04, 131-133	P4a	<i>Parasubbotina</i>
			14H-05, 131-133	P4a	<i>Parasubbotina</i>
5	Tanzania	TDP	3-5-1, 0-14	E4	<i>lozanoi</i> group
			3-5-1, 14-25	E4	<i>lozanoi</i> group

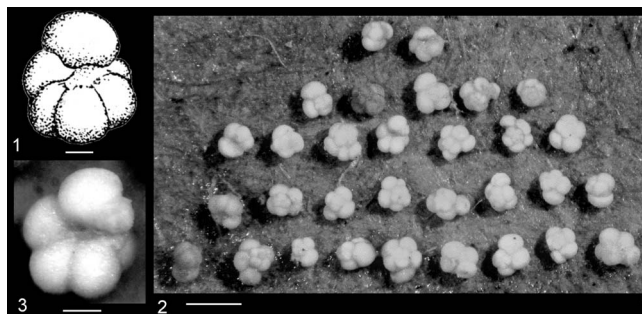


FIGURE 2. *Globigerina lozanoi* specimens. **1** Re-illustration of the lectotype of *Globigerina lozanoi* Colom, 1954, selected by Blow (1979) from Colom's pl. 2, fig. 45.; scale bar = 100 μm . **2** Colom's original slide (C.C.N. 12688) containing numerous, differently oriented *G. lozanoi* syntypes from Usera & Alberola (2009, pl. 33, fig. 3). These authors commented that the specimens are clearly similar/related except specimen 5 on line 2; scale bar = 500 μm . **3** Image of *Globigerina lozanoi* Colom, 1954 in line 3, no. 4 of Figure 2.2 (above) considered by Usera & Alberola (2009, pl. 35, fig. 1) as a good representative for replacing the missing holotype and Blow's lectotype, here up-ranked to neotype; scale bar = 100 μm .

Laboratory. He obtained SEM images of the umbilical and edge views of the neotype (see above, Fig. 3.1a, b), the full set of SEM images (including wall texture) of a paralectotype (Fig. 3.2a-d), and a spiral view of a larger specimen (n. 5, line 5, Fig. 3.3). In addition, Figure 3 includes the SEM images previously presented by Usera & Alberola (2009, pl. 32, refigured).

The set of SEM images from Colom's type material (see Fig. 3) show that the wall surface of *lozanoi* is irregularly cancellate and not praemuricate, even though the type of preservation of the wall texture on all images prevents the determination of whether spines were absent (i.e., spine holes not visible). Berggren et al. (2006a), who provisionally assigned the species *lozanoi* to the genus *Praemurica* (*P.?* *lozanoi*) based on the wall texture and on the position and extent of the aperture, excluded the origination of *P.?* *lozanoi* from *Acarinina*, most likely from the coeval *A. aspensis* because the latter species displays a well-developed muricate wall texture. Berggren et al.'s assumption is well supported by the two SEM images of the *aspensis* type-material, presented by Usera & Alberola (2009, pl. 27), that clearly show a coarsely muricate wall, confirming the correctness of attributing the species *aspensis* to the genus *Acarinina*.

Berggren et al. (2006a) indicated that *P.?* *lozanoi* may represent a terminal species of Paleocene praemuricate lineage, while Aze et al. (2011, fig. 5B) proposed a phylogenetic scheme in which *lozanoi* descends directly from *Praemurica inconstans*. Aze et al.'s (2011) reconstruction is here rejected because the last *P. inconstans* are confined to the early Paleocene (Subzone P3b; Olsson et al., 1999), whereas the oldest specimen of the *lozanoi* plexus is recorded in the early Eocene (late Zone E5, in Berggren et al., 2006a). In addition, no intermediate forms among these species have ever been found. The large stratigraphic gap suggests that no phylogenetic relationships between *lozanoi* and *Praemurica* exist and the ancestor of the *lozanoi* morphogroup should occur in the lower Eocene.

