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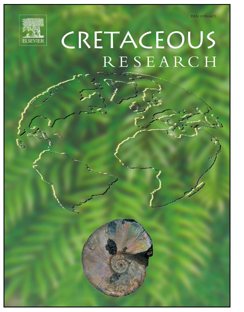


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# Rotaloidean foraminifera from the Upper Cretaceous carbonates of Central and Southern Italy and their chronostratigraphic age

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## Abstract

New rotaloidean foraminifera from the Upper Cretaceous shallow-water carbonates of Central and Southern Italy have been described, thus widening the knowledge on the Late Cretaceous rotaloidean foraminifera in the Central Tethyan realm. *Rotorbinella lepina* sp. nov., *Rotalispira vitigliana* sp. nov. and *R. maxima* sp. nov., belong to the family Rotaliidae (subfamilies Rotaliinae and Lockhartiinae, respectively). *Pilatorotalia pignattii* gen. nov. sp. nov. and *Neorotalia? cretacea* sp. nov. are placed in the family Pararotaliidae. Moreover, further studies are carried out on the associated *Rotalispira scarsellai* and "*Stensioeina*" *surrentina*. The age assignment of these rotaloideans has been calibrated by means of strontium isotope stratigraphy to late Santonian?-middle Campanian.

**Key Words**: Rotaloidean foraminifera, Architecture, Biostratigraphy, Strontium Isotope Stratigraphy, Upper Cretaceous, Italy

## 1. Introduction

The rotaloideans are a group of numerous, complex, larger (sometimes of small size) foraminifera that range from the Cenomanian (late Albian?) to recent. The known research history of the rotaloidean foraminifera started early in the 19th century with the description of *Rotalia trochidiformis* from the Lutetian of the Paris basin (Lamark, 1804), and was subsequently improved in the second half of the past century and the present century (see, for instance, the studies by

Hofker, 1951, 1971; Smouth, 1954; Reiss and Merling, 1958; Reiss, 1963; Torre, 1966; Müller-Merz, 1980; Billman et al. 1980; Haynes and Whittaker, 1990; Hottinger et al., 1991; Revets, 2001; Boix et al, 2009; Benedetti et al., 2011; Sirel, 2012; Benedetti and Briguglio, 2012; Hottinger, 2014; Benedetti, 2015, among others). However, only a few of these studies refer to the Cretaceous rotaloideans. The first ones come from the chalk deposits of North-western Europe (Boreal realm; see Reuss, 1862; Hofker, 1949; 1960; Visser, 1951; among others). In the Pyrenean realm, Hottinger (1966), Tronchetti (1981), and recently Boix et al. (2009) accurately described the morphology and structure of several new genera and species. Whereas, in the Central Tethys only two species were described from the Upper Cretaceous of Southern Italy (Sorrento Peninsula), *Rotalispira scarsellai* (named *Rotorbinella scarsellai* in Torre, 1966) and "*Stensioeina" surrentina* Torre. Although abundant sections of diverse rotaloidean foraminifera are commonly reported from shallow carbonate platform facies in ancient and recent geological literature, such as *Rotalia* or *Rotorbinella* (Crescenti, 1969; De Castro, 1974; Chiocchini and Mancinelli, 1977; Carbone and Catenacci, 1978; Luperto Sinni and Ricchetti 1978; Mariotti, 1982; Molinari Paganelli and Tilia Zuccari, 1987; Pirini Radrizzani et al., 1987; Luperto Sinni and Reina, 1996; Carannate et al., 1998; Tentor, 2007; Schlüter et al. 2008; Brandano and Loche, 2014, among others). The papers of Luperto Sinni (1976) and Luperto Sinni and Ricchetti (1978) are particularly interesting because they offer an extraordinarily richness of figured rotaloideans (pl. 49-54 and 60-63, respectively). Therefore, the aim of the present work is to study the rotaloidean foraminifera present in Central and Southern Italy, particularly in the deposits of the Lepini Mounts (Central Italy) and Cava Vitigliano (Southern Italy), which provide abundant, diverse, and sometimes well preserved, rotaloidean morphotypes associated with well known porcelaneous and agglutinated foraminiferal taxa, most of them stratigraphically branded by Chiocchini et al. (2012) and Frijia et al. (2015). The studied material allowed us the identification of the most important and diagnostic rotaloidean architectural elements and permitting the description of five new taxa, which greatly increase the knowledge of still poorly defined group of the Late Cretaceous Global Community Maturation Cycle *sensu* Hottinger (2001) in the Central Tethys. Moreover, we precisely define the age of the beds containing the new rotaloidean foraminifera by means of strontium isotope stratigraphy, which could lead to the use of these taxa as a potential tool for biostratigraphy.

## 2. Geological setting, provenance of the material and methods

### 2.1. Central Italy

The samples were mainly collected in the Lepini Mounts which are located in the Southern part of the Latium region (Fig. 1). Lepini Mounts, together with the neighbouring Ausoni and Aurunci Mounts, create a continuous mountain range of 80 km in length, composed mainly of a thick series of Mesozoic shallow-water carbonates (Accordi, 1966). The sedimentological and biostratigraphical data of the Cretaceous deposits of the Lepini Mounts are mainly from Angelucci and Devoto (1966), Carbone and Catenacci (1978), Chiocchini et al. (1977; 1994) and Brandano and Loche (2014). In terms of biostratigraphy, the 'Rava Santa Maria' section (see fig. 1 of Chiocchini et al., 1994; detailed in fig. 1 of Chiocchini and Mancinelli, 2001) remains one reference section not only for the Lepini Mounts, but also for the Santonian-Maastrichtian shallow-water series of Central Tethys. Moreover, the first revision of the Italian deposits containing *Keramosphaerina tergestina* (Stache), taxon erroneously assigned to the Palaeocene (Devoto, 1964), and the type-locality of the well-known genus *Accordiella conica* Farinacci come from the Lepini Mounts.

The investigated section is located on the south-western side of Monte delle Castagne (base of the section: N 41º38'49''-E 13º07'12''; top of the section: N 41º38'54''-E 13º07'23'', see also Fig. 1), which is located 1.5 km South-east of the village of Gorga and 2 km South-west of the 'Rava Santa Maria' section (Monte Filaro). The section consists of around 100m of shallow-water limestones, where some dolomitized levels alternate with foraminiferal-rich wackestone facies and rudist debris (Fig. 2). Brandano and Loche (2014) individuated a series of rudist pillarstone interbedded with cross-bedded grainstone- packstone and laminated mudstone-wackestone in this area. The deposits were interpreted formed in a shoreface setting characterised by scattered rudist constructions and bioclastic sand bars and/or floatstones. They contain an association of imperforate foraminifera and demosponge comprising *Dicyclina schlumbergeri* Munier-Chalmas (Fig. 3A), *Accordiella conica* Farinacci (Fig. 3A), *Scandonea mediterranea* De Castro (Fig. 3A) *Montcharmontia apenninica* (De Castro), *Nezzazatinella* sp. (Fig. 3B), *Murgella lata* Luperto Sinni (Figs. 3D, I), *Sarmentofascis zamparelliae* Schlagintweit et al. (Figs. 2, 3E), *Praemurgella valenciana* Luperto Sinni et al. (Figs. 3F, G),and *Keramosphaerina tergestina* (Stache) (Fig. 3H). *Rotalispira scarsellai,* "*Stensioeina" surrentina* and *Rotalispira maxima* sp. nov. (*Calcarinella shaubi* in Chiocchini et al., 2012) have been identified among the lamellar-perforated foraminifera. The demosponge *Sarmentofascis zamparelliae* Schlagintweit et al. has also been found (Figs. 2, 3E). According to Chiocchini et al. (1994), the studied deposits correspond to the middle and upper part of the Radiolitid Limestone unit, which belongs to the *'Accordiella conica and Rotorbinella scarsellai*' biozone (Coniacian to lower Campanian of Chiocchini et al., 1994; 2012). Based on strontium isotope stratigraphy (SIS), Frijia et al. (2015) assigned the *K. tergestina* level in Southern Italy as corresponding to the lower Campanian.

The rotaloidean foraminifera come from 31 samples of cemented carbonate rocks labelled from 01 to 035 (Appendix I: Supplementary Data; see their distribution in Fig. 2 and some representative facies in Figs. 4A-C). More than 170 thin sections were obtained from these samples for this study. A very interesting isolated sample (labelled 057, N 41º39'26''-E 13º07'05'', see the position also in Fig. 1B; Appendix II: Supplementary Data) consisting of foraminiferal-microbialitic facies (Fig. 4D) comes from a stratigraphic level that has been correlated in the field with the upper part of the studied section. Some additional samples are from Monte Rotondo and Monte Feuci (Ausoni Mounts), as well as from Monte Filaro (Lepini Mounts) (see their position in fig. 1 of Chiocchini et al., 1994). The samples of the two former areas are from the *"A. conica* and *R. scarsellai* biozone", while the samples from the last area are from the "*Discorbidae* and *ostracoda"* biozone (see Chiocchini et al., 1994, for details).

### 2.2. Southern Italy

The samples from Southern Italy have been collected mainly in Cava Vitigliano (Figs. 4E, F), but an additional one is from Trentinara (see Schlagintweit et al., 2016 for localization of the area). The well-known outcrops of the Cava Vitigliano, an abandoned quarry, are located 900 m north of the Vitigliano village in the Lecce province (Salento, South-east Italy, Fig. 1C). The quarry represents an almost  unique window looking to the Campanian inner/back-edge carbonate platform deposits of the Apulian platform. The outcrop, only visible in the flank of the quarry, consists of 3 m of horizontal massive limestone, characterised by abundant rudist bioclasts chaotically found as rudstone lenses. Deposits with similar lithology were named in Central Apennines as “Calcari cristallini” (Colacicchi, 1967). However, in recent times, they have been attributed to the upper part of the Santa Cesarea Limestone Unit (see stratigraphic considerations and complete litostratigraphy in Schlüter et al. 2008).

The quarry is famous for the optimally preserved fauna of rudists that have been studied in detail (Cestari and Sirna, 1987; Guarnieri et al., 1990; Laviano and Skelton, 1992; among others). The first ones to introduce the Cava Vitigliano in the foraminiferal specialised literature were Papetti and Tedeschi (1965). They did an exhaustive study of the main microfacies, and mentioned *Cuneolina pavonia parva* Henson, *Orbitoides tissoti* Schlumberger, and a new porcelaneous genus, *Cuvillierinella salentina.* Foraminiferal description from Cava Vitigliano deposits was subsequently improved by De Castro (1990), who mentioned a rich assemblage of foraminifera including *Accordiella conica* Farinacci, *Minouxia conica* Gendrot, *Montcharmontia apenninica* (De Castro), *Pseudocyclammina sphaeroidea* Gendrot, *Cuvillierinella salentina* (*Raadshovenia salentina* in the De Castro’s paper), *Pseudochubbina bruni* De Castro, *Murciella cuvillieri* Fourcade, *Orbitoides* sp., *Pseudosiderolites? vidali* (Douvillé), and the rotaloidean *Rotalispira scarsellai*  and “*Stensioeina*” *surrentina*. *Rotalispira maxima* sp. nov. is also present in our samples. The age given to the ensemble of Cava Vitigliano deposits by Papetti and Tedeschi (1965) was late Santonian, but De Castro (1990) suggested a Campanian age. Schlüter et al. (2008), based on Strontium Isotope stratigraphy, restricted the age to the latest middle Campanian (see their fig. 2).

The description of the new rotaloidean foraminifera from Cava Vitigliano is based on one sample of cemented carbonate rock labelled CC1 (Appendix III: Supplementary Data) collected in the north-eastern side of the quarry (N 40º02'50''-E 18º24'35''). The sample was fully used up, 22 thin sections were obtained from which about 60 sections (oriented and random) have been studied. A further sample comes from Trentinara (sample P-1023 in fig. 6 of Frijia et al. 2015) from which one axial section has been obtained. In this last area the level containing the new rotaloidean here described as *Rotalispira maxima* sp. nov. was dated by means of strontium isotope analysis as early Campanian (Frijia et al., 2015).

