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Late Cretaceous larger rotaliid Foraminifera from the westernmost Tethys

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Abstract

A detailed taxonomical study of the larger rotaliid foraminifera found in the Upper Cretaceous deposits from the External Prebetic Zones (SE Spain) has been carried out for the first time. The study of the samples has revealed the diversity and abundance of this foraminiferal group and its usefulness as a tool for regional biostratigraphy. Five new species and two new genera are described, *Pseudosulcoperculina bocairentina* gen. et sp. nov., *Plumopraelockhartia solanensis* gen. et sp. nov., *Rotalia baetica* sp. nov., *Suturina minima* sp. nov., and *Neorotalia*? *pinetensis* sp. nov. These and other species of larger benthic foraminifera have been found forming two different assemblages. The older assemblage, dated as middle to late Campanian, is composed of the rotaliid species *N.*? *pinetensis* sp. nov., *R. baetica* sp. nov., *Suturina globosa*, *Rotorbinella* sp., *Pararotalia tuberculifera* and *Rotalispira scarsellai.* The younger assemblage is dated

as late Maastrichtian, including the rotaliids *Pseudosulcoperculina bocairentina* gen. et sp. nov., *Plumopraelockhartia solanensis* gen. et sp. nov. and *Pararotalia tuberculifera*. In global terms, the Late Cretaceous rotaliids from the Prebetic are key in our understanding of the phylogenetic relationships among the Cretaceous and early Paleocene Tethyan species, allowing to root the origin of the lockhatiines sensu lato back to the Upper Cretaceous. Besides, the new data regarding the *Sulcoperculina*-like forms have revealed the differences and similarities among the species of both sides of the Atlantic, especially, between the architecture of the American genus *Sulcoperculina* and that of similar forms in Pyrenean and Tethyan realms, grouped into new a genus here introduced as *Pseudosulcoperculina*.

Keywords. Foraminifera, Rotaliidae, Prebetic, Cretaceous, Tethys, biostratigraphy.

1. Introduction

The major extinction at the end of Cenomanian extinguished all the k-strategic benthic foraminifera and left the shallow marine ecosystems available to be potentially colonized by other upcoming benthic communities (Raup and Sepkoski, 1986; Caus et al., 1993, 1997; Kaiho and Hasegawa, 1994; Silva and Sliter, 1999; Leckie et al., 2002; Hart et al., 2005; Parente et al., 2007, 2008; Consorti et al., 2015; Arriaga, 2016, among others). The group of larger foraminifers with lamellar-perforated (hyaline) tests, scarce in the Cenomanian times, took this opportunity, spreading and diversifying during the Coniacian to Maastrichtian ages. In the Iberian Peninsula, the Pyrenean basin is considered a hotspot for this and other biotic groups during post-Turonian times. The shallow-water carbonate successions deposited in this area contain rich assemblages of hyaline larger foraminifera, which have been the subject of many studies, especially in

the two last decades (Boix et al., 2009, 2011; Robles-Salcedo et al., 2013, 2018, 2019; Albrich et al., 2014, 2015; Caus et al., 2016; Consorti et al., 2017a, b; Villalonga et al., 2019, among many others). Among the lamellar-perforate foraminifera, the vast group of larger rotaliids, referring to representatives of the Rotaliidae *sensu stricto* as well as other closely related rotaliform taxa not strictly in this family, can be considered particularly successful as they not only diversified in terms of morphology but also colonized several types of shallow-water environments (Boix et al., 2009; Consorti et al., 2017a, b; Hottinger, 2014; Vicedo et al., 2019).

The abundance and diversity of larger rotaliids in the Late Cretaceous are the main factors that make them of interest for biostratigraphy. Nonetheless, to improve our understanding of the phylogenetic relationships, evolutionary patterns and biostratigraphical significance of rotaliids in global terms, as in any other group of larger foraminifers, it is essential to undertake architectural analysis of the poorly studied populations. This is the case of the larger rotaliids of the Betic margin, the western area of the Tethyan domain.

The aim of the present study is precisely to update a taxonomic revision of the aforementioned group. To this end, several stratigraphic series in the northeastern foothills of the External Prebetic Zones in the Iberian Peninsula have been sampled and their micropalaeontological content analysed with taxonomical, biostratigraphical and palaeobiogeographical approaches.

2. Geological and geographical settings

The Betic System, or Betic Cordillera, is one of the major mountain ranges located in the southern and eastern part of the Iberian Peninsula. It can be subdivided into the Internal and External Zones, which have different geological and topographical features. The Internal Zones, or Penibetic System, is composed of several tectono-sedimentary complexes including the basement and the sedimentary cover comprising the highest elevations. The External Zones, which are subdivided into Prebetic and Subbetic Systems, are composed of sedimentary rocks from Triassic to Miocene ages (Azañón et al., 2002; Vera, 2004, and references therein).

During Cretaceous times, the External Prebetic Zones formed the passive southern margin of the Iberian plate, and these are composed of a complex system of continental to outer platform environments, which developed in the context of regional rifting episode. The deposits accumulated in these environments consist of carbonates and clastics (Fourcade, 1970; Azema et al., 1979; Vera et al., 1982; Martín-Chivelet, 1996; Azañón et al., 2002; Vilas et al., 2003, among others).

3. Material and methods

To carry out this study, we sampled a total of four stratigraphic logs from the south of Valencia province, Spain (eastern Iberian Peninsula), namely, Serra de la Solana, Serra Grossa, Penya del Romaní and Serra de les Agulles sections. In addition, we also sampled two other isolated stratigraphic levels from other areas of the Iberian Peninsula that contain similar larger foraminifera assemblages (Fig. 1). One of them is from an outcrop also located in the Prebetic domain but in another sector, in the Sierra del Regalí near the village of Letur (Albacete, Spain). The other is from the locality of La Tosa near the village of Tremp (Lleida, Spain) in the Southern Pyrenees. We have

included these two isolated samples for comparison purposes, given their relevance in terms of paleobiogeography.

As many as 242 samples were collected and up to 700 thin sections of rocks were taken to carry out the micropalaeontological study. All the samples and thin-sections are housed under the acronym MGB in the collections of the Department of Palaeontology, Museu de Ciències Naturals de Barcelona (see Supplementary material).

We refer to Hottinger (2006, 2014) and Vicedo et al. (2019) for the definition of architectural terms in the systematic chapter.

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Description of the stratigraphic sections

Serra de la Solana section. UTM coordinates (ETRS89, H30) are: X: 705.611,35; Coord. Y: 4.292.919,06 (bottom) and X: 705.327,82; Coord. Y: 4.292.821,58 (top) (Fig. 2). This section was measured to the north-west of the village of Bocairent (Valencia, Spain), in a small mountain system called Serra de la Solana. In this area, the Upper Cretaceous succession is around 500 m thick (according to the IGME map *820 Onteniente*) consisting of carbonates deposited in a shallow-water platform. The deposits, that encompass from the Cenomanian to the Maastrichtian ages, are strongly affected by dolomitization resulting in an alternation of dolomites, dolomitic limestones, bioclastic limestones and sandy limestones. At the top, the Maastrichtian is truncated by a discontinuity, overlying by limestone deposits of Miocene age. The sampling was carried out in a composite section about 80 m thick corresponding to the uppermost Cretaceous deposits, paying special attention to the last few meters of the

succesion, in an interval dated Maastrichtian in age by Pons et al. (1994) and Granero et al. (2018). The interval sampled, was selected because of its relatively rich fossil assemblages, among which the hyaline larger benthic foraminifera (LBF) are abundantly represented. Further details concerning the sampling performed and the characteristics of fossil assemblages found in this stratigraphic interval can be found in Granero et al. (2018). The uppermost Cretaceous succession in this area has been lithostatigraphically controversial as it has been named in many ways. Vera et al. (1982) considered the succession as belonging to the Mariasnal formation (Fm). In the current geological maps provided by the Instituto Geológico y Minero de España (IGME) (see http://info.igme.es/visorweb/) it is referred from bottom to top as Sierra de la Solana (Vera et al., 1982) and Calizas de Carche formations (Fms) (Martín-Chivelet, 1994). Considering the litostratigraphical units defined for the sector Onteniente-Denia by Martín-Chivelet and Chacón (2004), the interval studied in the present paper could be ascribed to the Calizas Arenosas del Molar Fm (Martín-Chivelet, 1994) (see Fig. 2).

Serra Grossa section. UTM coordinates (ETRS89, H30) are: X: 704.123,35; Y: 4.302.446,50 (bottom) and X: 704.196,88; Y: 4.302.054,54 (top) (Fig. 3). This section is located to the north-west of the village of Ontinyent (Valencia, Spain), in a mountain range called Serra Grossa. In this locality, the Upper Cretaceous series is around 400 m thick (according to IGME map *820 Onteniente*), consisting mainly of dolomites, dolomitic limestones and limestones, with occasional sandy intercalations. The samples were collected along the CV-665 road in an approximately 100m thick stratigraphical section, corresponding mainly to limestones and dolomitic limestones which are rich in larger foraminifera. From bottom to top, the interval studied has been identified as belonging, from bottom to top, to the Calizas de la Sierra Utiel and Margas de los Cerrillares Fms (Martín-Chivelet, 1994) dated as Coniacian to Maastrichtian according

141 to the IGME maps. However, following the nomenclature of Martín-Chivelet and
142 Chacón (2004) the interval studied in the present paper could be considered as
143 belonging to the Calizas de la Rambla de los Gavilanes Fm (Martín-Chivelet, 1994)
144 (Fig. 3).

145

146 **Penya del Romaní section.** The UTM coordinates (ETRS89, H30) are: X: 731.117,41;
147 Y: 4.318.871,69 (bottom) and X: 730.894,63; Y: 4.318.542,62 (top) (Fig. 4). This
148 section was logged to the north-east of the village of Pinet (Valencia, Spain), between
149 Les Mamelles and Penya del Romaní hills. Here, the interval of the Upper Cretaceous
150 series sampled consists of around 150 m of fossiliferous shallow-water limestones
151 intercalated with marly clays, sandy limestones, sandstones, microconglomerates and
152 dolomites. The interval studied encompasses materials belonging to Rambla de los
153 Gavilanes Fm at the bottom, and probably Calizas Arenosas del Molar Fm at the top,
154 according to the IGME geological map 1:50.000 (see in http://info.igme.es/visorweb/).
155 On the basis of the larger foraminifera assemblages found, the interval studied was
156 recently dated as late Campanian (Robles-Salcedo and Vicedo, 2016).

157 **Serra de les Agulles section.** The UTM coordinates (ETRS89, H30) are: X: 732.297;
158 Y: 4.330.168 (bottom) and X: 732.229; Y: 4.330.297 (top) (Fig. 5). The section is found
159 to the north-east of the village of Tavernes de la Valldigna (Valencia, Spain, see Robles-
160 Salcedo, 2014, for the log location). The interval studied consists of a 70m thick layer
161 fossiliferous limestones intercalated with marly clays, sandy limestones,
162 microconglomerates and rudist limestones, belonging from bottom to top to the Calizas
163 de la Rambla de los Gavilanes Fm, according to the IGME geological map 1:50,000

(see in http://info.igme.es/visorweb/). This interval is dated as Campanian to Maastrichtian in age (Eckstaller, 1993; Pons and Vicens, 2002).

Serra del Regalí and La Tosa outcrops. Similar Upper Cretaceous larger foraminifera assemblages were found in two isolated samples at our disposal collected in the localities of Serra del Regalí (Albacete, Spain) and La Tosa (Lleida, Spain). The former has been included because of its proximity to the areas studied, belonging to the Prebetic of Albacete. The latter outcrop is located in the Pyrenean Basin, but it has been considered essential to include it in the present study because of the relevance of its larger foraminiferal content, this being useful in later phylogenetical and palaeobiogeographical discussions.

The outcrop of Serra del Regalí consists of a succession of limestones, occasionally dolomites, calcarenites and marls belonging to Serra de Utiel Fm. according to the IGME geological map 1:50,000 (see in http://info.igme.es/visorweb/). The stratigraphic level studied is located close to the village of Letur (Albacete, Spain). UTM coordinates (ETRS89, H30) are: X: 582.399.25; Y: 4.248.312,43.

The outcrop of La Tosa consists of a succession of calcarenites, limestones and marls belonging to the lower unit of the Arén Sandstone Fm (for more information see Robles-Salcedo, 2014; Caus et al., 2016; Robles-Salcedo et al., 2018). La Tosa is located a few kilometers to the north of the village of Tremp (Lleida, Spain). UTM coordinates (ETRS89, H31) are: X: 328.666,73; Y: 4.673.827,41.

4. Systematic descriptions

Phylum **Foraminifera** d'Orbigny, 1826

Class **Globothalamea** Pawlowski, Holzmann and Tyszka, 2013

Subclass **Rotaliana** Mikhalevich, 1980

Order **Rotaliida** Delage and Hérouard, 1896

Superfamily **Rotalioidea** Ehrenberg, 1839

Family **Rotaliidae** Ehrenberg, 1839

Genus ***Pseudosulcoperculina*** gen. nov.

LSID urn:lsid:zoobank.org:act:0FB6A4B6-999C-4967-BB7B-66CF7A4978E8

Type species. *Pseudosulcoperculina bocairentina* gen. et sp. nov.

Etymology. *Pseudo-*, latin word of "false", has been given due to the resemblance to specimens ascribed to the genus *Sulcoperculina*.

Diagnosis. Lamellar-perforated test with trochospiral chamber arrangement. Shell-shape lenticular to subglobular, involute growth in both, ventral and dorsal sides. Dorsal side smooth to slightly ornamented by beads. Ventral chamber wall feathered. Margin showing a deep fold or sulcus formed by a peripheral invagination of the wall. Sulcus wall showing a distinctive ornamentation based on multiple indentations. One single intraseptal canal connected to the sulcus. Umbilical structure of the ventral side composed of a spiral umbilical canal limited by an umbilical plate extending over the ventral surface of the chamber and covering the feathered grooves. Umbilicus composed of a central massive structure or umbo pierced peripherally by narrow funnels. Simple aperture consisting of a narrow slit in interiomarginal position.

Differences and similarities. *Pseudosulcoperculina* gen. nov. has a distinctive sulcoperculina-like morphology. Its characteristic marginal sulcus is quite similar to that of the genus *Sulcoperculina* Thalmann, 1939, typical from the Upper Cretaceous deposits of the American-Caribbean paleobioprovince. Although the shell-architecture of the latter has been very controversial since its description, which hamper later comparisons (see remarks below), the revision of the specimens of the type species *S. dickersoni* (Palmer, 1934) published in the original paper has allowed us to identify the main architectural differences between our morphotype and the genus *Sulcoperculina.* The main differences are the bilateral symmetry of *S. dickersoni* versus de trochospiral assymetric test of *P. bocairentina* gen. et sp. nov., and the presence of some kind of marginal canal system in the former versus the absence of such structure in the latter. The architecture of *Pseudosulcoperculina* gen. nov. is different from the other Cretaceous rotaliid genera by the presence of the following structures in the same form: the marginal sulcus plus the ventral feathered structure.

Pseudosulcoperculina bocairentina gen. et sp. nov.

(Figures 6, 7, 8A–E)

1994 *Sulcoperculina dickcersoni* (Palmer) var. vermunti (Thiadens); Ramírez del Pozo and Martín-Chivelet: pl. 3, fig. 5

2018 Rotaliidae indet.; Granero et al.: fig 11F–G

LSID urn:lsid:zoobank.org:act:2C546F64-291F-4CFC-9E6F-58720F455F88

Etymology. *bocairentina* is the female demonym of Bocairent, the village in which the type locality is found.

Types. The holotype is MGB 69778 LP05.005 (Fig. 6F). The other specimens illustrated in Figures 6 and 7 are paratypes.

Type horizon and locality. Calizas Arenosas del Molar Fm, upper Maastrichtian, Serra de la Solana, Bocairent (Valencia, Spain).

Diagnosis. Lamellar-perforated test with thick wall and trochospiral chamber arrangement. Dorsal and ventral sides involute. Shell-shape lenticular to subglobular. Acute margin showing a characteristic deep groove or sulcus. Ventral chamber wall feathered. Umbilical structure composed of a central umbo. Simple aperture consisting of a narrow slit in interiomarginal position. Intraseptal and spiral interlocular spaces or canals connected and opening into the sulcus. Shell with a diameter of around 1 mm and three whorls; variable proloculus, of around 50–110 µm.

Description. The surface of the dorsal side is smooth to slightly ornamented with beads, the ventral side is dominated by feathered ornamentation and a marked umbo. The peripheral margin is acute and asymmetric, showing a deep groove running in the direction of growth, parallel to the periphery and slightly displaced towards the ventral part of the shell. The spiral interlocular space is narrow, being separated from the chamber lumen by the umbilical plate and connected to the intraseptal interlocular spaces. Vertical umbilical canals or funnels connect the spiral interlocular space to the exterior. Several grooves run parallel from the intraseptal interlocular space to the chamber shoulder of the ventral side developing the feathered ornamentation. The intraseptal interlocular spaces or canals open into the sulcus through marginal openings. The shell has a maximum diameter of around 1 mm and 3 complete whorls, with around 20 chambers in the last whorl. The proloculus is spherical to subspherical, with a

diameter that varies from 35 to 60 µm. The central part of the shell is occupied by a solid umbilical mass.

Differences and similarities. Some morphological traits of *Pseudosulcoperculina bocairentina* gen. et sp. nov. are similar to those of the type species *Sulcoperculina dickersoni* (Palmer, 1934) from the Upper Cretaceous of Cuba, especially by their marginal groove. However, the former has an asymmetric shell and the latter is clearly a biumbilicate species with bilateral symmetry. The same differences can be noted when comparing *Pseudosulcoperculina bocairentina* sp. nov. with the other species of the *S.* gr. *dickersoni*. *Pseudosulcoperculina bocairentina* gen. et sp. nov. also differs from *S.* gr. *dickersoni* in having a marked feathered ornamentation in the ventral chamber wall. On the other hand, the asymmetry of the shell and the marked feathered ornamentation of the new species are similar to those of *S. kugleri*. *Pseudosulcoperculina bocairentina* gen. et sp. nov. differs from *S. kugleri* in having a thinner wall and higher trochospire.

Regarding the Prebetic domain, we have also identified *P. bocairentina* gen. et sp. nov. in some isolated samples collected in the Maastrichtian deposits from the *Sierra del Regalí* (Albacete, Spain) (Figs. 8A–E). The specimen identified as *S. dickcersoni* (Palmer) var. *vermunti* (Thiadens) by Ramírez del Pozo and Martín-Chivelet (1994, pl. 3, Fig. 5) found in equivalent deposits from the Maastrichtian of Sierra Larga (Murcia, Spain) should, in our opinion, also be ascribed to the species *P. bocairentina* sp. nov.

A closely related form to *P. bocairentina* gen. et sp. nov. has been observed in the lower Maastrichtian of the southern Pyrenees, in a locality called *La Tosa* (Fig. 9). The marginal sulcus seems to be less developed, but the feathered ornamentation is present. Due to the scarcity of material, we have been unable to identify it to species level, leaving this morphotype in open nomenclature as *Pseudosulcoperculina* sp.

Nonetheless, given its smaller proloculus and less developed marginal sulcus, we consider it likely that this morphotype will be defined as a new species in future studies, with new material. The LBF association found together with *Pseudosulcoperculina* sp. in *La Tosa* consists of *Dictypsella* sp., *Haddonia* sp., *Nummofallotia cretacea* (Schlumberger, 1900), *Fascispira colomi* Silvestri, 1940, undetermined species in the Fabularidae family, *Praestorrsella roestae* (Visser, 1951), *Linaresia* sp., *Pararotalia tuberculifera* (Reuss, 1862), *Pyrenorotalia* sp., *Lepidorbitoides socialis* (Leymerie, 1851), *Orbitoides gruenbachensis* Papp, 1955, *O.* aff. *concavatus* Rahaghi, 1976, and *Siderolites pyrenaicus* Robles-Salcedo, Vicedo and Caus, 2018.