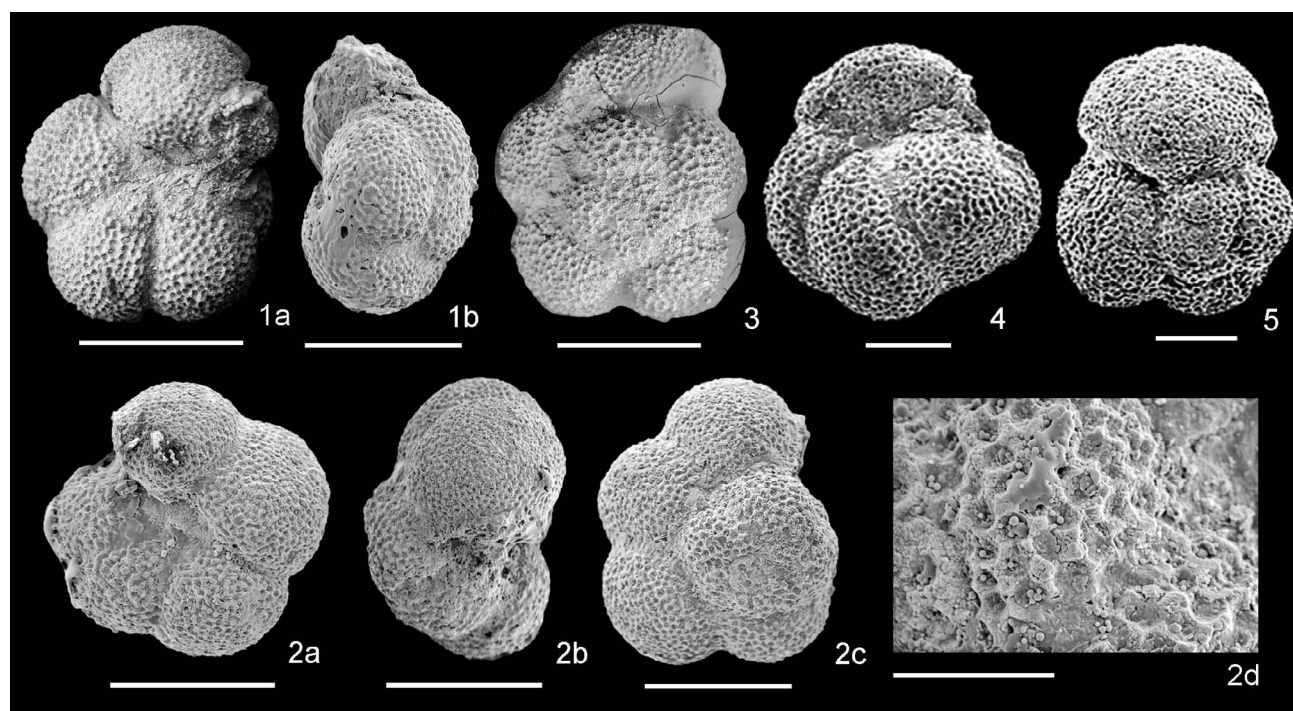


FIGURE 3. SEM images of the neotype and paralectotypes of *Alicantina lozanoi* (Colom, 1954), (syntype slide C.C.N. 12688, see Fig. 2.2 above). **1a-b** Neotype, C.C.N. 12688, line 3, no. 4. **2a-d** Paralectotype, C.C.N. 12688, line 5, no. 9. **3** Paralectotype, C.C.N. 12688, line 5, no. 5. **4** paralectotype possibly C.C.N. 12688, line 1, no. 2 (reproduced from Usera & Alberola, 2009, pl. 32, fig. 1). **5** paralectotype may be C.C.N. 12688, line 2, no. 1 (reproduced from Usera & Alberola, 2009, pl. 32, fig. 2). All specimens exhibit an irregularly cancellate wall texture. For 1a-b, 2a-c, 3, scale bar = 200 μm ; 2d, scale bar = 50 μm ; 4-5, scale bar = 100 μm .

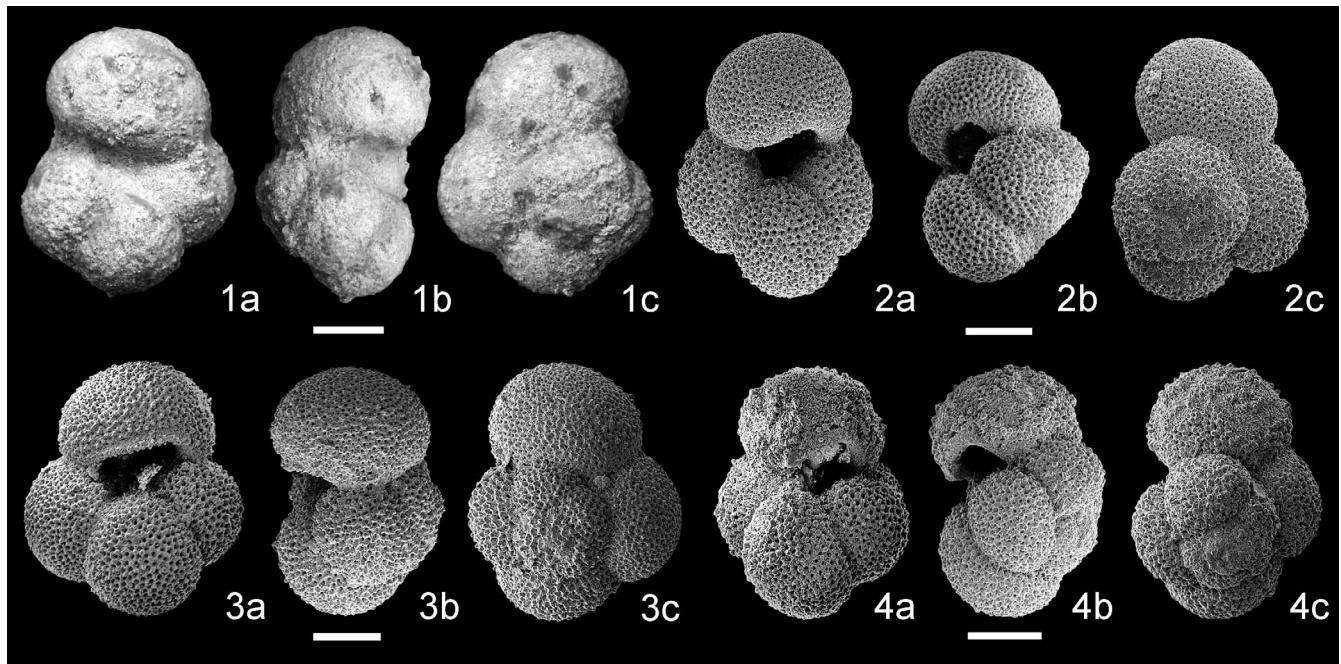


FIGURE 4. Specimens of *Alicantina prolata* that appear similar to the *G. prolata* holotype. 1 *Globigerina prolata* Bolli, 1957, holotype (USNM P5040), lower Eocene of Lizard Spring Formation (Trinidad). 2 *Alicantina prolata*, sample 143-865B-9H-5, 20-22 (Zone E7). 3 *Alicantina prolata*, sample 143-865B-9H-3, 125-127 (Zone E7). 4 *Alicantina prolata*, sample 143-865B-9H-3, 125-127 (Zone E7). Scale bars = 100 μm .

A taxon that shares some similarity with the species *lozano*i was described by Bolli (1957a) as *Globigerina prolata* from early-middle Eocene deposits (Lizard Spring Formation, Trinidad). This is a small globigerinid form characterized by four rounded chambers in the final whorl that are arranged in a rather loose spire with an elongate, low-arched aperture. Bolli (1957a) suggested that his new species probably branched off from *Globigerina collectea* Finlay in the *Globorotalia rex* Zone (= Zones E4–5). This relationship is here rejected as *G. collectea* is a muricate acarininid that appears in Zone E7 (see Berggren et al., 2006b). Bolli's *G. prolata* was regarded by Hillebrandt (1976) as phylogenetically linked to *lozano*i, which he interpreted as ancestral to *Globigerinoides higginsi* Bolli, 1957 [= *Guembeltrioides nuttalli* (Hamilton, 1953)], a suggestion that is also here rejected. Blow (1979) included *G. prolata* as a subspecies of *G. lozano*i, having observed transitional morphotypes between them. Although Berggren et al. (2006a) did not separate *G. prolata* from *lozano*i because the holotype of the former species is poorly preserved, we recovered numerous specimens that are very similar to the images of the *G. prolata* holotype (Fig. 4.1) and these display a wall texture identical to that of *G. lozano*i (see Fig. 5). As *G. prolata* appears earlier (late Zone E4) than *G. lozano*i (Zone E6; (Blow, 1979), it may be reasonably interpreted as the probable ancestor of the species *lozano*i. Considering the stratigraphic range, the abundance in the residues and the typical morphological characters, in our opinion *G. prolata* is a valid, discrete taxon belonging to the *lozano*i group. Despite the close similarity of the wall texture with the genus *Praemurica*, the *prolata-lozano*i plexus is interpreted to have evolved independently in the lower Eocene and a new genus *Alicantina* is here erected to accommodate these forms, designated as *Alicantina prolata* and *Alicantina lozano*i.

