The bathyal larger lituolid *Neonavarella* n. gen. (Foraminifera) from the Thanetian Scaglia Rossa Formation of northeastern Italy

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ABSTRACT: Larger agglutinated foraminifera resembling the Cretaceous genus *Navarella* Ciry and Rat 1951 were recently recovered in Thanetian hemipelagites from the Belluno Basin, northeastern Italy. These lituoids first appear in the basal Thanetian (uppermost calcareous nannofossils Zone CNP 8) and become common in the >500 µm washed residue from the uppermost Thanetian. They abruptly disappear at the Paleocene/Eocene boundary, in coincidence with the extinction of Paleocene small benthic foraminifera (the benthic foraminiferal extinction event - BEE).

In order to document the internal chamber arrangement and the agglutinated wall microstructure of the Thanetian lituolids and to compare them with similar individuals recovered from the Upper Cretaceous and Danian strata of the same section, the collected specimens were sectioned and analyzed using a Scanning Electron Microscope (SEM), equipped with an energy-dispersive X-ray spectrometer (EDX). Our results show a typical bi-layered wall microstructure in the Thanetian specimens, whereas the older Maastrichtian and Danian specimens, occurring in the same section, display a single, thicker agglutinated wall. The taxonomy of the Italian lituolids is discussed and compared with similar taxa known from the literature.

We describe the Thanetian lituolids as the new genus *Neonavarella*, which shows an apparently identical external morphology to mono-layered Maastrichtian–Danian specimens but differs in the microstructure of the agglutinated test wall that is bi-layered. The finding of new and well-preserved material from the Paleocene Scaglia Rossa beds of Italy helps shed light on the taxonomy of the still poorly known deep-water larger lituolids.

Key words: Larger agglutinated foraminifera, lituolids, Systematics; New genus, New species, Upper Cretaceous, Paleocene, northeastern Italy.

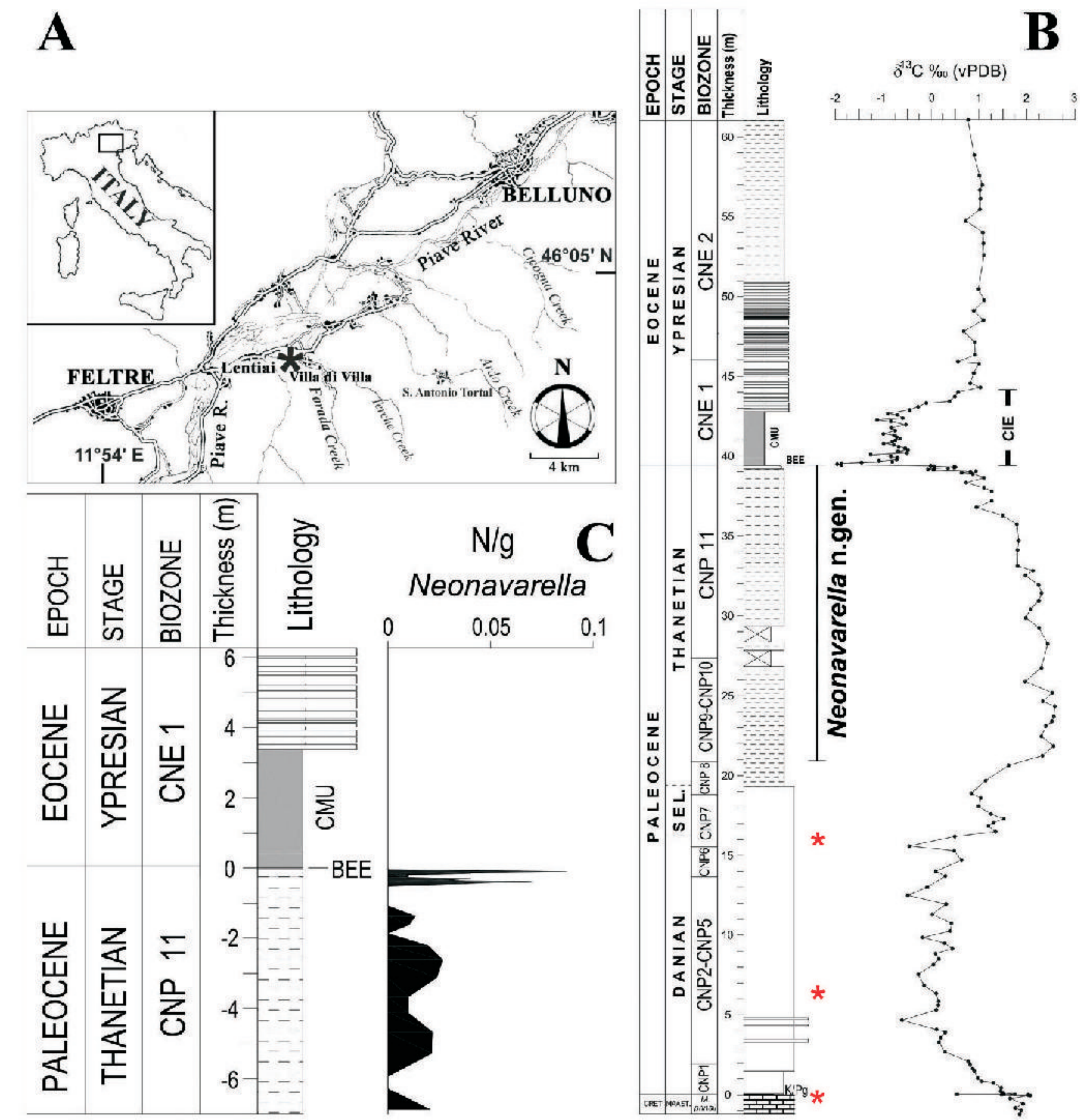
INTRODUCTION

Since the 19th century, large-sized lituolids have been widely reported in Upper Cretaceous turbiditic and hemipelagic successions of the Tethyan domain (e.g., Ciry and Rat 1951; Maync 1952; 1954; Cati 1960; Sampò 1972; Stacher 1980; Pandey 1981; Riegraf 1998; Radoičić et al. 2010). Such agglutinated foraminifera were generally ascribed to different species of the genera *Lituola* Lamarck 1804, *Navarella* Ciry and Rat 1951 and *Recurvoides* Earland 1934.

In the course of a study of the Paleocene/Eocene Thermal Maximum as recorded in a "Scaglia-type" bathyal succession of the Southern Alps of northeastern Italy (Forada section), several hundred specimens of larger agglutinated lituolids were detected for the first time in Thanetian hemipelagic rocks (Giusberti et al. 2016). After intensive research performed during this study, similar specimens were also sporadically observed in Danian hemipelagites of the same section, though with very rare abundance. The Paleocene specimens, generally larger than 500 µm, are virtually indistinguishable from Upper Cretaceous specimens recovered elsewhere and described in the literature as *Navarella*.

Navarella is a larger lituolid belonging to the family Ammobaculinidae Saidova 1981 and attaining a maximum length of 5 mm, with an initially streptospirally enrolled test, later uncoiled, and with an aperture varying during ontogeny from slit-like to cribrate. The genus was originally described from the Maastrichtian flysch of the Navarra region in the Spanish Pyrenees, and then reported elsewhere in Europe from Campanian to Maastrichtian rocks. The validity of this taxon and its range distribution is, however, controversial and strongly debated (Riegraf 1998).

In this study, we use high definition SEM EDX images of entire and sectioned specimens, and study the external and internal features of the Paleocene lituolids in order to investigate both their test morphology and microstructure of the agglutinated wall. The main purpose is to compare the recorded Paleocene specimens with similar Italian and foreign Cretaceous taxa in order to verify whether or not the newly discovered agglutinated foraminifera are ascribable to *Navarella*, thereby extending the known stratigraphical range of navarellids to the Paleocene.



TEXT-FIGURE 1
A) location of the Forada section; B) stratigraphic log of the Forada section with the range of Thanetian *Neonavarella* n. gen. plotted against the isotope curve of $\delta^{13}C$. Red asterisks mark samples from Danian and upper Maastrichtian records where sporadic specimens of navarellid lituolids were recovered; C) detail of the Thanetian–Ypresian portion of the Forada section plotted against the absolute abundance of *Neonavarella* n. gen. (number of specimens per gram of dry sediment). CNP and CNE calcareous nannofossil zones of text-fig. 1B and 1C according to Agnini et al. (2014)

TABLE 1
Diagnostic features (external morphology, chamber arrangement, aperture and test wall microstructure) of larger lituolids described in the literature from Upper Cretaceous records of Europe, Italy and in the present work from the Maastrichtian-Thanetian record of the Forada section (Belluno) and Monte San Lorenzo Quarry section (Maniago).

