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TRIASSIC AND JURASSIC CALCAREOUS NANNOFOSSILS OF THE PIZZO MONDELLO SECTION: A SEM STUDY

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Abstract. Pizzo Mondello is a ca. 500 m thick pelagic-hemipelagic succession cropping out in Sicily consisting of a nodular cherty limestone facies association of late Carnian to late Norian age. The uppermost portion was attributed to the Rhaetian and is represented by the plane-bedded Portella Gebbia Limestone. The section has been proposed as the stratotype for the base of the Norian stage. The calcareous nannofossil content of limestones was studied with Scanning Electron Microscope (SEM) in two portions of the Pizzo Mondello section, one within “La Cava” that encompasses all the proposed horizons for the base of the Norian, and one within the Portella Gebbia Limestone in the uppermost part of the section.

Calcareous nannofossil assemblages of the first portion display low diversity, being constituted exclusively by calcispheres, that may constitute up to 40% of the sediment volume. Species richness increases in the upper portion. Initially, samples are dominated by *Prinsiosphaera triassica*, a nannolite of unknown taxonomic affinity. Rare calcareous dinocysts (*Thoracosphaera* cf. *geometrica*) and coccoliths are present in few samples. Uppermost samples are still dominated by “calcispheres” comparable to *Thoracosphaera*, but also yield a variety of coccoliths and nannoliths.

Calcareous nannofossil distribution was calibrated with conodont and radiolarian biostratigraphy. On the basis of this integrated work, specimens attributed to cf. *Thoracosphaera*, observed in the lower portion of the section, are late Carnian to early Norian, while samples dominated by *Prinsiosphaera*, with rare *Thoracosphaera* and coccoliths are Rhaetian. The calcareous nannofossil assemblage of the uppermost samples, along with radiolarians and the absence of conodonts, point to a Jurassic age (Pliensbachian) for the uppermost Portella Gebbia Limestone at Pizzo Mondello. In conclusion, the age of the uppermost part of the Pizzo Mondello section is Jurassic, i.e., younger than previously thought. Calcareous nannofossils are present from the base of section and exhibit a significant taxonomic diversity, thus pro-

viding an auxiliary biostratigraphic frame for the Rhaetian - Jurassic interval in this area.

Riassunto. La sezione di Pizzo Mondello (Sicilia) consiste di una successione di carbonati pelagici-emipelagici dello spessore di ca. 500 metri. La porzione carnica superiore - norica è caratterizzata da calcari nodulari selciferi, mentre la porzione sommitale, considerata retica, comprende i calcari di Portella Gebbia, a stratificazione piano-parallela. Pizzo Mondello è stata proposta come stratotipo del Norico. È stato studiato, con l'ausilio del microscopio elettronico a scansione (SEM), il contenuto di nannofossili calcarei di due porzioni della sezione, una in località “La Cava” che comprende tutti gli orizzonti proposti come base del Norico, una seconda nei calcari di Portella Gebbia. Nel tratto di sezione inferiore sono presenti solamente calcisfere determinate come cf. *Thoracosphaera*, che possono costituire fino al 40% della roccia. La diversità specifica aumenta nella porzione superiore, alla base della quale i campioni sono dominati da *Prinsiosphaera triassica*, un nannolite di affinità tassonomica incerta. Sono presenti anche cisti calcaree di dinoflagellati (*Thoracosphaera* cf. *geometrica*) e coccoliti. I campioni più alti sono dominati da calcisfere (cf. *Thoracosphaera*), ma contengono anche una varietà di coccoliti e nannoliti.

La distribuzione dei nannofossili calcarei è stata calibrata tramite biostratigrafia a conodonti e radiolari. L'età della porzione inferiore, contenente cf. *Thoracosphaera*, comprende il limite Carnico/Norico, mentre i campioni dominati da *Prinsiosphaera*, con rari *Thoracosphaera* cf. *geometrica* e coccoliti, sono retici. La parte sommitale dei calcari di Portella Gebbia è invece attribuita al Giurassico (Pliensbachiano), per l'assenza di conodonti e in base alla biostratigrafia a nannofossili e radiolari. In conclusione, la parte sommitale della sezione di Pizzo Mondello è più recente di quanto finora ritenuto, è cioè giurassica. I nannofossili calcarei sono presenti sin dalla base della sezione e presentano una significativa diversità tassonomica. Essi possono quindi rappresentare un utile complemento per la biostratigrafia di Pizzo Mondello, soprattutto per l'intervallo Retico - Giurassico.

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Introduction

Biostratigraphic tools in Late Triassic – Early Jurassic pelagic settings

The biostratigraphy of hemipelagic and pelagic Triassic successions is mostly based on ammonoids and conodonts. These two groups evolved at a very fast pace and permit detailed biozonations throughout the Triassic, with ammonoid biostratigraphy having usually higher resolution than conodont biostratigraphy (see for example Krystyn 1978; Brack et al. 2005; Mietto et al. 2007, 2008). In truly pelagic successions ammonoids are often rare, and their collection in the field is more time-consuming than a standard sampling for micropaleontology. Conodonts thus became the routine tool for biostratigraphy of Triassic pelagic successions (Rigo et al. 2007; Giordano et al. 2010; Mazza et al. 2010, 2011). Conodonts are scarce or absent in latest Triassic samples, and disappear completely around the Triassic – Jurassic boundary. Therefore, they are not convenient for differentiating the Triassic from the Jurassic.