A set of specialised terms were used for the structural analysis of the rotaloidean foraminifera (see Hottinger 2006; 2014). The sections have been named according to Billmann et al. (1980) and Hottinger (2014). All the specimens are illustrated with a fixed enlargement in order to facilitate the comparison of the new taxa with other previously described taxa. We use the parameter D/H (test diameter against test height) for characterize the new species.

The specimens presented in this paper have been deposited in the Palaeontological collection of the Department of Geology (Palaeontology) of the *Universitat Autònoma de Barcelona* (PUAB 82475-82487), and in the Micropalaeontological collection of the Italian Geological Survey/ISPRA (Institute for Environmental Protection and Research, Rome) with thin sections labelled IS-1443, IS-A1051, IS-A957.

## 3. Systematic micropalaeontology

**Phylum FORAMINIFERA (Orbigny 1826) Pawlowski et al., 2013**

**Class GLOBOTHALAMEA Pawlowski et al., 2013**

**Order ROTALIIDA Delage and Hérouard, 1896**

*Remarks***:** phylum, class and order are from Pawlowski et al., 2013, and they are not discussed in this paper.

**Superfamily Rotaloidea Ehrenberg, 1839, revised Hottinger, 2014**

*Remarks*: Hottinger (2014) described the superfamily Rotaloidea (Rotaliacea in the Hottinger's work) as " Shell walls lamellar-perforate; chamber arrangement trochospiral; foramen single, in interiomarginal position; folium and umbilical plate present; face ventral" but in our work, we take Rotaloidea in a broad sense in order to include the representatives of the Pararotaliidae.

**Family Rotaliidae Ehrenberg, 1839, revised Hottinger 2014**

*Remarks*: The family Rotaliidae has been recently revised by Hottinger (2014) and re-defined as: bi-lamellar-perforate trochospiral shells with single intercameral foramen in an inter-marginal position. Dorsal side evolute and ventral side involute. Presence of folium and umbilical plate. The umbilicus filled with a single axial pile or columellar filling. Spiral and intraseptal interlocular spaces transformed into spiral and intraseptal canals.

**Subfamily Rotaliinae Ehrenberg 1839, revised Hottinger 2014**

*Remarks*: This subfamily, re-defined by Hottinger (2014), is characterised by the absence of dorsal ornamentation and the umbilical spaces subdivided by free-standing piles. The foliar suture is marked by a notch.

**Genus *Rotorbinella* Bandy 1944**

Type species: *Rotorbinella colliculus* Bandy, 1944

*Remarks*: The main characteristics of this genus are: the small to medium sizes, the umbilical plug, the small to medium wide, and slightly oblique, folia, and the intraseptal and umbilical open interlocular spaces. For further details see Revets (2001), Boix et al., (2009) and Hottinger (2014).

The genus *Rotorbinella*, with the Cenomanian species *R. mesogeensis* (Tronchetti) appeared in the fossil record probably in the late Albian (Consorti et al., 2014, Hottinger, 2014).

***Rotorbinella lepina*** **sp. nov.**

(Fig. 5)

1976 *Alabamina*? *cretacea* Hofker – Luperto Sinni: Pl. 50, figs 6–7.

1976 *Rotalia saxorum* d'Orbigny – Luperto Sinni: Pl. 49, figs 6–10.

1978 *Rotalia saxorum* d'Orbigny – Luperto Sinni and Ricchetti: Pl. 61, figs 1–4.

2003 *Rotalia reicheli* Hottinger – Polavder: figs 3.13, 3.14

*Holotype*: Specimen 'PUAB 82476', figured in Fig. 5A.

*Type locality*: Monte delle Castagne, Lepini Mounts, Lazio, Central Italy. See reference in the column (Fig. 2).

*Type horizon*: Middle-upper part of the Radiolitidae Limestone unit, lower Campanian.

*Etymology*: The specific name is given from Lepini Mounts

*Number of studied specimens*: 35

*Diagnosis*: medium-sized, high trochospiral shell. The dorsal side is highly convex, unornamented and perforated by pores of wide calibre. Chamber walls are particularly thick. The umbilical side is flat to slightly convex, and occupied by a massive plug surrounded by a narrow spiral interlocular space transformed into a spiral canal. The periphery is acute with a more or less pronounced imperforate keel. Folia are relatively wide and imperforate and never overlap the central part of the plug. The foliar chamberlet is separated from the main chamber lumen by the umbilical plate, which forms a rectilinear sutural notch. An interlocular intraseptal canal is present along the septa, which is slightly curved and thickens near the aperture. The trochospire consists of up to 3 whorls of trapezoidal chambers. There are at least 8-9 chambers in the last whorl. The average diameter of the proloculus is 30-35 µm. Shell diameter varies from 0.9 to 1 mm, while the height varies from 0.63 to 0.71 mm. The average D/H ratio is 1.42. Dimorphism not observed.

*Differential diagnosis*: *Rotorbinella lepina* n. sp. differs from the Cenomanian *R. mesogeensis* in its conical shape (high trochospire) and dimensions, which are 2-2.5 times wider. *Rotorbinella lepina* has similar morphology to *R. campaniola* Boix et al., 2009, from the upper Coniacian-lower Campanian of the Pyrenees, but this species has less chambers per whorl; six chambers in the last whorl for *R. campaniola,* and 8-9 for *R. lepina*, respectively. The sutural notch of *R. lepina* is straight, compared with the curved sutural notch of *R. campaniola*. Folia of *R. lepina* are wider and more inclined than those of *R. campaniola*.

*Associated fauna*: *Rotalispira scarsellai*, *Rotalispira maxima* sp. nov., *Montcharmontia apenninica*, *Dicyclina schlumbergeri*, *Scandonea mediterranea*, *Accordiella conica*, *Keramosphaerina tergestina*, *Murgella lata, Praemurgella valenciana*.

*Biostratigraphical and Geographical distribution*: This species is present in the upper Santonian?-lower Campanian of Central Italy (this work). Moreover, it was reported from the Campanian of the Apulian platform (Southern Italy, Luperto Sinni and Ricchetti, 1978; Luperto Sinni, 1976) and from the Campanian of Serbia (Western Vardar Zone, Polavder, 2003). See the synonym list for details.

**Subfamily Lockhartiinae Hottinger, 2014**

*Remarks*: According to Hottinger (2014), the subfamily Lockhartiinae is characterised by low trochospiral shells with long and oblique folia supported by piles covering large parts of the umbilicus.

**Genus *Rotalispira* Hottinger, 2014**

Type-species: *R. scarsellai* (Torre, 1966)

*Description*: According to Hottinger (2014), the genus *Rotalispira* is characterised by coarsely perforated shells with angular and keeled periphery. Hemispherical outline. Umbilicus often without or with few foliar piles, but filled with perforate, very long folia superposed like the blades of a propeller. There is a wide spiral canal. For more information see Hottinger (2014).

*Remarks*: The lack of umbilical plug and the presence of oblique folia supported by piles easily distinguish *Rotalispira* from *Rotorbinella*. From the Upper Cretaceous of the Western Tethys, the genus *Pyrenerotalia* Boix et al. (2009) shows a smooth dorsal surface and funnels in the umbilical side, characteristics not present in *Rotalispira*. The biconvex lens-shaped *Iberorotalia* Boix et al. (2009) differs from *Rotalispira* in having a composite umbilical plug fused with folia. *Rotalispira* differs from the Cretaceous representatives of the genus *Pararotalia* because this last genus possesses a visible tooth-plate, a large umbilical plug, and an acute periphery.

***Rotalispira vitigliana* sp. nov.**

(Figs. 6A-L, 6N-O)

*Holotype*: Specimen ‘PUAB 82475’, figured in Fig. 6A.

*Type locality*: Quarry at the northern side of Vitigliano village, Salento, Puglia, SE Italy.

*Coordinates*: N 40º02'50"-E 18º24'35".

*Type horizon*: Upper part of the Santa Cesarea Limestone unit, middle Campanian.

*Etymology*: The specific name is given from Vitigliano, the closest village to the locality type.

*Diagnosis*: Small to medium sized-shell with the architectural style of *Rotalispira*. Chambers are low trochospirally arranged and gradually increase in size. Rounded periphery. Dorsal side almost flat and ornamented. Ventral side plano-concave. Dimorphism not observed. The new species has at least 3 spiral whorls with 10 chambers in the last whorl. Septa, slightly curved, thicken at their base. Each folium produces a more or less sharp foliar pile in axial direction. Proloculus sizes between 40 μm and 60 μm. Chamber height is almost double its width. The D/H ratio varies from 1.8 to 2.2. The calibre of the coarse pores is 15 to 20 μm.

*Differential diagnosis*: *Rotalispira vitigliana* diameter is approximately 1.5 times bigger than *R. scarsellai*. The trochospire is high in R*. scarsellai* while in *R. vitigliana* is low-to flat. The shell elements (wall, folia, umbilical plate) are thicker in *R. scarsellai* than in *R. vitigliana*. Umbilical space in *R. scarsellai* is almost completely filled by folia, while in *R. vitigliana* folia are more spaced between them. Umbilical piles maybe fused to each other in *R. scarsellai,* while in *R. vitigliana* umbilical piles are distinctly isolated. Umbilical space is approximately 2 times wider in *R. vitigliana*, and its keel is less pronounced compared with *R. scarsellai*.

*Associated fauna*: *Accordiella conica*, *Pseudochubbina bruni*, *Minouxia conica*, *Montcharmontia apenninica*, *Nummofallotia apula*, *Orbitoides* sp, *Pseudosiderolites*? *vidali*, *Cuvillierinella salentina*, *Rotorbinella lepina* sp. nov, *Rotalispira scarsellai*, "*Stensioeina*" *surrentina*.

*Biostratigraphical and geographical distribution*: middle Campanian of the Apulian platform (this work) and Central Italy in association with *Cuvillierinella salentina* (Maria Rita Pichezzi, pers. comm.).

**_Rotalispira scarsellai_ (Torre, 1966)**

(Fig. 6M)

1966 *Rotorbinella scarsellai* n. sp. – Torre: p. 422, pl. 1, figs. 1–8, pl. 2, Fig. 10.

1972 *Rotorbinella scarsellai* Torre – Bignot: pl. 7, fig. 6.

1977 *Rotorbinella scarsellai* Torre – Chiocchini and Mancinelli: pl. 40, figs. 1, 2.

1976 *Rotorbinella scarsellai* Torre – Luperto Sinni: pl. 52, figs. 1–5.

1976 *Rotorbinella* sp. – Luperto Sinni: pl. 52, figs. 6,7.

1976 *Stomatorbina*? sp. – Luperto Sinni: pl. 53, figs. 8-10.

1978 *Rotalia viennoti* Greig – Luperto Sinni and Ricchetti: pl. 60, figs. 2, 3

1978 *Rotorbinella scarsellai* Torre – Luperto Sinni and Ricchetti: pl. 62, figs. 5, 6

1978 *Stomatorbina*? sp. – Luperto Sinni and Ricchetti: pl. 62, figs. 12–14

1978 *Stensioeina surrentina* Torre – Luperto Sinni and Ricchetti: pl. 62, figs 3, 11

1990 *Rotorbinella scarsellai* Torre – Gušić and Jelaska: pl. 20, fig. 1.

1994 *Rotorbinella scarsellai* Torre – Chiocchini et al: pl. 22, figs. 6,7,14,15.

2006 *Rotorbinella scarsellai* Torre – Tasli et al: fig. 7W.

2007 *Rotorbinella scarsellai* Torre – Tentor: fig. 7C.

