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***Canalispina iapygia* gen. et sp. nov.: the last Siderolitidae (Foraminiferida) from the upper Maastrichtian of southern Italy**

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Abstract

Siderolitid larger benthic foraminifera are widespread and abundant microfossils in high-energy shallow-water Tethyan carbonate platform facies of Campanian – Maastrichtian age. The more evolved representatives of this group, placed in the genus *Siderolites*, are characterized by a complex canal system and by canaliculate spines. For these characters they have been often compared to recent calcarinids. The specific name *Siderolites calcitrapoides* has been almost invariantly used for all Maastrichtian siderolitids with spines. In this paper we give the first accurate description of the siderolitids occurring in the Maastrichtian carbonate platform facies of the Salento Peninsula (southeastern Apulia) and of the Pachino area (southeastern Sicily). The architecture of the test of these siderolitids differs considerably from that of true *S. calcitrapoides*. For these morphotypes we erect the new taxon *Canalispina iapygia* gen. et sp. nov. The new taxon developed longer and more robust spines by changing the architecture of the canal system and by embodying the base of the spines within the chambers. Biostratigraphy and strontium isotope stratigraphy support a late Maastrichtian age for the studied material, indicating that *Canalispina iapygia* gen. et sp. nov., represents the last step in the evolution of siderolitids before the extinction of the group at the Cretaceous-Paleocene boundary.

Key words: Siderolitidae, Larger Benthic Foraminifera, Taxonomy, Maastrichtian, southern Italy

1. Introduction

The Siderolitidae represent a successful group of larger benthic foraminifera (LBF) that developed and spread with high diversity and abundance in shallow-water of Tethyan real (there

are no Siderolitidae in the Caribbean, so far) platforms during the Late Cretaceous times. Since the description of the first representative by Lamarck (1801), *Siderolites calcitrapoides*, the siderolitids have been extensively studied to elucidate their complex architecture and their phylogenetic relationships (among the others: Osimo, 1907, Arni, 1933, Wannier, 1983, Neumann, 1997, Robles-Salcedo, 2014 and Robles-Salcedo et al. 2018). In these studies, the complex canal systems are described with increasing detail and the siderolitid morphotypes are compared with those of the family Calcarinidae Schwager, 1876, which includes representatives living nowadays in the tropical and subtropical zones of the western Pacific Ocean (Langer and Hottinger, 2000; Förderer et al., 2018). In particular, Osimo (1907) based his specific classification of siderolitids on the form and number of the spines, erecting several species and variations of the genus *Siderolites*, such as *S. preveri*, *S. nummulitispira*, *S. calcitrapoides* var. *brevispina*, which have been put in synonymy with *S. calcitrapoides* by Wannier (1983). Furthermore *S. rhomboidalis*, *S. rhomboidalis* var. *latispina*, *S. rhomboidalis* var. *crassissima* and *S. vanderbroeckii*, which have been considered as synonyms of *S. denticulatus* by Wannier (1983). In the recent calcarinids (such as *Calcarina gaudichaudii* d'Orbigny in Ehrenberg), the number of spines varies in the same species between 3 to >8 (Hottinger and Leutenegger, 1980; Röttger and Krüger, 1990; Röttger et al., 1990; Renema and Hohenegger, 2005). This intraspecific variability in the spine's number should be produced by environmental and physiological conditions due to the spines attached to macro-algae in high-energy environments.. For this reason, we agree with the synonymy proposed by Wannier (1983).

On the other hand, with the recent digitalization of papers published in scientific journals printed in former Soviet Union (Zernetsky, 1961; Ashurov 1983; Ashurov, 1987; Ashurov et al., 1988), other species of *Pseudosiderolites* and *Siderolites* must be added to the list of taxonomic names used for siderolitids, including *P. muschketovi* Zernetsky, 1961 (not documented), *P. akdjarensis* Ashurov 1983, *P. darwasensis* Ashurov, 1987, *P. djalilovi* Ashurov, 1987, and *S. quadratoformata* Ashurov in Ashurov et al. (1988). The original material of these species should be studied in detail soon in order to ascertain if they are valid taxa or synonyms.