Auxiliary biostratigraphies exist. Thin-shelled bivalves (*Daonella*, *Halobia*, *Monotis*) have a benthic lifestyle but thrive in deep-water soft substrates and are thus common in hemipelagic and pelagic settings throughout the Triassic (De Capoa Bonardi 1984; Levera & McRoberts 2008; McRoberts 2010). Radiolarians are also extremely common, but due to their siliceous test are frequently calcified and coarsely recrystallized. In spite of this, radiolarians along with conodonts are the only resource for the biostratigraphy of successions deposited below or close to the CCD, as those formed in Panthalassa and now cropping out in Japan (Onoue & Sano 2007; Onoue & Yoshida 2010). Pollen and spores are also widely used for the biostratigraphy of hemipelagic sections, but are completely missing in truly pelagic sections and whenever the continental influence is limited.

A further potential biostratigraphic tool for the upper Triassic are calcareous nannofossils. Coccoliths and calcispheres appear in the Carnian, and have been documented in localities as various as the Alps, the Southern Apennines, Sicily, the Himalayas, Japan and the North Western Australian plateau (Di Nocera & Scandone 1977; Jafar 1983; Bralower et al. 1991, 1992; Bellanca et al. 1993, 1995; Rai et al. 2004; Onoue & Yoshida 2010; Clémence et al. 2010). However, their scarcity limited their biostratigraphic use in the Triassic. Older occurrences of calcispheres are documented (e.g., Munnecke & Servais 2008), but their possible affinity to Mesozoic and Cenozoic calcispheres is disputable. We show here the abundance of coccoliths and calcispheres in the Upper Triassic section of Pizzo Mondello, which is a candidate for the GSSP of the Norian, and by means

of calcareous nannofossil biostratigraphy, we attribute the uppermost beds of the section to the Lower Jurassic. In this study, coccolith and calcisphere occurrences are calibrated with conodont and radiolarian biostratigraphy.

Geological settings

Pizzo Mondello (Fig. 1) is a ca. 500 m thick, upper Carnian to Lower Jurassic succession of mostly nodular cherty limestones (Bellanca et al. 1995; Gullo 1996; Muttoni et al. 2004; Nicora et al. 2007) that is exposed in central Sicily. Two formations are encompassed by the section: most of the stratigraphic succession is made up by cherty limestones of the Scillato Formation (formerly named Calcari con Selce). The calcareous nannofossil content of this lower part of the section is only briefly described in this study. The uppermost part of the section consists of plane-bedded limestones with greenish clay intercalations of the Portella Gebbia Limestone, and was so far attributed to the Rhaetian (Gullo 1996). According to Gullo (1996), the Rhaetian of Pizzo Mondello is unconformably overlain by either lower Jurassic encrinites and shales or Cretaceous pink limestone-marlstones.

The section was deposited in deep-water settings of a vast basinal area corresponding to the westernmost Tethys ocean. Upper Triassic nodular cherty limestones of the same type are found also in the Southern Apennines (Lagonegro Basin), Northern Calcareous Alps, Balaton highlands in Hungary, eastern Julian Alps, Dinarids and Taurids (Preto et al. 2005).

Materials and methods

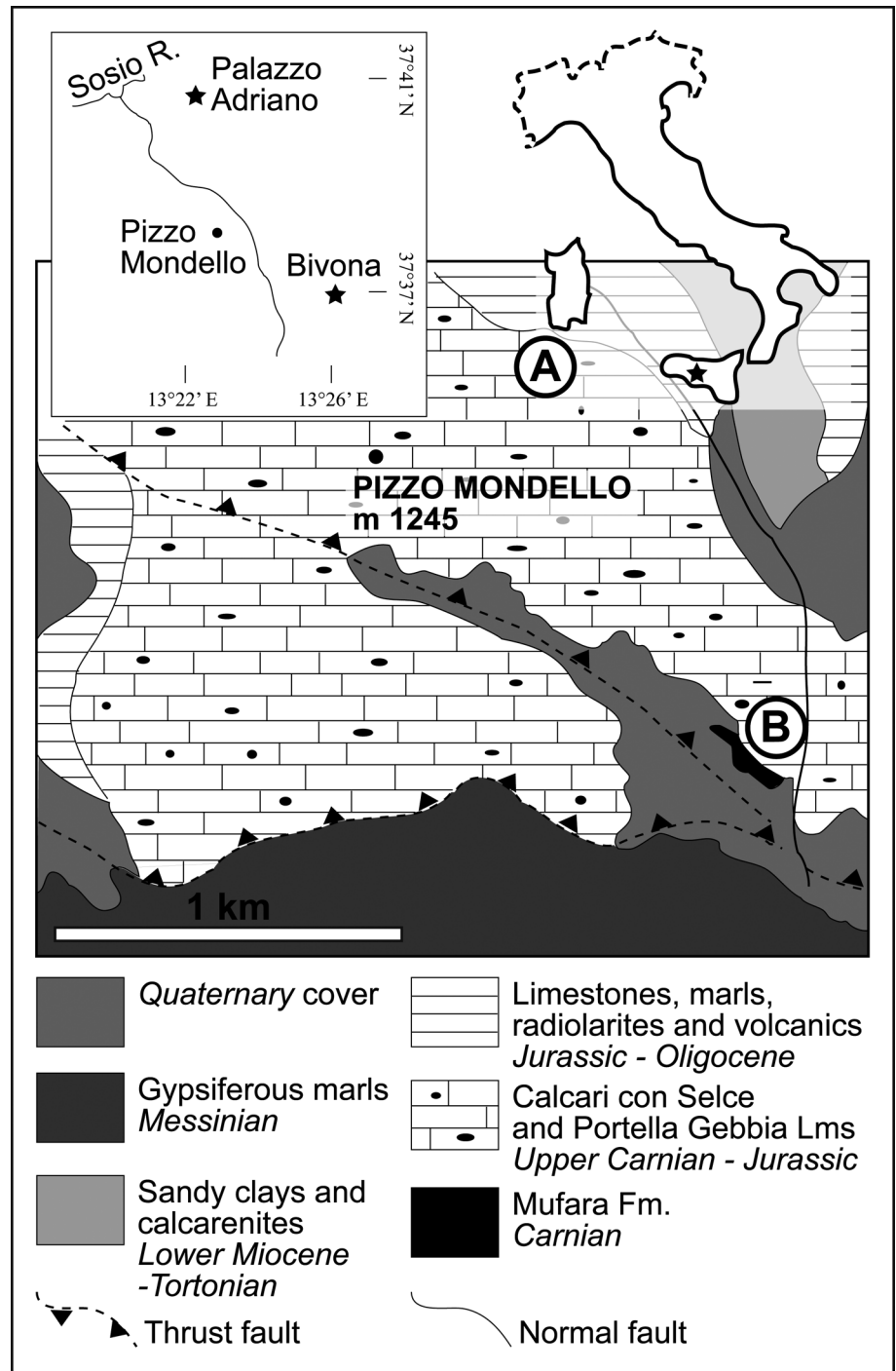
The lower Carnian-Norian interval of the Pizzo Mondello section was logged and described by Guaiumi et al. (2007) and Nicora et al. (2007) and we refer to these authors for detailed descriptions of the lithology and sedimentology of this interval.