2008 *Rotorbinella scarsellai* Torre – Chiocchini et al: pl. 30, fig. 1.

2008 *Rotorbinella scarsellai* Torre – Checchoni et al: pl. 1, figs. 11.

2008 *Stensioeina surrentina* Torre – Schlüter et al: fig. 4G.

2012 *Rotorbinella scarsellai* Torre – Chiocchini et al: Pl 132, figs. 1–8.

2014 *Rotalispira scarsellai* (Torre) – Hottinger: pl. 5.1

2015 *Rotorbinella scarsellai* Torre – Frijia et al: fig. 8G.

2015 *Rotalispira scarsellai* (Torre) – Schlagintweit et al: fig. 6A.

For the description of this species see Torre (1966) and Hottinger (2014).

*Biostratigraphical and geographical distribution*: This species has been largely reported in the Coniacian-Campanian deposits of Italy (Southern Alps, Central and Southern Apennines, Apulian platform), and also in Croatia, Albania, Greece and Turkey (see synonymy list for references). In our study it is reported from the upper Santonian?-lower Campanian of the Lepini Mounts and middle Campanian of Cava Vitigliano. *Rotalispira scarsellai* has never been reported in the Pyrenees.

***Rotalispira maxima* sp. nov.**

(Figs. 7, 8)

1972 *Stensioina surrentina* Torre – Bignot pl. 16, Fig. 19 – Note: magnification might not be correct.

1976 *Pseudorotalia*? shaubi Hottinger – Luperto Sinni: pl 50, figs. 1, 4, 5, 8.

1976 *Pararotalia tuberculifera* (Reuss) – Luperto Sinni: pl. 51 figs. 5, 7, 8.

1978 *Rotalia viennoti* Greig – Luperto Sinni and Ricchetti: pl. 60, figs. 1, 4, 7–10.

2008 *Rotorbinella scarsellai* Torre – Checchoni et al: pl. 1, fig. 12.

2012 *Calcarinella shaubi* (Hottinger) – Chiocchini et al: pl. 139, figs. 1–5.

*Holotype*: Specimen 'PUAB 82487', figured in Fig. 8C.

*Type locality*: Lepini Mounts, Lazio, central Italy.

*Coordinates*: N 41º39'26''-E 13º07'05''.

*Type horizon*: Middle-upper part of the Radiolitidae Limestone unit, lower Campanian.

*Etymology*: The specific name is given due to the large dimensions of the new species.

*Number of studied specimens:* 43

*Diagnosis*: Medium to large sized ornamented *Rotalispira*. It is composed of at least three trochospiral whorls consisting of 11-13 chambers in the last whorl. Chambers gradually increase in size throughout ontogeny. Chamber periphery keeled. Dorsal side slightly convex, ventral side plano-concave. Septa slightly dorsally curved. Dimorphism not observed. Proloculus diameter is around 88 μm. Shell diameter is 1.2- 1.3 mm, while shell thickness is about 0.8/0.9 mm; the D/H ratio is almost 1.5. Coarse pores are about 18 μm in diameter. The umbilical side hosts very long and markedly oblique folia, sometimes heavily bent at the contact with foliar plies.
Specimens exhibit strong ornamentation in both sides. The dorsal side is represented by thick spikes and by densely packed foliar piles in the ventral side.

*Remarks*: Luperto Sinni and Ricchetti (1978) also recognised foliar piles (*pilastri* in their work) in the umbilical position, and a strong ornamentation characterising the dorsal side of the shell in their

"*Rotalia viennoti*". The strong umbilical ornamentation produced by foliar piles may apparently generate funnels.

*Differential diagnosis*: Shells of *R. maxima* are distinguishable compared to their Cretaceous allies by their bigger size. Furthermore, the umbilical area of *R. maxima* is densely occupied by folia and foliar piles, while *R. vitigliana* leave more empty space between two successive folia. In *R. scarsellai* the umbilical area is reduced and the trochospire is higher with respect to those of *R. maxima*. Shell diameter of *R. maxima* is almost the double compared with that of *R.* scarsellai. Besides, the lack of tooth-plate easily distinguish *R. maxima* from *Pararotalia tuberculifera*, while *Calcarinella shaubi* has multiple apertures.

*Associated fauna*: *Rotalispira scarsellai*, *Rotorbinella lepina* sp. nov., *Montcharmontia apenninica*, *Dicyclina schlumbergeri*, *Scandonea mediterranea*, *Accordiella conica*, *Keramosphaerina tergestina*, *Murgella lata*, *Praemurgella valenciana*.

*Biostratigraphical and Geographical distribution*: This species is present in the lower-middle Campanian of Central and Southern Apennines (this work), and from the Upper Cretaceous of Apulian platform (Luperto Sinni and Ricchetti, 1978; Checconi et al., 2008). Fleury (1980) referred some *Pseudorotalia*? *shaubi* of Luperto Sinni (1976) to the Upper Cretaceous of Greece, while Bignot (1972) showed a specimen from Istria.

**"*Stensioeina*" *surrentina* Torre, 1966**

(Fig. 9A-G)

1978 *Stensioeina surrentina* Torre – Luperto Sinni and Ricchetti: pl 63, figs. 1–2.

2012 *Stensioeina surrentina* Torre – Chiocchini et al: pl. 137, figs 1–6.

*Remarks*: Torre (1966) described, using mostly isolated matrix-free specimens from the Upper Cretaceous of the Sorrento Peninsula, a rotaloidean foraminifera characterized by “dorsally keeled, possessing spikes and probably with a large intraseptal interlocular space (defined as double septa)”, but details on the canal system and the umbilical architecture are missing in the original description. This new rotaloidean has been attributed by Torre (1966) to the genus *Stensioeina* Brotzen*,* and erected as *S. surrentina*. The re-study of the specimens figured by Torre (1966) and our samples from Central Italy and Cava Vitigliano reveal the presence of folia, foliar piles umbilical plate and intraseptal interlocular space in *S. surrentina*. These elements are typical of the representatives of the Rotaliidae family (probably Lockhartiinae subfamily) but not of *Stensioeina* (see for details the revision of the genus by Dubika and Peryt, 2014). However, has not been possible describe a new genus due to the scarcity of the material at our disposition.

*Biostratigraphical and Geographical distribution*: This species is present in the lower Campanian of Lepini Mounts and in the middle Campanian of Cava Vitigliano (this work). Further data on the presence of this genus come from the Upper Cretaceous of Sorrento peninsula (Torre, 1966), and from the Santonian of Aurunci Mounts (Chiocchini et al., 2012).

*Differences*: “*Stensioeina” surrentina* from Lepini Mounts are bigger with respect those from Cava Vitigliano. These differences fall in the range of variability furnished by Torre (1966), but more detailed investigations are needed to confirm the presence of variability within the whole population due to age or ecological factors.

## Family Pararotaliidae Reiss, 1963

*Remarks*: After Reiss (1963), complemented by Hottinger et al., (1991), Revets (1993) and Hottinger (2014) the family Pararotaliidae is characterised by bi-lamellar-perforate trochospiral shells with single interiomarginal aperture, umbilical flap and tooth-plate separating the chamber lumen from the interlocular space. Dorsal side evolute, ventral side involute. The umbilicus shows plugs, piles or columellar structures, but lacks folia. Canal system consisting of intraseptal and spiral umbilical canals; the last one is formed by interconnected tooth-plates. They may have enveloping canal system produced by secondary lamination (see Hottinger et al., 1991, for details).

## Subfamily Pararotaliinae Reiss, 1963

*Remarks*: The suprageneric position of the new taxon described below, *Pilatorotalia* n. gen., remain difficult to assess. However, the presence of a distinctive tooth-plate and the lack of folia induce us to include the new genus into the family Pararotaliidae. To Propose a coherent classification of the family Pararotaliidae into subfamilies is not the scope of this work and will be taken in account in the future.

## Genus *Pilatorotalia* gen. nov.

Species-type *Pilatorotalia pignattii* sp. nov.

*Derivatio nominis*: The generic name is given from the presence of huge piles (*pilates* in Latin) in the umbilical side of the shell.

*Diagnosis*: Medium-sized, trochospiral biconvex shell. Dorsal side smooth and free of ornamentation. Ventral side largely occupied by fused piles producing an umbilical mass crossed by numerous vertical funnels. Trapezoidal chambers are higher than wider, and have an acute periphery. Ventral sutures are radial and feathered, especially marked at its proximal part at the contact with the piles. Canal system composed of intraseptal interlocular spaces and a tubular spiral interlocular space restricted by the tooth-plate. A reticulate canal network (funnels) is also present crossing the umbilical mass. Dimorphism has not been observed. No enveloping canals are observed.

*Differential diagnosis*: *Pilatorotalia* gen. nov. differs from *Pararotalia* Le Calvez in the un-ornamented dorsal side and the ventral sutural interlocular space divided by piles. This latter characteristic is shared with the genus *Neorotalia* Bermudez but this genus has pustules in both sides like *Pararotalia* and may develop an enveloping canal system.

### ***Pilatorotalia pignattii*** **sp. nov.**

(Figs. 9H, 10)

1978 *Pararotalia*? sp. – Luperto Sinni and Ricchetti: pl. 62 figs. 10, 15, 16.

*Holotype*: Specimen 'PUAB 82478', figured in Fig. 10A.

*Type locality*: Monte delle Castagne, Lepini Mounts, Lazio, central Italy. See reference in the column (Fig. 2).

*Type horizon*: Middle-upper part of the Radiolitidae Limestone unit, lower Campanian.

*Etymology*: The specific name is given in honour of Prof. J. S. Pignatti (Rome), a recognised expert on the systems and ecology of fossils and living benthic foraminifera.

*Number of studied specimens:* 34

*Diagnosis*: medium-sized, lamellar perforate trochospiral shell. Low convex dorsal side un-ornamented and showing lamellar thickening due to the formation of successive lamellae during ontogeny. The periphery of the shell is angular and keeled. Ventral side convex and largely occupied by piles and funnels. The massive funnelled plug is surrounded by a spiral interlocular space (spiral canal). The trochospire consists of 2-2.5 whorls and is composed by slightly rectangular chambers, which are higher than wider. There are at least 12-13 chambers in the last whorl. The small proloculus is 30 μm in diameter. Shell diameter varies from 1.1 to 1. 2 mm, while the height varies between 0.71-0.77 mm; the average D/H ratio is approximately 1.46. The intraseptal interlocular space is present along the straight septa. The spiral canal is restricted by the successive tooth-plates.

*Associated fauna*: *Rotalispira scarsellai*, *Rotalispira maxima* sp. nov., *Rotalispira vitigliana* sp nov., *Rotorbinella lepina* sp. nov., *Montcharmontia apenninica*, *Dicyclina schlumbergeri*, *Scandonea mediterranea*, *Accordiella conica*, *Keramosphaerina tergestina*, *Murgella lata, Praemurgella valenciana*.

*Biostratigraphical and Geographical distribution*: This species is present in the upper Santonian?-lower Campanian of Lepini Mounts and in the Upper Cretaceous of Apulian platform (Luperto Sinni and Ricchetti, 1978).

**Genus *Neorotalia* Bermudez, 1952**

(Species type: *Rotalia mexicana* Nuttall, 1928)

*Remarks*: this heavily ornamented rotaloidean, described from the Oligocene deposits of America, has been considered synonymous with *Pararotalia* Le Calvez by Loeblich and Tappan (1987). However, Hottinger et al. (1991) retained *Neorotalia* as a genus distinct from *Pararotalia* based on the presence of an enveloping canal system and a divided ventral sutural interlocular space in the latter. The similarities and differences between *Neorotalia* and the recently described *Granorotalia* and *Ornatorotalia* from the Palaeogene of Italy (Benedetti et al., 2011) included in the family Ornatorotaliidae Benedetti (2015) needs further investigations.

