

The new family Ornatorotaliidae (Rotaliacea, Foraminiferida)

Andrea Benedetti

Dipartimento di Scienze della Terra, University of Rome "La Sapienza", Piazzale A. Moro, 5, I-00185, Rome, Italy
GIRMM: Informal Group of Micropaleontological and Malacological Researches
email: andrea.benedetti@uniroma1.it

ABSTRACT: A well-preserved new specimen of *Granorotalia sublobata* from the type population shows the presence of spines in the microspheric generation, the same as for *Ornatorotalia spinosa*. The spines are irregularly distributed along the periphery of the test. The discovery of this taxonomic character points to a systematic redefinition, in which the two genera are assigned to a new family Ornatorotaliidae, in the superfamily Rotaliacea.

Aside from the microspheric spinosity, Ornatorotaliids are characterized among rotaliaceans by a complex enveloping canal system, vertical funnels in both ventral and dorsal sides of the tests, umbilical flap or toothplate, and the absence of folia.

INTRODUCTION

The superfamily Rotaliacea Ehrenberg 1839 groups foraminifera with trochospiral or planispiral involute to evolute lamellar test (Smout 1954), commonly with many small chambers in numerous whorls, in which apertures may be interiomarginal to areal and single or multiple; a septal flap, umbilical cavities, and intraseptal and subsutural canals may occur (Loeblich and Tappan 1987; Hottinger, Halicz and Reiss 1991). According to Loeblich and Tappan (1987, 1992), superfamily Rotaliacea includes six families: Pseudorbitoididae, Rotaliidae, Chapmaninidae, Calcarinidae, Elphidiidae, and Miogypsiniidae. Representatives of the superfamily range from the late Cretaceous to Recent, with genera that are usually distinguished by the characteristic chamber growth and canal systems. These foraminifera are difficult to analyze in thin sections due to the necessity to find precisely oriented planes. For example, Elphidiidae are usually only recognizable at specific rank in free matrix tests because definition is dependent on the architecture of the canal systems (e.g., Hottinger, Reiss and Langer 2001), and Miogypsiniidae require a high level of biometric analysis of megalospheric specimens (e.g., Drooger 1993; Boudagher-Fadel and Price 2010), while Calcarinidae possess an enveloping canal system and multiple apertures (Hottinger, Halicz and Reiss 1991). Rotaliids have been studied by SEM analysis (Hansen and Reiss 1971; Billman, Hottinger and Oesterle 1980), in serial sections (Müller-Merz 1980) and in oriented sections (Hottinger, Halicz and Reiss 1991; Hottinger 2014).

Several new species referred to the family Rotaliidae, some of them only preliminarily, have been recently described from the Cretaceous (Boix et al. 2009; Piuze and Meister 2013) to the Paleogene (Benedetti and Briguglio 2012; Benedetti, Di Carlo and Pignatti 2011; Boukhary, Kuss and Abdelraouf 2008; Hottinger 2014). The study of these and other "rotaliids", sensu lato, is complicated by a complex terminology (Hottinger 2006; 2014) and the need to recognize microscopic structures in transversal sections of the thin tests.