Other forms with a certain resemblance to *Pseudosulcoperculina bocairentina* gen. et sp. nov. have been observed in the Santonian–Campanian deposits outcropping close to the locality of Tragó de Noguera, southern Pyrenees (see Hottinger, 1966) and in the Santonian (?)–Campanian strata of Murge, Italy (see p. 594–595 in Luperto Sinni and Ricchetti, 1978). Nevertheless, there are some morphological differences among all these morphotypes. The Campanian *Sulcoperculina* specimens figured in Fig. 10C, D and Fig. 11A–E in Hottinger (1966) are architecturally closer to primitive Siderolitidae Finlay, 1939, than to *Sulcoperculina*, as previously pointed out by Wannier (1983). The only specimen that could be considered close to *Sulcoperculina* is the specimen illustrated in Fig. 10E (op. cit.) cited as *Sulcoperculina* aff. *cubensis* (Palmer) from the Santonian of the Montsec Mountains. On the other hand, the specimens of Luperto Sinni and Ricchetti (1978) cited as *Sulcoperculina* sp. seem to lack the sulcus and the feathered ventral ornamentation. More material is needed to confirm the generic and specific identification of all these morphotypes.

The feathered ornamentation, lenticular morphology and solid mass or umbo make the architecture of *P. bocairentina* sp. nov. somewhat similar to that of the representatives

of the subfamily Kathininae Hottinger, 2014, specially the group of elazigines. Nonetheless, the presence of a marked marginal sulcus, the canal system and the involute dorsal side in the former allows its differentiation from all Kathininae.

The morphotype identified as *Sulcoperculina globosa*? in Butterlin (1967) from the upper Maastrichtian of Greece seems to be different from *P. bocairentina* gen. et sp. nov. by the absence of a peripheral sulcus, which would permit also to remove it from the genus *Sulcoperculina*.

Subfamily **Praelockhartiinae** Vicedo and Robles-Salcedo, 2019

Genus ***Plumopraelockhartia*** gen. nov.

LSID urn:lsid:zoobank.org:act:AFBE0391-8775-4367-9722-344023E1CBC1

Type species. *Plumopraelockhartia solanensis* sp. nov.

Etymology. From *pluma*, the Latin name for feather, referring to the feathering ventral ornamentation, and *Praelockhartia*, the genus which shows architectural similarities.

Diagnosis. Lamellar-perforated test, trochospiral chamber arrangement and subacute periphery. Dorsal side evolute, surface smooth to slightly ornamented with beads. Ventral side involute with an umbilicus composed of foliar piles and funnels; chamber-wall surface feathered. The umbilical structure is composed of interpile and peripheral cavities, the latter produced by proximal folium folding. Aperture simple.

Differences and similarities. The architecture of the type species of the new genus, *Plumopraelockhartia solanensis* gen. et sp. nov., is reminiscent of that of the representatives of the Paleogene subfamilies Praelockhartiinae Vicedo and Robles-Salcedo, 2019, and Lockhartiinae Hottinger, 2014, due to its umbilical cavities;

however, the fact that these cavities are less developed and more irregularly arranged in the new genus suggest that this should be better ascribed to the subfamily Praelockhartiinae. Actually, the basic architecture of the new genus *Plumopraelockhartia* is very close to that of *Praelockhartia* Vicedo and Robles-Salcedo, 2019, from the Danian of Oman, the latter differing from the former mainly in its rounded periphery, its coarsely perforated wall, the absence of dorsal ornamentation consisting of more marked beads and the absence of ventral feathered ornamentation. The feathered ornamentation and the coarsely perforated wall are also absent in other genera considered in Vicedo et al. 2019 as belonging to the Praelockhartiinae, such as *Rotospirella* Hottinger, 2014, *Rotalispira* Hottinger, 2014, and *Rotalispirella* Consorti et al., 2017b. These last three genera also differ from *Plumopraelockhartia* in having thinner and more delicate folia. In addition, *Rotalispira* and *Rotalispirella* have less developed piles and *Rotospirella* has less developed interpile cavities.

The feathered ornamentation of *Plumopraelockhartia* is similar to that exhibited by the species ascribed to the Paleogene genus *Elazigina* Sirel, 2012, type species *E. subsphaerica* (Sirel, 1972). There are marked differences in the umbilical structure, however, these allowing its differentiation at generic and even at subfamily level.

Other Cretaceous rotaliid genera defined up to now in the literature show dissimilar architectures, lacking the umbilical cavities typical from the praelockhartiines. This umbilical structures are one of the most diagnostic features that differentiates the new genus *Plumopraelokhartia* from other Cretaceous rotaliids known so far.

Plumopraelockhartia solanensis gen. et sp. nov.

(Figures 8F–G, 10)

LSID urn:lsid:zoobank.org:act:23AE2E67-E247-4B51-B65E-731EBBBC88BF

Etymology. From the type locality of Sierra de la Solana.

Types. The holotype is MGB 84627 LP01.004 (Fig. 10B). The other specimens illustrated in Figure 10 are paratypes.

Type horizon and locality. Calizas Arenosas del Molar Fm, Maastrichtian, Serra de la Solana, Bocairent (Valencia, Spain).

Diagnosis. Lamellar-perforated test with trochospiral chamber arrangement. Dorsal side evolute and smooth to slightly ornamented with beads. Ventral side involute and feathered. Shell-shape lenticular with acute margin. Simple aperture in interiomarginal position. Umbilical structure composed of several piles. Interpile umbilical cavities occupying the tubular, vertical spaces among piles. Umbilical peripheral cavities located towards the periphery of the umbilicus. Shell has a diameter of around 0.8 mm and 2.5 whorls; proloculus of about 30 µm.

Description. The dorsal side is smooth to slightly ornamented with beads. The ventral side is dominated by feathered ornamentation, consisting of numerous parallel grooves extending in a perpendicular direction from suture onto chamber shoulders. The umbilical structure is typically composed of several foliar piles and funnels. The interpile umbilical cavities are irregular and located in the vertical umbilical spaces. The folia posterior folding or indentation produces the peripheral umbilical cavities. The shell has a diameter of 0.5 to 0.8 mm and around 2 to 2.5 whorls, with about 12–13 chambers in the last whorl. The proloculus is spherical to subspherical showing a diameter that varies from 25 to 30 µm.

Differences and similarities. The species *Elazigina siderea* Consorti and Rashidi, 2018, from the Maastrichtian of the Tarbur Formation, Iran, is similar to *Plumopraelockhartia solanensis* gen. et sp. nov. in having feathered ornamentation and

isolated umbilical piles. The main architectural difference between the two species is related to the umbilical structure. *Plumopraelockhartia solanensis* gen. et sp. nov. shows peripheral and interpile umbilical cavities, while *Elazigina siderea* has a central massive plug surrounded by secondary piles and a complex umbilical canal system. Besides, concerning this last species, the comparison of the specimens of *E. siderea* illustrated in Consorti and Rashidi (2018) with those of the type species of *Elazigina*, the Paleocene *E. subsphaerica* (Sirel, 1972) allows distinguishing a very different umbilical structure. The former has a central plug surrounded by a complex umbilical canal system and the latter shows a more massive umbilical structure. This clarification, which warrants a reanalysis of the complex umbilical architecture of *E. siderea*, would be crucial to reevaluate its generic ascription as well as the early evolution of the whole group of kathinines in the Tethyan domain.

Smoutina cruysi Drooger, 1960, the type species of the genus *Smoutina* Drooger, 1960, from the Upper Cretaceous deposits of the Atlantic-Caribbean palaeobioprovince differs from *P. solanensis* gen. et sp. nov. in lacking an umbilical plate and in having multiple and simple funnels.

Genus ***Rotalispira*** Hottinger, 2014

Type species. *Rotorbinella scarsellai* Torre, 1967.

Rotalispira scarsellai (Torre, 1967)

(Figure 11)

1967 *Rotorbinella scarsellai* n. sp.; Torre: p. 422, pl. 1, figs 1–8, pl. 2, Fig. 10.

1972 *Rotorbinella scarsellai* Torre; Bignot: pl. VII, fig. 6.

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.

1976 *Coleites*? sp.; Luperto Sinni: pl. 53, fig. 11.

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

1978 *Stomatorbina*? sp.; Luperto Sinni and Ricchetti: pl. 62, figs12–14.

1978 *Stensioeina surrentina* Torre; Luperto Sinni and Ricchetti: pl.62, fig 11.

1994 *Rotorbinella scarsellai* Torre; Chiocchini et al.: pl. 22, figs6,7,14,15.

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

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

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.

2017 *Rotalispira scarsellai* (Torre); Solak et al.: fig 11I.

2017 *Stensioeina surrentina* Torre; Solak et al.: fig 11O, P.

2017a *Rotalispira scarsellai* (Torre); Consorti et al.: fig 6M.

Description. The shell is lamellar perforated with biconvex morphology, keeled periphery and trochospiral chamber arrangement. The dorsal side is evolute, showing

413 rich ornamentation mainly based on limbate sutures. The proloculus is around 36–60
414 μm. The foramen consists of a slit in an interiomarginal position. The umbilical plate
415 separates the main chamber lumen from the foliar chamberlet. The foliar apertures
416 connect the subsequent foliar chamberlets forming a kind of spiral canal. The umbilical
417 structure is composed of large folia and slender umbilical piles.

418

419 Subfamily **Rotaliinae** Ehrenberg, 1839

420 Genus ***Rotalia*** Lamarck, 1804

421 Type species *Rotalites trochidiformis* Lamarck, 1804

422 ***Rotalia baetica*** sp. nov.

423 (Figure 12)

424 LSID urn:lsid:zoobank.org:act:EAF36C4D-D8B3-4A86-8336-A0CCEAFBEC9A
425 **Etymology.** From the Latin word *Baetica*, which was an ancient Roman province and is
426 the current name given to the Cordillera of southeastern Spain.

427 **Types.** The holotype is MGB 60323 LP03.007 (Fig. 12E). The other specimens
428 illustrated in Figure 10 are paratypes.

429 **Type horizon and locality.** Calizas de la Rambla de los Gavilanes Fm, upper
430 Campanian, *Penya del Romaní Hill* (Pinet, Valencia, Spain).

431 **Diagnosis.** Lamellar-perforated test with low-trochospiral chamber arrangement and
432 keeled periphery. Lenticular, biconcave shell. Aperture simple in an interiomarginal
433 position. Dorsal side evolute, smooth or with slight ornamentation. Ventral side flat to
434 slightly convex. Umbilical structure of fused folia forming a columella. Megalospheric

forms with a proloculus of around 26 μm, maximum diameter of adult shells of around 1 mm and a height of about 0.5 mm with four whorls. No microspheric forms identified.

Differences and similarities. The adult forms of the type species *Rotalia trochidiformis* (Lamarck) are smaller and with a dorsal side more concave. The scarce specimens of *Rotalia baetica* sp. nov. found seem to resemble, on first inspection, those of the megalospheric generation of *Iberorotalia reicheli* (Hottinger, 1966) from the lower Santonian of the southern Pyrenees, especially in having an acute margin; but the umbilical structure is different in the two morphotypes. *Iberorotalia reicheli* shows an umbilicus composed of multiple funnels and piles distributed fairly regularly, quite unlike the massive umbilical structure (some type of collumellar structure) that seems to be present in the specimens of *Rotalia baetica* sp. nov. figured in the present paper.

Genus ***Rotorbinella*** Bandy, 1944

Type species. *Rotorbinella colliculus* Bandy, 1944.

Rotorbinella sp.

(Figure 13)

Description. The specimens are lenticular to low-conical shaped. The aperture is simple. The chamber arrangement is low trochospiral with an evolute dorsal side and involute ventral side. The umbilicus is filled with a single pile; the folia are short. The dorsal surface is smooth. Proloculus of around 25 μm. The axial diameter is around 0.4–0.5 mm, with 2.5–3 whorls; the height is about 0.2–0.3 mm.

Rotaliids with uncertain affinities

? Subfamily **Rotaliinae** Ehrenberg, 1839

458 Genus ***Suturina*** Consorti, Vilallonga and Caus, 2017b

459 **Type species**. *Suturina globosa* Consorti, Vilallonga and Caus, 2017b.

460 **Remarks.** The genus *Suturina* was formerly defined by Consorti et al. (2017b) from the
461 Campanian of the Montsec Mountains (Pyrenees). The original diagnosis given is
462 complete but some structural elements cannot be properly observed in the material
463 figured. Notably, this is the case for the umbilical plate, the presence of which is not
464 clear in any of the specimens illustrated. Considering these limitations, we have
465 followed the description given in Consorti et al. (2017b, pg. 291) as a guide for the
466 generic identification of our specimens. There remains a need to conduct a study of
467 additional type material of the type species *S. globosa* Consorti et al., 2017b, focused on
468 the clarification and illustration of all its architectural features.

469 ***Suturina minima*** sp. nov.

470 (Figures 14–16, 17A–H)

471 LSID urn:lsid:zoobank.org:act:151F60CA-6511-457B-8DA1-FF09C7341968

472 **Etymology.** From the Latin word *minimus*, referring to its small size.

473 **Types.** The holotype is MGB 60335 LP02.036 (Fig. 14C). The other specimens
474 illustrated in Figures 14–16 are paratypes.

475 **Type horizon and locality.** Calizas de la Rambla de los Gavilanes Fm, upper
476 Campanian, *Penya del Romaní Hill* (Pinet, València, Spain).

477 **Diagnosis.** Lamellar-perforated test with coarsely perforated wall. Low-trochospiral
478 shell with rounded periphery. Simple aperture in an interiomarginal position. Dorsal
479 side evolute and flat with no ornamentation. Dorsal chamber sutures slightly marked.

Ventral side flat to slightly convex. Umbilical structure narrow and dominated by the extension of the folia. Successive folia not fused, producing multiple and superposed foliar chamberlets in the central part of the umbilical structure. Main lateral chamber wall and folium wall separated by marked indentation or notch and by an umbilical-plate suture. Main chamber lumen and spiral passage separated by an umbilical plate. Peripheral cavities delimited by notch indentation and successive folia. Adult chambers develop large folia, folded on the adaxial side. No dimorphism observed. Protoconch diameter of around 24 µm and deuteroconch of about 23 µm. Shell composed of around 2 whorls. Adult shells with a diameter of 260 to 380 µm and height of 140 to 210 µm, yielding a mean height-to-diameter ratio of about 0.54.

Differential diagnosis. *Suturina minima* sp. nov. differs from *S. globosa* from the Campanian–lowermost Maastrichtian rocks in the Serres Marginals (Lleida, N Spain) in having a smaller diameter, 0.3 mm vs. 0.8–1.2 mm, and smaller height, 0.2 mm vs. 0.5−0.7 mm, respectively. The proloculus is also smaller in the former than in the latter, 24 µm vs 40 µm. Although both morphotypes, *S. minima sp. nov.* and *S. globosa,* have the same biostratigraphical distribution, we have considered them as two different species because the vast majority of the specimens found in the Prebetic domain show a relative homogeneity in terms of morphometry, being smaller than the type species.

Remarks. The specimens figured as *Stensioeina surrentina* Torre, 1967, by Luperto Sinni (1976) from Murge, Italy, are very similar to *Suturina globosa* in terms of size and shell architecture. More material is needed to carry out future architectural studies of both morphotypes to confirm or to rule out whether they are the same species.

Suturina globosa Consorti, Vilallonga and Caus, 2017b

(Figure 17I–K)

1976 *Stensiöina surrentina* Torre; Luperto Sinni: tavola 53, figs. 1–5.

2017b *Suturina globosa* Consorti, Vilallonga and Caus; Consorti et al.: figs. 6.1–8, 10–17.

2017b *Suturin*a cf. *globosa* Consorti, Vilallonga and Caus; Consorti et al.: figs. 7.2–3.

Description. The material found is very scarce, but the specimens found seem to be architecturally close to the type species of the genus *Suturina*. The shell has 2–3 whorls and a diameter of around 0.8 mm. The chambers are rounded, increasing considerably in size through the ontogeny. The dorsal side is flat and the sutures are marked. The umbilicus is filled with non-fused folia.

Other taxa excluded from the Rotalioidea according to Hottinger, 2014

Subfamily **Pararotaliinae** Reiss, 1963

Remarks. According to Hottinger et al. (1991) and Hottinger (2014), the subfamily Pararotaliinae includes taxa whose shell-architecture consists of a low trochospiral chamber arrangement, evolute on the dorsal side and involute on the ventral side, simple aperture, toothplates and canal-system composed of intraseptal and spiral-umbilical canals. Some genera exhibit a simple enveloping canal system generated by the covering of the interlocular intraseptal space by the outer lamellae. Externally, the specimens are characterized by being strongly ornamented, some of them possibly having spines and keeled periphery. Despite the use of the term “enveloping canal system” to describe some genera belonging to Pararotaliinae, it should be underlined that this canal system is much simpler than that of other groups such as the calcarinids or siderolitids (Hottinger and Leutenegger, 1980, Wannier, 1980), for which this term is more commonly used. The enveloping canal system of these latter groups consists of

lateral meshes that differ in complexity with the canals being formed by the so-called "flying covers" in Pararotaliinae (see Figs. 3 and 4 in Hottinger, 1991). In order to avoid any possible misinterpretation, the term "enveloping canal system" should always be accompanied by a clarification of the diagnostic criteria on which the identification is based.

Genus ***Neorotalia*** Bermúdez, 1952

Type species. *Rotalia mexicana* Nuttall, 1928 accepted as *Neorotalia burdigalensis* (d'Orbigny, 1852).

Remarks. The canals of the so-called "enveloping canal system" observed in the specimens of the genus *Neorotalia* is the main architectural difference from the genus *Pararotalia* Le Calvez, 1949.

Neorotalia*? *pinetensis sp. nov.

(Figures 18, 19)

LSID urn:lsid:zoobank.org:act:EB4C7246-C587-4EB4-BD69-FA56D4FD8E68

Etymology. From the type locality of Pinet.

Types. The holotype is MGB 60316 LP04.005 (Fig. 18B). The other specimens illustrated in Figure 18 are paratypes.

Type horizon and locality. Calizas de la Rambla de los Gavilanes Fm, upper Campanian, *Penya del Romaní Hill* (Pinet, València, Spain).

Diagnosis. Lamellar-perforated test with trochospiral chamber arrangement and keeled periphery. Dorsal side planoconvex, evolute and ornamented with beads. Ventral side convex and involute. Simple aperture consisting of a narrow slit in an interiomarginal position. Umbilicus composed of a thick, dense structure composed of pile with

furrows. Chamber lumen shows a “toothplate” producing a primary spiral canal. Simple enveloping canal system formed by outer lamellae covering the interlocular intraseptal spaces seems to be present (see Fig. 18.A). The shells are between 0.5 to 0.7 mm in diameter and about 0.3 to 0.4 mm in height (thickness) with three and a half whorls. Embryo very small, formed by a protoconch and a deuteroconch. Protoconch of around 18 µm; deuteroconch of about 22 µm. No dimorphism has been observed.

Remarks. We have left our morphotype in open nomenclature at generic level because of the complexity in identifying from thin-section the flying covers, which are the main diagnostic criterion that differentiates *Neorotalia* from *Pararotalia*.

Differences and similarities. The Mesozoic new species *N.*? *pinetensis* (maximum diameter 0.7 mm) is smaller than the Cenozoic species *N. burdigalensis* (d’Orbigny, 1852), *N. mexicana* (Nutall 1952) (maximum diameter 1.1 mm) (synonym of *N. burdigalensis* according to Poignant, 1998), *Neorotalia litothamnica* (Uhlig, 1886) (maximum diameter around 1 mm) (synonym of *N. burdigalensis* according to Poignant and Pujol, 1978), *Neorotalia omanensis* Al-Sayigh, 2013 (maximum diameter 2.3 mm), *Neorotalia viennoti* (Greig, 1935) (maximum diameter around 2 mm), *Neorotalia calcar* (d'Orbigny in Deshayes, 1830) (maximum diameter around 1.5 mm), and *Neorotalia gaimardi* (d'Orbigny in Fornasini, 1908) (maximum diameter around 1 mm).

