Research Article
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# LATE CHATTIAN LARGER FORAMINIFERA FROM THE PREBETIC DOMAIN (SE SPAIN): NEW DATA ON SHALLOW BENTHIC ZONE 23

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ABSTRACT: This study focuses on an Oligocene succession dominated by larger foraminifera and coralline algae in the Benitatxell Range (Prebetic Domain, southeastern Iberian Peninsula). The foraminiferal assemblage, studied in thin sections, and interpreted as Shallow Benthic Zone 23, late Chattian, includes: *Austrotrillina asmariensis*, *Nephrolepidina* spp., *Eulepidina dilatata*, *E. elephantina*, *E. raulini*, *Amphistegina bohdanowiczi*, *A. mammilla*, *Operculina complanata*, *Nummulites* cf. *vascus*, *N.* aff. *kecskemetii*, *Heterostegina assilinoides*, *Spiroclypeus blanckenhorni*, *Cycloclypeus mediterraneus*, *Miogysinoides formosensis*, *Postmiogypsinella* aff. *intermedia*, *Neorotalia viennoti*, *Risananeiza pustulosa*, and *Victoriella conoidea.*

The Rebaldí section, a succession of late Oligocene limestones 3 km north of the Benitatxell section, shows a similar association with *Peneroplis thomasi*, *A. asmariensis*, *M. complanatus*, *Neorotalia viennoti*, *N. lithothamnica*, *Heterostegina* aff. *assilinoides*, *Spiroclypeus blanckenhorni*, *Cycloclypeus mediterraneus*, *A. bohdanowiczi*, and *Risananeiza pustulosa*; it is interpreted as the early part of SBZ 23. This section also contains *Praebullalveolina* aff. *oligocenica*, described from the early Rupelian of Turkey, and *Schlumbergerina alveoliniformis*, previously interpreted as Burdigalian-Recent.

Prior to this work, *Cycloclypeus mediterraneus* was considered to go extinct and be replaced by *C. eidae* at the SBZ 22B-23 boundary. However, its presence in the Benitatxell and Rebaldí sections extends its range to the late Chattian in the Eastern Betics and indicates an asynchronous extinction in the Tethys. The presence of *Amphistegina mammilla* Fichtel and Moll 1798 in late Chattian deposits from the western Tethys contradicts the currently accepted hypothesis that places its origin in the Indo-Pacific province in the early Miocene, from where it would have migrated into the Parathethys during the middle Miocene. In addition, the biogeographic range of *P. thomasi*, *A. asmariensisi*, and *P. oligocenica* is extended to the westernmost part of the Tethys.

## INTRODUCTION

Oligocene larger foraminifera include groups with biostratigraphic significance, such as miogypsinids, lepidocyclinids, and nummulitids, (e.g., Tan Sin Hok 1932; Cosijn 1938; Drooger 1963; van der Vlerk 1963; Drooger and Freudenthal 1964; Drooger and Laagland 1986).

Since the definition of the integrated biozonation of the late Paleogene based on larger foraminifera—i.e., Shallow Benthic Zones (Cahuzac and Poignant 1997, 1998)—numerous biostratigraphic studies of Oligocene deposits from Europe, Turkey, and the Middle East have been performed, refining knowledge of the paleogeographic distribution and chronostratigraphic significance of different foraminiferal groups.

Biostratigraphic studies of Oligocene larger foraminifera in Spain are few (e.g., Gómez Llueca 1929; Cosijn 1938, Didon et al. 1961; Hottinger 1963; Laagland 1990; Braga and Bassi 2011), partly due to the scarcity of shallow-marine outcrops and the highly tectonized context in which they are found. For example, a classical Oligocene section, San Vicente de la Barquera in

northern Spain (van Heck and Drooger 1984), consists of turbiditic deposits in which Oligocene lepidocyclinids and nummulitids are found together with middle-late Eocene nummulitids and orthophragminids, as well as with a few orbitolinids (Ferràndez-Cañadell et al. 1999).

Here we report a late Oligocene foraminiferal assemblage from the Benitatxell Range and Rebaldí, near Alacant (SE Spain), in the eastern end of the External Prebetic of the Betic Cordillera. The studied sections correspond to a carbonate platform with foraminifera, coralline algae and corals (see Bover-Arnal et al. 2017). Previous data on Chattian deposits from this zone, reporting foraminifera mainly at the generic level, come either from stratigraphic and tectono-stratigraphic studies (e.g., Serra-Kiel et al. 1998; Geel 1995, 2000; Stoklosa and Simo 2008) or from the explanation notes of the Geological Map of Spain 1:50,000 of the Instituto Geológico y Minero de España (e.g., Vegas et al. 1973; Lendínez Gonzalez et al. 1993).

The results of this study allow a better characterization of SBZ 23 in the late Chattian. Species previously unknown in the late Chattian are also reported within this zone. The association, located in the westernmost Tethys, also supplies useful data for paleobiogeographic reconstructions of late Chattian foraminifera.

## GEOLOGICAL SETTING

The investigated late Oligocene carbonate succession containing larger foraminifera is located in the External Prebetic Zone of the Betic Cordillera in the southeastern Iberian Peninsula (Fig. 1). The External Prebetic comprises a mixed carbonate-siliciclastic succession of Mesozoic to early Cenozoic deposits on the South Iberian passive continental margin of the Tethys (García-Hernández et al. 1980; Vera 2000; Höntzsch et al. 2013). This sedimentary succession, which is located in the eastern end of the External Prebetic Domain (Fig. 1), is strongly tectonized due to the Pyrenean collision (Oligocene), the Betic orogeny (Miocene), and perhaps the opening of the Gulf of València (late Oligocene–early Miocene) (Fontboté et al. 1990; Geel 1995).

The late Oligocene larger foraminifera were sampled in outcrops found in the surroundings of El Poble Nou de Benitatxell in the province of Alacant (Fig. 1). There, late Oligocene rocks, which are also characterized by the presence of coralline algae and corals, give rise to the western part of the Benitatxell Range, and also crop out in the Rebaldí area located to the north of El Poble Nou de Benitatxell (Fig. 1). In Rebaldí, the larger foraminifera-bearing platform carbonates of late Oligocene age, up to 9 m thick, unconformably overlie a Cretaceous substrate made up of well-bedded white limestones with planktic foraminifera (Vegas et al. 1973). This unconformity is the result of a compressive phase accompanied by uplift and subaerial exposure linked to the late Eocene–early Oligocene Pyrenean collision (Geel 1995; Stoklosa and Simo 2008). The top of the late Oligocene limestone succession examined is not preserved due to erosion.

In the Benitatxell Range, the analyzed late Oligocene platform carbonates, up to 40 m thick, overlie an early(?) to late Oligocene deeper-water sedimentary record, about 200 m thick, formed of echinoid-bearing limestones and interbedded marls and limestones with planktonic foraminifera and glauconite (Vegas et al. 1973). The limestones with echinoids contain *Eulepidina dilatata* (Vegas et al. 1973). The alternating marls and limestones with abundant planktonic foraminifera have been interpreted as a flysch succession by Vegas et al. (1973) and Lendínez Gonzalez et al. (1993). The late Oligocene carbonate system sampled in the Benitatxell Range was drowned around the Oligocene/Miocene boundary and buried by hundreds of meters of marls and silty limestones containing abundant planktonic foraminifera and glauconite of early Miocene age (Vegas et al. 1973; Lendínez Gonzalez et al. 1993).

The studied succession in interpreted as a homoclinal ramp that developed during a marine transgression of Oligocene age (Rebaldí) onlapping Cretaceous rock with a paleotopographically irregular surface. During the subsequent regression, the proximal parts of the ramp were subaerially exposed and the carbonate system prograded basinwards (Benitatxell Range). During this transgressive-regressive sequence, the proximal ramp (Rebaldí) was

characterized by the presence of abundant colonial corals in life position, benthic foraminifera and coralline algae, whereas more distal parts (Benitatxell Range) were dominated by benthic foraminifera and coralline algae. These benthic foraminifera- and coralline algae-bearing deposits pass basinwards into deeper hemipelagic deposits rich in echinoids and planktonic foraminifera (Benitatxell Range). For a detailed description of the depositional architecture and the recorded changes in accommodation see Bover-Arnal et al. (2017).

## MATERIAL AND METHODS

Three sections, Torre Garcia-Cim del Sol Road, Accés Sud Road, and Albacete Road, were logged and sampled along a kilometer-scale continuous carbonate succession of Oligocene age with larger foraminifera and coralline algae in the northwestern part of the Benitatxell Range (Prebetic Domain, southeastern Iberian Peninsula) (Fig. 1). The foraminifera and coralline red algal limestone beds overlie turbiditic levels and are capped by a Miocene marly succession with interbedded marls, clays and silty limestones with glauconite; the succession is barren of larger foraminifera, except for the uppermost part of the turbidites. A fourth section, Rebaldí, was logged in a northern outcrop, in which a short succession (< 8m) of Chattian limestones unconformably overlies Late Cretaceous limestones (Fig. 1). For more detailed descriptions of the sections see Bover-Arnal et al. (2017).

All the studied specimens come from 134 thin sections of 35 limestone samples (Fig. 1), collected along 207 m of stratigraphic section. Except for a very few specimens, the studied thin sections are not strictly centered equatorial or axial sections. Consequently, the measurements provided in the descriptions are approximate, and might be slightly smaller than the real values. The thin sections are reposited at the Faculty of Geology of the University of Barcelona. Following Zalasiewicz et al. (2004), we use the terms ‘early’ and ‘late’ to qualify both geological time units and lithological-time units (avoiding ‘lower’ and ‘upper’ for the latter), except when referring to previous work, in which case we respect the term used by the original author.

## RESULTS

### Benitatxell Range

The foraminiferal assemblage characterized in the three studied sections in the Benitatxell Range shows slight vertical and lateral variations due to changes in environmental factors. Large rotaliids dominate in the lower part of the sedimentary record, while porcellaneous *Austrotrillina* is found only in the middle part of the succession, together with colonial corals and fragments of green algae. Miogypsinids are more abundant in the upper part.

The foraminiferal assemblage includes the following taxa: *Austrotrillina asmariensis* Adams 1968, *Eulepidina dilatata* (Michelotti 1861), *E. raulini* (Lemoine and Douvillé 1904), *Eulepidina elephantina* (Munier-Chalmas 1891), *Miogypsinoides formosensis* Yabe and Hanzawa 1928, *Postmiogypsinella* aff. *intermedia* Sirel and Gedik 2011, *Operculina complanata* (Defrance 1822), *Operculina* sp., *Heterostegina assilinoides* Blanckenhorn 1890 emend. Henson 1937, *Spiroclypeus blanckenhorni* Henson 1937, *Cycloclypeus mediterraneus* Matteucci and Schiavinotto 1985, *Nummulites* cf. *vascus* Joly and Leymerie 1848, *N.* aff. *kecskemetii* Less 1991, *Risananeiza pustulosa* Boukhary, Kuss and Abdelraouf 2008, *Neorotalia viennoti* Greig 1935, *Amphistegina bohdanowiczi* Bieda 1936, *Amphistegina mammilla* (Fichtel and Moll 1798), *Victoriella conoidea* (Rutten 1914), *Carpenteria* sp., *Planorbulinella* sp., *Sphaerogypsina* sp., and *Gypsina vesicularis* (Parker and Jones 1860).

This association corresponds to Shallow Benthic Zone SBZ 23 of Cahuzac and Poignant (1997, 1998), late Chattian, defined by the presence of *M. formosensis*; other species, such as *H. assilinoides*, *S. blanckenhorni*, *E. dilatata*, *E. elephantina*, are also common in this zone. The distribution of the species with biostratigraphic relevance in the sections from the Benitatxell Range is shown in Figure 2.

Rebaldí Section

The association in the Rebaldí section (Fig. 3) includes *Peneroplis thomasi* Henson 1950, *A. asmariensis*, *Praebullalveolina* aff. *oligocenica* Sirel and Özgen-Erdem 2013, *M. complanatus* (Schlumberger 1900), *H. assilinoides*, *S. blanckenhorni*, *C. mediterraneus*, *N. viennoti*, *N. lithothamnica* (Uhlig 1886), *R. pustulosa*, *A. bohdanowiczi*, *Planorbulina* sp., *Planorbulinella* sp, *Carpenteria* sp., *Sphaerogypsina* sp., *Gypsina* sp., *Miniacina* sp., *Haddonia heissigi* Hagn 1968, and *Schlumbergerina alveoliniformis* (Brady 1879).

This association also corresponds to SBZ 23, although the presence of *M. complanatus* instead of *M. formosensis*, together with the smaller embryo size observed in *H. assilinoides* and *S. blanckenhorni* indicates an older age relative to the association from the Benitatxell Range.

The distribution of the species with biostratigraphic relevance in Rebaldí is shown in Figure 2.

DISCUSSION

The extension of the description and discussion of the different species depends on the available data, the current state of their systematics, and the novelty and relevance of the results with respect to previous knowledge of their late Oligocene biostratigraphy and paleobiogeography. Because this study is based on random sections of foraminifera in thin section, some species determinations are tentative. However, in order to simplify the text, we have limited the use of *affinis* and *confer* (aff., cf.) assignments to those species for which we had a small number of specimens or insufficient data or thin sections.

Family SCHLUMBERGERINIDAE Mikhalevich 1980

*Schlumbergerina alveoliniformis* (Brady 1879)

Figure 3L

1879 *Miliolina alveoliniformis* n. sp., Brady, p. 268.
1884 *Miliolina alveolinaformis* H.B. Brady, Brady, p. 181, pl. 8, figs. 15–20.
1971 *Schlumbergerina areniphora* Munier-Chalmas, Hofker, p. 15, pl. 4, figs. 16–24.
2006 *Schlumbergerina alveoliniformis* (Brady), Hottinger, fig. 6F–6H.
2006 *Schlumbergerina* sp., Daneshian and Yazdani, pl. 2, fig. 3

Test elongate, fusiform, with quinqueloculine chamber arrangement. Wall porcellaneous, later chambers irregularly agglutinated with coarse sediment grains. Only one specimen was found: a megalospheric form in centered axial section, measuring 8.5 mm in length and 4.2 mm in thickness; the section of the embryo measures 44 μm in diameter. The characteristic trematophore aperture of this species is not clearly visible, but the size of the test and the embryo and the chamber arrangement and agglutinating pattern is very similar to the few specimens figured in section (Hofker 1971; Hottinger 2006). The genus was transferred from the Order Miliolida (Family Hauerinidae) to the the Order Schlumbergerinida (Family Schlumbergerinidae) by Mikhalevich and Kaminski (2008). Recent *S. alveoliniformis* has a world-wide distribution in shallow-reefal environments, but there are few references to the fossil record of this genus, all of them of Miocene age, and with a wide geographic range. *Schlumbergerina alveoliniformis* has been reported from the Burdigalian of the Chipola Formation in Florida (Baker 2011), while *Schlumbergerina* sp. has been reported from the Burdigalian of Iran (Daneshian and Yazdani 2006; Roozbahani 2011; Ghiami et al. 2014; Roozbahani and Sabzevari 2015). The specimen figured in Daneshian and Yazdani (2006, fig. 3, pl. 2) is very similar to the specimen from the Rebaldí section. Other figured specimens (e.g., Roozbahani 2011, fig. 23) show a small and simple test that cannot be assigned with certainty to *S. alveoliniformis*. The identification of *S. alveoliniformis* in the Prebetic Zone extends the fossil record of this species to the late Chattian (i.e., from SBZ 25 to SBZ 23).

Family PENEROPLIDAE Schultze 1854

Genus *Peneroplis* de Montfort 1808

*Peneroplis thomasi* Henson 1950

Figure 3B

1981 *Peneroplis thomasi* Henson, Radoičić, pl. 1, figs. 3, 4.
2011 *Peneroplis thomasi* Henson, Yazdi-Moghadam, pl. 2, fig. 8.
2014 *Peneroplis thomasi* Henson, Habibi, pl. 2, fig. 15.
2014 *Peneroplis thomasi* Karevan et al., fig. 5C.

A *Peneroplis* with involute nepionic stage and and evolute post-nepionic chambers tending to become annular. It lacks endoskeleton (pillars), but according to Hottinger (2007) could be the ancestral form that gave rise to a phylogenetic lineage of archaiasines, starting with *Archaias asmaricus* Smout and Eames 1958.

Its stratigraphic range is Rupelian-Aquitanian (e.g., Eames et al. 1962). According to Bassi et al. (2007), who did not find it in the upper Oligocene of northeastern Italy, it is known only in the Middle East (Iran, Iraq, Oman, and Turkey). The identification of this species in the Rebaldí section (sample OM-5, Fig. 3B) thus considerably extends its geographic distribution towards the western Tethys.

Family AUSTROTRILLINIDAE Loeblich and Tappan 1987

Genus *Austrotrillina* Parr 1942

*Austrotrillina asmariensis* Adams 1968

Figures 3A, 4A–4G

1968 *Austrotrillina asmariensis*, Adams, pl. 1, figs. 1–12.
1994 *Austrotrillina* sp., Parente, pl. 3, fig. 5.
1998 *Austrotrillina asmariensis*, Accordi et al., pl. 8, fig. b.; pl. 17, fig. 10.
2001 *Austrotrillina asmariensis*, Gallardo et al., pl. 1, fig. 11.
2005 *Austrotrillina asmariensis*, Boudagher-Fadel and Lokier, pl. 1, figs. 1, 2.
2005 *Austrotrillina howchini*, Boudagher-Fadel and Lokier, pl. 1, fig. 3.
2007 *Austrotrillina asmariensis*, Bassi, Hottinger, and Nebelsick, text-fig. 6A, 6B.
2011 *Austrotrillina striata*, Singh et al., pl. III, figs. ?5, 10.
2014 *Austrotrillina asmariensis*, Gedik, pl. 4, figs. 1–13.
2015 *Austrotrillina asmariensis*, Gedik, pl. 1, figs. 12–16, 24, 29.
2015 *Austrotrillina howchini*, Lawa and Ghafur, pl. 4, figs. 2, 3.

This species is characterized by trilocular growth and exoskeletal pattern (Figs. 3A, 4A–4G) with fine but not bifurcating and closely spaced alveoli (see original diagnosis in Adams 1968, p. 83). The specimens from the Prebetic are slightly larger than those in the original description by Adams (1968). The diameter of the microspheric form (Fig. 4E) is 1.29 mm, slightly larger than the 0.5–1.0 mm reported by Adams (1968). The diameter of the alveoli (15–26 μm) and the thickness of the wall (84–95 μm, reaching locally 118 μm) are also somewhat larger than those in the original description by Adams (1968, p. 83: 10–20 μm, usually 50–80 μm, rarely up to 110 μm). The number of alveoli/100 μm in cross section, 2–4, is intermediate between *A. striata* and *A. asmariensis* in the description in Adams (1968: three or more in *A. asmariensis*, 2–3 in *A. striata*), but similar to the 2–3 described by Bassi et al. (2007).

The most similar species are *A. striata* Todd and Post 1954, and *A. howchini* (Schlumberger) 1893, from which it can be distinguished mainly by the size and pattern of the alveoli. In *A. striata* the alveoles are broad and widely spaced, whereas in *A. howchini*, they are broad and bifurcating (Fig. 4A). Adams (1968) stated the difficulty in determining certain specimens which show intermediate characters between these two species (see Adams 1968, pl. 5). The specimens from Rebaldí (Fig. 3A) and Benitatxell (Fig. 4C–4G) show a few bifurcations in the exoskeleton, a feature also observed in microspheric forms by Adams (1968), and belong clearly to *A. asmariensis*. The alveoli are finer and more closely spaced than in the specimens

from Italy (Accordi et al. 1998), similar to the alveoli in specimens from northern Italy (Bassi et al. 2007), and especially similar to those from the Rupelian–early Chattian of the Develi section in western Malatya, Turkey, figured by Gedik (2015).