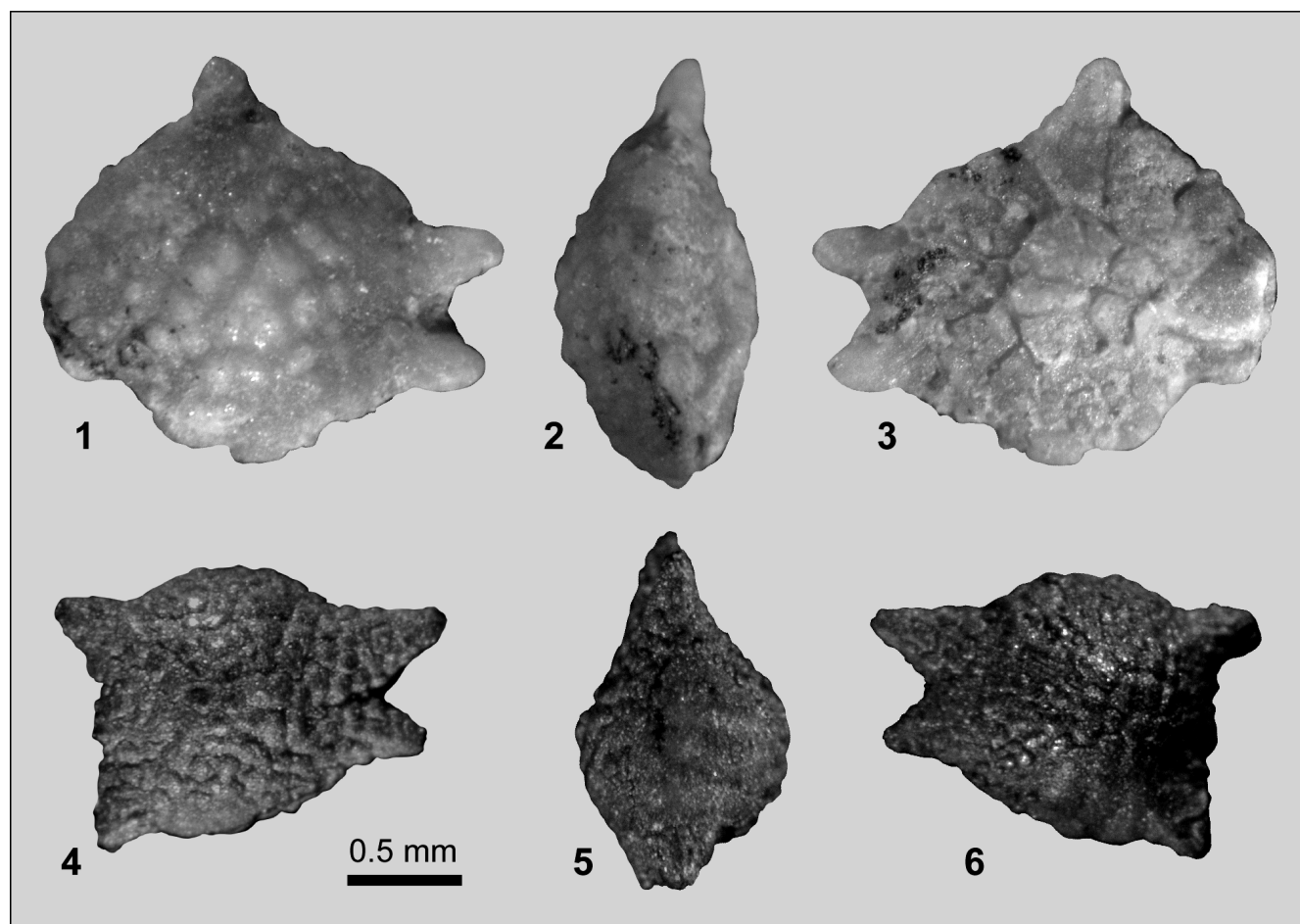
The aim of this work is to discuss how taxonomical characters recognized in recently recovered material of species previously ascribed to Rotaliidae support their assignment to a new family and subfamily of superfamily Rotaliacea

THE FAMILY ROTALIIDAE AND RELATIVE TAXA

The family Rotaliidae Ehrenberg 1839 groups genera characterized by lamellar-perforate walls (e.g., Smout 1954), by trochospiral arrangement of the chambers, by septa with open interocular spaces or canals, and by the presence of folia, all combined with additional structures that delimit and restrict an umbilical space (e.g., Hottinger 2006).

According to Loeblich and Tappan (1987, 1992), family Rotaliidae is comprised of four subfamilies: Cuvillierinae, Pararotaliinae, Rotaliinae, Ammoniinae, but Hottinger, Halicz and Reiss (1991) suggested that Pararotaliinae and Cuvillierinae might be put into a different family. Hottinger (2014) subsequently also removed Ammoniidae because of the occurrence of an umbilical cover plate, and then revised Rotaliinae into five subfamilies of Rotaliinae, Redmondinae, Lockhartinae, Kathininae and Daviesininae. The nominate subfamily Rotaliinae is characterized by the absence of dorsal ornamentation and of umbilical spaces subdivided by a single undivided pile or by a columellar infilling of the umbilicus with superposed fused folia.