	Coiling	Wall structure	Aperture	External morphology	Notes	Age and localities
***Navarella joaquini* Ciry & Rat, 1951**	The initial 3–4 globular chambers arranged in a close clew-like whorl, followed by about 10 strongly involute ovoid chambers forming a slight irregular coil (not strictly planispiral) and rapidly increasing in size. The succeeding 3–4 chambers are detached from the close spire and arranged in a wide spire. Uncoiled portion usually short.	External layer of quartz grains bounded by calcareous cement. Inner calcareous-ferruginous layer (likely of diagenetic origin according to Mayne, 1954).	In the early coil an arched slit, followed by multiple aperture consisting of a slit associated with small circular pores. The terminal aperture is truly cribrate (up to a maximum of 12 pores).	Ovoidal or pear-shaped, rather irregular, slightly depressed sutures visible in some individuals. The uncoiled portion is a short protuberance slightly forward curved. Sometimes gently depressed sutures visible.		Uppermost Cretaceous flyschoid deposits outcropping in the Navarra Region of Spain.
***Navarella joaquini* Ciry & Rat emend. by Mayne, 1954**	Three to four globular initial chambers in a tight coil followed by 6–9 narrow chambers rapidly increasing in size overlapping one another with a spire usually irregular, wholly involute. The succeeding 3–4 chambers gradually become detached from the close coil and uncoil either straight or sometimes in a very loose spire. Two or three conically shaped chambers effect the transition of the spire into the detached adult portion.	Only one layer of fine sugary quartz grains held together by a small amount of calcareous cement. A calcareous inner layer is not present.	In the early coil an arched slit, followed by multiple aperture consisting of a slit associated with small circular pores. The terminal aperture is truly cribrate. Cribrate in the microspheric generation, multiple in the megalospheric generation. In the microspheric generation the cribrate aperture consists of about a dozen elongate or vermicular openings.	Microspheric: Test stout, large, with coiled portion large and nodulous. Broadly rounded periphery. Rectilinear or slightly forward-curved uncoiled portion present rarely. Faint restrictions on adult specimens. Megalospheric: Small test elongate-cylindrical, club-like, broadly rounded. Externally, no sharply defined coiled portion visible, usually tapering into the uncoiled part. Chambers and sutures very indistinct.	According to Riegraf (1998), *Navarella joaquini* sensu Mayne 1954 and *Lituola westfalica* are convergent taxa. The relationships between *N. joaquini* from Switzerland and *Lituola westfalica* need to be explored.	Uppermost Cretaceous topotypes from the Navarra region of Spain; Maastrichtian Wang beds, Switzerland.
***Navarella joaquini* var. *helvetica* Mayne, 1954**	Differs from the typical *Navarella joaquini* sensu Mayne (1954) in showing a consistent second reinforcing layer of fibrous calcite on top of the finely agglutinated walls and septa. Consequently, both walls and septa are much thicker in this variety in respect to the typical forms.					Maastrichtian Wang beds of Glarner Flysch, Switzerland
"*Recurvoides*" *manfredii* Cati, 1960	Test streptospirally coiled with each whorl inclined at approximately 14° to the preceding one. Adult specimens possess 2.5 to 3 whorls with a maximum of 20–24 reniform chambers. Arched septa with forward-oriented convexity. Large spherical proloculus, eccentric, never included in the first whorl.	External layer mostly consisting of quartz. Sometimes occur calcareous bioclastic grains and small foraminifers. Abundant calcareous "spatic" cement.	Aperture consisting of an arched slit	Test large, robust, subsphaerical. Periphery rounded. Convex lateral sides, slightly asymmetrical. Sutures indistinct.	The quartz grains of the wall described by Cati (1960) were not observed in the sectioned type specimens we examined. The taxon of Cati is not a *Recurvoides*, it is clearly a *Lituola*/*Navarella*	Campanian Scaglia Rossa, Berici Hills, Vicenza province, Italy.
"*Recurvoides*" *manfredii* var. *lobatulum* Cati, 1960	Differs from the typical *Recurvoides manfredii* in showing more compressed test, slightly concave lateral sides and rather lobate outline. Sutures distinct, slightly depressed. The last whorl shows a tendency to uncoil.				The quartz grains of the wall described by Cati (1960) were not observed in the sectioned type specimens we examined. The taxon of Cati is not a *Recurvoides*, it is clearly a *Lituola*/*Navarella*	Campanian Scaglia Rossa, Berici Hills, Vicenza province, Italy.
***Navarella joaquini* Ciry & Rat sensu Sampò (1972)**	Early chambers irregularly coiled ("a gomitolo"), later planispirally arranged with 8–9 chambers in the last whorl. It rarely presents a distinct uncoiled portion (megalospheric individuals). Septa falciform, slightly backwards curved.	Only one layer made of foraminiferal fragments and other calcareous grains held together by very scarce calcareous cement.	Single (arched slit) in the first stage, multiple (arched slit associated with small circular pores) in the second stage and finally truly cribrate in the third stage.	No description of the external features. All the specimens ascribed to *Navarella joaquini* are strictly coiled and interpreted as microspheric individuals. Only one specimen with cylindrical test is dubitatively ascribed to a megalospheric individual.	Sampò (1972) recognized some specimens planispirally coiled and others with initial chambers with trochoid coiling and ascribed them to "*Lituola grandis* Reuss". We suspect that *Lituola* and *Navarella* in Sampò are the same thing.	Maastrichtian of the Scaglia Rossa Formation, Verona province, northern Italy.
Thanetian *Neoavarella sudalpina* n. gen., n. sp.; present work	Juvenile specimens generally strictly coiled. Early chambers streptospirally then planispirally arranged (7–8 chambers in the last whorl) passing to uncoiled in the adult specimens. Uncoiled portion of the test usually less well-developed, consisting of 3–4 chambers.	Clearly bi-layered formed by an external layer of silicilastic grains mainly of quartz and an inner thicker layer of calcareous grains (also biogenic remains, as foraminiferal tests). Grains held together by calcitic cement.	Slit from almost rectilinear in the juvenile specimens to markedly arched. In adult individuals, the apertural slit is associated with small circular pores (up to a maximum of 4 pores). A truly cribrate aperture (with 6–7 small rounded pores) is less frequent in the adult uncoiled specimens.	Test stout, strictly coiled in juvenile specimens and in the initial part. Broadly rounded periphery. Several adult individuals show a tendency to uncoiling, with forward-curved uncoiled portion, more rarely a rectilinear uncoiled portion has been observed. Presence of gently depressed, slightly arched sutures in adult individuals, mostly in the spiral portion of the test.	External morphology similar to *Navarella* Ciry and Rat, 1951	Thanetian of the Scaglia Rossa Formation. Forada section, Belluno, northern Italy; Monte San Lorenzo Quarry section, Maniago, Pordenone.
Maastrichtian-Danian "*Navarella*" specimens; present work	Early chambers streptospirally/trochospirally arranged, then planispiral. Usually coiled and poorly developed uncoiled part.	Only one layer made of foraminiferal fragments and other calcareous grains held together by calcitic cement.	Slit in juvenile specimens and cribrate aperture in adult specimens. Never observed specimens with a slit associated with circular pores	Test stout, strictly coiled in juvenile specimens and in the initial part. Broadly rounded periphery. Several adult individuals show a tendency to uncoil.	Wall structure similar to *Navarella joaquini* sensu Sampò (1972) and "*Recurvoides*" *manfredii* Cati, 1960	Maastrichtian and Danian Scaglia Rossa Formation, Forada section, Belluno, northern Italy

MATERIALS AND METHODS

Forada section

The investigated section (46.036083°N, 12.063975°E) crops out along the Forada Creek, roughly 2 km east of the Lentiai village in the Venetian Prealps (northeastern Italy), and consists of ~62 m of pink-reddish Scaglia Rossa limestones and marly limestones, locally rhythmically organized (text-fig. 1). It records a continuous stratigraphic interval from the uppermost Cretaceous to the lower Eocene (upper Maastrichtian–lower Ypresian nannofossil Zone CNE2 of Agnini et al. 2014) and is virtually unaffected by structural complications (Fornaciari et al. 2007; Giusberti et al. 2007).

At Forada, ichnofossils are well represented (e.g., *Zoophycos*, *Thalassinoides*) as they generally occur in the upper portion of the Scaglia Rossa Formation in the Belluno Basin (Miller 2000). The only macrofossils observed are rare irregular echinoids and possibly an octocoral, all recovered in the Danian beds (Giusberti et al. 2005; J. Stolarski, pers. comm.).

The lowermost Danian record, above the K/Pg boundary clay, is represented by a subnodular/irregularly bedded red-brown limestone and marly limestone, and has been object of a study aimed to investigate the recovery of the calcareous plankton in the aftermath of the K/Pg boundary event (Fornaciari et al. 2007). The rest of the Danian and Selandian succession is represented by red carbonate and marly lithofacies, sometimes strongly bioturbated by *Zoophycos* (“massive unit”); three thin biocalciturbiditic beds (4.5 to 10 cm thick), with an erosive base, also characterize the lower Danian portion of the section (text-fig. 1).

The Danian–Selandian “massive unit” is overlain by Thanetian “scaly” reddish calcareous marls mottled by greenish “flames” (“scaly unit”). At about -20 cm below the Paleocene/Eocene boundary, the lithology shifts to greenish marls with *Zoophycos* and *Chondrites* (intervals Pa I and Pa II of Giusberti et al. 2007). The entire Paleocene record, 40 m thick, is capped by about 3.5 m thick greenish and reddish clay marl unit (CMU; Giusberti et al. 2007), a lithological “anomaly” which marks the so-called Paleocene/Eocene Thermal Maximum (PETM; e.g., McInerney and Wing 2011) in the study area (Giusberti et al. 2007; text-fig. 1). The CMU is followed by 4-5 m of marl-limestones couplets, fading into 15 m of scaly, still strongly cyclical reddish marls, Ypresian in age (text-fig. 1).

Based on benthic foraminiferal content, the upper Paleocene to lower Eocene Scaglia Rossa interval has been probably deposited at middle-lower bathyal paleodepth, likely between 1000 and 1500 m (Giusberti et al. 2016). The wealth of micropaleontological, sedimentological, and geochemical data so far collected from the Forada section (e.g., Giusberti et al. 2007; Agnini et al. 2007; Luciani et al. 2007; Tipple et al. 2011; Giusberti et al. 2016) provides probably the most complete paleoenvironmental reconstruction across the PETM in Europe to date.

Agglutinated foraminifera

The larger lituolids here investigated were observed for the first time by Giusberti et al. (2016) analyzing the >500 µm washed fraction, originally used for the quantitative study of microbenthic foraminifera across the Paleocene/Eocene Ther-

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PLATE 1A

Intraspecific morphological variability of Paleocene lituolids from the Forada section.
Note that Thanetian and Danian specimens are morphologically identical. Images are in secondary electrons (SE).

1 Thanetian juvenile specimen (MGP-PD 32076) with a typical strongly involute coiling (sample BRI-6); a: lateral view, b: profile. Note that the prime slit-like aperture is still not manifest.

2 Thanetian juvenile specimen (MGP-PD 32076) with a slit-like aperture (sample BRI-6); a: lateral view, b: profile showing the slit-like aperture.

3 Thanetian quasi-adult specimen (MGP-PD 32077) with a complex aperture characterized by a slightly arched slit coupled with two small rounded pores (sample BRI-6); a: lateral view, b: profile; c: detail of the complex aperture.

4 Thanetian adult specimen (MGP-PD 32073) characterized by a larger test with, a partly developed uncoiled portion and a complex aperture formed by a slightly arched slit coupled with some elongated pores (sample BRI-29.5); a: lateral view, b: profile; c: detail of the complex aperture.

