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Chapter 16

TAXONOMY, BIOSTRATIGRAPHY, AND PHYLOGENY OF OLIGOCENE GLOBIGERINITIDAE (*DIPSIDRIPELLA*, *GLOBIGERINITA*, AND *TENUITELLA*)

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ABSTRACT

The taxonomy, biostratigraphy, and phylogeny of the Oligocene Globigerinitidae (comprising the genera *Dipsidripella*, *Globigerinita* and *Tenuitella*) is reviewed. This family is here included in the Superfamily Globigerinitoidea based on the distinctive wall texture. The group is united by possessing a 'radially crystalline' wall texture (the *glutinata*-type wall) which typically bears pyramidal pustules and in most species is microperforate (pores <1 µm in diameter). The genus *Dipsidripella* is included in the family here for the first time. In *Dipsidripella* the wall is often medioperforate (pores 1-2 µm in diameter; *danvillensis*-subtype). The following species are recognized as valid and occurring in the Oligocene: *Dipsidripella danvillensis* (Howe and Wallace), *Dipsidripella liqianyui* Huber and Pearson, *Globigerinita glutinata* (Egger), *Globigerinita uvula* (Ehrenberg), *Tenuitella angustiumbilicata* (Bolli), *Tenuitella gemma* (Jenkins), *Tenuitella munda* (Jenkins), and *Tenuitella praegemma* (Li).

INTRODUCTION

Modern *Tenuitella* and *Globigerinita* (the two living genera of the Globigerinitidae) inhabit the surface mixed-layer of the open ocean, where they tend to bloom opportunistically in response to seasonal nutrient availability, or in upwelling environments (e.g., Hemleben and others, 1989; Sautter and Thunell, 1991; Oda and Yamasaki, 2005; Mohtadi and others, 2009; Harbers and others, 2010; Wilson, 2012). Multi-species stable isotopic analysis suggests that their Oligocene and early Miocene predecessors had a similar life habit (Poore and Matthews, 1984; Pearson and others, 1997; Pearson and Wade, 2009). Depending on the paleoenvironment, these genera can be found in very large numbers in the fine fraction (<150 µm) of seafloor sediment, and are sometimes the dominant component, especially at high latitude sites. Taxonomic discrimination can be difficult because of the small size and generalized morphology of many of the species. The extinct genus *Dipsidripella* also comprises small, opportunistic forms, but unlike the tenuitellids and globigerinitids it is found predominantly in marginal and shelf environments, sometimes where other planktonic foraminifera are rare or absent. Isotopic evidence suggests that this genus may have had a partly benthic ('tychopelagic') life habit (Huber and others, 2006:501; Darling and others, 2009; Leckie, 2009).

The most important corpus of work on the taxonomy of Oligocene microperforate planktonic foraminifera is that of Li Qianyu and co-workers

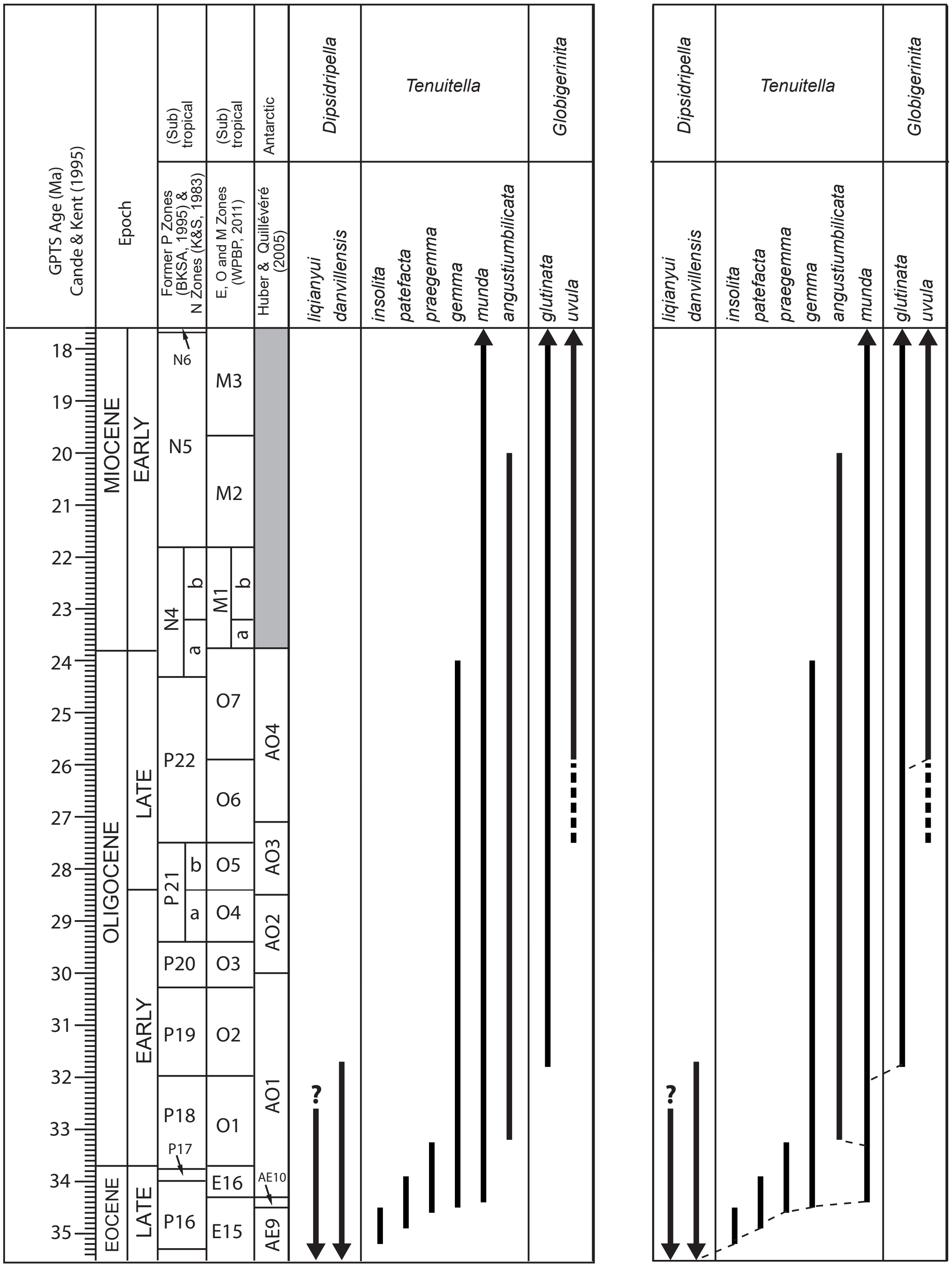

FIGURE 16.1. Stratigraphic ranges and inferred phylogenetic relationships of Oligocene Globigerinitidae BKSA, 1995 = Berggren and others, 1995; K&S, 1983 = Kennett and Srinivasan, 1983; WPBP, 2011 = Wade and others (2011).

(especially Li, 1987; Li and others, 1992; Li and Radford, 1991; Radford and Li, 1992). Our taxonomic philosophy follows earlier publications of the Paleogene Planktonic Foraminifera Working Group (see Pearson and others, 2006:16-18) in that the classification presented here is conservative: we have elected to lump rather than split species unless very clear morphological divisions can be demonstrated, communicated, and proved to be of use. We have avoided form-genera, and base our higher taxonomy instead on perceived phylogenetic relationships. Our approach contrasts with that of Li (1987), Li and Radford (1991), and Li and others (1992) in the taxonomic re-assignment of some species and genera, but any worker confronted with abundant and diverse Oligocene microperforate foraminifera should have Li's papers directly at hand.

The Globigerinitidae are united by possession of a distinctive 'radially crystalline' wall that on the surface is microperforate and smooth except for numerous pustules (described in Chapter 15, this volume, as the *glutinata*-type wall). The wall in *Dipsidripella* has more variable pore sizes, making it technically both micro- and medioperforate, and a somewhat different pustule morphology (Huber and others, 2006), but is otherwise similar. Layering of the wall is often difficult to observe, but can be seen clearly in some dissections. The radially crystalline microstructure of the Globigerinitidae is very different from the microgranular wall of most macroperforate planktonic foraminifera that comprise the Family Globigerinidae. This difference in wall texture indicates that the group probably evolved its planktonic habit independently from some other as-yet unidentified benthic taxon. We suggest that *Dipsidripella*, which is the first member of the group to appear in the record during the middle Eocene and may have had a partially planktonic mode of life (Huber and others, 2006), was the ancestor of the Globigerinitidae, although morphological intermediates between *Dipsidripella* and the first *Tenuitella* have yet to be discovered.

Stratigraphical ranges and inferred phylogenetic relationships are shown in Figure 16.1. There seems to have been a distinct radiation of Globigerinitidae in the late Eocene and earliest Oligocene. *Globigerinita glutinata* is one of the oldest of the living 'species' of planktonic foraminifera, over 30 million years old. However, this may be more a function of its generalized morphology and the 'lumped' approach we have taken to the taxonomy than of biological reality. The Globigerinitidae are of some biostratigraphic utility (Radford and Li, 1992) and probably have considerable unrealized potential, especially in high latitude settings. Detailed and quantitative morphometric analysis would seem the most promising approach for future subdivision of the group.

SYSTEMATIC TAXONOMY

Order FORAMINIFERIDA d'Orbigny, 1826
Superfamily GLOBIGERINITOIDEA Bermúdez, 1961

Type genus: *Globigerinita* Brönnimann, 1951

DISCUSSION.— Superfamily Globigerinitoidea comprises the single Family Globigerinitidae. The superfamily level classification in this work follows the wall texture observations of Chapter 15 (this volume). This superfamily is characterized by the *glutinata*-type wall (and, in some cases, the *danvillensis*-subtype). It includes the genera *Dipsidripella*, *Globigerinatella*, *Globigerinita*, *Mutabella*, and *Tenuitella*. The modern species *Candeina nitida* is genetically close to *Globigerinita* (Ujiié and Lipps, 2009) and a close relationship has also been suggested from the fossil record (Blow 1969, 1979). However our own observations (unpublished) indicate that *Candeina* has a very different wall texture. Further detailed investigation of both the genetics and morphology may determine whether *Candeina* should be included in the Globigerinitoidea. Note that "Superfamily Globigerinitoidea" has been employed for a heterogeneous mixture of unrelated micro- and macroperforate taxa by BouDagher-Fadel (2012a:145, 206) wherein it was erroneously attributed to Carpenter, Parker and Jones (1862). This was later described as a 'new superfamily' by BouDagher-Fadel (2012b) but the correct attribution is to the author of the original family (Bermúdez, 1961) according to the 'Principle of Coordination' (International Code of Zoological Nomenclature, 1999, Article 36.1) which states that "a name established for a taxon at any rank in the family group is simultaneously established for nominal taxa at all other ranks in the family group".

Family GLOBIGERINITIDAE Bermúdez, 1961, revised Li, 1987; Pearson and Wade, 2009

Type genus: *Globigerinita* Brönnimann, 1951

Tenuitellidae BouDagher-Fadel (2012a:146)

DISCUSSION.— Bermúdez's (1961) original concept of this family was based on the globigeriniform test morphology and presence of an umbilical bulla. As such, it united various macro- and microperforate genera with convergent morphology that are now considered unrelated. The modern concept of the family has its roots in the work of Parker (1962) (for which see discussion below under Genus *Globigerinita*). The distinctive microperforate wall texture of *Globigerinita* (named in Chapter 15, this volume, as the *glutinata*-type wall) was first described in detail by Fleisher (1974) who also described the same wall in his new genus *Tenuitella*. Following earlier observations by Jenkins (1965), Fleisher suggested that the more globigeriniform genus *Globigerinita* had evolved from the more globorotaliform *Tenuitella* via intermediate forms.

Banner (1982) and Loeblich and Tappan (1984) united *Tenuitella* and *Globigerinita* within the Subfamily Globigerinitinae in Family Cassigerinellidae (type genus *Cassigerinella*). Huber and others (2006) also included Eocene *Tenuitella* in the Cassigerinellidae. However, as discussed by Pearson and Wade (2009), Chapter 15 (this volume), and Chapter 18 (this volume), we now reject the suggestion that *Cassigerinella* is closely related to *Tenuitella* or any other of the Globigerinitidae.

Li (1987) employed the Family Globigerinitidae in a similar sense to that used here, uniting *Globigerinita* and *Tenuitella* and a species ('*Tenuitella* sp.') that was later to be included in the genus *Mutabella* (Pearson and others, 2001), while excluding *Cassigerinella*. Li and others (1992) implicitly included *Globigerinatella* in the same group as *Globigerinita* and *Tenuitella* because of its microperforate wall. The similarity of the wall texture of *Globigerinatella* and *Mutabella* to other Globigerinitidae was confirmed by Pearson and Wade (2009).

BouDagher-Fadel (2012a:146) erected the Family Tenuitellidae to include *Tenuitella* and *Praetenuitella*. In our work these genera are considered part of the Globigerinitidae because they share a common wall texture.

Genus *Dipsidripella* Brotea, 1995, emended Huber, Olsson, and Pearson, 2006

TYPE SPECIES.— *Dipsidripella hodisensis* Brotea, 1995:31, pl. 1, figs. 1-12.

DESCRIPTION.

Type of wall: Microperforate to medioperforate, with pore diameters ranging from 0.5-2.0 µm, smooth with surface weakly to densely covered by small, blunt or, more commonly, hispid pustules; radially crystalline internal structure (*glutinata*-type wall, *danvillensis*-subtype; see Pearson, Chapter 15, this volume).

Test morphology: Test trochospiral, small- to medium-sized, peripheral margin rounded, peripheral outline subquadrate to subcircular, moderately lobate; chambers globular, inflated, arranged in a low to moderate spire; sutures strongly depressed, radial on both sides; aperture interiomarginal, umbilical-extraumbilical, variable from a low broad to narrow arch; small semicircular secondary apertures may occur at the intersection of the spiral and chamber sutures (description modified from Huber and others, 2006).

Size: Small, mostly <150 µm.

DISTINGUISHING FEATURES.— Differs from normal perforate planktonic foraminifera by having a radially crystalline wall covered with randomly scattered short, blunt to hispid pustules; differs from *Tenuitella* by the greater range of pore sizes and tendency to have dispersed pustules; differs from *Praepararotalia* Liu and others (1998) by the more even distribution of pustules on both sides of the test rather than restriction of pustules to the umbilical side; by the absence of fused or linearly aligned pustules; and by having a rounded rather than subrounded to subcarinate peripheral margin (modified from Huber and others, 2006).

DISCUSSION.— This genus was treated in detail in the *Atlas of Eocene Planktonic Foraminifera* by Huber and others (2006), where two species (*D. danvillensis* and *D. liqianyui*) were included. At that time we assigned *Dipsidripella* to the Problematica because the wall is subtly different from *Tenuitella* and related forms. Subsequent study (Chapter 15, this volume) suggests that the wall texture differences are not as great as previously thought and the fundamental structure is similar, so we here assign *Dipsidripella* formally to the Globigerinitidae. (We note in passing that Fleisher, 1974:1033, already suggested that *danvillensis* had a wall similar to *Tenuitella*.) We suggest that *Dipsidripella* was the first of the Globigerinitidae to evolve (in the middle Eocene) giving rise to *Tenuitella*. Its semi-planktonic shelf sea habitat makes it a plausible intermediate between an as yet unidentified benthic taxon (possibly a species of *Praepararotalia*; see Liu and others, 1998) and the later, more fully planktonic members of the Globigerinitidae.