The other new rotaliid subfamilies were characterized by Hottinger (2014) as follows: species in subfamily Redmondinae have coarsely perforated and thick chamber walls, and a reduced umbilical filling with a canal system; a few coarse funnels may appear in the umbilical filling. Subfamily Lockhartinae is distinguished by low trochospiral tests having a dorsal side ornamented by limbate spiral and ribbed or cancellate cameral sutures, and an umbilical structure characterized by umbilical cavities that are delimited by successive foliar walls and numerous parallel umbilical piles. Subfamily Kathininae groups rotaliids with a solid umbilical mass pierced by radial slits, rows of funnels or open but feathered interocular



TEXT-FIGURE 1

Microspheric larger spinose form of *Granorotalia sublobata* Benedetti, Di Carlo and Pignatti 2011 (1-3) specimen MPUR NS254.33, and *Ornatorotalia spinosa* Benedetti, Di Carlo and Pignatti 2011, holotype MPUR NS154.1 (4-6). 1. dorsal view, 2. lateral view, 3. ventral view; 4. dorsal view, 5 lateral view, 6. ventral view. Scale bar=0.5mm.

spaces. Finally, subfamily Daviesininae consists of only the eleven known species of *Daviesina*, characterized by bilamellar-perforate, heavily ornate shells with a very low trochospiral growth with funnels on both sides of the test; intraseptal canals produce an enveloping canal system forming a supplemental skeleton of considerable thickness.

As previously suggested by Hottinger, Halicz and Reiss (1991), Hottinger (2014) included the genera *Pararotalia* and *Neorotalia* within the family Pararotaliidae according to the occurrence of a single foramen, umbilical flaps complemented by toothplates, and umbilical structure characterized by plugs and piles, but without folia. Both genera are characterized by a heavy ornamentation of the trochospiral test that is usually evolute on the dorsal and involute on the ventral side and presents pseudospines along the periphery of the chambers. In particular *Pararotalia* presents an open umbilical fissure, whereas in *Neorotalia* the umbilical space around the umbilical fill is covered by secondary outer lamellas and transformed into a spiral canal. Debenay et al. (2001) erroneously included *Pararotalia* in the subfamily Cuvillierininae Loeblich and Tappan 1964.

Hottinger (2014, p. 153) stated that taxa with a single foramen and a dense enveloping canal system covering the complete sur-