Boudagher-Fadel and Banner (1999), in their chronostratigraphic chart (reproduced in McGowan 2012, fig. 15) interpreted *A. asmariensis* as a Miocene descendant of Oligocene–Miocene *A. striata*. Their interpretation of the biostratigraphic range of *A. asmariensis* as early Miocene (Aquitanian?–Burdigalian) is not in agreement with the range given by Adams (1968), Rupelian–Aquitanian, and it is contradicted by its occurrence in the Rupelian and early Chattian sediments in Oman (Gallardo et al. 2001) and Turkey (Gedik 2015), and in upper Chattian deposits from northern Italy (Bassi et al. 2007 and references therein), western Greece (Accordi et al. 1998), and southern Spain (this paper). A comprehensive revision of the distribution of this species can be found in Bassi et al. (2007). Also, the specimens reported by Singh et al. (2011) from the upper Chattian (SBZ 23, with *Miogypsinoides complanatus*) of Gujarat (India) as *A. striata* probably belong to *A. asmariensis*.

Previous studies set the westernmost record of *A. asmariensis* in northern Italy (Bassi et al. 2007, text-fig. 9). Its occurrence in Benitatxell (Prebetic domain) extends the geographic distribution of this species almost 1,000 km westward, depending on different paleogeographic reconstructions (Lorenz et al. 1993; Rögl 1998; Meulenkamp and Sissingh 2003). The presence of *Austrotrillina* in the upper Oligocene of the Betic realm (Moratalla, southeastern Spain) was previously reported by Hottinger (1963), although it corresponds to *A. howchini*.

Family ALVEOLINIDAE Ehrenberg 1839

Genus *Praebullalveolina* Sirel and Acar 1982

*Praebullalveolina* aff. *oligocenica* Sirel and Özgen-Erdem 2013

Figure 3C

Only three subaxial sections were found; the largest (Fig. 3C) is 647 μm long and 433 μm thick. Although the details of the structure are not clearly visible, this form is very similar in size, in the miliolid initial growth, and the subdivision of chambers to the early Rupelian species of *Praebullalveolina* from central Turkey described by Sirel et al. (2013). It is more similar to *P. oligocenica* Sirel and Özgen-Erdem 2013 in the simple pattern of chamber subdivision, although it resembles *P. minuta* Sirel and Özgen-Erdem 2013 in test size. It occurs together with *Miogypsinoides complanatus* and *Risananeiza pustulosa*, so that it is placed in SBZ 23 (lower part). Based on the difference in age with the known species (early Rupelian; Sirel et al. 2013), it could belong to a new species. More material is needed for a confident species characterization.

*Praebullalveolina* was defined from late Eocene deposits (*P. afyonica*, Sirel and Acar 1982), and later recognized (and redefined) in early Rupelian deposits (*P. oligocenica*, *P. minuta*, Sirel et al. 2013). Although it requires confirmation, its presence in the Prebetic Range extends its range into the late Chattian. Otherwise it could be a similar form of polyphyletic origin.

Family LEPIDOCYCLINIDAE Scheffen 1932

Two genera were identified in the samples, *Nephrolepidina* and *Eulepidina*, with multiple species. While the determination of *Eulepidina* species is relatively easy, in the case of *Nephrolepidina* it is difficult in the absence of loose material allowing a representative number of centered sections.

Genus *Nephrolepidina* H. Douvillé 1911

In western Tethys, the evolutive lineage of *Nephrolepidina praemarginata–N. morgani–N. tournoueri* is used in Oligo-Miocene biostratigraphy. Following De Mulder (1975), the lineage is subdivided into three chronospecies based on two biometric parameters: *Ai*, the grade of enclosure of the deuteroconch on the protoconch, and *C*, the number of "adauxiliary" chamberlets (those directly originated from the deuteroconch). De Mulder decided to use the combination of these two parameters as a compromise between the evolutive importance given to the degree of

embracement (van der Vlerk 1963) and the better results given by the use of the number of "auxiliary chambers" to subdivide the lineage (Drooger and Freudenthal 1964).

Intermediate forms are also recognized, using the terminology "ex. interc." (*exemplum intercentrale*). The parameters used for the characterization and identification of these chronospecies and intermediate populations are not linear and direct measures, but includes curved measurements and complex indexes relating different parameter (see Benedetti and Pignatti 2013, and Schiavinotto 2010 for a revision of the biometric methods).

Although the typological characterization of species is still applied (e.g., Amirshahkarami 2013; Sirel 2013), most authors use this biometric method (or other similar methods, e.g., Schiavinotto 1987). This method is not easy to apply, because it requires measurements of arched walls using a curvimeter, and because the parameters are difficult to obtain from random sections. For example, the number of "adauxiliary" chambers is not visible in uncentered sections, and it may even be difficult to observe in centered sections, as already noted by De Mulder (1975, p. 62). Furthermore, because it is based on the study of populations (Drooger 1993) the biometric method requires statistical analysis that is almost impossible to apply in the absence of loose material allowing a representative number of centered sections. Most authors show the results of their biometric study in a plot or give only the results of the indexes, without including the raw data. This fact hinders comparison when working with thin sections and only simple measurements or minimum estimates (such as the diameter of the embryonic chambers) can be obtained.

The method has other difficulties. One of the parameters, the number of "adauxiliary chambers" might be misleading, because there may be an evolutive increase in the number of these chamberlets but alternatively there might be an increase in chamberlet size (see Drooger and Freudenthal 1964). Also, the variability in the size of embryonic chambers can be very high, (e.g., up to 222% in American *Nephrolepina chaperi* according to Cole 1957).

The main parameters to measure in this method, the degree of embracement of the protoconch by the deuteroconch or the number of "adauxiliary chamberlets," are directly linked to the embryo size. However, the diameter of the megalospheric embryo in lepidocyclinids and the neanic acceleration are thought to be related to environmental parameters, such as depth (e.g., Chaproniere 1980; Schiavinotto and Verrubbi 1994; Schiavinotto 1995, 2010; Giannini et al. 2007; Benedetti and Pignatti 2013; see also Fermont 1982; Nigam 1988; Pécheux 1995). The range of variability of embryo size for each chronospecies thus depends on environmental factors and might overlap considerably with that of the next chronospecies. In other words, populations of different chronospecies from diverse environments might show similar values (or the same chronospecies from different environments might show different values) and lead to biostratigraphic misinterpretations. Benedetti and Pignatti (2013) studied the effect of environment on biometry and showed that fluctuations in embryo size along a stratigraphic series may be related to environmental factors rather than to evolution. They concluded that the size of the embryo "is not an adequate parameter for discriminating the chronospecies of the Mediterranean *Nephrolepidina* lineage" (Benedetti and Pignatti 2013, p. 381).

This does not imply that biometry of *Nephrolepidina* is not useful for biostratigraphy, only that there is a limit of resolution when variability due to environmental factors obscures variation due to evolution (which, otherwise, is not linear, e.g., Schiavinotto and Verrubbi 1994). The use of intermediate populations in biostratigraphic interpretations probably exceeds this limit.

In the studied section, however, the variability in the maximum diameter of the deuteroconch in *Nephrolepidina* specimens ranges from less than 300 μm to more than 850 μm. This degree of variability is found not only in the total assemblage, but also among specimens from a single sample. Such a wide range in the size of embryonic chambers would include two or three successive chronospecies. Sections of *Nephrolepidina* megalospheric

embryos from the Benitatxell Range are figured (Fig. 5). Figure 5A–5U show a rather continuous series from smaller to larger embryos that might be related to the *N. praemarginata-N. tournoueri* series. The specimens in Figure 5V–5X are larger, two of them irregular, and show a flat wall between the protoconch and the deuteroconch. The deuteroconch has a maximum diameter (minimum estimate) of about 740 µm, although the three sections are oblique. These three specimens probably belong to another species that could not be identified. In the entire assemblage, great variability is seen in axial sections (Fig. 6A–6J) in the size and the shape of the test, but also in the pattern of lateral chamberlets and in the presence and size of piles, as well as in the size of the megalospheric embryo. Recently, two new *Nephrolepidina* species have been defined: *N. sinaica* Boukhary et al. (2008) from the upper Chattian of Egypt, and *N. musensis* Özcan et al. (2010) from the late Rupelian–late Chattian of Keleşdere, eastern Turkey. As pointed out by Özcan et al. (2010), the lineage of *N. praemarginata–morgani–tournoueri* is not the only lineage of *Nephrolepidina* in the western Tethys. The low number of specimens of these particular forms in our samples, together with the irregular shape and the obliquity of the sections prevent a conclusive determination, which we leave open as *Nephrolepidina* spp. A few specimens with large piles (Fig. 6G, 6H) resemble *N. partita* Douvillé 1925, a species reported from diverse Oligocene sites, from France, Spain and Tunisia (Douvillé 1925, Gómez Llueca 1929) to Turkey (e.g., Sirel 2013; Gedik 2015) and Iran (e.g., Amirshahkarami 2013). According to Gómez Llueca (1929, p. 348), there is a continuous gradation from pustulated *N. partita* to *N. praemarginata* without pustules, as well as pustulated *N. morgani* indistinguishable from *N. partita* in external appearance. Most probably, *N. partita* is an ecophenotypic form of the lineage *N. praemarginata-N. morgani.*

Genus *Eulepidina* H. Douvillé 1911

Within *Eulepidina*, two species were recognized, *E. dilatata* and *E. elephantina*.

The two species are distinguished by the different size of the test and the megalospheric embryo. They clearly differ from *Nephrolepidina* species in the shape of equatorial chamberlets, which show true secondary septa as long radial walls (in equatorial section), and become considerably larger through ontogeny. Only two centered equatorial sections were obtained (Fig. 5Y, 5Z).

*Eulepidina dilatata* (Michelotti 1861)

Figures 5Y, 5Z, 6K–6M

1965 *Eulepidina dilatata* (Michelotti), Pieroni, p. 164, pl. 3, fig. 1–3.
1991 *Lepidocyclina (Eulepidina) dilatata* (Michelotti 1861), Less, p. 443, pl. 5, figs. 3–6; pl. 6, figs. 1–6.
1999 *Eulepidina dilatata* (Michelotti), Báldi et al., pl. 1, figs. 4, 5.
2008 *Eulepidina dilatata* (Michelotti 1861), Gedik, p. 38, pl. 3, figs. 1–6.
2009a *Eulepidina dilatata* (Michelotti 1861), Özcan et al., figs. 15.19, 15.20.
2010 *Eulepidina dilatata* (Michelotti 1861), Özcan et al., text-fig. 10, pl. 3, figs. 9–12.
2010 *Eulepidina dilatata* (Michelotti), Işik, p. 72, pl. 6, figs. 1–7.
2011 *Eulepidina dilatata* (Michelotti), Işik and Hakyemez, pl. 1, figs. 4, 5.
2011 *Lepidocyclina (Eulepidina) elephantine*, Seyrafian et al., fig. 9m.
2011 *Eulepidina dilatata* sp., Seyrafian et al., fig. 10y.
2011 *Eulepidina* cf. *dilatata*, Seyrafian et al., fig. 10z.
2013 *Eulepidina dilatata*, Fenero et al., pl. 2, fig. h.
2013 *Eulepidina* cf. *raulini* (Lemoine and Douvillé 1904), Amirshahkarami, p. 344, pl. 3, fig. 1.
?2013 *Eulepidina raulini* (Lemoine and Douvillé 1904), Sirel, p. 303, pl. 7, figs. 1–10.
2014 *Eulepidina* cf. *raulini* (Lemoine and Douvillé 1904), Habibi, pl. 1, fig. 13.
2015 *Eulepidina* sp., Mohammadi et al., fig. 7h–7j.

In this species, the embryo has a subcircular protoconch completely embraced by the deuteroconch, which has a characteristic thick wall (up to 80 µm, much more if the wall is cut

obliquely). In the only two centered equatorial sections obtained (Fig. 5Y, 5Z), the diameter of the protoconch and the maximum diameter of the deuteroconch are 714–1,300 µm and 1,238–1,995 µm. Adding measures in oblique and axial sections, the range is estimated as 675–1,240 µm for the protoconch and 1,200–2,178 µm for the deuteroconch.

The specimens from the Benitatxell Range are slightly larger than those reported for *E. dilatata* from central Italy (Pieroni 1965), Hungary (Less 1991), the Kelereşdere section in eastern Turkey (Özcan et al. 2010), and southeastern Anatolia (Işik 2010; Işik and Hakyemez 2011). They differ from the specimens from Denizli reported by Gedik (2008), which are much smaller and might belong to upper Chattian *E. anatolica* defined by Özcan et al. (2010).

Axial sections (Fig. 6K–6M) show a great deal of continuous variability in megalospheric forms, from small and flat specimens with only 2–4 layers of lateral chamberlets and a test thickness of 700–800 µm to larger, flat or lenticular specimens with up to 17 axially superposed lateral chamberlets and a test more than 2,200 µm thick.

Some specimens from the Benitatxell Range might be assigned to *E. raulini* (Lemoine and Douvillé 1904), which is characterized by a flat test, barely bulged in the central part, without piles, and a slightly larger megalospheric embryo, 1.7 to 2.4 mm in diameter (Douvillé 1925). Sirel (2013) assigned specimens with protoconch diameters of 850–1050 µm and deuteroconch diameters of 1,550–2,000 µm to *E. raulini*. Roozpeykar and Moghaddam (2016, fig. 11I) illustrate an axial section of *Eulepidina* sp. from the Asmari Formation with a large embryo of at least 1,470 µm in diameter, that would correspond to *E. raulini*. Other authors assign specimens of *Eulepidina* to *E. raulini* mainly based on the shape of the test rather than on the size of the embryo (e.g., Amirshahkarami 2013; Habibi 2014). These minor differences between *E. dilatata* and *E. raulini*, together with the fact that the two species usually occur together (e.g., Cosijn 1938; Amirshahkarami 2013; Habibi 2014; Sirel 2013, 2015) probably indicates that *E. raulini* is actually an ecophenotypic form of *E. dilatata*. In this case, *E. raulini* would be a junior synonym of *E. dilatata.* A statistical analysis is needed to solve this question, similar to the population study performed by Frost and Langenheim (1974) that clarified the long-discussed dichotomy between *E. favosa* and *E. undosa*. Specimens of *Eulepidina* '*raulini*' are here included into *E. dilatata*.

*Eulepidina elephantina* (Munier-Chalmas 1891)

Figure 6N, 6O

2010 *Eulepidina elephantina* Lemoine and R. Douvillé 1904, Özcan et al., text-fig. 10; pl. 3, figs. 18–20.

*Eulepidina elephantina* can reach 8–10 cm in diameter (Douvillé 1925), and is difficult to study in thin sections; only a few subaxial sections of the megalospheric embryo could be observed. From estimates in uncentered sections, the observed minimum diameters were 1,375 µm and 1,636 µm for the protoconch (n = 2) and 1,700 µm to 3,676 µm for the deuteroconch (n = 8). These measures are similar to the estimated diameter of the embryo in *E. elephantina* from Keleşdere (eastern Turkey) as 3–4 mm (Özcan et al. 2010). The test is very flat and it differs from *E. dilatata* in the megalospheric embryonic wall, which is not as thick and definite, and in the pattern of the lateral chamberlets, which are less defined and not ordered in tiers.

Cahuzac and Poignant (1997) considered *E. elephantina* as a synonym of *E. dilatata*. However, the two species differ considerably in both test size and megalospheric embryo size, in the thickness of the embryonic wall, and in the shape and arrangement pattern of the lateral chamberlets and should be considered as separate species. This is in agreement with the observations by Özcan et al. (2010) of embryonic diameters of 2,525 to 4,225 µm in *E. elephantina*, much larger than in *E. dilatata.* They also pointed out that this is a poorly known species and needs an improved description.

In the definition of the Shallow Benthic Zones, Cahuzac and Poignant (1997) placed the first occurrence of European *E. dilatata* in SBZ 22A, without discarding its occurrence in the

Aquitanian. Recent papers restrict its range to SBZ 22B-23 (Báldi et al. 1999; Özcan et al. 2010; Işik and Hakyemez 2011), or to SBZ 23 in Turkey (Gedik 2008; Sirel 2015). In Iran, *E. elephantina* has been reported from Rupelian assemblages associated with *N. fichteli* (Habibi 2014; Karevan et al. 2014; Roozpeykar and Moghaddam 2016). In part, these discrepancies are due to systematics, as Cahuzac and Poignant (1997) considered *E. elephantina* to be a synonym of *E. dilatata*. According to Laagland (1990), microspheric forms of *E. dilatata* might have been confused with *E. elephantina*.

Özcan et al. (2010) suggested that a replacement of *Eulepidina* species occurred during the late Chattian with *Eulepidina dilatata* being replaced in the lower part of the SBZ23 by immigrant *E. anatolica* and *E. elephantina.* In the Benitatxell Range, *E. dilatata* is found together with *E. elephantina* and *E. anatolica* is absent. The biogeographic distribution of species must therefore be taken into account in biostratigraphic correlation.

Family NUMMULITIDAE De Blainville 1827

*Genus Operculina* d'Orbigny 1826

Figures 7A–7M, 10O

At least two species of *Operculina* were distinguished, one can be assigned to *O. complanata* (Defrance 1822), characterized by septa with incipient septula and protoconch diameter of about 220–245 μm (as estimated in two subequatorial sections, Fig. 7F, 7G). Other specimens with a smaller test and protoconch diameters ranging from 102 to 216 μm could not be determined, although some of them could also belong to *O. complanata*. Some subequatorial sections resembling *Operculina* were observed to have trabeculae and were assigned to *Nummulites* (see below).

*Operculina complanata* has a long stratigraphic range, from the base of the Oligocene to the Tortonian (Cahuzac and Poignant 1997), and according to Özcan et al. (2009a, 2009b, 2010), it does not show significant evolutionary change over this interval. The observed proloculus diameter in the specimens from the Benitatxell Range (220–245 μm, Fig. 7 F, 7G) are large compared with values reported from Chattian specimens, about 100 to 200 μm (e.g., Henson 1937; Gedik 2008; Özcan et al. 2010, 2009a). Özcan et al. (2010) observed an increase in megalospheric proloculus diameter mean in Chattian *O. complanata* from about 108 μm in SBZ 22B to about 188 in SBZ 23, followed by a subsequent reduction in lower Burdigalian specimens to values similar to those in SBZ 22B. The large size of the megalospheric proloculus in the specimens from the Benitatxell Range could reflect a (possibly local) maximum in this late Oligocene trend. Also the specimens from Ramleh (Israel) reported by Hottinger (1977) as *Planoperculina complanata* show proloculus diameter of 100–225 μm , together with small and rare incomplete septula similar to our specimens, although they are placed in SBZ 22B according to Özcan et al. (2009a). Otherwise, a polyphyletic origin and parallel evolution of *Operculina* with incipient septula (the diagnostic characteristic of *O. complanata*), similar to that in the different *Heterostegina* lineages cannot be ruled out.

Genus *Heterostegina*

*Heterostegina assilinoides* Blanckenhorn 1890 emend. Henson 1937

Figures 3G, 3H, 8A–8F, 8L, 8M

1937 *Heterostegina assilinoides* Blanck, Henson, p. 48, figs. 1, 2.

1975 *Heterostegina assilinoides* Blanckenhorn s.l., Hottinger, fig. 3 (the scale should be 2 mm, not 2 cm).

1977 *Heterostegina assilinoides* Blanckenhorn emend. Henson, Hottinger, fig. 47A, 47B.

2009a *Heterostegina assilinoides* Blanckenhorn emend. Henson, Özcan et al., p. 756, figs. 20.5–20.9.

2010 *Heterostegina assilinoides* Blanckenhorn 1890, emend. Henson 1937, Özcan et al., p. 480, pl. 5, figs. 1–4, 7.

2014 *Heterostegina assilinoides* Blanckenhorn 1890 emend. Henson 1937, Gedik, p. 105, pl. 13, figs. 8–10, 12–15.
2015 *Heterostegina assilinoides* Blanckenhorn 1890 emend. Henson 1937, Gedik, pl. 6, figs. 7–10, 20.

The estimated diameter of the protoconch in eight subequatorial sections from Benitatxell ranges from 210 to 338 μm, with a mean of 268 μm. These values fit into the variability of *H. assilinoides* (Henson 1937; Özcan et al. 2010). The few subequatorial-oblique sections are insufficient to obtain meaningful statistical data, or to observe other characters, such as the number of unsubdivided chambers, or the pattern of the spiral and the density of chambers. Therefore, we could not compare our specimens with the different populations distinguished by Özcan et al. (2009a) and considered as possible different species. In the Rebaldí samples, minimum diameters of 210–234 μm were estimated from a few axial and oblique sections (Fig. 3H).