Huber and others (2006) suggested that *Dipsidripella danvillensis* was restricted to the Eocene whereas *D. liqianyui* survived into Oligocene Zone O1. Subsequent study has shown that both species persisted well into the early Oligocene (discussed below).

Dipsidripella danvillensis (Howe and Wallace, 1932)

Plate 16.1, Figures 1-16

Globorotalia danvillensis Howe and Wallace, 1932:74, pl. 10, figs. 9a-c [upper Eocene, Jackson Group, Danville Landing on the Ouachita River, Catahoula Parish, Louisiana].

Dipsidripella danvillensis (Howe and Wallace).—Huber and others, 2006:496-501, pl. 16.8, figs. 1-3 (reillustration by SEM of holotype of *Globorotalia inconspicua aculeata* Jenkins), figs. 4, 5, 7, 14 (reillustration by SEM of holotype and topotypes of *Globorotalia danvillensis* Howe and Wallace), fig. 6 (reproduction of holotype image of *Dipsidripella hodisensis* Brotea), figs. 8, 10, 11 [upper Eocene Zone E14/15, ODP Site 150X, Atlantic City Borehole, New Jersey], fig. 7 [upper Eocene Zone E15/16, Shubuta Clay, Wayne County, Mississippi], figs. 9, 12, 13, 16, 17 [upper Eocene Yazoo Fm., Cynthia, Mississippi], fig. 15 [Oligocene nannofossil Zone NP22, Wachsberg unit, Ottenthal, Austria].—Miller and others, 2008, figs. 6, O-Q [upper Eocene Zone E16, St. Stephens Quarry borehole, Alabama].

Globigerinella evoluta Subbotina 1960:58, pl. 8a, b (holotype); 9a, b (topotype) [upper Oligocene (Chattian), Polyanitsa Fm., Velikiy Lukavets River, Ciscarpathian region, Ukraine].

Globorotalia inconspicua Howe subspecies *aculeata* Jenkins, 1965:1118-1120, fig. 13, nos. 119-125 [middle – upper Eocene, *Globigerinatheka index index* through *Globorotalia* (*Testacarinata*) *inconspicua* Zones, Hampden Beach, South Island, New Zealand].

Globorotalia aculeata Jenkins.—Jenkins and Srinivasan, 1986:807, pl. 2, fig. 4 [upper Eocene, *Globorotalia aculeata* Zone, DSDP Site 592, Lord Howe Rise, southwest Pacific Ocean].—Poore and Bybell, 1988:17, pl. 3, figs. 7-9 [upper Eocene, *Turborotalia cunialensis* Zone, U. S. Geological Survey ACGS #4 borehole, Mays Landing, New Jersey Coastal Plain].

"*Tenuitella*" *aculeata* (Jenkins).—Malumián, 1990:382 [Eocene, Man Aike Fm., Santa Cruz Province, YCF SEC-7 borehole].

"*Acarinina*" *aculeata* (Jenkins).—Nocchi and others, 1991:266, pl. 4, figs. 27, 28 [upper Eocene Zone P15, ODP Hole 703A, Meteor Rise, southern South Atlantic Ocean].

Praepararotalia aculeata (Jenkins).—Liu and others, 1998 (partim; not pl. 1, fig. 10 = *Praepararotalia inconspicua* (Jenkins):16-17, pl. 1, figs. 11-13 [middle Eocene, Claiborne Member, Cook Mountain Fm., Couley Creek, Winn Parish, Louisiana].

Dipsidripella hodisensis Brotea, 1995:31-32, pl. 1, figs. 1-9 [uppermost Eocene – lowermost Oligocene, upper Brebi Marls Fm., Hodis Salai district, northern Transylvania, Romania].

DESCRIPTION.

Type of wall: Wall micro- to medioperforate, surface smooth to moderately pustulose, hispid to bluntly pustulose, pustules randomly scattered on umbilical and spiral sides of test, radially crystalline in section (*glutinata*-type, *danvillensis*-subtype; see Chapter 15, this volume).

Test morphology: Test small, moderately lobate, subquadrate to circular or elliptical in equatorial outline, axial periphery rounded; chambers globular or radially extended, coiled in a low trochospire, increasing moderately in size, 4-6 in the final whorl; sutures radial and depressed on umbilical and spiral sides; umbilicus narrow to broad and moderately deep; aperture an interiomarginal, umbilical-extraumbilical arch that is narrow and high or broad and low, may or may not be bordered by a narrow, equidimensional lip; a semicircular accessory aperture may occur on the spiral side at the intersection of the spiral and and/ or penultimate chamber sutures (modified from Huber and others, 2006).

Size: Holotype maximum diameter 110 µm, breadth 70 µm; hypotypes maximum diameter 110-150 µm, maximum breadth 50-60 µm.

DISTINGUISHING FEATURES.—This species differs from *Dipsidripella liqianyui* by its more lobate and broadly rounded equatorial periphery, less flattened spiral side, and absence of pustules in the umbilicus; differs from *Acarinina medizzai* by its distinctive *glutinata*-type, *danvillenis*-subtype wall texture, hispid, rather than muricate wall, and distinctive, often highly arched aperture.

DISCUSSION.— See the *Atlas of Eocene Planktonic Foraminifera* (Huber and others, 2006) for previous discussion. Here we add *Globigerinella evoluta* Subbotina in synonymy following new observations of the type material (see Chapter 20, this volume). We include within our concept forms with four to six chambers in the final whorl, forms with or without supplementary apertures, and forms with globular or radially extended chambers. Clearly there is much scope for taxonomic subdivision should detailed morphometric, stratigraphic, and biogeographic studies be undertaken.

PHYLOGENETIC RELATIONSHIPS.— The origin of the form is uncertain; it is probably derived from a benthic species, possibly of *Praepararotalia* (Liu and others, 1998; but see also comments in Huber and others, 2006). It probably gave rise to *Dipsidripella liqianyui* (Huber and others, 2006) and *Tenuitella praegemma* (Chapter 15, this volume).

STRATIGRAPHIC RANGE.—Middle Eocene (Liu and others, 1998) to lower Oligocene, probably lowermost part of Zone O2. At the time of publication of the *Atlas of Eocene Planktonic Foraminifera*, the confirmed stratigraphic range was restricted to the middle and upper Eocene although a single specimen from the lower Oligocene was illustrated (Huber and others, 2006, plate 16.8, fig. 15). Here we confirm its range into the Oligocene and illustrate Oligocene specimens from various localities. At ODP Site 647, with moderate sampling intensity, its disappearance is at the same level as that of *Pseudohastigerina naguewichiensis* (H.K. Coxall, unpublished data). The latter is absent from the Ottenthal Fm., which is probably lowermost Zone O2. Its absence from younger clays and marls in the Paratethys region suggest extinction somewhere in Zone O2, although this has not so far been observed in any continuous section.

TYPE LEVEL.— Upper Eocene.

GEOGRAPHIC DISTRIBUTION.—Generally reported from to mid- to outer neritic sediments. Also occurs in continental slope environments (e.g. ODP Site 647).

STABLE ISOTOPE PALEOBIOLOGY.— *Dipsidripella danvillensis* either lived in a benthic habitat for part of its life cycle or it occupied a much deeper level of the water column than co-occurring planktonic foraminifera (Huber and others, 2006).

REPOSITORY.— Holotype (cat. no. HVH 712) deposited in the Louisiana State University Museum Collection, Baton Rouge, Louisiana.

Dipsidripella liqianyui Huber and Pearson, 2006

?*Globorotalia denseconnexa* Subbotina, 1960:67, pl. 13, fig. 3a-c (holotype); 4a-6c (topotypes) [upper Oligocene (Chattian), Polyanitsa Fm., Velikiy Lukavets River, Ciscarpathian region, Ukraine].

Dipsidripella liqianyui Huber and Pearson, 2006 *in* Huber and others, 2006:501-502, pl. 16.9, figs. 1-3, 5-7, 9-17 [holotype and paratypes, middle to upper Eocene Zone AE8, ODP Hole 738B, Kerguelen Plateau, southern Indian Ocean], figs. 4, 8 [reillustration from Stott and Kennett, 1990, pl. 7, figs. 13, 14, upper Eocene Zone AE8, ODP Site 689, Weddell Sea, Antarctic Ocean].

DISCUSSION.— This species was described in the *Atlas of Eocene Planktonic Foraminifera* (Huber and others, 2006). Here we include *Globorotalia denseconnexa* Subbotina, 1960, in questionable synonymy (see Chapter 20, this volume). See under *D. danvillensis* for how to distinguish the two species. The highest known occurrence is in ODP Hole 738B where the range is truncated by a hiatus in Zone AP13 (lower Oligocene) in a sample that also contains *Pseudohastigerina micra* and is therefore equivalent to (sub)tropical Zone O1, probably the upper part (see Huber, 1991, Table 1). The precise extinction level has yet to be confirmed,

Plate 16.1 *Dipsidripella danvillensis* (Howe and Wallace, 1932)

1, **2** (holotype of *Globorotalia danvillensis* Howe and Wallace, LSU 712; re-illustration from Huber and others, 2006, pl. 16.8, figs. 4, 5) upper Eocene Jackson Fm., Danville Landing, Louisiana; **3-5**, Zone O1, Red Bluff Fm., Alabama; **6-8**, **12**, **16**, Nannofossil Zone NP22 (probably lower Zone O2), Ottenthal Fm., Austria (6 and 7, same specimen; note supplementary aperture); **9-11**, Zone O1, ODP Hole 647A/28R/3, 44.5-46.0 cm, North Atlantic Ocean; **13-15**, Zone O1, ODP Hole 647A/28R/3, 76.5-78.5 cm, North Atlantic Ocean. Scale bars: **1-16** = 50 µm.

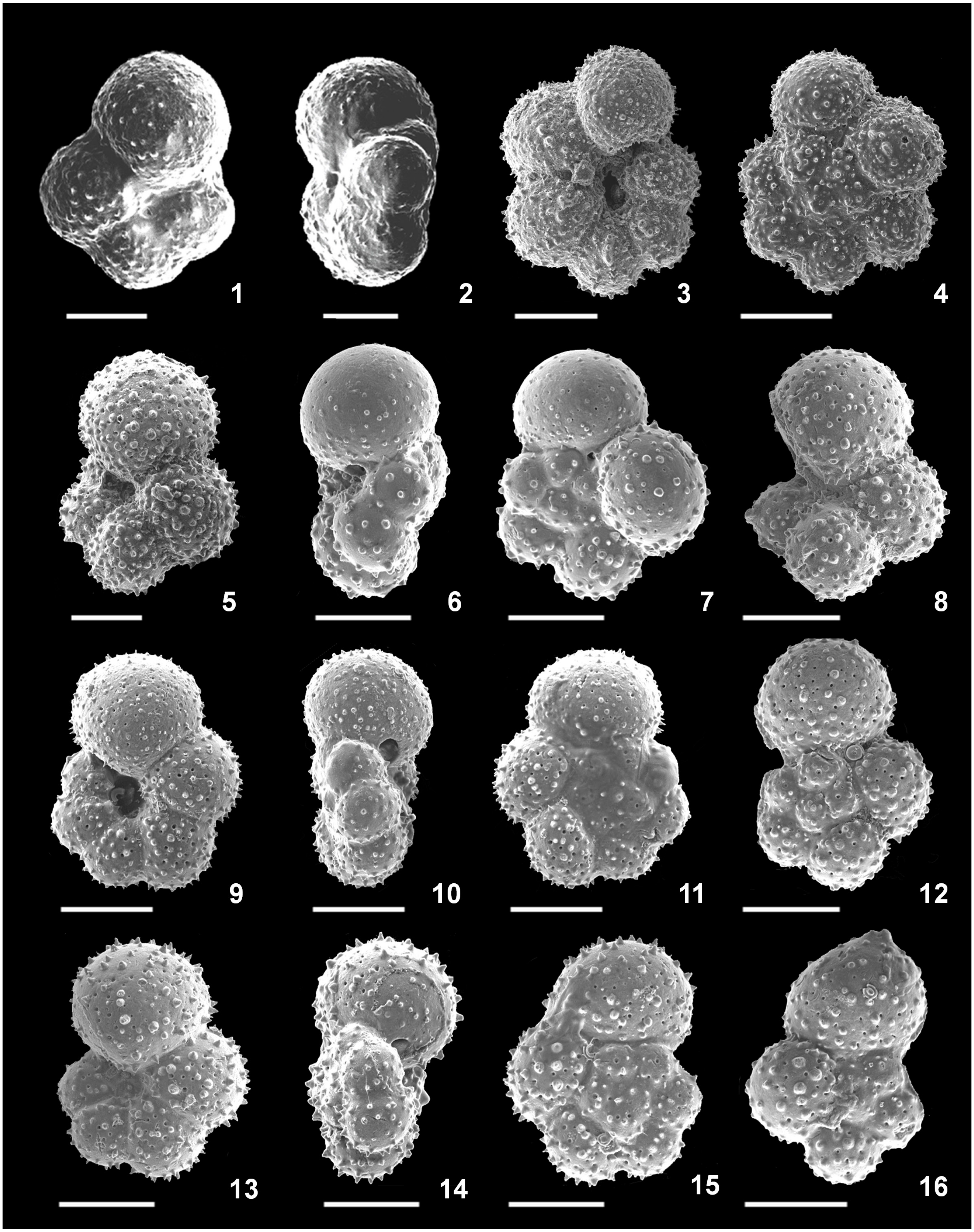

Plate 16.1 *Dipsidripella danvillensis* (Howe and Wallace, 1932)

and it is not known whether it preceded, followed, or was simultaneous with the extinction of *D. danvillensis*.

Genus *Globigerinita* Brönnimann, 1951

Globigerinita Brönnimann, 1951:18.
Tinophodella Loeblich and Tappan, 1957 (type species *Tinophodella ambitacrena* Loeblich and Tappan, 1957).

TYPE SPECIES.— *Globigerinita naparimaensis* Brönnimann, 1951.

DESCRIPTION.

See under *Globigerinita glutinata.*

DISTINGUISHING FEATURES.— Distinguished from other globigeriniform genera (e.g., *Globigerina*, *Globoturborotalita*, *Subbotina*) by its nonspinose, microperforate *glutinata*-type wall. Distinguished from *Dipsidripella*, *Mutabella*, and most *Tenuitella* by its intraumbilical aperture. Distinguished from *Globigerinatella* by lacking multiple superimposed bullae. Intermediates between *Tenuitella munda* and *Globigerinita glutinata* are common and should be distinguished by the intra- or intra-extraumbilical apertural position.