WALL TEXTURE AND PHYLOGENETIC RELATIONSHIP OF THE *LOZANO*I GROUP

Although the wall of *Globigerina lozano*i was originally described as smooth and finely reticulate by Colom (1954), Berggren et al. (2006a) clearly demonstrated that *G. lozano*i has a non-spinose, cancellate *Neogloboquadrina*-type wall (see Berggren et al., 2006a, pl. 12.6, fig. 16). In Figure 6, the non-spinose walls similar to the *dutertrei*-type wall present in the Paleocene genera *Praemurica* and *Igorina* (Olsson et al., 1999; Soldan et al., 2011) are shown for comparison. In *Neogloboquadrina dutertrei* (Fig. 6.1a–d), the pores are regularly distributed on test surface and calcitic subparallel ridges grow between the funnel pit connecting with shorter ridges forming growths or pustules at the connection point. On the

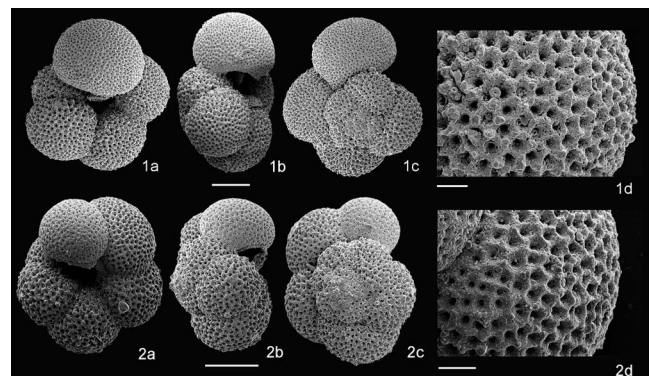


FIGURE 5. Wall textures. 1a–d *Alicantina prolata*, sample 143-865B-9H-3, 130–132 (Zone E7). 2a–d *Alicantina lozano*i, sample 143-865B-10H-3, 130–132 (Zone E5). For 1a–c, 2a–c, scale bar = 100 μm ; 1d and 2d, scale bar = 20 μm .

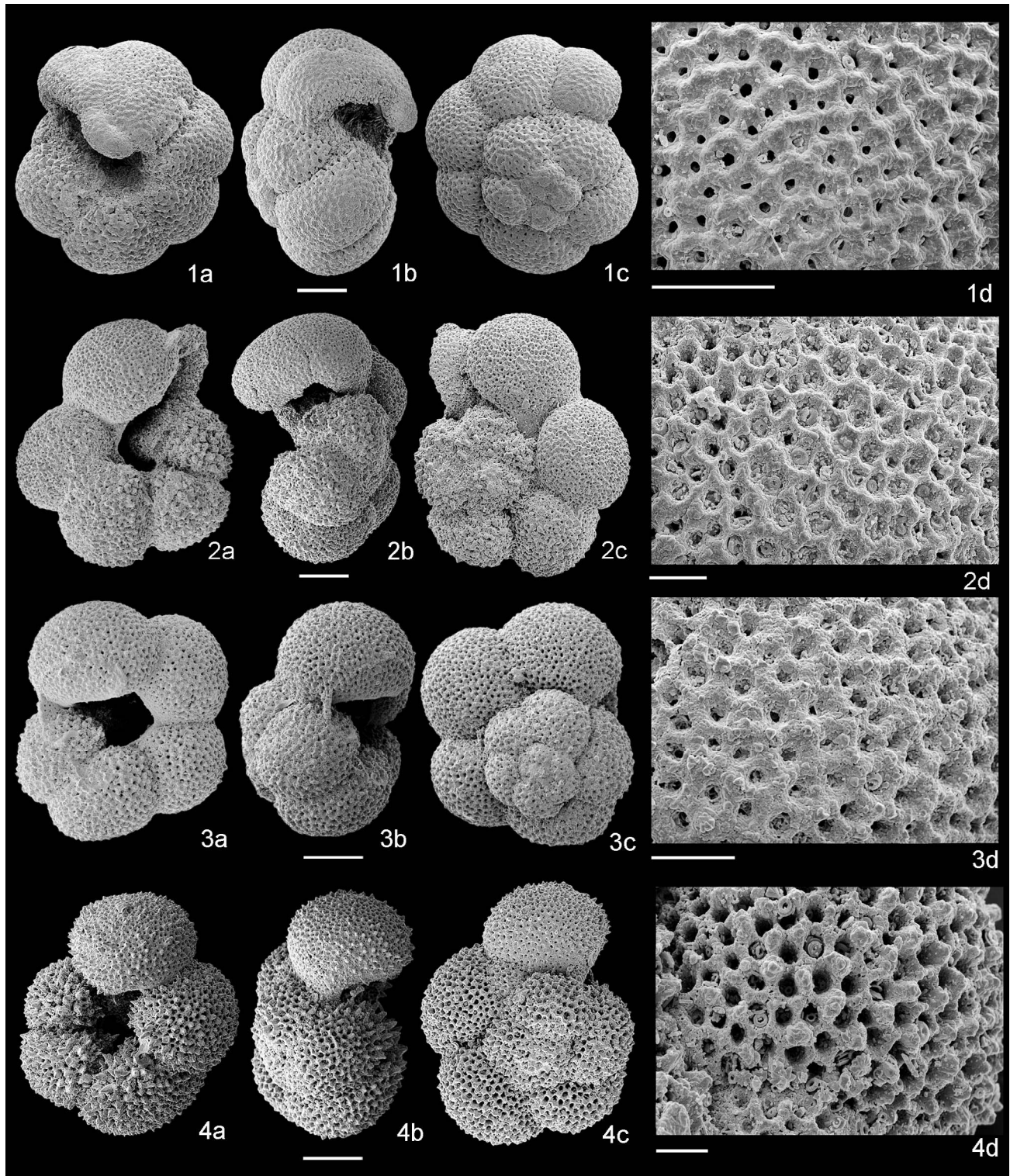


FIGURE 6. Non-spinose walls compared with the *dutertrei*-type wall. **1** *Neogloboquadrina dutertrei*, sample 198-1210A-2H-CC (Zone PT1b, Wade et al., 2011). **2** *Praemurica inconstans*, sample 198-1209A-24H-5, 127–128 (Zone P3a). **3** *Alicantina lozanoi*, sample 143-865B-9H-5, 20–22 (Zone E7). **4** *Acarinina pentacamerata*, sample 143-865B-8H-2, 130–132 (Zone E8). *Neogloboquadrina dutertrei* (1d) shows a wall texture with pores surrounded by calcite subparallel ridges forming a cancellate surface. As described by Olsson (1976) sometimes in *N. dutertrei* the wall is crystallized giving a coarse appearance (1a–c). However, the same type of wall structure can be observed in the Paleocene forms as *Praemurica inconstans* (2a–d) and in Eocene forms such as *Alicantina lozanoi* (3a–d). In *Acarinina pentacamerata* (4a–d) calcite layered pustules grew among the pores to form muricae (or pseudospines). For 1a–c, 2a–c, 3 a–c and 4a–c, scale bar = 100 μm ; 2d, 3d and 4d = 20 μm ; 1d = 50 μm .