***Neorotalia*? *cretacea* sp. nov.**

(Fig. 11)

2010 ? *Sulcoperculina* sp. – Radiočić et al: pl. 3, figs. 4-6.

*Holotype*: Specimen 'PUAB 82482', shown in Fig. 11A.

*Type locality*: Monte delle Castagne, Lepini Mounts, Lazio, central Italy. See reference in the column (Fig. 2).

*Type horizon*: Middle-upper part of the Radiolitidae Limestone unit, lower Campanian.

*Etymology*: The specific name is given in allusion of the age of the new species

*Number of studied specimens:* 37

*Description*: Medium size, biconvex lamellar perforate shell with chambers arranged in a low trochospire. Both sides of the shell are strongly ornamented. Un-ornamented shell areas are perforated by pores of large calibre. Radial-to-vertical piles occupied the dorsal side, producing clearly visible rounded pustules on shell surface. Funnels developed between piles. The ventral side piles show a particular stellate disposition resembling a rose, due the radial arrangement of the thin funnels. Periphery of the shell is slightly keeled. Funnelled plug is surrounded by a thin spiral canal. The shell is composed of two to two and half whorls with trapezoidal chambers, relatively angular. The last whorl hosts 12-14 chambers. The proloculus is around 30 µm in diameter. Height of the shell varies from 0.52 to 0.58 mm, while the maximum diameter measured reaches 0.98 mm, producing a D/H average of 1.78. Canal system consists of a spiral canal present between two adjacent whorls and interconnected with reticulate canals of the central plug (funnels), and by a spiral (enveloping) and intraseptal interlocular canals.

*Associated fauna*: *Rotalispira scarsellai*, *R. maxima* sp. nov., *Rotorbinella lepina* sp. nov., *Pilatorotalia pignattii* gen. nov, sp. nov, *Montcharmontia apenninica*, *Dicyclina schlumbergeri*, *Scandonea mediterranea*, *Accordiella conica*, *Keramosphaerina tergestina*, *Murgella lata. Praemurgella valenciana.*

*Biostratigraphical and Geographical distribution*: At present is known from the lower Campanian of Lepini Mounts (Central Italy) and probably from western Serbia.

**4. The age of the rotaloidean Foraminifera: Chronostratigraphy based on SIS**

The chronostratigraphic age of the beds containing the rotaloideans studied in this work has been constrained by means of Sr-isotope stratigraphy using both the Sr-data from Schlüter et al. (2008) and Frijia et al. (2015) and the analysis of new samples. The two new studied samples used for SIS come from Central Italy, from a rudist level situated 1m below the bed with the first occurrence (FO) of *K. tergestina* (Fig. 2) allowing to precisely date the type level of *N.*? *cretacea*.

The preservation of the analysed fossils was evaluated using an accurate diagenetic screening following the procedure described in detail in previous works (Steuber et al., 2005; Boix et al.,2011; Frijia et al., 2015). Trace element analysis (high Sr content vs. low Mn and Fe concentrations, Table 1) and petrographic observations show no evidence of significant diagenetic alteration of the rudist shells, suggesting that they preserve their pristine chemical composition. Furthermore, internal consistency of the Sr-isotope ratios of the two shell fragments reinforces the hypothesis that they preserve the original Sr-isotope signature of seawater (Table 1).

The $^{87}Sr/^{86}Sr$ value of 0.707478± 11× 10−6 obtained from the analysed sampled translate into an age of 82.09 (+0.88, - 0.89; Table 1) Ma compared with the $^{87}Sr/^{86}Sr$ reference curve for Cretaceous seawater (McArthur et al. 2001; age derived using the look-up table version 4: 08/04). This age corresponds to the early Campanian, according to the time scale of Gradstein et al. (2004). Moreover, the$^{87}Sr/^{86}Sr$ average value from the Lepini Mounts section is almost within analytical uncertainty of the values measured by Frijia et al. (2015) from a level 20 m below the FO of *K. tergestina* in the Campanian Apennine Platform (0.707502 ±9). Finally, the Sr-isotope value from the studied section is almost undistinguishable from that measured by Steuber et al. (2005) from the levels yielding the FO of *K. tergestina* from Brac island (Croatia) (0.707481 ± 9*10-6). We can therefore conclude that the new Sr data from the Lepini Mounts of central Italy are in agreement with the general early Campanian age of the FO of *K. tergestina* in the periadriatic area. Unfortunately the beds with the new rotalidean species (*P. pignatti* gen. nov, sp. nov*, R. lepina* sp. nov.) found in the lower part of the studied section cannot be dated as precisely as the level with

*N.*? *cretacea,* due to the lack of suitable material for SIS. These two new taxa occur 45 and 55 metres below the *N.*? *cretacea* type level. Using the bio-chronostratigraphic scheme developed by Frijia et al. (2015) we suggest an upper Santonian?-lowermost Campanian stage assignment for these two levels.

The published biostratigraphic charts (Velić, 2007; Chiocchini et al., 2012) and chronostratigraphic scheme (Frijia et al., 2015) suggest that *R. scarsellai* is the first rotaloidean foraminifera appearing in the Late Cretaceous GCMC of Central Tethys. It is at least present from the upper Turonian (Frijia et al., 2015), probably in association with some representatives of the genus *Rotorbinella*, with which it has been frequently confused (see Hottinger, 2014 for comments and the synonym list proposed here). The deposits, today disappeared in the neighbourhood of Pontone (Sorrento peninsula, localities type of *R. scarsellai* and *"Stensioeina" surrentina*) studied by Torre (1966) were probably older than the localities presented in our study, suggesting that the FO of "*Stensioeina*" *surrentina* take place before the studied rotaloidean ensemble and after the FO of *R. scarsellai*.

## 5. Rotaloideans in the middle and Late Cretaceous Global Community Maturation Cycle

The data at our disposal (Boix et al., 2009; Puiz and Meister, 2014; Hottinger, 2014, and the papers cited therein) suggest that the origin of the rotaloidean foraminifera took place near the Albian-Cenomanian boundary (middle Cretaceous GCMC) with two parallel lineages represented at their bases by *Rotorbinella mesogeensis* (Tronchetti) and *Pararotalia boixae* Puiz and Meister. The first one, characterised by the presence of folium and umbilical plate, is considered the progenitor of all rotaliids (Rotaliidae family) as already stated by Boix et al.(2009), while the last one exhibiting a tooth-plate closing the spiral chamber probably represents the root of the pararotaliids (Pararotaliidae family). Their small sizes, relatively simple umbilical architecture, and the lack of adult dimorphism suggest an r-strategy of life for these rotaloideans (Hottinger, 2014), which probably helped them to escape extinction at the Cenomanian-Turonian boundary Event

(CTB). Moreover, Cenomanian rotaloideans are widely distributed. In addition to the Pyrenean realm, they are known in the Tethyan realm from the Iberian Peninsula to Oman and Iran. In America, *R. mesogeensis* is present in the Cenomanian deposits of Peru (unpublished data), and rotaliids with strong affinities to *R. mesogeensis* have been demonstrated by Rosales-Dominguez et al. (1997, fig. 4E) from the Cenomanian of Chiapas (Mexico).

After the Cenomanian/Turonian mass extinction (Late Cretaceous GCMC) Rotaliidae and Pararotaliidae diversified independently, at least into three separated palaeobioprovinces: Tethyan, Pyrenean and Caribbean (Caus et al., 2007). However, at present the regional data are insufficient to evaluate if this diversification was contemporaneous or not. In the Pyrenean palaeobioprovince, the diversification started during the late Turonian-early Coniacian with *Rotorbinella campaniola* Boix et al., 2009, and reached maximum diversity near the Coniacian-Santonian boundary with the appearance of very large morphotypes (*Pyrenerotalia* Boix et al., *Iberorotalia* Boix et al., and *Orbitokathina* Hottinger) interpreted as k-strategists (Boix et al., 2011). In the Tethyan palaeobioprovince, *R. scarsellai* appeared in the late Turonian (Frijia et al., 2015), while large morphotypes such as *R. maxima* sp. nov. appear only in the early Campanian. Finally, rotaloideans seem to lose importance in both Pyrenean and Tethyan palaeobioprovinces during late Campanian and Maastrichtian stages, when only non-described small forms and the genus *Laffiteina* existed. In the Caribbean palaeobioprovince "*Kathina" jamaicensis* Cushmann and Jarvis, and "*Lockhartia" susuaensis* Pesagno associated with non-described morphotypes seem to characterise the latest Cretaceous near the K/Pg boundary (Brown and Brönnimann, 1957; Boix et al., 2009).

## 6. Conclusions

The study of the Upper Cretaceous shallow-water carbonates of Central and Southern Italy has led to the description of five new rotaloidean foraminifera, which are included in the family Rotaliidae (*Rotorbinella lepina*, *Rotalispira vitigliana* and *R. maxima)* and in the family Pararotaliidae (*Pilatorotalia pignattii* and *Neorotalia? cretacea*). Moreover, the two rotaloidean taxa, *Rotalispira* *scarsellai* and "*Stensioeina" surrentina*, previously described (Torre,1966) have been identified, and their architecture has been discussed. Strontium Isotope stratigraphy allowed to precisely date the new described taxa to the late Santonian?-middle Campanian. Therefore, these foraminifera could permit the lower Campanian shallow-water deposits of the perimediterranean area to be biostratigraphically characterised when other taxa are missing.

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**Figure Captions**

Fig. 1 - 1A: Sampled Localities. 1B: Base and top of the sampled column, white arrow indicate the position of the sample 057 (PUAB 82487). 1C: White arrow indicate the position of the sample CC1 (PUAB 82475).

Fig. 2 - Details of the sampled column from Central Italy (Lepini Mounts). Position of some type-levels are also indicated.

Fig. 3 - Foraminifera from the sampled column, Lepini Mount. Scale bar 1 mm except in C, E, H. A. From left to right: *Accordiella conica*, *Dicyclina schlumbergeri*, *Scandonea mediterranea*. B. *Nezzazatinella* sp. C. Undetermined high trochospire rotaloidean, the same form has been cited by Luperto Sinni and Ricchetti (1978) as *Allomorphina*? Scale bar 0,2 mm. D. *Mugella lata*. E. *Sarmentofascis zamparelliae*, scale bar 1 mm. F,G. *Praemurgella valenciana*. H. *Keramosphaerina tergestina*, scale bar 2 mm. I. *Murgella lata* in longitudinal section.

Fig. 4 - Rotaloideans-bearing facies. Scale bar 2 mm for all figures. A. Dolomitized wackestone with *Dicyclina* (D) and rotaloideans (R). B. Miliolids and rudist shells grainstone with rotaloidean (R). C. Packstone with *Pilatorotalia pignattii* gen. nov., sp. nov. (Pp), rotaloidean (R) and *Sarmetofascis zamparelliae* (S). D. Facies representing a foraminiferal-microbial environment with *Accordiella conica* (Ac). Note the differences in size difference between *Rotalispira maxima* sp. nov. (Rm) and *Rotalispira scarsellai* (Rs). E. Packstone with *Rotalispira vitigliana* sp. nov. (Rv) and rudist fragments. F. Packstone with *R. vitigliana* sp. nov. (Rv), *Cuvillierinella salentina* (Cs) and *Pseudochubbina bruni* (Pb). A-D. From Lepini Mounts. E,F From Cava Vitigliano. A: sample 010 (PUAB 82476); B: sample 014 (PUAB 82478); C: sample 027 (PUAB 82483); D: sample 057 (PUAB 82487); E,F: sample CC1 (PUAB 82475).