In terms of size and external morphology, the species *Neorotalia*? *pinetensis* sp. nov. seems to be closely related to the group of neorotalias from the Eocene of Alicante. The diameter of its test is similar to *Neorotalia alicantina* Colom, 1954, being around 0.7 mm; however, the latter has a biconvex test. *Neorotalia bicarinata* Colom, 1954, is similar to *N.*? *pinetensis* sp. nov. in having a dissymmetric test, but the former is smaller (around 0.4 mm in diameter) and also lacks the ventral keel. *Neorotalia minuta* Colom,

1954, is similar to *N.*? *pinetensis* sp. nov. in having a keeled periphery, but the former is smaller (around 0.4 mm in diameter) and has a biconvex test. The neorotalias described from the Oligocene of Mallorca, *N. ornatissima* Escandell and Colom, 1962, and *N. semiornata* Escandell and Colom, 1962, are also different from *N.*? *pinetensis* sp. nov. The tests of *N. semiornata* are smooth, biconvex and larger (diameter of around 1–2 mm) than those of the latter. The tests of *N. ornatissima* are biconvex and larger (diameter of around 2 mm) than those of the new species. A study of the internal structure of topotypes of these and other species of *Neorotalia*, described only based on their external features, should be carried out in future in order to define the inner skeletal elements, this being essential to obtain a reliable classification, as in all LBF.

The species *Neorotalia tethyana* Boudagher-Fadel and Price, 2013, is a rotaliform species from the upper Oligocene–earliest Miocene of Java that calls for a restudy, as its internal structure is not clear from observing the scarce specimens figured. In any case, its maximum diameter, of 1.5 mm, is larger than that of *N.*? *pinetensis* sp. nov.

The species *Neorotalia*? *pinetensis* sp. nov. is architecturally close to *Neorotalia*? *cretacea* Consorti et al., 2017a, from the lower Campanian of the Lepini Mountains, differing mainly in the smaller size and in the flatter dorsal side of the former. Nonetheless, in our opinion, no toothplates are visible in the specimens figured in Consorti et al. (2017a, see Fig. 11 of this paper).

Genus ***Pararotalia*** Le Calvez, 1949

Type species. *Rotalina inermis* Terquem, 1882.

Pararotalia tuberculifera (Reuss, 1862)

(Figure 20)

1862 *Rotalia tuberculifera* Reuss: p. 313, pl. 2, fig. 2.

1959 *Pararotalia tuberculifera* (Reuss); Hofker: p. 345, fig. 132–134.

1966 *Pararotalia tuberculifera* (Reuss); Hottinger: fig. 9b, p. 296.

2007 *Pararotalia tuberculifera* (Reuss); Boix: pl. XXIII and XXIV.

2009 *Pararotalia tuberculifera* (Reuss); Boix et al.: Figs. 12.1–12.21.

Description. The shell is lamellar-perforated, biconvex to planoconvex, and low-trochospiral chamber arrangement. The periphery is keeled. The ventral side shows a central plug. The dorsal side presents ornamentation based on beads. The proloculus is small, around 12 μm in diameter, with a maximum diameter of around 0.4 mm.

5. Biostratigraphy based on larger benthic foraminifera

5.1. Larger rotaliid assemblages

The study of the larger foraminifera found in the samples collected has allowed the identification of two assemblages:

Assemblage 1. This assemblage is characterized by the presence of the rotaliids *Neorotalia*? *pinetensis* sp. nov., *Rotalia baetica* sp. nov., *Suturina globosa, S. minima*, and *Rotalispira scarsellai*. They are found in association with other foraminifera, such as *Goupillaudina shirazensis* Rahaghi, *Praestorsella roestae* (Visser), *Pararotalia tuberculifera, Praesiderolites douvillei* Wannier, *Orbitoides* cf. *media* (d'Archiac), indeterminate Gavelinellidae, small agglutinated and simple miliolids and discorbids.

In the Penya del Romaní section, other species found include *Nummofallotia cretacea* (Schlumberger), *Haddonia* sp., *Cuneolina cylindrica* Henson, *Navarella joaquini* Ciry

& Rat, *Stomatorbina binkhorsti* (Reuss), aff. *Sivasella* sp., *Sirtina ornata* (Rahaghi), *Lepidorbitoides* cf. *campaniensis* van Gorsel, "*Orbitoides*" cf. *concavatus* Rahaghi, *O. megaloformis* Papp & Küpper, *Pseudosiderolites vidali* (Douvillé), and cf. *Wannierina* sp. (Fig. 21).

In the Serra de les Agulles section, other foraminifera have been identified including *Moncharmontia* sp., *Dictyopsella* sp., *Idalina antiqua* Schlumberger and Munier-Chalmas, *Murgeina apula* (Luperto Sinni), *Lepidorbitoides* sp., *Orbitoides* sp. and *Arnaudiella grossouvrei* Douvillé (Fig. 22).

At the bottom of the Serra Grossa section, the other species found are *Dictyopsella* sp., *Nezzazzatinella* sp., *Fleuryana* sp., *Scandonea* sp., *Cuvillerinella* cf. *salentina* Papetti and Tedeschi, *Rotorbinella* sp., and *Pseudosiderolites vidali.* At the top of this section, the following species were identified: *Nezzazzatinella* sp., *Fleuryana* sp,, *Cuneolina cylindrica*, *Murgeina apula*, *Murciella* aff. *cuvillieri* Fourcade, *Orbitoides* cf. *megaloformis*, *Lepidorbitoides* cf. *bisambergensis* and *Siderolites* cf. *praecalcitrapoides* Neumann (Fig. 23).

Biostratigraphical discussion. The biostratigraphic distribution of *Rotalispira scarsellai* has been reported classically from Coniacian to Campanian deposits, but in Frijia et al. (2015) the first occurrence of this species was constrained to upper Turonian. Consorti et al. (2017a) constrained its age to upper Santonian?–lower Campanian deposits in the Lepini Mountains (Central Italy) and middle Campanian in southern Italy. *Suturina globosa* were also reported by Consorti et al. (2017b) in the lower?–middle Campanian deposits in the southern Pyrenees (Spain). *Praesiderolites douvillei*, *Arnaudiella grossouvrei* and *Pseudosiderolites vidali* were reported in the middle–upper Campanian in the southern Pyrenees (Wannier, 1983; Robles-Salcedo,

2014). Schlüter et al. (2008) dated the deposits in the type locality of *Cuvillierinella salentina* as late Campanian. The species *Siderolites praecalcitrapoides* and *Orbitoides* cf. *megaloformis* were reported in the deposits of the uppermost Campanian in the southern Pyrenees (Caus et al., 1996, 2016; Robles-Salcedo et al., 2018). The representatives of the genus *Murciella* Fourcaude and other similar forms was limited from upper Campanian to lower Maastrichtian deposits in several studies along the Tethyan realm (see Fourcade, 1966; De Castro, 1988; Ramírez del Pozo and Martín-Chivelet, 1994; Vicedo, 2009, Fleury, 2018, among others).

According to this information obtained from the literature, the rotaliid assemblage 1 of the Prebetic would be dated as middle to late Campanian, given that no Maastrichtian fauna have been identified. On the other hand, it is important to note that the assemblage of the uppermost interval in the Serra Grossa section, which presents several taxa in open nomenclature (Fig. 3), might include the Campanian/Maastrichtian boundary. Further studies of the murciellas, among other taxa found, would likely help constrain the Campanian–Maastrichtian boundary.

Assemblage 2. This assemblage is characterized by *Suturina minima* sp. nov., *Plumopraelockhartia solanensis* sp. nov. and *Pseudosulcoperculina bocairentina* gen. et sp. nov. In the Serra de la Solana section they are found in association with *Idalina antiqua* Schlumberger & Munier-Chalmas, *Nummofallotia cretacea* (Schlumberger), *Cibicides* sp., *Goupillaudina* sp., *Praestorsella roestae, Selimina spinalis* Inan, *Fissolphidium operculiferum* Smout, *Sirtina orbitoidiformis* Brönnimann and Wirz, *Sivasella monolateralis* Sirel and Gündüz 1978, *Hellenocyclina beotica* Reichel, *Omphalocyclus macroporus* (Lamarck), *Orbitoides apiculata* Schlumberger, *Siderolites calcitrapoides* Lamarck, small agglutinated, simple miliolids and discorbids (Fig. 24).

668 **Biostratigraphical discussion.** This assemblage gives an age of late Maastrichtian,
669 which is in accordance with dates proposed in the studies of Pons et al. (1994) and
670 Granero et al. (2018). These deposits of the interval studied represent the latest deposits
671 of the Cretaceous period in the area.

672 **5.2. Correlation with other sectors of the Prebetic**

673 The deposits containing these LBF assemblages can be correlated at a regional scale
674 with the three units defined in terms of sequential stratigraphy for the Coniacian–
675 Maastrichtian from the Prebetic domain (Ramírez del Pozo and Martín-Chivelet, 1994;
676 Martín-Chivelet and Chacón, 2007). These authors described three megasequences or
677 "event bounded stratigraphic units (EBUSs)" separated by major discontinuities. The
678 first and oldest unit was dated as Coniacian–lowermost Campanianby Ramírez del Pozo
679 and Martín-Chivelet (1994), , age that was updated as upper Coniacian to upper
680 Santonian by Martín-Chivelet and Chacón (2007), being lithostratigraphically
681 represented by the Margas de Alarcón and Calizas y brechas calcáreas de Sierra de Utiel
682 Fms. The second as lower Campanian–lower Maastrichtian by Ramírez del Pozo and
683 Martín-Chivelet (1994) , and uppermost Santonian–lower Maastrichtian by Martín-
684 Chivelet and Chacón (2007), corresponding to the Calizas del Carche and Calizas de la
685 Rambla de los Gavilanes Fms. And the third and youngest unit as late Maastrichtian in
686 age with the Margas de los Cerrillares, Calizas Arenosas del Molar and Margas de
687 Raspay Fms. According to Ramírez del Pozo and Martín-Chivelet (1994) and Martín-
688 Chivelet and Chacón (2007) the ages given for the megasequences were supported by
689 correlations with equivalent units containing planktonic foraminifera. These authors
690 distinguished the planktonic zones for the latter two EBSUs or megasequences, from the
691 bottom to the top:

- Second megasequence or EBSU-2: *Dicarinella asymetrica* (only its uppermost part), *Globutruncanita elevata*, *Globotruncana ventricosa*, *Rodotruncana calcarata*, *Globotruncana falsostuarti* and *Gansserina gansseri* Zones (only its lower-middle part).
- Third megasequence or EBSU-3: upper part of the *G. gansseri* Zone and *Abathomphalus mayaroensis* Zone.

Nevertheless, this work propose to recalibrate these chronostratigraphical ages based on the biozone of the planktonic foraminifera in Gradstein et al. (2012), suggesting that the second megasequence ranges from late Santonian to late Campanian and the third from early to late Maastrichtian.

Regarding LBF, in the case of the second megasequence, Ramírez del Pozo and Martín-Chivelet (1994) identified the biozone of the *Murciella cuvillieri* Fourcade (in the present study, *Murciella* aff. *cuvillieri*) and other rhapydioninid relatives, found in this study in the same unit as the rotaliids *Neorotalia*? *pinetensis* sp. nov., *Rotalia baetica* sp. nov., *Suturina minima* sp. nov., *Suturina globosa*, *Rotalispira scarsellai* and *Rotorbinella* sp. Those authors dated this megasequence by correlation with the *Globotruncanita elevata*, *Globotruncana ventricosa*, *Radotruncana calcarata*, and *Globotruncana falsostuarti* zones and the lowermost *Gansserina gansseri* zone. In the case of the younger and third megasequence, Ramírez del Pozo and Martín-Chivelet (1994) cited the species *Sulcoperculina dickersoni* var. *vermunti* (Thiadens), specimens of which we have identified as *Pseudosulcoperculina bocairentina* gen. et sp. nov., together with *Plumopraelockhartia solanensis* sp. nov. and *Suturina minima* sp. nov., in the biozone of *Siderolites calcitrapoides* Lamarck and ascribed to the *Gansserina gansseri* zone.

In the case of the Prebetic areas studied in the present paper, the deposits containing assemblage 1 can be correlated with the second megasequence or EBSU-2 from middle to late Campanian ages, and assemblage 2 with the third from late Maastrichtian ages, extending the geographical distribution of the LBF biozones identified from the Murcian sector to the Valencia and Albacete Prebetic sector.

6. Paleobiogeographic and phylogenetic discussion

6.1. The occurrence of *Sulcoperculina*-like morphotypes in both sides of the Late Cretaceous Atlantic

The genus *Sulcoperculina* was erected by Thalmann in 1939 to accommodate the species *Camerina dickersoni* Palmer, 1934 (type species of the genus), *C. cubensis* Palmer, 1934 and *C. vermunti* Thiadens, 1937 from the Upper Cretaceous of Cuba. Since then, several species have been described and also assigned to the genus *Sulcoperculina*, namely, *S. cosdeni* Applin and Jordan, 1945, *S. globosa* Cizancourt, 1949, *S. obesa* Cizancourt, 1949, *S. angulata* Brown and Bronnimann, 1957, *S. minima* Seiglie and Ayala-Castañares, 1963, *S. diazi* Seiglie and Ayala-Castañares, 1963, *S. inaequalis* Ho, 1976 and *S. kugleri* Hottinger, 1977. All the species seem to have common features, such as the marginal sulcus and the involute spiral chamber arrangement. Nevertheless, among the species assigned to *Sulcoperculina*, there are significant differences that deserve to be discussed. According to the detailed study of Cole (1947) and other observations by previous authors (e.g., Voorwijk, 1937; Vaughan, 1945), remarkable variability in terms of morphology and size can be observed in closely related *Sulcoperculina* populations. These observations led Cole (1947) to consider some of the species described until then as infraspecific varieties (see

740 pg. 235 in Cole, 1947), ruling out that they constituted distinct natural species. Leaving
741 aside this hypothesis and other synonymies proposed by various authors (see also Frost,
742 1974), observing in broad terms the morphology of the specimens figured in the
743 literature to date, it seems that there are at least two different morphotypes of
744 sulcoperculinas. On the one hand, there is one large morphological group represented by
745 the type species, *S.* gr. *dickersoni*, which have a nearly bilateral symmetry and
746 ornamentation restricted to the central plug and inflated septal sutures or beads. Its shell
747 has an extremely low to almost planispiral chamber arrangement. Apart from the type,
748 the vast majority of the species described, namely, *S. vermunti, S. cubensis, S. cosdeni,*
749 *S. globosa, S. obesa, S. angulata, S. minima* and *S. diazi* seem to have similar
750 architecture and, therefore, they would be included in the same group. On the other
751 hand, there is a second morphotype represented by Hottinger's species, *S. kugleri*,
752 which is characterized by a clear trochospiral chamber arrangement, asymmetric shell
753 and marked feathered ornamentation on the ventral chamber wall. Our observations
754 regarding the separation of the American forms into two groups based on their
755 dissimilar test-architecture are in accordance with those of Hottinger (1977) who stated
756 that the Campanian trochospiral species *S. kugleri* should be separated from the
757 Maastrichtian planispiral forms (see pg. 29 in Hottinger, 1977). The species *S.*
758 *inaequalis* from the Upper Cretaceous of Tibet, China, could belong to *S.* gr. *kugleri*
759 according to its assymetrical shell. Nonetheless, the generic ascription of the species *S.*
760 *inaequalis* should be revised in future as it appears to show some differences in its
761 marginal and umbilical structures.

762 The resemblance of *P. bocairentina* gen. et sp. nov. to the trochospiral species *S. kugleri*
763 Hottinger, 1977, from the Campanian of Jamaica prompts discussion about the origin of
764 their architectural similarities. According to Hottinger (1977), the trochospiral structure

765 of *S. kugleri* found in Jamaica can be considered "primitive" with respect to the other
766 species of sulcoperculinas with planispiral coiling, which develop later during the
767 Maastrichtian ages in the American-Caribbean domain. The presence of the trochospiral
768 growth in architecturally similar younger forms, in particular in the Maastrichtian
769 "sulcoperculina-like" specimens from the western Tethys, raises the question of
770 dispersal versus vicariance groups. This would mean either the persistence of that
771 primitive rotaloid architecture between older and younger phylogenetically related
772 forms or an environmental adaptation in species of different phylogenetic lines, not
773 directly related, represented by *S. kugleri* for the American forms and *P. bocairentina*
774 gen. et sp. nov. for the Tethyan forms.

775 The relationship between the *Pseudosulcoperculina*? sp. from the early Maastrichtian of
776 the Atlantic Pyrenean domain and *P. bocairentina* gen. et sp. nov. from the lowermost
777 upper Maastrichtian of the western Tethys also deserves careful analysis in the future.
778 Further, these forms should be compared with other rotaliiforms which are cited as
779 *Sulcoperculina*, but poorly illustrated and difficult to identify, in other palaeogeographic
780 areas of the Tethyan domain (Butterlin, 1967, Luperto Sinni and Ricchetti, 1978,
781 Abdelghany, 2003; Dimitrova, 2003; Al-Dulaimi and Al-Obaidy, 2017; Akmaluddin et
782 al., 2019, among others). The possibly existence of a paleo-Gulf-stream during the late
783 Cretaceous connecting the American and the Tethyan domains (Fourcade and Michaud,
784 1987) would be in favor of considering the dispersion of species as key to find closely
785 related forms in both sides of the Atlantic. Nonetheless, the answer to all these
786 questions is far beyond the scope of the present paper. Reaching firm conclusions in
787 terms of phylogenetic relationships would need a reanalysis of all the morphotypes
788 found so far in the American, Pyrenean and Tethyan domains, and with a solid
789 stratigraphical framework.

In any case, the trochospiral *Sulcoperculina*-like forms of both sides of the Atlantic ocean show architectural differences, but also similarities, which are proven in the present study. Considering all the information available to date, it seems that the operculiniform planispiral symmetrical younger forms from the American-Caribbean domain, *S.* gr. *dickersoni,* are absent in the eastern domains, Pyrenean and Tethyan domains, only the similar trochospiral rotaloid forms having spread widely. The future revision of the entire group would not only lead to a better understanding of the evolutionary trends and the phylogenetic relationships of the species involved, but also to a redefinition of the architectural traits of the genus *Sulcoperculina*, which should be considered to date as an endemic form of the American-Caribbean palaeobioprovince.

6.2. Early evolution of praelockhartiines

The cavities observed in the umbilical structure of *Plumopraelockhartia solanensis* gen. et sp. nov. makes this species resemble to the representatives of the subfamily Praelockhartiinae Vicedo and Robles-Salcedo, 2019, defined in the early Paleocene of the Oman Mountains. The ascription of that species to this subfamily roots the origin of the group of lokhartiines sensu lato, which would include the closely related forms belonging to both, Praelockhartiinae and Lockhartiinae, back to the Upper Cretaceous and expands its palaeogeographic distribution to the westermost Tethys.