According to Cahuzac and Poignant (1997), *H. assilinoides* is restricted to SBZ 23; references to its presence in SBZ 22B need confirmation. In more recent papers it has been reported from the early Chattian (SBZ 22) of southwestern Turkey (Özcan et al. 2009a), and from the late Rupelian–early Chattian (SBZ 21-22) of eastern Turkey (Gedik 2014). Hottinger (1977) gave an age of early Oligocene to the specimens from the Prebetic of Benidorm.

Genus *Spiroclypeus*

*Spiroclypeus blanckenhorni* Henson 1937

Figures 3I, 8A–8F, 8L, 8M

1937 *Spiroclypeus blanckenhorni*, Henson, p. 50, figs. 3, 4, pl. 5, figs. 1–3.
1937 *Spiroclypeus blanckenhorni* var. *ornata*, Henson, p. 51, text-figs. 3, 4, pl. 5, figs. 4–7.
2010 *Spiroclypeus tidoenganensis* Van der Vlerk, Işik, p. 102, pl. 26, figs. 1–7.
2010 *Spiroclypeus* sp., Işik, pl. 26, figs. ?8, 9.
2014 *Spiroclypeus vermicularis* Tan 1937, Gedik, p. 104, pl. 13, figs. 1, 2, 5.
2015 *Spiroclypeus vermicularis* Tan 1937, Gedik, pl. 6, figs. 1, 2, 4.

*Spiroclypeus* is present in most samples from both both Benitatxell and Rebaldí; however, few equatorial sections were obtained from the thin sections. Our measurements are approximate because most sections are somewhat oblique. Axial sections show that the diameter of the protoconch is usually larger in axial direction than in the equatorial plane. Thus, the diameter measured in oblique sections will give larger values than the real equatorial diameter. In the few embryos we could measure (four subequatorial sections), the equatorial diameter of the proloculus ranges from 320 to 470 μm (mean = 394 μm), although centered axial sections provided additional measurements of 320–360 μm. These values are larger than those given by Henson (1937) for *S. blanckenhorni* (150–310 μm, mean = 220 μm) and *S. blanckenhorni* var. *ornata* (150–380 μm; mean = 240). They are also larger than the values given by Özcan et al. (2010) for *S. blanckenhorni* from the Kelereşdere Section in eastern Turkey: 140–410 μm (mean = 246 μm), but similar to the values for the SBZ 23 specimens assigned to *S. tidoenganensis* by Işik (2010). The range of proloculus diameter partially overlaps with that of *H. assilinoides*, the larger proloculus observed in *H. assilinoides* was about 338 μm in diameter, whereas the smaller proloculus observed in *S. blanckenhorni* was 320 μm. Because of this overlap in embryonic size, together with the involute character of *H. assilinoides*, the differentiation between *H. assilinoides* and *S. blanckenhorni* is not easy in subequatorial-oblique sections.

In the Rebaldí section, *Spiroclypeus* seems to be smaller. The maximum protoconch size, measured in an axial section (Fig. 8H), gives a minimum equatorial diameter of 326 μm, and is thus more similar to the sizes given by Henson (1937), Özcan et al. (2010) for *S. blanckenhorni*, and for late Chattian "*S. vermicularis*" given by Gedik (2014). They are

assigned to *S. blanckenhorni*, although, as pointed out by Özcan et al. (2009b), the Oligo-Miocene species need revision.

According to Cahuzac and Poignant (1997), *S. blanckenhorni* indicates SBZ 23, although they do not discount its presence in SBZ 22. Özcan et al. (2009b) reported the occurrence of *Spiroclypeus* specimens in lower Aquitanian (SBZ 24) deposits, which they assigned to *S. blanckenhorni*. These Miocene forms have a considerably smaller proloculus, although the axial sections resemble those of *S. blanckenhorni* var. *ornata* (Henson 1937).

Genus *Cycloclypeus* Carpenter 1856

*Cycloclypeus mediterraneus* Matteucci and Schiavinotto 1985

Figure 9A–9D

1985 *Cycloclypeus (Cycloclypeus) mediterraneus* n. sp., Matteucci and Schiavinotto, p. 128, pl. 3, figs. 2, 4, 6.

1990 *Cycloclypeus mediterraneus*, Laagland, pl. 8, figs. 1, 2, pl. 9, figs. 1, 2.

2015 *Cycloclypeus mediterraneus*, Renema, fig. 3D.

*Cycloclypeus* is very rare in both the Rebaldí and Benitatxell Ranges. Two subequatorial-oblique sections, one from the Rebaldí section (sample OM-6) and another from the Benitatxell Range (sample OM-36) show heterosteginid chambers with a small megalospheric embryo that differs considerably from the diameters observed in *Heterostegina* and *Spiroclypeus* specimens and are therefore assigned to *Cycloclypeus*.

The dimensions of parameter $d_1$ (maximum diameter of the protoconch through the protoconch-deuteroconch axis), used for the diagnosis of the species, is ~ 154 µm in the Rebaldí specimen and ~ 145 µm in the Benitatxell specimen. They conform to the diagnosis of *C. mediterraneus*, $d_{1mean}$ > 120 µm (Matteucci and Schiavinotto 1985), from the Chattian (N3 of Blow 1968, = P22) of central Italy, and within the range of *C. mediterraneus* (120–160 µm) according to Özcan and Less (2009). Because the sections are oblique and incomplete, no other parameters could be measured, although the observable pattern of chamber growth is consistent with that of *C. mediterraneus* illustrated in Matteucci and Schiavinotto (1977, 1985) and Laagland (1990).

Our specimens differ from the small embryo of *C. droogeri* Matteucci and Schiavinotto 1985 ($d_{1mean}$ <120µm) and the even smaller embryo of *C. eidae* Tan 1930 (e.g., Laagland 1990; Cahuzac and Poignant 2002). They are also larger than *Cycloclypeus* sp. from SBZ 22B of southwestern Turkey in Özcan et al. (2009a), subsequently determined to be *C.* aff. *droogeri* (Özcan et al. 2010), and differ considerably from the large embryo (195–375 µm) of *C. pseudocarpenteri* Özcan and Less 2010 (*in* Özcan et al. 2010) from the lower Chattian of Keleşdere section, eastern Turkey (Özcan et al. 2010). They are somewhat larger than the specimen of *C. mediterraneus* from the Chattian of Vilajoiosa (125 µm) illustrated in Renema (2015), and very similar to the specimens of *C. mediterraneus* figured in Laagland (1990), especially to the specimen from the type locality, l'Aquila (central Italy), co-occurring with *Miogypsinoides complanatus* (Giannini et al. 2007), and thus similar in age to the Rebaldí section. They are also similar to the specimens from the upper samples of the Lanuza section in Spain (mean of maximum protoconch diameter = 145–164 µm), associated with *M. complanatus* and *L. (N.)* ex. interc. *praemarginata-morgani* (Laagland 1990). They might correspond to the small *Cycloclypeus* sp. 2 reported (although not figured) by Cahuzac and Poignant (1987) from the late Oligocene of Aquitaine (southern France).

According to the original description (Matteucci and Schiavinotto 1985), the test of *C. mediterraneus* is smooth without granulations, and it has a more or less pronounced central knob. Subaxial sections from Benitatxell (Fig. 9E, 9F) show a smooth surface test, without granules despite the presence of piles. No central swelling or knob is seen, but this is expected in a subaxial (uncentered) section. A possible microspheric form (Fig. 9F) has a test size > 6

mm, larger than the maximum 5 mm observed in the assemblage from the type locality (Matteucci and Schiavinotto 1985).

In the definition of Shallow Benthic Zones (Cahuzac and Poignant 1997), the association of larger foraminifera of SBZ 23 includes *Cycloclypeus eidae*, and possibly also *C. mediterraneus*. Although further evidence is needed, the specimens from the Rebaldí section and the Benitatxell Range, associated with *Miogypsinoides complanatus-formosensis* and *Risananeiza pustulosa*, and with both test and megalospheric embryo larger than those from the early Chattian, confirm the presence of *C. mediterraneus* in SBZ 23. The presence of *C. eidae* in the Benitatxell Range cannot be ruled out.

It is currently assumed that in the western Tethys there is a replacement of the *C. droogeri-C. mediterraneus* lineage by the immigrant *C. eidae* during the Chattian, either at the SBZ 22B-23 boundary (Cahuzac and Poignant 1997), in "the upper part of the upper Oligocene" (Laagland 1990), or during the middle Chattian (Renema 2015). This is documented, for example in the Navazuelo section (southern Spain), where the three species, *C. droogeri*, *C. mediterraneus*, and *C. eidae* are found in vertical succession within NP 25. Laagland (1990) notes that there is no documented overlap of the two lineages, which would occur in the stratigraphic range of *Miogypsinoides complanatus*. According to Renema (2015), the extinction of *C. mediterraneus* was instantaneous and probably due to a reduction in depth of the photic zone or to the steepening of the bathymetric temperature profile.

The presence of *C. mediterraneus* associated with *M. complanatus* in the Rebaldí section, and with *M. formosensis* in the Benitatxell Range indicates that its extinction was not synchronous in different regions of the western Tethys.

*Genus Nummulites* Lamarck 1801

*Nummulites* cf. *vascus* Joly and Leymerie 1848

Figure 10I

2007 *Nummulites* cf. *vascus* Joly and Leymerie 1848, Bassi et al., pl. 4, figs. 7, 11, 12.
2008 *Nummulites vascus* Joly and Leymerie, Gedik, p. 36, pl. 1, figs. 15–21, pl. 2, figs. 1–5.
2010 *Nummulites vascus* Joly and Leymerie 1848, Amirshahkarami et al., pl. 1, figs. 5, 8.
2011 *Nummulites vascus*, Seyrafian et al., fig. 10o.
2013 *Nummulites vascus* Joly and Leymerie 1848, Amirshahkarami, 342, pl. 1 (*partim*), figs. 4, 5 (not fig. 7: *Amphistegina* sp.).
2014 *Nummulites* cf. *vascus* Joly and Leymerie, Gedik, pl. 13, figs. 16–19.
2015 *Nummulites* cf. *vascus* Joly and Leymerie, Gedik, pl. 6, figs. 14–16.

This species is reported by many authors, usually as *N.* cf. *vascus*, determined from axial or subaxial sections. Detailed studies including biometry of equatorial sections (e.g., Schaub 1981; Less et al. 2011) usually do not provide figured axial sections, so it is difficult to compare and identify this species from random section; the original description (Joly and Leymerie 1848) does not include axial sections either. Some exceptions are found in the literature, illustrating both equatorial and axial sections (Gedik 2008; Benedetti 2010). We have neither loose material nor equatorial sections. Hence, following Bassi et al. (2007), we assign some specimens of *Nummulites* to *N.* cf. *vascus* based on the fact that *N. vascus* is the only Oligocene species that corresponds to the size and outline in axial section. The synonymy list is limited to those works including comparable axial sections.

*Nummulites* cf. *vascus* was only found in the samples from the Benitatxell Range. The test is lenticular, biconvex; it might have a more or less defined central boss. The maximum observed test diameter in our samples is 2.2 mm, which falls within the range of test sizes, 1.5–4.9 mm, provided by Gedik (2008). For more detailed descriptions including internal parameters see Benedetti (2010), Gedik (2008), Less et al. (2011), and Schaub (1981).

The specimens from the Benitatxell Range differ from the only axial section figured in Benedetti (2010), of lower Rupelian age (SBZ 21), which is more robust and with pronounced

central bosses, and most similar to the specimens from SBZ 23 of northeastern Italy figured in Bassi et al. (2007).

There is no consensus in the literature on the stratigraphic range of *N. vascus*. According to several authors, the stratigraphic range of *Nummulites vascus* is limited to the Rupelian (Laursen et al. 2009; Amirshahkaram 2013; Maghfouri-Moghadam et al. 2014), or to the Rupelian–lower Chattian, SBZ 21-22B (Cahuzac and Poignant 1997, 1998; Báldi et al. 1999; Gedik 2008, 2014, 2015; Özcan et al. 2010; Braga and Bassi 2011; Zoeram et al. 2013; Sirel 2013, 2015). The presence of *N.* cf. *vascus* in SBZ 23, associated to *Miogypsinoides* as observed in Benitatxell is consistent with the observations in northern Italy (Bassi et al. 2007) and south-central Turkey (Işik 2010; Işik and Hakyemez 2011; Sirel and Isik 2011).

According to Less et al. (2011) and Özcan et al. (2009a), *N. vascus* is absent in the upper Rupelian (SBZ 22A) and lower Chattian (SBZ 22B) assemblages of southwestern Turkey, as well as in the late Chattian (SBZ 23) of the Keleşdere section in eastern Turkey (Özcan et al. 2010). Gedik (2014, 2015) limits the range of *N. vascus* to the Rupelian–early Chattian (SBZ 21a-22) in eastern Turkey. However, *N. vascus* has been reported from the late Chattian of south-central Turkey (Işik 2010; Işik and Hakyemez 2011; Sirel and Isik 2011). These inconsistencies might reflect systematic discrepancies rather than paleobiogeographic differences. The assumed last occurrence of *N.* cf. *vascus* in the latest Rupelian in some sections (e.g., Amirshahkarami and Taheri 2010; Zoeram et al. 2013; Habibi 2014; Maghfouri-Moghadam et al. 2014) might be due to a change of facies to shallow-water assemblages dominated by porcellaneous genera.

*Nummulites* aff. *kecskemetii* Less 1991

Figure 10J–10R

1952 *Nummulites bouillei* de la Harpe, Grimsdale, p. 234, pl. 24, figs. 9–11.
1991 *Nummulites kecskemetii*, Less, p. 439, pl. 1, figs. 1–6, pl. 2, figs. 1–3 (with synonymy).
1997 *Nummulites bouillei* de la Harpe, Cahuzac and Poignant, pl. 1, figs. 5, 6.
1999 *Nummulites kecskemetii* Less, Less, pl. 2, figs. 14–16.
1999 *Nummulites kecskemetii* Less, Báldi et al., pl. 1, figs. 7, 9, 10.
1999 *Nummulites kecskemetii* Less, Ferrandez-Cañadell et al., text-fig. 3n, 3o, pl. 1, fig. h (left).
2007 *Nummulites* cf. *bouillei* de la Harpe 1879, Bassi et al., pl. 4, fig. 13.
2009a *Nummulites kecskemetii* Less 1991, Özcan et al., p. 755, fig. 17.6–17.10.
2010 *Nummulites kecskemetii* Less 1991, Özcan et al., p. 479, pl. 4, figs. 23, 24.

Because of its operculiniform growth, with an equatorial section similar to that of *Operculina*, and the lack of figured axial sections in the literature to compare with, this species is difficult to identify in thin section. A few operculiniform subequatorial sections from the Benitatxell Range were identified as *Nummulites* from the presence of trabeculae (Fig. 10R). The few subequatorial sections (n = 7) only allowed the measurement of the protoconch diameter: 94–141 μm (mean = 120.7 μm). No measurements of other parameters (such as the diameter and number of chambers of the first two whorls) could be made in these sections. Some axial sections of *Nummulites* from the Benitatxell Range samples (Fig. 10J–10N) show very flat tests, different from those assigned to *N.* cf. *vascus*, and were interpreted as belonging to the same species. The larger axial section shows a test diameter of 2.4 mm.

The protoconch diameter is larger than in topotypes of *N. kecskemetii*, 40–100 μm (Less 1991). It is also larger than reported in *N. kecskemetii* from the lower Chattian (SBZ 22B) in northern Spain, 70–115 μm (Ferràndez-Cañadell et al. 1999) and central Turkey, 50–95 μm (Özcan et al. 2009a). Most similar values are found in late Chattian *N. kecskemetii* from Kelereşdere Section in eastern Turkey (Özcan et al. 2010): 55–135 μm. The specimens from Benitatxell seem to have intermediate characters between *N. bouillei* de la Harpe 1879 and *N. kecskemetii* Less 1991. Apart from a larger proloculus, in the forms from Benitatxell, the septa

are not as dense in the initial whorls and their shape is not as angular as in the topotypes of *N. kecskemetii.*

*Nummulites kecskemetii* was previously included into *N. bouillei* de la Harpe 1879, which spans from the Priabonian to the late Oligocene (Cahuzac and Poignant 1997) in Europe and the Middle East (e.g., Grimsdale 1952). Less (1991) erected this new species considering that the characteristic small proloculus of late Oligocene forms would require a very unusual phylogenetic reduction in proloculus size from lower Oligocene populations. Furthermore, Less (1991) postulated a possible American origin for *N. kecskemetii* based on a close resemblance of these forms to the American Oligocene "*Nummulites*" *panamensis* Cushman together with the evidence for trans-Atlantic migration of other foraminifera, such as miogypsinids (see also Bassi et al 2007). In later papers (Less 1999; Less et al. 2011), he biometrically differentiated three species in this group: *N. budensis* Hantken 1875 in the Priabonian, *N. bouillei* in the (early) Rupelian, and *N. kecskemetii* in the Chattian. Based on data from Spain (Ferràndez-Cañadell et al. 1999), Hungary (Less 1991, 2008; Báldi et al. 1999) and southwestern Turkey (Özcan et al. 2009a, 2010), the stratigraphic range of *N. kecskemetii* has been set to SBZ 22B-23.

The specimens from Benitatxell show somewhat larger proloculi that otherwise fall partially within the variability of *N. kecskemetii* and could be interpreted as a derived population according to a biostratigraphic interpretation of the Benitatxell levels as uppermost Chattian. Alternatively, because of the larger proloculus, together with the possible differences in the shape and density of septa, they could be Chattian representatives of *N. bouillei* de la Harpe 1879. The specimens from Benitatxell are similar to the axial section from the late Chattian (SBZ 23) attributed to *N.* cf. *bouillei* in Bassi et al. (2007). Further data are needed to reach a conclusion.

Family MIOGYPSINIDAE Vaughan 1928

Genus *Miogypsinoides* Yabe and Hanzawa 1928

*Miogypsinoides complanatus* (Schlumberger 1900)

Figure 3D

*Miogypsinoides formosensis* Yabe and Hanzawa 1928

Figure 11A–11K

Based on the number of postembryonic spiral chambers, successive biostratigraphically significant chronospecies of *Miogypsinoides* have been defined, (Drooger and Laagland 1986; Drooger 1993). In reality, there is considerable stratigraphic overlap among these chronospecies (e.g., Cahuzac and Poignant 1997; Bassi et al. 2007; Amirshahkarami 2008; Özcan et al. 2010; Boudagher-Fadel and Price 2013) as well as considerable population variability. For example, Özcan et al. (2010) reported a variability of 4–14 spiral chambers in *M. formosensis*. Furthermore, the origin of miogypsinids could be polyphyletic, which led Bassi et al. (2007) to conclude that, if identified only from the number of spiral chambers, *M. bantamensis* has no biostratigraphic value. A few specimens from the Benitatxell Range show intermediate traits between *Risananeiza* and *Miogypsinoides*, with piles and funnels on both sides of the equatorial plane (Fig. 12A, 12B).

In the original definition of Oligocene–Miocene Shallow Benthic Zones 21 to 26, Cahuzac and Poignant (1997) overlap the stratigraphic distribution of three species (*M. complanatus*, *M. formosensis*, and *M. bantamensis-dehaartii*) within SBZ 23 (late Chattian). The terminology for intermediate forms (ex. interc., *exemplum intercentrale*) is also used by some authors (e.g., Parente et al. 1994).

Based on the available data from Benitatxell, mostly subequatorial sections, the estimates on the number of spiral chambers in *Miogypsionides* specimens range from 7 to 18, with a mean of 13.6 (n = 17), and they are assigned to *M. formosensis* Yabe and Hanzawa 1928. Alternatively, co-occurrence of *M. complanatus* and *M. formosensis* or an intermediate form (i.e., *Miogypsinoides* ex. interc. *complanatus-formosensis*) could also be interpreted. In the Rebaldí section, the average number of spiral chambers is higher (16–21, n = 5) and would correspond to

*M. complanatus*. These two species are placed in the Chattian, SBZ 23, but the substantial stratigraphic overlap they show (e.g., Amirshahkarami 2008) precludes a clear differentiation of two sub-biozones based only in *Miogypsinoides* (e.g., Báldi et al. 1999).