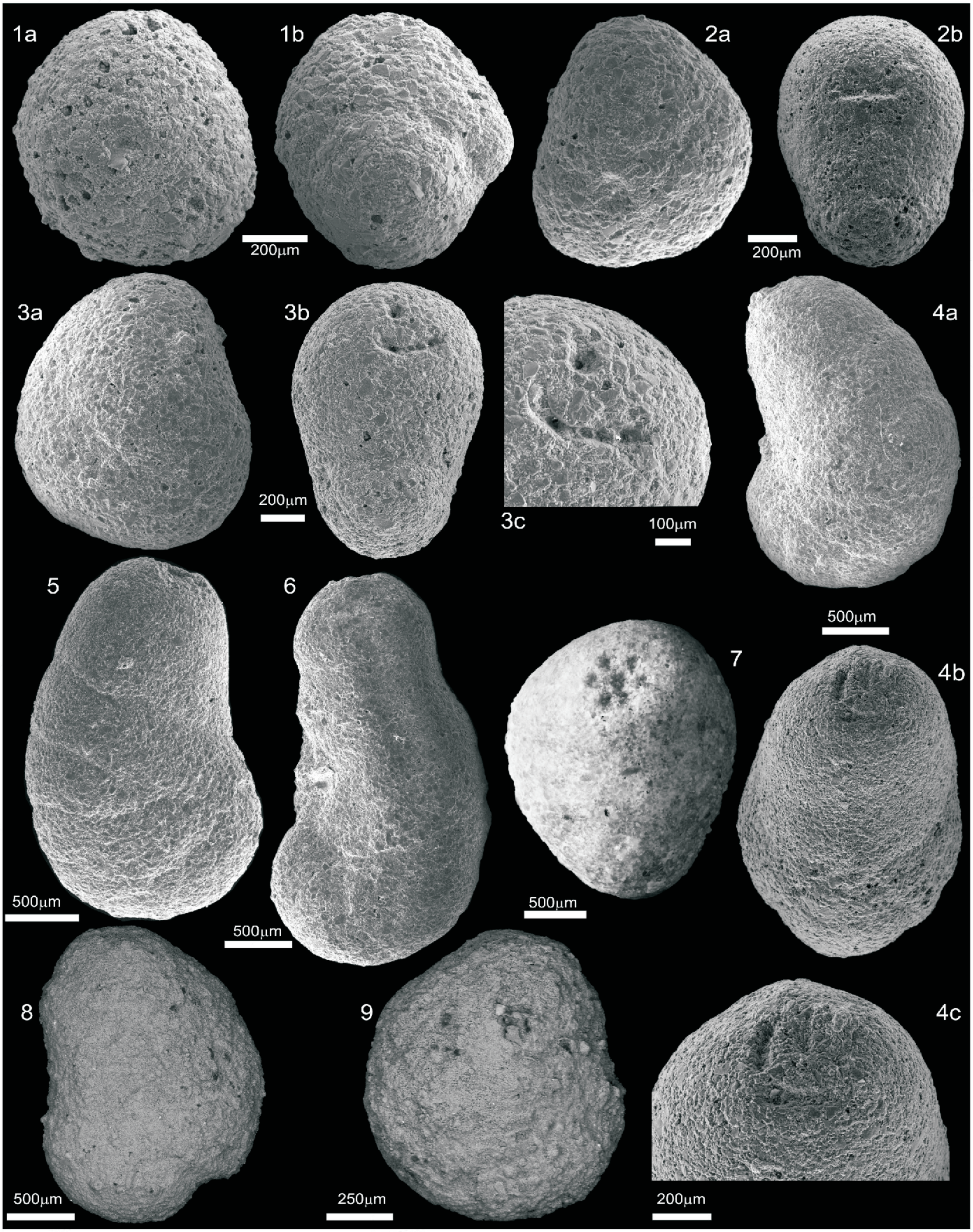
5 Lateral view of a Thanetian adult specimen (MGP-PD 32073) with a typical large test characterized by a developed uncoiled portion (sample BRI-11);

6 Lateral view of an adult specimen (MGP-PD 32073) with a very large test (exceeding 3 mm long and 1 mm wide) characterized by a well developed uncoiled portion (sample BRI-9).

7 Detail of the cribrate aperture of a Thanetian adult specimen (MGP-PD 32081; sample BRI-9).

8 Lateral view of a Danian quasi-adult specimen (MGP-PD 32074; RF-670, picked about 6.35 m above the K/Pg boundary, Fig. 1).

9 Lateral view of a Danian juvenile specimen (MGP-PD 32074) very similar to the Thanetian specimen shown in image 3a (sample RF-670).


1a
1b
200μm
2a
2b
200μm
3a
3b
200μm
3c
100μm
4a
500μm
5
500μm
6
500μm
7
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4b
8
500μm
9
250μm
4c
200μm

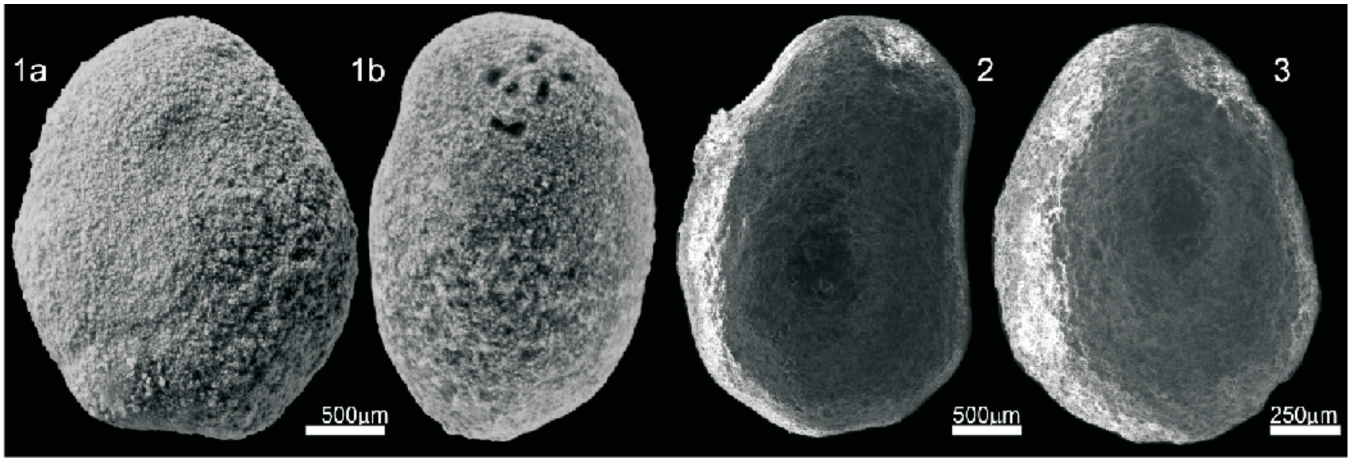


PLATE 1B

Morphological details of upper Maastrichtian specimens of "*Navarella*" Ciry and Rat 1951 from the Forada section. To note that upper Cretaceous and Paleocene specimens seemingly possess very similar test morphologies. Images are in secondary electrons (SE).

1 Adult specimen (MGP-PD 32089) characterized by a large, ovoidal test (sample RF-24, just below the K/Pg boundary; Fig. 1); a: lateral view, b: profile showing the complex aperture formed by seven rounded or elliptical pores.

2 Lateral view of an adult specimen (MGP-PD 32069) showing a large test with the chambers initially spirally arranged then becoming detached from the close spire according to a rectilinear arrangement (sample RF-24).

3 Lateral view of a small-size quasi-adult specimen (MGP-PD 32070; sample RF-24).

PLATE 2

Sectioned specimens picked from the Thanetian record of the Forada section showing the internal chamber arrangement and the microstructure of the agglutinated wall. In both juvenile and adult specimens the test wall results typically bi-layered, with a thinner external portion made of coarse-grained mineral grains and a thicker, more homogeneous carbonatic portion, which sometimes contains remains of planktonic foraminifera. Images of sectioned specimens are in back-scattered electrons (BSE).

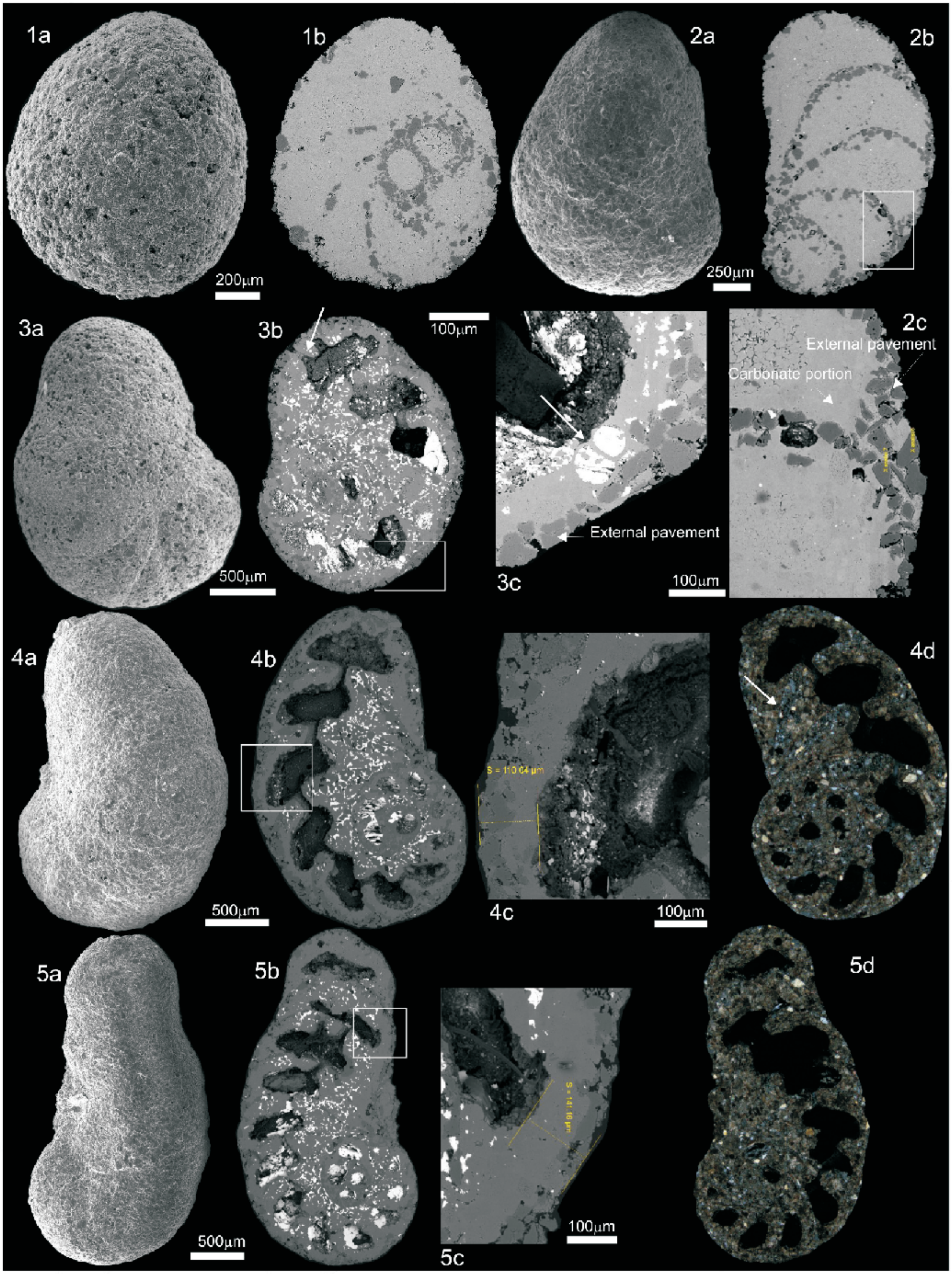
1 Juvenile specimen showing the chambers spirally arranged and the bi-layered microstructure of the agglutinated wall (MGP-PD 32075; sample BRI-37); a: lateral view, b: longitudinal section.