7. Conclusions

The revision of the larger rotaliid specimens found in the Upper Cretaceous series from the Valencian sector of the external Prebetic domain has allowed us to present the following:

1. Five new species and two new genera, namely, *Pseudosulcoperculina bocairentina* gen. et sp. nov., *Plumopraelockhartia solanensis* gen. et sp. nov., *Rotalia baetica* sp. nov., *Suturina minima* sp. nov., and *Neorotalia*? *pinetensis* sp. nov.
2. The rotaliids found characterize two different assemblages. The older assemblage is composed of *Neorotalia*? *pinetensis* sp. nov., *Rotalia baetica* sp. nov., *Suturina globosa*, *Rotorbinella* sp., *Pararotalia tuberculifera* and *Rotalispira scarsellai* that were found in middle to upper Campanian deposits. The younger assemblage is composed of *Pseudosulcoperculina bocairentina* gen. et sp. nov., *Plumopraelockhartia solanensis* gen. et sp. nov. and *Pararotalia tuberculifera* that were found in upper Maastrichtian deposits. The species *Suturina minima* sp. nov. was found in both assemblages, dated in deposits from middle Campanian to Maastrichtian.
3. The rotaliid assemblages can be correlated with the main megasequences defined for the Prebetic, extending the geographical distribution of the LBF biozones and enhancing their regional biostratigraphical value.
4. A discussion based on a detailed comparison of the test architecture of the species found with other similar taxa from the Caribbean, Pyrenean and Tethyan domains reveals significant differences, but also similarities, among the *Sulcoperculina*-like forms. According to all the data available up to now, the genus *Sulcoperculina* would be restricted to the American-Caribbean palaeobioprovince and, therefore, its use in the species ascription of other realms should be avoided.
5. A proposal to root the origin of lockhartiines sensu lato back to the late Cretaceous.

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Figure captions

Figure 1. Geographical location of the stratigraphical sections and the two outcrops.

Figure 2. Stratigraphic succession and distribution of larger foraminifera and other fossil groups in the Serra de la Solana section, Bocairent (Valencia, Spain).

Figure 3. Stratigraphic succession and distribution of larger foraminifera and other fossil groups in the Serra Grossa section, Ontinyent (Valencia, Spain).

Figure 4. Stratigraphic succession and distribution of larger foraminifera and other fossil groups in the Penya del Romaní Hill section, SE of Serra del Buixcarró, Pinet (Valencia, Spain).

Figure 5. Stratigraphic succession and distribution of larger foraminifera and other fossil groups in the Serra de les Agulles section, Benifairó de la Valldigna (Valencia, Spain).

Figure 6. *Pseudosulcoperculina bocairentina* gen. et sp. nov. from the Maastrichtian deposits of Serra de la Solana, Bocairent (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. A–-E and G–-U, paratypes. F, holotype. *Abbreviations*: ft, feathering; fu, funnel; p, proloculus; pg, umbilical plug; pi, pile; s, septum; spc, spiral canal; su; sulcus; up, umbilical plate. The accession numbers from A to U are 64072 LP16.008; 84627 LP01.008; 64072 LP08.002; 84627 LP01.009; 64072 LP03.011; 69778 LP05.005; 64072 LP14.021; 64072 LP03.013; 64072 LP19.008; 64072 LP03.002; 64072 LP13.013; 64072 LP08.012; 64072 LP21.002; 64072 LP01.005; 64072 LP06.010; 64072 LP14.004; 64072 LP13.002; 64072 LP17.004; 84632 LP02.003; 64072 LP01.010; 64072 LP07.009, respectively, all of them under the acronym MGB.

Figure 7. *Pseudosulcoperculina bocairentina* gen. et sp. nov. from the Maastrichtian deposits of Serra de la Solana, Bocairent (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. All the specimens are paratypes. *Abbreviations*: foa, foliar aperture; ft, feathering; ic, intraseptal canal; pg, umbilical plug; spc, spiral canal; su, sulcus; up, umbilical plate. The accession numbers from A to L are 69778 LP04.030; 64072 LP13.008; 64072 LP14.003; 64072 LP04.002; 64072 LP01.009; 62072 LP03.010; 64072 LP11.011; 69950 LP01.018; 64072 LP16.001; 64072 LP14.005; 69950 LP01.016; 84627 LP01.002, respectively, all of them under the acronym MGB.

Figure. 8. A–**E,** *Pseudosulcoperculina bocairentina* gen. et sp. nov.; **F**–**G,** *Plumopraelockhartia solanensis* gen. et sp. nov.; **H,** and *Pararotalia tuberculifera* (Reuss, 1862) from the Maastrichtian deposits of Serra del Regalí (Albacete, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. *Abbreviations*: ft, feathering; fu, funnel; pi, pile; su, sulcus; uc, umbilical cavity; upc, umbilical peripheral cavity. The accession numbers from A to H are 84665 LP03.001; 84666 LP01.005; 84665 LP01.008; 84666 LP01.002; 84666 LP02.001; 84666 LP01.004; 84665 LP01.009; 84665 LP01.002, respectively, all of them under the acronym MGB.

Figure 9. *Pseudosulcoperculina* sp. from the lower Maastrichtian deposits of the south Pyrenees (Lleida, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. The accession numbers from A to D are 82546 LP01.001; 82547 LP01.001; 82548 LP01.001; 82549 LP01.001, respectively, all of them under the acronym MGB.

Figure 10. *Plumopraelockhartia solanensis* gen. et sp. nov. from the Maastrichtian deposits of Serra de la Solana, Bocairent (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. A, C–V, paratypes. B, holotype. *Abbreviations*: do, dorsal ornamentation; f, foramen; foa, foliar aperture; ft, feathering; fu, funnel; is, interlocular intraseptal space; n, notch; p, proloculus; pi, pile; s, septum; uc, umbilical cavity; up, umbilical plate; upc, umbilical peripheral cavity. The accession numbers from A to V are 64072 LP01.012; 84627 LP01.004; 64072 LP11.007; 64072 LP07.004; 64072 LP11.013; 64072 LP01.034; 64072 LP14.011; 84633 LP01.003; 64072 LP14.018; 69950 LP01.013; 84633 LP01.001; 64072 LP17.020; 64072 LP15.022; 64072 LP18.018; 84632 LP02.013; 64072 LP03.009; 64072 LP17.023; 84633 LP01.002; 64072 LP18.018; 84627 LP01.005; 84629 LP01.009; 69778 LP04.021, respectively, all of them under the acronym MGB.

Figure 11. *Rotalispira scarsellai* (Torre, 1966) from the upper Campanian deposits of Serra Grossa, Ontinyent (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. *Abbreviations*: f, foramen; fo, folium; s, septum. The accession numbers from A to X are 69816 LP02.009; 69817 LP03.057; 69817 LP01.051; 69817 LP02.060; 69817 LP02.047; 69817 LP01.070; 69817 LP02.064; 69817 LP02.062; 69817 LP02.073; 69816 LP01.053; 69816 LP01.058; 69817 LP01.063; 69817 LP01.054; 69816 LP01.056; 69817 LP01.055; 69817 LP01.073; 69817 LP02.053; 69817 LP02.044; 69816 LP02.001; 69816 LP01.057; 69817 LP01.052; 69817 LP01.062; 69817 LP01.064; 69817 LP02.061, respectively, all of them under the acronym MGB.

Figure 12. *Rotalia baetica* sp. nov. from the upper Campanian deposits of Penya del Romaní Hill, SE of Serra del Buixcarró, Pinet (Valencia, Spain). Transmitted light

photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. A–D, F–R, paratypes. E, holotype. *Abbreviations*: col, columella; f, foramen; fo, folium; s, septum; up, umbilical plate. The accession numbers from A to R are 60322 LP18.002; 69733 LP06.002; 60323 LP02.001; 69735 LP06.002; 60323 LP03.007; 69737 LP07.001; 60322 LP06.010; 60323 LP01.001; 60321 LP09.003; 60319 LP02.002; 60322 LP07.007; 69734 LP10.005; 60324 LP01.013; 60322 LP11.001; 60321 LP04.002; 60322 LP14.003; 60321 LP06.009; 62321 LP04.001, respectively, all of them under the acronym MGB.

Figure 13. -*Rotorbinella* sp. from the upper Campanian deposits of Penya del Romaní Hill, SE of Serra del Buixcarró, Pinet. Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. *Abbreviations*: p, proloculus; pg, umbilical plug; s, septum. The accession numbers from A to F are 60323 LP03.002; 60323 LP03.006; 60322 LP14.002; 60322 LP14.005; 69734 LP09.003; 60323 LP03.008, respectively, all of them under the acronym MGB.

Figure 14. *Suturina minima* sp. nov. from the upper Campanian deposits of Penya del Romaní Hill, SE of Serra del Buixcarró, Pinet (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 250 µm. A, B, D–T, paratypes. C, holotype. *Abbreviations*: f, foramen; fo, folium; n, notch; s, septum; up, umbilical plate. The accession numbers from A to T are 60335 LP02.040; 60335 LP03.009; 60335 LP02.036; 60335 LP02.044; 60334 LP05.013; 60335 LP02.045; 60335 LP03.006; 60335 LP01.007; 60334 LP05.001; 60334 LP02.006; 60334 LP05.010; 60335 LP03.010; 60334 LP02.007; 60335 LP02.027; 60334 LP02.008; 60334 LP05.008; 60335 LP02.031; 60330 LP02.005; 60334 LP05.013; 60335 LP02.032, respectively, all of them under the acronym MGB.

Figure 15. *Suturina minima* sp. nov. from the upper Campanian deposits of Penya del Romaní Hill, SE of Serra del Buixcarró, Pinet (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 250 µm. All the specimens are paratypes. *Abbreviations*: f, foramen; fo, folium; foa, foliar aperture; ic, intraseptal canal; n, notch; s, septum; spc, spiral canal; up, umbilical plate. The accession numbers from A to Q are 60334 LP05.002; 60334 LP05.012; 60334 LP02.010; 60334 LP05.011; 60335 LP02.033; 60335 LP01.005; 60335 LP01.011; 60335 LP01.006; 60334 LP02.006; 60335 LP01.008; 60334 LP02.011; 60335 LP01.008; 60335 LP01.010; 60335 LP01.009; 60334 LP02.004; 60335 LP01.001; 60335 LP02.041, respectively, all of them under the acronym MGB.

Figure 16. *Suturina minima* sp. nov. from the upper Campanian deposits of Penya del Romaní Hill, SE of Serra del Buixcarró, Pinet (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 250 µm. All the specimens are paratypes. *Abbreviations*: f, foramen; fo, folium; s, septum; up, umbilical plate. The accession numbers from A to H are 60334 LP04.008; 60334 LP04.009; 60334 LP04.006; 60334 LP04.007; 60334 LP04.001; 60334 LP03.006; 60334 LP03.002; 60334 LP03.001, respectively, all of them under the acronym MGB.

Figure 17. *Suturina minima* sp. nov. (**A**–**H**) and *Suturina globosa* Consorti, Vilallonga and Caus, 2017 (**I**–**K**) from the upper Campanian deposits of Serra Grossa, Ontinyent (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. The accession numbers from A to K are 69833 LP01.010; 69843 LP01.028; 69833 LP01.005; 69818 LP01.002; 69830 LP01.001; 69843 LP01.026; 69843 LP01.022; 69811 LP01.001, 69817 LP03.058; 69817 LP01.066; 69817 LP02.075, respectively, all of them under the acronym MGB.

Figure 18. *Neorotalia*? *pinetensis* sp. nov. from the upper Campanian deposits of Penya del Romaní Hill, SE of Serra del Buixcarró, Pinet (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. A, C–X, paratype. B, holotype. *Abbreviations*: f, foramen; fu, funnel; is, interlocular intraseptal space; p, proloculus; pi, pile; tp, toothplate. The accession numbers from A to X are 60316 LP03.002; 60316 LP04.005; 60316 LP03.008; 60316 LP03.014; 60316 LP05.001; 60316 LP03.011; 60316 LP01.014; 60319 LP01.008; 60316 LP06.006; 60316 LP04.004; 60316 LP05.006; 60316 LP04.003; 60316 LP06.004; 60316 LP05.007; 60316 LP03.013; 60316 LP04.002; 60318 LP02.004; 60316 LP05.010; 60318 LP02.006; 60316 LP03.012; 60316 LP06.001; 60318 LP02.002; 60316 LP06.005; 60318 LP02.007, respectively, all of them under the acronym MGB.

Figure 19. *Neorotalia*? *pinetensis* sp. nov. from the upper Campanian deposits of Serra de les Agulles, Benifairó de la Valldigna (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. *Abbreviations*: f, foramen; is, interlocular intraseptal space; spc, spiral canal; tp, toothplate. The accession numbers from A to D are 60354 LP01.001; 60354 LP01.002; 60356 LP01.001; 60357 LP01.002, respectively, all of them under the acronym MGB.

Figure 20. *Pararotalia tuberculifera* (Reuss, 1862). **A**–**J**, specimens from the upper Campanian deposits of Penya del Romaní Hill, SE of Serra del Buixcarró, Pinet; **K**–**N,** specimens from the upper Maastrichtian deposits of Serra de la Solana, Bocairent. Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar 500 µm. *Abbreviations*: pg, umbilical plug. The accession numbers from A to N are 69733 LP05.004; 69737 LP06.004; 69733 LP05.002; 69736 LP06.004; 69733 LP05.003; 69733 LP01.003; 60324 LP01.012; 60322 LP01.008; 69736 LP11.002;

60322 LP08.001; 64072 LP13.010; 64072 LP03.023; 64072 LP17.011; 64072 LP06.009, respectively, all of them under the acronym MGB.

Figure 21. Selected larger foraminifera from the late Campanian deposits of Penya del Romaní Hill, SE of Serra del Buixcarró, Pinet (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar: 500 μm for A, C, E–K and M, 1 mm for B, D and L. **A,** *Cuneolina cylindrica* Henson; **B,** *Haddonia* sp. encrusted with *Polystrata alba* (Pfender) Denizot (aragonitic red coralline algae); **C,** *Nummofallotia cretacea* (Schlumberger); **D,** *Orbitoides* cf. *media* (d'Archiac); **E,** "*Orbitoides*" cf. *concavatus* Rahaghi; **F,** *Praesiderolites douvillei* Wannier; **G,** *Lepidorbitoides* cf. *campaniensis* van Gorsel; **H**, *Stomatorbina binkhorsti* (Reuss); **I,** *Wannierina* cf. *vilavellensis* Robles-Salcedo, Vicedo and Caus; **J,** *Sirtina ornata* (Rahaghi); **K,** *Planorbulina cretae* (Marsson); **L,** *Pseudosiderolites vidali* (Douvillé); **M,** aff. *Sivasella* sp. The accession numbers from A to M are 60330 LP01.001; 69732 LP07.001; 60322 LP01.007; 60322 LP01.018; 60324 LP02.005; 60324 LP01.006; 69734 LP02.004; 60319 LP08.005; 60329 LP01.003; 60322 LP01.012; 60322 LP04.002; 60324 LP14.002; 60323 LP02.005, respectively, all of them under the acronym MGB.

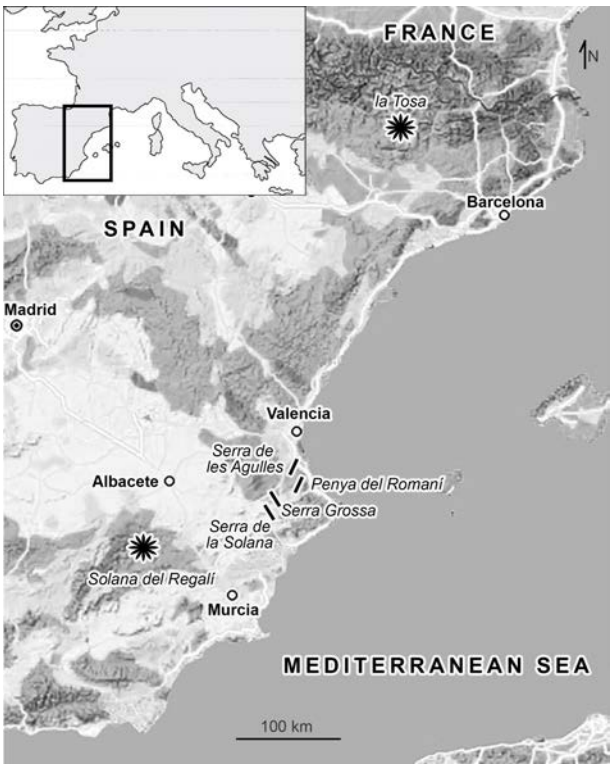
Figure 22. Selected larger foraminifera from the upper Campanian deposits of Serra de les Agulles, Benifairó de la Valldigna (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bar: 1 mm for A–C, 500 μm for D–I. **A,** *Orbitoides* sp.; **B,** *Arnaudiella grossouvrei* Douvillé; **C,** *Lepidorbitoides* sp.; **D,** *Praesiderolites douvillei* Wannier; **E,** *Goupillaudina shirazensis* Rahaghi; **F,** *Nummofallotia cretacea* (Schlumberger); **G,** *Idalina antiqua* Schlumberger & Munier-Chalmas; **H,**

Praestorrsella roestae (Visser); **I,** Textulariid. The accession numbers from A to I are 60354 LP01.010; 60356 LP01.002; 60367 LP01.002; 60344 LP01.002; 60345 LP01.001; 60354 LP01.012; 60354 LP01.009; 60344 LP01.004; 60344 LP01.001, respectively, all of them under the acronym MGB.

Figure 23. Selected larger foraminifera from late Campanian deposits of Serra Grossa, Ontinyent (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bars: A–D, 200 μm, E–G, I, 500 μm, H, J, 1 mm. **A,** *Fleuryana* sp.; **B,** *Nezzazatinella* sp.; **C,** *Murgeina apula* (Luperto Sinni); **D,** *Dictyopsella* sp.; **E,** *Scandonea* sp.; **F,** *Cuneolina cylindrica* Henson; **G,** *Praseiderolites douvillei* Wannier; **H,** *Orbitoides* cf. *media* (d'Archiac); **I,** *Murciella* aff. *cuvillieri* Fourcade (M) and *Cuvillierinella* cf. *salentina* Papetti and Tedeschi (C); **J,** *Pseudosiderolites vidali* (Douvillé). The accession numbers from A to J are 69817 LP02.070; 69817 LP03.009; 69833 LP01.004; 69822 LP01.003; 69812 LP01.001; 69816 LP01.001; 69822 LP01.001; 69823 LP01.001; 69817 LP03.024; 69817 LP03.025; 69819 LP01.006, respectively, all of them under the acronym MGB.