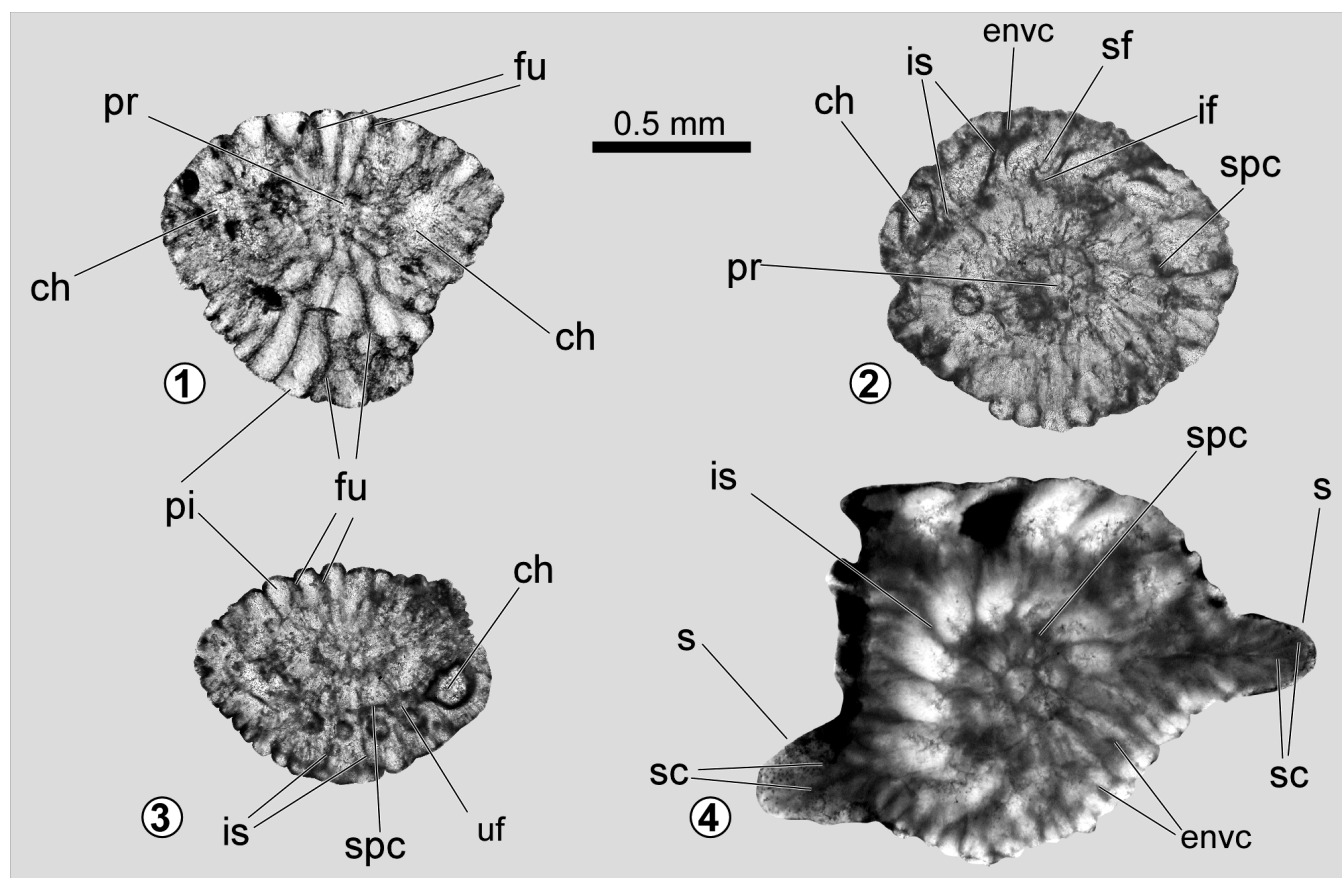
face of the shell and incorporating the numerous funnels in dorsal and ventral side, such as *Laffitteina* and *Cuvillierina*, should be placed together in Cuvillierininae, but he then reassigned these two genera to the new subfamily Laffitteininae (Hottinger 2014, p. 160). Leppig (1988) and Sirel (1998) assigned the genera with dorsally opened and sutural canals, such as *Cuvillierina*, to Miscellaneidae Sigal 1952, a planispiral family that has been recently reassigned by Hottinger (2009) to the superfamily Nonionacea.

The description of morphological features here uses the terms employed by Hottinger (2006).

THE INVESTIGATED MATERIAL

The present study is based on optical microscopy analysis of a new matrix-free specimen and of thin sections and SEM images published in Benedetti, Di Carlo and Pignatti (2011).

The material was collected in a stratigraphic section of the Monte Bosco Formation that crops out near Baglio Beatrice, Buseto Palizzolo (NW Sicily, Southern Italy; co-ordinates: 38°0'13.47"N, 12°44'8.54"E; elevation: 297m).



TEXT-FIGURE 2

Ornatorotalia spinosa from sample MB14 and MB14 bis, modified after Benedetti, Di Carlo and Pignatti (2011). 1. axial section, 2. equatorial section of megalospheric form, 3. oblique section, 4. equatorial section of microspheric form with spines. Abbreviations - ch: chamber lumen; fu: funnel; if: intercameral foramen; is: intraseptal canal system; pi: pile; pr: proloculus; s: spine; sc: spinal canal; sf: septal flap; spc: spiral canal; uf: umbilical flap. Scale bar=0.5mm.

The Monte Bosco Formation, according to the planktonic foraminiferal assemblages, is dated as lower Oligocene, Zone O2 (*Turborotalia ampliapertura* highest occurrence zone) of Wade et al. (2011), and consists mainly of clays and marls with turbiditic layers and rounded clasts. The turbiditic layers are composed mainly of planktonic foraminifera with reworked Upper Eocene larger foraminifera such as *Chapmanina gassinensis*, *Halkyardia minima*, *Pellatispira madaraszii*, *Nummulites incrassatus* and *Silvestriella tetraedra*, whereas the dm-sized rounded clasts are composed by grainstone to packstone with *Alveolina cremae*, *A. decastroii*, *A. distefanoii* and *Cuvillierina vallensis* marking the Late Ypresian (i.e., middle Cuisian; Hottinger 1960, Schaub 1981), belonging to the Shallow Benthics chronobiozone SBZ 11 of Serra-Kiel et al. (1998), according to Benedetti, Di Carlo and Pignatti (2011).