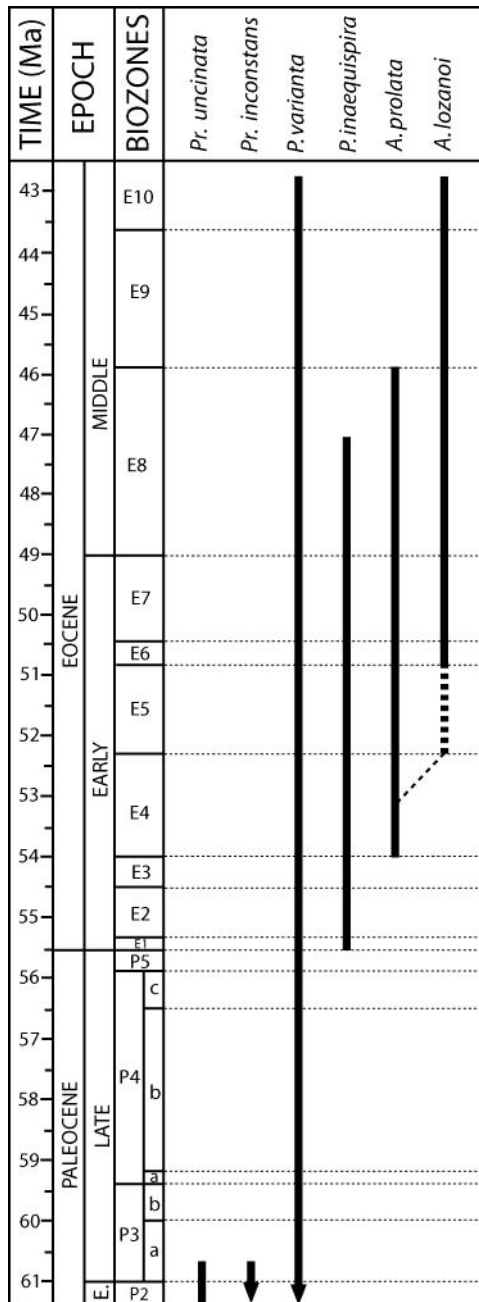


FIGURE 7. Stratigraphic ranges of the youngest *Praemurica* (*Pr. uncinata* and *Pr. inconstans*), *Alicantina prolata* and *Alicantina lozano*, and *Parasubbotina varianta* and *P. inaequispira* plotted against planktonic foraminiferal biozones, epoch, and time scale (after Olsson et al., 1999; Pearson et al., 2006).

wall of Paleocene *Praemurica inconstans* (Fig. 6.2a–d) and an Eocene specimen of *A. lozano* (Fig. 6.3a–d), it is possible to observe very similar features. However, the wall texture of *A. lozano* does not show the long and transverse ridges typical of the *dutertrei*-type wall texture. The degree of development of the features of the wall surface is determined by test growth. In fact, during ontogeny the size of pustules increases with the addition of each new chamber (Hemleben

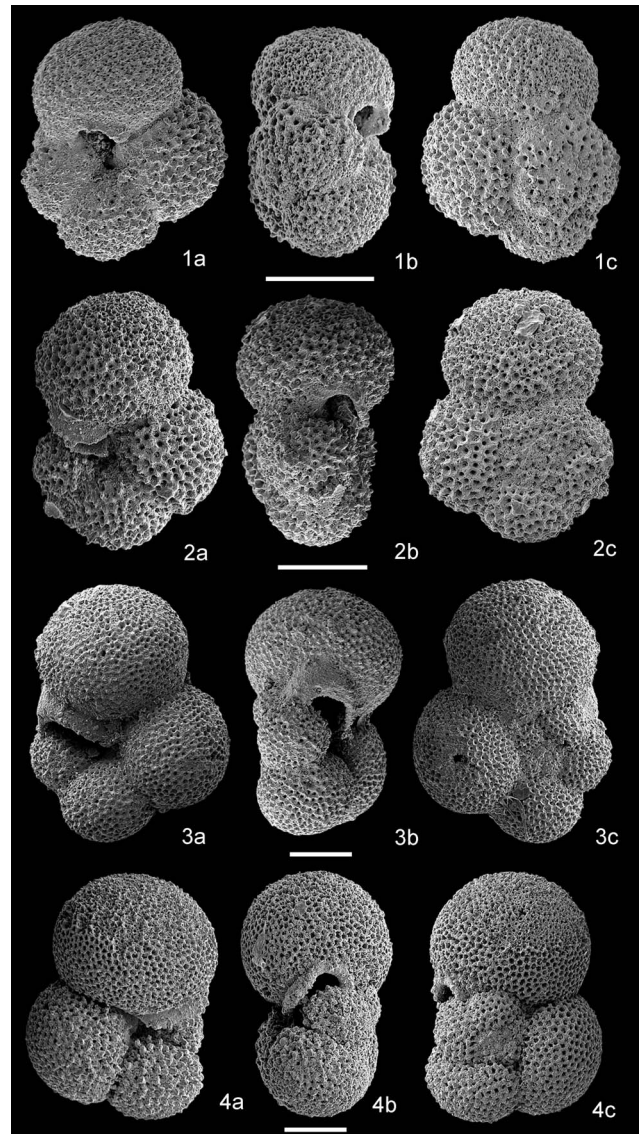


FIGURE 8. *Parasubbotina* specimens. 1 *Parasubbotina varianta*, sample 143-865B-11H-3, 130–132 (Zone E4), Eocene form. 2 *Parasubbotina varianta*, sample 143-865B-14H-5, 130–132 (Zone P4a), Paleocene form. 3 *Parasubbotina inaequispira*, sample 143-865B-8H-3, 130–132 (Zone E8). 4 *Parasubbotina inaequispira*, sample 143-865B-8H-3, 130–132 (Zone E8). Scale bars = 100 μ m.