Figure 24. Selected larger foraminifera from the upper Maastrichtian depostis of Serra de la Solana, Bocairent (Valencia, Spain). Transmitted light photographs of thin sections of cemented carbonate rocks. Scale bars: A–C, 1 mm, D–K, 500 μm. **A,** *Omphalocyclus macroporus* (Lamarck); **B,** *Orbitoides apiculata* Schlumberger; **C,** *Orbitoides gensacicus* (Leymerie); **D,** *Hellenocyclina beotica* Reichel; **E,** *Selimina spinalis* Inan; **F,** *Sivasella monolateris* Sirel and Gündüz; **G,** *Idalina antiqua* Schlumberger and Munier-Chalmas; **H,** *Nummofallotia cretacea* (Schlumberger); **I,** *Fissoelphidium operculiferum* Smout; **J,** *Sirtina orbitoidiformis* Brönnimann and Wirz;

K, *Siderolites calcitrapoides* Lamarck. The accession numbers from A to K are 64072 LP17.002; 64072 LP03.001; 64072 LP05.002; 64072 LP01.023; 84627 LP01.018; 67870 LP01.001; 67891 LP01.001; 67885 LP01.002; 64072 LP15.004; 64072 LP02.007; 84632 LP01.004, respectively, all of them under the acronym MGB.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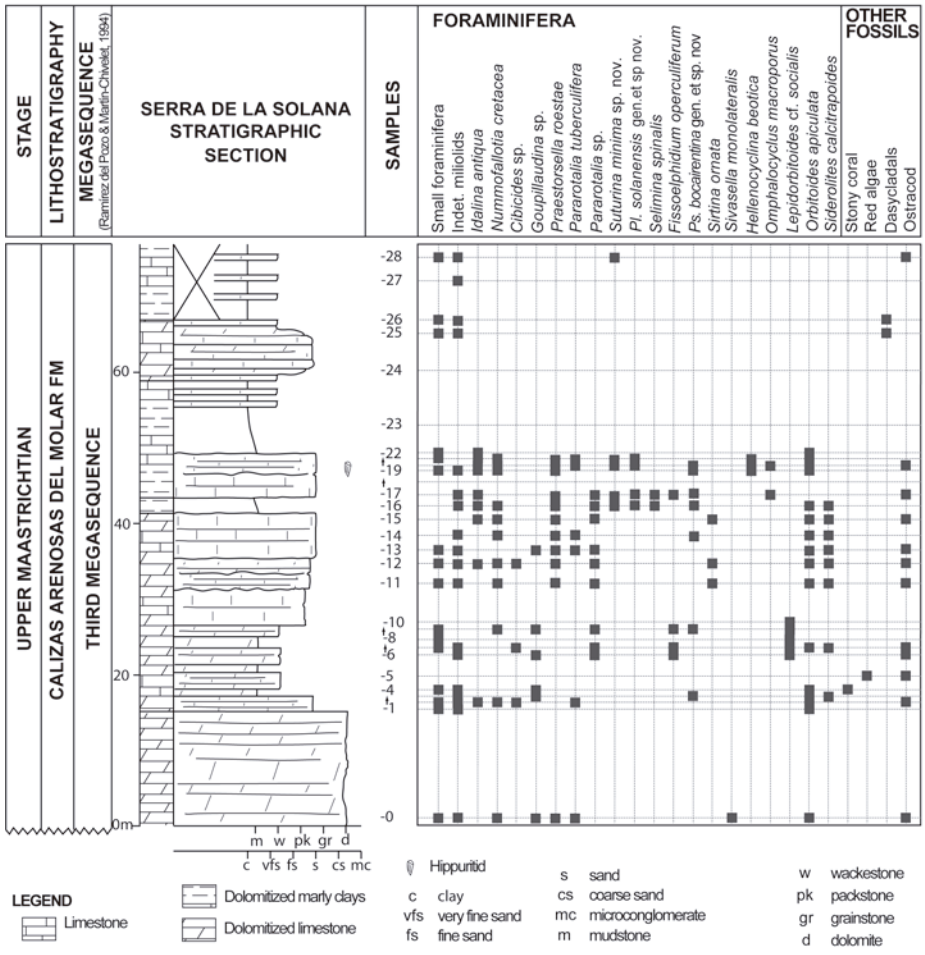
STAGE
LITHOSTRATIGRAPHY
MEGASEQUENCE
(Ramírez del Pozo & Martín-Chivelet, 1994)
SERRA DE LA SOLANA
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Small foraminifera
Indet. miliolids
Idalina antiqua
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Goupillaudina sp.
Praestorsella roestae
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Pararotalia sp.
Suturina minima sp. nov.
Pl. solanensis gen.et sp nov.
Selimina spinalis
Fissoelphidium operculiferum
Ps. bocairentina gen. et sp. nov
Sirtina ornata
Sivasella monolateralis
Hellenocyclina beotica
Omphalocyclus macroporus
Lepidorbitoides cf. socialis
Orbitoides apiculata
Siderolites calcitrapoides
Stony coral
Red algae
Dasycladals
Ostracod
UPPER MAASTRICHTIAN
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LEGEND
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Dolomitized limestone
Hippuritid
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vfs very fine sand
fs fine sand
s sand
cs coarse sand
mc microconglomerate
m mudstone
w wackestone
pk packstone
gr grainstone
d dolomite

STAGE
LITHOSTRATIGRAPHY
MEGASEQUENCE
(Ramírez del Pozo & Martín-Chivelet, 1994)
SERRA GROSSA
STRATIGRAPHIC
SECTION
SAMPLES
FORAMINIFERA
Small foraminifera
Nezzazatinella sp.
Fleuryana sp.
Scandonea sp.
Dictyopsella kiliani
Cuneolina cylindrica
Indet. miliolids
Murgeina apula
Cuvillierinella cf. salentina
Murciella aff. cuvillieri
Praestorsella roestae
Pararotalia tuberculifera
Suturina minima sp. nov.
Suturina globosa
Rotalia baetica sp. nov.
Rotalispira scarsellai
Rotorbinella sp.
Lepidorbitoides cf. socialis
Orbitoides cf. megaloformis
Praesiderolites douvillei
Pseudosiderolites vidali
Siderolites praecalcitrapoides
Discorbids
OTHER FOSSILS
Carophyte
Ostracod
MIDDLE - UPPER CAMPANIAN
LOWER MAASTRICHTIAN?
CALIZAS DE LA RAMBLA DE LOS GAVILANES FM
SECOND MEGASEQUENCE
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60
40
20
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QUARRY
-77
-71
-70
-64
-61
-60
-59
-58
-57
-56
-55
-54
-53
-52
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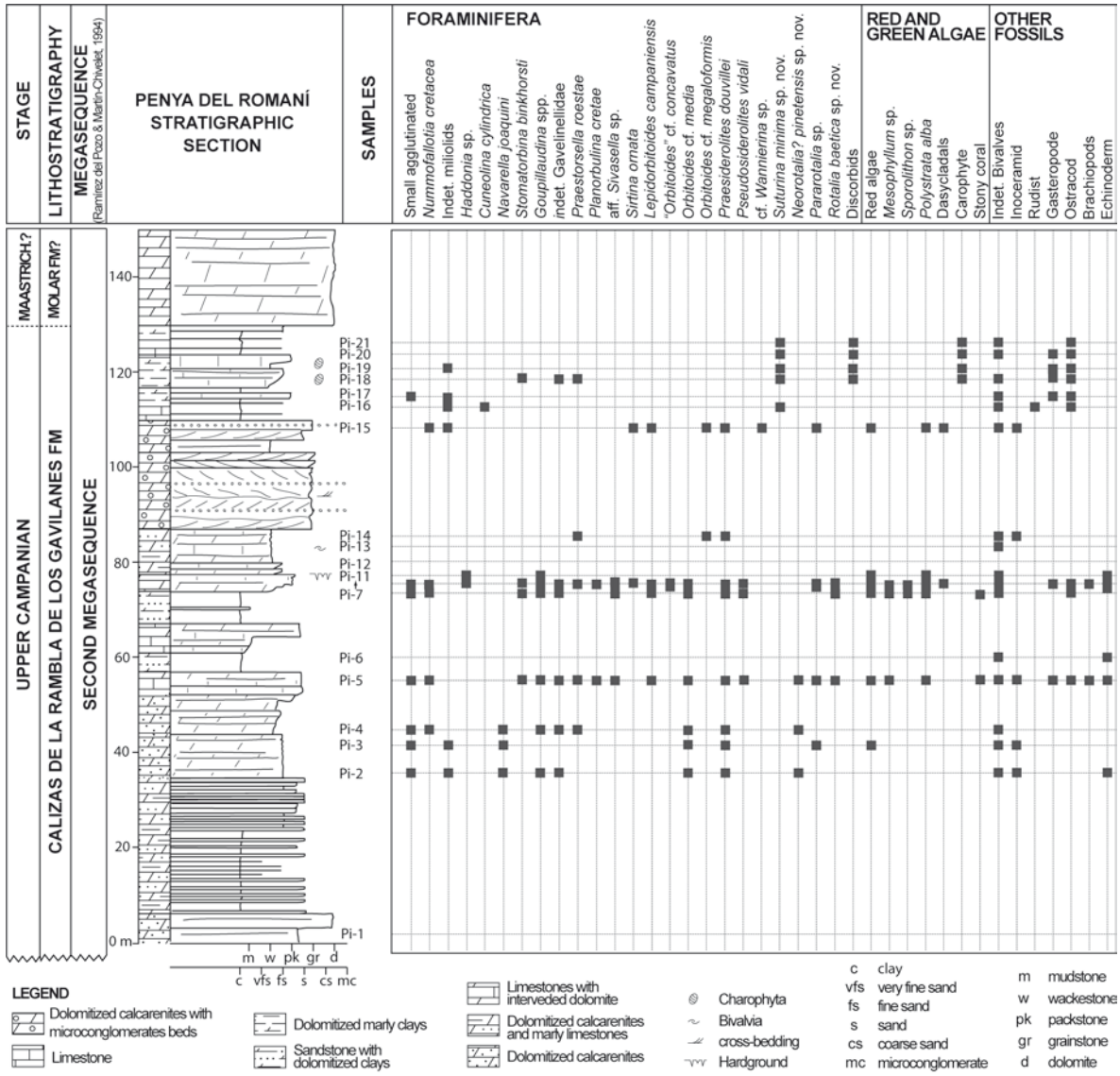
-47
-45
-44
-39
-34
-18-8
-18-7
-18-6
-18-5
-18-4
-18-9
m w pk gr d
cvfs fs s cs mc
LEGEND
Dolomitized calcarenites with microconglomerates beds
Limestone
Marl
Sandstone with dolomitized clays
Limestones with interveded dolomite
Marly clays
Dolomitized calcarenites
Charophyta
cross-bedding
c clay
vfs very fine sand
fs fine sand
s sand
cs coarse sand
mc microconglomerate
m mudstone
w wackestone
pk packstone
gr grainstone
d dolomite


STAGE
LITHOSTRATIGRAPHY
MEGASEQUENCE
(Ramírez del Pozo & Martín-Chivelet, 1994)
PENYA DEL ROMANÍ STRATIGRAPHIC SECTION
SAMPLES
FORAMINIFERA
RED AND GREEN ALGAE
OTHER FOSSILS
Small agglutinated
Nummofallotia cretacea
Indet. miliolids
Haddonia sp.
Cuneolina cylindrica
Navarella joaquini
Stomatorbina binkhorsti
Goupillaudina spp.
indet. Gavelinellidae
Praestorsella roestae
Planorbulina cretae
aff. Sivasella sp.
Sirtina ornata
Lepidorbitoides campaniensis
"Orbitoides" cf. concavatus
Orbitoides cf. media
Orbitoides cf. megaloformis
Praesiderolites douvillei
Pseudosiderolites vidali
cf. Wannierina sp.
Suturina minima sp. nov.
Neorotalia? pinetensis sp. nov.
Pararotalia sp.
Rotalia baetica sp. nov.
Discorbids
Red algae
Mesophyllum sp.
Sporolithon sp.
Polystrata alba
Dasycladals
Carophyte
Stony coral
Indet. Bivalves
Inoceramid
Rudist
Gasteropode
Ostracod
Brachiopods
Echinoderm
UPPER CAMPANIAN
MAASTRICHT?
MOLAR FM?
CALIZAS DE LA RAMBLA DE LOS GAVILANES FM
SECOND MEGASEQUENCE
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60
80
100
120
140
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Pi-2
Pi-3
Pi-4
Pi-5
Pi-6
Pi-7
Pi-11
Pi-12
Pi-13
Pi-14
Pi-15
Pi-16
Pi-17
Pi-18
Pi-19
Pi-20
Pi-21
m w pk gr d
c vfs fs s cs mc
LEGEND
Dolomitized calcarenites with microconglomerates beds
Limestone
Dolomitized marly clays
Sandstone with dolomitized clays
Limestones with interveded dolomite
Dolomitized calcarenites and marly limestones
Dolomitized calcarenites
Charophyta
Bivalvia
cross-bedding
Hardground
c clay
vfs very fine sand
fs fine sand
s sand
cs coarse sand
mc microconglomerate
m mudstone
w wackestone
pk packstone
gr grainstone
d dolomite