The key material for this work is a collection of matrix-free reworked specimens of *Ornatorotalia spinosa* and *Granorotalia sublobata* (Benedetti, Di Carlo and Pignatti 2011) that were picked from washing residues of the clays derived from reworked clasts. The most significant taxonomic indications come from the finding of new microspheric individual of *Granorotalia sublobata* labeled MPUR NS154.33 (text-fig. 1; 1-3). This large biconvex test reaches a diameter of 1.99mm and a thickness of

0.89mm and presents three spines along the peripheral margin (a fourth spine is eroded). This character was not observed in the type material previously collected, but was observed and recognized as distinctive in *Ornatorotalia spinosa* (text-fig. 1, 4-6). The spines are canaliculate (text-fig. 2, 4) as for the Recent *Neorotalia* and *Calcarina* (Hottinger, Halicz and Reiss 1991) but short and few compared to the long numerous spines of calcarinids, as well as being more irregular than the pseudospine of pararotaliids, that often appear on each chamber. The pattern of distribution of the spines is similar in *Granorotalia* and *Ornatorotalia*, with the closest spines arranged at about 31° in *G. sublobata* and 32° in *O. spinosa* respectively, whereas there is no recurrent arrangement for the other spines as we can see from the figure 1 and from the figure 7, b of Benedetti, Di Carlo and Pignatti (2011). Such characteristics point to functional homoplasies among “rotaliids” that require the distinction of a new family group. The occurrence of vertical canals on both ventral and dorsal side, the absence of folia, the presence of a toothplate are sufficient additional taxonomic elements to define a new family and a nominate subfamily.

The investigated material is deposited in the Paleontological Museum at the Department of Earth Sciences, “La Sapienza” University, Rome, Italy.

SYSTEMATIC MICROPALAEONTOLOGY

Order FORAMINIFERIDA Eichwald 1830

Superfamily ROTALIACEA Ehrenberg 1839

Family ORNATOROTALIIDAE nov.

Type genus: *Ornatorotalia* Benedetti, Di Carlo and Pignatti 2011

Description: Test trochospiral to nearly planispiral; dorsal and ventral side are poorly differentiated and characterized by strong ornamentation composed by canal orifices, pustules and pillars. The members of this new family have a single foramen at the base of the last chamber. No folia are present. Intraseptal canals evolve in an intensive enveloping canal system opening from the chamber sutures to a system of spiral canals and external grooves. The umbilical plate separates the chamber lumen from the umbilical-spiral canal.

Occurrence: Maastrichtian to Chattian.

Remarks: Based on the occurrence of funnels in both dorsal and ventral sides, the presence of a complex enveloping canal system, umbilical plate and a single foramen, the genera *Cuvillierina* and *Laffitteina* were recently assigned to the new subfamily Laffitteininae Hottinger (2014). As previously noted, in the same work just prior to the definition of the new subfamily, Hottinger (2014) suggested that the two genera were best placed within the subfamily Cuvillierininae Loeblich and Tappan 1964. According to the Principle of Priority (ICZN, article 23), while it is unnecessary that the type-genus of a new taxon of family or subfamily rank has the oldest name (ICZN, article 64), the previously named Cuvillierininae Loeblich and Tappan 1964 should be preferred and Laffitteininae Hottinger 2014 considered as a junior synonym.

Hottinger (2014) excluded the subfamily Cuvillierininae from the family Rotaliidae, and also questioned its transfer to Pararotaliidae. While the structures recognized in equatorial sections of *Cuvillierina*, *Ornatorotalia* (text-figs. 2-3) and *Laffitteina* (Hottinger 2014, figs. 8.3-8.6) are comparable to those observed over other species in the family Pararotaliidae (i.e., *Neorotalia* and *Pararotalia*, Hottinger, Halicz and Reiss 1991), the latter are characterized by vertical canals only in the ventral side of the test.

The former species are even less comparable to Calcarinidae, which have multiple foramina, to Rotaliidae which have folia and no vertical funnels in the dorsal side, or to Elphidiidae which have two spiral umbilical canals and foliar chamberlets.