& Olsson, 2006). As argued above due to the stratigraphic gap, it is unlikely that the Eocene *lozano* group descended from the praemuricate forms despite the similarity in wall texture (Fig. 7).

The test morphology of *prolata* (see Fig. 4.1a–d) suggests that this taxon could have evolved from parasubbotinids. In particular, the species *prolata* shows an umbilical-extraumbilical aperture very similar to the genus *Parasubbotina* (Olsson et al., 1992). *Parasubbotina* displays a cancellate spinose wall texture, low trochospiral test and globular chambers that increase rapidly in size in the ultimate whorl. In particular, *P. varianta* (Subbotina, 1953) and *P. inaequispira* (Subbotina, 1953; Fig. 8) resemble the

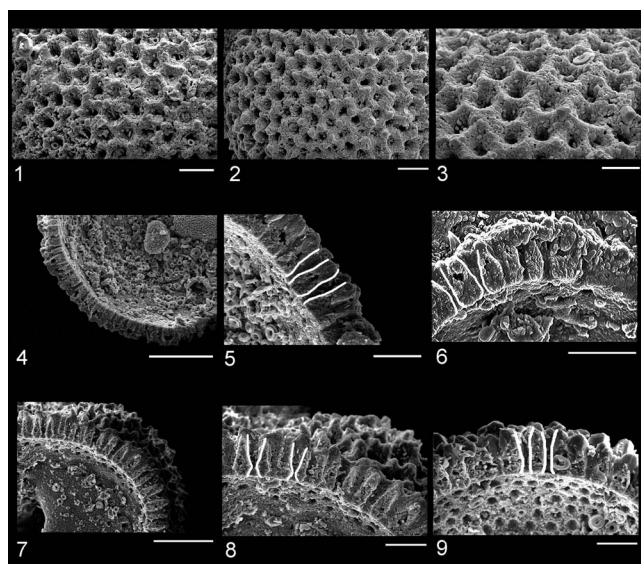


FIGURE 9. Wall textures and pores in cross sections. 1 Cancellate spinose wall texture (*sacculifer*-type) of *Parasubbotina inaequispira* (sample 143-865B-8H-03, 130-132) compared with 2 nonspinose wall texture (*dutertrei*-type) of *prolata* (sample 143-865B-9H-5, 20-22) and 3 *lozanoi* (143-865B-10H-3, 130-132). 4–5 The pores in *P. inaequispira* (sample 143-865B-8H-3, 130-132) and 6 *Parasubbotina varianta* (sample 143-865B-11H-3, 124-126) are elongate and become narrower in the distal part of outer calcitic layer. These pore structures are similar in 7–8 *lozanoi* (sample 143-865B-8H-3, 130-132) and 9 *prolata* (sample 143-865B-9H-3, 50-52). For 1, 2, 5, 6, 8, 9, scale bar = 20 μ m; 4, 7, scale bar = 50 μ m; 3, scale bar = 10 μ m.

morphology of earlier *prolata*. *Parasubbotina varianta* displays a *ruber/sacculifer*-type wall texture. According to Hemleben & Olsson (2006), this type of wall is characterized by parts of the test wall where the cancellate structures are symmetrical (honeycomb structure) while in other parts of the test wall this structure may be asymmetrical. The same wall arrangement is present in *P. inaequispira* (Fig. 9.1) although it may show a *sacculifer*-type wall texture (symmetrical cancellate structure) in adult specimens (Olsson et al., 2006).

To verify the phylogenetic affinities between the *lozanoi* group (Fig. 9.2–3) and the lower Eocene taxon *P. inaequispira* (Fig. 9.1), we have also studied in detail the cross sections of the pores (Fig. 9.4–9) using the method of Soldan et al. (2014). In cross section, the pores of *prolata* and *lozanoi* show an hourglass shape that extends into the calcitic outer layer (see Fig. 9.7–9). In *Parasubbotina* (Fig. 9.4–6), the pores are elongate and gradually tend to shrink. In the distal part, towards the inner part of the outer layer, the pores become narrower and successively enlarge again. Representatives of the *lozanoi* group (Fig. 9.7–9) display a similar pore structure. Despite the morphological similarities between the *lozanoi* group and parasubbotinids, due to typical cancellate spinose wall texture in the latter, an evolutionary relationship remains still very speculative.

In the evolutionary history of planktonic foraminifera, wall texture similar to the *dutertrei*-type evolved independently several times during the Paleogene and it can be considered a convergent character. Thus, despite the similarity of the wall structures between the *lozanoi* group and the Paleocene genus *Praemurica*, the different origin and different

phylogenetic relationship support the erection of the new genus *Alicantina* that evolved in the early Eocene.

CONCLUSIONS

A new planktonic foraminiferal genus, *Alicantina*, is here erected to accommodate Eocene globigerinid forms with a non-spinose *dutertrei*-type wall texture based also on their consistent occurrences and distinctive features. *Alicantina* n. gen. includes two distinct species: *Alicantina prolata*, which is characterized by a globigerinid test with 4–4½ globular chambers in last whorl, and *Alicantina lozanoi*, which is generally larger in size with more numerous chambers and a high spire. In agreement with Blow (1979), *Alicantina prolata* appears earlier than *Alicantina lozanoi* and it is considered as the ancestor of the latter. Moreover, stratigraphic and taxonomic data suggest that *Alicantina* n. gen. did not descend from the Paleocene genus *Praemurica* but evolved independently in the lower Eocene. In fact, there is no evidence to support the existence of any transitional forms between these genera. Presumably, the ancestor of early specimens of *Alicantina* must be searched among Eocene species possessing a non-spinose wall texture. The similarities between *Alicantina* and *Praemurica* represent a homoplasy and are the result of convergent evolution. *Alicantina* became extinct in the middle Eocene without leaving any descendants.

SYSTEMATIC TAXONOMY

Order FORAMINIFERIDA Eichwald, 1830
Superfamily GLOBIGERINACEAE Carpenter, Parker & Jones, 1862
Family GLOBIGERINIDAE Carpenter, Parker & Jones, 1862

Genus *Alicantina* n. gen.

Type species *Globigerina lozanoi* Colom, 1954

Figs. 2.1–2.3, 3.1–3.5, 4.1–4.4, 5.1–5.2, 6.3, 9.2, 9.3, 9.7, 9.8, 9.9, 10.1–10.8

Wall texture. Non-spinose, *dutertrei*-type, irregularly cancellate.