2 Quasi-adult specimen (MGP-PD 32072) showing the same bi-layered microstructure of the agglutinated wall previously evidenced in the juvenile specimen (sample BRI-9); a: lateral view, b: longitudinal section; c: detail of the sectioned agglutinated wall with a thicker internal carbonatic portion externally covered by coarse-grained mineral granules.

3 Adult specimen (MGP-PD 32071) showing the chambers initially spirally arranged then becoming detached from the close spire according to a rectilinear arrangement and a more complex aperture (arrow). The microstructure of the agglutinated wall is still bi-layered, with a thicker, internal carbonatic portion and a thinner, external mineral pavement (sample BRI-14.5); a: lateral view, b: longitudinal section; c: detail of the sectioned agglutinated wall, note in the carbonatic portion, a globigerinid test (arrow) filled by a white mineral (barite).

4 Adult specimen (the same of Plate 1A, image 4a) showing the uncoiled portion of the test and the typical complex aperture (sample BRI-29.5); a: lateral view, b: longitudinal section; c: detail of the thick bi-layered wall (ca. 110 µm), d: thin section of the same specimen analysed at the polarized microscope showing the bi-layered structure of the agglutinated wall with the coarse-grained, external gains mostly made of quartz (arrow).

5 Adult specimen (the same of Plate 1A, image 6) showing a very large test, with a particularly well developed uncoiled portion and the typical complex aperture (sample BRI-9); a: lateral view, b: longitudinal section showing the evolution of the aperture, from a simple slit in the earlier chambers to complex cribrate in the last chamber; c: detail of the thick bi-layered wall (ca. 140 µm), d: thin section of the same specimen analyzed at the polarized microscope showing the bi-layered structure of the agglutinated wall with the coarse-grained, external gains mostly made of quartz.


1a
1b
2a
2b
200µm
250µm
3a
3b
100µm
2c
External pavement
Carbonate portion
External pavement
3c
500µm
100µm
4a
4b
4d
500µm
4c
100µm
5a
5b
5d
500µm
100µm
5c

mal Maximum. Very rare small juvenile lituolids were also observed in the fraction >250 µm and <500 µm. The study of Giusberti et al. (2016), based on 54 samples across an ~11 m thick interval straddling the Paleocene/Eocene boundary (-467 to ca. +600 cm), revealed that these larger lituolids abruptly disappear at the Paleocene/Eocene boundary, in coincidence with the base of the CMU, where the benthic foraminiferal extinction (BEE) is recorded (Giusberti et al. 2016).

In order to verify the distribution of the investigated foraminifera throughout the entire section, 25 supplementary samples were analyzed in search for the larger lituolids (text-fig. 1), including those washed residues used for the study of foraminifera by Fornaciari et al. (2007) from the interval straddling the Cretaceous/Paleogene (K/Pg) boundary. Furthermore, 8–9 new samples of a minimum weight of 200 g from the interval richest in the investigated lituolids (ca. from -35.5 to -6 cm below the P/E boundary) were treated for isolating a high number of specimens for the present study.

Foraminifera were extracted from most of the indurate marls and limestones using the "cold acetolysis" technique of Lirer (2000) as described in Luciani et al. (2007); on the other hand soft marly samples (the CMU, the greenish marl below the CMU and some marly intercalations in the Thanetian portion of the section) were prepared following standard procedures (chemical disaggregation using a 10–30% solution of hydrogen peroxide and subsequent washing through two sieves with meshes of 500 and 63 µm). The absolute abundance of the stated lituolids (N g-1: number of benthic foraminifera per gram of bulk dried sediment) was calculated for the >500 µm fraction in the interval 11 m thick straddling the P/E boundary (text-fig. 1).

SEM-EDS analysis

A total of about 240 lituolid specimens from the Paleocene record and 12 specimens from the uppermost Cretaceous portion of the Forada section were isolated and identified, picked and stored in micro-slides. Moreover, another three specimens were isolated from the uppermost Thanetian Scaglia Rossa cropping out at Monte San Lorenzo Quarry (Maniago, Pordenone province, Friuli region; see Grandesso et al. 2008).

Following the methodology of Mancin et al. (2014), 61 representative Paleocene specimens and 6 Maastrichtian specimens from the Forada section (including one specimen from Monte San Lorenzo Quarry) were mounted on stubs using carbon conductive adhesive tapes and gold-coated for morphological analyses (*inBeam technique*) by Scanning Electron Microscope (SEM, Tescan FESEM, series Mira 3XMU) at the CISRiC-Arvedi Laboratory (University of Pavia). Among the most representative specimens previously analysed and photographed, 38 (respectively, 35 from the Paleocene and 3 from Maastrichtian samples) were selected, then oriented and embedded in epoxy resin, cut and polished with diamond pastes from 0.25 to 6 µm in grain-size and finally analysed using the SEM equipped with an x-ray EDS. Back Scattered Electron (BSE) images of sectioned specimens highlighted compositional similarities (or dissimilarities) among agglutinated grains through the wall thickness, on the basis of the mean atomic number of each grain forming the agglutinated test. The elemental composition of the single grains forming the agglutinated wall was provided through standardless spot microanalyses; moreover in order to check the chemical-mineralogical variability of the agglutinated grains within the sectioned test wall of each studied specimen, two-dimensional x-ray maps of selected elements

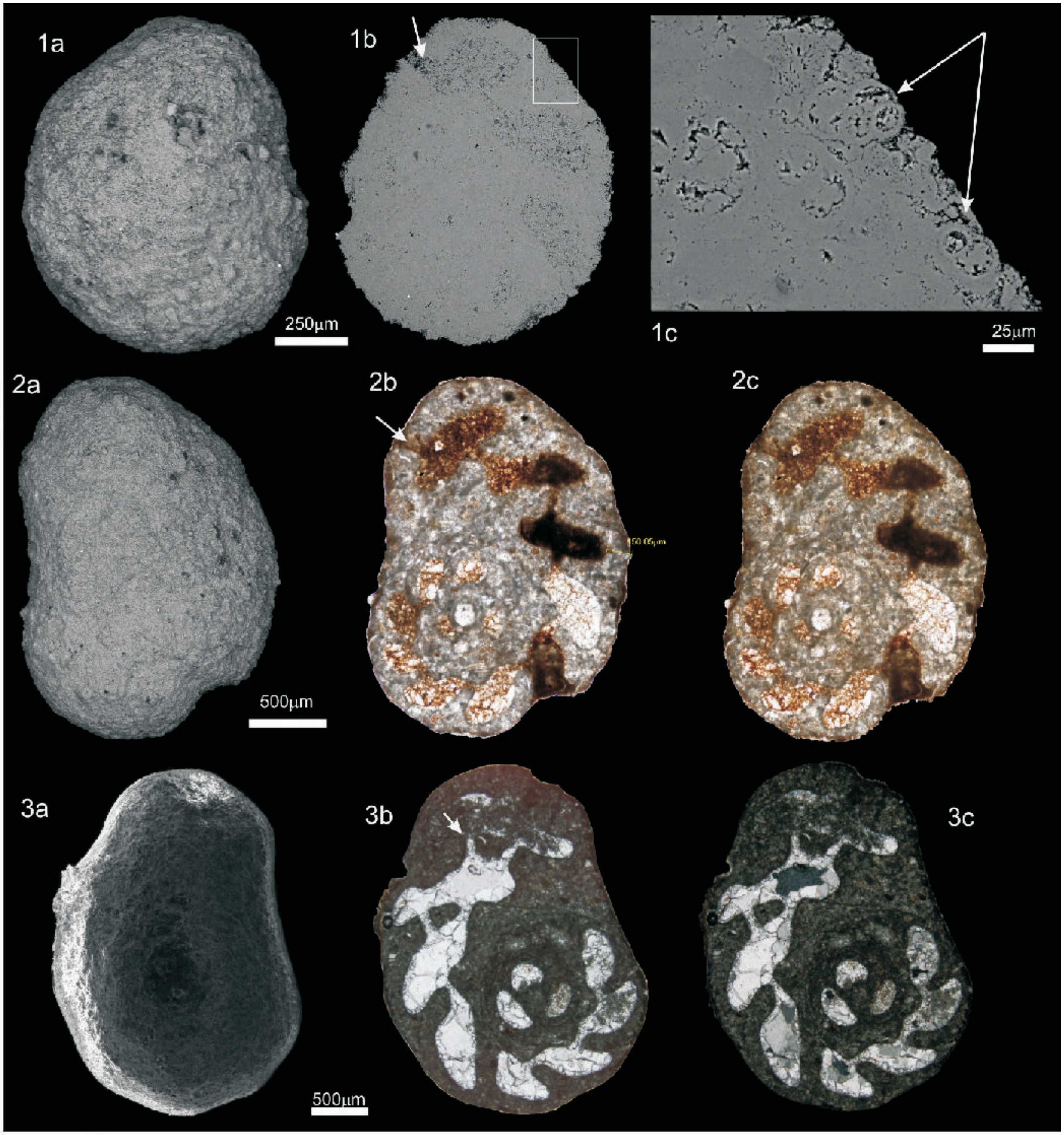
PLATE 3

Sectioned specimens picked from Danian and upper Maastrichtian records of the Forada section showing the internal chamber arrangement and the microstructure of the agglutinated wall. To note that in both Danian and Maastrichtian specimens the microstructure of the test wall is evidently different with respect to Thanetian specimens and is characterized by a single, thicker, homogeneous portion mostly made by carbonatic particles, sometimes containing tests of planktonic foraminifera.

1 Danian juvenile specimen (the same of Plate 1A, image 9); a: lateral view, b: longitudinal section (in back scattered electrons-BSE) showing the chambers spirally arranged and the simple slite-like aperture (arrow), c: detail of the agglutinated wall made of a single portion of fine-grained carbonatic particles and tests of planktonic foraminifera.

2 Danian quasi-adult specimen (the same of Plate 1A, image 8); a: lateral view, b-c: longitudinal prepared as thin section and photographed at the light polarized microscope showing the chambers initially spirally arranged, then becoming partly detached from the close spire and the more complex aperture (arrows); note that the agglutinated wall is homogeneous and made by a single carbonatic portion (ca. 150 µm thick).