Pending these further revisions, five genera and twelve species can be ascribed to the family Siderolitidae, according to the most recent taxonomical reviews (Robles-Salcedo, 2014; Robles-Salcedo et al., 2018): *Siderolites calcitrapoides*, *S. praecalcitrapoides* Neumann, 1986, *S. denticulatus*, Douvillé, 1907, *S. pyrenaicus* Robles-Salcedo, Vicedo, Caus, 2018, *Wannierina cataluniensis* (Wannier, 1983), *W. vilavellensis* Robles-Salcedo, Vicedo, Caus, 2018, *Pseudosiderolites vidali* (Douvillé, 1907), *Arnaudiella grossouvrei* Douvillé, 1907, *Praesiderolites dordoniensis* Wannier, 1983, *Pr. douvillei* Wannier, 1983, *Pr. praevidali* (Andreieff and Neumann, 1983) and *Pr. santoniensis* Wannier, 1983. In some cases, the species

replace each other in time, which gives to siderolitids a prominent role as biostratigraphical markers for Upper Cretaceous shallow-water deposits.

The most recent studies on siderolitids are a further demonstration that, for complex LBF, correct species identification, based on a careful interpretation of shell architecture, is a prerequisite for boosting their biostratigraphic use (Robles-Salcedo et al., 2018). However, despite their wide biostratigraphic application and their common occurrence, there are still several populations of siderolitids that are not well known yet. In particular, the siderolitids found in many Maastrichtian shallow-water carbonate deposits of the central and the eastern Tethys are generally reported under the all-catching name of *Siderolites calcitrapoides*, which has been used for all the morphotypes with long spines. A careful architectural revision of these morphotypes is needed, in order to confirm their taxonomic identification.

In this paper, we present a new description of a siderolitid taxon occurring in two classical localities for Maastrichtian shallow-water carbonates of southern Italy: the Salento peninsula (southeastern Apulia) and the Pachino area (southeastern Sicily). These localities are of particular interest because they have been dated by biostratigraphy and strontium isotope stratigraphy to the late Maastrichtian time (Colacicchi, 1963; Matteucci et al., 1982; Camoin et al., 1988; Parente, 1994, 1997; Steuber et al., 2007; Schlüter et al., 2008; Steuber and Schlüter, 2012). They record the last evolutive step in the development of LBF before the end-Cretaceous mass extinction.

2. Geological and stratigraphical setting

The Maastrichtian carbonates of the Salento Peninsula are part of the Meso-Cenozoic succession of the Apulian Carbonate Platform (ACP). One of the carbonate banks (Bernoulli, 2001; Bosellini, 2004) that developed in the southern Tethyan Ocean at the margin of Adria, a continental block that has been interpreted either as a northern promontory of the African plate (Channell et al., 1979; d'Argenio and Horvath, 1984) or as an independent microplate (Stampfli and Mosar, 1999). Along the southeastern coast of the Salento peninsula, the Apulian Carbonate Platform is represented by Campanian to upper Oligocene platform margin limestones (Parente, 1994; Bosellini et al., 1999). The samples studied for this paper come from the type locality of the Ciolo Limestone Fm, the Ciolo cove (Parente, 1994; Bosellini and Parente, 1994) (Fig.1). This unit consists of about 50 m of alternating bioclastic floatstone-rudstone and grainstone-packstone with rudists, calcareous algae (corallinaceans, peyssonneliaceans and dasycladaceans) and larger benthic foraminifera (Fig. 2.1-2.2). The LBF fauna reported by Parente (1994) includes *Omphalocyclus macroporus* (Lamarck, 1816), *Orbitoides gensacicus* (Leymerie, 1851), *Orbitoides apiculata*, Schlumberger, 1902, *Siderolites calcitrapoides*,

Lepidorbitoides socialis (Leymerie, 1851) and *Clypeorbis mamillatus* (Schlumberger, 1902) (Fig. 3). Based on this LBF fauna, and on the occurrence of rare specimens of *Contusotruncana contusa* (Cushman, 1926), the limestones of the Ciolo cove were attributed to the late Maastrichtian (Parente, 1994). A late Maastrichtian age was later confirmed by strontium isotope stratigraphy (Steuber et al., 2007; Schlüter et al., 2008; Steuber and Schlüter, 2012).