The Portella Gebbia Limestone of Pizzo Mondello was logged and sampled in locality a' of Gullo (1996), A in Figure 1. The studied section crops out rather poorly, and consists of three main short tracts separated by covered intervals (Fig. 2), that are considered as part of a continuous section because of the uniform bedding dip. Chert occurs only in the upper part of the measured section, and whitish fine-grained limestones are the dominant lithology throughout. All samples studied in this work were collected from limestones.

Limestone samples of ca. 8–10 kg each were collected for conodont biostratigraphy throughout the Pizzo Mondello section, in several field campaigns. Samples were crushed and carbonate dissolved by repeated baths in diluted acetic or formic acid. The fraction of the residue coarser than 104 µm was separated by sieving, and the conodonts hand-picked without concentration with heavy liquids. Sampling consistence and density is described, for the Carnian-Norian interval, in Nicora et al. (2007) and Mazza et al. (2010). In the Rhaetian - Jurassic segment of the section, 20 samples were collected and processed, which corresponds to more than one sample per meter, although intervals covered with debris and/or soil were not sampled.

Some limestone samples processed for conodonts provided well-preserved radiolarians, and some other samples were treated to

Fig. 1 - Location of Pizzo Mondello in Sicily (southern Italy) and simplified geological map of the area (modified from Muttoni et al. 2004). A: Rhaetian-Jurassic interval (Portella Gebbia lms.) corresponding to locality a' of Gullo (1996); B: Upper Carnian - Norian interval at La Cava locality.



extract radiolarians from cherts. Cherty samples were crushed and dissolved by repeatedly etching with 2-5% hydrofluoric acid for several hours. The obtained residue was separated and gently washed using a Polyethylene sieve (43 μm mesh) and dried in an oven (50°C). Dried residues were analyzed by a stereomicroscope to hand-pick well preserved specimens. Picked radiolarians were examined and photographed by a Philips 515 SEM of the Department of Earth Sciences, University of Perugia.

Carbonates were prepared for observation at the SEM in order to describe their petrology. Most samples revealed abundant calcareous nannofossils that have been thus studied. Samples of limestone were cut in blockets ca. 5 mm in edge, and polished with 1200 corundum powder on a face perpendicular to bedding. Surfaces were then etched for 10 to

20 seconds with 0.3% (0.1 N) hydrochloric acid, carbon- or gold-coated and observed either with the CamScan MX 2500 SEM of the Department of Geosciences, University of Padova, or with the Zeiss Supra 40 of Geowissenschaften, University of Bremen. The morphology of calcareous nannofossil taxa was described with SEM, and specimens were determined. Although studied limestones are often highly lithified, we have prepared a total of 20 samples for calcareous nannofossils with two standard smear slides per sample from unprocessed material (Bown 1998), to be examined using a Zeiss optical microscope at 1250x magnification, in order to confirm the SEM determinations. Nonetheless, calcareous nannofossils were found to be very rare when studied with standard techniques and any quantitative counts are thus virtually impossible.