DISCUSSION.— Brönnimann's (1951) original concept of *Globigerinita* and Family Globigerinitidae was based on the presence of an umbilical bulla with multiple infralaminal openings (see also Bolli and others, 1957:37). This included his species *Globigerinita naparimaensis* along with other macroperforate forms such as *Catapsydrax* that are now regarded as unrelated. The genus *Globigerinita* was used in this sense (essentially a form-genus) by several workers including Brönnimann and Resig (1971) and Blow (1979). However Parker (1962:252-253) drew attention to the distinctive wall texture of *Globigerinita*, which she described as "smooth, or finely hispid, and nonspinose". Parker took the bold step of uniting in the genus Brönnimann's (1951) *Globigerinita naparimaensis* with Bolli's (1957) *Globigerina juvenilis*, and two modern species that had been described in the nineteenth century, *Globigerina glutinata* Egger, 1893 and *Pylodexia uvula* Ehrenberg, 1861. She also described a new species from Holocene sediments, *Globigerinita iota* (now placed in the closely related genus *Tenuitella*). She clearly stated her opinion that *Globigerinita* constitutes a separate group from the other planktonic foraminifera and was of uncertain family affiliation ('Incertae Familiae') possibly "developed independently from some other ancestry" (Parker, 1962:244). Fleisher (1974:1021-1022) used high quality SEM images to illustrate and describe the microperforate wall and followed Parker in suggesting that the genus should be restricted to forms with this distinctive wall texture.

Loeblich and Tappan (1957) distinguished what they regarded as forms with a 'true' bulla from forms with a final chamber (that may have multiple openings) positioned over the umbilicus. They revised their concept of *Globigerinita* to include forms with an encroaching final chamber and erected a new genus and species, *Tinophodella ambitacrena*, for what they regarded as 'truly' bullate forms, using one of Brönnimann's paratypes of *Globigerinita naparimaensis* to typify their genus and species. We do not follow the distinction between 'true' bullae and encroaching final chambers, hence we regard *Tinophodella* as a synonym of *Globigerinita* (see also Parker, 1962:246).

PHYLOGENETIC RELATIONSHIPS.— Genus evolved from *Tenuitella* in the lower Oligocene (Jenkins, 1965) and is extant.

STRATIGRAPHIC RANGE.— Lower Oligocene to Recent.

GEOGRAPHIC DISTRIBUTION.— Global.

Globigerinita glutinata (Egger, 1893)

Plate 16.2, Figures 1-16, Plate 16.3, Figures 1-13
(Pl. 16.2, Fig. 1: reproduction of type illustration of *Globigerina glutinata* Egger, 1893)
(Pl. 16.2, Figs. 2, 3: new SEMs of holotype of *Globigerinita boweni* Brönnimann and Resig, 1971)
(Pl. 16.2, Figs. 5-7: new SEMs of holotype of *Globigerina juvenilis* Bolli, 1957)
(Pl. 16.2, Figs. 9-11: new SEMs of holotype of *Globigerina parva* Bolli, 1957)
(Pl. 16.2, Figs. 13-15: new SEMs of holotype of *Globigerinita incrusta* Akers, 1955)
(Note: this is a common living species; we restrict this synonymy list to references that are relevant to the taxonomic placement of the species, and Oligocene to lower Miocene occurrences.)

Globigerina glutinata Egger, 1893:371, pl. 13 (on p. 356), figs. 19-21 (three views of same specimen: locality of figured specimen not given; probably Holocene sediment from the cruise of the *Gazelle*).—Rhumbler, 1911:148, pl. 29, figs. 14-16; pl. 33, fig. 20; pl. 34, fig. 1 (fide Parker, 1962).

Globigerinita glutinata (Egger).—Parker, 1962:246, pl. 9, figs. 1-9 [Holocene, 'Downwind' Expedition Station BG 134, equatorial eastern Pacific Ocean], pl. 9, figs. 10-16 [Holocene, 'Downwind' Expedition Station BG 70, mid-latitude South Pacific Ocean].—Kennett and Srinivasan, 1983:224, pl. 56, figs. 1, 3-5 [lower Miocene Subzone N4b, DSDP Site 289, western equatorial Pacific Ocean].—Leckie and others, 1993:124, pl. 6, fig. 1 [upper Oligocene, ODP Hole 628A, Little Bahama Bank, western North Atlantic Ocean].—Chaisson and Leckie, 1993:157, pl. 10, fig. 2 [lower Miocene Zone N6, Hole 806B, Ontong Java Plateau, western equatorial Pacific Ocean].—Spezzaferri, 1994:62-63, pl. 27, figs. 6a-c [lower Miocene Zone N5, DSDP Hole 526A, western South Atlantic Ocean], pl. 28, figs. 1a-c [lower Miocene Zone N5, ODP Hole 709C, equatorial Indian Ocean].—Pearson, 1995:47, pl. 2, figs. 1-6 [lower Miocene Zone N6/7, ODP Hole 871A, Limalok Guyot, Marshall Islands, equatorial western North Pacific Ocean].—Pearson and Chaisson, 1997:59-60, pl. 1, fig. 1 [lower Miocene Zone N5/6, ODP Hole 925A, equatorial western Atlantic Ocean].—Pearson and others, 2001, pl. 4, figs. 5, 6, 9 [lower Miocene Zone N8, ODP Hole 872C, Lo-En Guyot, Marshall Islands, equatorial western Pacific Ocean], fig. 10 [lower Miocene ODP Hole 959A, equatorial eastern Atlantic Ocean].—Li and others, 2003a:20, pl. 2, figs. 4, 5 [lower Miocene Zone SAN4, Hole 1134A, Great Australian Bight], pl. 6, fig. 30 [Pleistocene Subzone PT1a, ODP Hole 1126B, Great Australian Bight].

Globigerinita glutinata glutinata (Egger).—Fleisher, 1974:1022, pl. 9, figs. 1, 2 [Pleistocene Zone N22, DSDP Site 219, Arabian Sea].

Globigerinita naparimaensis Brönnimann, 1951:18, figs. 1-144 [lower Miocene *Globorotalia menardi* and *Globorotalia mayeri* Zones, Cruse Fm., Lengua Beds, South Trinidad].—Bolli and Saunders, 1985:188, figs. 17.7a-c [holotype redrawn].—Li and others, 1992:581, pl. 2, fig. 8 [lower Miocene ODP Hole 747A, central Kerguelen Plateau, southern Indian Ocean].—Li, and others, 2003b:16, pl. 2, fig. 12 [upper Oligocene Subzone P21b, ODP Hole 1134A, Great Australian Bight].—Li, and others, 2003a:53, pl. 6, fig. 29 [Pleistocene Subzone PT1a, ODP Hole 1134A, Great Australian Bight].

Globigerinita incrusta Akers, 1955:655, pl. 65, figs. 2a-d [Miocene *Cibicides cartensi* var. *opimus* Zone, Humble Oil and Refining Co., Ellender No. 1 borehole, 10,132-10,142 feet, Terrebonne Parish, Louisiana].—Stainforth and others, 1975:286, fig. 124, nos. 1-3, 6 [middle Miocene *Globorotalia fohsi peripheroronda* Zone, subsurface of Louisiana, nos. 4, 5 (reproduction of holotype and paratype images from Akers, 1955), no. 7 [lower Miocene, Pozón Fm., Venezuela].—Quilty, 1976:642, pl. 8, fig. 14 [middle Miocene Zone N10-N11, DSDP Site 319, Nazca Plate, southeastern Pacific Ocean], pl. 8, figs. 15, 16 [middle Miocene Zone N9, DSDP Site 319, Nazca Plate, southeastern Pacific Ocean].—Nocchi and others, 1991:268, pl. 5, figs. 18-20 [upper Oligocene Subzone P21b, ODP Hole 703A, southern South Atlantic Ocean].—Spezzaferri, 1994:62, pl. 27, figs. 7a-c [lower Miocene Zone N8, DSDP Site 94, Gulf of Mexico].

Globigerinita naparimaensis incrusta Akers.—Blow, 1959:206, pl. 15, figs. 100, 101 [Miocene *Globigerinatella insueta* Zone, loc. R.M. 19285, Pozón Fm., Pozón-El

Plate 16.2, 1-16, *Globigerinita glutinata* (Egger, 1893)

Globigerinita glutinata **1**, type specimen reproduced from Egger, 1893, pl. 17, fig. 19, original illustration in umbilical view, scale estimated, locality unknown; **2**, **3** (*Globigerinita boweni* Brönnimann and Resig, 1971, holotype, umbilical and side view), Zone O7, DSDP Hole 64.1, Ontong Java Plateau, tropical western Pacific Ocean); **4**, **8**, **12**, **16**, Holocene, from Parker, 1962, pl. 9, figs. 13, 6b, 1b, and 15b, illustrating part of modern variability for comparison with type specimens (4, 8, 16, from 'Downwind' station BG 134, tropical eastern Pacific Ocean; 12, from 'Downwind' station BG 70, mid-latitude South Pacific Ocean); **5-7**, (*Globigerina juvenilis* Bolli, 1957, holotype), middle Miocene *Globorotalia fohsi robusta* zone, Cipero Fm., Trinidad; **9-11**, (*Globigerina parva* Bolli, 1957, holotype), *Globigerina ampliapertura* Zone, Cipero Fm., Trinidad (specimen transitional to *Tenuitella munda*); **13-15**, (*Globigerinita incrusta* Akers, 1955, holotype, showing bulla), Miocene *Cibicides cartensi* var. *opimus* Zone, Humble Oil and Refining Co., Ellender No. 1 borehole, 10,132-10,142 feet. Scale bars: **1-16** = 50 μm.

Plate 16.3, 1-13, *Globigerinita glutinata* (Egger, 1893); 14, 15 *Globigerinita uvula* (Ehrenberg, 1861)

Globigerinita glutinata **1-3**, Zone O7, Cipero Fm., Trinidad (from Pearson and Wade, 2009, pl. 8, figs. 1a-c); **4**, **5**, Nannofossil Zone NP22, probably lower Zone O2, Ottenthal Fm., Austria; **6-8**, Zone O4-O6 undifferentiated, ODP Hole 872C/16H/1, 20-22 cm, equatorial North Pacific Ocean; **9-12**, upper Oligocene Zone O7, ODP Site 1237/29H/1, 85-87 cm, eastern Pacific Ocean; **13**, lower Oligocene Zone AO1, ODP Site 1137/19R/CC, Elan Bank, Kerguelen Plateau, Southern Ocean (specimen transitional to *Tenuitella munda*; compare pl. 16.6, fig. 4); *Globigerinita uvula* **14**, upper Oligocene Zone O4-O6 undifferentiated, ODP Hole 872C/16H/1, 20-22 cm, equatorial North Pacific Ocean (specimen transitional from *Globigerinita glutinata*; specimen tilted to show trochospiral); **15**, Zone O6, ODP Hole 925/24R/5, 20-22 cm, Ceara Rise, equatorial western Atlantic Ocean. Scale bars: **1-10**, **12-15** = 50 μm; **11** = 5 μm.

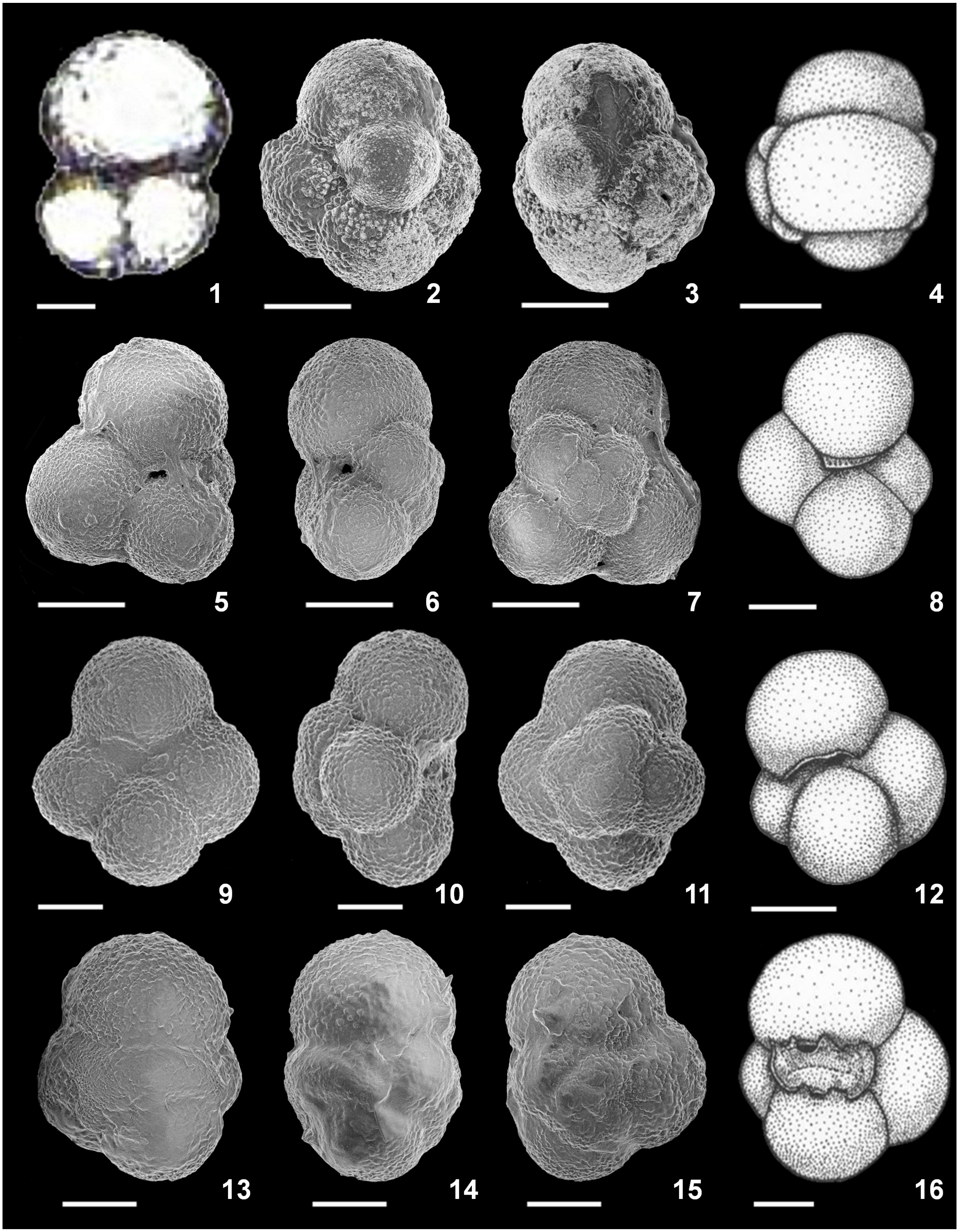

Plate 16.2 *Globigerinita glutinata* (Egger, 1893)