The Maastrichtian carbonates of the Pachino area (southeastern Sicily) are part of an isolated carbonate bank that developed above a submarine high of upper Campanian – lower Maastrichtian basalts (Camoin et al., 1988). From a paleogeographic point of view, these deposits are part of the Hyblean domain, which is a pelagic plateau developed in the Early Jurassic by drowning of a Late Triassic carbonate platform (Catalano et al., 2001). The studied samples have been collected on the Capo Passero Island from the Portopalo Limestone (Colacicchi, 1963) (Fig. 1). The succession consists of about 10 m of coral-rudist limestones (coral framestones, rudist biostromes, bioclastic floatstones and grainstones to packstones; Fig. 2.3 and 2.4) overlying a basaltic substrate and with thin intercalations of basaltic pillow-lavas (Camoin et al., 1988). The following assemblage of LBF was reported by previous authors (Colacicchi, 1963; Matteucci et al., 1982): *O. gensacicus*, *O. apiculata*, *Om. macroporus*, *Hellenocyclina beotica* Reichel, 1949, *S. calcitrapoides*. Based on the composition of the rudist and larger foraminifera assemblages the Portopalo Limestone was dated as Maastrichtian (Colacicchi, 1963; Matteucci et al., 1982; Camoin, 1988).

3. Material and methods

All the samples used for this study consist of well cemented limestones from which it was impossible to obtain isolated specimens of LBF. Therefore, the studied material consists of more than 60 random thin-sections, obtained from 19 rock samples. The morphological and taxonomical study of siderolitids is based on the same parameters and terminology used in Robles-Salcedo et al. (2018). The genus level classification is based in the absence or presence of morphostructural parameters, while morphometrical parameters have been used at the species level (Hottinger, 1978).

Most of the material figured in this paper is stored in the Museu de Ciències Natural de Barcelona (thin sections **MGB**), in Spain. The thin sections A.8697c and A.8696a (figured in Fig. 3 of this paper) are housed at the Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università di Napoli Federico II (Naples, Italy), collection Parente.

4. The architecture of the test of the new genus *Canalispina*

The siderolitids are lamellar-perforate LBF with a bilamellar wall (Smout, 1954), composed of an inner and an outer lamella. The combination and disposition of the imperforate refolds of the outer lamellae and of the septal flap and umbilical plate, formed by inner lamellae, generate a mesh of interconnected spaces, which is called canal system (see Hottinger, 2006 and Robles-Salcedo et al., 2018). This canal system is more or less complex in different genera. The Campanian morphotypes, such as *Praesiderolites*, have a simpler architecture than the Maastrichtian ones, such as *Siderolites*, which is characterized by a more complex canal system and by the development of canaliferous spines. The siderolitids occurring in the Maastrichtian carbonates of Salento (Apulia) and Pachino (Sicily) were identified by previous authors (see chapter 2) as *S. calcitrapoides*. However, a detailed revision of the material revealed a new architectural pattern for which a new genus of siderolitid is proposed: *Canalispina* gen. nov.

Embryonic stage

The embryo of *Canalispina* gen. nov. is similar to the other representatives of the Family Siderolitidae. The megalospheric generation starts with a spherical protoconch followed by a spherical deutoconch. The two embryonal chambers are connected by a single foramen. The embryo communicates with the first chamber of the nepionic stage by a single intercameral foramen situated in the proximal part of the deutoconch (see fig. 8 in Robles-Salcedo et al., 2018). The embryo of the microspheric generation has not been observed.

Nepionic stage

The nepionic, or juvenile stage is characterised by planispiral-involute chamber arrangement. The communication between the chambers is provided by a row of intercameral foramina placed at the base of the septa, as in the other siderolitids. Therefore, the number of foramina of the nepionic stage (with multiple foramina) differs from those of the embryonic stage (with single foramen). The canal system appears in the first whorl of the nepionic stage, developing the main types of canals, the umbilico-spiral, intraseptal, enveloping and marginal canals. The canaliferous spines, which also appear in this stage of the ontogeny, can be observed as little protuberances with arborescent canals in the equatorial plane.

Ephebic stage

In the adult, or the ephebic stage of growth, the planispiral-involute chamber arrangement and the type of intercameral foramina are the same as in the nepionic stage. However, we can observe other architectural features in the later stages of growth of *Canalispina* gen. nov. that differs from the other siderolitid genera known so far. In the ephebic stage, the chambers cover partially the spines, giving a characteristic triangular shape in oblique section. Moreover, in this