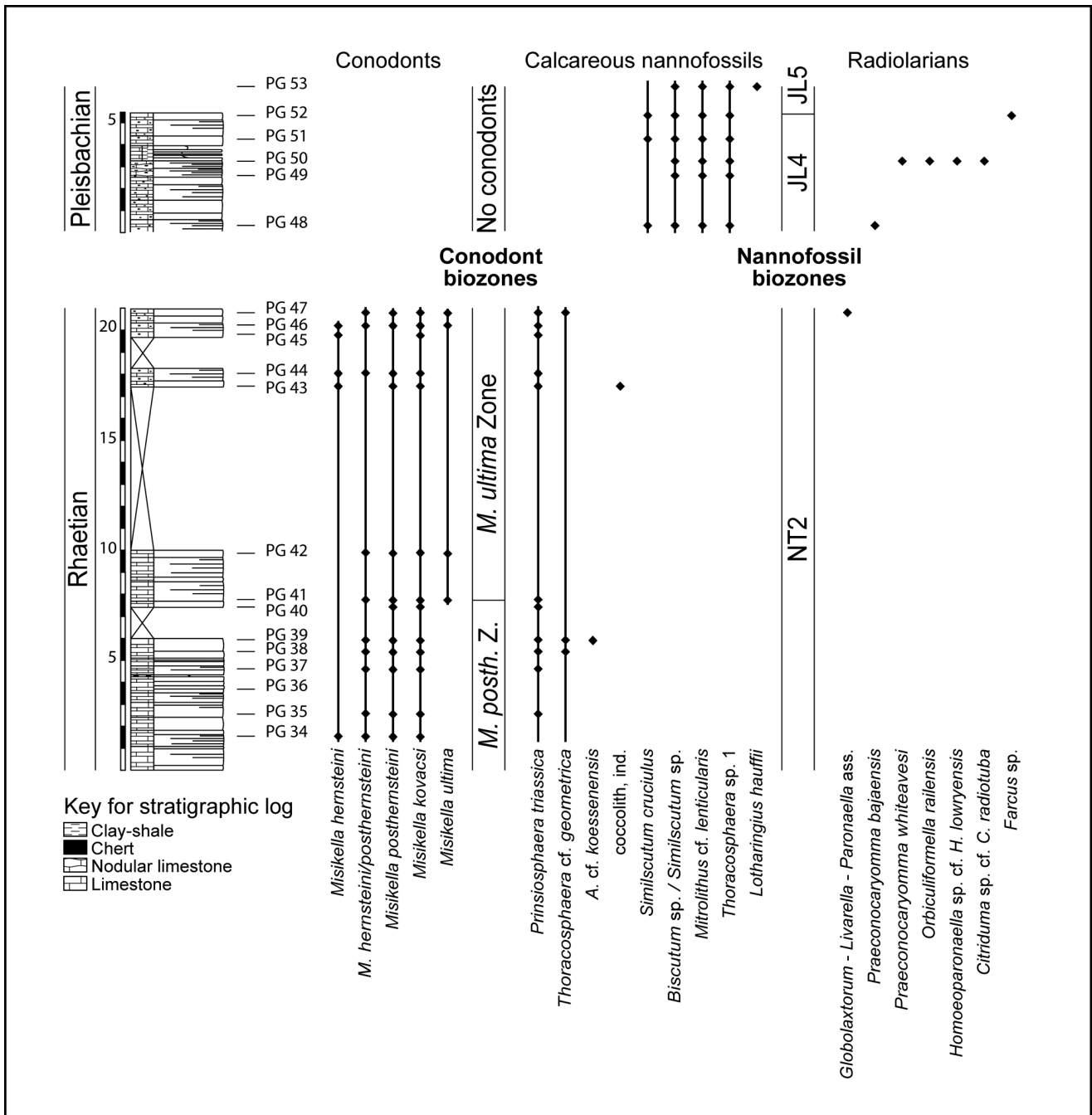


Fig. 2 - Stratigraphic section and stratigraphic distribution of conodonts, calcareous nannofossils and radiolarians in the Rhaetian – Jurassic interval at Pizzo Mondello. Triassic nannofossil biozonation from Bralower et al. (1991); Jurassic biozonation from Bown (1987).

Results

Radiolarians

Radiolarians were studied for the Carnian/Norian interval (Nicora et al. 2007; Bertinelli & Giordano 2010) and, for the purposes of this study, in the Rhaetian/Jurassic interval. The lower interval of the Pizzo Mondello section exposed at “la Cava” yielded radiolarian faunas considered to be early Norian in age, and samples characterized by low-diversity assemblages in the lowermost part, that could be attributed to the late Car-

nian (Nicora et al. 2007). Radiolarian biostratigraphy thus supports the late Carnian to early Norian age of the lower Pizzo Mondello section.

The upper Pizzo Mondello section yielded well preserved radiolarian assemblages. The Rhaetian portion (sample PG 47) is characterized by a typical assemblage with *Globolaxtorum* sp. cf. *G. tozeri* Carter, *Globolaxtorum?* sp. A (sensu Carter 1993), *Livarella magna* Tekin, *Livarella valida* Yoshida and *Paronaella* sp. cf. *P. pacifiensis* Carter (Fig. 3, A-F). Radiolarian assemblages from the uppermost 5 m of the Portella Gebbia lime-