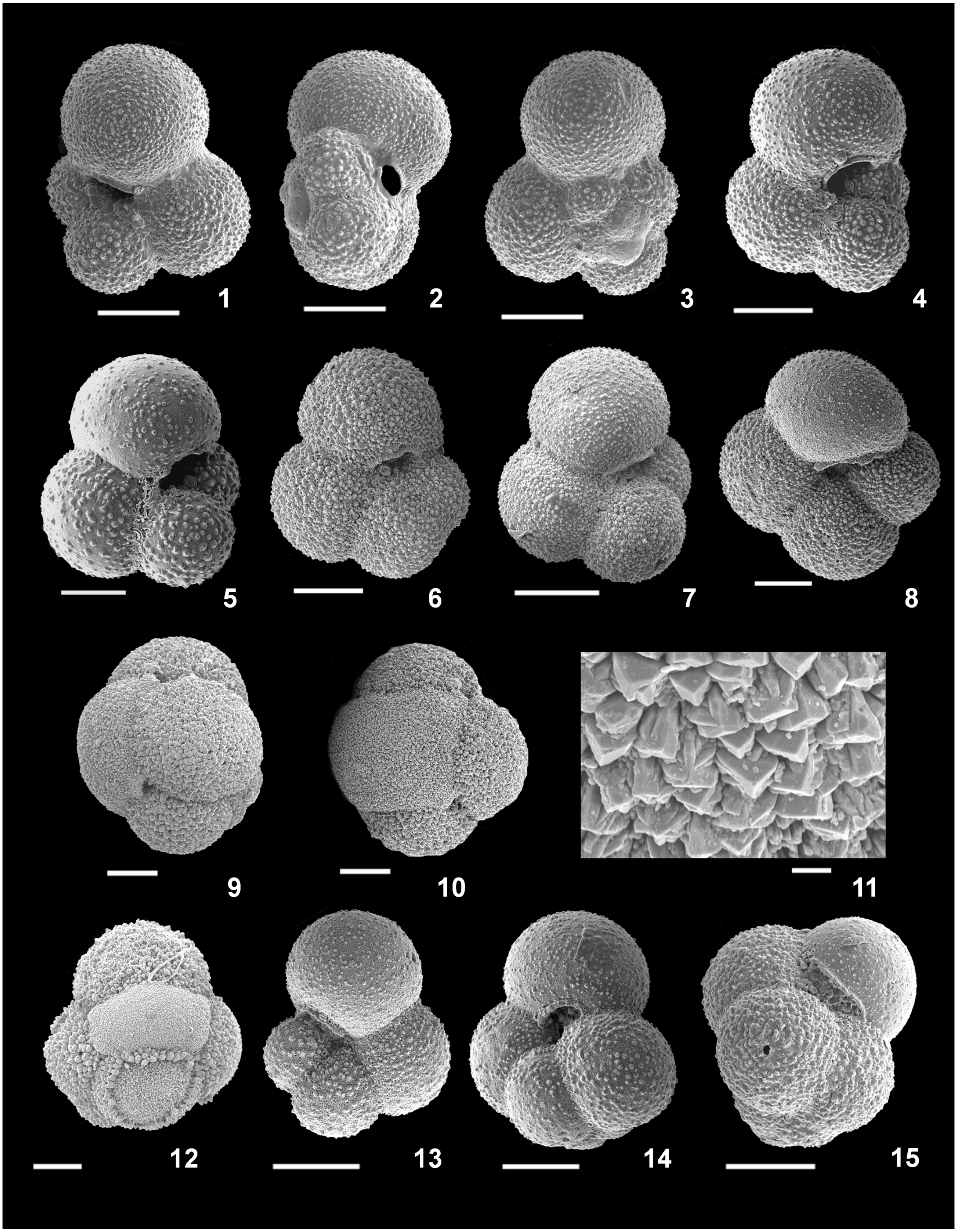

Plate 16.3 *Globigerinita glutinata* (Egger, 1893), *Globigerinita uvula* (Ehrenberg, 1861)

Mene Road Section, Eastern Falcón, Venezuela].

Tinophodella ambitacrena Loeblich and Tappan, 1957:114, fig. 3 [Recent, *Albatross* Station D2763, Atlantic Ocean off Brazil].—Bolli and Saunders, 1985:188, fig. 17.6 (reillustration of holotype).

Globigerinita glutinata ambitacrena (Loeblich and Tappan).—Fleisher, 1974:1022, pl. 9, fig. 3 [Pleistocene Zone N22, DSDP Site 219, Arabian Sea].

Globigerina parva Bolli, 1957:108, pl. 22, figs. 14a-c [lower Oligocene *Globigerina ampliapertura* Zone, Cipero Fm., Trinidad].

Globigerina juvenilis Bolli, 1957:110, pl. 24, figs. 5a-c [middle Miocene *Globorotalia fohsi robusta* zone, Cipero Fm., Trinidad], fig. 6 [middle Miocene *Globorotalia fohsi lobata* zone, Cipero Fm., Trinidad].—Jenkins, 1985:274, fig. 7.1 (reillustration of holotype).

Tenuitellinata juvenilis (Bolli).—Li, 1987:311 [not illustrated].—Li and others, 1992:579, pl. 2, fig. 3 [lower Oligocene, ODP Hole 749B, southern Kerguelen Plateau, southern Indian Ocean], figs. 4-6 [lower Pliocene, ODP Hole 747A, central Kerguelen Plateau, southern Indian Ocean].—Li and others, 2003a:20, pl. 2, fig. 3, pl. 6, fig. 28 [lower Miocene Zone SAN4 and middle Miocene Zone SAN10, ODP Hole 1134A, Great Australian Bight].

Tenuitellinata juveniles (sic) (Bolli).—Li and others, 2003b:16, pl. 2, fig. 11 [upper Oligocene Subzone P21b, ODP Hole 1134A, Great Australian Bight].

Globigerinita juvenilis (Bolli).—Spezzaferri, 1994:62, pl. 27, figs. 1a-c [lower Miocene Subzone N4a, DSDP Site 593, south Pacific Ocean], fig. 2a-c [lower Miocene Zone N6, ODP Hole 709C, equatorial Indian Ocean].—Pearson and Wade, 2009:211, pl. 8, figs. 1a-d [upper Zone O6 (=Zone O7 of this work), Cipero Fm., Trinidad].

Globigerinita boweni Brönnimann and Resig, 1971:1271, pl. 26, figs. 1-4 [upper Oligocene Zone N3 (=Zone O7), DSDP Hole 64.1, Ontong Java Plateau, equatorial western Pacific Ocean].—Fleisher, 1975, pl. 3, fig. 1 [upper Oligocene *Globigerina ciperoensis* Zone, DSDP Site 305, central north Pacific Ocean].—Li and others, 1992:581, pl. 2, fig. 7 [upper Oligocene, ODP Hole 749B, southern Kerguelen Plateau, southern Indian Ocean].—BouDagher-Fadel, 2012a, pl. 5.3, fig. 1 (re-illustration of holotype).

DESCRIPTION.

Type of wall: Microperforate, smooth with pustules, radially crystalline in section (*glutinata*-type).

Test morphology: Trochospiral, low to medium spired, globigeriniform, primary aperture intraumbilical or intra-extraumbilical, usually a broad low arch with a fine lip of constant thickness; 3-3½ globular chambers in final whorl; umbilical sutures radial, incised; spiral sutures depressed, radial or slightly curved; may lack bulla (*juvenilis* morphotype), or may possess a small umbilical bulla (*boweni* morphotype), a large inflated umbilical bulla, a wide deflated umbilical bulla (*incrusta* morphotype), or a deflated bulla with infralaminar apertural tunnels extending along sutures (*ambitacrena* morphotype). Supplementary sutural apertures may be present on the spiral side.

Size: Mostly small to medium size (150-400 µm); generally smaller in the Oligocene than Recent.

DISTINGUISHING FEATURES.— *Globigerinita glutinata* is distinguished from other globigeriniform species by its distinctive *glutinata*-type microperforate wall texture. It is distinguished from *Globigerinita uvula* by having a low to medium trochospiral coiling mode.

DISCUSSION.— This is a very abundant living species for which there is a stable taxonomic concept as a microperforate form (e.g., Parker, 1962; Hemleben and others, 1989). Egger's (1893) original type material is lost. The illustration (the umbilical view of which is reproduced in Plate 16.2, Fig. 1) shows a specimen with a globigeriniform test and just three chambers in the final whorl that is not typical of the species. There is no scale, but the same plate contains many other foraminifera apparently drawn to a common scale and the specimen is about one third the maximum diameter of *Trilobatus sacculifer* (for example) suggesting a maximum diameter between 200-250 µm. The accompanying description emphasizes the difference in wall texture from *Globigerina triloba* (=*Trilobatus trilobus*): "...in larger specimens the difference between the species becomes particularly clear in that the test of *Globigerina glutinata* remains delicate and matt [dull sheen], whilst the pores of *Globigerina triloba* appear very large and associated with a rough network [of ridges]" (translated by M. Kučera). Parker (1962) first appreciated that the nonspinose wall texture distinguished this species from *Globigerina* and related forms (see discussion under Genus *Globigerinita*, above). Clearly she regarded Egger's illustrations as insufficient to prove this, but based her concept on the figures of Rhumbler (1911) who, she indicated, must have seen Egger's material (Parker, 1962:248). Parker (1962:219) aimed for a natural classification of modern species "which recognizes variation and intergradation... The artificial splitting of species produces complications which are endless, as each worker emphasizes different criteria". Accordingly, when describing *glutinata*, she showed a wide range of morphotypes including specimens with supplementary apertures on the spiral side and specimens with bullae of various shapes and sizes alongside specimens lacking bullae (a subset of which is shown on Plate 16.2). Subsequent workers on modern planktonic foraminifera have tended to base their concepts on Parker's excellent illustrations (e.g., Hemleben and others, 1989). Other workers, however, have elected to formally split the group into species and/or subspecies (e.g., Brönnimann and Resig, 1971).

Egger's figured specimen does not possess a bulla, a point that has a bearing on subsequent taxonomic debates. There is considerable discussion in the biological and paleontological literature on the significance or otherwise of an umbilical bulla of varying degrees of complexity and inflation in planktonic foraminifera, in general, and *Globigerinita*, in particular, and how to reflect that variation in the species and genus level taxonomy. It seems that some species have a tendency to form a bulla of a particular morphology as a necessary reproductive structure whereas in other species bullae can occur, but are not obligate. Relative to chamber form, bullae seem to be particularly plastic and variable between individuals as to degree of inflation, extensions along the sutures, and the number of infralaminal apertures, and hence provide considerable scope for taxonomic splitting. Some authors (e.g., Spezzaferri, 1994) have restricted their concept of *glutinata* to include only inflated bullate forms, but this conflicts with the fact that Egger's illustrated specimen does not have a bulla and also makes the identification of pre-adult specimens problematic. In this work we do not regard the bulla as being of high taxonomic value in this group (following Parker, 1962; Kennett and Srinivasan, 1983; Hemleben and others, 1989; Pearson, 1995; Pearson and Chaisson, 1997; Nathan and Leckie, 2003), which simplifies the taxonomy considerably. We do, however, acknowledge that the Miocene *Globigerinatella* lineage, which descends from *glutinata*, can only be recognized and divided on the basis of its complex and overlapping obligate bullae (e.g., Pearson, 1995). We observe that bullae tend to be rarer and less complicated in the Oligocene and lower Miocene than they are in modern *Globigerinita*, but they do occur frequently (e.g., the Oligocene *Globigerinita boweni* morphotype of Brönnimann and Resig, 1971, and the Miocene *Globigerinita incrusta* morphotype of Akers, 1955, both of which are illustrated in SEM here for the first time; see Pl. 16.2, Figs. 2-3 and 13-15; see also Oligocene bullate specimens of Nocchi and others, 1991; Leckie and others, 1993; and Li and others, 2003b).

Oligocene and Miocene *Globigerinita glutinata* have commonly been described under the designation *Globigerina juvenilis* Bolli, 1957 (the holotype of which is middle Miocene). We illustrate here new SEMs of the holotype of *juvenilis* (Plate 16.2, Figs. 5-7) and confirm that it is a microperforate form that falls within our concept of *glutinata*. In the Oligocene it is common to find populations that appear to intergrade from *Globigerinita glutinata* morphotypes (usually with 3½ chambers in the final whorl and an intra-extrumbilical aperture) to *Tenuitella munda* morphotypes (usually with four chambers in the final whorl, an extraumbilical aperture and a slightly lower trochospiral). This occurs, for example, in the Ottenthal Formation of Austria (probably lower Zone O2, close to the first appearance of *glutinata*), but also at higher stratigraphic levels within the Oligocene (e.g., Jenkins, 1965; Jenkins and Srinivasan, 1986; Li and others, 2003a). We use the apertural position as the primary means of distinguishing the species (and genera). On Plate 16.2, Figs. 9-11 we illustrate the holotype of *Globigerina parva* Bolli (1957), in SEM for the first time (a form originally described from the lower Oligocene). We confirm the microperforate wall texture and note that this morphotype falls within this concept of *glutinata* but shows transitional features to *munda* (see also Pearson and Wade, 2009). On Plate 16.3, Fig. 13, we illustrate a specimen that is very close to typical *munda* in several respects but has an aperture that extends into the umbilicus and so is placed by us, on this arbitrary basis, in *glutinata.*

PHYLOGENETIC RELATIONSHIPS.— Descended from *Tenuitella munda* in the lower Oligocene (Jenkins, 1965; Jenkins and Srinivasan, 1986).

STRATIGRAPHIC RANGE.— If a broad concept is taken of this taxon, as here, it ranges from the lower Oligocene to Recent. Bolli (1957) recorded the lowest occurrence (LO) of *Globigerina juvenilis* (= *Globigerinita glutinata* in this study) in Trinidad at the base of the *Globorotalia kugleri* Zone (= approximately Zone O7, upper Oligocene). Li (1987) recorded the LO of *Tenuitellinata juvenilis* (=*Globigerinita glutinata*) at the base of Zone P21 (= base of Zone O4). Jenkins (1965) described the transition between *Globorotalia munda* and *Globigerina juvenilis* (= *Globigerinita glutinata* in this study) in the upper part of the lower Oligocene of New Zealand (see also Jenkins, 1985) (= approximately Zone O4 in this study). Bolli (1957) described his species *Globigerina parva* from a level equivalent to Zone O2 in the lower Oligocene. The *parva* form is herein regarded as an intermediate between *T. munda* and *G. glutinata* but within the morphological range of the latter species (see Pearson and Wade, 2009:211). We have observed a similar population of *munda-glutinata* intermediates in the Ottenthal Formation of Austria (nannofossil Zone NP22, probably equivalent to lower Zone O2).

TYPE LEVEL.— Holocene.

GEOGRAPHIC DISTRIBUTION.— Global.

STABLE ISOTOPE PALEOBIOLOGY.— Oligocene and lower Miocene forms have been recorded with an isotopic signature indicative of a shallow, mixed-layer habitat (Pearson and others, 2001; Majewski, 2003; Pearson and Wade, 2009).

REPOSITORY.— Lost (see discussion).

Globigerinita uvula (Ehrenberg, 1861)

Plate 16.3, Figures 14-15

(Note: this is a living species; we restrict this synonymy list to references that are relevant to Oligocene to lower Miocene occurrences.)

Pylodexia uvula Ehrenberg, 1861:308 [modern ocean, Gulf Stream off Florida].