On the other side, according to the description of Ornatorotaliidae fam. nov, which is characterized by dorsal and ventral funnels, a complete enveloping canal system and the absence of folia, the subfamily Cuvillierininae, as emended in the description of Laffitteininae Hottinger 2014, should be included in this new taxon. A comprehensive revision of the genera belonging to this subfamily will be provided by the investigation of type material, but according to Hottinger (2014) this subfamily certainly includes *Cuvillierina* Debourle 1955, *Laffitteina* Marie 1946, *Storssella* Drooger 1960, and the unidentified rotaliids described by Sirel (1988) under the family Miscellaneidae, but not *Smoutina* Drooger 1960, in having a smooth dorsal side, without ornamentation or canal orifice because of the absence of vertical funnels and a complete enveloping canal system that extends to the dorsal side.

The Oligocene genus *Risananeiza* Boukhary, Kuss and Abdelraouf 2008, with the two known species *Risananeiza pustulosa* and *R. crassaparies* characterized by an ornamented shell with pustules and piles, chambers arranged in very low trochospiral coiling, an enveloping canal system consisting of spiral, intraseptal and vertical canals (Boukhary, Kuss and Abdelraouf 2008; Benedetti and Briguglio 2012), and that differs from *Neorotalia* in having funnels on both ventral and dorsal side, is herein included in the new family Ornatorotaliidae. *Risananeiza* is placed in the subfamily Cuvillierininae because it lacks the key taxonomic characters typical of Ornatorotaliinae new subfam.

The attribution to Ornatorotaliidae of the new genus *Elazigina* described by Sirel (2012) is uncertain, since its type species *Elazigina subsphaerica* has been placed in the rotaliid genus *Plumokathina* by Hottinger (2014).

ORNATOROTALIINAE Benedetti, subfam. nov.

Type genus: *Ornatorotalia* Benedetti, Di Carlo and Pignatti 2011

Description: Chambers are arranged in low-trochospiral involute coiling. The whole shell is covered by coarse pustules and the periphery is subacute. The dorsal and ventral sides are pierced by numerous funnels. Interlocular, spiral and intraseptal canals result in a complex enveloping canal system. The foramen is a single slit extending obliquely over the adaxial apertural face. A toothplate separates the chamber lumen from the umbilical cavity.

Sexual dimorphism is evident, the larger microspheric forms present up to four coarse spines along the periphery of the ultimate whorl (text-fig. 1).