later stage the spines are fully developed, showing two different types, namely, main and secondary. The main spines are big and located at the equatorial plane. The secondary ones are smaller and located in the marginal zone, but slightly displaced with respect to the equatorial plane. In *Canalispina* n. gen., the canal system has a more complex structure than in any other siderolitid described so far. In the present work, we propose a new nomenclature to describe this complex spinal canal system, composed by **enveloping spinal canals** at the central part and **asymptotic feathered canals** at the peripheral part (Fig. 4). This architectural configuration produces differences in the density of the canals of the spines, developing a very complex marginal zone with a high density of canals, and leaving a more solid central part with a lower density of canals. Longitudinal sections through the centre of the spines do not show the arborescent club-shaped structure (see Hottinger, 2006, for more information) typical of *Siderolites*. Instead of that, towards the central part of the spine, we observe successive imperforated outer lamellae (free of canals) intercalated with a discontinuous convex canal system (enveloping spinal canals). Those convex canals take the shape of a feather duster in the periphery of the spine (asymptotic feathered canals in Figs. 4 and 5).

5. Systematic Paleontology

Phylum Foraminiferida d'Orbigny, 1826

Class Globothalamea Pawlowski, Holzmann and Tyszka, 2013

Order Rotaliida Delage and Hérouard, 1896

Superfamily Rotaloidea Ehrenberg, 1839

Family Siderolitidae Finlay, 1939

Canalispina gen. nov.

Type species: *Canalispina iapygia* sp. nov.

Etymology. From canals (*canalis* in latin) and spine (*spina* in latin), referring to the presence of superposed marginal canals in the spines.

Diagnosis. Lamellar perforate, lenticular to almost circular shell with two types of spines, main and secondary. Ornamentation consisting of large piles, beads and ridge piles. Reniform embryo, consisting of spherical protoconch and deuteroconch, followed by chambers with planispiral-involute arrangement. A row of intercameral foramina at the base of the septa connects successive chambers. Canaliculate test composed of intraseptal, umbilico-spiral, marginal and a dense network of enveloping canals. Canaliculated spines with a heavy ornamentation and a complex spinal canal system with asymptotic feathered and enveloping spinal canals.

Differential diagnosis. *Canalispina* gen. nov. differs from *Siderolites* (type species: *S. calcitrapoides* Lamarck, 1801) by the presence of the complex spinal canal system with enveloping spinal and asymptotic feathered canals, instead of arborescent club-shaped spinal canals typical of *Siderolites* (Fig. 5). Furthermore, *Canalispina* gen. nov. differs from *Siderolites* by having an extension of the chamber growth over the spines, giving the typical triangular shape of the chambers in oblique sections. The new genus *Canalispina* displays also a denser enveloping canal system than any other representative of siderolitids.

***Canalispina iapygia* gen. et.sp. nov.**

Figures 6 and 7

1988 *Siderolites denticulatus* (Douvillé) – Meriç, pl. I, figs. 1-8

1994 *Siderolites calcitrapoides* Lamarck – Parente, pl. I, fig. 6

1997 *Siderolites calcitrapoides* Lamarck – Parente, pl. XXVI, fig. 4

2003 *Siderolites calcitrapoides* Lamarck – Abdelghany, figs. 10.13-10.14

2004 *Siderolites calcitrapoides* Lamarck – dalla Vecchia et al., figs. 6-7

2014 *Siderolites* n. sp. – Robles-Salcedo, pl. XVIII, figs. A-D and pl. XIX, Figs. A-J

In press *Siderolites calcitrapoides?* Lamarck – Vicedo et al., fig. 14D

Locality and horizon. Ciolo, east of Gagliano del Capo, Apulia, SE Italy (Coordinates: 39° 50'39N, 18°23'06E; Fig. 1.1); upper Maastrichtian, Ciolo Limestone Fm.

Etymology. From Iapigia (in greek Ἰαπυγία), the root name of the pre-romans populations settled in Apulia, actual Puglia region (southern Italy).

Material. Holotype: MGB 87955LP1.1 in Fig. 6.1.

Occurrence. Salento Peninsula, Sicily Island (southern Italy) and Monti della Bernadia (Nimis, Udine, northern Italy; dalla Vecchia et al., 2004), Anatolian peninsula (Turkey; Meriç, 1988), Arabian plate (Abdelghany, 2003).