Fig. 5 - *Rotorbinella lepina* sp. nov. from Lepini Mounts. Scale bar 1 mm for all figures. A. Holotype, axial section (PUAB 82476 LP01). B. Tangential section (PUAB 82480 LP01). C. Oblique section (PUAB 82484 LP02). D. Tangential section showing umbilical plug and folia (PUAB 82476 LP04). E. Axial section (PUAB 82476 LP07). F. Oblique centered section (PUAB 82480 LP01). G. Transversal section of the umbilical side (PUAB 82476 LP05). H. Tangential section of the umbilical side, note folia and central plug (PUAB 82480 LP02). I. Oblique section showing proloculus (PUAB 82483 LP08). J. Transversal slightly oblique section of the umbilical side, note folia (PUAB 82476 LP02). K,L. Tangential sections of the dorsal side (PUAB 82476 LP03 and LP06 respectively). M, N. Tangential sections showing plug surrounded by folia (PUAB 82476 LP01 and LP09 respectively).,ch: chamber lumen, fo: folia if: intercameral foramen, is: intraseptal interlocular canal, n: notch p: pore, pr: proloculus, upg: umbilical plug.

Fig. 6 - *Rotalispira vitigliana* sp. nov. from Cava Vitigliano. Scale bar 1 mm, all figures are referred to the sample CC1 (PUAB 82475). A. Holotype, oblique section showing intercameral foramen and foliar piles (LP01). B. Oblique slighlty transverse section (LP01). C. Tangential section showing three chambers (LP07). D, E. Close to the axial sections (LP09 and LP11 respectively). F. Tangential section showing two chambers (LP05). G. Close to the axial section, note vertical foliar piles and oblique folia (LP01). H. Oblique transversal section showing umbilical plate and folia (LP08). I. Oblique section (LP13). J. Transversal section (LP03). K. Transversal section displaying folia and foliar piles (LP10). L. Detail of folia from a transversal section (LP12). M. *Rotalispira scarsellai* (Torre) in axial section (LP02). N. Close to the axial section, note oblique folia (LP02). O. Oblique centered section (LP10). ch: chamber lumen, fo: folia, fp: foliar pile, if: intercameral foramen, is: intraseptal interlocular canal, k: keel, p: pore, pr: proloculus, up: umbilical plate.

Fig. 7 - *Rotalispira maxima* sp. nov. from Lepini Mounts. Scale bar 1 mm for all figures. A. Tranversal cut of half shell, chambers are arranged in almost three whorls (PUAB 82482 LP05). B. Close to the axial section of a partially dissolved shell (PUAB 82482 LP04). C. Oblique section, note ornamentation of the dorsal side (PUAB 82483 LP05). D. Axial section of half shell showing three chambers, note superposed folia and foliar piles filling the umbilicus (PUAB 82486 LP01). E. Oblique centered section (PUAB 82483 LP07). F. Tangential section (PUAB 82476 LP07). G. Tangential section showing folia and foliar piles (PUAB 82477 LP02). ch: chamber lumen, fo: folia, fp: foliar pile, if: intercameral foramen, is: intraseptal interlocular canal, k: keel, p: pore, pr: proloculus.,

Fig. 8 - *Rotalispira maxima* sp. nov. Scale bar 1 mm for all figures. A. Axial section (PUAB 82482 LP01). B. Axial section, note wide folia running slantwise within the umbilicus and

producing vertical foliar piles at their inner end (P-1023). C. Holotype. Transversal section of the lasts 1,5 whorls. Some septa (lower side) are broken (PUAB 82487 LP01). D. Axial section from Monte Feuci (IS-A1051). E. Axial section of a specimen composed by 2 whorls (PUAB 82487 LP01). F. Tangential section, note strongly curved folia and huge foliar piles (PUAB 82483 LP01). G. Tangential section of the umbilical side, note umbilicus almost totally filled by foliar piles (PUAB 82487 LP01). H. Tangential section (PUAB 82481 LP02). I. Two chambers are here cut tangentially, note foliar bending (PUAB 82481 LP01). ch: chamber lumen, fo: folia, fp: foliar pile, if: intercameral foramen, is: intraseptal interlocular canal, , k: keel, p: pore, pr: proloculus up: umbilical plate.

Fig. 9 - A-G: "*Stensioeina*" *surrentina* Torre. A-D: from Cava Vitigliano, E: from Aurunci Mounts, G: from Monte Filaro (Lepini Mounts). H: *Pilatorotalia piagnattii* gen. nov., sp. nov. Scale bar 1 mm for all figures. A-D. Transverse and tangential sections of umbilical sides, showing folia, umbilical plate and foliar piles (PUAB 82475 LP07,04,09). E. Transverse section of the umbilical side with foliar piles (IS-A957). F. Tangential section of the umbilical side, note the presence of small folia (PUAB 82481 LP01). G. Oblique section showing large intraseptal interlocular space, umbilical plate and the adjoining folia (IS-1443). H. Tranverse section of the dorsal side, here tooth-plate develop between two succesive whorls constraining the spiral canal (PUAB 82483 LP01). fo: folia, fp: foliar pile, if: intercameral foramen, is: intraseptal interlocular canal, p: pore, tp: tooth-plate, up: umbilical plate.

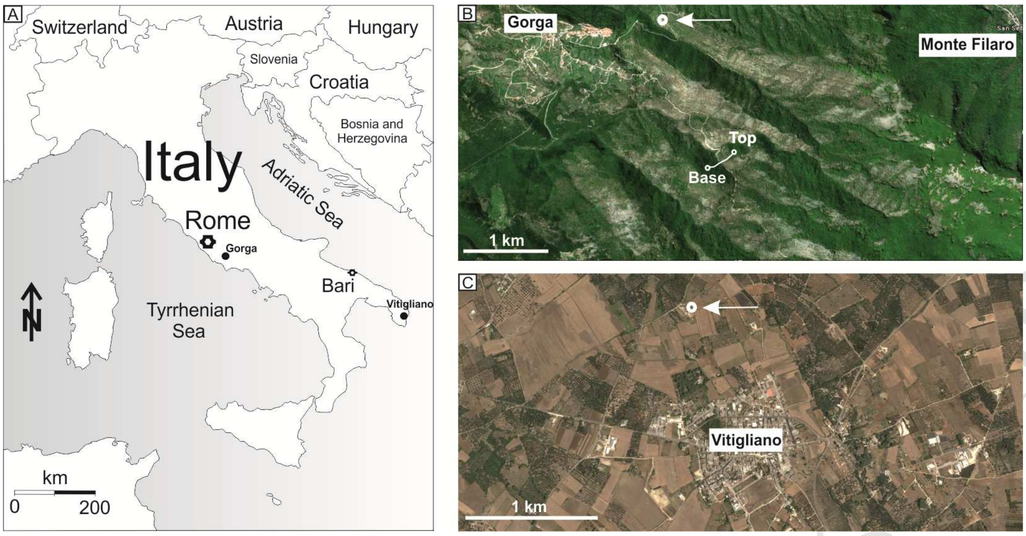
Fig. 10 - *Pilatorotalia pignattii* gen. nov., sp. nov. from Lepini Mounts. Scale bar 1 mm for all figures. A. Holotype. Axial section, inner part of the shell appear altered (PUAB 82478 LP02). B. Oblique centered section (PUAB 82483 LP04). C. Oblique section (PUAB 82478 LP01). D. Transversal section showing tooh-plates and the spiral interlocular space filled

with fine mud. (PUAB 82483 LP06). E. Transversal section of the umbilical side, note feathered suture (PUAB 82433 LP03). F. Tangential section of feathered sutures and piles (PUAB 82484 LP01). G Transversal section showing tooh-plate (PUAB 82482 LP02). H. Tangential section cutting feathered sutures (PUAB 82476 LP08). I,J. Tangential sections of the umbilical side (PUAB 82482 LP01 and LP03 respectively). K. Tangential sections of the dorsal side (PUAB 82482 LP06). ch: chamber, fhs: feathered suture, fu: funnel, if: intercameral foramen, is: intraseptal interlocular canal, pi: piles, spi: spiral interlocular space, tp: tooth-plate.

Fig. 11 - *Neorotalia*? *cretacea* sp. nov. from Lepini Mounts. Scale bar 1 mm for all figures. A. Holotype. Axial secton (PUAB 82482 LP09). B. Close to the axial section (PUAB 82482 LP10). C. Tangetial section of the dorsal side showing piles (PUAB 82482 LP01). D. Near to the axial section (PUAB 82482 LP07). E. Tangential section passing trought the proloculus (PUAB 82476 LP08). F. Tangential section (PUAB 82482 LP08). G. Axial section, note the envelopping canal occupying the chamber edge (PUAB 82479 LP01). H. Oblique section of a small specimen (PUAB 82478 LP01). I. Close to the axial section (PUAB 82477 LP01). J. Oblique section (PUAB 82482 LP07). K, M. Tangential sections of the umbilical side showing the disposition of umbilical piles and the spiral interlocular space (PUAB 82476 LP06 and LP08 respectively). L. Oblique section (PUAB 82485 LP01). N. Oblique centered section (PUAB 82482 LP12). ecs: envelopping canal system, fu: funnel, if: intercameral foramen, is: intraseptal interlocular canal, p:pore, pi: piles, spi: spiral interlocular space.

Table 1 - Elemental concentration (ppm), Sr-isotope ratio and SIS ages (Ma) of the studied sample.

| Sample | $^{87}Sr$ / $^{86}Sr$ measured | ± 2 s mean | $^{87}Sr$ / $^{86}Sr$ sample corrected to difference: USGS EN -1 value Mc Arthur and USGS EN-1 | ± 2 se | Ca | Mg | Sr | Fe | Mn | Age min | Age mean | Age max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L - A | 0,707464 | 0,000005 | 0,707478 | | 391310 | 1256 | 1424 | 5,5 | 0,4 | | | |
| L - B | 0,707464 | 0,000005 | 0,707478 | | 390160 | 1157 | 1269 | 6,3 | 0,2 | | | |
| | | **mean** | **0,707478** | 0,000011 | | | | | | **81,2** | **82,09** | **82,97** |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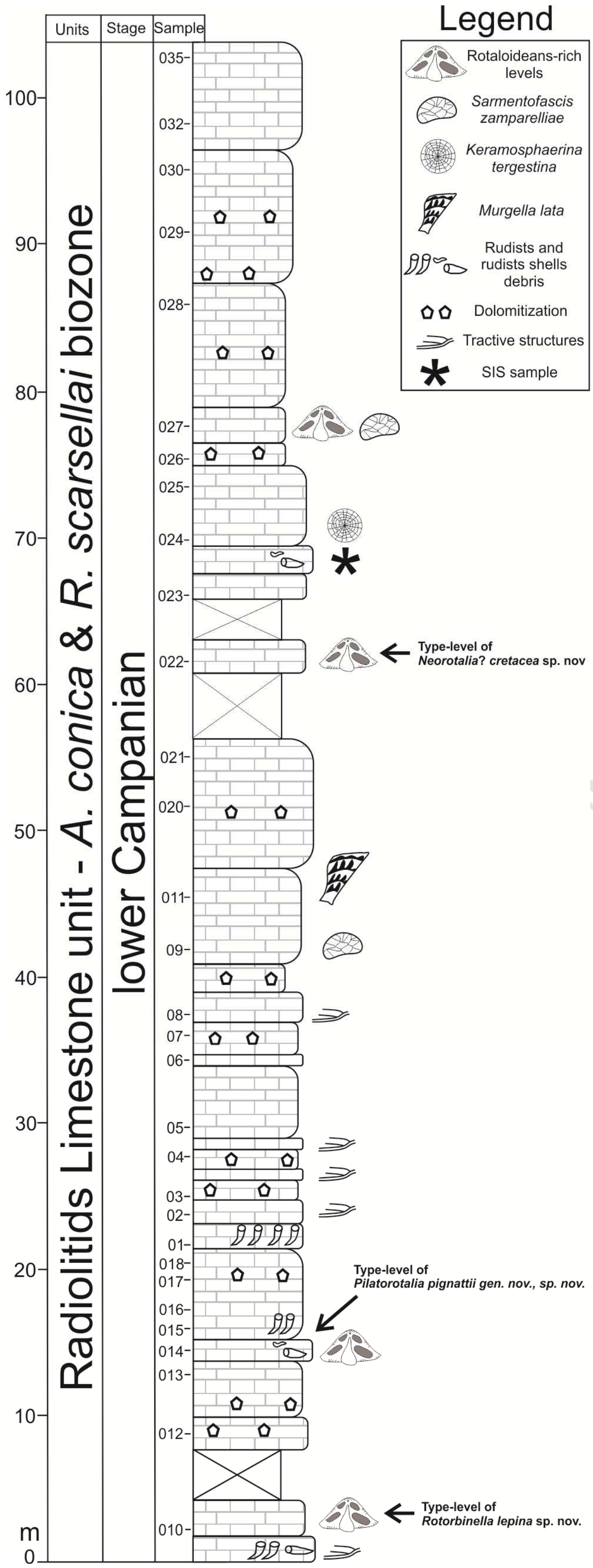