3 Maastrichtian adult specimen (the same of Fig. Plate 1B, image 2); a: lateral view, b-c: longitudinal section prepared as thin section and photographed at the light polarized microscope (parallel and crossed nicols, b and c respectively). Note the chambers that are at first spirally arranged then becoming detached from the close spire, note also the aperture that becomes more complex during ontogeny (arrow). The agglutinated wall is still homogeneous and made by a single carbonatic portion.


1a
1b
1c
250µm
25µm
2a
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2c
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3b
3c
500µm

were also collected. Each elemental map (silicon, calcium, aluminium, sodium, potassium and magnesium) was collected simultaneously, since the color intensity results proportional to the element concentration in every pixel of the image (in black areas the element is lacking) the comparison of the maps collected in the same area of the sample provided an overview of the mineralogical distribution in that area (Mancin et al. 2014).

Thin sections

Because most of the Cretaceous lituolids reported in the literature has been studied on thin sections, the most significant Paleocene and Cretaceous specimens from the Forada section were also prepared accordingly. Twenty-two specimens previously embedded in epoxy resin for EDS analysis (respectively, 15 from the Thanetian, 4 from the Danian and 3 from the Maastrichtian) were cut and polished using standard hard rock thin sectioning equipment and technique with minor modifications. Four 30 µm-thick thin sections pasted with epoxy onto a glass slide were prepared for petrographic analysis using polarized transmitted light optical microscopy. The studied specimens (both isolated and sectioned) are housed in the micropaleontological collections of the Museum of Geology and Paleontology of Padova University (Italy).

RESULTS

Lituolid distribution pattern and foraminiferal assemblage composition

Two sporadic occurrences of larger lituolids resembling to *Navarella* have been observed in the Danian record of the Forada section (at about + 6.35 and +16 m above the K/Pg boundary; text-fig. 1); conversely no similar specimens occur in the Selandian portion of the section. Rare specimens of larger lituolids also occur in the Maastrichtian of the Forada section exclusively at -24 cm below the K/Pg boundary (text-fig. 1).

The investigated lituolids appear consistently in the basal Thanetian (calcareous nannofossils Zone CNP8 of Agnini et al. 2014) at about 21 m above the K/Pg boundary with an absolute abundance of <0.05 specimen per gram, and become more abundant at about -40 cm below the Paleocene/Eocene boundary (up to ca. 0.1 specimen per gram). Moreover, these lituolid specimens are a significant component of upper Paleocene benthic foraminiferal assemblage in the >500 µm fraction, that mostly consists of clavulinids, *Cicicidoides*, anomalinids and trochamminids. This assemblage of larger-sized foraminifera, including some characteristic Paleocene taxa, such as *Clavulinoides globulifera*, *Cibicidoides dayi* and *C. velascoensis* (CET, Cosmopolitan Extinction Taxa of Giusberti et al. 2016), abruptly disappear at about +39,5 m, in coincidence with the onset of the negative carbon isotopic excursion of the PETM and associated benthic foraminiferal extinction event (BEE; text-fig. 1), the most severe extinction of deep-sea benthic foraminifera of the Cenozoic (e.g., Thomas 2007). Up section, no specimens of benthic foraminifera >500 µm have been observed in the overlying six meters of Ypresian sedimentary rocks and not one specimen of larger lituolids or CET taxa has been recorded.

According to Giusberti et al. (2016), the entire benthic foraminiferal assemblage composition (>63 µm) of the Thanetian portion of the Forada section is dominated by bolivinids that exploited refractory, laterally advected organic matter. Such infaunal-dominated fauna of the Thanetian Scaglia Rossa shows a high diversity, suggesting that seasonal to periodical increases in primary productivity may have occurred in the Belluno Basin area. The marked increase in abundance of larger lituolids at about -40 cm below the Paleocene/Eocene boundary at Forada (text-fig. 1) coincides with the onset of the peak in the planktonic foraminifera *Acarinina* observed by Luciani et al. (2007) and slightly precedes some of the faunal changes detected by Giusberti et al. (2016), indicating warming of water column and increased surface nutrient availability and deep-water food availability.

Test morphology

The studied Paleocene lituolids show a high intraspecific morphological variability (Plate 1A and figure A, available online as supplementary material). The agglutinated tests vary from small sphaerical to ovoidal (ranging in size from about 0.76 to 1.25 mm), and are characterized by a strongly involute coiling of the chambers in juvenile individuals (Plate 1A, figures 1–3, 9), to larger (also exceeding 3 mm length and 1 mm wide), mostly planispiral shells that become uncoiled in the last growth stages, with a more or less developed uniserial chamber arrangement in adult individuals (4–8). Chambers gradually increase in size during the spiral stage, then they gradually reduce the size in the uniserial stage (6), moreover, chambers are separated by slightly arched septa, that are more visible and depressed on the test surface of adult specimens (4a, 5 and 6). In both juvenile and adult specimens, the agglutinated tests are covered by a rough, coarse-grained surface (1–9).

Even the primary aperture morphologically changes during test growth; it modifies from a simple straight slit-like opening in juvenile specimens (2b) to a slightly arched slit coupled with one or two pores in quasi-adult specimens (3b,c), finally reaching a more complex morphology characterized by a higher numbers of elongated or circular pores (cribrate aperture), with or without a small slit at the base in adult specimens (4c, 7).

Paleocene and Maastrichtian specimens show an apparently identical external morphology: Cretaceous specimens have a larger test (1.1–2.2 mm wide and 2.6–3 mm long), with a rough surface, and chambers spirally arranged in the first growth stages, then becoming uncoiled in the last growth stage (Plate 1B, figures 2,3) but the uncoiled portion is usually more common and well-developed in Thanetian specimens. In adult specimens, the aperture is complex and formed by numerous (up to seven), rounded or elliptical openings (Plate 1B, figure 1b).

Sectioned specimens and microstructure of the agglutinated wall

In Paleocene and Cretaceous sectioned specimens, (Plates 2-3 and supplementary material, figures B-E), chambers are streptospirally arranged in the initial coiling of the test, then they become detached from the close spire according to a rectilinear arrangement during the last growth stage, more evident in Thanetian specimens. In the sectioned adult specimens the evolution of the aperture is well manifest; it changes from a single opening connecting the lumina in the earlier chambers to a double or multiple opening in the last chamber (Plate 2, figures 3b, 4b, 5b; Plate 3, figures 2b-c, 3b-c).

The wall of Thanetian specimens (both juvenile and adult, Plate 2) is thick (up to about 140 µm) and complex with a typical layered microstructure formed by two distinct overlain layers (2c, 3c, 4c and 5c): an internal, thicker, carbonatic portion and an ex-

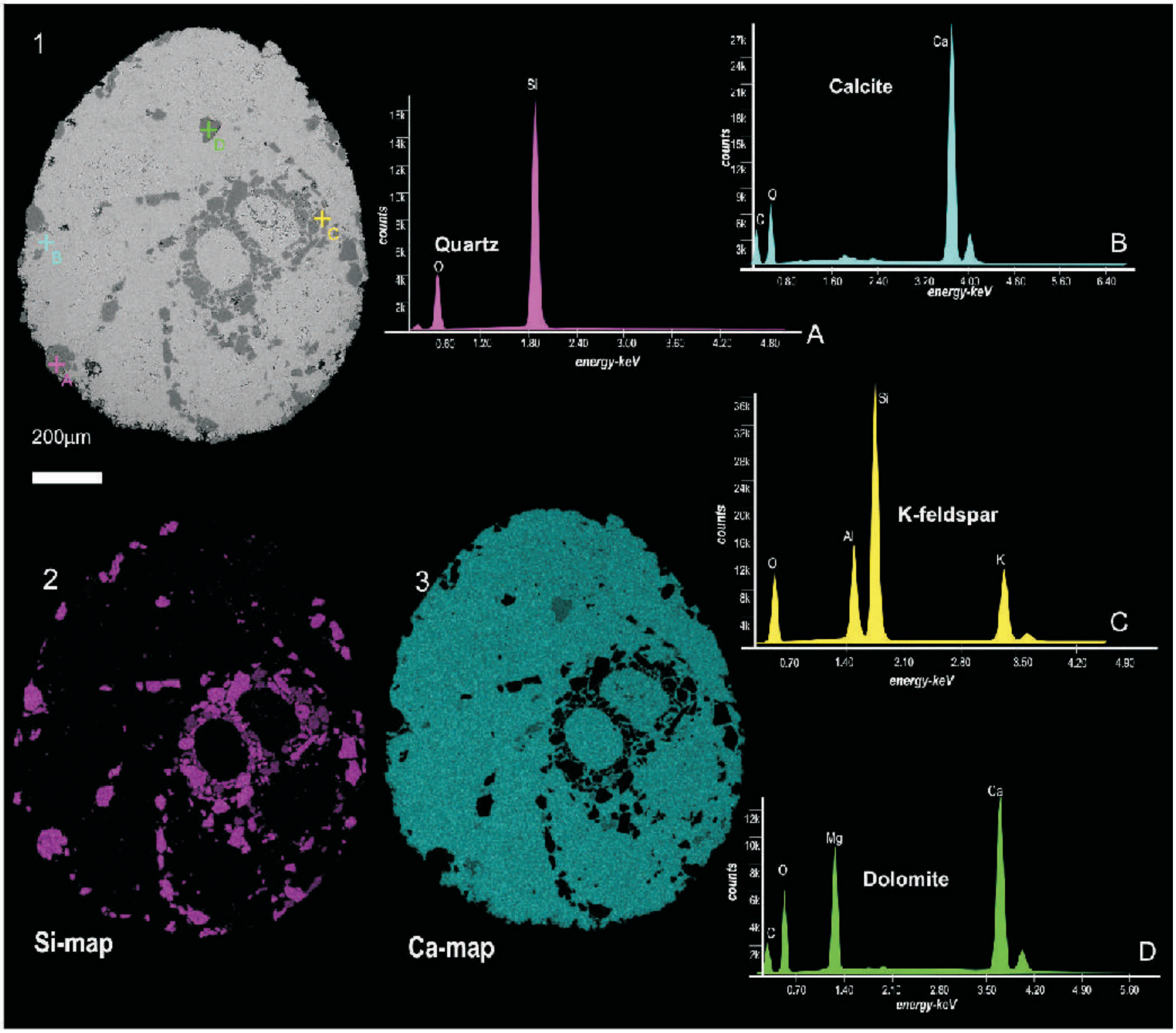


PLATE 4

Elemental characterization of the agglutinated grains in a Thanetian juvenile specimen (sample BRI-37; MGP-PD 32075) from the Forada section. Note that the external coarse-grained particles are mostly of quartz and silicates whereas the internal portion of the wall is of calcite. Images are in back-scattered electrons (BSE).