Globigerinita uvula (Ehrenberg).—Parker, 1962:252, pl. 8, figs. 14-20 [Holocene, Discovery Station 385, southeast Pacific Ocean west of Drake Passage], pl. 8, figs. 21-23 [Holocene, 'Downwind' Expedition Station BG 68, Pacific Antarctic Ridge, south Pacific Ocean], figs. 24-26 [Scripps Station V-1, offshore California, Pacific Ocean].—Quilty, 1976:642, pl. 8, fig. 18 [middle Miocene Zone N9, DSDP Site 319, Bauer Deep, eastern Pacific Ocean].—Kennett and Srinivasan, 1983:224, pl. 56, figs. 6-8 [lower Miocene Subzone N4b, DSDP Site 289, Ontong Java Plateau, equatorial western Pacific Ocean].—van Eijden and Smit, 1991:111 [Broken Ridge and Ninetyeast Ridge, eastern Indian Ocean; not illustrated].—Chaisson and Leckie, 1993:157, pl. 10, fig. 1 [lower Miocene Zone N7, ODP Hole 806B, Ontong Java Plateau, equatorial eastern Pacific Ocean], fig. 7 [lower Miocene Zone N5, ODP Hole 806B, Ontong Java Plateau, equatorial eastern Pacific Ocean].—Spezzaferri, 1994:62, pl. 27, figs. 5a-c [lower Miocene Subzone N4b, DSDP Site 151, Beata Ridge, Caribbean Sea].—Pearson, 1995:47, pl. 1, fig. 21 [lower Miocene Zone N6/7, ODP Hole 871A, Limalok Guyot, Marshall Islands, equatorial western Pacific Ocean], fig. 22 [upper Oligocene / lower Miocene Zone N4/5, ODP Hole 871A, Limalok Guyot, Marshall Islands, equatorial western Pacific Ocean].

Globigerinita juvenilis (Bolli) / *Globigerinita uvula* (Ehrenberg) transitional form.—Spezzaferri, 1994:pl. 27, figs. 3a-c [lower Miocene Zone N5, DSDP Hole 667A, equatorial Atlantic Ocean], figs. 4a-c [lower Miocene Subzone N4b, ODP Hole 709B, equatorial Indian Ocean].

DESCRIPTION.

Type of wall: Microperforate, smooth with pustules (*glutinata*-type).

Test morphology: High to very high trochospiral, primary aperture intra-extraumbilical, a broad low arch with a fine lip of constant thickness; 3-3½ globular chambers in final whorl; umbilical and spiral sutures incised, radial or slightly curved. The final chamber may have a pointed 'sacculiferid' shape.

Size: Mostly small (150-250 µm).

DISTINGUISHING FEATURES.— *Globigerinita uvula* is distinguished from *Globigerinita glutinata* by its high to very high trochospiral coiling (Parker, 1962).

DISCUSSION.— This species is common in the Neogene but also occurs rarely in the Oligocene (Quilty, 1976; Kennett and Srinivasan, 1983; van Eijden and Smit, 1991; Spezzaferri, 1994; Pearson, 1995). We defer detailed treatment to future works on modern and Neogene taxonomy.

PHYLOGENETIC RELATIONSHIPS.— Descended from *Globigerinita glutinata* in the Oligocene (cf. Spezzaferri, 1994).

STRATIGRAPHIC RANGE.— The lowest recorded occurrence is in upper Zone O5 (Quilty, 1976:662; near the top of Zone N2). It becomes more common towards the upper part of the Oligocene.

TYPE LEVEL.— Holocene.

GEOGRAPHIC DISTRIBUTION.— Global. Note

that Spezzaferri (1994:62) suggested that *uvula* was restricted to the South Atlantic Ocean in the Oligocene but occurrences are known in the Indian (van Eijden and Smit, 1991) and Pacific (Quilty, 1976; Pearson, 1995) Oceans.

STABLE ISOTOPE PALEOBIOLOGY.— No data available.

REPOSITORY.— Unknown.

Genus *Tenuitella* Fleisher, 1974, emended Li, 1987, Huber and others, 2006

Tenuitella Fleisher, 1974:1033.
Tenuitella Fleisher, 1974, emended Li, 1987:309.
Praetenuitella Li, 1987:309 (type species *Praetenuitella praegemma* Li, 1987).
Tenuitellinata Li, 1987:311 (type species *Globigerina ciperoensis angustiumbilicata* Bolli, 1957).

TYPE SPECIES.— *Globorotalia gemma* Jenkins, 1965:1115-1118, fig. 11, nos. 97-103.

DESCRIPTION.

Type of wall: Microperforate *glutinata*-type (Fleisher, 1974; Chapter 15, this volume).

Test morphology: Test small, low trochospiral, occasionally becoming pseudoplanispiral, periphery rounded; chambers globular to ovate, 4-6 in final whorl; sutures radial on umbilical side, radial to obliquely curved on spiral side; wall microperforate (*glutinata*-type), thin, smooth to weakly pustulose; umbilicus small, open to nearly closed; aperture a low extraumbilical to umbilical arch, bordered by a thin lip (modified from Huber and others, 2006).

Size: Mostly small <150 μm to very small <75 μm.

DISTINGUISHING FEATURES.— Distinguished from *Globigerinita* by the intra-extraumbilical aperture (in most forms), more chambers per whorl, lower trochospiral coiling, and more globorotaliiform morphology.

DISCUSSION.— This genus was revised by Huber and others (2006). As in Fleisher's (1974) original concept, we include forms with an umbilical aperture as well as those with intraumbilical-extraumbilical and wholly extraumbilical apertures, hence we include Li's (1987) form-genus *Tenuitellinata* in synonymy (following Pearson and Wade, 2009; see additional discussion under *Tenuitella angustiumbilicata*).

Tenuitella angustiumbilicata (Bolli, 1957)

Plate 16.4, Figures 1-16
(Pl. 16.4, Figs. 1-3: new SEMs of holotype of *Globigerina ciperoensis angustiumbilicata* Bolli)

Globigerina ciperoensis angustiumbilicata Bolli, 1957:109 (partim), pl. 22, fig. 12 [Oligocene *Globorotalia opima opima* Zone, Cipero Fm., Trinidad].—Bolli and Saunders, 1985:182, pl. 13, fig. 8a-c (reproduction of holotype illustration).

Globigerina angustiumbilicata Bolli.—Jenkins and Orr, 1972:1085 (partim), pl. 4, fig. 6 [lower Miocene *Globorotalia kugleri* Zone, DSDP Hole 77B, eastern equatorial Pacific Ocean], pl. 5, figs. 6-8 [lower Oligocene *Globigerina ampliapertura* Zone, DSDP Hole 77B, eastern equatorial Pacific Ocean].—Stainforth and others, 1975:253 (partim), fig. 105, no. 3 [Oligocene *Globigerina ciperoensis* Zone, Cipero Fm., Trinidad], no. 5 (reproduction of holotype illustration).—Quilty, 1976:637, pl. 1, figs. 12, 13 [lower Oligocene Zone P19, DSDP Site 321, Nazca Plate, southeastern Pacific Ocean], pl. 1, figs. 14, 15 [level uncertain, DSDP Hole 320A, Nazca Plate, southeastern Pacific Ocean].—Poore, 1984:444, pl. 3, figs. 5-7 [lower Oligocene Zone OL2, DSDP Site 522, Walvis Ridge, South Atlantic Ocean].—Keller, 1985, fig. 3 [lower Oligocene Zone P18-19, Shubuta Member, Red Bluff Fm., Wayne County, Mississippi].—van Eijden and Smit, 1991:110, pl. 2, fig. 9 [upper Oligocene Zone P22, ODP Hole 758A, Ninetyeast Ridge, equatorial Indian Ocean].

?*Globigerina* (*Globigerina*) *angustiumbilicata* (Bolli).—Kennett and Srinivasan, 1983:31, pl. 4, figs. 3-5 [middle Miocene Zone N11, DSDP Site 289, Ontong Java Plateau, equatorial western Pacific Ocean] (possibly reworked).

Tenuitellinata angustiumbilicata (Bolli).—Li, 1987:311, pl. 2, figs. 15, 17-19 [*G. ciperoensis* Zone, Cipero Fm., Trinidad].—Spezzaferri and Premoli Silva, 1991:257, pl. 18, figs. 2a-d, 5a-d [lower Oligocene Zone P20, DSDP Hole 538A, Gulf of Mexico].—Leckie and others, 1993:125, pl. 6, figs. 4, 5 [upper Oligocene Zone P22, ODP Hole 628A, western North Atlantic Ocean].—Chaisson and Leckie, 1993:166, pl. 1, fig. 9 [lower Miocene Subzone N4b, ODP Hole 806B, Ontong Java Plateau, western equatorial Pacific Ocean].—Spezzaferri, 1994:61, pl. 32, fig. 6 [lower Oligocene Zone

P20, DSDP Hole 538A, Gulf of Mexico], fig.7a-c [lower Miocene Zone N8, DSDP Site 94, Gulf of Mexico].—Pearson, 1995:53, pl. 1, fig. 17 [upper Oligocene to lower Miocene, ODP Hole 872C, Lo-En Guyot, Marshall Islands, equatorial western North Pacific Ocean].—Li and others, 2003b:16, pl. 2, fig. 8 [lower Oligocene Zone P18/P19, ODP Hole 1134A, Great Australian Bight].—Hernitz Kučenjak and others, 2006, pl. 4, figs. 2, 3 [lower Oligocene Zone O3, Jihar-1 well, Syria].

Tenuitella angustiumbilicata (Bolli).—Pearson and Wade, 2009:213, pl. 8, figs. 4a-d [upper Oligocene Zone O6 (= O7), Cipero Fm., Trinidad].

Globigerinita stainforthi praestainforthi Blow, 1969:383, pl. 25, figs. 3-5 [upper Oligocene part of *Globorotalia kugleri* Zone = Zone O7, Cipero Fm., Trinidad].

Globigerinita praestainforthi Blow.—Li and others, 1992:581, pl. 3, fig. 1 [lower Miocene ODP Hole 747A, Kerguelen Plateau, southern Indian Ocean].

Tenuitellinata praestainforthi (Blow).—Spezzaferri, 1994:61, pl. 32, figs. 1a-c [lower Miocene Zone N5, ODP Hole 709C, equatorial Indian Ocean], figs. 3a-c [lower Miocene Subzone N4a, ODP Hole 667A, equatorial Atlantic Ocean].

Tenuitella praestainforthi (Blow).—Pearson and Wade, 2009:213, pl. 8, figs. 5a-e [upper Oligocene Zone O6 (=O7), Cipero Fm., Trinidad].

Tenuitellinata cf. *T. pseudoedita* (Subbotina).—Li, 1987:312, pl. 3, figs. 1-5 [lower Miocene *Catapsydrax dissimilis* Zone, Cipero Fm., Trinidad], pl. 4, figs. 11-13, pl. 5, figs. 1, 4, 7, 11 [upper Oligocene *G. ciperoensis* Zone, Cipero Fm., Trinidad] (not Subbotina, 1953 = Problematica).

Tenuitella cf. *T. pseudoedita* (Subbotina).—Li and others, 2003b:16, pl. 2, fig. 9 [lower Oligocene Zone P18/P19, ODP Hole 1134A, Great Australian Bight]. [Not Subbotina, 1953 = Problematica.]

Tenuitella gemma (Jenkins).—Li and others, 1992:579, pl. 1, fig. 5 [upper Oligocene ODP Hole 747A, Kerguelen Plateau, southern Indian Ocean]. [Not Jenkins, 1965.]

Tenuitellinata sp. 1 Spezzaferri, 1994, pl. 32, figs. 2a-c [upper Oligocene Subzone P21b, DSDP Hole 526A, western South Atlantic Ocean], fig. 4a-c [upper Oligocene Zone P22, DSDP Site 151, Beata Ridge, Caribbean Sea], fig. 5a-c [lower Miocene Subzone N4b, ODP Hole 709B, equatorial Indian Ocean].

Tenuitella postcretacea (Myatliuk).—BouDagher-Fadel, 2012a [Oligocene Zone P21, Cipero Fm., Trinidad]. [Not Myatliuk, 1950.]

Tenuitella praepseudoedita BouDagher-Fadel, 2012a:396, pl. 5.3, fig. 3 (reproduced without attribution from Li, 1987, pl. 3, fig. 1), fig. 4 (reproduced without attribution from Li, 1987, pl. 3, fig. 40) (invalid taxon, see discussion below).

Not *Globigerina ciperoensis angustiumbilicata* Bolli, 1957:109, pl. 22, fig. 13 [Oligocene *Globorotalia opima opima* Zone, Cipero Fm., Trinidad] (paratype, of uncertain affinity).

Not *Globigerina angustiumbilicata* Bolli.—Blow and Banner, 1962:85, pl. 9, figs. x-z [lower Oligocene *Globigerina oligocaenica* Zone, Lindi area, Tanzania] (= *Ciperoella ciperoensis* group).—Jenkins and Orr, 1972:1085, pl. 4, fig. 5 [lower Oligocene *Globigerina ampliapertura* Zone, DSDP Hole 77B, eastern equatorial Pacific Ocean] (= probable juvenile *Ciperoella*).—Stainforth and others, 1975:253, fig. 105, figs. 1, 2, 4 [Oligocene *Globigerina ciperoensis* Zone, Cipero Fm., Trinidad] (= *Ciperoella ciperoensis*).—Poore and Brabb, 1977:255, pl. 8, fig. 6 [Oligocene Rices Mudstone member, San Lorenzo Fm., California] (= *Ciperoella ciperoensis* group).

DESCRIPTION.

Type of wall: Microperforate *glutinata*-type wall, surface smooth to finely pustulose, pustules irregularly scattered on both sides of test. May become densely pustulose, especially in bullate individuals.

Test morphology: Test small, very low trochospiral, equatorial periphery lobate, circular in outline, axial periphery rounded; chambers globular to slightly subquadrate, slightly compressed and inflated on the umbilical side, 4-5 in the final whorl, 10-12 comprising adult tests, increasing slowly in size; sutures straight, radial, depressed on spiral and umbilical sides; umbilicus narrow, deep, sometimes closed; aperture arched, bordered by a narrow lip, variable in position, either intraumbilical or intra-extraumbilical in position. Specimens may exhibit a single, encroaching umbilical bulla with 3-5 small, arched, infralaminal apertures (‘*praestainforth*’ morphotype).

Size: Holotype 0.16 mm diameter; hypotypes 0.13-0.17 mm diameter, 0.70-0.80 mm breadth.

Plate 16.4 *Tenuitella angustiumbilicata* (Bolli, 1957)

1-3 (holotype, note fig. 1 is tilted to show aperture), *Globorotalia opima opima* Zone, Cipero Fm., Trinidad; **4**, **5**, Zone O4-O6 undifferentiated, ODP Hole 872C/16H/1, 20-22 cm, equatorial North Pacific Ocean; **6-8**, Zone AO1, ODP Site 1137/19R/CC, Elan Bank, Kerguelen Plateau, Southern Ocean; **9**, Base of Zone O6, ODP Hole 925A/27R/5, 75-77 cm, Ceara Rise, equatorial western Atlantic Ocean; **10**, ODP Hole 1218B/17H/3, 90 cm, equatorial eastern Pacific Ocean; **11-16**, upper Oligocene Zone O7, Cipero Fm., Trinidad (11, 12 same small specimen; 13, 15 same specimen, bullate form, heavily pustulose, ‘*praestainforthi*’ morphotype, from Pearson and Wade, 2009, pl. 8, figs. 4c, 4d, 5a, 5c). Scale bars: **1-11**, **13-15** = 50 µm; **12**, **16** = 10 µm.