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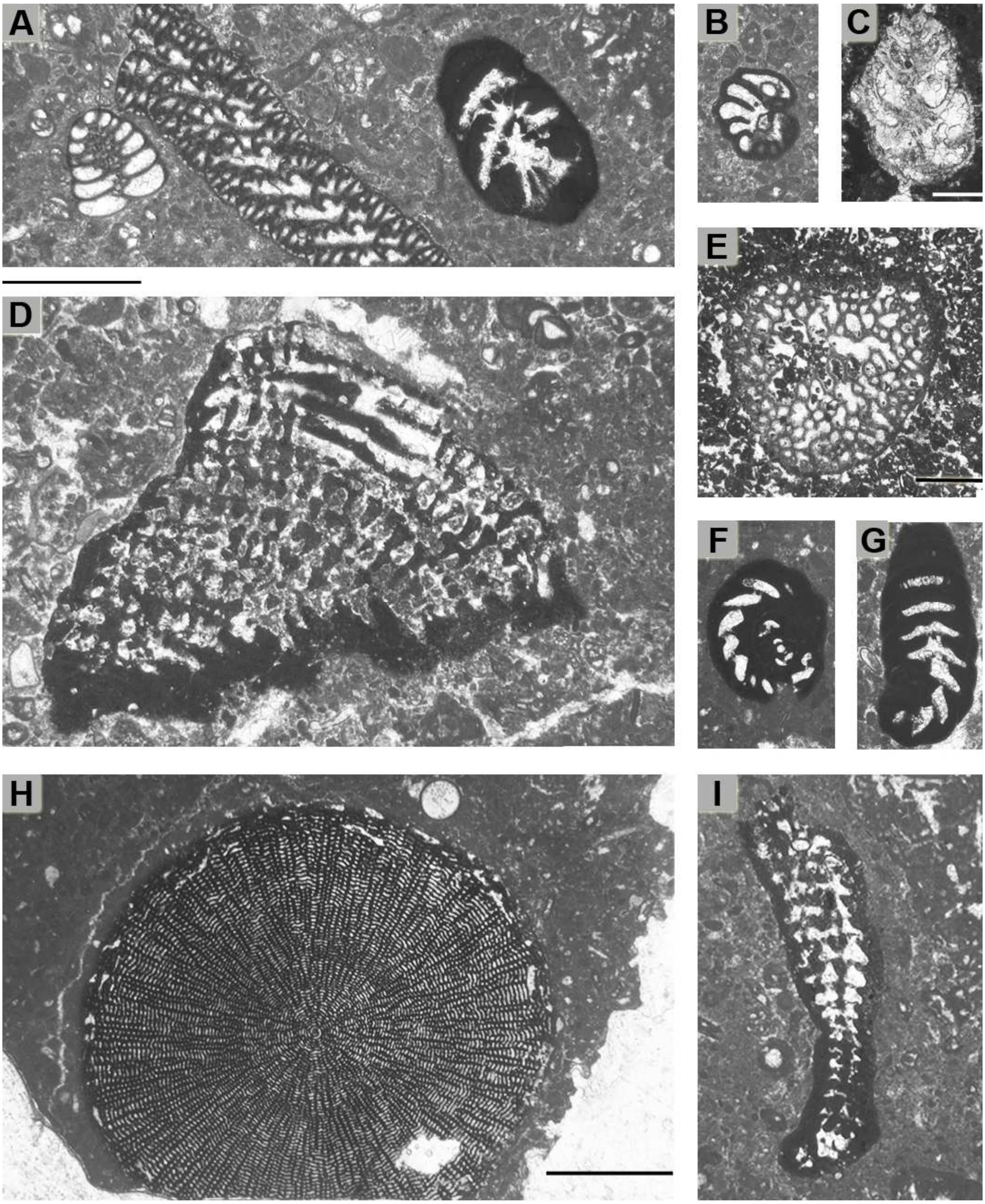
Type-level of Rotorbinella lepina sp. nov.
Type-level of Pilatorotalia pignattii gen. nov., sp. nov.
Type-level of Neorotalia? cretacea sp. nov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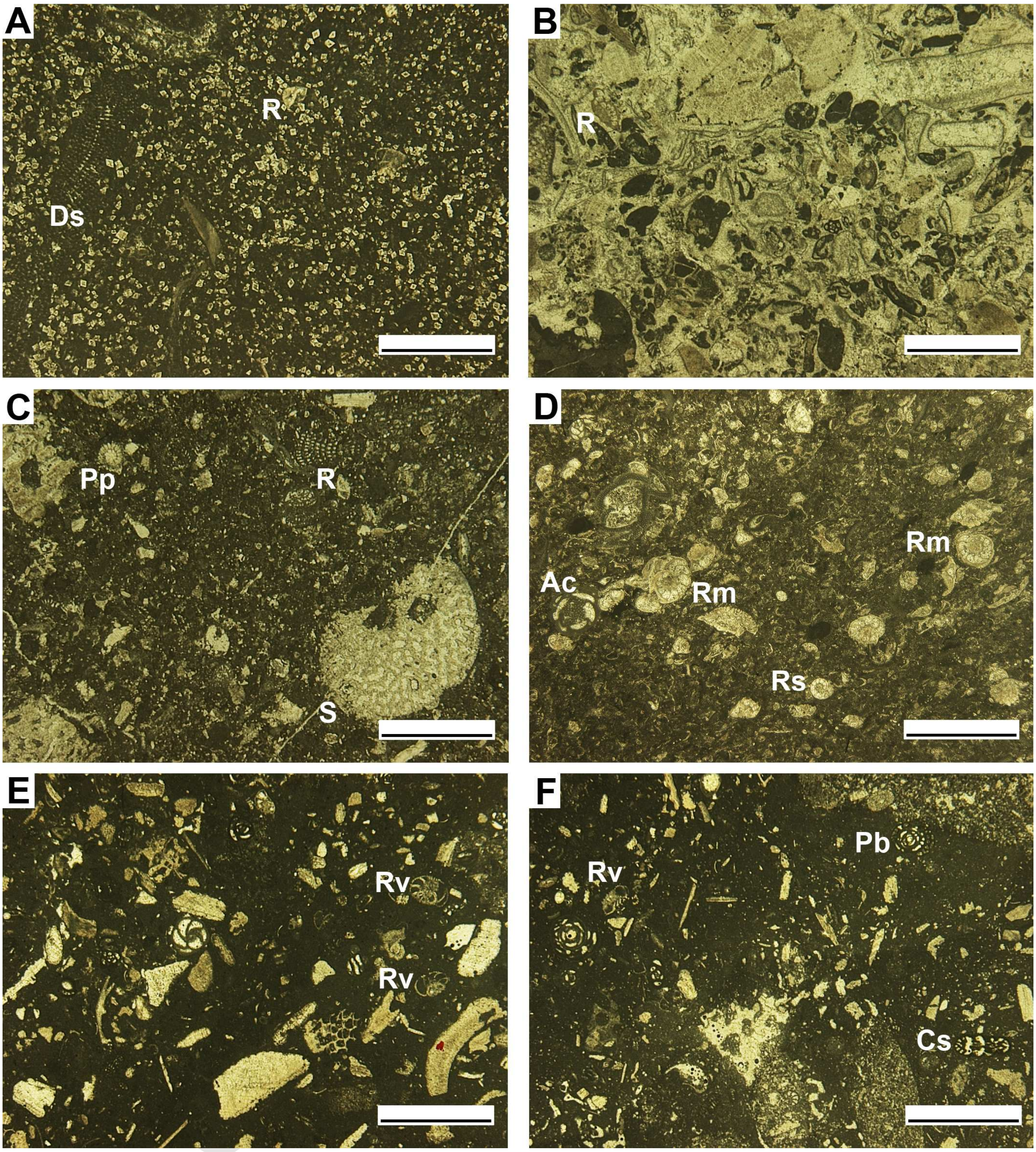