Diagnosis and description. Lamellar-perforate, lens-shaped test with the architecture of the genus *Canalispina* gen. nov. Ornamentation composed by large beads, piles and ridge piles. Canal system consisting of intraseptal, umbilico-spiral, marginal and a dense network of enveloping canals. 3-4 main, large spines with a complex enveloping spinal canal system and presence of secondary spines. Dimorphism is not observed. Index of axial compression or axial thickness/diameter ratio of 0.57. Adult shell with an equatorial diameter of around 3.5 mm (excluding spines), varying from 3 to 4.8 mm with 5 to 6 whorls. Specimens starting with a protoconch of 70-110 µm in diameter followed by a deuteroconch of 70-120 µm.

Associated larger foraminifera. *Omphalocyclus macroporus*, *Orbitoides gensacicus*, *Orbitoides apiculata*, *Sirtina orbitoidiformis* Brönnimann and Wirz, 1962, *Lepidorbitoides socialis*, *Clypeorbis mamillatus*, *Hellenocyclina beotica*, *Elazigina siderea* Consorti and Rashidi, 2018, *Rotorbinella* sp..

6. Phylogenetic development of siderolitids

The first appearance of siderolitids is in the late early to middle Campanian, with species ascribed to the genus *Praesiderolites* Wannier, 1983. Later, during the late Campanian, the siderolitids evolve to species architecturally more complex, belonging to the genus *Arnaudiella* Douvillé, 1907, and then *Pseudosiderolites* Smout, 1955. Species of these genera co-occur with the most evolved species of *Praesiderolites*. All of them are morphotypes without canaliferous spines. Only in some species of *Praesiderolites*, such as *Praesiderolites douvillei*, there is a narrow denticular periphery that hints to the beginning of spines, like in *Neorotalia calcar* (d'Orbigny in Deshayes, 1830). During the latest Campanian and Maastrichtian, the siderolitids with spines become more and more frequent up to the appearance of specimens with true canaliferous spines, such as species belonging to the well-known genus *Siderolites*.

Morphotypes with strong keel and without spines, belonging to species of the genus *Wannierina*, are also found in the same time interval. Therefore, there are two stages that are important in the phylogeny of the Siderolitidae in the Late Cretaceous carbonate platforms of the Tethyan Ocean. The first occurs during the early Campanian, with the first appearance of siderolitids in the fossil record, with *Praesiderolites santoniensis*. The second one is represented by the evolutionary radiation of the species with canaliferous spines during the latest Campanian. *Canalispina iapygia* gen. et.sp. nov. is the last species of siderolitids known from the fossil record before the Cretaceous–Paleogene (K–Pg) boundary. Its morphology confirms the evolutive trend of development of more and more complex and longer spines in LBF dwelling in high-energy shallow-water environments.

7. Biostratigraphy and strontium isotope stratigraphy

The LBF associated with *Canalispina iapygia* gen. et.sp. nov. indicate the *Lepidorbitoides socialis* zone of Van Gorsel (1978), which supports a latest early to late Maastrichtian age. In particular, in European basins the first occurrence of *Orbitoides gensacicus* and *Hellenocyclina beotica* is considered to mark the base of the upper Maastrichtian (Arnaud-Vanneau and Bilotte, 1998). The presence of *Contusotruncana contusa* and of *Racemiguembelina fructicosa* (Egger, 1900), recorded in the upper part of the Ciolo Limestone exposed in the Ciolo cove (Parente, 1997; Steuber et al., 2007), indicates an age not older than the latest part of the early Maastrichtian (*R. fructicosa* zone). Finally, a late Maastrichtian age is supported by strontium

isotope stratigraphy, which gave a numerical age of 66.4 ± 1.5 Ma (Steuber et al., 2007; Schlüter et al., 2008), later recalculated to 67.1 ± 0.7 Ma (Steuber and Schlüter, 2012).

8. The canaliculated spine architecture and its palaeoenvironmental significance

The palaeoenvironmental distribution of siderolitids, the functional morphology of their shells and their comparison with recent calcarinids have been discussed by several authors (see for instance: Wannier, 1983; Robles-Salcedo et al., 2013; Robles-Salcedo, 2014; Hart et al., 2016; Robles-Salcedo et al., 2018). Recent calcarinids dwell mainly on firm substrates exposed to high energy waves and swells and they are particularly abundant on substrates covered by macro-algae (Hottinger and Leutenegger, 1980; Reiss and Hottinger, 1984; Hohenegger, 1994, 2005; Renema and Troelstra, 2001; Renema, 2008, 2010, 2018). A similar paleoenvironmental distribution can be hypothesized for siderolitids with strong spines, such as *Siderolites* and *Canalispina* gen. nov. The star outline and also canaliculated spines could serve to facilitate anchoring to the thalli of filamentous macro-algae, to prevent detachment in high-energy environments, as in *Calcarina splengeri* (Gmlein, 1791) or *C. gaudichaudii* d'Orbigny in Ehrenberg, 1840 (Röttger and Krüger, 1990; Hohenegger, 1994). *Canalispina iapygia* gen. et sp. nov. has been found so far only in grainstones and rudstones suggesting deposition in high-energy environments above the wave base (Fig. 2). In the microfacies with *Canalispina* gen. nov., spine sections with asymptotic feathered and enveloping spinal canals are a very common component (Figs. 4.1 and 6.5).