Genus *Postmiogypsinella* Sirel and Gedik 2011

aff. *Postmiogypsinella intermedia* Sirel and Gedik 2011

Figure 12C–12H

2011 *Postmiogypsinella intermedia*, Sirel and Gedik, p. 591, pl. 1, figs. 1–12.
2014 *Postmiogypsinella intermedia* Sirel and Gedik, Gedik, pl. 5, figs. 6–10.
2015 *Postmiogypsinella intermedia* Sirel and Gedik, Gedik, pl. 4, figs. 5–9.

A second miogypsinid form was recognized in the samples from Benitatxell. It is characterized by a pustulose test of slightly trochospiral initial rotaloid growth with pillars and canal at both sides of the rotalid stage and occasional small lateral chamberlets on both sides (Fig. 12C–12H). These features correspond to *Postmiogypsinella intermedia* Sirel and Gedik (2011), a species erected from specimens from upper Chattian sediments in the Malatya Basin in eastern Turkey, and not yet reported from elsewhere. *Postmiogypsinella* is considered an intermediate form between *Miogypsinella* and *Miogypsina*, characterized by pillars and funnels on both sides of the test (absent in *Miogypsina*), but with small ("underdeveloped") lateral chamberlets on both sides (Sirel and Gedik 2011; see also Gedik 2014, 2015).

Family ROTALIIDAE Ehrenberg 1839

Genus *Neorotalia* Bermúdez 1952

*Neorotalia viennoti* (Greig 1935)

Figures 3F, 13A–13L

*Neorotalia lithothamnica* (Uhlig 1886)

Figure 3K

*Neorotalia* is frequent in Oligocene–Miocene foraminiferal associations. There are two main species in the Oligocene: *N. viennoti* (Greig) 1935 and *N. lithothamnica* (Uhlig 1886).

The most common species is characterized by a trochospiral test with a very thick and protruding ventral pile that gives the test a very asymmetrical outline. This species is assigned by most authors to *N. viennoti* (e.g., Rikhtehgarzadeh et al. 2008; Amirshahkarami and Taheri 2010; Habibi 2014; Zoeram et al. 2014), but also to *N. lithothamnica* (e.g., Yazdi-Moghadam 2011), and to a new species, *N. tethyana* (Boudagher-Fadel and Price 2013). The comparison with the original descriptions (Uhlig 1886; Greig 1935) shows that this form corresponds to *N. viennoti*.

*Neorotalia lithothamnica* has a lower trochospiral test with a less developed and protruding ventral pustulose zone and walls with thin elongated piles. In axial section, the chamber outline is less triangular and with the distal end more rounded than in *N. viennoti*. This form is sometimes difficult to distinguish from trochospiral specimens of *Risananeiza*, and it has been assigned to *N. viennoti* by several authors (e.g., Bassi et al. 2007; Amirshahkarami and Taheri 2010; Hottinger 2014). On the other hand, according to Poignant (1998) and Cahuzac and Poignant (2005), *N. lithothamnica* Uhlig 1886 is a synonym of *N. burdigalensis* (d'Orbigny 1852). However, this synonymy is based only on the comparison of the external features and needs confirmation from internal parameters.

While *N. viennoti* is easy to distinguish in axial section based on its larger protruding ventral zone, the co-occurrence in our samples with worn specimens of *Risananeiza* hinders the identification of subequatorial sections. Similarly, the co-occurrence of *N. viennoti*, *N. lithothamnica*, and *Risananeiza* in the Rebaldí samples hampers the identification of the specimens in random sections.

The supposed limited biostratigraphic value of *Neorotalia* might be an artefact due to the systematic confusion between species; some reports of its presence in the late Chattian actually correspond to *Risananeiza* (e.g., Didon et al. 1961). As pointed out by Hottinger

(2014), a revision of these rotaliids to clearly differentiate among *Neorotalia* species might confer upon them a more precise biostratigraphic usefulness for the Oligocene. In addition, it could clarify the phylogenetic relationships with miogypsinids.

Family ORNATOROTALIIDAE Benedetti 2015

Subfamily Cuvillierininae Loeblich and Tappan 1964

Genus *Risananeiza* Boukhary, Kuss and Abdelraouf 2008

*Risananeiza pustulosa* Boukhary, Kuss and Abdelraouf 2008

Figures 3J, 14A–14N

1961 *Rotalia pustulosa*, Didon et al., pl. 1R.

2008 *Risananeiza pustulosa* n. sp., Boukhary, Kuss, and Abdelraouf, p. 184, pl. 1, figs. 1–18.

2010 *Risananeiza postulosa* Boukhary, Kuss, and Abdelraouf, Işik, p. 74, pl. 7, figs. 1–16, pl. 8, figs. 1–20.

2011 *Risananeiza pustulosa* Boukhary, Kuss, and Abdelraouf, Sirel and Isik, p. 40, pl. 3, figs. 1–15, pl. 4, figs. 1–19.

*Risananeiza* is characterized by very low trochospiral coiling, and a canal system with funnels on both ventral and dorsal sides; see Boukhary et al. (2008) and Benedetti and Briguglio (2012) for a detailed description of the genus. From the observations of our material, a characteristic feature of *Risananeiza* that can be added to the description is that the megalospheric proloculus is elliptical instead of subspherical, with its axial diameter up to 25% larger than the equatorial diameter (e.g., Fig. 14D, 14F).

Besides the type species, *R. pustulosa*, Benedetti and Briguglio (2012) erected a second species, *R. crassaparies*, from Italy, also of late Chattian age, characterized by a smaller test size and a smaller megalospheric proloculus. The equatorial diameter of the megalospheric proloculus of *R. crassaparies* is 90–225 μm, and the diameters reported in *R. pustulosa* are 150–250 μm (Boukhary et al. 2008), 140–220 μm (Işik 2010), and 166–220 μm (Sirel and Isik 2011). Thus, the range of protoconch diameter exclusive for *R. crassaparies* is 90–140 μm.

The specimens of *Risananeiza* from the Benitatxell Range show intermediate values when compared with the two defined species, *R. pustulosa* and *R. crassaparies*. The equatorial diameter of the megalospheric proloculus (P) reaches 254 μm, outside the range reported for *R. crassaparies*, 90–225 μm (Benedetti and Briguglio 2012), and the range reported for *R. pustulosa* by Işik (2010), 140–220 μm, and Sirel and Isik (2011), 166–200 μm, although roughly within the range of *R. pustulosa* according to the original definition by Boukhary et al. (2008), 150–250 μm.

The diameter of the microspheric test, 2.74–3.4 mm (n = 3, mean = 3.18 mm) falls within the range of *R. crassaparies* (1.59–3.82 mm). The larger megalospheric test has a diameter of 2.23 mm, outside the range of *R. crassaparies*, 1.10–1.81 mm (Benedetti and Briguglio 2012), and within the range of *R. pustulosa*, 0.925–2.9 mm (Boukhary et al. 2008). From these data, the conclusion would be that the population from Benitatxell corresponds to a somewhat small *R. pustulosa*.

The specimens of *Risananeiza* from Rebaldí show a generally smaller test size, < 2.6 mm (including a microspheric form), but they have a larger megalospheric proloculus, reaching 286 μm in equatorial diameter (206–286 μm, mean = 231.8 μm, n = 6) (Fig. 3J).

The two known species, *R. pustulosa* and *R. crassaparies* have an identical stratigraphic range, limited to SBZ 23 (Benedetti and Briguglio 2012). In the Rebaldí section, *Risananeiza* is associated with *Miogypsinoides complanatus*, and in the Benitatxell Range with *M. formosensis*. However, the small *Risananeiza* in the older Rebaldí section shows similar or even larger protoconch diameter, so a clear phylogenetic trend is not observed. Giving more importance to the embryo size than to test size, specimens from both the Benitatxell Range and Rebaldí are assigned to *R. pustulosa*

*Risananeiza* seems to be frequent in late Oligocene rocks from the western Tethys. It has usually been reported as *Neorotalia* (e.g., *N. pustulosa* in Didon et al. 1961; *N. viennoti* in

Bassi et al. 2007 and Brandano et al. 2009). The specimens reported as *Pararotalia* cf. *lithothamnica* by Bassi et al. (2007) are probably flat specimens of *Risananeiza*. In addition, the specimens reported as *Rotalia tuberculata* from Umbria (central Italy) by Renz (1936), associated with *M. complanatus* and *E. dilatata*, might belong to *Risananeiza*.

As already pointed out by Benedetti and Briguglio (2012), *Risananeiza* is a potentially useful genus for biostratigraphy, possibly being a marker for the late Chattian. Some specimens from the Asmari Formation (Iran) assigned to the genus *Bozorgniella* (e.g., Daneshian and Hoseinzadeh 2011) most probably belong to *Risananeiza*, so that the presence of this genus in the Aquitanian needs confirmation. The "Aquitanian" specimen of *Rotalia* sp. from the Keleşdere section (eastern Anatolia) in Sancay et al. (2006, pl. 14, fig. 14) probably belongs to *Risananeiza*, although the age has been re-interpreted as late Chattian, SBZ 23 (Özcan et al. 2010).

Family AMPHISTEGINIDAE Cushman 1927

*Amphistegina bohdanowiczi* Bieda 1936

Figures 3E, 15A–15J, 15P

1936 *Amphistegina bohdanowiczi*, Bieda, p. 266, pl. 8, fig. 4a–4c.
1993 *Amphistegina bohdanowiczi* Bieda, Rögl and Brandstätter, pl. 3, figs 20–34, pl. 4, figs 1–6, pl. 6, figs. 5, 6).
2007 *Amphistegina* cf. *bohdanowiczi* Bieda 1936, Bassi et al., pl. 2, figs. 5, 8, 10, pl. 3, figs. 12–18, 22.
2007 *Amphistegina* cf. *conoides* Kleinpell 1954, Bassi et al., pl. 3, figs. 19–21.
2008 *Amphistegina bohdanowiczi* Bieda 1936, Popescu and Crihan, pl. 10, figs. 8–10.
2008 *Amphistegina* sp., Gedik, pl. 2, fig. 12.
2009 *Amphistegina lessonii*, Brandano et al., fig. 5A.
2011 *Amphistegina* sp., Braga and Basi, fig. 4D.
2011 *Amphistegina* sp., Behforouzi and Safari, fig. 8a, 8b.
2011 *Asterigerina* sp., Yazdi-Moghadam, pl. 1, fig. 12.
2012 *Amphistegina* sp., Benedetti and D'Amico, fig. 7.8.
2013 *Amphistegina bohdanowiczi* Bieda 1936, Amirshahkarami, pl. 4, figs. 5–7, 13.
2013 *Amphistegina mammilla* (Fichtel and Moll 1798), Amirshahkarami, pl. 4, fig. 4.
2013 *Amphistegina* aff. *radiata* (Fichtel and Moll 1798), Amirshahkarami, pl. 4, fig. 8.
2014 *Amphistegina lessonii* (d'Orbigny), Zoeram et al., fig. 7.3.

This is a common species in the Oligocene and early Miocene of the western and central Tethys. It is a small species, usually planoconvex in shape, with short secondary lobes on the ventral side and a triangular pustulate area in front of the aperture. For a detailed description see Rögl and Branstätter (1993). The specimens from the Benitatxell Range show a small proloculus of 65–80 μm in estimated diameter (n = 19). The triangular pustulate zone (the most distinct feature of this species according to Rögl and Branstätter 1993) is shown in Figure 15J (compare with Popescu and Crihan 2008).

*Amphistegina mammilla* (Fichtel and Moll 1798)

Figure 15K–15O, 15Q

1846 *Amphistegina hauerina*, d'Orbigny, p. 207, pl. 12, figs. 3–5.
1846 *Nummulina radiate*, d'Orbigny, p. 115, pl. 5, figs. 23, 24.
1846 *Amphistegina mamillata*, d'Orbigny, p. 208, pl. 12, figs. 6–8.
1978 *Amphistegina hauerina* d'Orbigny 1846, Larsen, p. 224, pl. 12, figs. 1, 4.
1978 *Amphistegina mamilla* (Fichtel and Moll 1798), Larsen, p. 224, pl. 1, figs. 8, 9, 11, 12, pl. 6, fig. 3.
1978 *Amphistegina hauerina* d'Orbigny 1846, Larsen, p. 224, pl. 12, figs. 1, 4.
?1984 *Amphistegina* sp., Belford, pl. 5, figs. 4, 5.
1985 *Amphistegina hauerina* d'Orbigny, Papp and Schmid, p. 75, pl. 67, figs. 2–6.

1992 *Amphistegina hauerina* d'Orbigny 1846, Wightman, p. 235, pl. 4, figs. 13, 14.
1993 *Amphistegina mammilla* (Fichtel and Moll) 1798, Rögl and Brandstätter, p. 129, pl. 1, figs. 1–4, pl. 2, figs. 7, 8, pl. 4, figs. 10, 11, pl. 5, figs. 1–3, pl. 6, fig. 2).
2004 Nummulitids, Stoklosa and Simo, fig. 4.
2008 *Amphistegina mammilla* (Fichtel and Moll) 1798, Popescu and Crihan, pl. 10, figs. 6, 7.
2010 *Nummulites* sp.1, Işik, p. 99, pl. 27, figs. 9–18.
2011 *Nummulites* sp., Sirel and Isik, pl. 2, fig. 13.
2012 *Amphistegina hauerina* d'Orbigny 1846, Gonera, fig. 3.
2015 *Nummulites vascus*, Mohammadi et al., fig. 7e–7g.

This species has a small test that is nearly planispiral with a symmetrical lenticular-rhomboidal outline that becomes asymmetrical during ontogeny, and has umbonal bosses on both sides (Figs. 15L–15O). A pustulate zone is restricted to the keel, with pustules roughly arranged in rows parallel to the test margin (Fig. 15K). Large stellar chamberlets leave a small lobe of the primary chamberlet near the periphery in the ventral side (Fig. 15P). From estimates of the best 9 axial sections, test size is 1.2–2 mm (mean = 1.59 mm) in diameter, and 0.6–0.87 mm (mean = 0.76 mm) in thickness. The largest observed specimen, probably a microspheric test, measures 2.81 mm in diameter and at least 0.97 mm in thickness. The estimated thickness to diameter ratio (T/D) in specimens from different samples (i.e., possibly different depth), ranges from 0.41 to 0.54, and seems to decrease during ontogeny, with a T/D of about 0.35 in the largest specimen.

Some authors consider *A. mammilla*, *A. hauerina*, and *A. radiata* as separate species (Larsen 1978; Papp and Schmid 1985; Gonera 2002). Rögl and Brandstätter (1993) have shown biometrically that they are synonyms. The specimens from Benitatxell are similar in shape and morphological characters to Miocene *A. mammilla* illustrated in Larsen (1978) and Rögl and Brandstätter (1993).

*Amphistegina mammilla* is very similar to some forms of *Nummulites*, and often the two genera are difficult to distinguish (see for example the packstone with *A. mammilla* and *N.* cf. *vascus* in Stoklosa and Simo 2008, fig. 4). The specimens of *Nummulites vascus* reported by Mohammadi et al. (2015) from the Oligocene of the Qom Formation in Iran are probably *A. mammilla*, but the low resolution of the photographs in that publication prevents a conclusive determination. Their biostratigraphic interpretation as Rupelian is based on their assignment to *N. vascus*, which Mohammadi et al. (2015) suppose to occur only in the Rupelian. Actually, these specimens are associated either with *Eulepidina elephantina* (Varkan section) or with "*Nephrolepidina tournoueri*" (Khurabad section), so their age is probably late Chattian and early Miocene, respectively.

Similarly, the late Chattian (SBZ 23) specimens from south-central Turkey attributed to *Nummulites* sp. 1 by Işik (2010), or to *Nummulites* sp. (and used to re-define SBZ 23) by Sirel and Isik (2011) are probably *A. mammilla.* Their shape is more rhomboidal and symmetrical, similar to the middle Miocene "*Amphistegina radiata*" illustrated by Chaproniere and Pigram (1993, fig. 9d). Other Oligocene specimens assigned to *Nummulites* are possibly *A. mammilla*, such as the specimens from the Asmari Formation in Iran attributed to *Nummulites* sp. and *N. vascus* by Seyrafian et al. (2011), or those from western Malatya in Turkey attributed to *Nummulites* cf. *vascus* by Gedik (2015).

Belford (1984, pl. 5, figs. 4, 5) illustrated two axial sections of *Amphistegina* sp. from the late Oligocene–early Miocene ("Te, undifferentiated") of Papua New Guinea. They are included in the synonymy because they are strikingly similar to the ones from Benitatxell, albeit with question marks due to the great geographic distance. They occur associated with *Spiroclypeus margaritatus* (Schlumberger), *Nephrolepidina* sp., *Cycloclypeus* sp., *Heterostegina* sp., and *Elphidium* sp. (Belford 1984).

The first occurrence of *A. mammilla* is currently placed in the base of the Badenian (= late Burdigalian, Hohenegger et al. 2014). Here we show the presence of this species, characterized by a small size, in late Chattian sediments, extending the biostratigraphic range down to SBZ 23 in the Mediterranean region.

*Amphistegina* is not usually considered in the biostratigraphy of the Tethyan Oligocene (e.g., Cahuzac and Poignant 1997). However, it is used in Miocene biostratigraphy. For example, the presence of *A. bohdanowiczi* and *A. mammilla* occurring alone or together is used to define the zonation of the early-middle Miocene (Rögl and Brändstätter 1993).

There are some previous references to Oligocene species of *Amphistegina* other than *A. bohdanowiczi*. Amirshahkarami (2013) cites *A. mammilla* from the Rupelian, and *A.* aff. *radiata* from the late Oligocene–early Miocene of the Zagros Basin (southeastern Iran). All these specimens in Amirshahkarami (2013) correspond to *A. bohdanowiczi*. This is clearly seen when their figured specimen of *A. bohdanowiczi* (pl. 4, fig. 5) is superposed on the specimen assigned to *A. mammilla* (pl. 4, fig. 5): they match perfectly. The specimens assigned to *A. lessonii* (d'Orbigny) from the late Oligocene of the central Zagros Basin in Iran by Zoeram et al. (2014, fig. 7.3), and from the Chattian of Malta (Brandano et al. 2009, fig. 5A), as well as those from the late Chattian (SBZ 23) of northeast Italy assigned to *Amphistegina* cf. *conoides* Kleinpell 1954 by Bassi et al. (2007, pl. 3, figs. 19–21) are here interpreted as *A. bohdanowiczi*. Finally, there are some references not figured: *A. hauerii* and *A. vulgaris* (*lessonii*) in the Chattian of the Aquitaine basin (southern France) (Cahuzac and Poignant 1993), or *A. lessonii* in the Oligocene of the Qom Formation in Iran (Behforouzi and Safari 2011).

Henson (1937) described *Amphistegina* cf. *hauerina* d'Orbigny from the early Miocene of Aintab, Turkish Syria, (previously reported as Eocene or Oligocene by Blanckenhorn 1890, 1935), stating that the Aintab specimens "agree closely with examples from the Oligocene of Palestine and the Burdigalian of Syria" reported by Henson (1936), although "they are only about half the diameter"; and also "very similar," although smaller, to topotype specimens of *A. hauerina* from Nussdorf (Austria). Though not figured, from Henson's description (1937, p. 53) the specimens from Aintab are very similar to those from Benitatxell in both size and shape. They are associated with *O. complanata*, *H. assilinoides*, *S. blanckenhorni*, *Cycloclypeus* cf. *eidae* Tan Sin Hok, *Miogypsina* sp. indet. and *"Rotalia" viennoti*, which Henson (1937) interpreted as early Miocene based on the presence of *Miogypsina*, although the age would not be very different from the upper Oligocene from Palestine because the two associations have at least five species in common. The age of this association can be re-interpreted as SBZ 23, because of the presence of *Cycloclypeus eidae*, together with a species of a *Miogypsina* (*M. septentrionalis*) in this biozone (e.g., Cahuzac and Poignant 1997). Actually, Henson had previously (1936) reported the presence of *Amphistegina* cf. *hauerina* from Palestine associated to *N.* cf. *vascus*, *O. complanata*, *H. assilinoides*, *C. eidae*, *E. dilatata*, *E. elephantina*, *E. raulini*, *N. marginata*, *N. praetournoueri*, *N. tournoueri*, and "*Rotalia" viennoti*, an association that he interpreted as upper Oligocene, and that, except for the presence or *C. eidae* matches the one from Benitatxell.