1 Longitudinal section (the same specimen of Plate 2, image 1b) showing the elemental characterization of the agglutinated grains. The colored crosses indicate the spots for standardless microanalyses (A-D); on the right the corresponding EDS spectra are reported. In the violet spectrum (A) the very high counts of Si, together with O, indicates that the analysed grain is quartz; similarly in the blue spectrum (B) the high counts of Ca indicates that the grain is calcite. In the yellow spectrum (C), the presence of Si, Al, K and O reveals the silicatic nature (K-feldspar) of the analysed grain; finally in the green spectrum (D) the co-occurrence of Ca, Mg, O and C is indicative of a dolomitic grain.

2-3 Elemental maps reporting the areal distribution of Si (image 2) and Ca (image 3) in the whole longitudinal section of the specimen imaged above (1). Silicon and Ca maps (here considered as discriminating elements between quartz and calcite) show that Si is mostly concentrated in the grains forming the external portion of the agglutinated wall (the external pavement), on the other hand, Ca homogeneously and abundantly occurred in the internal part of the agglutinated wall.

ternal, thinner, coarse-grained pavement of mineral granules; in the internal carbonatic portion, some particles are remains of planktonic foraminiferal tests (3c white arrow). The agglutinated grains from both layers are embedded in a homogeneous calcareous matrix (2c; 3c, 4c and 5c). Note that these features persist unchanged in both juvenile and adult specimens (1b, 2b; 3b, 4b, 5b) and during the test growth.

Noteworthy, in the Danian sectioned specimens (Plate 3, figures 1a-c, 2a-c) the agglutinated wall is clearly different: it is characterized by a thick (up to about 150 µm), homogeneous, single portion, mostly made of carbonate particles embedded together by an abundant calcitic cement (1b-c, 2b); the largest particles are tests of planktonic foraminifera (arrows in 1c). The external portion of the wall, made of coarse-grained mineral particles, a feature that is clearly visible in Thanetian specimens, is here missing. It is noteworthy that these characteristics persists unchanged during the test growth and are the same in juvenile and adult specimens (1b-e and 2 b-d).

Likely, in the Cretaceous sectioned specimen imaged in Plate 3, figures 3a-c, the agglutinated wall consists of a single carbonate layer, without the external coarse grained-portion that appears as a peculiar feature of the Thanetian specimens.

Chemical-mineralogical composition of the agglutinated grains

In both juvenile and adult Thanetian specimens (Plates 4–6 and supplementary material, Figures B-E), the agglutinated grains are always selected within the test wall, in terms of chemical-mineralogical composition, size and disposition. The largest grains are mainly of quartz (more rarely of other silicates, such as plagioclase and k-feldspar) and are arranged toward the outside of the agglutinated wall to form a distinct coarse-grained layer (a sort of external pavement) that externally covers both the wall and the septa (Plates 4-6, Si-maps). This external pavement is usually thinner with respect to the entire thickness of the agglutinated wall (i.e., Plate 5, figure 1b; Plate 6, figure 1b) and is formed by granules which are also selected on the basis of their size and disposition, with the largest grains arranged close to the outside and the smallest grains towards the inside (Plates 4-6, Si-maps). Most of the remaining agglutinated wall is formed by fine-grained carbonate particles (Plates 4-6, Ca-maps), mostly of calcite and, more rarely, of dolomite or of remains of planktonic foraminiferal tests (i.e., Plate 6, figures 1c, 2); these carbonatic grains can be less evident within the calcite matrix mainly when the diagenetic process has been particularly invasive (Plate 4, figure 1; Plate 5, figure 1b).

It is interesting to note that in all the studied Thanetian specimens, the agglutinated grains are strongly selected maintaining the same mineralogical composition even in specimens collected from different stratigraphic sections (e.g., uppermost Thanetian of the Monte San Lorenzo Quarry, Friuli-Venezia Giulia region; supplementary material, Fig. B, specimen 4). The ability for selecting grains from the substratum to form their test is also confirmed by the mineralogical composition of the sediments containing the studied Thanetian lituolids (supplementary material, Table A). In the Thanetian record of the Forada section, quartz is not a dominant component (it occurs in the sediment with percentages varying from 8.3 to 17%; Giusberti et al. 2007); in spite of this, quartz is always selected by the Thanetian lituolids to construct the external portion of the test; on the contrary, phyllosilicates, that are always more abundant in the sediments (with percentages varying from 29% to 57%; Giusberti et al. 2007), are never observed in the studied agglutinated tests.

Comparison with other lituolids described in the literature

Significant differences emerged when we compared the sectioned Thanetian specimens from the Forada section with Upper Cretaceous specimens attributed to *Navarella* Ciry and Rat 1951 and similar lituolids from other European and Italian localities and previously described in the literature (e.g., Maync 1952; 1954; Cati 1960; Sampò 1972; Riegraf 1998) (Table 1). The investigated specimens were also directly compared with the type material (both isolated and sectioned specimens) of the larger lituolid "*Recurvoides*" *manfredii* Cati (1960) from the Campanian Scaglia Rossa of Berici Hills, presently housed at the Museo Capellini of Bologna University (Italy). We tried to locate the original material studied by Sampò (1972) from the Maastrichtian Scaglia Rossa of the Lessini Mountains (Veneto region) in the collections of the Department of Earth Sciences of Turin University, but unfortunately it seems to be lost.

In term of external morphology, Thanetian lituolid specimens more closely resemble the genus *Navarella* Ciry and Rat 1951 for possessing a more developed uncoiled portion of the test in comparison with the Campanian lituolids from Scaglia Rossa described by Sampò (1972) and Maastrichtian and Danian specimens from Forada section analyzed in this study (Table 1).

The agglutinated wall of our Thanetian specimens is typically bi-layered, with the grains selected on the basis of their size, shape and chemical-mineralogical composition. The larger grains are of quartz and are arranged towards the outside of the test wall to form a sort of rough external pavement; on the contrary towards the inside, the wall is formed by a more regular, thicker calcareous portion, made of smaller carbonate grains of calcite and more rarely of dolomite and planktonic foraminiferal test remains. All the agglutinated grains forming both the external and the internal layers are cemented by calcite. None of the investigated Thanetian specimens show an agglutinated wall formed exclusively by a single layer of fine sugary quartz grains, as reported for *Navarella joaquini* by Maync (1954), nor a test wall formed by agglutinated grains of different sizes, randomly arranged and exclusively composed by foraminiferal tests and carbonate particles as reported by Sampò (1972) for Maastrichtian specimens ascribed to *Navarella joaquini* from the Scaglia Rossa of Verona province.

Maastrichtian and Danian specimens of lituolids recovered at Forada are morphologically quite similar to the specimens described by Cati (1960) as "*Recurvoides*" *manfredii*, even if the composition of the agglutinated grains is more characteristic of the lituolids described by Sampò (1972) as "*Lituola grandis*" and "*Navarella joaquini*" (Table 1).

Summarizing, we conclude that the studied Thanetian lituolid specimens cannot be attributed to the genus *Navarella* Ciry and Rat 1951: they clearly differ with respect to the emended description of Maync (1954), whose specimens from Switzerland were compared by Riegraf (1998) to *Lituola westfalica* Bartenstein 1952. Riegraf (1998) also considered *Navarella joaquini* and *Lituola westfalica* as convergent but not synonymous taxa, whose relationships should be explored through careful study.

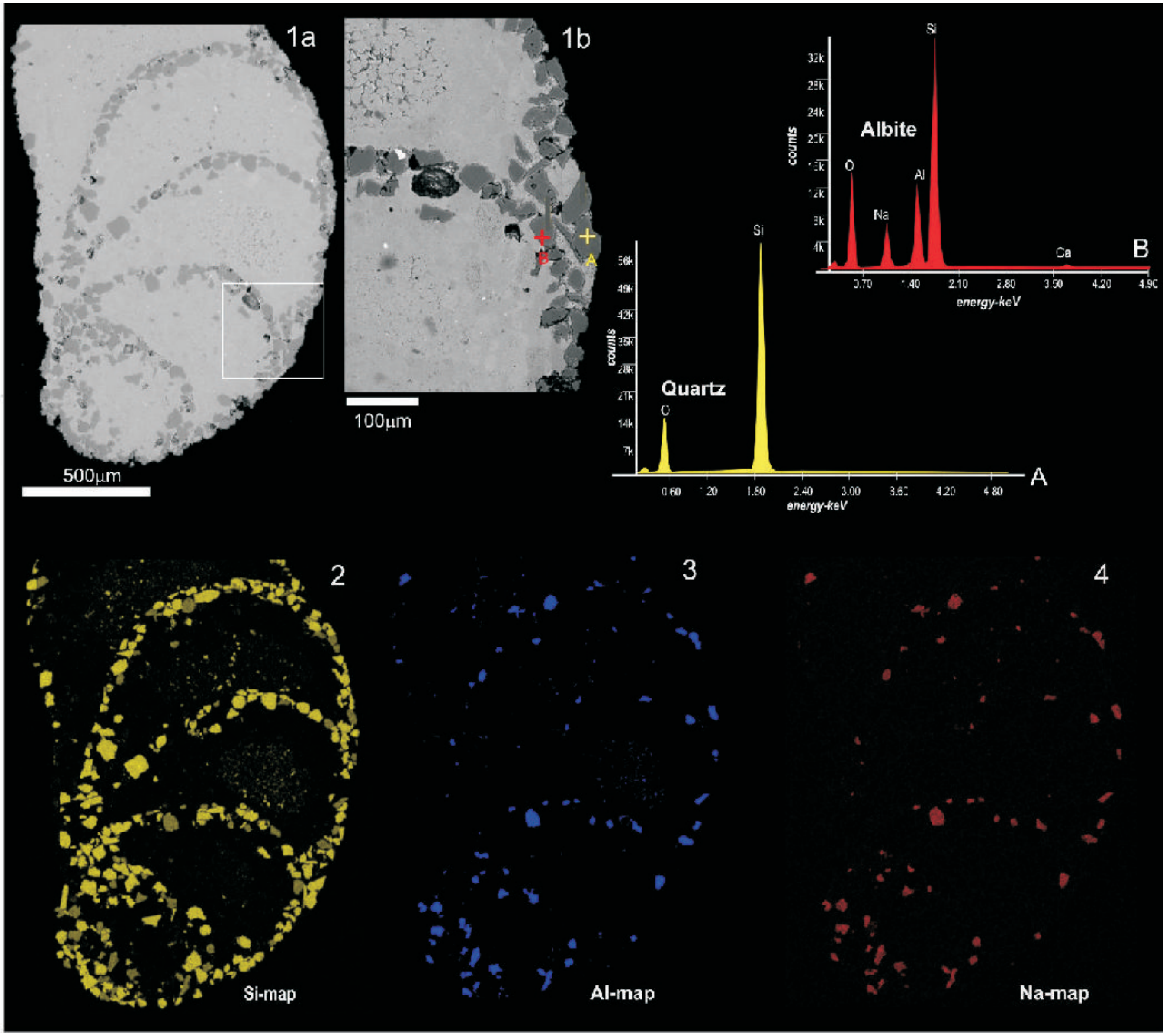


PLATE 5

Elemental characterization of the agglutinated grains in a Thanetian quasi-adult specimen (sample BRI-9; MGP-PD 32072). Note that the compositional features of the agglutinated grains are the same previously describe for the juvenile specimen. Images are in back-scattered electrons (BSE).