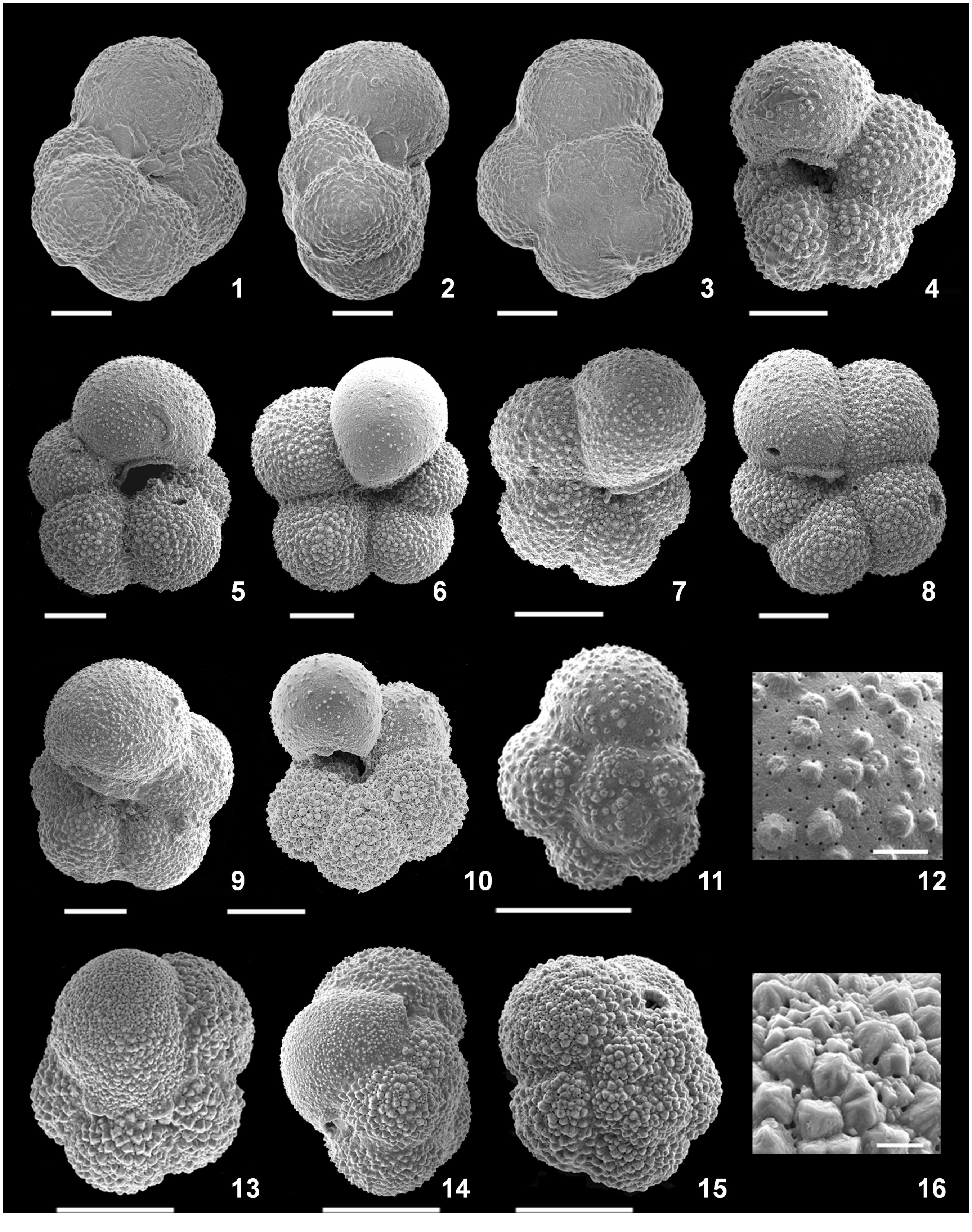

Plate 16.4 *Tenuitella angustiumbilicata* (Bolli, 1957)

DISTINGUISHING FEATURES.— Distinguished from *Tenuitella gemma* by its more inflated chambers, especially as seen in edge and umbilical view, and slightly higher trochospiral, and also by typically having 4½ rather than 5-6 chambers in the final whorl. The wall texture is distinctly more pustulose.

DISCUSSION.— Bolli (1957) described this form as a subspecies of *Globigerina ciperoensis* (=*Ciperoella ciperoensis* in this work) and always maintained the close affinity of the two forms (up to and including Bolli and Saunders, 1985). For Bolli, its distinguishing feature was the narrow umbilicus (*angustus*, L. = narrow). Fleisher (1974:1018) included *angustiumbilicata* in the macroperforate spinose genus *Globigerina* but regarded its wall texture as a "possible exception" from being spinose. Jenkins and Orr (1972), Quilty (1976), and Kennett and Srinivasan (1983) all illustrated what are clearly microperforate specimens under the name *angustiumbilicata* while other authors (e.g., Poore and Brabb, 1977) illustrated macroperforate forms which we would now assign to the *Ciperoella* group. Li (1987) reported that R. Fleisher had re-examined the holotype at the U.S. National Museum in December, 1986, and informed him that the test has a "microperforate wall texture rather than a spinose one" (quoted in Li, 1987:311). We confirm this observation with new SEMs of the holotype which is clearly microperforate and pustulose as opposed to macroperforate and pitted (see Plate 16.4, Figs. 1-3). Bolli's figured paratype is, by contrast, macroperforate and of uncertain affinity.

As discussed above, Bolli (1957:109) distinguished his subspecies from *ciperoensis* by the small umbilicus. He also noted that "the aperture, which is umbilical in position, may in some specimens show a tendency towards an umbilical-extraumbilical position". Li (1987), following long tradition in foraminiferal taxonomic practice, regarded the supposedly intraumbilical position of the aperture as a genus level character and named the genus *Teneuitellinata* for *Tenuitella*-like forms with an intraumbilical aperture. The genus was, for Li, a form-genus, because the intraumbilical position evolved more than once (in *angustiumbilicata* and a form he called '*Tenuitellinata* cf. *pseudoedita*'). Pearson and Wade (2009:213) noted that the apertural position in populations of *angustiumbilicata* is variable and that the holotype itself, which is a specimen with a very narrow umbilicus, has an intra-extraumbilical aperture (see Plate 16.4, Fig. 1). For these reasons we follow Pearson and Wade (2009) in regarding *Tenuitellinata* as synonymous with *Tenuitella*.

Blow (1969) described *Globigerina stainforthi praestainforthi* from the Mosquito Creek outcrop locality in the Cipero Fm., Trinidad. Given our modern understanding of wall textures, it is quite clear from Blow's own images of *stainforthi* and *praestainforthi* that the two are unrelated, notwithstanding their similarity in gross morphology: *stainforthi* is a cancellate macroperforate form whereas *praestainforthi* is clearly microperforate and pustulose. Li (1987) pointed out the close similarity between *praestainforthi* and *angustiumbilicata*. Pearson and Wade (2009) re-collected from the type locality and illustrated a specimen similar to the holotype (Pearson and Wade, 2009, pl. 8, figs. 5a-e) and also showed the wall in cross-section, demonstrating a radial crystalline structure typical of the *glutinata*-type wall (Chapter 15, this volume). Following Li, they emphasized the strong similarity to *Tenuitella angustiumbilicata*, which is very common in the Cipero Fm., except for the large umbilical bulla and strongly pustulose surface texture. They suggested that *angustiumbilicata* and *praestainforthi* "may be morphs of the same biospecies", the latter being a late ontogenetic stage (i.e., with gametogenic features). The two forms have virtually identical stratigraphic ranges, both becoming extinct at the same level in the early Miocene (Li and others, 1992:581). Here we place them formally in synonymy, consistent with our view that the presence or absence of an umbilical bulla is not a species-defining characteristic.

Li (1987:312) distinguished a form as *Tenuitellinata* cf. *T. pseudoedita* (Subbotina) based on the "slightly convex spiral side and low arched (often variable) aperture, which is strongly anterioumbilical". We have been unable to confirm a clear distinction between these morphs and so regard them as within the variability of populations of *T. angustiumbilicata*.

BouDagher-Fadel (2012a, pl. 5.3, figs. 3, 4) attempted to establish a new species *Tenuitellinata praepseudoedita*. The two published images (one an umbilical view, the other a side view) are both reproduced from Li (1987) without acknowledgment or attribution. In the caption to the plate, both images are indicated as the holotype, but actually they are two different specimens (No. P52020 and P52022 as documented by Li, 1987:301). There is no formal description, diagnosis or notice of repository. We regard the taxon as invalid because of 1) inadequate identification of the true nature of the type material, and 2) ambiguity as to which of the figured specimens is the holotype. When these facts were brought to her attention, BouDagher-Fadel (2012b) attempted to amend and validate *praepseudoedita* in a taxonomic note by citing Li (1987) and providing a short diagnosis. However the ambiguity over the type specimen was not resolved and hence the taxon remains invalid. We should also bear in mind Recommendation 73B of the code: "An author should designate as a holotype a specimen actually studied by him or her, not a specimen known to the author only from descriptions or illustrations in the literature" (International Code of Zoological Nomeclature, 1999).

PHYLOGENETIC RELATIONSHIPS.— This species is very rare in the lower Oligocene but becomes more abundant at higher levels. Presumably it evolved from *Tenuitella munda* which has a similar wall texture and morphology, although transitional forms have yet to be identified.

STRATIGRAPHIC RANGE.— The earliest confirmed occurrences are in the lower Oligocene. Premoli Silva and Spezzaferri (1990) record a clear lowest occurrence along with *Cassigerinella chipolensis* in the lower part of Zone P18 (= Zone O1) in ODP Site 709. According to van Eijden and Smit (1991) and Li and others (1992) it is very rare in the lower Oligocene, becoming abundant only in the upper Oligocene: this pattern seems to be true globally. The highest reliable occurrences are in the lower Miocene (*Tenuitella minutissima* Zone of ODP Hole 747A, Kerguelen Plateau; Li and others, 1992:585: probably equivalent to (sub)tropical Zone M2). Reported occurrences throughout the Neogene by various authors are considered doubtful in view of the homeomorphy within this group but this question is reserved for future study.

TYPE LEVEL.— Upper Oligocene Zone P22 (O7).

GEOGRAPHIC DISTRIBUTION.— Global, from the tropics to high latitudes.

STABLE ISOTOPE PALEOBIOLOGY.— Inhabited the warm surface mixed-layer (Poore and Matthews, 1984; van Eijden and Ganssen, 1995; Pearson and others, 1997; Pearson and Wade, 2009).

REPOSITORY.— Holotype (USNM P5608) deposited at the Smithsonian Museum of Natural History, Washington, D.C.

Tenuitella gemma (Jenkins, 1965)

Plate 16.5, Figures 1-16

Globigerina postcretacea Myatliuk.—Subbotina, 1953:60, pl. 2, figs. 16a-20c [lower Oligocene, northern Caucasus].—Saito and Bé, 1964, fig. 2 (two specimens on figure, as indicated in the caption) [Oligocene, Vicksburg Group, U.S. Gulf Coast region]. [Not Myatliuk, 1950.]

Globorotalia (*Turborotalia*) *postcretacea* (Myatliuk).—Blow and Banner, 1962:120-121, pl. 12, figs. G-J [Oligocene *Globigerina oligocaenica* Zone, Lindi area, Tanzania]. [Not Myatliuk, 1950.]

"Globorotalia" postcretacea (Myatliuk).—van Eijden and Smit, 1991:112, pl. 4, figs. 15-17 [lower Oligocene Zone P19/P20, ODP Hole 756C, Ninetyeast Ridge, equatorial Indian Ocean]. [Not Myatliuk, 1950.]

?*Globigerinella liverovskae* Bykova, 1960:322, pl. 7, figs. 1a-3c (no holotype or repository given; lectotype designated by Samuel and Salaj, 1968:122) [lower Oligocene (Rupelian), *Globigerinella liverovskae* Zone (Pg_3), southern Mangyshlak, Kazakhstan].

?*Globigerina khadumica* Bykova, 1960:322, pl. 7, figs. 4-7 (no holotype or repository given; regarded as junior synonym of *Globigerinella liverovskae* Bykova by Samuel and Salaj, 1968) [lower Oligocene (Rupelian), *Globigerinella liverovskae* Zone (Pg_3), southern Mangyshlak, Kazakhstan].

Globorotalia gemma Jenkins, 1965:1115, fig. 11, nos. 97-103 [lower Oligocene, Kakanui River, New Zealand].—Poore and Brabb, 1977:255, pl. 8, figs. 1-4 [Oligocene Rices Mudstone member, San Lorenzo Fm., California].—Toumarkine, 1978, pl. 8, figs. 1, 2 [lower Oligocene *Turborotalia ampliapertura* to *Cassigerinella chipolensis* / *Pseudohastigerina micra* Zone, DSDP Site 360, Cape Basin, South Atlantic Ocean].—Krasheninnikov and Basov, 1983:841, pl. 10, figs. 6-9 [lower Oligocene, DSDP Site 511, Falkland Plateau, South Atlantic Ocean].—Poore, 1984:444, pl. 3, figs. 1-4 [lower Oligocene Zone OL1, DSDP Site 522, Walvis Ridge, South Atlantic Ocean].—Jenkins and Srinivasan, 1986:807, pl. 2, figs. 12-14 [lower Oligocene *Globigerina brevis* Zone, DSDP Site 592, Lord Howe Rise, South Pacific Ocean].