Accepting these interpretations, *A. mammilla* would be present in the late Chattian of southeastern Spain (Benitatxell), Turkish Syria (Henson 1937), and probably also in Palestine (Henson 1936), central and south central Turkey (Sirel and Isik 2011; Gedik 2015), and Iran (Seyrafian et al. 2011; Mohammadi et al. 2015).

Family VICTORIELLIDAE

*Victoriella conoidea* (Rutten 1914)

Figures 16A–16E, 17

1914 *Carpenteria conoidea*, Rutten, p. 47, pl. 7, figs. 6–9.

1955 *Victoriella aquitanica*, Debourle and Delmas, p. 47, pl. 1a, figs. 1–4.

1957 *Victoriella plecte* Chapmann and Crespin, Reiss, pl. B, figs. 1, 2.
1959 *Victoriella conoidea* (Rutten 1914), Glaessner and Wade, p. 199, text-figs. 1–4; pl. 1, figs. 1–5, pl. 2, figs. 1–5, 7–10, pl. 3, fig. 3.
2005 *Victoriella abnormis* (Hantken 1875), Ozsvárt, pl. 2, fig. 6.
2010 *Victoriella conoidea* (Rutten 1914), Benedetti, pl. 2, fig. 6.
2010 *Victoriella conoidea* (Rutten 1914), Işik, p. 67, pl. 3, figs. 1–15.
2011 *Victoriella conoidea* (Rutten 1914), Yazdi-Moghadam, pl. 1, fig. 6.
2011 *Victoriella conoidea* (Rutten), Sirel and Isik, pl. 2, figs. 10, 11.
2013 *Victoriella conoidea* (Rutten 1914), Amirshahkarami, p. 345, pl. 4, figs. 9, 10.

This species is characterized by an elongated trochospiral test and inflated chambers with a thick pustulate wall perforated by coarse pores. There is general agreement in considering *V. plecte* (Chapman), and *V. aquitanica* Debourle and Delmas as junior synonyms of *V. conoidea* (e.g., Glaessner and Wade 1959; Matsumaru et al. 1993; Benedetti 2010). Our samples yielded few specimens, but they are of considerable size; one of them, more than 3 mm long, is larger than any other specimen reported in the literature (Fig. 16A). A similar form, more than 4 mm long, has been reported from the upper Eocene of Saipan, Mariana Islands by Cole (1957) as *Eorupertia plecte* (Chapman) and from the early Miocene of Papua New Guinea by Belford (1984) as *Eorupertia* cf. *cyclindricum* (Carter). Following Benedetti (2010), we reproduced the plot of length and width by Glaessner and Wade (1959), adding measurements of Oligocene and Miocene specimens from different sites (Fig. 17). Upper Chattian specimens show the largest sizes, close to the holotype of *V. conoidea*, although larger than the size given by Rutten 1914 in the original description: L = 2.5 mm, W = 1.5 mm, and larger than early Miocene specimens (e.g., Hayward and Buzas 1979; Chaproniere 1984; Matsumaru et al. 1993; BouDagher-Fadel 2008).

Victoriellidae are rotaliid foraminifera of uncertain affinities (Hottinger 2014). They have an elementary canal system, which in *Victoriella* is limited to an umbilical interlocular space ("vertikalen Kanal" of Rutten 1914; "axial hollow" in Loeblich and Tappan 1987), which communicates with the external side of the test by narrow canals located between chambers of consecutive whorls ("open axial spaces radiating from the axis", Glaessner and Wade 1959). According to Glaessner and Wade (1959), the interlocular spaces in *Victoriella* are not a true canal system because they are not organized and there is no spiral canal connecting them. However, another victoriellid genus, *Gyroidinella*, shows more regular interlocular spaces organized into an "interlocular canal system" (Hottinger 2014). Glaessner and Wade interpreted the interlocular structures in *Victoriella* to be morphologically convergent with the Rotaloiidea. The different morphology and regularity of interlocular spaces in some genera (*Victoriella*, *Gyroidinella*), and their absence in other genera (*Carpenteria*) is consistent with Glaessner and Wade's interpretation. One of our specimens shows small basal apertures instead of canals (Fig. 16E), a feature previously not described in this genus. Other victoriellidae, assigned to *Carpenteria* sp. (Figs. 3P, 16F) were very scarce in the samples.

## CONCLUSIONS

### Biostratigraphy

The foraminiferal association of the Benitatxell Range corresponds to SBZ 23, characterized by *Miogypsinoides formosensis*, *Heterostegina assilinoides*, *Spiroclypeus blanckenhorni*, *Eulepidina dilatata-raulini*, *E. elephantina*, *Risananeiza pustulosa*, and *N.* aff. *kecskemetii*. The Rebaldí section shows a similar association, differing in the occurrence of *M. complanatus* instead of *M. formosensis*, and in the smaller embryo size of *H. assilinoides* and *S. blanckenhorni*. Consequently, the Rebaldí assemblage is placed in the early part of SBZ 23 and the Benitatxell assemblage in the late part of SBZ 23.

Some taxa occurring in Benitatxell are absent in Rebaldí: *Nummulites* spp., *Eulepidina* spp., *Amphistegina mammilla*, *Victoriella conoidea*. Conversely, some taxa occurring in Rebaldí

are absent in Benitatxell: *Schlumbergerina alveoliniformis*, *Peneroplis thomasi*, and *Praebullalveolina* aff. *oligocenica*.

The oldest occurrence of *Schlumbergerina alveoliniformis* was previously in the Burdigalian (SBZ 25); its presence in Rebaldí extends the fossil record of this species to the late Chattian SBZ 23.

*Praebullalveolina* is known from late Eocene (*P. afyonica*, Sirel and Acar 1982) and early Rupelian deposits (*P. oligocenica*, *P. minuta*, Sirel et al. 2013). Although it requires confirmation, its presence in the Prebetic Range extends its range into the late Chattian.

Shallow Benthic Zone 23 was defined mainly by the occurrence of *Miogypsinoides* (Cahuzac and Poignant 1997, 1998), absent in SBZ 22B. Some taxa, common in SBZ 23, such as *E. dilatata*, *N. kecskemetii*, *H. assilinoides*, or *S. blanckenhorni* are already present in the early Chattian. Biometric studies on the lineage of *Nephrolepidina praemarginata–morgani–tournoueri* have also been used to characterize Shallow Benthic Zones 22A-24. However, as discussed above, this method is hindered by the difficulty of taking some measurements, the variability of populations, the presence of intermediate forms, the problems of the characters used in biometry (increase in the number of "adauxiliary chamberlets" vs. increase in chamberlet size), and the influence of environment on an embryo's size. Furthermore, it can be applied only when loose material is available. In addition, the diversity of western Tethys *Nephrolepidina* is not limited to this lineage. Biometric analysis of chronospecies in *Nephrolepidina* as well as in nummulitids (*Heterostegina*, *Spiroclypeus*, *Cycloclypeus*) is useful to characterize species and there is no doubt regarding its biostratigraphic usefulness. However, variability of populations is high, and ranges of the values of the different parameters of successive species overlap significantly. This fact, together with the lack of illustrations of axial sections (the *critical transverse section*, quoting Grimsdale 1952, p. 234) in most biometric studies limits its use when no loose material is available.

In lepidocyclinids, the main biostratigraphic analyses have focused on the biometry of the equatorial section, and mainly in the *N. praemarginata–morgani– tournoueri* lineage, without paying much attention to the axial sections, which are significant for identifying some species in thin section. Some lepidocyclinid species not often considered, such as *Nephrolepidina partita* or *Eulepidina raulini* could be ecophenotypic forms of *N. praemarginata–morgani* and *E. dilatata*, respectively.

In *Miogypsinoides*, the biometric comparison is easier if it is based on the number of spiral chambers. The variability is also high and the range of successive species overlaps considerably, but a representative number of measurements can be done only from thin sections. However, polyphyletism in miogypsinids is a problem yet to be resolved. Different miogypsinid lineages probably originated recurrently from different rotaliid ancestors, most likely *Neorotalia* spp., but other ancestors cannot be ruled out. A few forms from the Benitatxell Range look like intermediate forms between *Risananeiza* and *Miogypsinoides*, with pillars and funnels on both sides of the equatorial plane (Fig. 12A, 12B).

Large (>2.5 mm in length) specimens of *Victoriella conoidea* seem to be found only in the late Chattian and are thus useful for characterizing SBZ 23 (Fig. 17).

The presence of *Nummulites* cf. *vascus* in the Benitatxell Range associated with *Miogypsinoides* is consistent with observations in northern Italy (Bassi et al. 2007) and south-central Turkey (Işik 2010; Işik and Hakyemez 2011; Sirel and Isik 2011) and confirms its occurrence in SBZ 23. Disparity in the reported stratigraphic range of this species probably reflects systematic uncertainity rather than paleobiogeographic patterns. This species is usually reported as *N.* cf. *vascus*, determined from axial or subaxial sections, while detailed biometric studies focus on equatorial sections and overlook the axial section.

A second *Nummulites* species, *N. kecskemetii* occurs in SBZ 23. Although it is similar to *N. bouillei*, it was assigned to a different species by Less (1991) based on its particular

features, mainly its small proloculus, because he considered a phylogenetic reduction in proloculus size unlikely. The specimens from Benitatxell assigned to *N.* aff. *kecskemetii* show a similar flattened test and angular septa, but differ in having a slighly larger proloculus and in the pattern of septa in the first whorl (not so densely arranged). Their possible relationship to *N. bouillei* cannot be ruled out.

*Cycloclypeus mediterraneus* was previously considered to have become extinct at SBZ 22B in the Mediterranean region, being replaced by immigrant *C. eidae*. Its presence in both Benitatxell and Rebaldí extends its range to SBZ 23 and indicates that its extinction was not synchronous in different regions of the western Tethys.

*Risananeiza* is known only in late Chattian assemblages. Two species have been defined based on test size and megalospheric proloculus size, although they would have the same stratigraphic range. The specimens from our samples show embryo dimensions most similar to those of *R. pustulosa*. However, the specimens from the Rebaldí section, associated with *M. complanatus*, show smaller tests but also larger embryos (up to 286 μm in diameter), than the specimens from the Benitatxell Range (maximum observed diameter = 254 μm). In fact, the embryo's size in the Rebaldí specimens is larger than the largest specimens previously reported (250 μm, Boukhary et al. 2008). Thus, while *Risananeiza* stands as a diagnostic genus for SBZ 23, no evolutionary trend has yet been recognized to give the genus finer biostratigraphic resolution.

A main conclusion of this study is the recognition of *A. mammilla* in the Benitatxell association. The oldest occurrence of *A. mammilla* was placed in the middle Miocene. Reported Oligocene species other than *A. bohdanowiczi*, assigned to *A. mammilla* (Rupelian, Zagros, Amirshahkarami 2013), *A.* aff. *radiata* (late Oligocene–early Miocene, Zagros, Amirshahkarami 2013), *A. lessonii* (late Oligocene, Zagros , Zoeram et al. 2014; Chattian, Malta, Brandano et al. 2009), and *Amphistegina* cf. *conoides* (late Chattian, north Italy, Bassi et al. 2007) are actually *A. bohdanowiczi.* The exception would be the *Amphistegina* cf. *hauerina* reported by Henson (1936) from the late Oligocene of Palestine, associated with *N.* cf. *vascus*, *O. complanata*, *Heterostegina assilinoides*, *Cycloclypeus eidae*, *Eulepidina dilatata*, *E. elephantina*, *E. raulini*, *N. marginata*, *N. praetournoueri*, *N. tournoueri*, and "*Rotalia*" *viennoti*, an association that, except for the presence or *C. eidae* matches the one from Benitatxell quite well. Conversely, some late Oligocene specimens of *A. mammilla* have been interpreted as *Nummulites* (e.g., Stoklosa and Simo 2008; Mohammadi et al. 2015).

We conclude that *A. mammilla* occurs in the late Chattian of southeastern Spain (Benitatxell), and probably also in Palestine (Henson 1936), Turkish Syria (Henson 1937), central and south central Turkey (Sirel and Isik 2011; Gedik 2015), and Iran (Seyrafian et al. 2011; Mohammadi et al. 2015). Thus, *A. mammilla* is added to the species association that characterizes SBZ 23.

Paleobiogeography

Paleobiogeography must be taken into account in biostratigraphic correlations. For example, according to Özcan et al. (2010) in eastern Turkey, *E. dilatata* became extinct during early SBZ 23, being replaced by immigrant *E. anatolica* and *E. elephantina*. In the western Tethys, however, *E. elephantina* co-occurs with *E. dilatata* and *E. anatolica* is absent, indicating a diachronous extinction of *E. dilatata*, possibly related to the geographical extension of the dispersal of *E. anatolica*.

The suggested relationship of late Chattian *N. kecskemetii* (Less 1991), or *N.* cf. *bouillei* (Bassi et al. 2007), with American forms of similar age should be verified.

The presence of *Peneroplis thomasi* and *Austrotrillina asmariensis* in the Prebetic domain extends their paleogeographic extent from the central Tethys and northern Italy, respectively, to the westernmost Tethys.

Because it had only been reported in Europe from the early Badenian (understood then as middle Miocene), but was known in the early Miocene of the Indo-Pacific province, Rögl and Brandstätter (1993) concluded that *A. mammilla* (including *A. hauerina* types) entered the Parathethys from the east in the middle Miocene (see also Harzhauser and Piller 2007). Its presence in the late Chattian in the Middle East and the western Tethys would change the interpretation of its region of origin and reverse its migration route. However, the report of late Oligocene?–early Miocene *A. hauerina* from the Mariana Basin, in the western equatorial Pacific (ODP site 802, Wightman 1992) should be taken into account in biogeographic interpretations.

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Figure Captions

FIG. 1.—Geological setting. Geological map of the study area (modified from Vegas et al. 1973). The black stars indicate the locations of the sections logged. 1, Torre Garcia-Cim del Sol Road section (Rupelian?–early Miocene); 2, Accés Sud Road section (Chattian–early Miocene); 3, Albacete Road section (Chattian–early Miocene); 4, Rebaldí composite section (Cretaceous and Chattian). Inset is map of the Prebetic Zone, the Betic Cordillera and the study area in the southeastern Iberian Peninsula.

FIG. 2.—Stratigraphic distribution of larger foraminifera species in the studied sections.

FIG. 3.—**A**) *Austrotrillina* sp., OM-13. **B**) *Peneroplis thomasi* Henson 1950, OM-5. **C**) *Praebullalveolina* aff. *oligocenica* Sirel and Özgen-Erdem 2013, OM-13. **D**) *Miogypsinoides complanatus* (Schlumberger 1900), OM-13. **E**) *Amphistegina bohdanowiczi* Bieda 1936, OM-11. **F**) *Neorotalia viennoti* Greig 1935, subaxial section, OM-13. **G**, **H**) *Heterostegina* sp., axial sections, OM-13. **I**) *Spiroclypeus blanckenhorni* Henson 1937, axial section, OM-6. **J**) *Risananeiza pustulosa* Boukhary, Kuss, and Abdelraouf 2008, axial section, OM-12. **K**) *Neorotalia lithothamnica* (Uhlig 1886), axial section, OM-5. **L**) *Schlumbergerina* aff. *alveoliniformis* (Brady 1879), axial section, OM-13. **M**) *Planorbulina* sp., OM-12. **N**) *Planorbulinella* sp., OM-5. **O**) *Sphaerogypsina* sp., OM-5. **P**) *Carpenteria* sp., OM-12. **Q**) *Haddonia heissigi* Hagn 1968, OM-11. Scale bars: A–N = 200 μm; O, P = 500 μm.

FIG. 4.—**A**, **B**) Exoskeletal pattern in different *Austrotrillina* species, redrawn from Adams (1968) (A), and in *Austrotrillina* from Benitatxell (B). Not to scale. **C**–**G**) *Austrotrillina asmariensis* Adams 1968 from Benitatxell Range. (C–F: OM-27; G: OM-26).

FIG. 5.—**A**–**X**) *Nephrolepidina* spp., megalospheric embryos at the same scale, most of them in somewhat oblique section. **Y**, **Z**) *Eulepidina dilatata* (Michelotti 1861)—including *E. raulini* (Lemoine and Douvillé 1904), equatorial sections. (A: OM-26; B, I, Y,: OM-35; C–F, H, O, R: OM-20; G: OM-28; J: OM-21; K: AA-28; L, Q, S, W, X: OM-37; M: OM-40; N, P: OM-33; T: OM-34; U: OM-38; V: OM-32; Z: OM-39).

FIG. 6.—Variability in lepidocyclinids from Benitatxell in axial section. **A**–**J**) *Nephrolepidina* spp. **K**–**M**) *Eulepidina dilatata* (Michelotti 1861)—including *E. raulini* (Lemoine and Douvillé 1904). **N**–**O**) *Eulepidina elephantina* (Munier-Chalmas 1891). (A, E, I, L: OM-32; B, F: OM-35; C: AA-28; D: OM-18; G: OM-26; H: OM-25; J: OM-37; K: OM-36; M-O: OM-21).

FIG. 7.—**A**–**D**) *Operculina* sp. equatorial sections, megalospheric form. **E**) *Operculina* sp. equatorial sections, microspheric form. **F**, **G**) *Operculina complanata* (Defrance 1822), equatorial sections of megalospheric forms. **H**–**L**) *Operculina* sp., axial sections of megalospheric forms, with *Amphistegina bohdanowiczi* Bieda 1936 (F), and *Nummulites* cf. *vascus* Joly and Leymerie 1848 (I). **M**) *Operculina* sp. axial section, microspheric form. Note the large marginal cord. (A, J, K, L: OM-20; B, F, G, I: OM-21; C: AA-27; D: AA-28; E: OM-30; H, M: OM-29)

FIG. 8.—**A**–**F**, **L**, **M**) *Heterostegina assilinoides* Blanckenhorn 1890 emend. Henson 1937. Equatorial sections of megalospheric forms (A–F); axial sections (L, M). **G**–**K**, **M**–**O**) *Spiroclypeus blanckenhorni* Henson 1937. Equatorial sections of megalospheric forms (G–J); axial sections (K, M–O). (A-I: AA-28; B-C, F-G: OM-20; D, J: OM-21; E: OM-30; H, K, N: OM-34; L: OM-26; M, O: OM-33).

FIG. 9.—**A**–**C**) *Cycloclypeus* aff. *mediterraneus* Matteucci and Schiavinotto 1985. Subequatorial-oblique section and detail, Rebaldí, sample OM-6 (A, B); subequatorial section, Benitatxell Range, Accés Sud Road section, sample OM-36 (C). **D**–**F**) ?*Cycloclypeus* sp., oblique section, OM-26 (D); subaxial section, megalospheric form, OM-24 (E); axial section, microspheric specimen, OM-20 (F). Scale bars: A–C = 200 μm; D–F = 500 μm.

FIG. 10.—**A**–**I**) *Nummulites* cf. *vascus* Joly and Leymerie 1848. Axial sections. **J**–**R**) *Nummulites* aff. *kecskemetii* Less 1991, axial (J–N) and equatorial sections (O–R), in O with *Operculina* sp.

(left). Note the trabeculae in R (arrow). (A: OM-33; B: OM-21; C: OM-35; D: OM-20; E: OM-33; F: OM-20; G-H: OM-34; I: OM-35; J: OM-21; K: OM-33; L: OM-40; M: OM-20; N: AA-35; O: AA-28; P-R: OM-20; I: OM-29).

FIG. 11.—*Miogypsinoides formosensis* Yabe and Hanzawa 1928. Equatorial sections of megalospheric forms and one microspheric form (F). (A: OM-20; B, D, E, G, I: OM-30; C: OM-29; F: OM-26; H: OM-37).

FIG. 12.—**A**, **B**) Undetermined form, with characteristics intermediate between *Risananeiza* and *Miogypsinoides*, OM-24. **C**–**H**) *Postmiogypsinella* aff. *intermedia* Sirel and Gedik 2011, note the occasional lateral chamberlets. (C: OM-29; D, E: OM-24; F–H: OM-35).