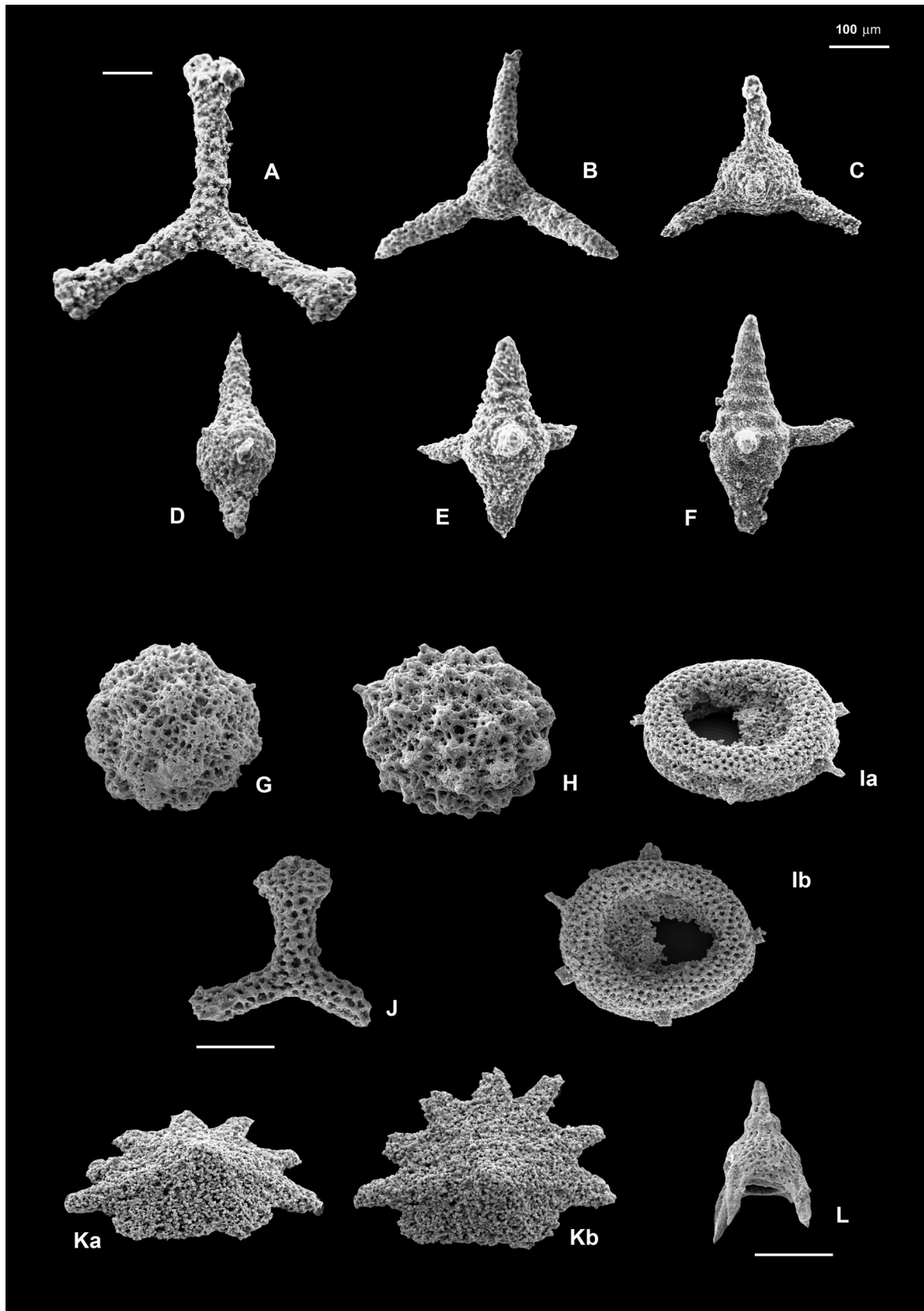


Fig. 3 - Scanning electron micrographs of radiolarians from Pizzo Mondello (Rhaetian- Early Jurassic). A) *Paronaella* sp. cf. *P. pacofiensis* Carter (sample PG 47, Rhaetian); B) *Livarella magna* Tekin (sample PG 47, Rhaetian); C) *Livarella valida* Yoshida (sample PG 47, Rhaetian); D) *Globolaxtorum* sp. cf. *G. tozeri* Carter (sample PG 47, Rhaetian); E-F) *Globolaxtorum?* sp. A (*sensu* Carter 1993) (sample PG 47, Rhaetian); G) *Praeconocaryomma bajaensis* Whalen (sample PG 48, Pliensbachian); H) *Praeconocaryomma whiteavesi* Carter (sample PG 50, upper Pliensbachian); I) *Orbiculiformella railensis* (Pessagno) (sample PG 50, upper Pliensbachian); J) *Homoeoparonaella* sp. cf. *H. lowryensis* Whalen & Carter (sample PG 50, upper Pliensbachian); K a-b) *Citriduma* sp. cf. *C. radiotuba* De Wever (sample PG 50, upper Pliensbachian); L) *Farcus* sp. (sample PG 52).

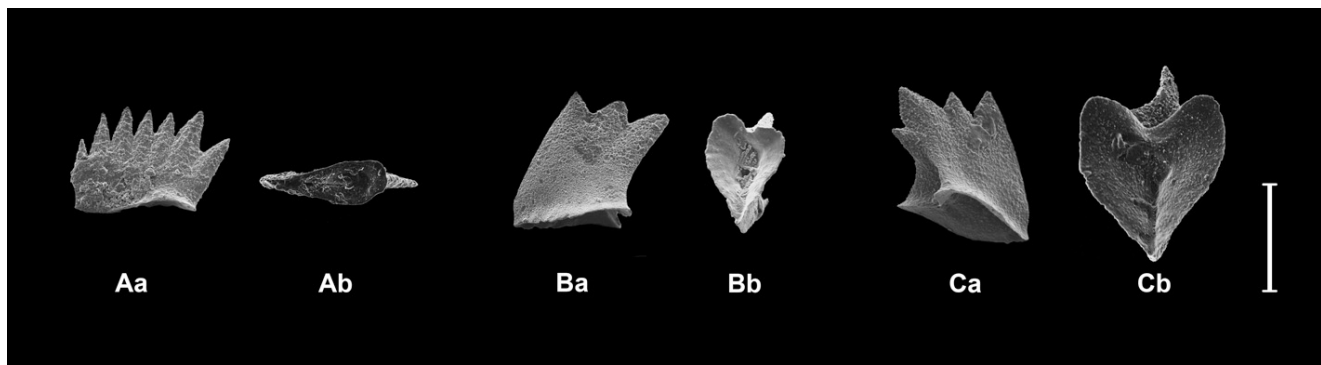


Fig. 4 - Scanning electron micrographs of conodonts from the uppermost Pizzo Mondello section. A) *Misikella bernsteini* (Mostler), mature growth stage, sample NR 59 (few m below base of section in figure 1). B) *Misikella postbernsteyni* Kozur & Mock, mature growth stage, sample PG 34. C) *Misikella ultima* Kozur & Mock, mature growth stage, sample PG 41. Scale bar 200 μm . a = lateral view, b = lower view.

stone contain *Praeconocaryomma bajaensis* Whalen (sample PG 48, Fig. 3 G), *Praeconocaryomma whiteavesi* Carter (sample PG 50, Fig. 3 H), *Orbiculiformella railensis* (Pessagno) (sample PG 50, Fig. 3 I), *Homoeoparonaella* sp. cf. *H. lowryensis* Whalen & Carter (sample PG 50, Fig. 3 J), *Citriduma* sp. cf. *C. radiotuba* de Wever (sample PG 50, Fig. 3 Ka-b), *Farcus* sp. (sample PG 52, Fig. 3 L). This latter association is typical of the Early Jurassic (Pliensbachian).