1a Longitudinal section (the same specimen of Plate 2, image 2b) showing the elemental characterization of the agglutinated grains.

1b Detail of the agglutinated test wall. The colored crosses indicate the spots for standardless micro-analyses (A-B); on the right the corresponding EDS spectra are reported: A) quartz (in yellow) and B) albite (in red). Note that silicates (e.g. K-feldspar and plagioclase) are characterized by very high counts of Si, together with similar counts of Al and O; the presence of Na and/or Ca, with significant counts, discriminates plagioclases (albite *vs*. anortite), while the K peak may be considered as indicative of K-feldspars.

2-4 Elemental maps reporting the areal distribution of Si (image 2) Al (image 3) and Na (image 4) in the longitudinal section of the quasi-adult specimen imaged above (1). Silicon (here considered as indicative of quartz and silicates) is mostly concentrated in the grains forming the external portion of the agglutinated wall (the external pavement), on the other hand, most of the internal agglutinated wall is made of calcite (in black in image 2).

Based on all the above mentioned considerations, we ascribe the Thanetian specimens from the Forada section to a new genus of navarellid lituolid, *Neonavarella* n. gen. described below, whereas the Maastrichtian–Danian specimens from the Forada section are assigned to "*Navarella*" sp. (Plate 1A, figures 8, 9; Plate 1B and Plate 3), pending further revision of all larger lituolids from Italian Scaglia-type rocks.

SYSTEMATIC PALEONTOLOGY

We formally describe a new genus and species belonging to the subfamily Ammobaculininae, and compare it with the stratigraphically older and possibly ancestral genus *Navarella* Ciry and Rat 1951. The following description is based on the traditional morphology-based classification system of Loeblich and Tappan (1987; see Loeblich and Tappan 1989) partly integrated and emended by Kaminski (2014), which uses test wall microstructure and grain composition.

Class FORAMINIFERA d'Orbigny 1826
Order LITUOLIDA Lankester 1885
Suborder LITUOLINA Lankester 1885
Family AMMOBACULINIDAE Saidova 1981
Subfamily AMMOBACULININAE Saidova 1981

Genus ***Neonavarella*** Giusberti, Kaminski and Mancin **n. gen**.

Type species: Neonavarella sudalpina n. gen., n. sp.

Diagnosis: Test large, initially streptospirally enrolled, involute, later uncoiling, with numerous, broad and low chambers overlapping the earlier ones, septa strongly arched. Agglutinated wall consisting of two layers: an outer layer of larger agglutinated quartz grains that forms an outer pavement, and a thicker inner calcareous layer consisting of smaller calcareous particles in a calcareous ground mass. Cement of calcite. Aperture a basal or areal slit in the early coiled stage, areal in the later coiled stage, consisting of small circular openings in addition to the larger interiomarginal one; the uncoiled stage has a terminal cribrate aperture.

Etymology: From the Ancient Greek, "νεοζ" (= new) and "*Navarella*", the Upper Cretaceous genus defined by Ciry and Rat (1951) that is morphologically similar.

Composition of the genus: At the moment the genus is represented only by the type species *Neonavarella sudalpina* n. sp.

Type horizon: Thanetian (upper Paleocene) reddish and greenish marls and calcareous marls; calcareous nannofossil zones CNP8-CNP11 of the scheme of Agnini et al. (2014).

Type locality: Forada Creek, Belluno province of northeastern Italy (text-fig. 1).

Stratigraphic and geographic range: Thanetian (upper Paleocene) of the Veneto region and Thanetian of San Lorenzo Quarry, Maniago (Pordenone province, Friuli region).

Remarks: Neonavarella n. gen. differs from *Navarella* Ciry and Rat 1951 in its two-layered clearly differentiated wall and younger stratigraphic range (Table 1).

Neonavarella sudalpina Giusberti, Kaminski and Mancin **n. sp.**

Plate 1A, figures 1–7; Plate 2; Plates 4–7; supplementary material, figures A (pages 1–4), figures B–E, F (page 1)

"Large lituolids" of Giusberti et al. 2016, p. 219, pl. 4, figs. 14, 20.

Diagnosis: As *Neonavarella* is monotypic, the diagnosis of its type species is the same as that of the genus.

Type horizon: Thanetian (upper Paleocene) reddish and greenish marls and calcareous marls; calcareous nannofossil zones CNP8-CNP11 of the scheme of Agnini et al. (2014).

Type locality: Forada Creek section, Belluno province of northeastern Italy.

Etymology: After "Sudalpino" (Southern Alps), the name of the sector of the Alpine Chain in which the new taxon was discovered.

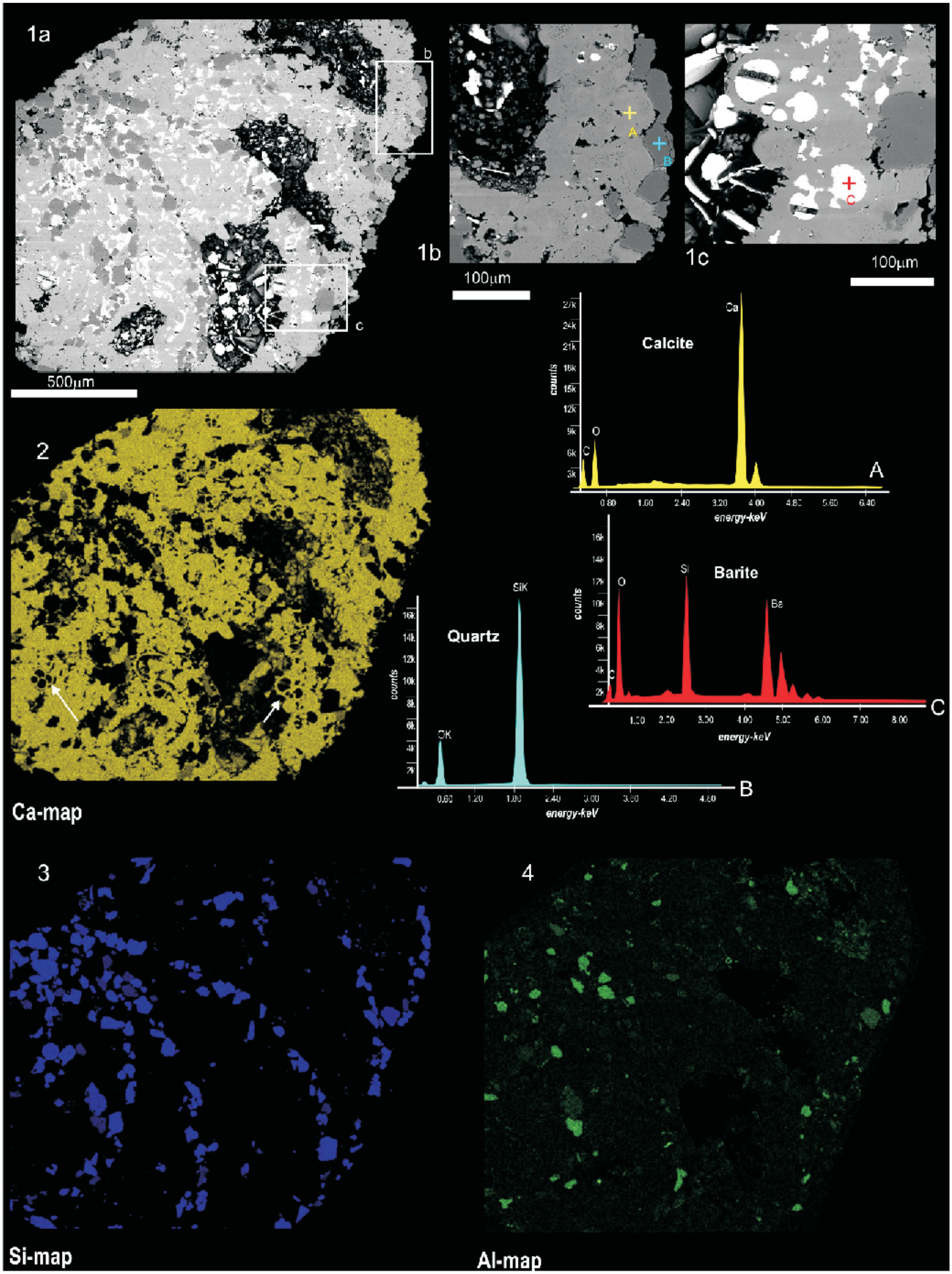
PLATE 6

Elemental characterization of the agglutinated grains in a Thanetian adult specimen (thin section MGP-PD 32072, sample BRI-9). Note that also in the adult specimen the compositional features of the agglutinated wall do not change. Images are in back-scattered electrons (BSE).

1a Longitudinal section showing the elemental characterization of the agglutinated grains.

1b-c Details of the agglutinated wall. The colored crosses indicate the spots for standardless microanalyses (A-C); on the right the corresponding EDS spectra are reported: A) calcite (in yellow); B) quartz (in blue) and C) barite (in red).

2-4 Elemental maps reporting the areal distribution of Ca (image 2), Si (image 3) and Al (image 4) in the longitudinal section of the adult specimen imaged above (1). Silicon (here considered as indicative of quartz and silicates) is mostly concentrated in the grains forming the external portion of the agglutinated wall (the external pavement), on the other hand, most of the internal agglutinated wall is made of calcite (image 2). Note the remains of planktonic foraminifera (arrows) within the carbonate portion of the agglutinated wall.