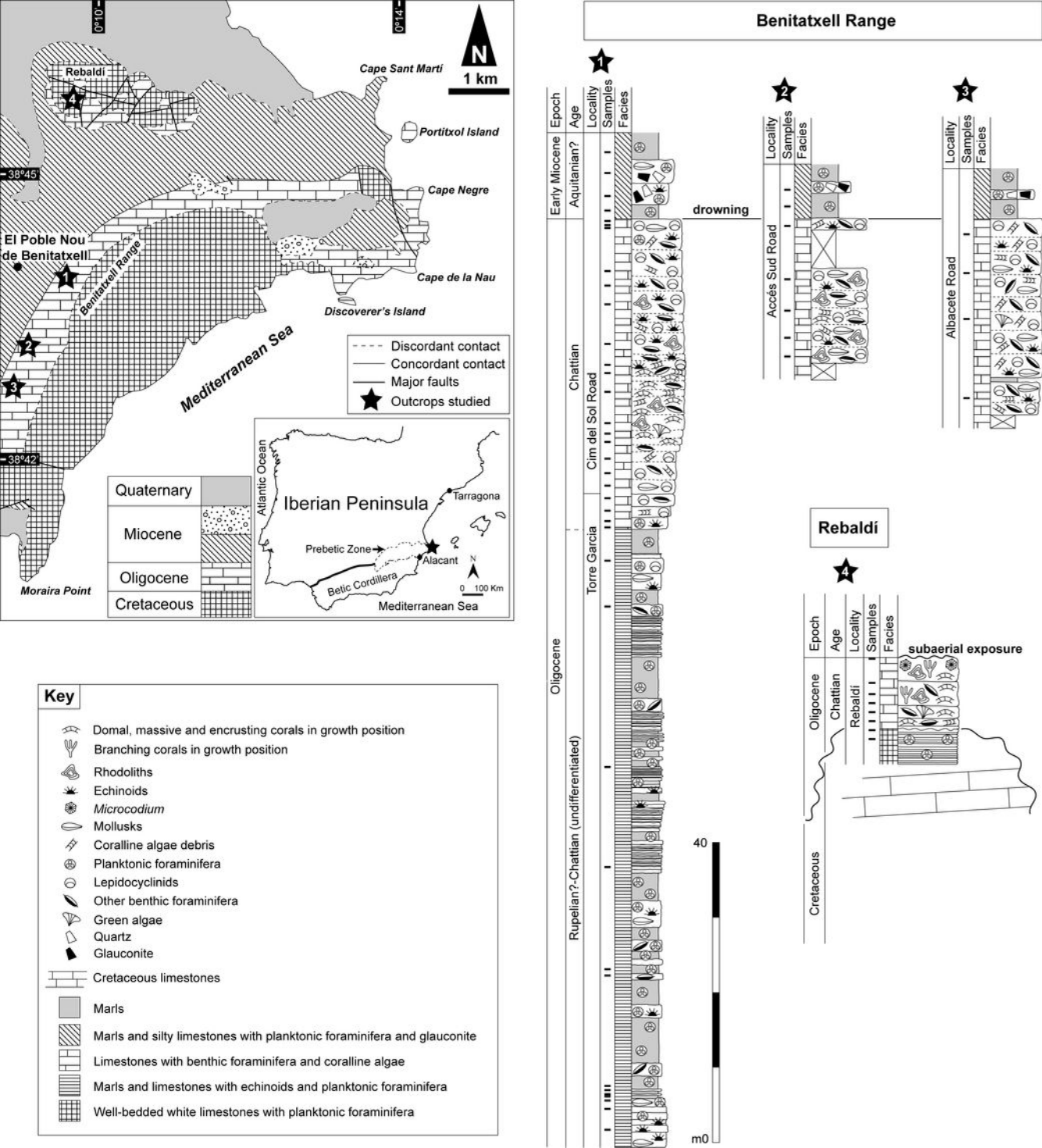
FIG. 13.—**A**–**L**) *Neorotalia viennoti* (Greig 1935). Axial and subaxial sections of megalospheric forms, (A–G, J), in G with *Heterostegina assilinoides*); equatorial, somewhat oblique section of megalospheric form and detail (H, I); axial sections of microspheric forms (K, L).
(A, H: OM-21; B, G, K: OM-37; C: OM-32; D: OM-35; E, J: OM-26; F, I: OM-40)

FIG. 14.—**A**–**N**) *Risananeiza pustulosa* Boukhary, Kuss and Abdelraouf 2008. Axial sections of megalospheric forms (A–F); axial sections of microspheric forms (G–J); equatorial sections of megalospheric forms (K–N). (A, M: AA-27; B: OM-24; C: OM-32; D: OM-35; E, G: OM-24; F: OM-29; H-I: OM-33; J: OM-26; K: OM-40; L: OM-21; N: OM-20).

FIG. 15.—**A**–**J**, **P**) *Amphistegina bohdanowiczi* Bieda 1936. A) Equatorial section (A); oblique section (B); axial and subaxial sections (C–H); tangential-equatorial section showing the pattern of stellate chamberlets (I); tangential-axial section showing the pustulate zone (J). **K**–**Q**) *Amphistegina mammilla* (Fichtel and Moll 1798). Subequatorial section showing the pustulate zone (K); axial sections (L–O); subequatorial section showing the pattern of stellate chamberlets (P); subequatorial section (Q). (A, P: OM-29; B, H: OM-35; C-D, G: OM-24; E: OM-24; F: OM-20; J: OM-25; K: OM-26; L: OM-33; M-O: OM-32; P-Q: OM-34).

FIG. 16.—**A**–**E**) *Victoriella conoidea* (Rutten 1914). A-B) Axial sections (A, B); details showing interlocular spaces (*is*, arrows) (C, D), connected with chamber lumen in D (detail of A); axial section showing small basal apertures (arrows) (E). **F**) *Carpenteria* sp., axial section. Scale bars = 200 μm. (A, D: OM-39; B, E: OM-40; C: OM-18; F: O-24).

FIG. 17.—Biometric comparison of *Victoriella conoidea*. Following Benedetti (2010) we reproduced the plot of length and width by Glaessner and Wade (1959), adding measurements of specimens from different sites. Late Chattian specimens show the largest sizes, close to the holotype, and larger than early Miocene specimens.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El Poble Nou de Benitatxell
Benitatxell Range
Cape de la Nau
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Samples
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Aquitanian?
Chattian
Oligocene
Rupelian?-Chattian (undifferentiated)
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Torre Garcia
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Accés Sud Road
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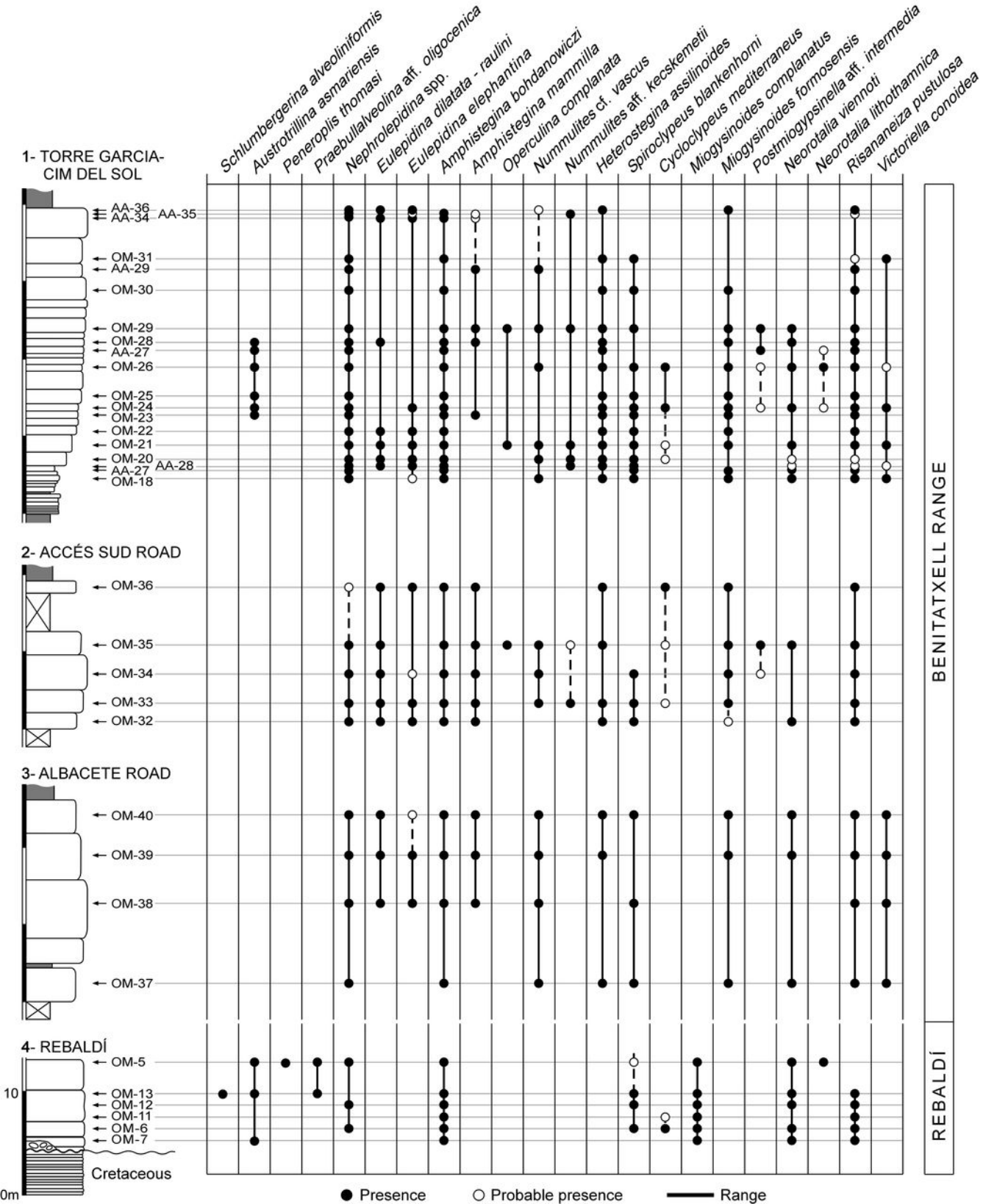
Echinoids
Microcodium
Mollusks
Coralline algae debris
Planktonic foraminifera
Lepidocyclinids
Other benthic foraminifera
Green algae
Quartz
Glauconite
Cretaceous limestones
Marls
Marls and silty limestones with planktonic foraminifera and glauconite
Limestones with benthic foraminifera and coralline algae
Marls and limestones with echinoids and planktonic foraminifera
Well-bedded white limestones with planktonic foraminifera