STAGE
LITHOSTRATIGRAPHY
MEGASEQUENCE
(Ramirez del Pozo & Martin-Chivelet, 1994)
SERRA DE LES AGULLES
STRATIGRAPHIC
SECTION
SAMPLES
FORAMINIFERA
Small aglutinated
Moncharmontia sp.
Dictyopsella sp.
Indet. miliolids
Idalina antiqua
Murgeina apula
Goupillaudina sp.
Cibicides sp.
Praestorsella roestae
Pararotalia tuberculifera
Neorotalia? pinetensis sp. nov.
Rotorbinella sp.
Lepidorbitoides sp.
Orbitoides sp.
Orbitoides cf. media
Praesiderolites douvillei
Arnaudiella grossouvrei
Discorbids
OTHER FOSSILS
Stony coral
Red algae
Ostracod
MIIDDLE - UPPER CAMPANIAN
CALIZAS DE LA RAMBLA DE LOS GAVILANES FM
SECOND MEGASEQUENCE
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-24
-25
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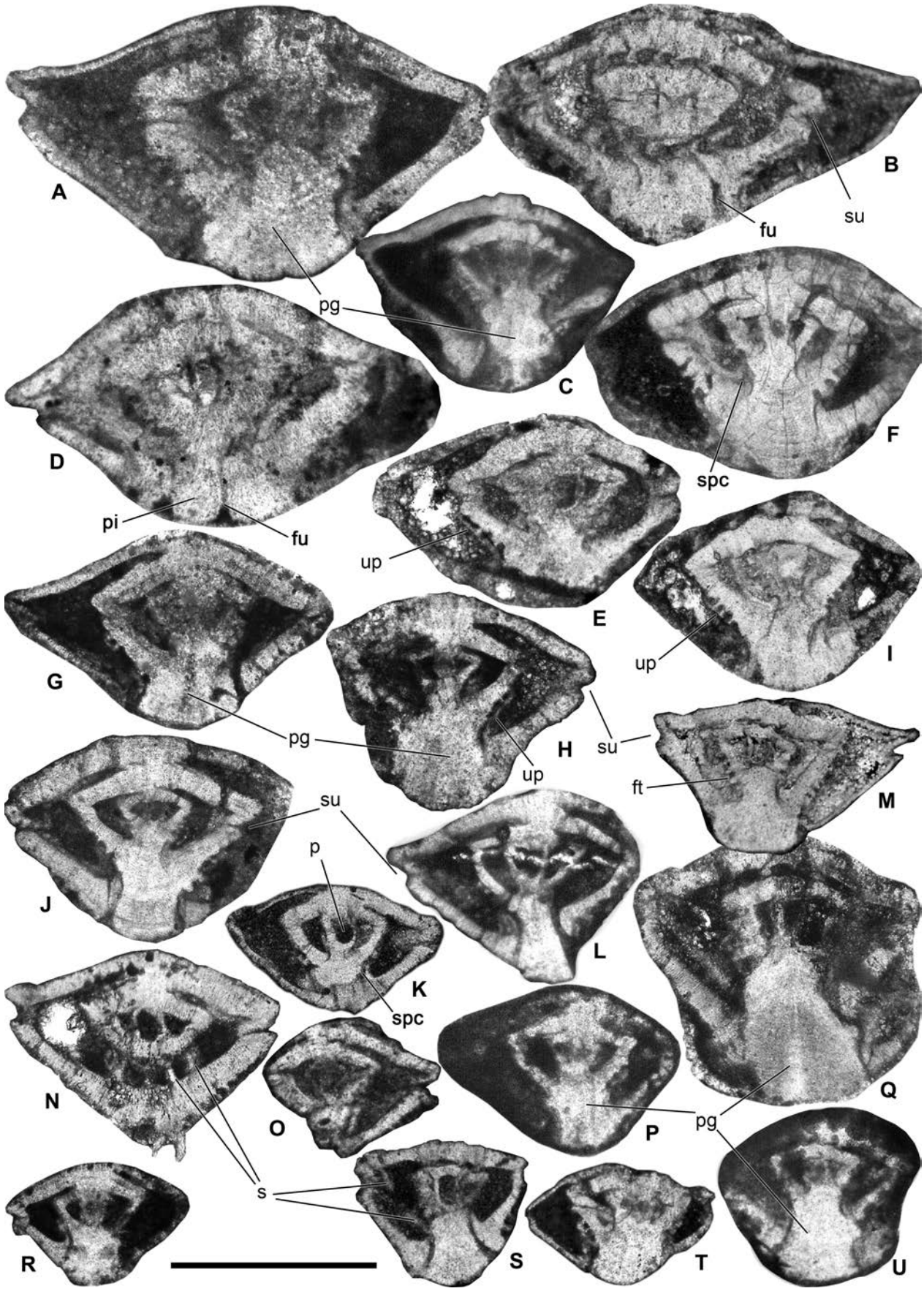
-28
-29
-30
-31
-32
m w pk gr d
c vfs fs s cs mc
LEGEND
Marl
Limestone
Sandstone
Limestone
Calcarenite
Charophyta
Hippuritid
Gasteropod
c clay
vfs very fine sand