1a
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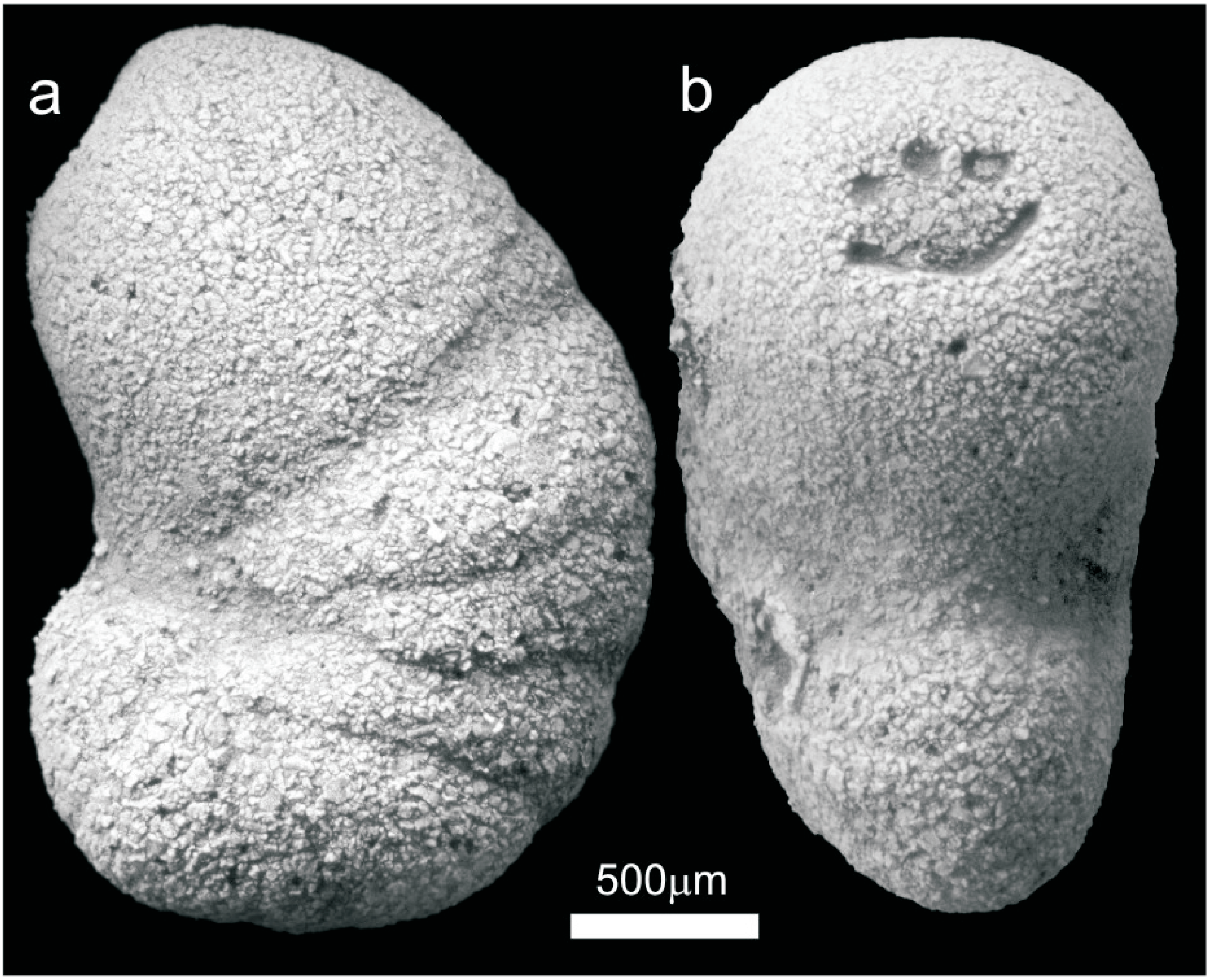

PLATE 7
Neonavarella sudalpina n. gen., n. sp. Holotype. Slide MGP-PD 32068. Sample BRI-466. Scaglia Rossa Formation, Thanetian, Forada section, northeastern Italy. a) lateral view, b) apertural view showing a slit-like aperture coupled with three pores

Repository: The type series (MGP-PD 32071-32073, 32075-32088) is housed in the micropaleontological collections of the Museum of Geology and Paleontology of the University of Padova (Italy). Additional topotypic specimens are housed in the personal collection of one of the authors (L.G.) at the Department of Geosciences of Padova University (Italy), and in the collections of the European Micropalaeontological Reference Centre, at Micropress Europe, Kraków Poland; such specimens are labelled with the sample number assigned during the sampling of the section.

Designated holotype: The isolated specimen illustrated in Plate 7 and registered as MGP-PD 32068.

Paratypes: Figured paratypes (MGP-PD 32071-32073, 32075-32081) are in Plate 1A, figures 1–7; Plate 2; Plates 4–6; and supplementary material, figs. A (pages 1–4) and B–F (page 1). Unfigured paratypes are registered as MGP-PD 32082-32087.

Description: High intraspecific morphological variability from juvenile to adult specimens. Juvenile specimens generally smaller in size (ranging from ~0.76 to 1.25 mm), ovoidal to subspherical with chambers strictly coiled. Early chambers streptospirally, then planispirally arranged (7–8 chambers in the last whorl) passing to uncoiled in the adult larger specimens (also exceeding 3 mm length and 1 mm wide). Uncoiled portion of the test usually less well-developed, consisting of 3–4 small chambers. Primary aperture that morphologically changes during test growth: slit from almost rectilinear in the juvenile specimens to markedly arched. In adult individuals, the apertural slit is associated with small circular pores (up to a maximum of 4 pores); a truly cribrate aperture (with 6–7 small rounded pores) is less frequent in the adult uncoiled specimens. Agglutinated wall typically bi-layered, formed by an external coarse-grained layer of silicilastic grains mainly of quartz and an inner thicker layer of calcareous grains (also biogenic remains, as foraminiferal tests). Grains held together by calcitic cement.

Remarks: quite similar to Maastrichtian–Danian specimens from the Forada section ("*Navarella*" sp.) from which *Neonavarella sudalpina* n. sp. differs in the bi-layered wall structure (Table 1).

Stratigraphic and geographic range: Thanetian (upper Paleocene; calcareous nannofossil zones CNP8-CNP11 of Agnini et al. 2014) of the Veneto region (Italy) and uppermost Thanetian (calcareous nannofossil zone CNP11 of Agnini et al. 2014) of San Lorenzo Quarry, Maniago (Pordenone province, Friuli region, Italy). The taxon becomes extinct at the Paleocene/Eocene boundary, in coincidence with the BEE (benthic foraminiferal extinction event).

Paleoenvironment: Basinal setting at middle-lower bathyal depth (~1000–1500 m). The new taxon is a minor component of the >63 µm fraction benthic foraminiferal assemblage, strongly dominated by bolivinids. *Neonavarella sudalpina* n. gen., n. sp. is associated in the >500 µm fraction with deep-water taxa such as clavulinids, *Cicicidoides*, anomalinids and trochamminids. This assemblage includes also some characteristic Paleocene extinction taxa, such as *Clavulinoides globulifera*, *Cibicidoides dayi* and *C. velascoensis* (CET, Cosmopolitan Extinction Taxa of Giusberti et al. 2016).

CONCLUSIONS

A direct comparison among Maastrichtian, Danian and Thanetian specimens of larger lituolids from the Forada section (Belluno basin, northeastern Italy) permitted the assignment of the Thanetian lituolids to a new genus here formally designated as *Neonavarella* n. gen., a singleton taxon (sensu Foote 2000) morphologically similar to *Navarella* Ciry and Rat 1951, but characterized by a peculiar bi-layered agglutinated wall.

The older Maastrichtian-Danian specimens from the Forada section are here ascribed to "*Navarella*" sp.; nonetheless the relationships between *Navarella* sensu Ciry and Rat 1951 and the specimens of "*Navarella*" from the Upper Cretaceous Scaglia-type rocks of northeastern Italy need to be more fully explored.

This study also allows the stratigraphic range of larger bathyal navarellid lituolids, previously thought to be limited to the Upper Cretaceous, to be extended into the Paleocene. Finally, we demonstrate the importance of compositional and microstructural studies based on sectioned specimens for establishing the taxonomic significance of the wall structure in agglutinated foraminifera.

ACKNOWLEDGMENTS

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Supplementary materials (Available on-line)

FIGURE A

Intraspecific morphological variability of the studied lituolids picked from the whole upper Maastrichtian, Danian and Thanetian stratigraphic record of the Forada section. Collected specimens vary from small juvenile individuals with a simple slit-like aperture and a strongly involute coiling of the test to larger adult individuals with a complex aperture and a test that becomes uncoiled in the last growth stages. Pages 1-4: Thanetian specimens (*Neonavarella* n. gen.). Page 5: Danian specimens ("*Navarella*" sp.). Page 6: Maastrichtian specimens ("*Navarella*" sp.).

Page 1: all specimens from slide MGP-PD 32078 (except the specimen n. 9 from section MGP-PD 32075. Page 2: all specimens from slide MGP-PD 32079 (except the specimens n. 5 and 9 from MGP-PD 32075 and the specimen 7 from MGP-PD 32071). Page 3: all specimens from slide MGP-PD 32080 (except the specimen 8 from MGP-PD 32071 and the specimens n. 10 and 12 from MGP-PD 32073). Page 4: all specimens from slide MGP-PD 32080 (except the specimen 16 from MGP-PD 32071 and the specimens n. 17 and 18 from MGP-PD 32073). Page 5: specimens 1, 3 and 5 from MGP-PD 32074, specimens 4 from slide with sample number RF +670C. Page 6: specimens 1, 2, 3, 7 are housed in slides labeled "RF-24", specimen 4, 5 from slide MGP-PD 32089, specimens 6 and 9 sectioned (MGP-PD 32069) and specimen 8 sectioned (MGP-PD 32070).

FIGURES B-E

Sectioned specimens of Thanetian lituolids (*Neonavarella sudalpina* n. gen., n. sp.) from the Forada and Maniago sections, showing the microstructure of the agglutinated wall formed by two distinct layers and the chemical-mineralogical composition of the agglutinated grains of both adult and juvenile specimens. Note that the microstructural and compositional features of the agglutinated tests persist unchanged in both juvenile and adult specimens and during the test growth. Similarly, no evident differences merged in individuals picked from different stratigraphic layers.

Figure B: thin section MGP-PD 32072 (including the specimen 4, coming from the uppermost Thanetian of Monte San Lorenzo Quarry section, Friuli region), Figure C: thin section MGP-PD 32071, Figure D: thin section MGP-PD 32075, Figure E: thin section MGP-PD 32073. Thin section MGP-PD 32071 in Figure C includes also four sectioned specimens of Pliocene *Colominella* published by Mancin and Kaminski 2017 - Systematic updates of the agglutinated foraminiferal genus *Colominella* Popescu 1998: insights from sectioned specimens. *Geologica Carpathica* 68(2), 109-118.

FIGURE F

Images of Thanetian, Danian and Maastrichtian sectioned specimens prepared as thin sections and analyzed with a light polarized microscope. Page 1: specimens from section MGP-PD 32073. Page 2: specimen from section MGP-PD 32069. Page 3: specimen from section MGP-PD 32074.

TABLE A

Mineralogical characterization (RDX data) of the sediments containing the studied lituolids (from Giusberti et al. 2007).