Description. Trochospiral test, with moderate coiling axis; equatorial periphery moderately elongate to subcircular and the internal spire tends to increase in height; peripheral margin broadly rounded; in spiral view 4–6 (rarely 7) globular chambers in the last whorl increase gradually in size as added; spiral sutures slightly curved to straight, depressed; in umbilical view chambers subtriangular with strongly depressed, straight sutures; umbilicus deep and medium sized, aperture wide generally intraumbilical, tending to extend extraumbilically; aperture a distinct low to moderately high arch.

Etymology. From the Alicante Province, Southeastern Spain, type location of *Globigerina lozanoi*.

Distinguishing features. *Alicantina* n. gen. is identified by its globular chambers coiling in a medium-high trochospire and its intraumbilical aperture that somewhat extends extraumbilically associated to a non-spinose, *dutertrei*-type, irregularly cancellate wall.

Discussion. The illustrations, even if only in one view, presented by Colom in 1954 to support the erection of *Globigerina lozanoi* cover the entire spectrum of the genus *Ali-*

cantina. In particular, the morphotypes with $4-4\frac{1}{2}$ are close to the species *A. prolata* (Bolli), morphotypes with up to 6–7 chambers in last whorl typify Colom's species *lozano*, while some drawings illustrate transitional forms in between the two. Colom (1954) described the species *lozano* as having a smooth surface, but it is finely reticulate in comparison with the associated muricate species *Acarinina aspen-sis* (see above). Colom's specification anticipates Berggren et al. (2006a) description about the presence of a non-spinose, *dutertrei*-type, irregularly cancellate wall texture in the new genus *Alicantina*. There are discrete evolutionary changes in the *Alicantina* lineage: increase in the total number of chambers of the last whorl (4–6) and in the umbilical diameter as well as the tendency to increase the height of the spire (Fig. 9.8). *Alicantina prolata* appears in Zone E4 and gave rise to *Alicantina lozano* in the early Eocene.

Phylogenetic relationship. Blow (1979) recognized that the origin of the *lozano* group is unknown. In addition, this author suggested that the taxon *lozano* gave rise to *Guembeliriodes nuttalli* (= *Globigerinoides higginsii*) by increasing the spire height but Berggren et al. (2006a) demonstrated through detailed SEM images that the latter belongs to a different lineage as it displays a spinose wall texture. *Alicantina* n. gen. evolved in the early Eocene presumably from a parasubbotinid-like taxon possessing a non-spinose wall texture and left no descendants.

Stratigraphic range. Upper part of Zone E4 (mid early Eocene) to Zone E10 (middle Eocene).

Geographic distribution. Cosmopolitan, common in mid to low latitudes (see Fig. 1).

Alicantina prolata (Bolli, 1957)

Figs. 4.1–4.4, (1a–c holotype), 5.1a–d, 9.9, 10.1

Globigerina prolata Bolli, 1957a, p. 72, pl. 15, figs. 24–26, (lower Eocene, *Globorotalia formosa formosa*, Lizard Springs Fm., Trinidad).

Globigerina prolata Bolli. Bolli, 1957b, p. 162, pl. 35, figs. 7a–b, (upper lower Eocene, Navet Fm., Trinidad).

Globorotalia thebaica Said, 1960, p. 284, pl. 1, figs. 6a–c, (Ypresian, Thebes Fm., Egypt).

Globigerina prolata Bolli. Samanta, 1973, p. 442, pl. 1, figs. 10–12, (lower Eocene, Zinda Pir, Rakhi Nala, Sulaiman Range, Pakistan).

Globigerina prolata Bolli. Krashenninnikov & Hoskins, 1973, p. 121, pl. 10, figs. 2–3, (lower Eocene, DSDP Hole 200A, Ita Mai Tai Guyot, western Pacific).

Globigerina lozano prolata Bolli. Blow, 1979, p. 856–858, pl. 145, fig. 1, (lower Eocene, Zone P9, Langley Fm., Jamaica); pl. 250, fig. 10, (topotype).

Globigerina prolata Bolli. Lu & Keller, 1993, p. 120, pl. 3, fig. 20, (lower Eocene, Kerguelen Plateau, S Indian Ocean).

Globigerina prolata Bolli. Warraich & Natori, 1997, pl. 2, figs. 2a–c, (lower Eocene, Dunghan Fm., Zinda Pir section, Sulaiman Range, Pakistan).

Subbotina prolata (Bolli). Warraich, Ogasawara & Nishi, 2000, p. 292, fig. 18.12–14, (lower Eocene Zone P7–8, Shaheed Ghat Fm., Sulaiman Range, Pakistan).

Globigerina prolata Bolli. Warraich & Ogasawara, 2001, p. 46, fig. 13. 16, 20–21, (lower Eocene Zone E5, Dungan Fm., Sulaiman Range, Pakistan).

Globigerina (*Eoglobigerina*) *lozano* Colom. Hillebrandt, 1976, p. 336, pl. 3, fig. 17, (lower Eocene, Agost section, SE Spain).

Original description. Shape of test low trochospiral, bi-convex. Equatorial periphery elongate, distinctly lobate. Axial periphery rounded. Wall calcareous, perforate, surface smooth. Chambers inflated globular to slightly compressed; about 12, arranged in $2\frac{1}{2}$ whorls, the 4–5 chambers of the last whorl increasing rapidly in size. Sutures on spiral side radial or slightly oblique, depressed; on umbilical side radial, depressed. Umbilicus fairly wide, open. Apertures distinct arches, interiomarginal, umbilical; in some specimens the aperture of the last chamber tends to become extraumbilical-umbilical in position. Coiling in two-thirds of the specimens counted in the *Globorotalia aragonensis* zone, sinistral. Largest diameter of holotype 0.40 mm.

Emended description. Test small, low trochospiral, equatorial periphery moderately elongate, lobulate in outline; peripheral margin rounded; in spiral view $4-4\frac{1}{2}$ globular depressed, moderately embracing chambers in ultimate whorl, increasing rapidly in size, sutures radial or slightly curved, moderately depressed; in umbilical view $4\frac{1}{2}-5$ globular, moderately embracing chambers, increasing moderately in size, sutures moderately depressed, straight; umbilicus a moderate sized opening, enclosed by surrounding chambers; aperture wide essentially intraumbilical, apparently slightly extraumbilical; in edge-view, chambers globular in shape, moderately embracing, aperture visible as a low arch.