fs fine sand
s sand
cs coarse sand
mc microconglomerate
m mudstone
w wackestone
pk packstone
gr grainstone
d dolomite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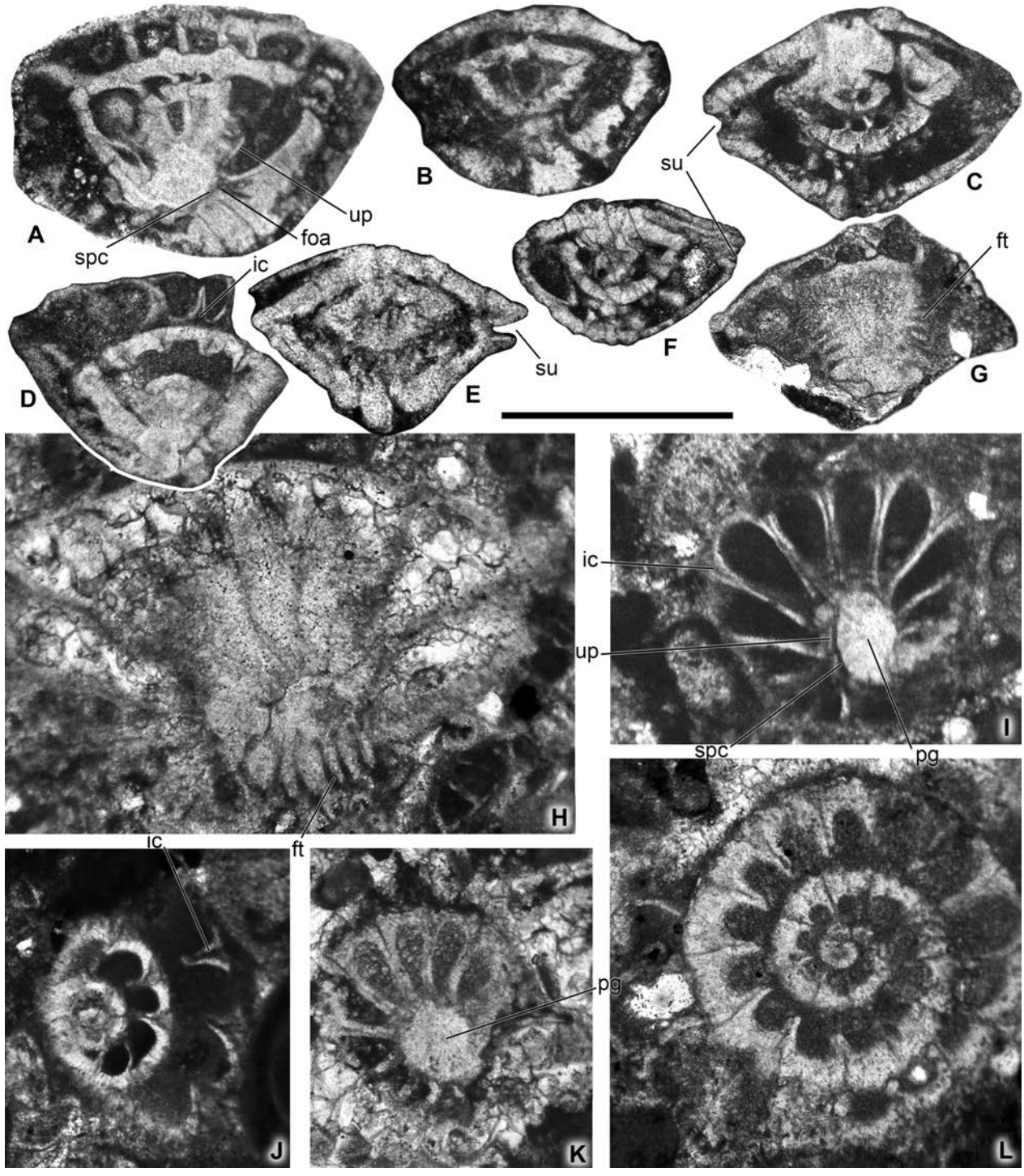
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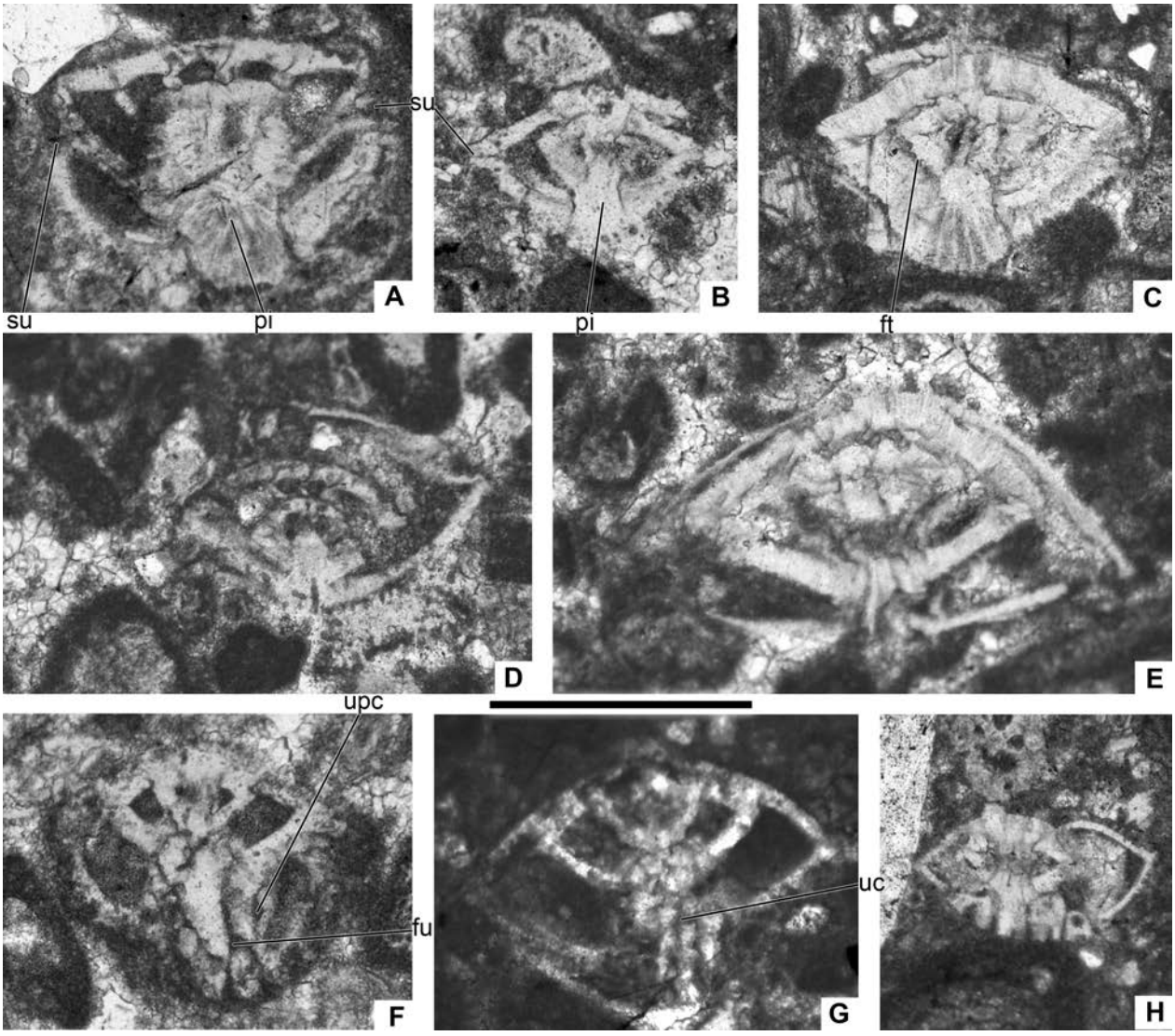
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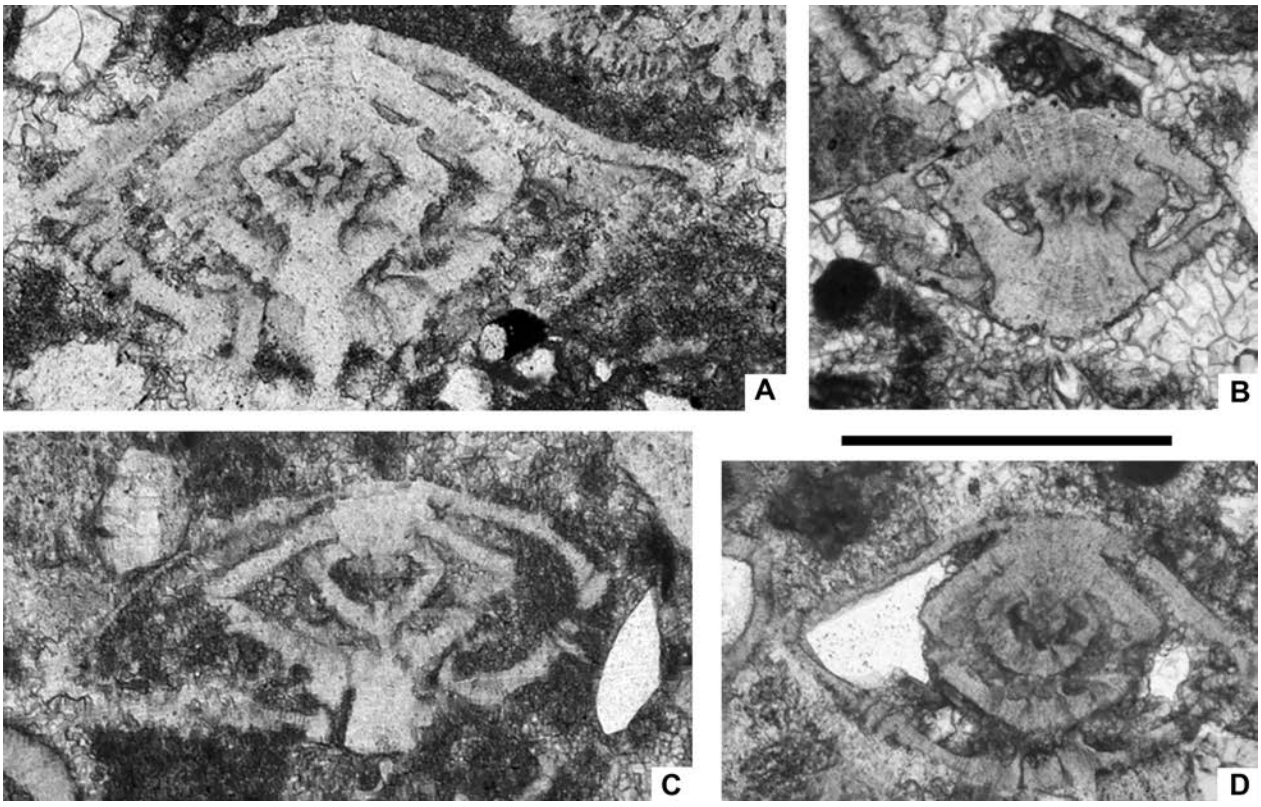
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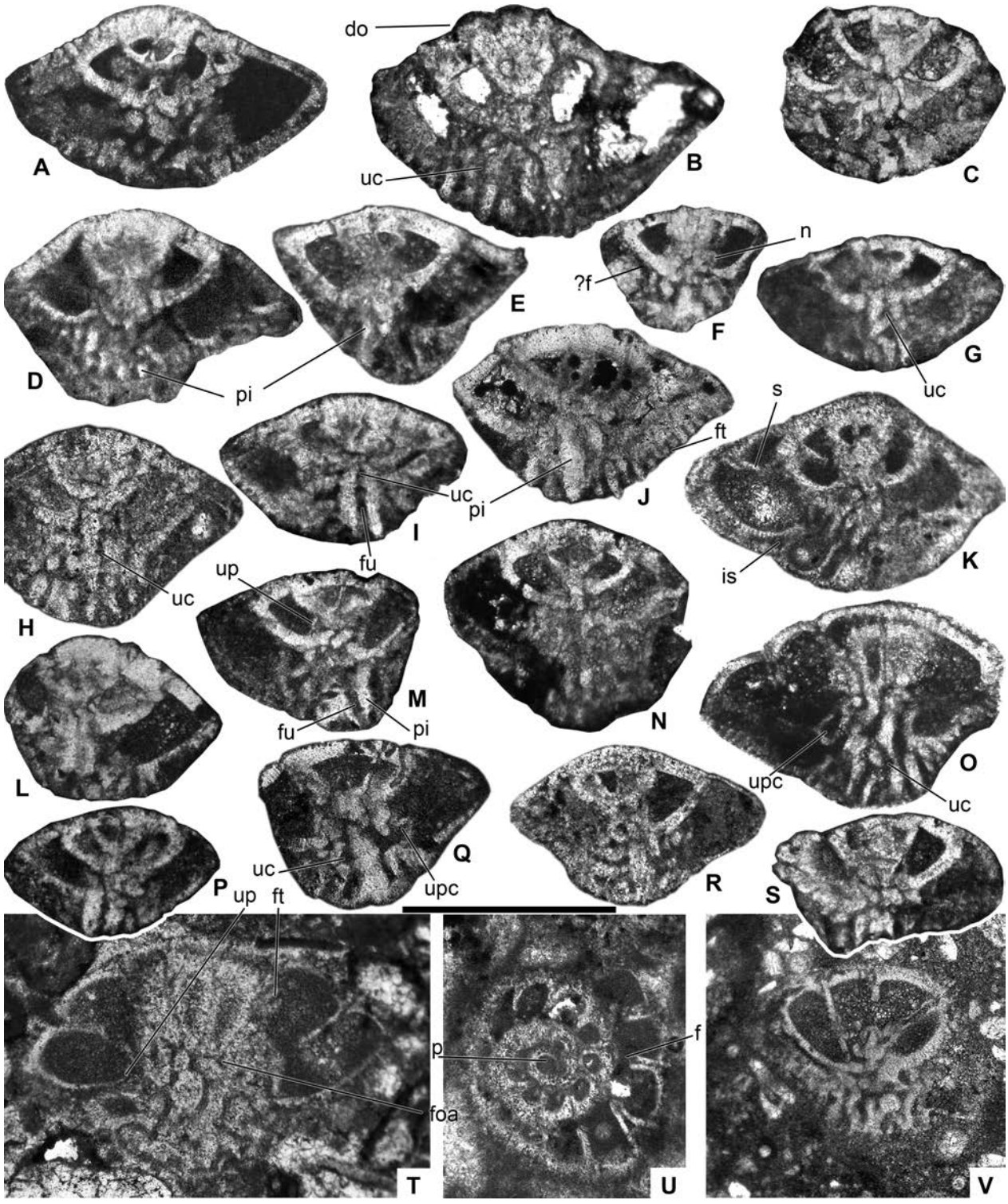
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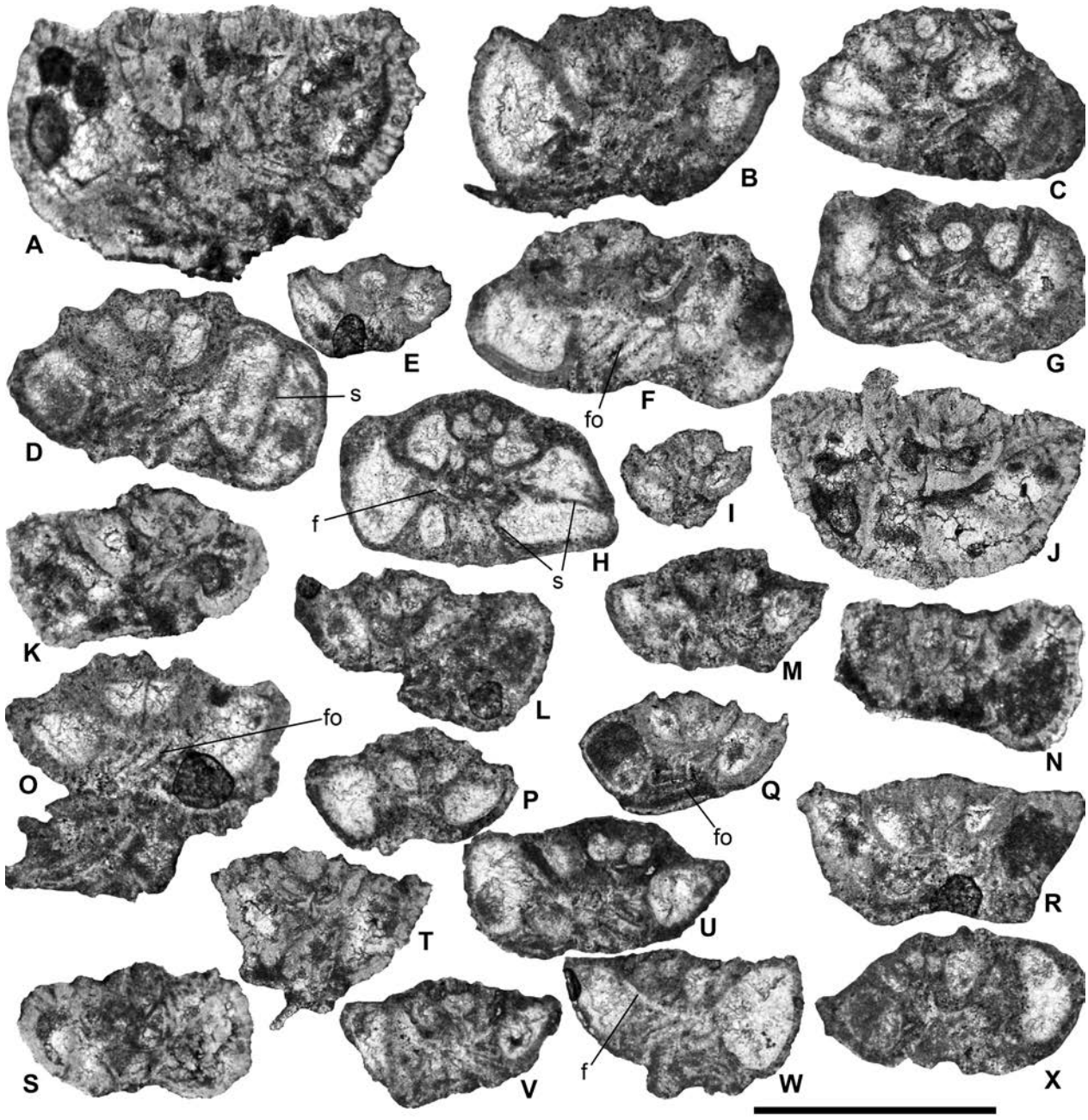
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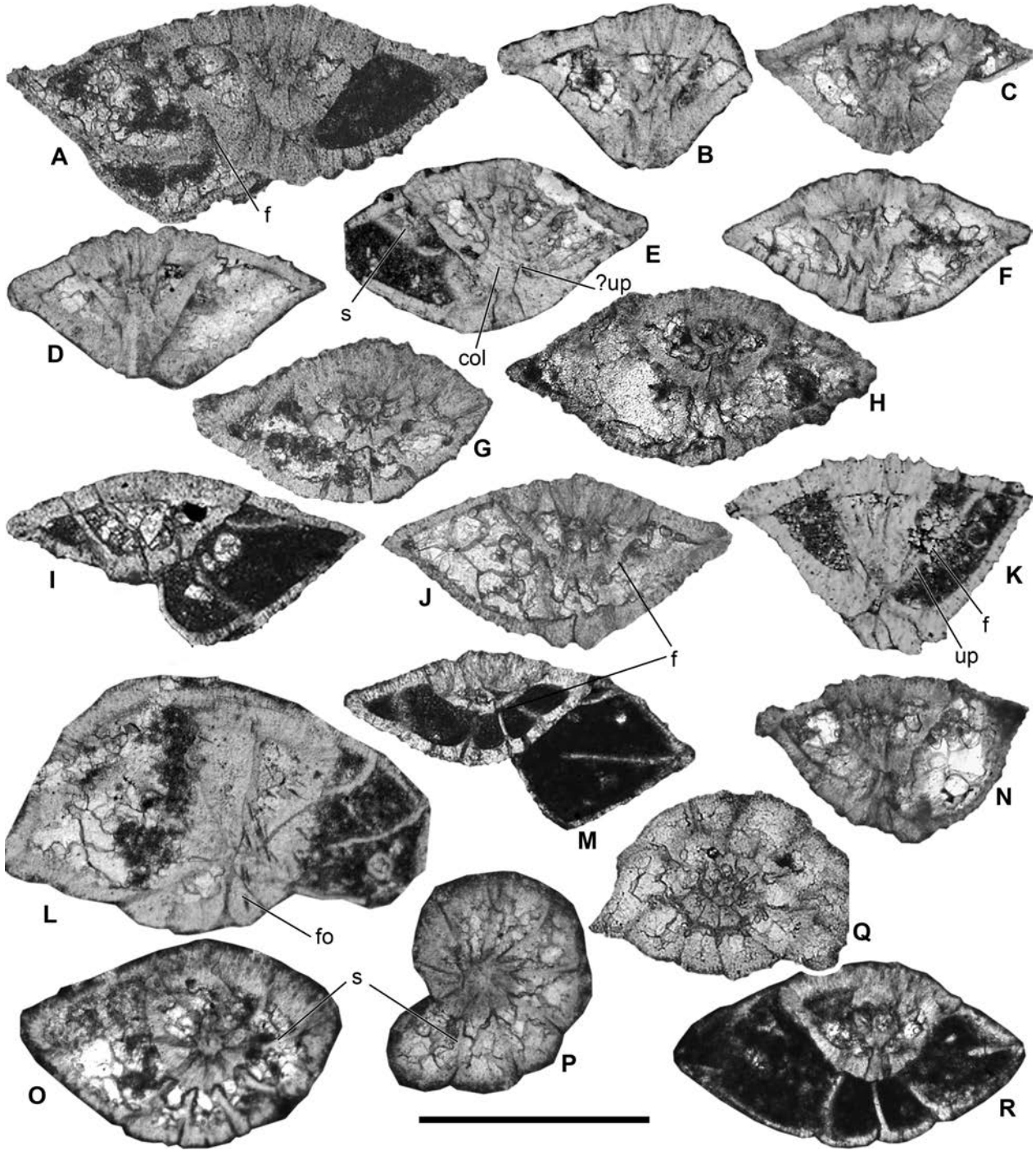
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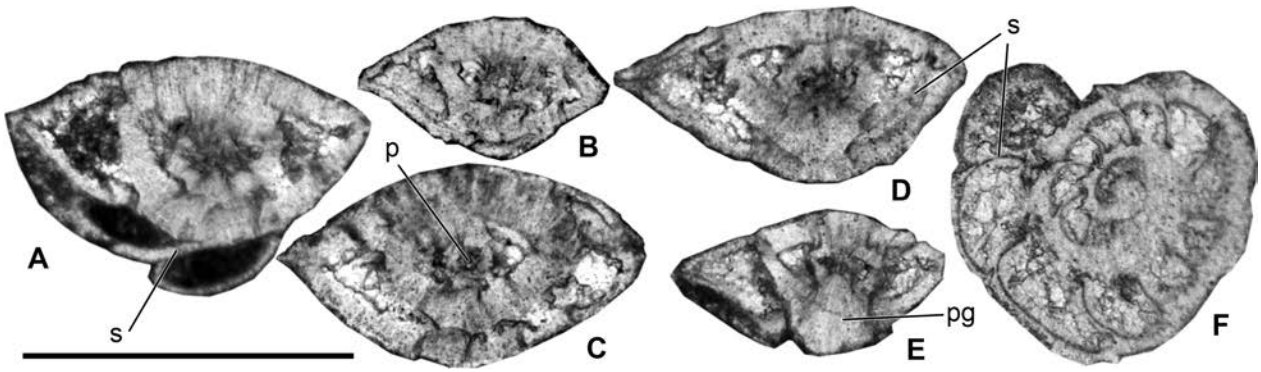
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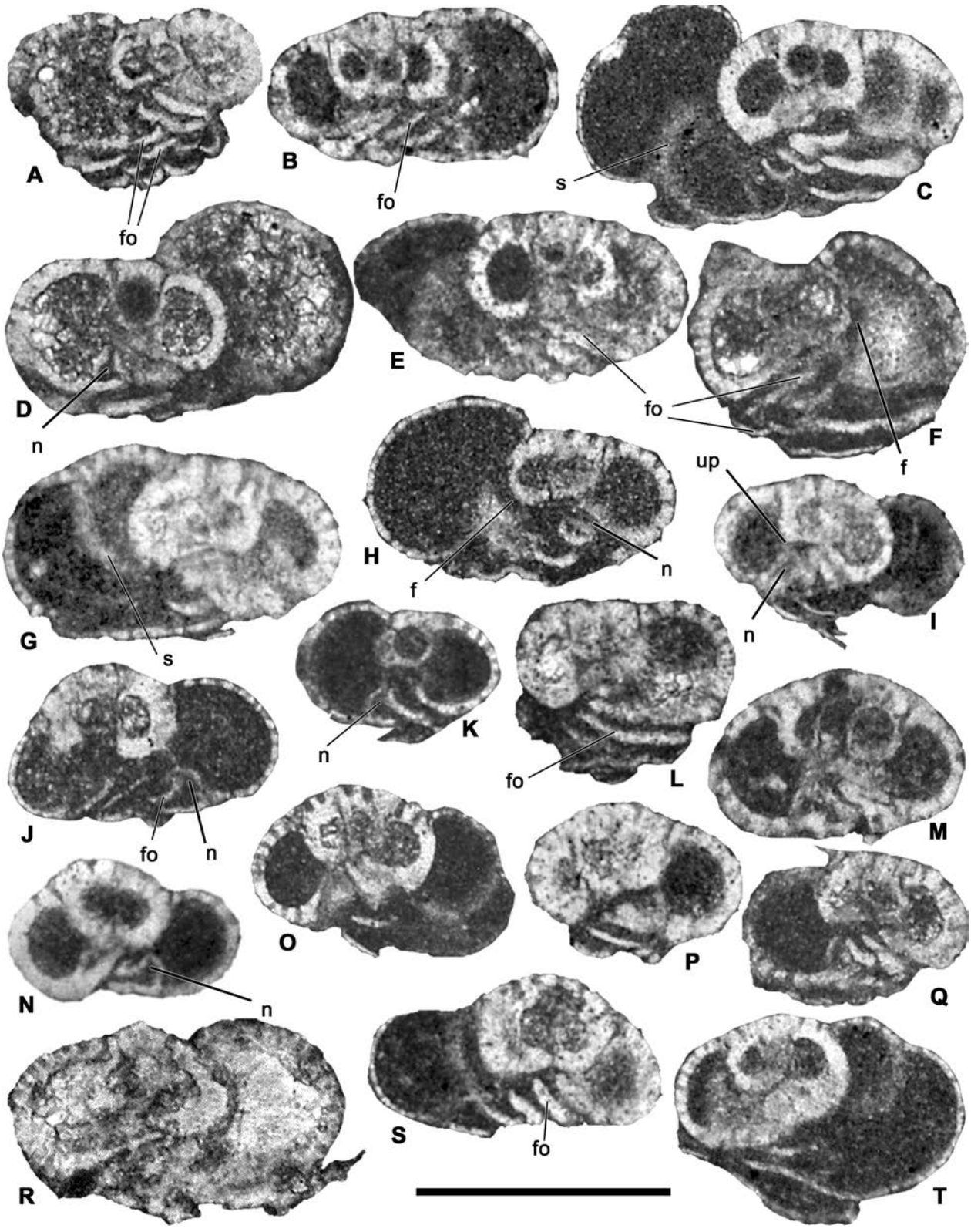
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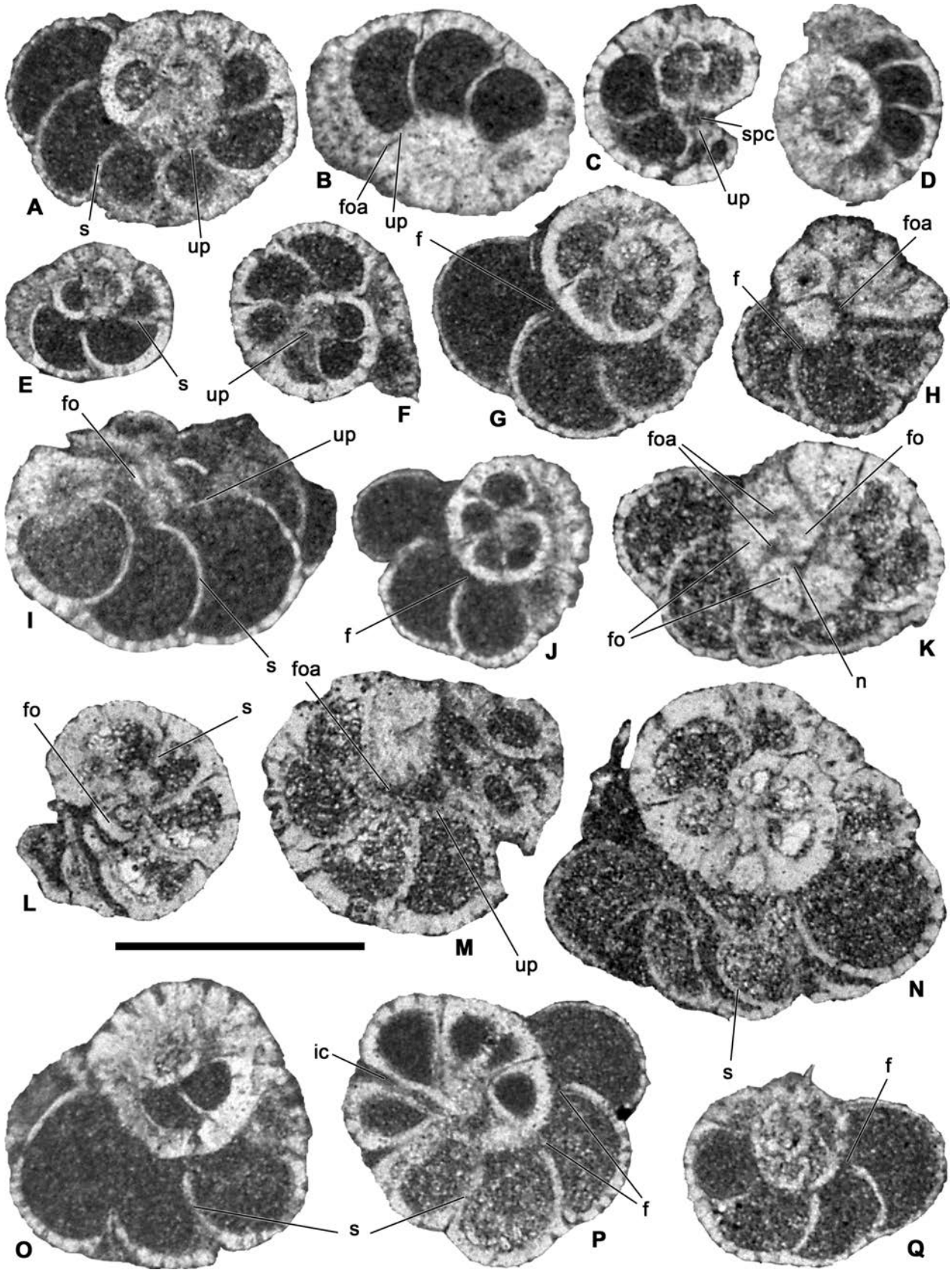