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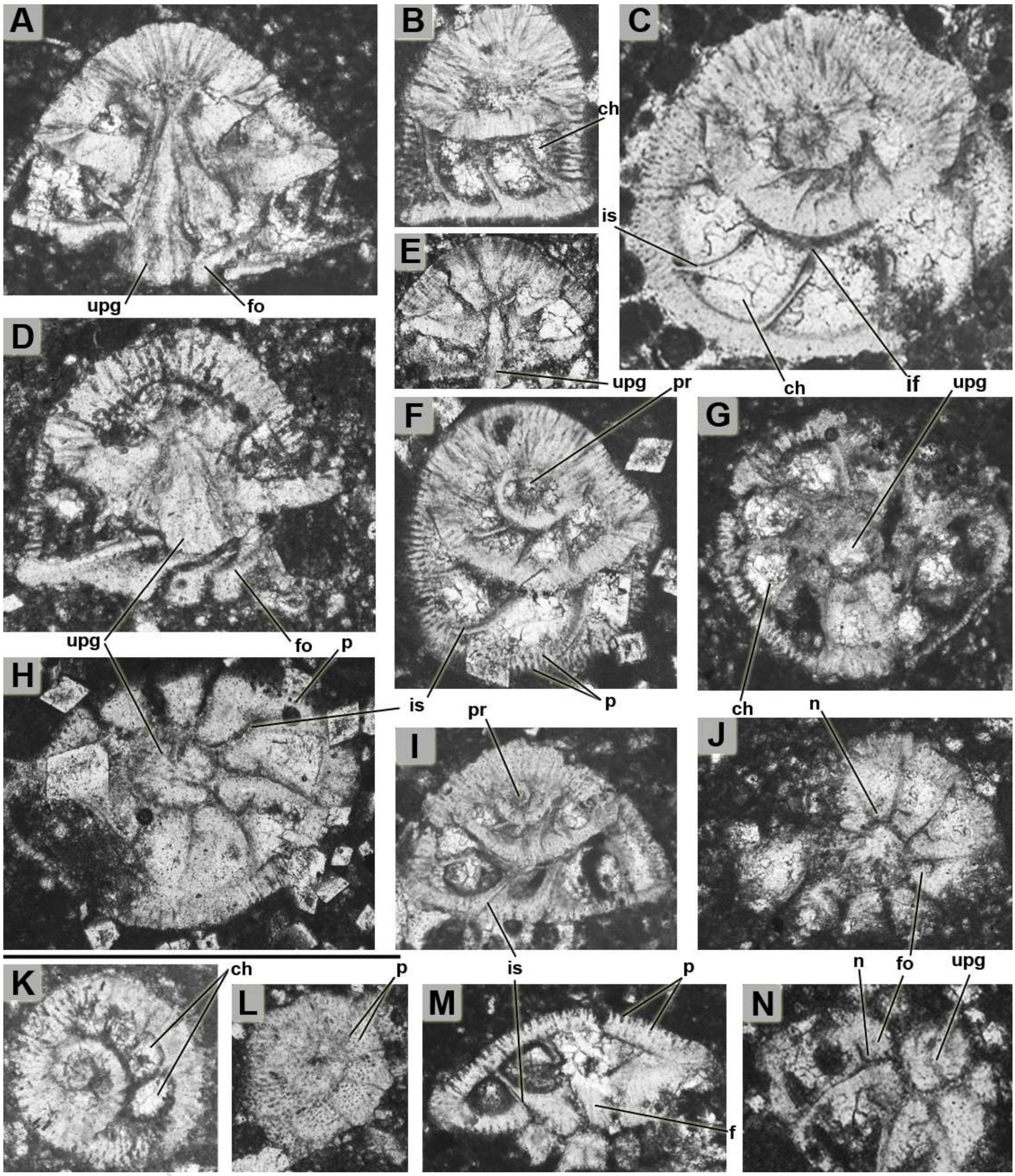
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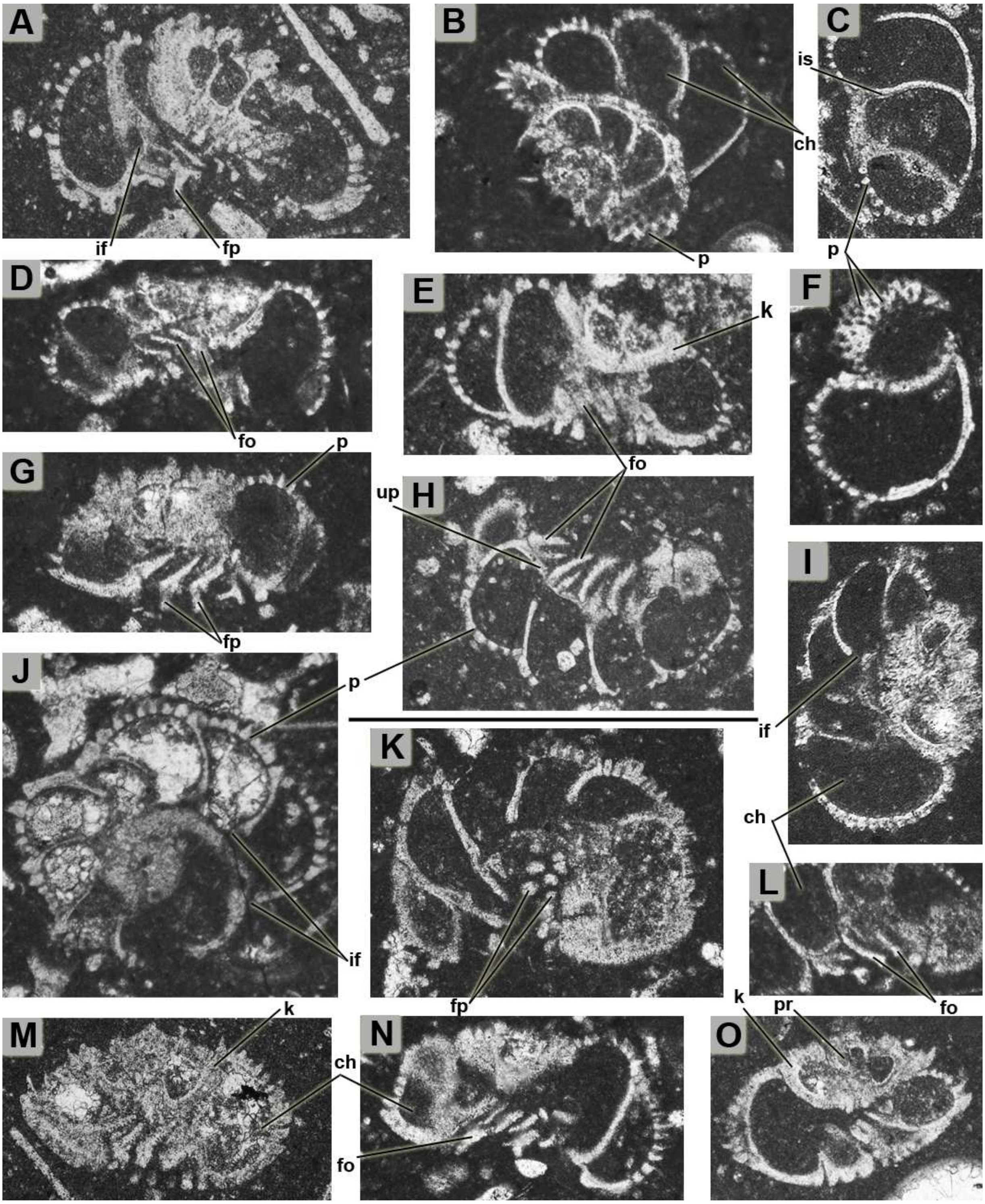
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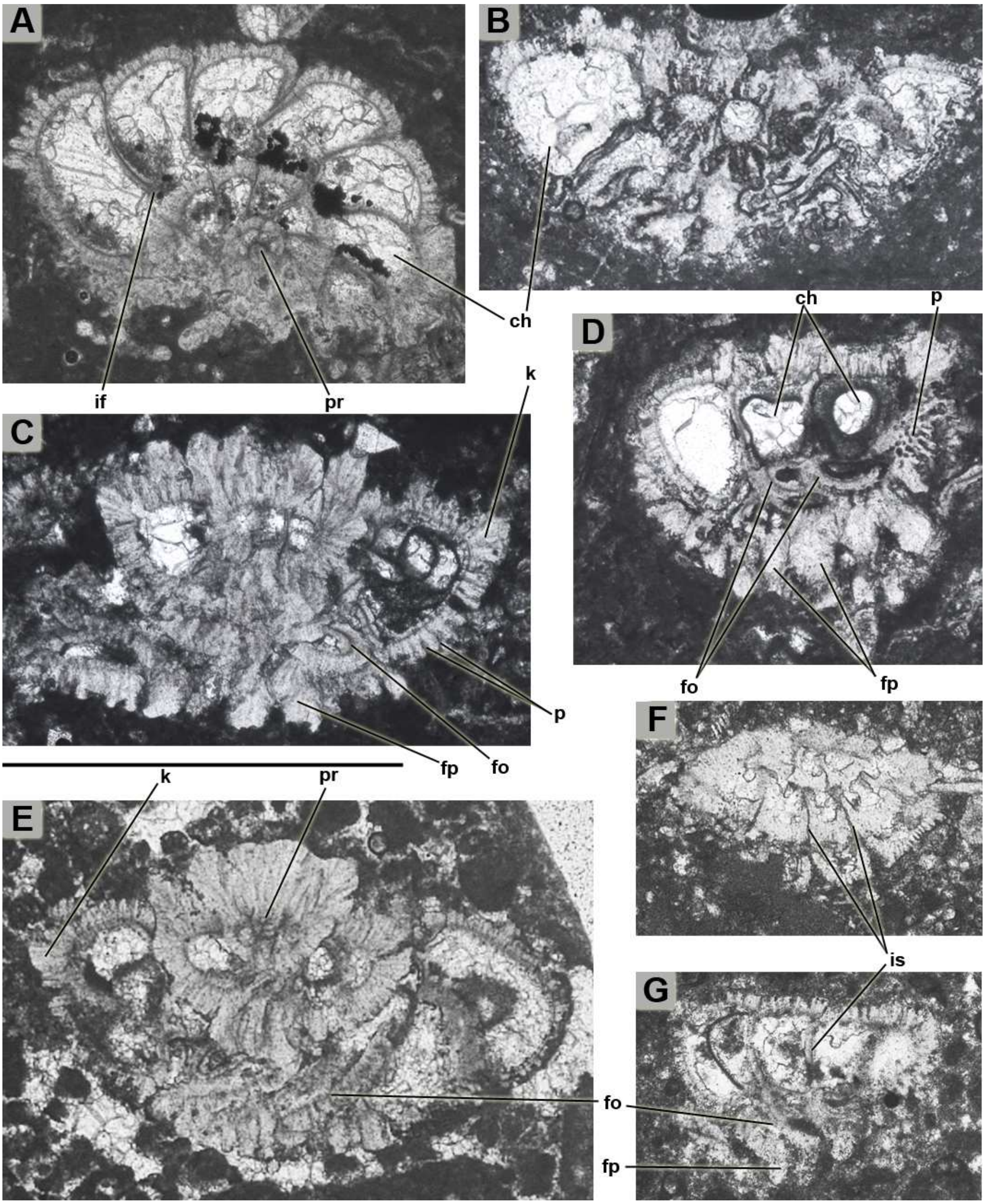
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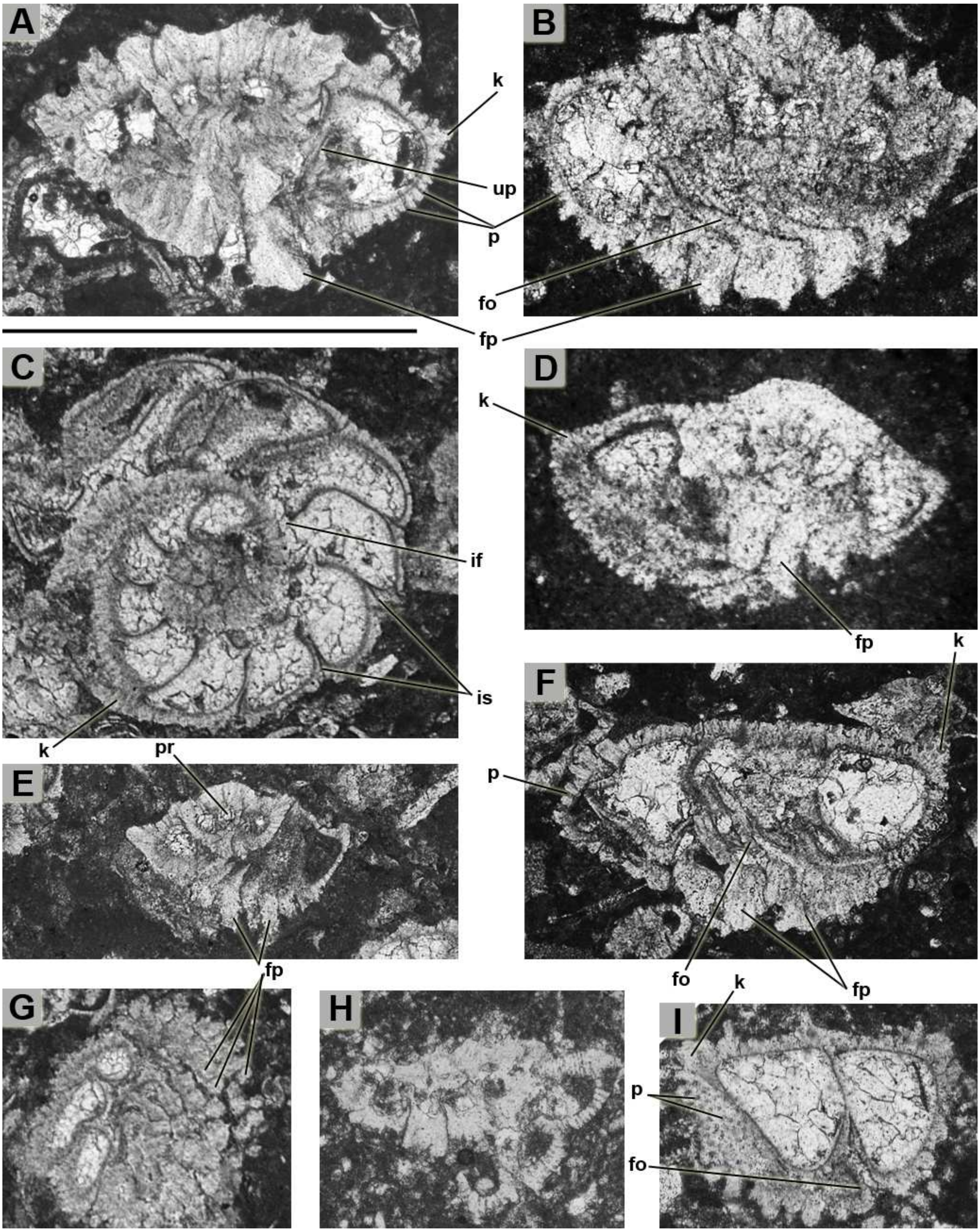