We want to emphasize that the change in the architectural pattern of canaliculated spines introduced with the appearance of *Canalispina iapygia* gen. et sp. nov. could represent an innovative adaptative solution to life in a shallow-water high-energy environment. The spines of the well-known genus *Siderolites* have an arborescent radial canal system and are not very long (1-1.5 mm). A longer spine with an arborescent club-shaped canal system would be more fragile. In *Canalispina iapygia* gen. et sp. nov. the architecture of the spine and of their canal system is functional to growing longer spines (> 2 mm) that are also more robust at the same time. This is attained with two innovations. The first one is to replace the arborescent radial canals in the central part of the spine (typical of *Siderolites*) with a more solid central part surrounded by a complex canal system, consisting of enveloping spinal and asymptotic feathered canals. The second “trick” is to reinforce the base of the spine by growing the chambers around it (Figs. 6.4-6.6 and 7.1-7.2). Developing an enveloping canal system would also give an additional benefit. A higher number of canals would increase the ability of extending and retracting the protoplasm rapidly, favouring a faster response to rapid changes in the environmental conditions.

9. Conclusions

The population of siderolitids found in the upper Maastrichtian platform carbonates of Apulia and Sicily (southern Italy) record the last step in the evolution of this group of larger benthic foraminifera before their demise at the K/Pg boundary. The fossil record of siderolitids, as in many other groups of LBF, depict an evolutionary trend of increasing size and architectural complexity of the shell. The small size of the oldest representatives of the genus *Siderolites*, e.g. *S. praecalcitrapoides* (less than 2.1 mm), found in the latest Campanian of the Pyrenean domain, contrast with the large size of the late Maastrichtian morphotypes of *Canalispina iapygia* gen. et sp. nov. (up to 3 mm). These youngest morphotypes show a remarkable complexity, reflected in the presence of longer spines, with a complex spinal canal system, and a denser network of enveloping canals. Long spines are a very successful adaptive innovation, appearing only in the youngest and most evolved forms of siderolitids, which include all the species ascribed to the genus *Siderolites* and *Canalispina iapygia* gen. et sp. nov.. In the latter taxon, even longer and more robust spines are developed, by changing the architecture of the canal system and by embodying the base of the spines within the chambers.

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Figure 1. Geographic and simplified geologic location of the studied areas and position of the type locality of *Canalispina iapygia* gen. et sp. nov. 1. Location of the type locality in Ciolo inlet, Salento, Apulia (modified from Schlülter et al., 2008); 2. Location of the Capo Passero field near Pachino in Sicily Island (modified from Camoin et al., 1988). Legend is based in geometric patterns.

Figure 2. Microfacies with *Canalispina iapygia* gen. et sp. nov. from the upper Maastrichtian of Apulia and Sicily. 1. Bioclastic floatstone-wackestone with rudist fragments encrusted by red algae (marked with a black arrow) in the lower part of the Ciolo Limestone, Apulia (MGB 87951LP1); 2. Bioclastic rudstone-grainstone with *Orbitoides gensacicus* and bivalves fragments in the upper part of the Ciolo Limestone, Apulia (MGB 60267LP01). Note the canaliferous spine of *Canalispina* gen. nov. *iapygia* sp. nov. (black arrow); 3 and 4 Bioclastic grainstone-packstone with *Orbitoides gensacicus*, *Omphalocyclus macroporus* and *Solenomeris* cf. *ogormani* in Portopalo Limestone, Sicily (MGB 87956LP2 and LP3); Scale bar: 2 mm; Abbreviations: Ci: *C. iapygia* gen. nov. sp. nov. Cm: *Clypeorbis mamillatus*; O: *Orbitoides* sp.; Om: *Om. macroporus*; Ru: rudist; So: *S. ogormani*