Schlumbergerina alveoliniformis
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Nephrolepidina spp.
Eulepidina dilatata - raulini
Eulepidina elephantina
Amphistegina bohdanowiczi
Amphistegina mammilla
Operculina complanata
Nummulites cf. vascus
Nummulites aff. kecskemetii
Heterostegina assilinoides
Spiroclypeus blankenhorni
Cycloclypeus mediterraneus
Miogysinoides complanatus
Miogysinoides formosensis
Postmiogypsinella aff. intermedia
Neorotalia viennoti
Neorotalia lithothamnica
Risananeiza pustulosa
Victoriella conoidea
1- TORRE GARCIA-CIM DEL SOL
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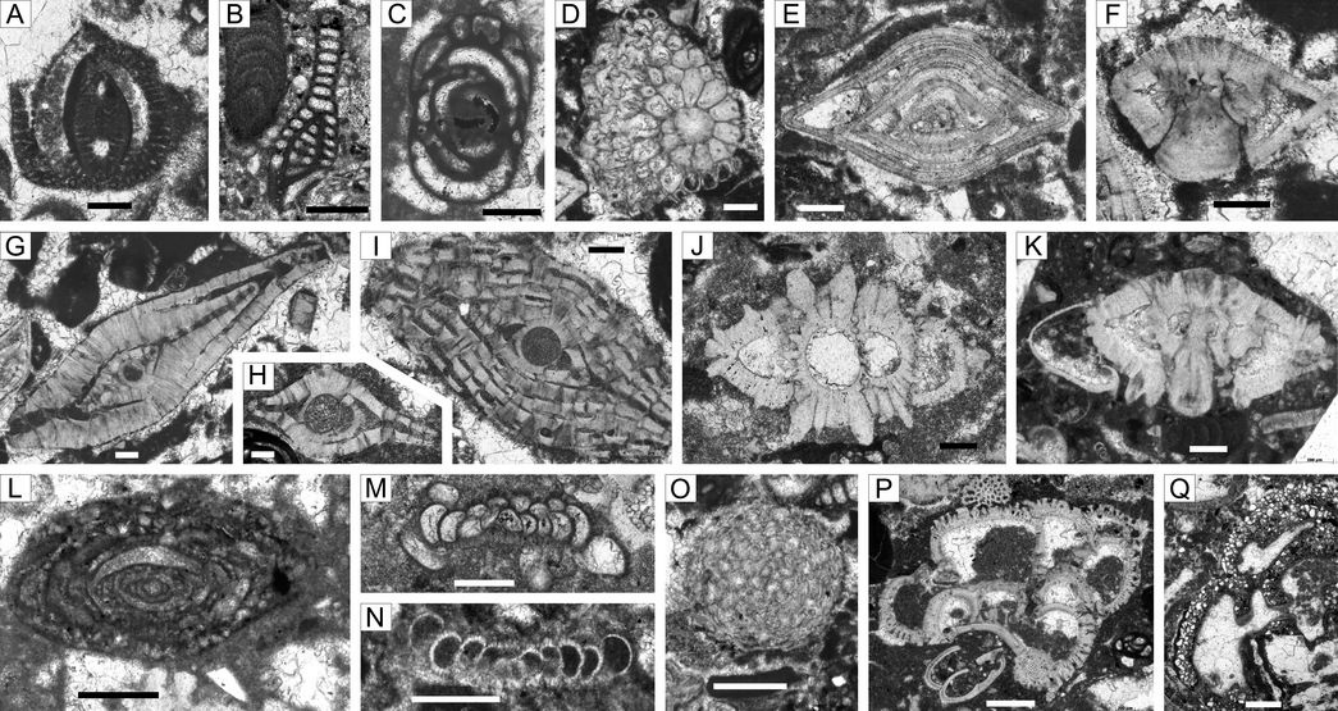
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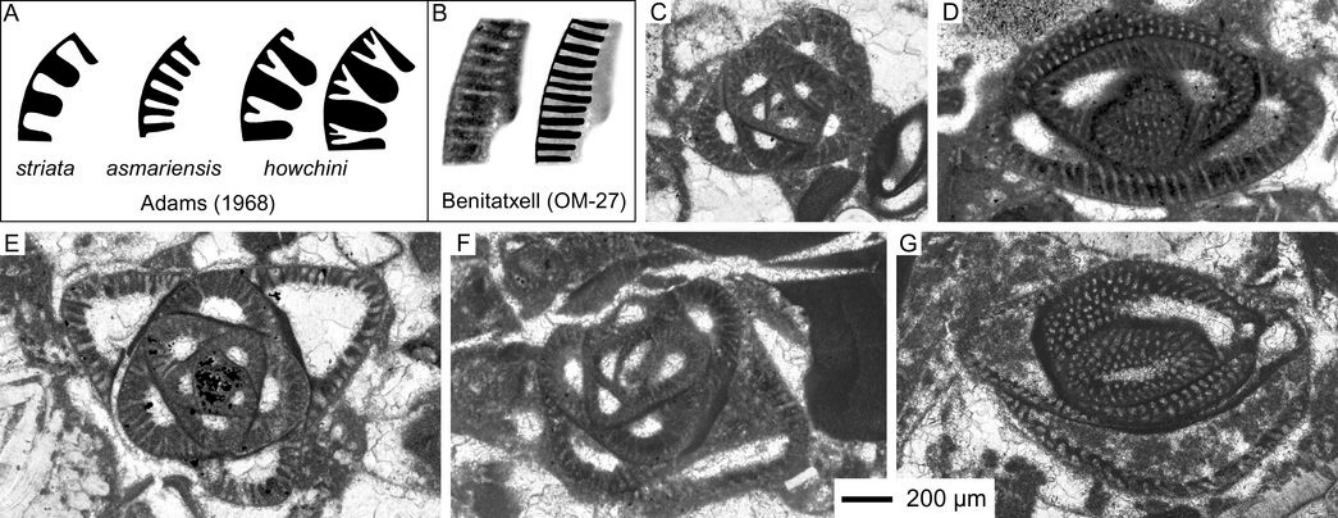
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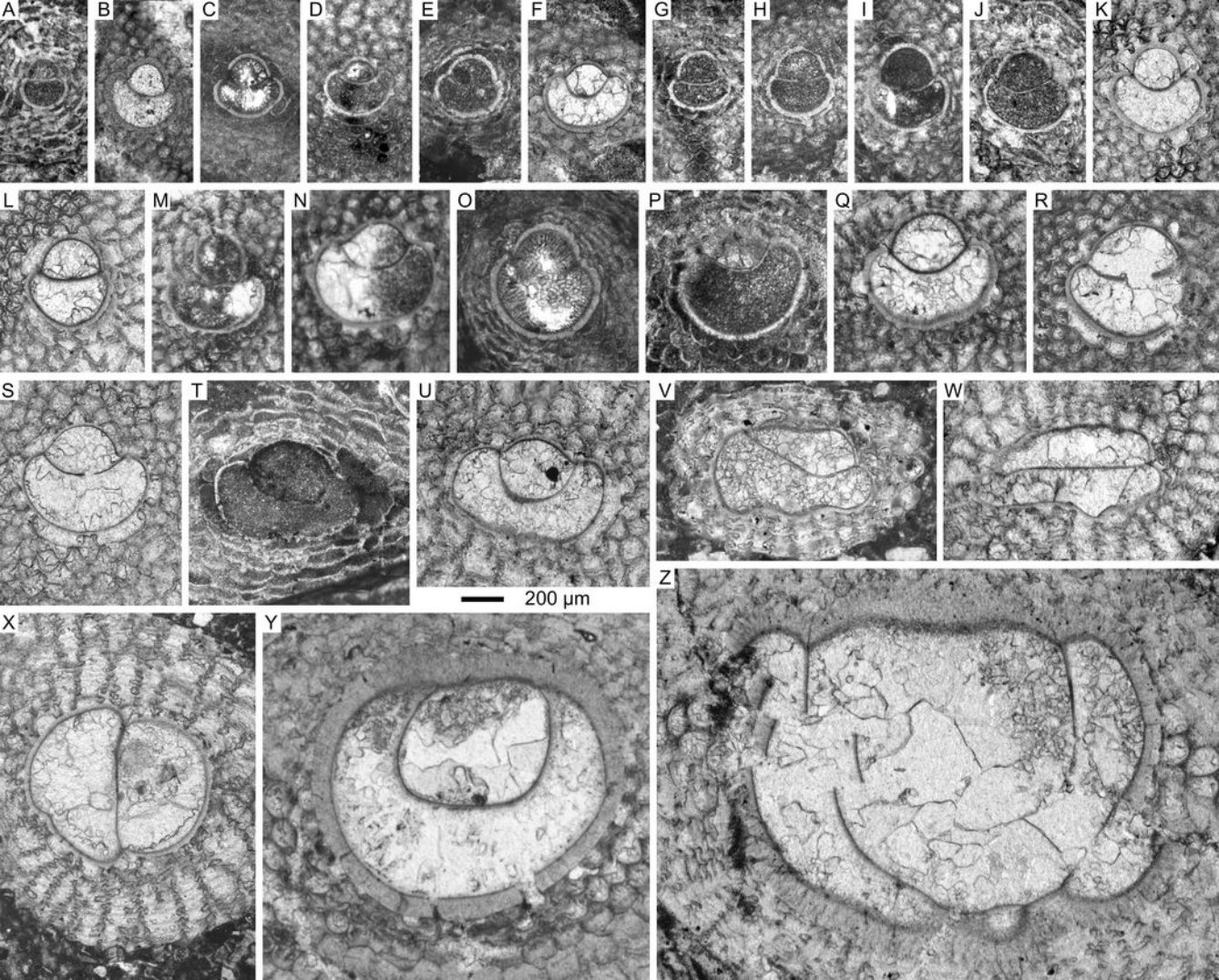
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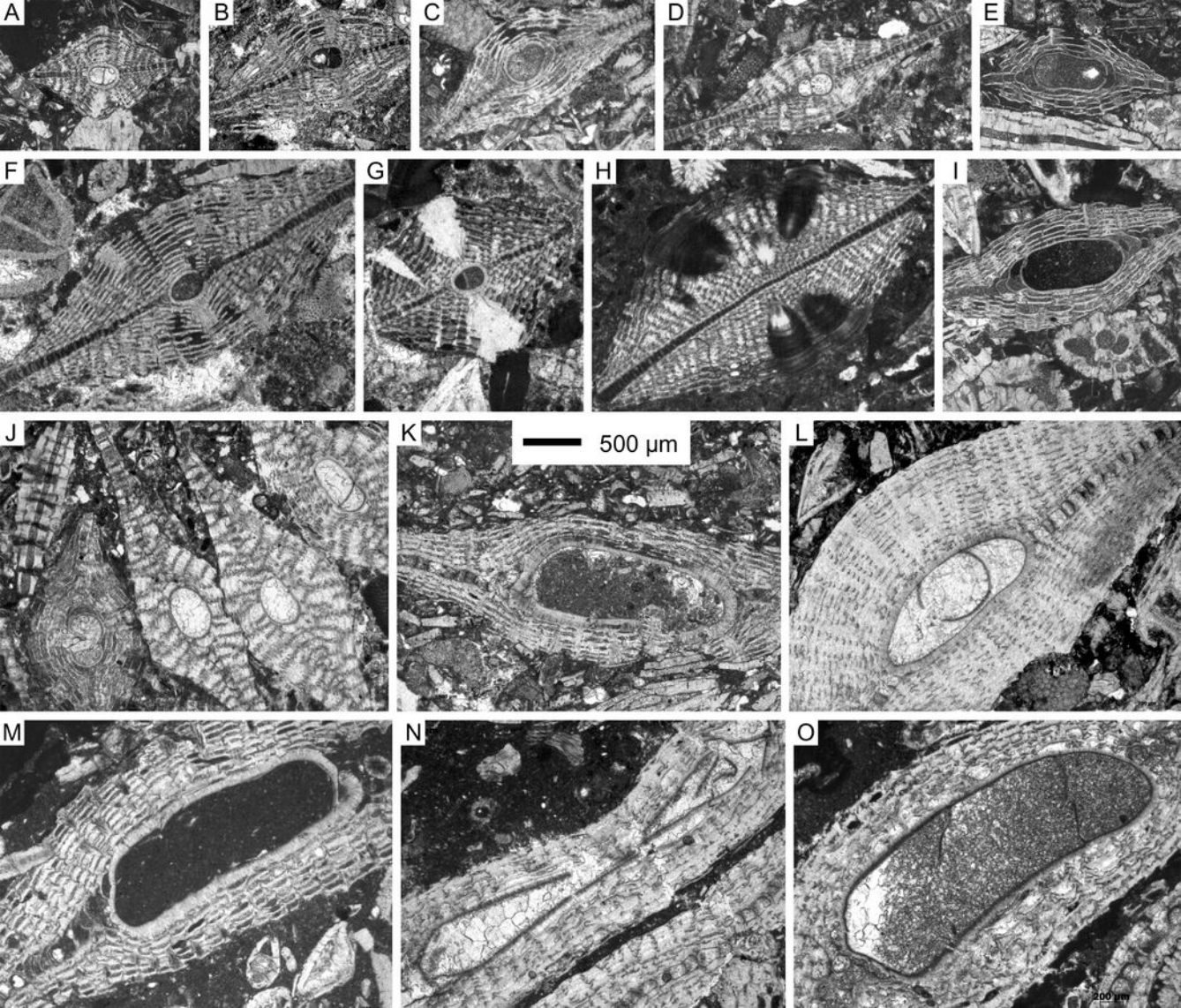
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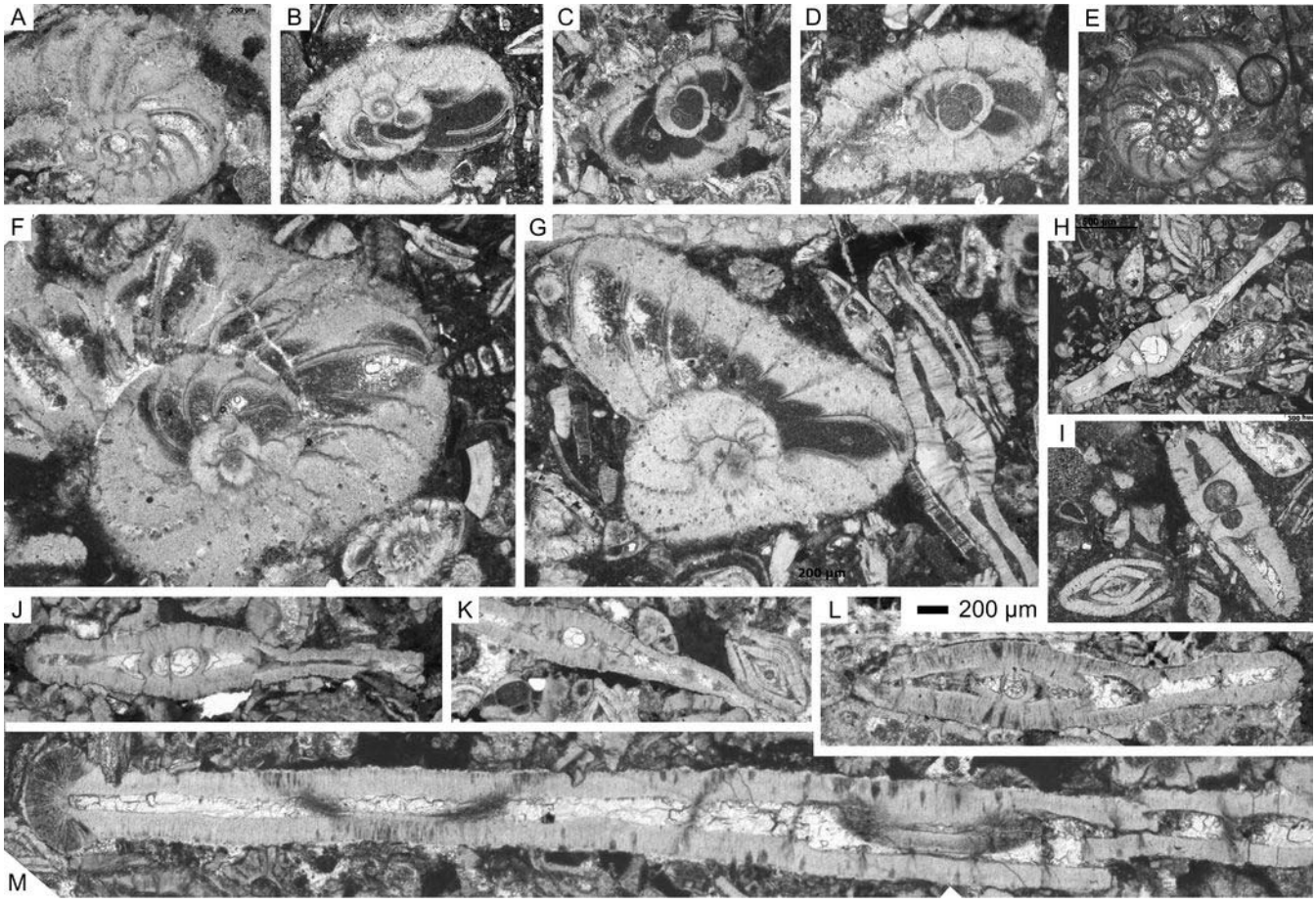
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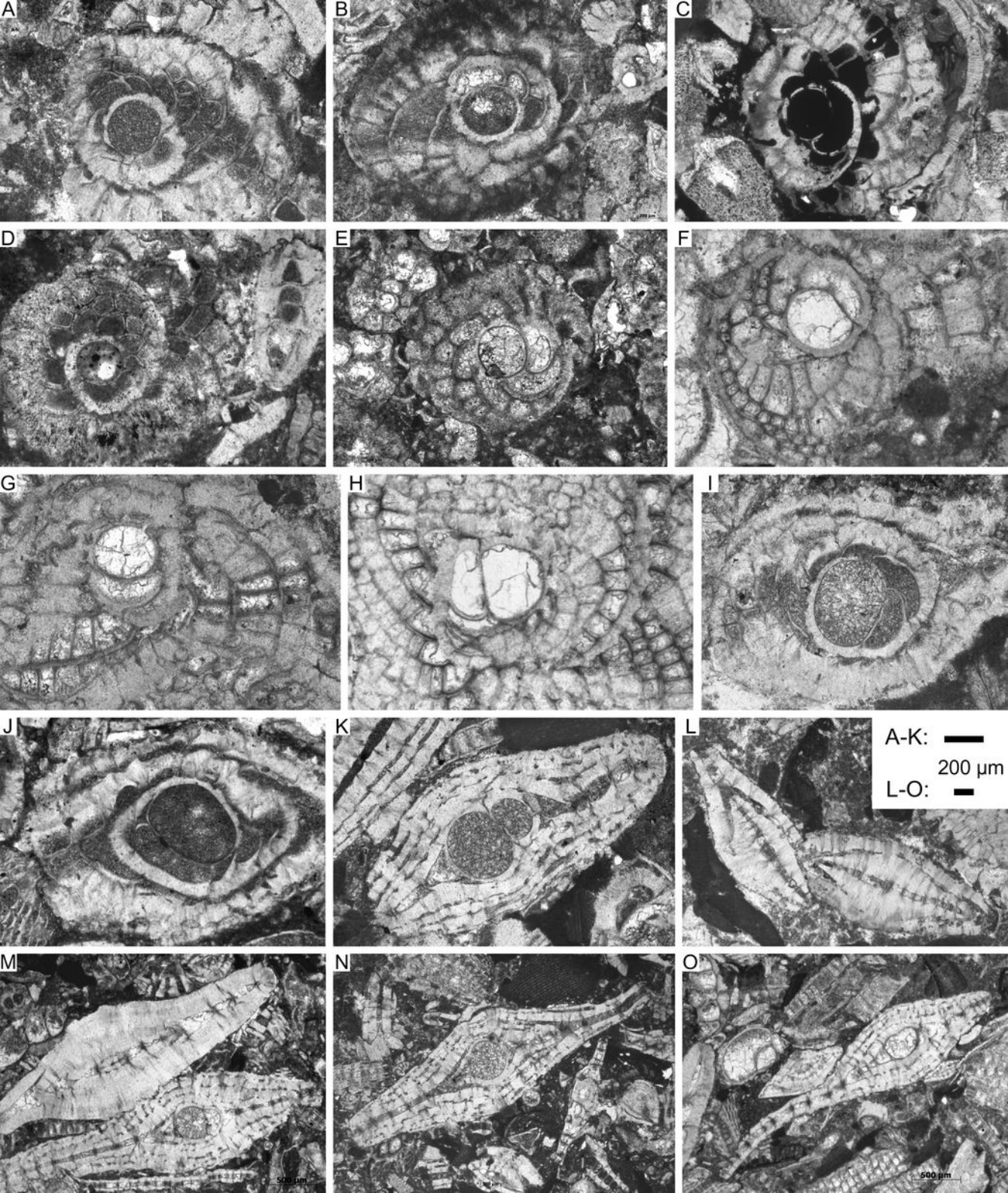
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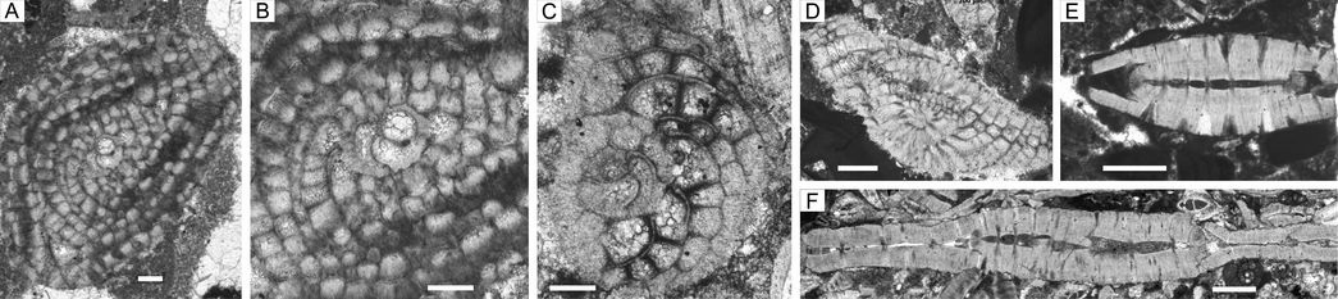