Conodonts

Conodonts are abundant at Pizzo Mondello. The conodont biostratigraphy of the Carnian - Norian interval of Pizzo Mondello is described in detail by Mazza et al. (2010, 2011, 2012). Briefly, the lower Pizzo Mondello section at “la Cava” is initially characterized by typical late Carnian forms of genera *Carnepigondolella* and *Paragondolella*, which are later replaced by *Metapolygnathus* and *Epigondolella*, the latter being typical Norian genera. Some species of these genera record a turnover that occurs through the occurrence of transitional forms.

The upper Pizzo Mondello section (Portella Gebbia lms.) yielded a Rhaetian association characterized by *Misikella bernsteini*, *M. postbernsteyni* and *M. kovacsi* (Fig. 4A, B). *Misikella ultima* (Fig. 4C) first appears at ca. 7.5 m from the base of the measured section and defines the base of the *M. ultima* conodont zone, which is the last conodont zone of the Rhaetian and Triassic. The upper 5 meters sampled within the Portella Gebbia limestone are barren of conodonts.

Calcareous nannofossils

Calcareous nannofossils are abundant in the studied samples of Pizzo Mondello section. The lower (late Carnian - early Norian) interval exhibits a substantially monospecific assemblage of calcispheres. Their attribution to a taxonomic group is, however, hampered by

diagenetic alteration. Calcispheres are constituted by hollow spherical crystal aggregates, 10-30 μm in diameter. A thick syntaxial overgrowth almost invariably encrusts the primary structure, and by growing inwards, also tends to fill the central cavity (Fig. 5P). The best-preserved calcispheres in this interval still exhibit some degree of recrystallization, which only allows interpretation of a thin test composed of a mosaic of calcite crystals (Fig. 5Q). These calcispheres are thus tentatively attributed to calcareous dinocysts (cf. *Thoracosphaera*), because their structure resembles that of living thoracopherids, which is hollow, lacks of a persistent aperture and possesses a continuous wall. We here follow the nomenclature of Bralower et al. (1991, 1992) for calcispheres.

Samples from the lower Portella Gebbia Limestone, bearing Rhaetian conodonts, exhibit a distinctive calcareous nannofossil assemblage dominated by the nannolith *Prinsiosphaera triassica*, of unknown taxonomical affinity. This form is associated with other less common taxa, as the calcareous dinocyst *Thoracosphaera geometrica* and coccolith *Archeozygodiscus* cf. *A. koessenensis*.

Samples from the uppermost 5 meters of the Portella Gebbia limestone, which are barren of conodonts, yielded a distinctive calcareous nannofossil assemblage consisting mostly of calcispheres up to 25 μm in diameter, with a exoskeleton of calcite prisms (Fig. 5C, F). Though we were not able to identify a clear and well-preserved archeopyle, the absence of any structure in the inner part of the calcisphere suggests an affinity to calcareous dinocysts for these Jurassic forms. Common coccoliths and nannoliths also occur in this interval (Fig. 5A, B, D, E, G, H). Among them, *Similiscutum cruciulus*, *Lotharingius hauffii* and *Mitrolithus* cf. *lenticularis* are particularly significant for biostratigraphy (see discussion below). The distribution of Rhaetian-Jurassic calcareous nannofossils is provided in Fig. 2.