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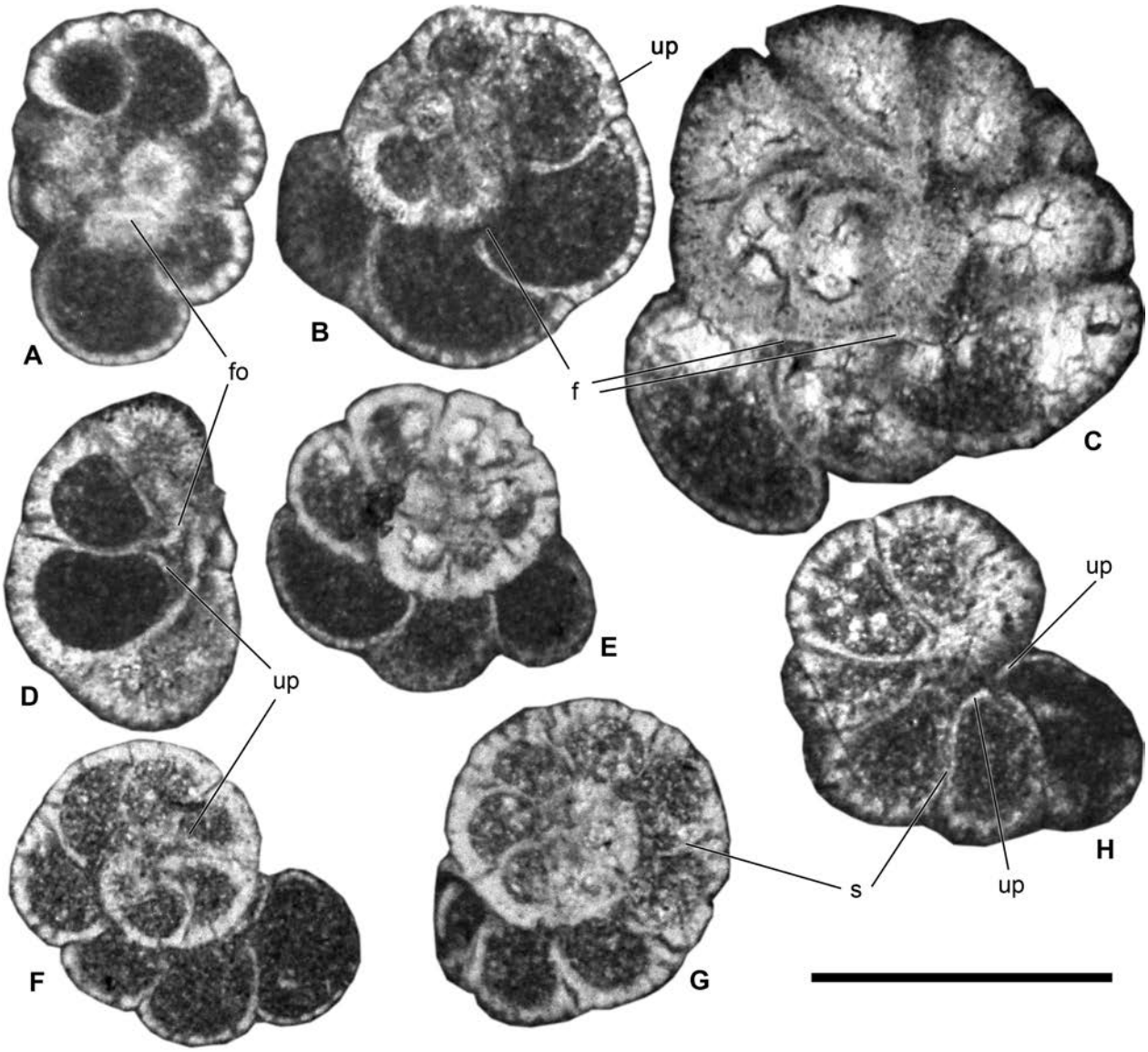
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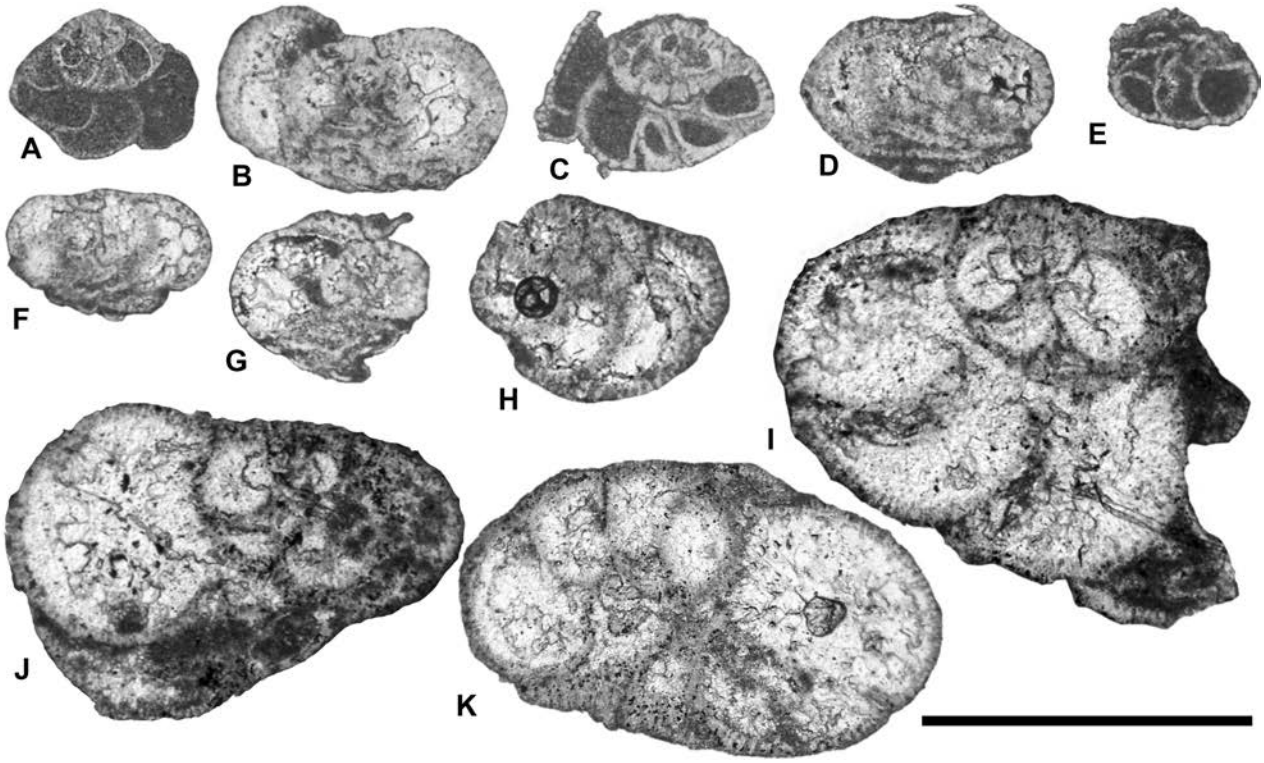
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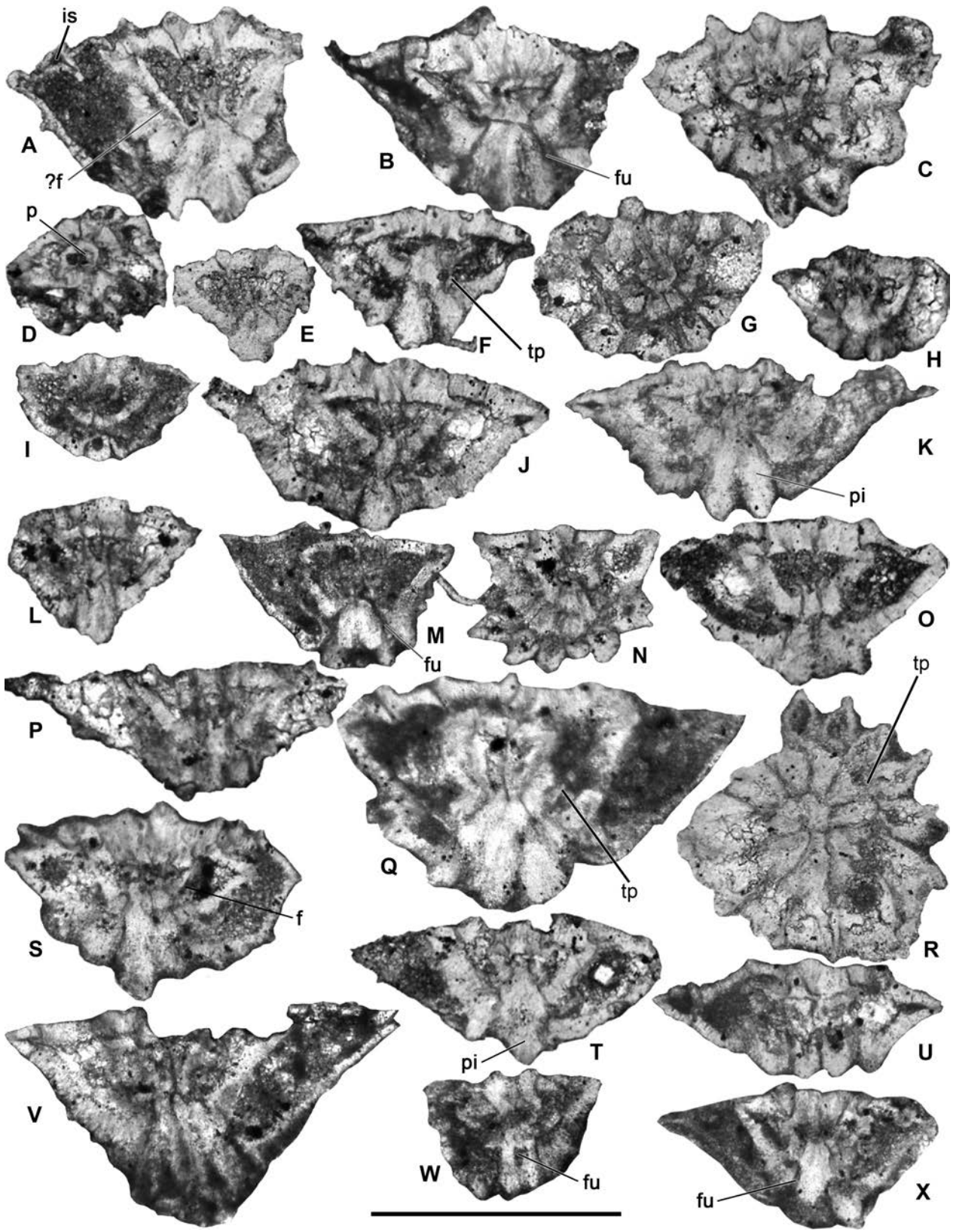
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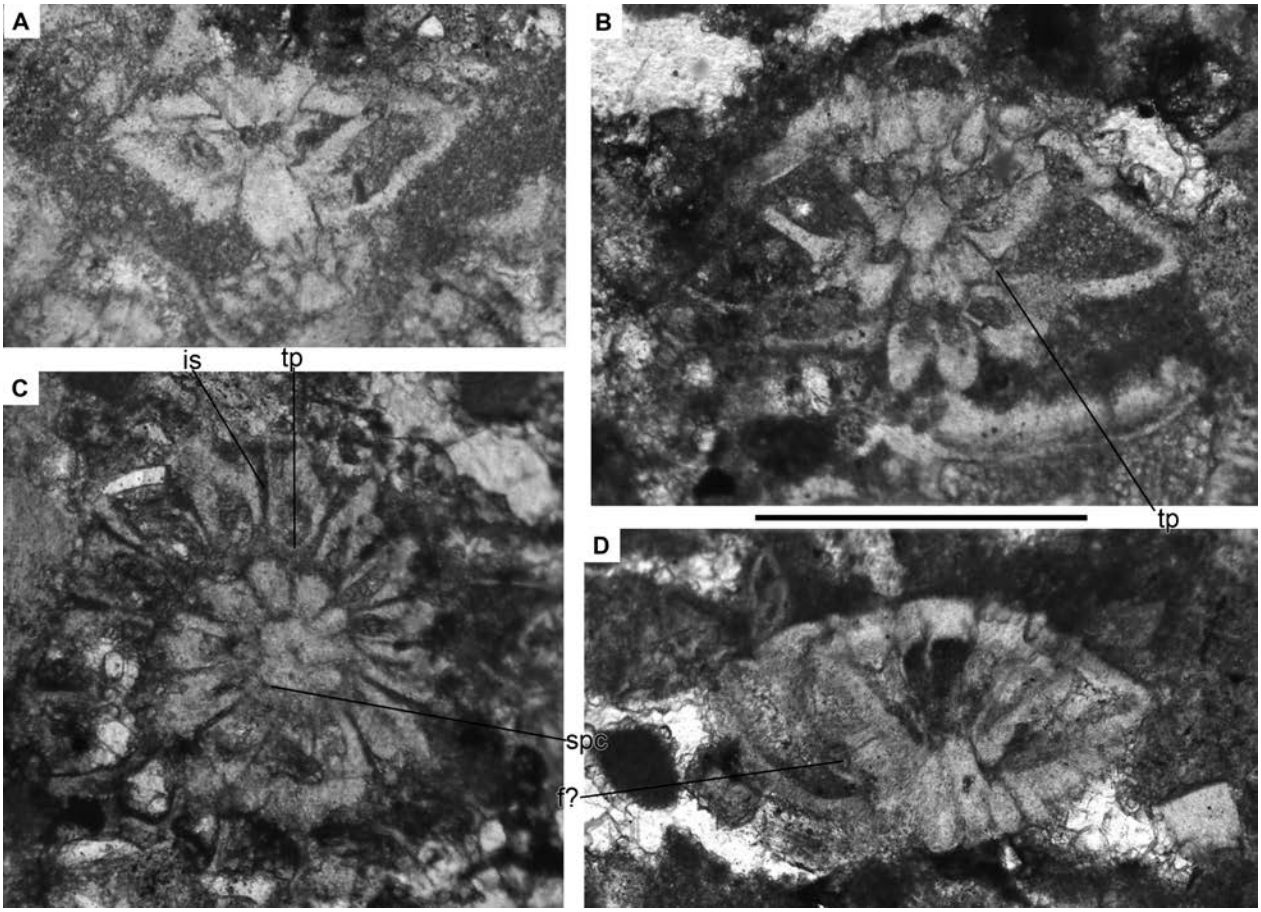
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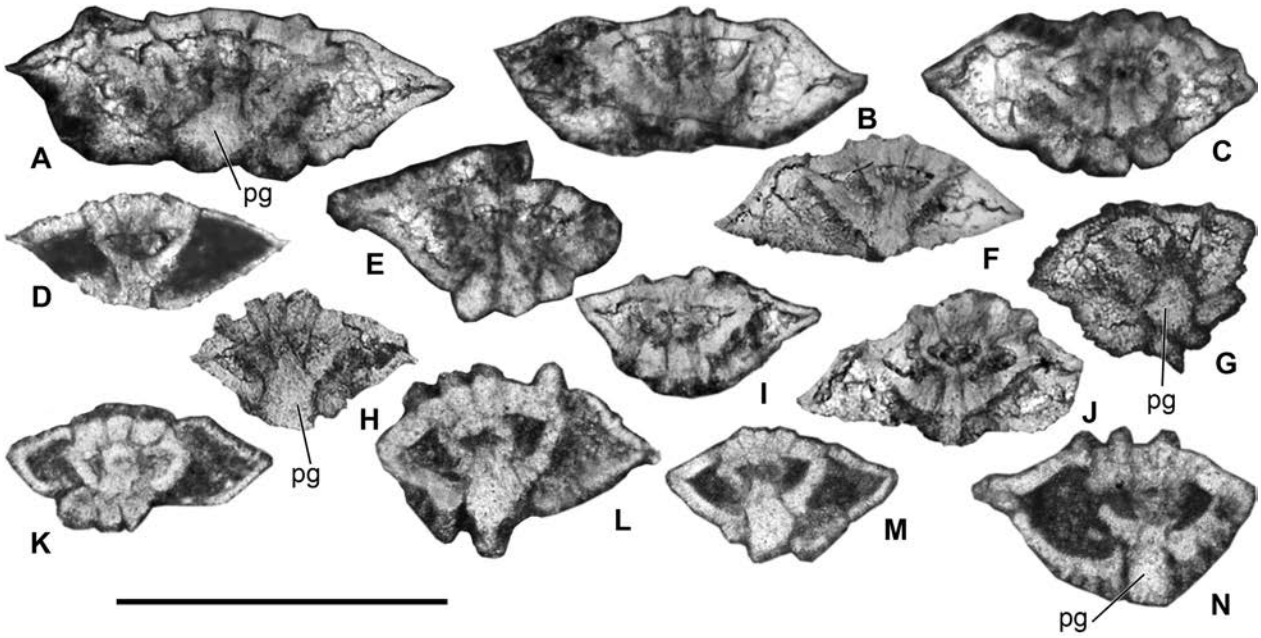
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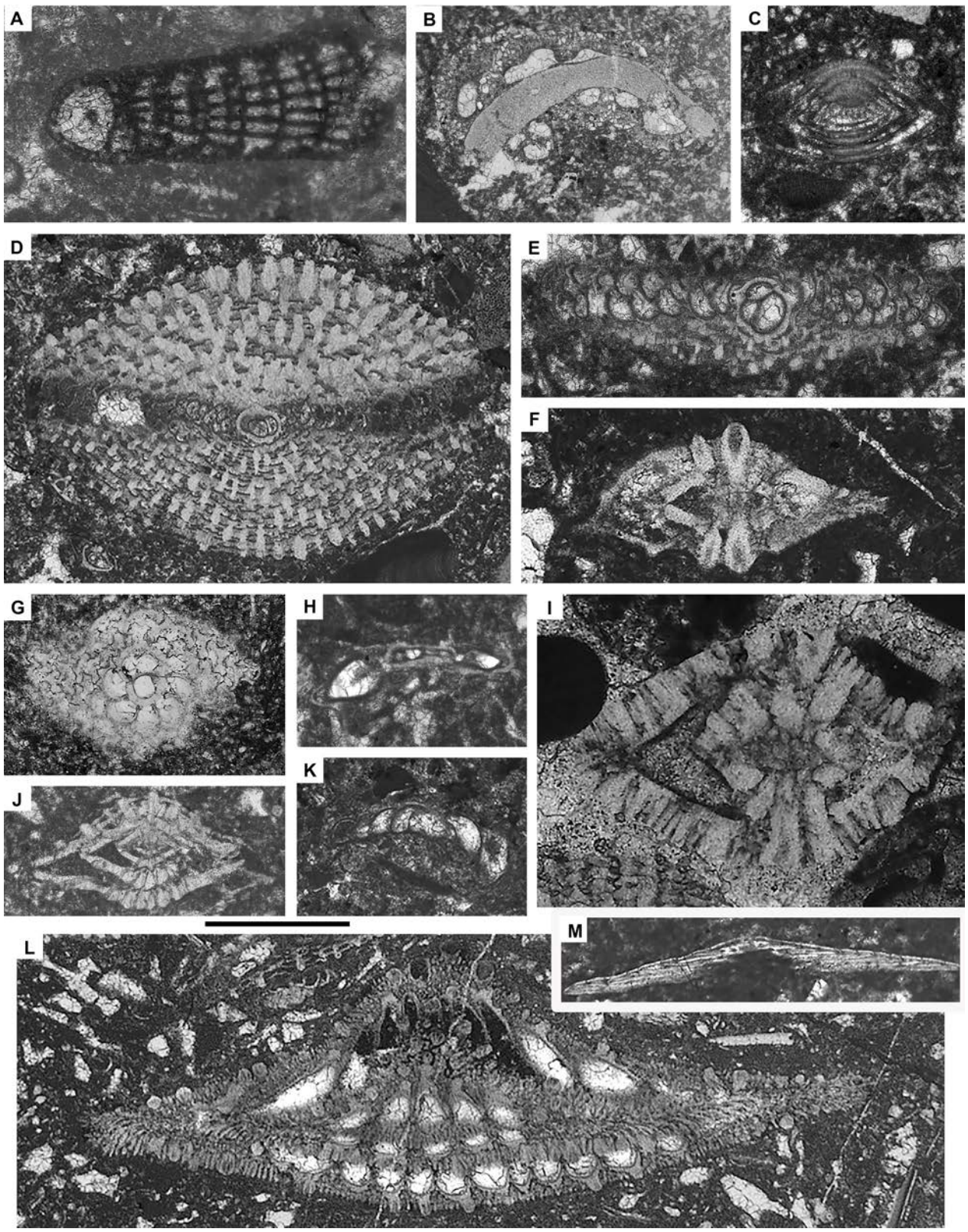
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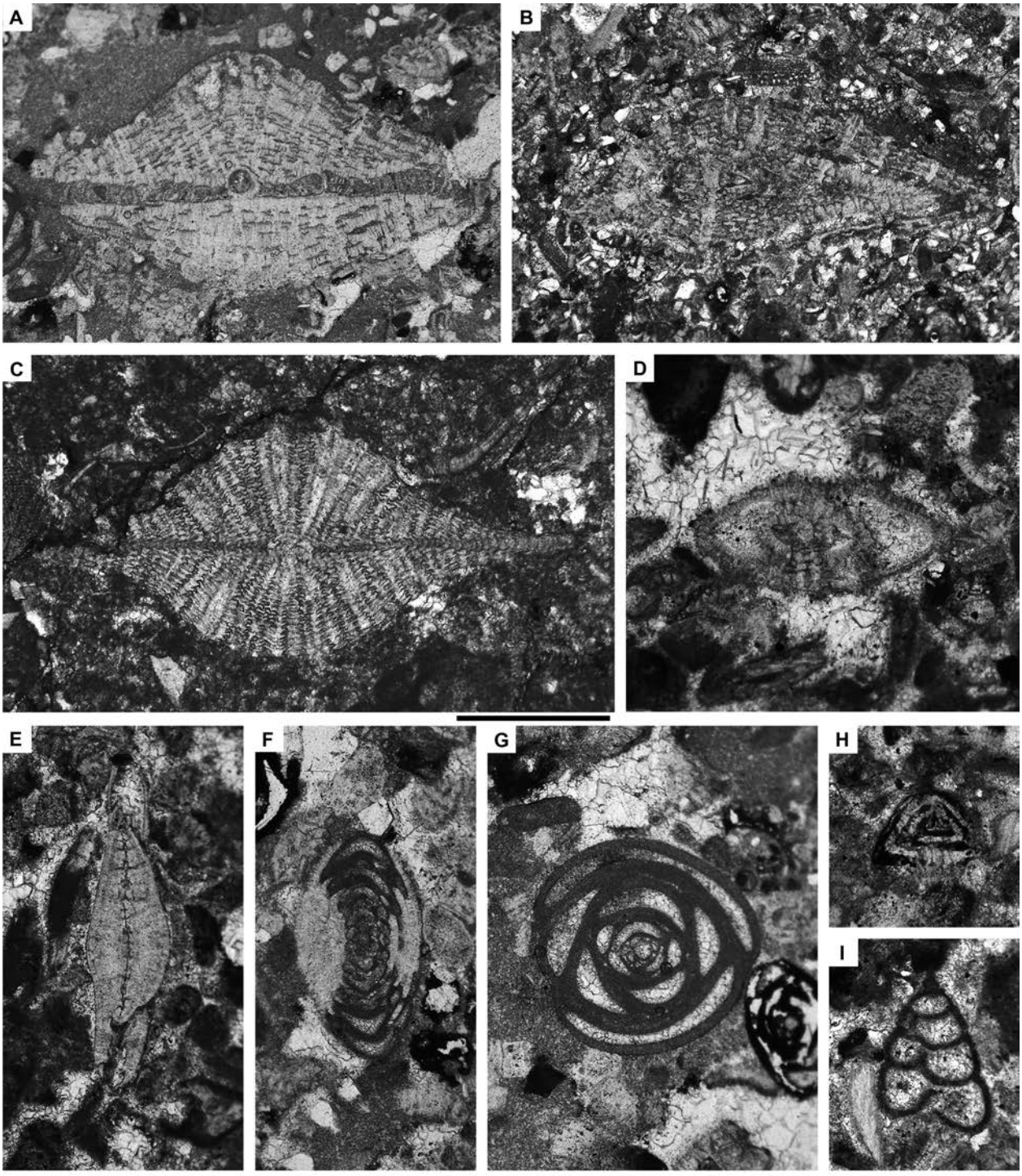
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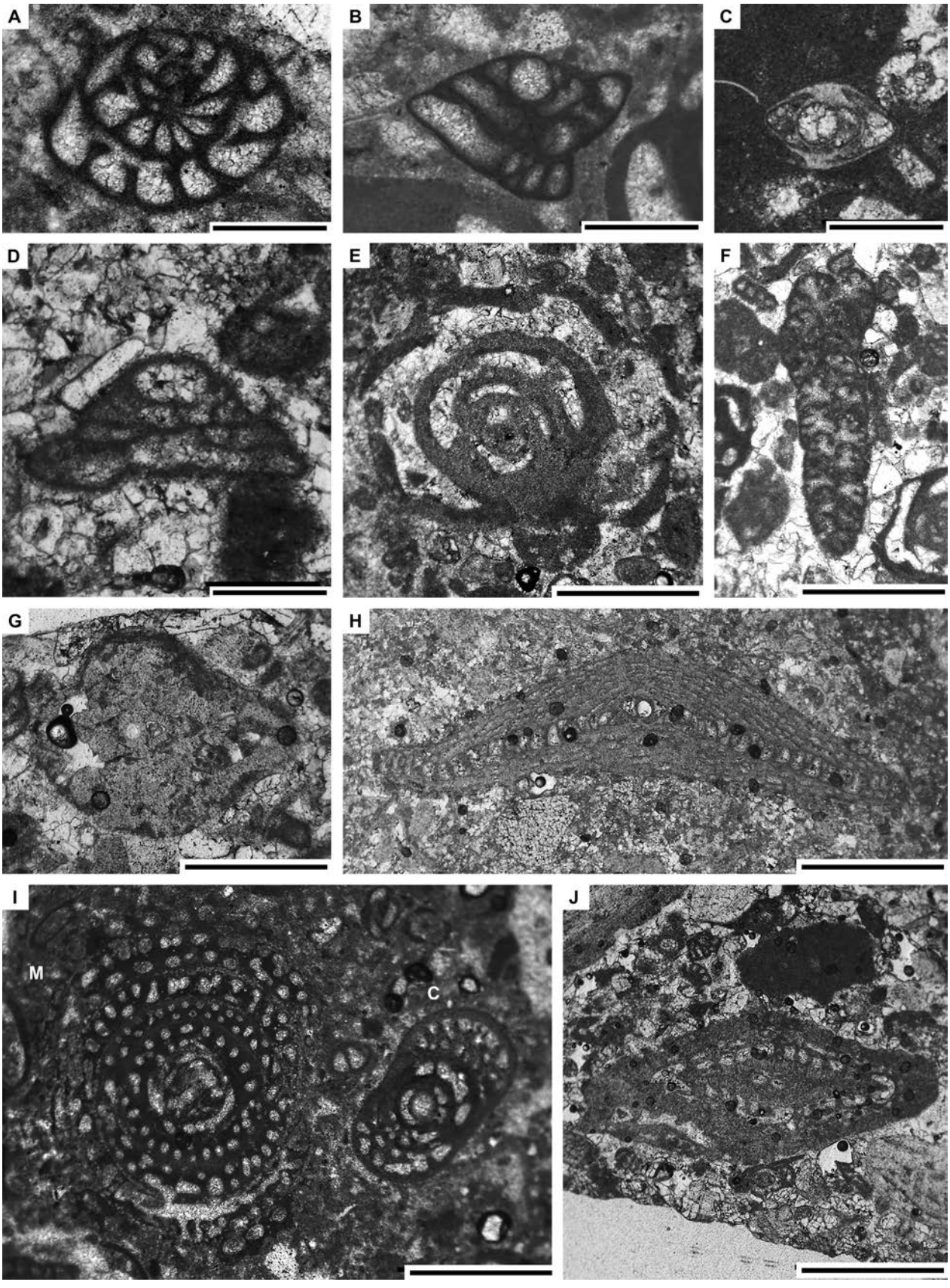
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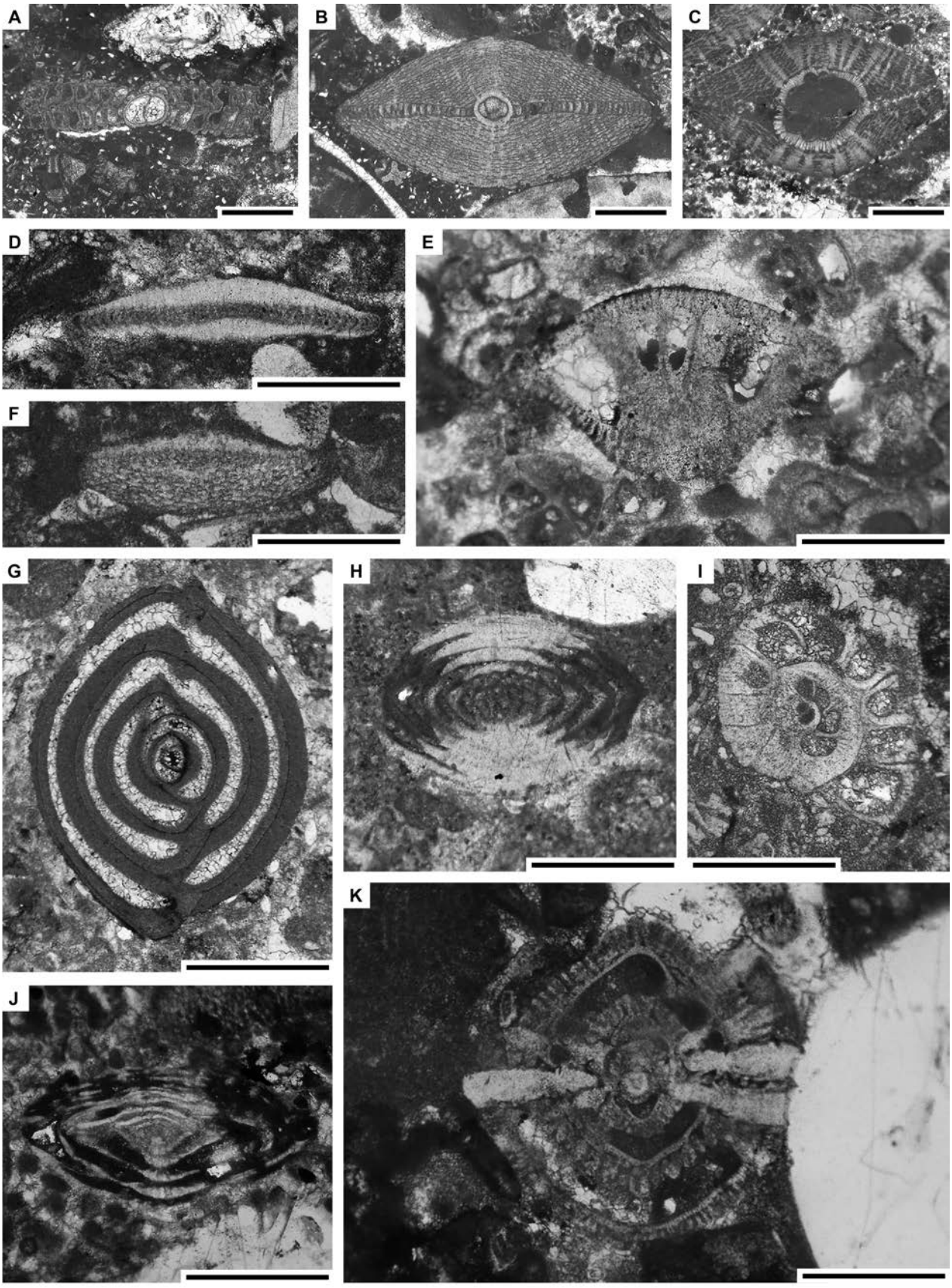
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