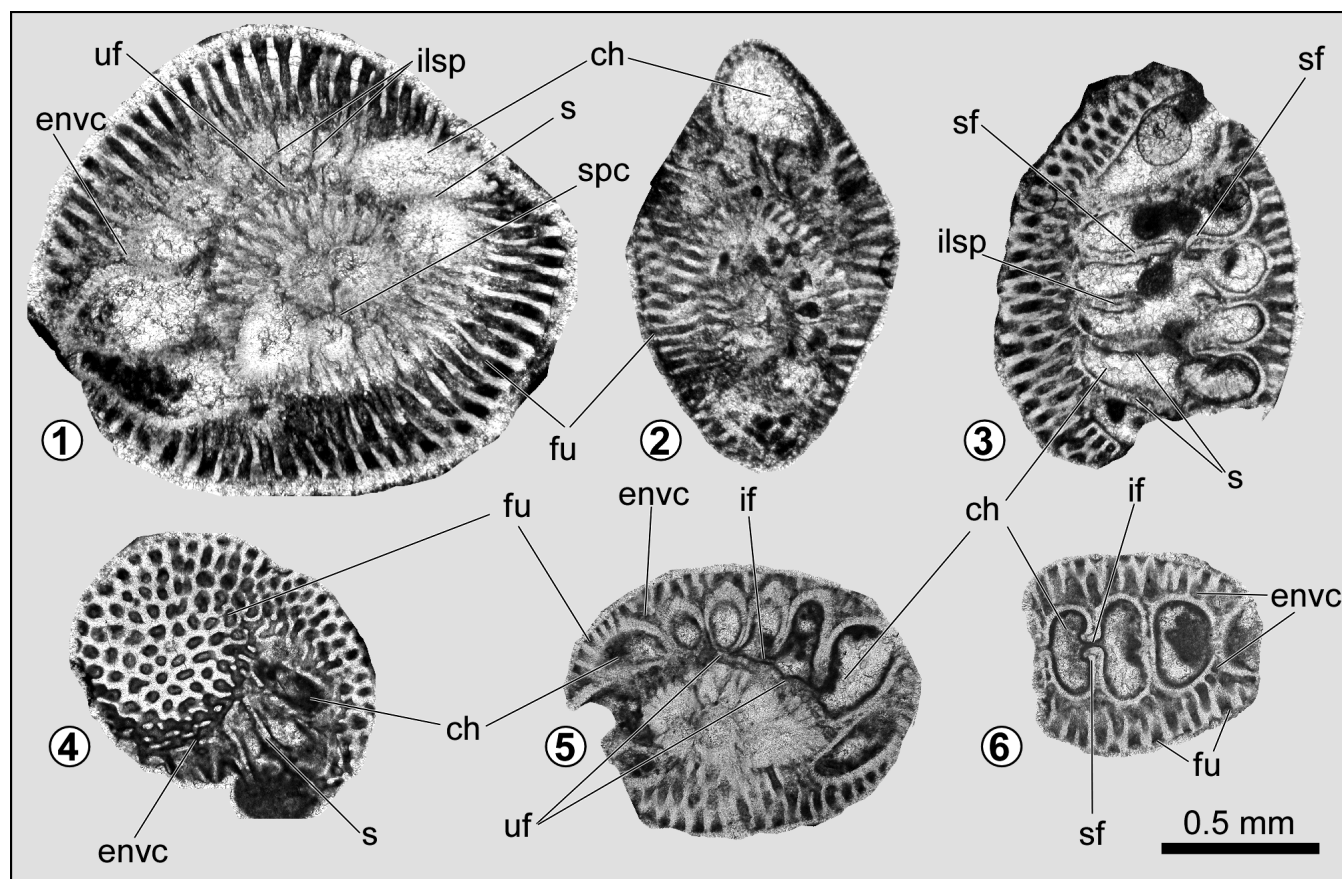
Occurrence: late Ypresian (Cuisian).

Remarks: Benedetti and Briguglio (2012) suggested the creation of a new family, including both *Ornatorotalia* and *Granorotalia* described by Benedetti, Di Carlo and Pignatti (2011) from the Cuisian of Tethys and *Risananeiza* from the Chattian. The discovery of the important taxonomic character of the spines in the microspheric forms of the two former genera prevents the inclusion of *Risananeiza* within the nominate subfamily Ornatorotaliinae as it is now understood, and requires its assignment within Cuvillierininae as noted above.

CONCLUSIONS

Ever since the lamellar theory of Smout (1954), rotaliacean foraminifera have been object of dedicated investigation of the wall structure and type and distribution of canals (e.g., Hottinger, Reiss and Langer 2011). In the last decade more than ten new genera of rotaliids or related taxa have been illustrated, such that the monograph recently published (Hottinger 2014) is not adequate to solve the systematic of this heterogeneous group of Paleogene foraminifera.

The new family Ornatorotaliidae is here erected to separate rotaliid-type foraminifera with low-trochospiral involute coiling, complete enveloping canal system, vertical canals (funnels) in both ventral and dorsal sides, and lacking folia. Ornatorotaliidae fam. nov. is comprised of the previously described subfamily Cuvillierininae (= Laffitteininae sensu Hottinger 2014), whereas the genera *Ornatorotalia* and *Granorotalia* are here included in the nominate subfamily Ornatorotaliinae, dis-



TEXT-FIGURE 3

Cuvillierina vallensis (Ruiz de Gaona 1948), sample MB14bis, middle Cuisian. 1. transversal subequatorial section; 2. axial section; 3. f. subaxial section; 4. tangential section; 5. oblique section. Abbreviations - ch: chamber lumen; envc: enveloping canals; fu: funnel; if: intercameral foramen; ilsp: intraseptal interocular space; s: septum; sf: septal flap; spc: spiral canal; uf: umbilical flap.

tinguished by the presence of rough spines along the periphery of microspheric forms.

The recognition of this family is a step in establishing some required homologies to differentiate the main groups among the large number of taxa presently included in the informal group of "rotaliids".

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