Figure 3. Association of foraminifera and algae. 1. *Sirtina orbitoidiformis* Brönnimann and Wirz, 1962 and *Orbitoides gensacicus* (Leymerie, 1851) (MGB 87956LP1.1 and MGB 87956LP1.2; scale bar: 500 µm); 2. *Clypeorbis mamillatus* (Schlumberger, 1902) (MGB 87953LP2.1; scale bar: 1 mm); 3. *Orbitoides gensacicus* (Leymerie, 1851) (MGB 87956LP1.3; scale bar: 1 mm); 4. *Orbitoides apiculata* Schlumberger, 1902 (A.8697c; scale bar: 1 mm); 5. *Cympolia barattoloi* Parente, 1994 (A.8696a; scale bar: 1 mm); 6. *Rotorbinella* sp. (MGB 87957LP1.1; scale bar: 500 µm); 7. *Elazigina siderea* Consorti and Rashidi, 2018 (MGB 84632 LP2.13; scale bar: 500 µm); 8. *Contusotruncana contusa* (Cushman, 1926) (A.8696a.2; scale bar: 500 µm); 9. *Racemiguembelina* sp. (A.8696.6; scale bar: 500 µm)

Figure 4. *Canalispina* gen. nov. and *Siderolites* canaliferous spines, showing the differences of the pattern of canals in the spine. 1. Tangential section of *Canalispina iapygia* gen. et sp. nov. showing its spine in longitudinal section. Note the distribution pattern made by asymptotic feathered and enveloping spinal canals; 2. Axial section of *Siderolites* with arborescent club-shaped canals; Abbreviations: afc: asymptotic feathered canal; bd: bead; ch: chamber; csp: canaliferous spine; esc: enveloping spinal canals; ic: interseptal canal; pil: pile; rpil: ridge pile; s: septum; vuc: vertical umbilical canal or funnel

Figure 5. Schematic 3D models of internal cavities (canal system and chambers) of the two genera with canaliferous spines. 1. Genus *Siderolites* (redrawn from Wannier, 1980); 2. Genus *Canalispina* gen. nov.; Abbreviations: afc: asymptotic feathered canal; ch: chamber; csp:

canaliculated spine; envc: enveloping canals; ic: intraseptal canal; P: protoconch; pmc: parallel marginal canal; rmc: radial marginal canal; sc: spiral canal; ssp: secondary spine

Figure 6. *Canalispina iapygia* gen. et sp. nov. from the upper Maastrichtian of southern Italy; 1. Axial section, specimen from the Ciolo Limestone, Apulia (holotype, MGB 87955LP1.1); 2. Oblique section of a specimen from the Portopalo Limestone, Sicily (MGB 87958LP1.1); 3. Equatorial section of a specimen from the Ciolo Limestone, Apulia (MGB 87955LP2.1); 4. Specimen in transversal section slightly oblique; Portopalo Limestone, Sicily Island. See the triangular shape made due to the covering of the spine by the chambers (MGB MGB 87958LP1.2); 5. Transversal section of a canaliferous spine. Note that the spine is surrounded by chambers. From Portopalo Limestone, Sicily Island (A.8696a.3); 6. Tangential section with the spine and the chambers. Ciolo Limestone, Apulia (MGB 87955LP2.2); Scale bar: 1 mm; Abbreviations: afc: asymptotic feathered canal; ch: chamber; e: embryo; envc: enveloping canals; esc: enveloping spinal canals; p: pile; rpil: ridge pile; s: septum.

Figure 7. *Canalispina iapygia* gen. et sp. nov. from the upper Maastrichtian of the Ciolo Limestone, Apulia. 1: Tangential section showing the main spines and the secondary ones (MGB 60267LP1.5; scale bar: 500 μ m); 2 and 6. Tangential sections (MGB 87954LP1.1 and MGB 87959LP1.1; scale bar: 1 mm); 3: Detail of Figure 8.1 (scale bar: 200 μ m); 4: Axial section slightly oblique (MGB 87953LP1.1; scale bar: 1 mm); 5: Transversal section (MGB 87954LP2.1; scale bar: 1 mm); 7. (MGB 87953LP3.1; scale bar: 1mm) Abbreviations: ch: chamber; e: embryo; envc: enveloping canals; esc: enveloping spinal canals; p: pile; rpil: ridge pile; ssp: secondary spine.