Distinguishing features. *Alicantina prolata* differs from *Alicantina lozano* in having a smaller test size with 4–5 chambers in the final whorl, looser coiling and a lower spire.

Remarks. Bolli (1957a) described *Globigerina prolata* from the lower Eocene of Lizard Spring Formation (Trinidad). In the original illustration, *G. prolata* is distinguished by having a smooth surface test, with 4–5 globular chambers in final whorl and rounded axial periphery. Hillebrandt (1976) illustrated from the Agost section, Spain several specimens of *lozano*. In his opinion, the morphotypes with 4 chambers in the last whorl and low spire represent transitional forms to *G. prolata*. Blow (1979) included *prolata* as a subspecies of *lozano* indicating the specimens n. 1, 3, 6, 7, 9, 13, 15, and 43 of Colom's original plate 2 as representative; he also pointed out a complete transition between the two taxa *prolata* and *lozano*. In addition, Blow (1979) suggested a possible evolutionary link also with turborotaliid forms. However, the genus *Turborotalia* displays a different wall texture and this assignment is not correct (Berggren et al., 2006a). Warraich & Nishi (2003) illustrated specimens of *lozano* from central Pakistan that display five chambers in the last whorl; this form can probably be included in the variability of *prolata*. Berggren et al. (2006a) did not consider the taxon *prolata* because of the uncertain taxonomic validity and included it in the variability of *P.?* *lozano*. However, in the examined samples (Hole 865B), specimens of *Alicantina prolata* are common and, as discussed by Blow (1979), it appears earlier (Zone E4) than typical morphotypes of *lozano* (Zone E6). Moreover, according to Blow (1979) *Globorotalia thebaica* Said, 1960, described from the lower Eocene of Egypt, falls in the variability of *Alicantina prolata*.

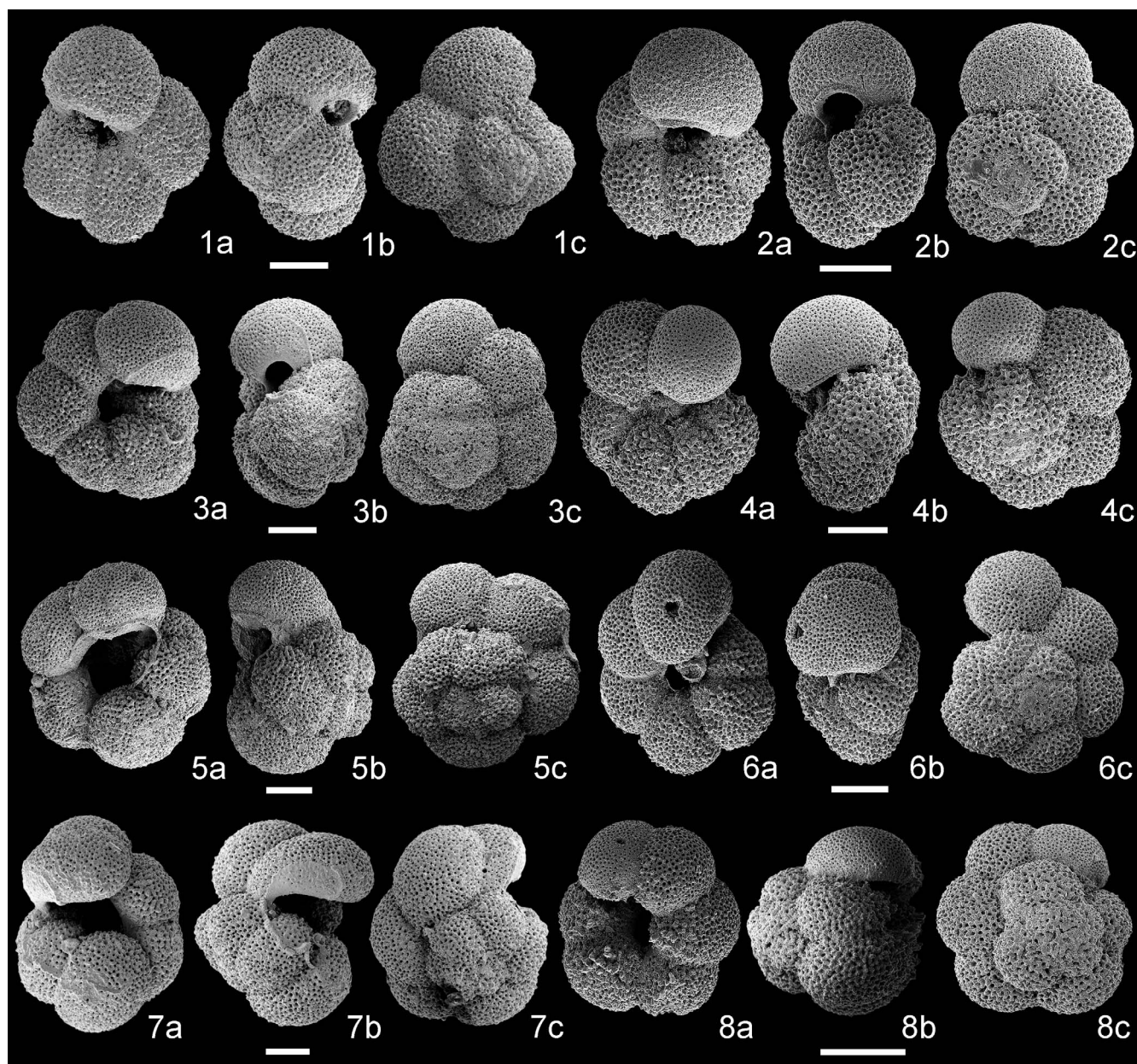


FIGURE 10. *Alicantina* specimens. 1 *Alicantina prolata*, sample 143-865B-9H-5, 20–22 (Zone E7). 2 *Alicantina lozano*i, sample 143-10H-3, 130–132 (Zone E5). 3 *Alicantina lozano*i, sample 143-865B-9H-3, 130–132 (Zone E7). 4 *Alicantina lozano*i, sample 143-865B-10H-2, 130–132 (Zone E5). 5 *Alicantina lozano*i, sample 115-707C-13R-1, 50–52 (Zone E7). 6 *Alicantina lozano*i, sample 143-865B-10H-3, 130–132 (Zone E5). 7 *Alicantina lozano*i, sample 115-707C-13R-1 50–52 (Zone E7). 8 *Alicantina lozano*i, sample 143-865B-9H-5, 20–22 (Zone E7). All scale bars = 100 μ m.