Globorotalia (*Turborotalia*) *gemma* (Jenkins).—Jenkins, 1971:115, pl. 10, figs. 263-269 [lower Oligocene, Kakanui River, New Zealand].—Brönnimann and Resig, 1971:1313, pl. 32, figs. 2, 3 [upper Oligocene Zone N2, DSDP Hole 64.1, Ontong Java Plateau, western equatorial Pacific Ocean].—Quilty, 1976: pl. 12, fig. 7 [upper

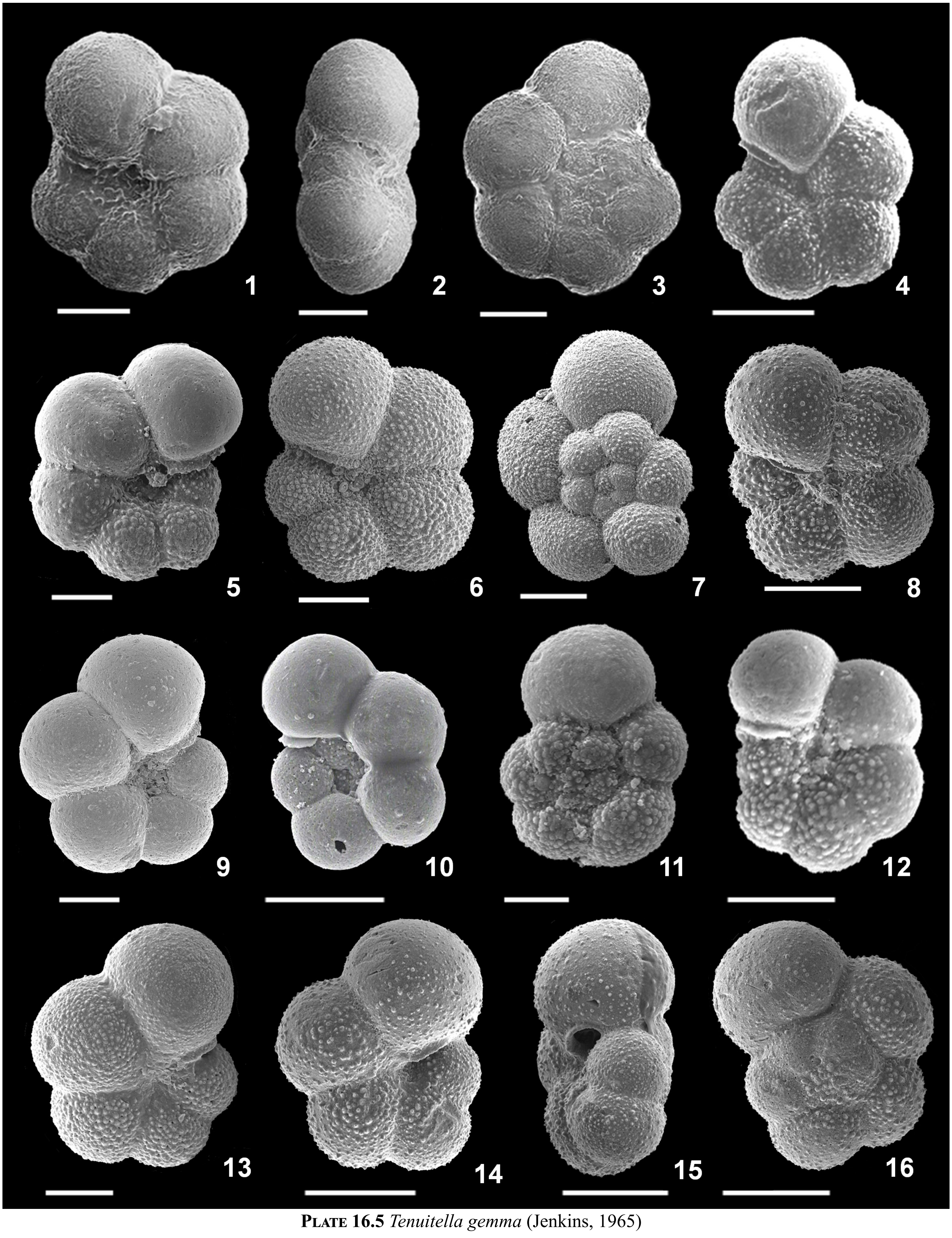

Plate 16.5 *Tenuitella gemma* (Jenkins, 1965)

Oligocene Zone N4, DSDP Hole 320B, southeastern Pacific Ocean].

Tenuitella gemma (Jenkins).—Fleisher, 1974:1033-1034, pl. 17, figs. 4, 6, 7 [lower Oligocene Zone P18-P19, DSDP Site 219, Arabian Sea].—Fleisher, 1975, pl. 3, figs. 5-7 [lower Oligocene "*Turborotalia*" *ampliapertura* Zone, DSDP Site 313, North Pacific Ocean].—Li, 1987:309, pl. 2, figs. 6, 7 [upper Oligocene *Gr. opima opima* Zone, Cipero Fm., Trinidad], fig. 8 [lower Oligocene *G. ampliapertura* Zone, Cipero Fm., Trinidad].—Stott and Kennett, 1990:560, pl. 7, fig. 10 (dissolved and peeled specimen) [Oligocene Zone AP11, ODP Hole 689B, Kerguelen Plateau, Southern Ocean].—Spezzaferri and Premoli Silva, 1991:257, pl. 18, fig. 6a-c [lower Oligocene Subzone P21a, DSDP Hole 538A, Gulf of Mexico].—Leckie and others, 1993:125 (part), pl. 6, fig. 6 [upper Oligocene Zone P22, ODP Hole 803D, Ontong Java Plateau, western equatorial Pacific Ocean], fig. 13 [upper Oligocene Zone P22, ODP Hole 628A, western North Atlantic Ocean].—Spezzaferri, 1994:60, pl. 31, figs. 1a-c [upper Oligocene Zone P22, DSDP Site 516, South Atlantic Ocean], pl. 32, fig. 8 [lower Oligocene Subzone P21a, DSDP Hole 538A, Gulf of Mexico].—Galeotti and others, 2002:379, pl. 3, figs. 11, 12 [upper Eocene / lower Oligocene, ODP Hole 1090B, Agulhas Ridge, South Atlantic Ocean].—Li and others, 2003b:16, pl. 2, fig. 7 [lower Oligocene Zone P18/P19, ODP Hole 1134A, Great Australian Bight].—Huber and others, 2006:488-489, pl. 16.7, figs. 15-17 (new illustrations of the holotype using SEM), figs. 19, 20 [upper Eocene Zone E16, ODP Hole 150X, Cape May Borehole, New Jersey].—Pearson and Wade, 2009:213, pl. 8, figs. 2a-c [upper Oligocene Zone O7, Cipero Fm., Trinidad].—Pearson and Wade, 2015, fig. 30.2a-b [lower Oligocene Zone O1, TDP Site 12, Stakishari, Tanzania].

Globorotalia cf. *Globorotalia gemma* Jenkins.—Leckie and Webb, 1986:1116, pl. 15, figs. 12, 13 [upper Oligocene-lower Miocene, DSDP Site 270, Ross Sea, Antarctica].

Globorotalia (*Turborotalia*) *cifellii* Brönnimann and Resig, 1971:1278 (partim), pl. 42, figs. 2-5, 8, 9 [uppermost Oligocene Zone N3, DSDP Hole 64.1, Ontong Java Plateau, western equatorial Pacific Ocean]. Not pl. 42, fig. 1 = ? *Ciperoella angulisuturalis*. Not pl. 42, fig. 7 = ? *Globorotaloides* sp. Not pl. 42, fig. 6 = ? *Ciperoella ciperoensis*.

?*Globorotalia* (*Turborotalia*) *nkbrowni* Brönnimann and Resig, 1971:1279-1280, pl. 40, figs. 1-8 [uppermost Oligocene Zone N3, DSDP Hole 64.1, Ontong Java Plateau, western equatorial Pacific Ocean].

?*"Tenuitella" nkbrowni* (Brönnimann and Resig).—Li, 1987:310 [not illustrated].

Globorotalia munda Jenkins.—Krasheninnikov and Basov, 1983:841, pl. 10, figs. 10, 12 [lower Oligocene, DSDP Site 511, Falkland Plateau, South Atlantic Ocean]. [Not Jenkins, 1965.]

Tenuitella neoclemenciae Li, 1987:310, pl. 2, figs. 1-4 [Oligocene *G. ampliapertura* Zone, Cipero Fm., Trinidad].—Spezzaferri, 1994:60, pl. 31, figs. 4a-c [upper Oligocene Zone P22, DSDP Hole 516F, eastern South Atlantic Ocean].

Not *Tenuitella gemma* (Jenkins).—Berggren, 1992:564, pl. 4, fig. 12 [Oligocene, ODP Hole 748B, southern Kerguelen Plateau, Southern Ocean] (=*Tenuitella munda*).

DESCRIPTION.

Type of wall: Microperforate *glutinata*-type wall, surface smooth to finely pustulose, pustules irregularly scattered on both sides of test.

Test morphology: Test small, very low trochospiral, equatorial periphery lobate, circular to elliptical in outline, axial periphery rounded; chambers globular, slightly compressed, 4½-6 in the final whorl, 10-12 comprising adult tests, increasing slowly in size; sutures slightly recurved, depressed on spiral and umbilical sides; umbilicus narrow, deep, sometimes nearly closed; aperture a very low arch bordered by a narrow lip, intra- to extraumbilical in position, sometimes extending to periphery ('*neoclemenciae*' morphotype) (description modified from Huber and others, 2006).

Size: Holotype 0.16 mm diameter; hypotypes 0.13-0.17 mm diameter, 0.07-0.08 mm breadth.

DISTINGUISHING FEATURES.— Distinguished from *T. praegemma* by its slightly more compressed test, less lobate equatorial periphery and nearly closed umbilicus and by the absence of ovoid or subcrescentic chambers

Plate 16.5. *Tenuitella gemma* (Jenkins, 1965)

1-3 (holotype) lower Oligocene, Kakanui River, New Zealand; **4** (*Tenuitella neoclemenciae* Li, 1987, holotype, reproduced from Li, 1987, pl. 2, fig. 3), Oligocene *Globorotalia opima* Zone, Trinidad; **5**, Zone O1, TDP Site 17, Pande Fm., Tanzania; **6**, Zone O4-O6 undifferentiated, ODP Hole 872C, equatorial North Pacific Ocean; **7**, Zone AO1, ODP Site 1137/19R/CC, Elan Bank, Kerguelen Plateau, Southern Ocean; **8**, Zone O3, ODP Hole 647A/19/4, North Atlantic Ocean; **9**, Zone E16, ODP Hole 647A/36R/2, 74-77 cm, North Atlantic Ocean; **10**, Zone O1, ODP Hole, 647A/30/2, 25-29 cm, North Atlantic Ocean; **11**, **12**, Zone O2, Istra More-3 well, Adriatic Sea; **13-16**, Zone O7, Sample PP07/T5, Cipero Fm., San Fernando, Trinidad (14-16 same specimen, Pearson and Wade, 2009, pl. 8, figs. 2a-c). Scale bars: **1-16** = 50 µm.

and secondary apertures. Distinguished from *T. munda* by usually having 5-6, rather than 4 chambers in the final whorl. Distinguished from *T. angustiumbilicata* by its lower trochospiral coiling mode, less inflated chambers, and more compressed equatorial periphery.

DISCUSSION.— This species was discussed in the *Atlas of Eocene Planktonic Foraminifera* by Huber and others (2006). Here we extend / modify the synonymy list as follows:

Globigerina postcretacea Myatliuk, 1970, is not considered to be a potential prior synonym but rather as *nomen dubium non conservandum* (see Chapter 20, this volume, for discussion).

Globigerinella liverovskae Bykova, 1960, and *Globigerina khadumica* Bykova, 1960 from the lower Oligocene of Kazakhstan are considered possibly referable to *gemma* although the specimens are now lost and these taxa are also considered *nomen dubium non conservandum* (Chapter 20, this volume).

Globorotalia (*Turborotalia*) *cifellii* Brönnimann and Resig was described from heavily recrystallized and overgrown material and it was unclear to us from the illustrations whether the figured specimens are of macroperforate or microperforate forms. We obtained new material from the type level to conduct new SEM investigations of the taphonomy and have concluded that the holotype of *cifellii* is a microperforate form most easily assigned to *gemma*, but that diagenesis has accentuated the pustules creating a misleading texture (which was used as part of the diagnosis by Brönnimann and Resig). However three of the figured paratypes are questionably referred by us to different small macroperforate species (see synonymy list above).

Globorotalia (*Turborotalia*) *nkbrowni* Brönnimann and Resig was described from the same recrystallized material as *cifellii*. It has a similar overall test morphology and wall texture to *gemma* (albeit recrystallized). The holotype and paratypes of *nkbrowni* exhibit a small arched supplementary aperture on the spiral side which, according to its authors, is the main distinguishing feature. Although we have re-sampled the type level of *nkbrowni* and found similar specimens, we have not found the morph anywhere else; hence we provisionally include it in synonymy with *gemma*. We note also that it is very difficult to distinguish with the light microscope.

Li (1987) introduced his taxon *neoclemenciae* for *gemma*-like forms in which the aperture and lip extend to the periphery and in which the spiral side is flattened to concave. In his investigations of sections in Trinidad, Li (1987:310) found it to have a similar range to *gemma*. We report that the final chamber of the holotype was inadvertently broken off in our attempts to obtain a new SEM: images of the broken specimen (not shown here) allow us to confirm that the aperture on the penultimate chamber is also marginal in position. Spezzaferri (1994) recognized *neoclemenciae* and suggested it had fewer chambers than *gemma* although the holotypes of both have 5 chambers in the final whorl. She illustrated specimens attributed to both *gemma* and *neoclemenciae* that show a peripherally extended aperture, hence her concept was seemingly different from Li (1987). Various authors have documented *neoclemenciae* in taxonomic lists without illustrating the taxon or noting its distinguishing feature (e.g., Poag and Commeau, 1995; Miller and others, 1996; Malumián and Olivero, 2006; Alegret and others, 2008). We have observed that the apertural position in *gemma* is quite variable, sometimes even approaching a pseudoplanispiral condition (e.g., Plate 16.5, Figs. 10, 12). We also note that the holotype of *gemma* itself has an aperture that extends almost to the periphery and a somewhat concave spiral side (Plate 16.5, Figs. 1-3). With our current knowledge, there seems little to be gained stratigraphically in separating the forms so we have adopted the conservative approach and included *neoclemenciae* in synonymy with *gemma*.

PHYLOGENETIC RELATIONSHIPS.— Descended from *Tenuitella praegemma* in the late Eocene (Li, 1987). Ancestral to *Tenuitella munda* in the late Eocene (see discussion under that species).

STRATIGRAPHIC RANGE.— The lowest confirmed occurrences are in the uppermost Eocene (e.g., Toumarkine, 1978; Huber and others, 2006) although we note that Premoli Silva and Boersma (1988) recorded an occurrence in the uppermost middle Eocene Zone P14. The highest confirmed occurrences are in the uppermost Oligocene close to the Oligocene/Miocene boundary (Li and others, 1992; Li and Radford, 1991; Spezzaferri, 1994; Pearson and Wade, 2009). Spezzaferri (1994) and Pälike and others (2010) record specimens in the lower Miocene but none are illustrated and we have been unable to confirm those observations.

TYPE LEVEL.— Lower Oligocene.

GEOGRAPHIC DISTRIBUTION.— Global, from tropics to Ross Sea, Antarctica (Leckie and Webb, 1986; see map in Li and Radford, 1991, fig. 15).

STABLE ISOTOPE PALEOBIOLOGY.— No data available.

REPOSITORY.— Holotype and four paratypes (NZGS TF1505) deposited at the Geological and Nuclear Research Institute, Lower Hutt, New Zealand.

Tenuitella munda (Jenkins, 1965)

Plate 16.6, Figures 1-16

(Pl. 16.6, Figs. 1-3: new SEMs of holotype of *Globorotalia munda* Jenkins)

Globorotalia munda Jenkins, 1965:1121-1122, fig. 14, nos. 126-133 [lower Oligocene *Globigerina* (*Subbotina*) *angiporoides angiporoides* Zone, Earthquakes marl / base of Kokoamu Greensand, Waitaki, New Zealand].—Berggren, 1969:147-148, pl. VI, figs. 1-8 [lower Oligocene, lower part of type Rupelian, Boom Clay, Deroeck and Verstrepen Quarry, Boom, Belgium], pl. VI, figs. 9-11 [upper Oligocene, Chattian, Astrup, Germany].—Jenkins, 1985:278, fig. 7.5a-c (reproduction of holotype illustration).—Jenkins and Srinivasan, 1986:812, pl. 4, figs. 4-9 [upper Oligocene *Globigerina euapertura* Zone, DSDP Site 591, Lord Howe Rise, southwest Pacific Ocean].—Loubere, 1985:558, pl. 4, figs. 7-9, 13 [lower Oligocene Zone P20, DSDP Hole 549A, northeastern Atlantic Ocean].