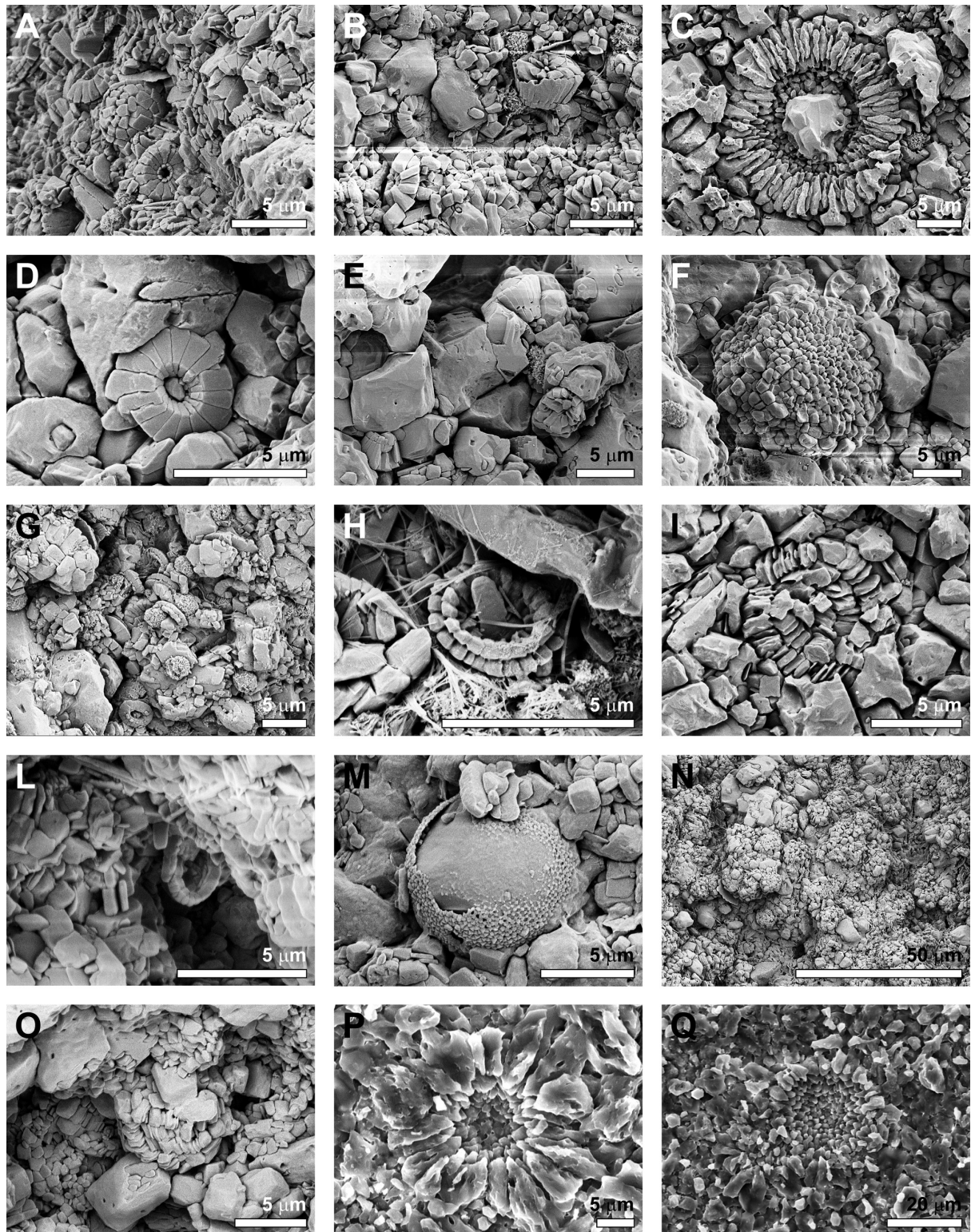


Fig. 5 - Calcispheres, nannoliths and coccoliths of Pizzo Mondello under the SEM. A) *Similiscutum* sp. and *Mitrolithus* cf. *lenticularis*, sample PG 49, Pliensbachian (Jurassic). The spherical structure in the centre may be interpreted as the calcite infilling of a coccosphere, now disaggregated; B) *Mitrolithus* cf. *lenticularis* and *Similiscutum* sp., sample PG 52, Pliensbachian (Jurassic); C) *Thoracosphaera* sp.1, sample PG 53, Pliensbachian (Jurassic); D) *Similiscutum* *cruciolus*, sample PG 48, Pliensbachian (Jurassic); E) *Mitrolithus* cf. *lenticularis*, sample PG 48, Pliensbachian (Jurassic); F) *Thoracosphaera* sp. 1, sample PG 48, Pliensbachian (Jurassic); G) *Lotharingius* *hauffii*, *Mitrolithus* cf. *lenticularis* and *Biscutum* sp., sample PG 53, Pliensbachian (Jurassic); H) *Bussonius* sp., sample PG 52, Pliensbachian (Jurassic); I) *Prinsiosphaera* *triassica*, sample PG 41, Rhaetian (Triassic), *M. ultima* conodont zone; L) *Archeozygodiscus* cf. *A. koessenensis*, sample PG 39, Rhaetian (Triassic); M) *Thoracosphaera* cf. *geometrica*, sample PG 39, Rhaetian (Triassic), *M. posthernsteini* conodont zone; N) *Prinsiosphaera* sp., sample PG 39, Rhaetian (Triassic), *M. posthernsteini* conodont zone; O) *Prinsiosphaera* cf. *triassica*, sample PG 35, Rhaetian (Triassic), *M. posthernsteini* conodont zone; P) cf. *Thoracosphaera*, sample FNP 130, Lacin (early Norian, Triassic); Q) cf. *Thoracosphaera*, sample FNP 134, Lacin (early Norian, Triassic).

Discussion

Age of the upper Pizzo Mondello section

The conodont assemblages recorded in the limestones of the Portella Gebbia limestone are Rhaetian in age, and represent part of the *Misikella posthernsteini* and *M. ultima* conodont zones (Kozur & Mock 1991). The two index species *M. hernsteini* and *M. posthernsteini* were recognized. *M. hernsteini* evolves to *M. posthernsteini* through a morphocline (Giordano et al. 2010). *M. posthernsteini*, which is considered a marker for the base of the Rhaetian stage, was compared and distinguished from *M. hernsteini* - *M. posthernsteini* transitional forms co-occurring in the section. The lower part of the Portella Gebbia limestone can be thus confidently attributed to the Rhaetian, in agreement with Gullo (1996).

Recently, the new *M. rhaetica* conodont zone has been introduced, which index species was illustrated by Gallet et al. (2007). As discussed by Moix et al. (2007), however, the definition of this biozone is flawed. The index species of the biozone, which coincides with *Misikella koessenensis*, erroneously determined as *Misikella rhaetica* by Gallet et al. (2007), is a rare species (Moix et al. 2007). This is probably the reason why *M. koessenensis* was not found at Pizzo Mondello in this study, as well as in Gullo (1996).

Radiolarians confirm a Rhaetian age, mainly because of the presence of the genus *Globolaxtorum* (Carter, 1990). The calcareous nannofossil assemblage is typical of a late Triassic age, because of the massive presence of *Prinsiosphaera triassica* and the rare occurrence of *Archaeozygodiscus* cf. *A. koessenensis*.

The uppermost 5 m of fine-grained Portella Gebbia limestones that were analyzed in this study are barren of conodonts, but contain radiolarians and abundant calcareous nannofossils. Nannofossils were identified in all samples and always constitute at least 10% of the rock volume (visual estimate).