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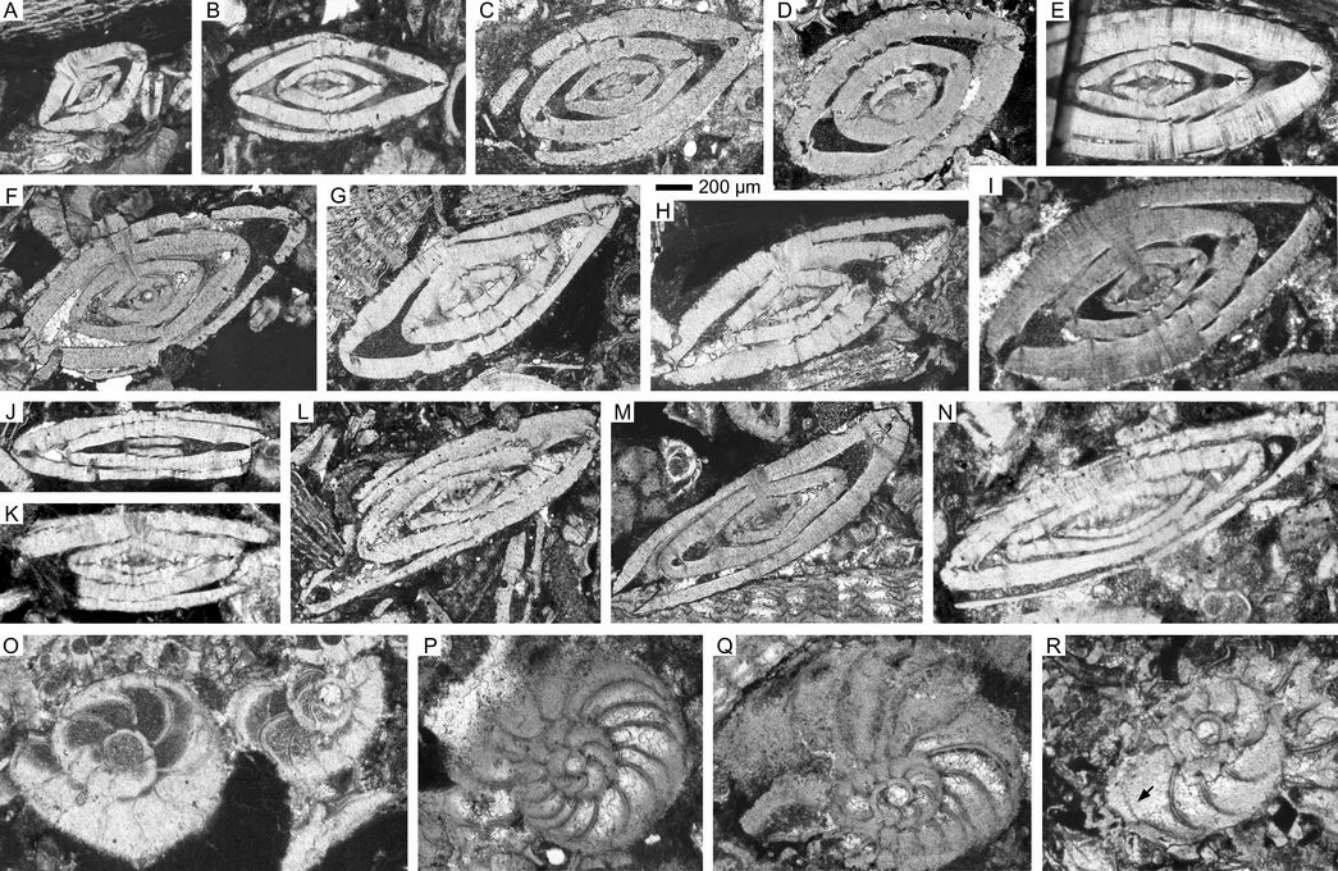
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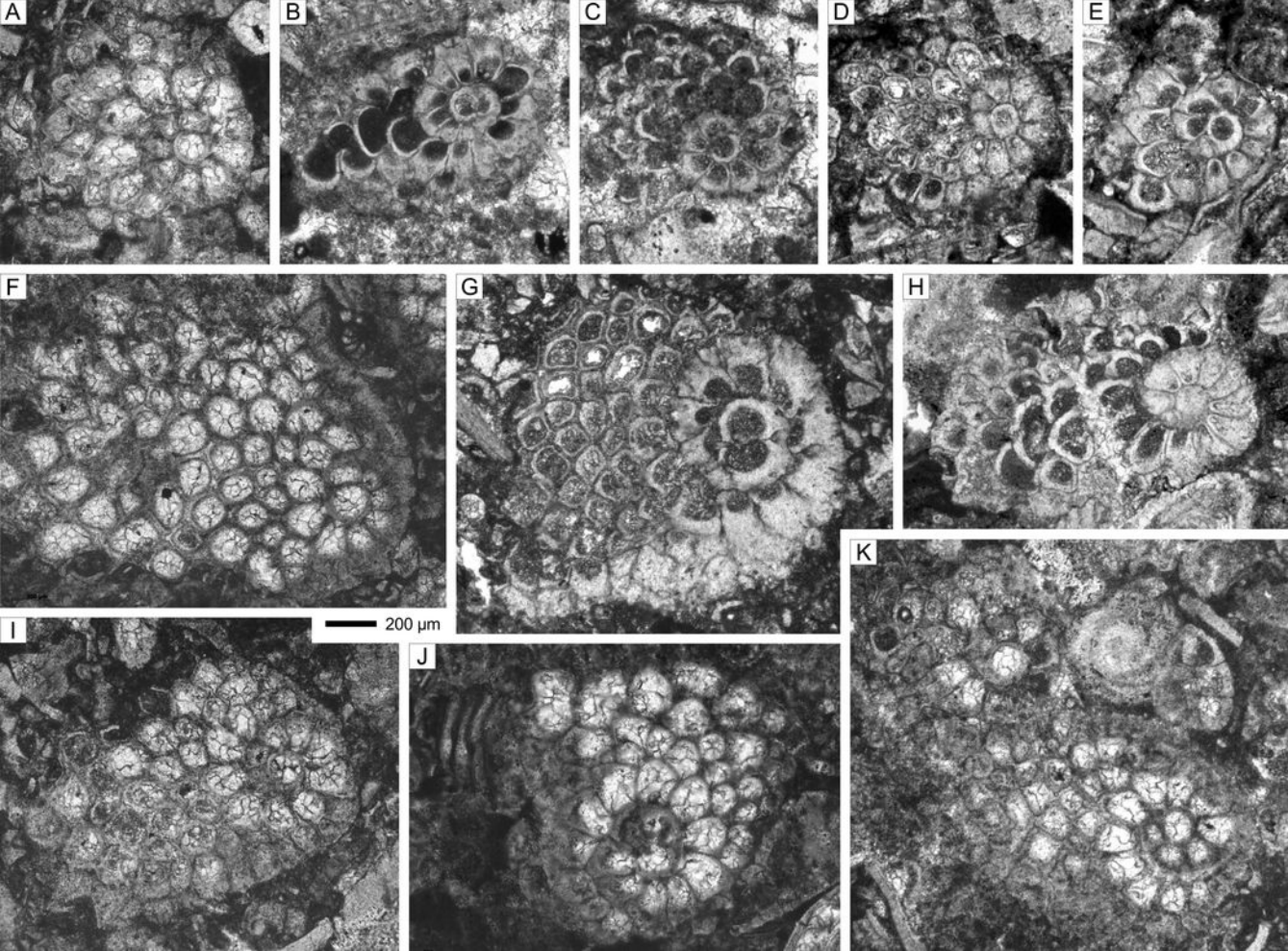
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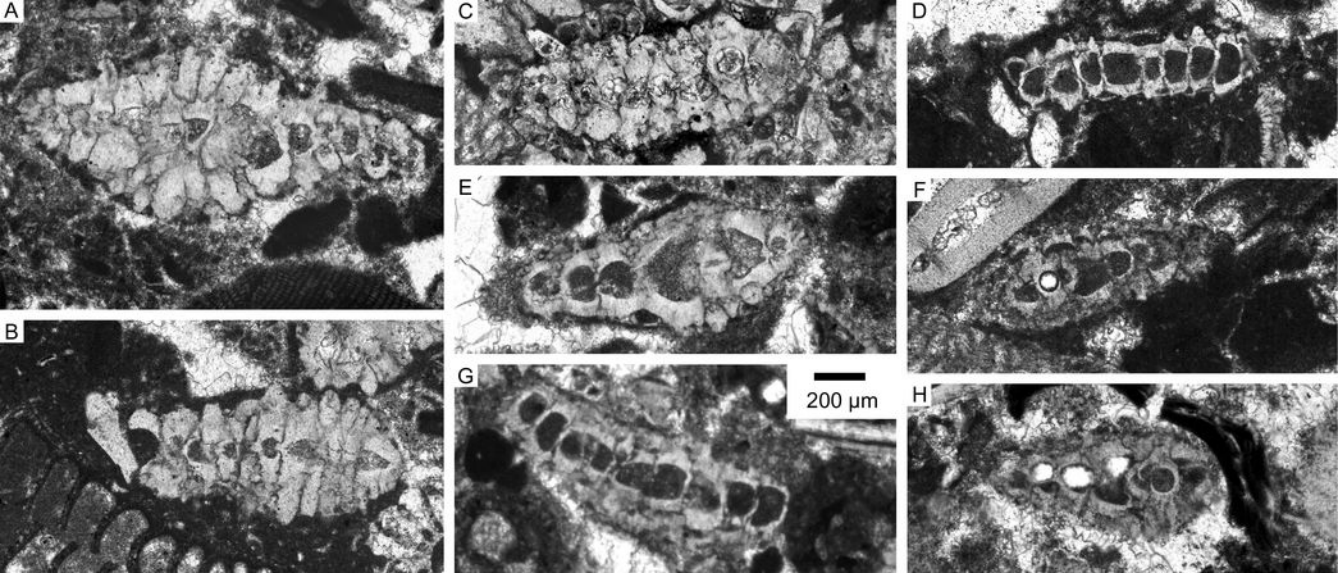
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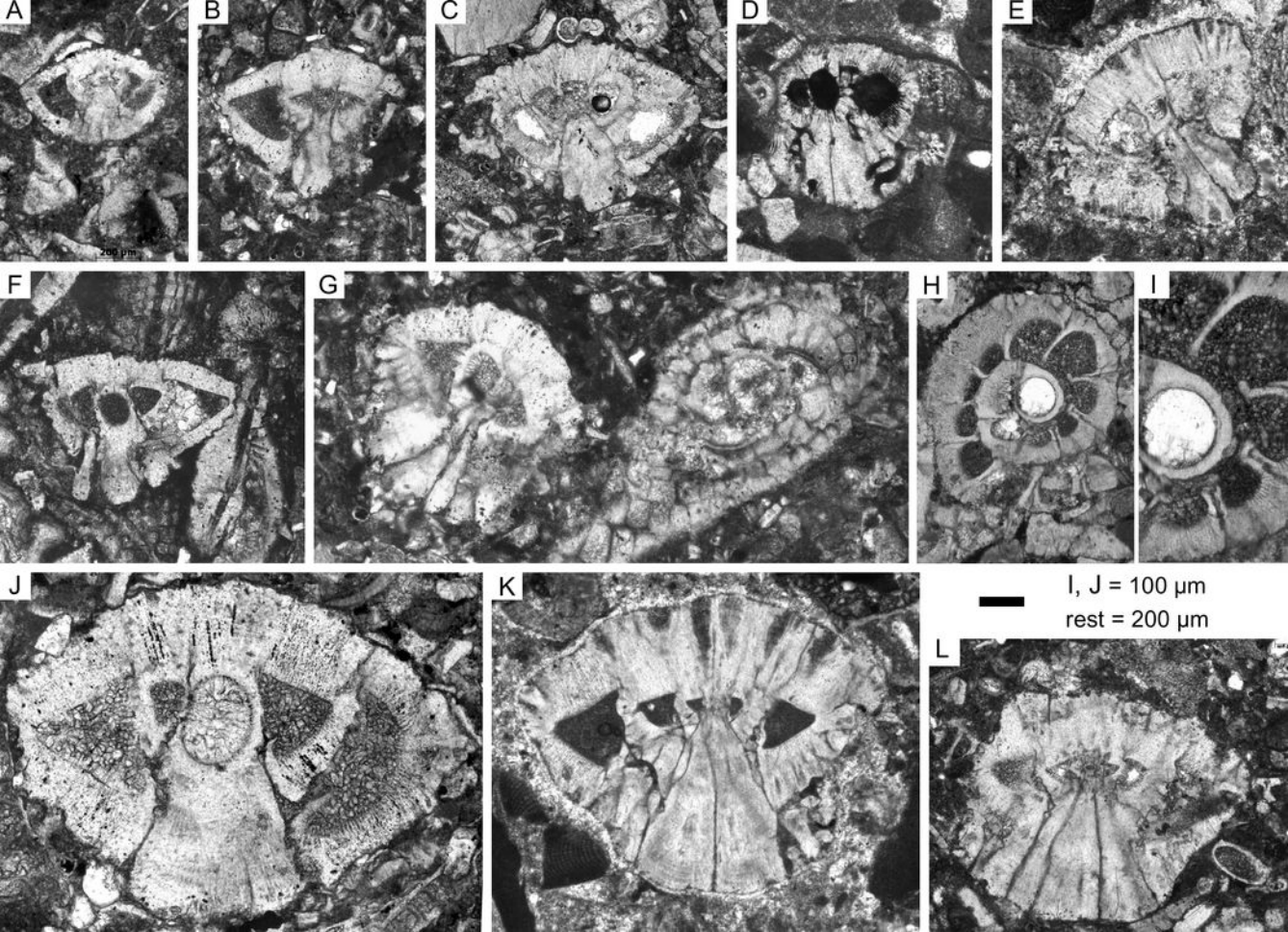
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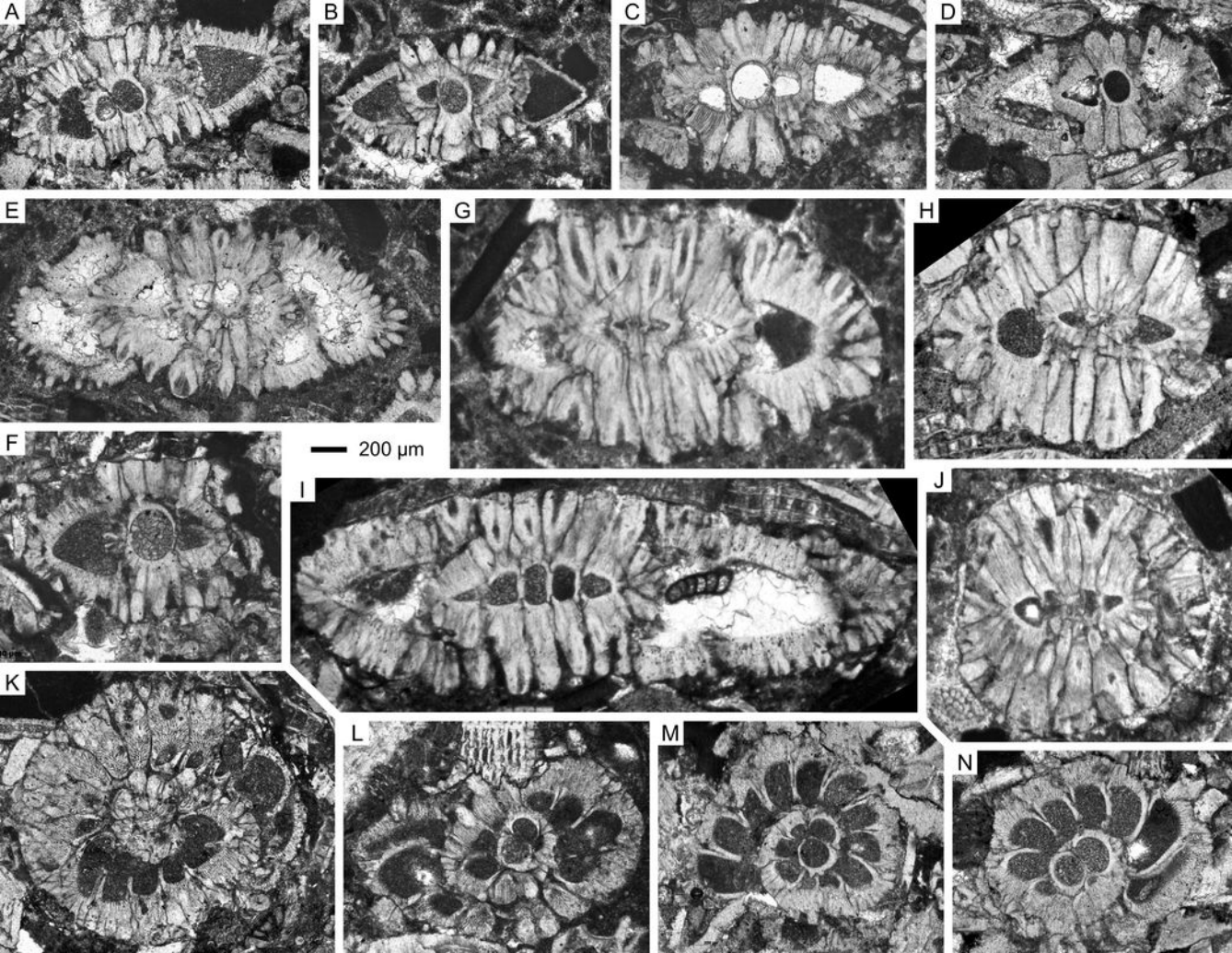
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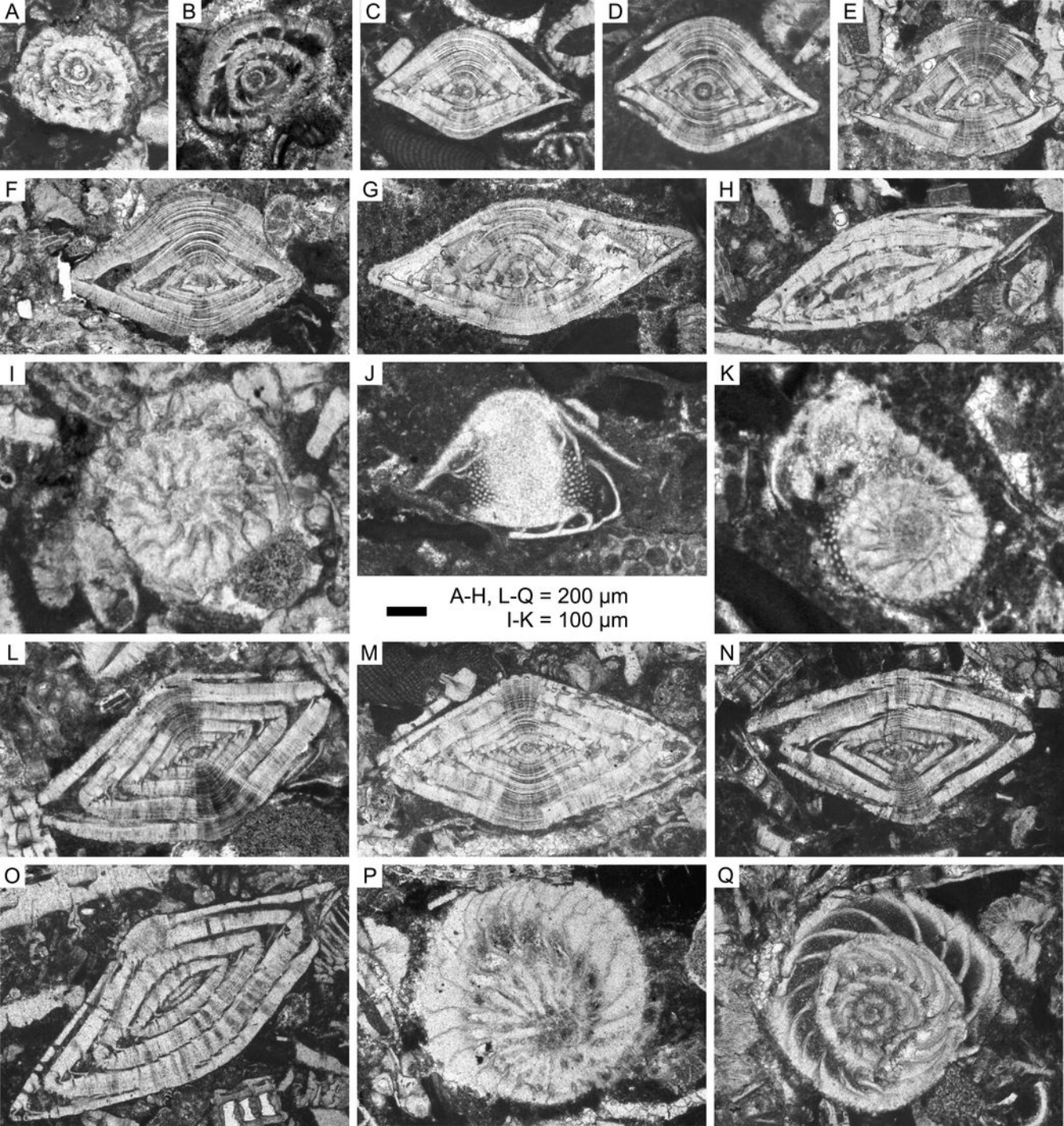
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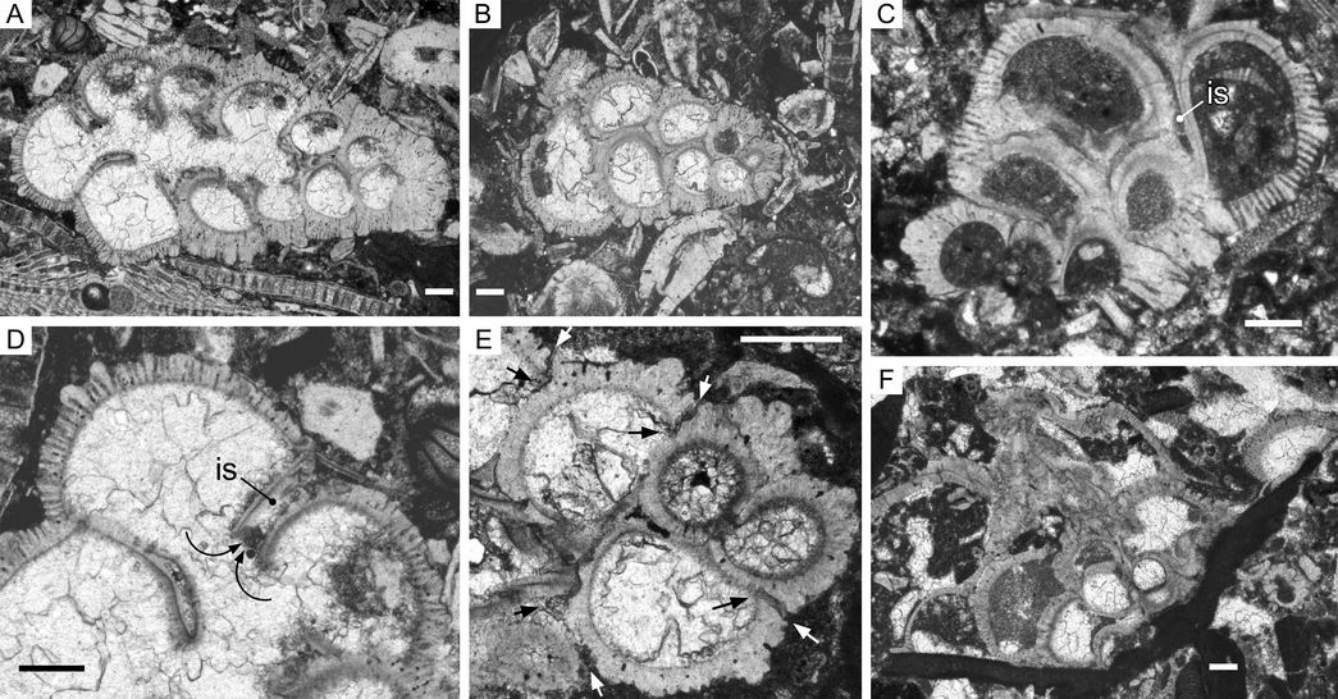
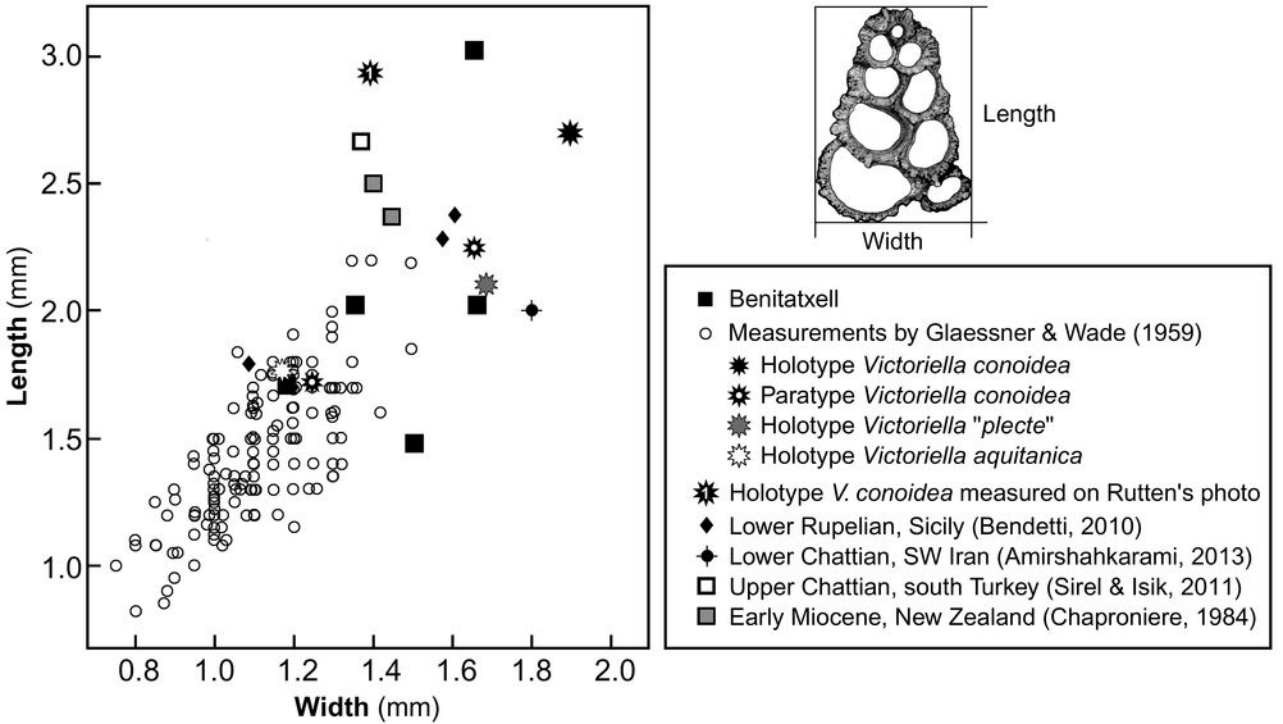
I-K = 100 µm
L
M
N
O
P
Q


A
B
C
is
D
is
E
F


3.0
2.5
2.0
1.5
1.0
Length (mm)
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Width (mm)
Length
Width
Benitatxell
Measurements by Glaessner & Wade (1959)
Holotype Victoriella conoidea
Paratype Victoriella conoidea
Holotype Victoriella "plecte"
Holotype Victoriella aquitanica
Holotype V. conoidea measured on Rutten's photo
Lower Rupelian, Sicily (Bendetti, 2010)
Lower Chattian, SW Iran (Amirshahkarami, 2013)
Upper Chattian, south Turkey (Sirel & Isik, 2011)
Early Miocene, New Zealand (Chaproniere, 1984)