Globorotalia (*Turborotalia*) *munda* Jenkins 1965.—Jenkins, 1971:123, pl. 12, figs. 328-335 (reproduction of holotype and paratype illustrations).

Globorotalia (*Tenuitella*) *munda* (Jenkins).—Kennett and Srinivasan, 1983:162, pl. 39, figs. 5-7 [lower Miocene *Globoquadrina dehiscens* Zone, DSDP Site 206, southwest Pacific Ocean].

Tenuitella munda (Jenkins).—Li, 1987, pl. 2, fig. 13 [lower Oligocene *G. ampliapertura* Zone, locality not given].—Huber, 1991:441, pl. 7, fig. 2 [upper Eocene Zone AP12, ODP Hole 738B, southern Kerguelen Plateau].—Li and others, 1992:579, pl. 1, figs. 6, 7 [lower Oligocene, ODP Hole 749B, Kerguelen Plateau, southern Indian Ocean].—Leckie and others, 1993, pl. 6, figs. 2, 3 [uppermost Oligocene Zone P22 or lowermost Miocene Zone N4, DSDP Hole 803D, Ontong Java Plateau, western equatorial Pacific Ocean].—Chaisson and Leckie, 1993:166, pl. 1, fig. 5 [lowermost Miocene Subzone N4a, Hole 806B, Ontong Java Plateau, western equatorial Pacific Ocean].—Spezzaferri, 1994:59, pl. 31, figs. 2a-c [lower Miocene Subzone N4a, DSDP Site 593, South Pacific Ocean].—Wade and others, 2007:177, pl. 2, figs. J-K [upper Oligocene Zone O5, ODP Hole 1218B, equatorial Pacific Ocean].—Pearson and Wade, 2009:213, pl. 8, fig. 3 [upper Oligocene upper Zone O6 (=O7 of this work), Cipero Fm., Trinidad].

Tenuitella clemenciae (Bermúdez).—Li, 1987:309, pl. 2, fig. 9 [upper Oligocene *Gr. opima opima* Zone, locality not given].—Spezzaferri and Premoli Silva, 1991, pl. 18, figs. 1a-c, 4a-c [lower Oligocene Zone P20, DSDP Site Hole 538A, Gulf of Mexico].—Spezzaferri, 1994:60, pl. 31, fig. 3a-c [lower Oligocene Zone P20, DSDP Hole 538A, Gulf of Mexico].—Pearson, 1995:53, pl. 1, fig. 16 [upper Oligocene Zone P21/22, ODP Hole 872C, Lo-En Guyot, Marshall Islands equatorial western Pacific Ocean]. [Not Bermúdez, 1961.]

Tenuitella gemma (Jenkins).—Berggren, 1992:564, pl. 4, fig. 12 [Oligocene, ODP Hole 748B, southern Kerguelen Plateau, Southern Ocean]. [Not Jenkins, 1965.]

Globorotalia (*Turborotalia*) *permicra* Blow and Banner, 1962.—Blow, 1979:1089-1091 (partim), pl. 245, fig. 4 [lower Oligocene Zone P18, DSDP Site 14, South Atlantic Ocean]. [Not Blow and Banner, 1962.]

Not *Globorotalia munda* Jenkins.—Krasheninnikov and Basov, 1983:841, pl. 10, figs. 10, 12 (= *Tenuitella gemma*) [lower Oligocene, DSDP Site 511, Falkland Plateau, South Atlantic Ocean], fig. 11 (=*Globorotaloides eovariabilis*) [lower Oligocene, DSDP Site 511, Falkland Plateau, South Atlantic Ocean].

DESCRIPTION.

Type of wall: Microperforate *glutinata*-type wall, surface smooth to finely pustulose, pustules irregularly scattered on both sides of test.

Test morphology: Test small, very low trochospiral, equatorial periphery lobate, subquadrate in outline, axial periphery rounded; chambers globular and inflated, 4 in the final whorl (occasionally 3½), 10-14 comprising adult tests, increasing rapidly in size; sutures straight to slightly recurved, incised on spiral and depressed on umbilical side; umbilicus narrow, deep; aperture an irregular arch bordered by a prominent lip of constant thickness (in most cases), interiomarginal, intra- to extraumbilical in position.

Size: Holotype 0.22 mm diameter.

DISTINGUISHING FEATURES.— Distinguished from *Tenuitella gemma* by having fewer, more inflated chambers in the final whorl. Distinguished from *T. angustiumbilicata* by its more rapidly expanding chambers and fewer chambers in the final whorl,

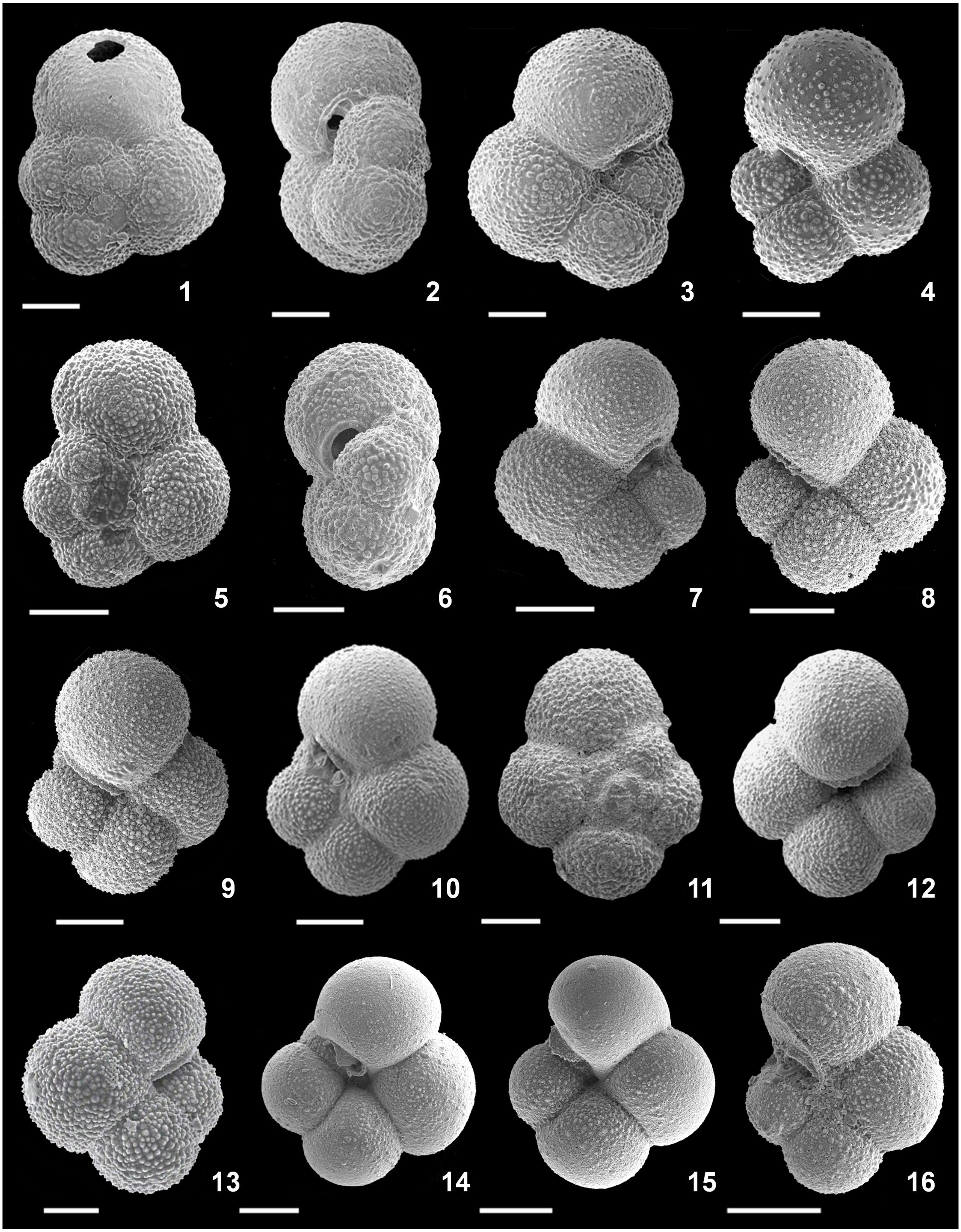

Plate 16.6 *Tenuitella munda* (Jenkins, 1965)

and also by the less pustulose test surface. *Tenuitella angustiumbilicata* also tends to have a more umbilical aperture, although it is not a constant feature. Distinguished from *Globigerinita glutinata* by the intra-extraumbilical aperture and by typically having four, rather than 3½, chambers in the final whorl. Forms intermediate between the two are common and the apertural position is used to distinguish them.

DISCUSSION.— Prior to its formal description in 1965, specimens that are probably referable to this common species were described under a variety of names or in open nomenclature (see, for example, the synonymy list given by Berggren, 1969). Berggren (1969) compared topotypes of Jenkin's taxon to specimens from classic Chattian and Rupelian sites in Europe, confirming their identity. Jenkins (1965:1121) originally placed his species in the form-genus *Globorotalia* and described the wall as "finely perforate". Fleisher (1974:1033) suggested that it ought to be placed in his new genus *Tenuitella* "on the basis of published descriptions". The microperforate wall is confimed here with new illustrations of the holotype by SEM (Plate 16.6, Figs. 1-3). Li (1987) included it in his review of microperforate planktonic foraminifera and it appears to have enjoyed a relatively stable taxonomic concept since then.

Blow (1979) proposed that *Globorotalia clemenciae* Bermúdez, 1961, a Miocene taxon, was a senior synonym of *munda*. Kennett and Srinivasan (1983) separated the taxa on the grounds that *T. clemenciae* is larger and has five chambers in the final whorl, and a more flattened lip (although the holotype actually has four chambers in the final whorl). Li (1987) separated the forms based on the more strongly inflated chambers in *munda*, a distinction that was followed by Spezzaferri (1994), and both of those authors illustrated specimens from the Oligocene. However the fine distinction in chamber inflation is not obvious from the published illustrations and seems to be part of the natural variability of the populations. We have obtained new SEM illustrations of the holotype of *Globorotalia clemenciae* Bermúdez (not shown) and suggest that it is a likely senior synonym of *Mutabella mirabilis* Pearson and others, 2001, as it is a relatively large form and shows the fused teeth common in that species. Further investigation of the type material may be required to confirm this. We do not, however, recommend the use of the name *clemenciae* for the sake of nomenclatorial stability, as it has been used quite frequently in the literature for *munda*-like tenuitellids and never for forms like *Mutabella mirabilis*.

We note that the Eocene and lowermost Oligocene specimens from the Kerguelen Plateau are unusual in commonly possessing an irregular apertural lip, or flange (see Plate 16.6, Figs. 14, 15). These forms show transitional features to *T. gemma* and may ultimately prove distinct.

PHYLOGENETIC RELATIONSHIPS.— Li (1987) suggested that *Tenuitella munda* evolved from *T. gemma*, with which it shares the same wall texture. Huber (1991) illustrated a specimen from the uppermost Eocene of ODP Hole 738A (which is on the southern tip of the Kerguelen Plateau), raising the possibility that the evolution of *munda* could have occurred in the high southern latitudes in the late Eocene. We have re-studied the upper Eocene of Sites 738 and 744 and confirm that *munda* is present in the Eocene alongside *Tenuitella gemma* and *Globigerinatheka index*, but without *Tenuitella angustiumbilicata*, which apparently evolved later (see Pl. 16.6, Figs. 14-16). *Tenuitella munda* was ancestral to *Globigerinita glutinata* and several authors have described transitional forms (see discussion under that species). It was probably also ancestral to *Tenuitella angustiumbilicata* but transitional populations have yet to be identified.

STRATIGRAPHIC RANGE.— Li (1987) recorded a first occurrence for this species in Zone O1. We have confirmed its presence in the upper Eocene (see discussion above). Premoli Silva and Boersma (1988) recorded it as low as uppermost middle Eocene Zone

Plate 16.6 *Tenuitella munda* (Jenkins, 1965)

1-3 (holotype), lower Oligocene Earthquakes marl / base of Kokoamu Greensand, New Zealand; **4**, Nannofossil Zone NP22, probably lower Zone O2, Ottenthal Fm., Austria (specimen transitional to *Globigerinita glutinata*); **5**, Zone O3, ODP Hole 647A/19/4, North Atlantic Ocean; **6**, Zone O4, Atlantic Slope Project corehole 5B/23A/29, 35", western North Atlantic Slope; **7-9**, Zone AO1, ODP Site 1137, Elan Bank, Kerguelen Plateau, Southern Ocean; **10**, Zone O7, Cipero Fm., Trinidad (Pearson and Wade, 2009, pl. 8, fig. 3); **11**, **12**, upper Oligocene, Gulf Slope, Gulf of Mexico; **13**, Zone O2, ODP Hole 647A/23/CC, North Atlantic Ocean; **14**, lowermost Oligocene Zone AP13, ODP Hole 738B/5H/2, 90-95 cm, Kerguelen Plateau, Southern Ocean (note unusual lip and features transitional to *T. gemma*); **15**, **16**, upper Eocene Zone AP12, ODP Hole 744A/19H/3, 90-95 cm, Kerguelen Plateau, Southern Ocean. Scale bars: **1-16** = 50 µm.

P14 but we have not confirmed that (see also Huber and others, 2006). According to Li (1987), it persists to upper part of lower Miocene Zone M3. More recently it has been recorded to Subzone M5a at Site U1338 in the equatorial Pacific Ocean (Pälike and others, 2010). Blow (1979) records it as high as the upper Miocene but renewed study would be needed to confirm this.

TYPE LEVEL.— Lower Oligocene Zone AO1.

GEOGRAPHIC DISTRIBUTION.— Global, most abundant in the mid- to high latitudes in both hemispheres.

STABLE ISOTOPE PALEOBIOLOGY.— Lived near the sea surface (Majewski, 2003), or perhaps slightly subsurface compared with other small species (Pearson and Wade, 2009).

REPOSITORY.— New Zealand Geological Survey, TF 1508 (holotype and three paratypes), deposited at the Department of Geological and Nuclear Sciences, Lower Hutt, New Zealand.

Tenuitella praegemma (Li, 1987)

Praetenuitella praegemma Li, 1987:309, pl. 1, figs. 11-22 [upper Eocene Zone P15-P16, Cocoa Sand, Jackson Group, Choctaw County, Alabama and Wayne County, Mississippi].—BouDagher-Fadel, 2012a: pl. 5.2, figs. 18, 19 (reproduction of holotype images).

Tenuitella praegemma (Li).—Huber and others, 2006:491-493, pl. 16.6, figs. 1-3 (reproduction of holotype image), figs. 4, 5, 16 (re-illustration from Poore and Bybell, 1988), figs. 6-13 [Zone E15/16, Cape May Borehole, New Jersey], figs. 15-19 (re-illustration from Poag and Commeau, 1995).

Praetenuitella praegemma Li, forma *pendulocamerata* Poag and Commeau, 1995:155, pl. 9, figs. 11-15 [upper Eocene Zone P15, U.S. Geological Survey Exmore core, Virginia].

DISCUSSION.— This species was discussed in the *Atlas of Eocene Planktonic Foraminifera* by Huber and others (2006) where a more complete synonymy list is presented. It persists from the upper Eocene to lowermost Oligocene Zone O1.

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