Phylogenetic relationship. Probably evolved from a parasubbotinid-like taxon possessing a non-spinose wall texture in the early Eocene and is ancestral to *Alicantina lozano*i.

Stratigraphic range. Zone E4 (mid lower Eocene) to E8 (lower part of middle Eocene).

Geographical distribution. Described from the lower Eocene E4 of Trinidad, this species has been recorded at low and mid-latitudes in (sub)tropical assemblages from the North and South Atlantic, Pacific (Shatsky Rise, Caroline Abyssal Plain) and Indian (Kerguelen Plateau) Oceans, as well as in numerous regions like Cuba and Jamaica, Italy,

Syria, Egypt, Tunisia, central Pakistan (Sulaiman Range) and especially Spain (Alicante Province, Agost, etc.).

*Alicantina lozano*i (Colom, 1954)

Figs. 2.1–2.3, (2.1 lectotype), 3.1–3.5 (3.1a–b neotype; 3.2–3.5 paralectotypes), 5.2, 6.3, 9.3, 9.7, 9.8, 10.2–10.8

*Globigerina lozano*i Colom, 1954, p. 149, pl. 2, figs. 1–48, fig. 45 lectotype (designated by Blow, 1979) (lower Eocene, upper Ypresian and lower Lutetian, Aspe-Crevillente Road, southern Alicante Province, SE Spain).

- Globigerina lozanoi* Colom. Bermudez, 1961, p. 1188, pl. 4, fig. 7 (lower Eocene Zone P9, Universidad Fm., Havana, Cuba).
- Globigerina* (*Eoglobigerina*) *lozanoi* Colom. Hillebrandt, 1976, p. 336, pl. 3, figs. 8–11, 13–16 (lower Eocene, *Globorotalia* (*Planorotalites*) *palmerae* Zone, Agost section, SE Spain).
- Globigerina lozanoi lozanoi* Colom. Blow, 1979, p. 854–855, pl. 145, figs. 2–9 (lower Eocene Zone P9, Langley Fm., Jamaica); pl. 250, fig. 1 (lower Eocene Zone P9, Universidad Fm., Havana, Cuba).
- Globigerina lozanoi* Colom. Toumarkine, 1983, p. 115–116, pl. 9, figs. 6–8 (reproduced from Colom, 1954, pl. 2, figs. 31, 36, 45; 45 = lectotype); pl. 9, figs. 9–11 (lower Eocene *A. pentacamerata* Zone, Richmond Fm., Jamaica).
- Globigerina lozanoi* Colom. Toumarkine & Luterbacher, 1985, p. 127, figs. 28.6–11 (re-illustrated from Toumarkine, 1983, pl. 9, figs. 6–11).
- Subbotina lozanoi* (Colom). Nocchi, Amici & Premoli Silva, 1991, pl. 2, figs. 13–15 (lower Eocene, DSDP Hole 702B, S. Atlantic).
- Globigerina lozanoi* Colom. Warraich & Ogasawara, 2001, p. 45, figs. 14.1–3 (lower Eocene Zone E5, Dungan Fm., Sulaiman Range, Pakistan).
- Praemurica? lozanoi* (Colom). Berggren, Olsson & Premoli Silva, 2006a, p. 391, pl. 12.6, figs. 1–16 (Pl. 12.6, fig. 1: re-illustration of the lectotype of *Globigerina lozanoi* Colom).
- Praemurica? lozanoi* Colom. Usera & Alberola, 2009, p. 225–227, pl. 31, fig. 1; pl. 32, figs. 1–2; pl. 33, figs. 1–2; pl. 34, figs. 1–3, pl. 35, figs. 1–2 (lower Eocene, reproductions of original material of Colom, 1954).
- Subbotina lozanoi* (Bolli). Warraich & Nishi, 2003, p. 228, pl. 2, figs. 12a–b (lower Eocene Zone P7–8, Shaheed Ghat Fm., Zinda Pir section, Sulaiman Range, Pakistan).

Original description (translated from Spanish). Diagnosis: Small species with globular chambers arranged in a relatively loose trochospire that is quite high in the adult specimens, with more than two whorls on the dorsal side. Characters: Species rather small with a diameter ranging between 0.35–0.40 mm in height in specimens with a low trochospire and up to 0.45 mm in specimens with higher trochospire. Spiral side clearly trochoid with about 10–15 clearly visible chambers developing very regularly and increasing gradually in size in about two whorls. Chambers are globular, somewhat flattened on the outside, with 5–6 chambers in the last whorl, rarely 4 and only in the case of specimens that are clearly juvenile. In the same portion of the shell, the majority of the specimens show a marked rise of the inner portion and, in turn, a steep slope with respect to the chambers of the last whorl, with the presence of all terms of variability. The general shape of the shell is rather globular with very appressed chambers with those of the last whorl being higher than wide. The umbilical side shows a deep depression to the side of the last chamber next to the small, arched aperture, which is not always visible. Surface is smooth, but finely reticulate.

Remarks. This taxon was exhaustively discussed in the Atlas of Eocene Planktonic Foraminifera by Berggren et al. (2006a, p. 397–398) under *Praemurica? lozanoi* (see synonymy). Blow (1979), besides selecting a lectotype (= n.

45, pl. 2), indicates that out of Colom's type plate 2, the specimens illustrated at no. 2, 8, 10–12, 14, 16–29, 31–32, 40–42, 44, 46–47 can be assigned to typical *lozanoi lozanoi*. Furthermore, after having identified *lozanoi prolata* specimens (see above), Blow (1979) also indicated which specimens he considered as transitional between the two subspecies. We totally agree with Blow's choice and contrary to Berggren et al. (2006a), we consider *A. prolata* Bolli as a distinct taxon deserving recognition as a valid species (see above).

Phylogenetic relationship. *Alicantina lozanoi* evolved from *Alicantina prolata* in the early Eocene.

Repository. Museu Balear de Ciències Naturals, Sóller, Spain, "Guillem Colom Casanovas" Collection, C.C.N. 12688; Neotype and Paralectotypes, Figure 3, C.C.N. 12688b.

Stratigraphic range. Zone E5–E6 (lower Eocene) to E10 (lower part of middle Eocene).

Geographical distribution. Colom (1954) recorded *A. lozanoi* as abundant in lower Eocene strata from Alicante Province (SE Spain), and mentioned that it occurs also in the lower and middle Eocene of Central America and Cuba. *Alicantina lozanoi* has been recorded at low- and mid-latitudes in (sub)tropical assemblages as mentioned for *A. prolata* (see above).

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