The radiolarian association includes the genus *Praeconocaryomma*, typical of the Early Jurassic, and lacks Rhaetian genera. Jurassic radiolarian assemblages occur from sample 48 upsection, and suggest a Pliensbachian age.

In the uppermost part of the section, a major change in calcareous nannofossil assemblage is found. *Prinsiosphaera triassica* characterizes the assemblages up to the end of the Triassic, that corresponds to sample PG 47, but from sample PG 48 upwards the calcareous nannofossil assemblages consist of frankly Jurassic taxa (Fig. 2). In particular, the presence of *Mitrolithus* cf. *lenticularis*, previously reported from the late Sinemurian to the late Toarcian (Bown & Cooper in Bown 1998; Mattioli & Erba 1999), and the First Occurrence (FO)

of *Similiscutum cruciulus* (Mattioli & Erba 1999; Mattioli et al. 2004), recorded from the base of the Pliensbachian (de Kaenel et al. 1996; Mattioli & Erba 1999), indicate that the base of this interval lies in the Early Jurassic. Finally, the FO of *Lotharingius hauffii*, which defines the base of Zone JL5 (Bown 1987), was observed in sample PG 53. On this basis, the uppermost Pizzo Mondello section spans from Zone NT2 (Bralower et al. 1991) to Zone JL5 (Bown 1987), that is from Norian-Rhaetian to upper Pliensbachian. A large hiatus, covering at least Hettangian, Sinemurian and Pliensbachian *p.p.*, is thus present. This unconformity was already known for western Sicily and was discussed, e.g., by Gullo (1996). Here we show that at Pizzo Mondello, it is to be placed within the succession of pelagic-hemipelagic limestones and marls and not at the base of a calcarenitic unit.

Distribution of calcareous nannofossils in the Upper Triassic

Calcareous nannofossils are one of the main biostratigraphic tools used in the Cenozoic (Perch-Nielsen 1985a; Berggren et al. 1995; Bown 1998), and in the Mesozoic as well (e.g., Thierstein 1976; Perch-Nielsen 1985b; Bown 1987, 1998; deKaenel et al. 1996; Mattioli & Erba 1999). Triassic calcareous nannofossils are usually considered to be rare and poorly differentiated (Bralower et al. 1991; Bown 1998), and although a Upper Triassic calcareous nannoplankton biozonation exists (Bralower et al. 1991, 1992), it is not the standard biostratigraphic tool for this time interval. Upper Triassic calcareous nannofossils are very common in sediments of western Tethys. Specifically, Carnian - Norian limestones of Pizzo Mondello contain abundant calcisphaeres. Stratigraphically upward, in the Rhaetian, nannofossil assemblages are dominated by the enigmatic nannolith *Prinsiosphaera triassica*, consistently with results from the northwestern Australian plateau (Bralower et al. 1991).

The abundance of *Prinsiosphaera triassica* in the Rhaetian, and its worldwide distribution (Bralower et al. 1991; Bellanca et al. 1993, 1995; Rai et al. 2004; Onoue & Yoshida 2010; Clémence et al. 2010), make it a useful biostratigraphic tool. *Prinsiosphaera* last occurs at the end of the Rhaetian, being affected by the end-Triassic extinction, and the following Jurassic nannofossil assemblages are peculiar, including, e.g., *Schizosphaerella* that is dominant in the south Tethyan ocean (e.g., Kálin et al. 1979; Bown 1987; Mattioli & Pittet 2002) and numerous and diverse nannoliths and coccoliths (Bown 1987; deKaenel et al. 1996; Mattioli & Erba 1999; Bown & Cooper in Bown 1998; Erba 2004). Thus, the upper 5 m of Portella Gebbia limestones logged for this study were unequivocally attributed to the Jurassic, and distinguished from Rhaetian samples, already by

the identification of nannofossils during petrographic analyses. The differentiation between Triassic and Jurassic cannot be uniquely inferred on the base of conodont absence. In fact, absence could be due to taphonomical (preservation) or ecological factors. This distinction could not be straightforward with conodont biostratigraphy, because absence of conodonts in the upper part of the section could not be unambiguously interpreted as a significant biostratigraphic datum. The upper Carnian - Rhaetian interval at Pizzo Mondello yielded several samples rich in calcareous nannoplankton. The nannoplankton abundance, already observed by Bellanca et al. (1993, 1995) in the Carnian-Norian interval, thus extends to the full length of the exposed succession. Pizzo Mondello, along with correlated successions in Sicily and the Lagonegro Basin (Southern Apennines), may be the target of studies for future improvement of Triassic calcareous nannoplankton biostratigraphy.

Conclusions

Upper Triassic hemipelagic succession of Pizzo Mondello in Sicily bears abundant calcareous nannofossils throughout. Calcareous nannofossil assemblages provide coarse time constraints, especially about the Triassic/Jurassic boundary, though taxonomic richness

is low. Calcareous nannofossils, which include coccoliths, nannoliths and calcispheres, can be readily studied with SEM after adequate preparation (polishing and mild etching). They could thus provide an ancillary biostratigraphic tool in the definition of the Norian GSSP. However, their use is limited in the Carnian-Norian interval by poor preservation, due to syntaxial overgrowth of calcite cement on calcispheres. Better preparation techniques should be developed to overcome this limitation. The uppermost beds of the Portella Gebbia Limestone at Pizzo Mondello, GSSP candidate for the Norian stage, are proved to be Jurassic (Pliensbachian) rather than Rhaetian, based on calcareous nannofossils and radiolarian biostratigraphy, and a major hiatus is identified within pelagic-hemipelagic limestone-marls.

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