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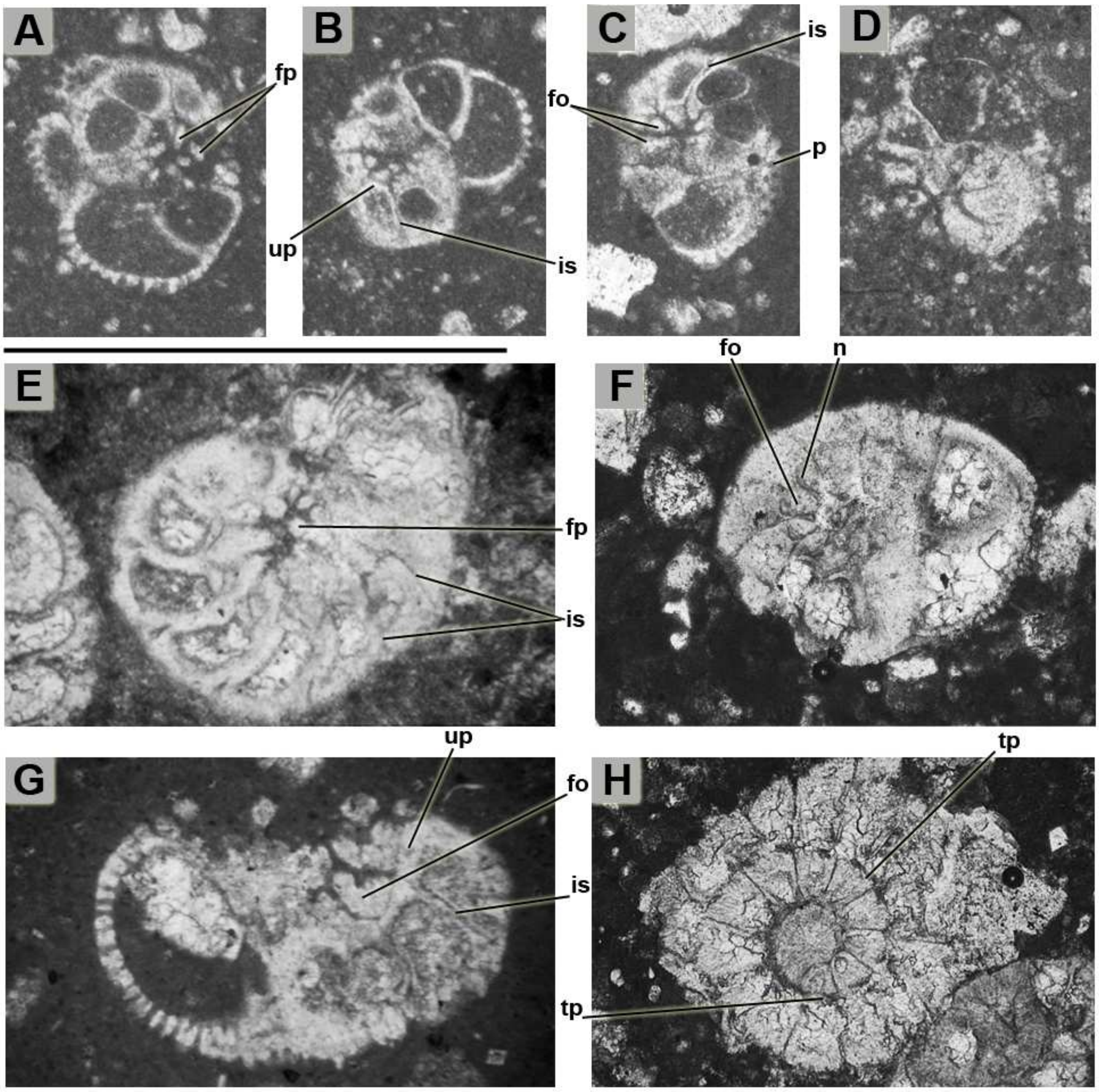
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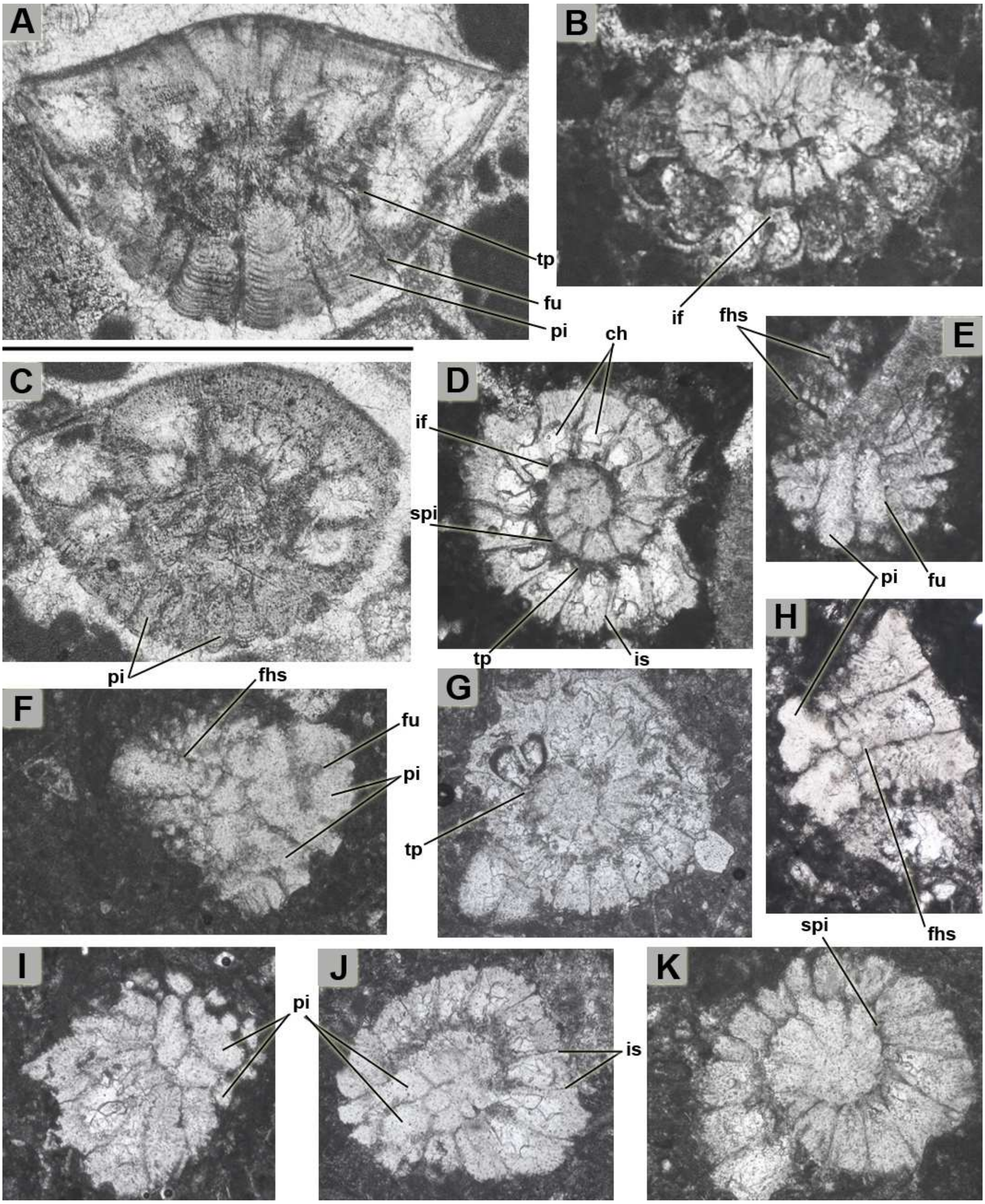
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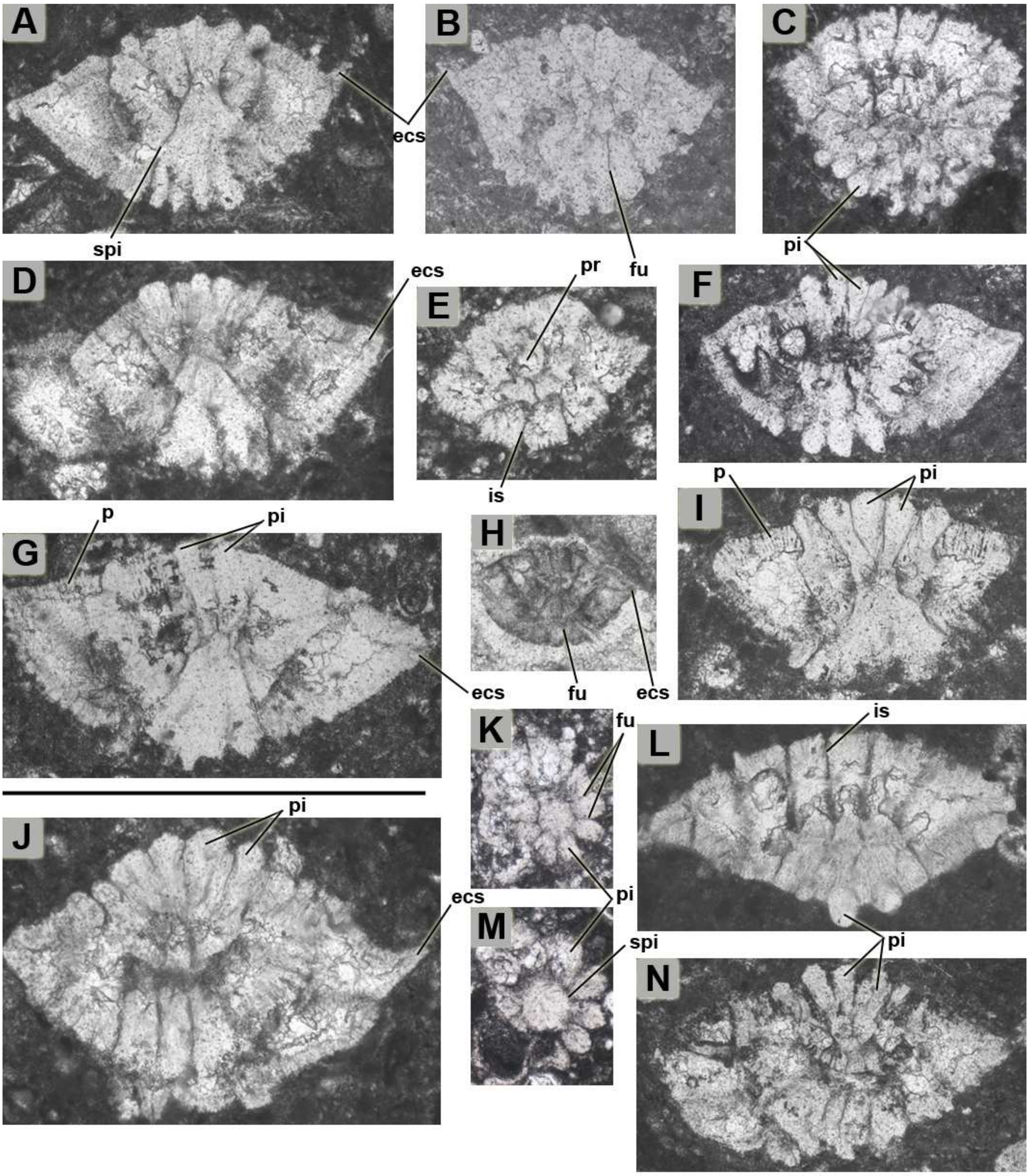
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