

NODULINA KUHNTEI N. SP. AND NODULINA EUGUBINA N. SP., NEW AGGLUTINATED FORAMINIFERA FROM THE LOWER PALEOCENE OF THE SCAGLIA ROSSA, UMBRIA–MARCHE BASIN, ITALY

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ABSTRACT

This paper describes two Paleogene deep-water agglutinated foraminiferal species from the Contessa Highway Section of the Umbria–Marche Basin, Italy. The foraminiferal assemblages in the lowermost Paleogene are dominated by opportunistic species belonging to the *Reophax* group. Previous studies of the agglutinated foraminifera from the Scaglia Rossa Formation have reported hormosinids (*Reophax* spp.) mostly using open nomenclature. To facilitate the proper species assignment according to accurate species descriptions, we describe the new species *Nodulina kuhntei* n. sp. and *Nodulina eugubina* n. sp. Both species are characterized by their more or less straight elongated tests with horizontal sutures, and therefore are best assigned to the genus *Nodulina*. They constitute a significant component of the benthic foraminiferal assemblage in the stratigraphic interval above the K/Pg boundary.

INTRODUCTION

The Gubbio sections in Italy's Umbria–Marche Basin contain a thick sequence of Cretaceous to Paleogene deep-water limestone formations. Given that the Iridium anomaly was first discovered in the Gubbio area by Alvarez et al. (1980), the area serves as an important reference section for the Cretaceous/Paleogene boundary. The distribution and assemblages of the deep-water agglutinated foraminifera (DWF) preserved in the boundary section show significant changes across the boundary in Contessa (Kuhnt & Kaminski, 1996; Hikmahtiar et al., 2022). Kuhnt (1990) and Kaminski et al. (2011) presented the Upper Cretaceous taxonomy and biostratigraphy of the DWF at Contessa. The detailed investigation of the lowermost Paleocene DWF at Contessa revealed many specimens that can be assigned to Kuhnt's "*Reophax* sp. 2" and "*Reophax* sp. 4" (see Hikmahtiar et al., 2022). This finding provoked a more detailed study of the reophacids. The current study involves the formal description of two of the forms first reported by Kuhnt (1990), which contribute to our understanding of the paleoecological and paleogeographic history of the DWF fauna.

In his study of the DWF recovered from Western Mediterranean Upper Cretaceous pelagic limestones in Umbrian Apennines, Italy and Betic Cordillera, Southern Spain, Kuhnt (1990) illustrated four different species of "*Reophax*", all in open nomenclature. "*Reophax* sp. 2" and "*Reophax* sp. 4", which are the subject of this paper, were described from Upper Campanian, Upper Maastrichtian, and Santonian in the Gubbio area. In subsequent studies of the basal Paleocene in

Contessa, Kuhnt & Kaminski (1996) revealed that these forms bloomed after the K/Pg boundary event and even scavenged impact-derived mineral grains and incorporated them into their agglutinated wall (Kaminski et al., 2008).

Abundant new specimens of reophacids were recovered from high-resolution sampling (bed by bed) from the Contessa Highway outcrop (Hikmahtiar et al., 2022). The HCl-extracted samples show excellent preservation, allowing us to resolve their morphological features and formalize them as new species.

MATERIALS AND METHODS

In total, 44 samples were collected from the lower Paleocene of the Contessa Highway section for this research. The measurement starts at the K/Pg boundary. Samples were collected at 10-cm intervals between 1 and 2 m and 20-cm intervals between 2 and 5 m above K/Pg. The samples were dissolved in diluted hydrochloride acid (HCl) and then washed through a 63- μ m sieve to extract the agglutinated foraminifera. Specimens were chosen from the >125- μ m fraction and mounted on cardboard microslides. The specimens were photographed using a Neoscope JCM-7000 scanning electron microscope (SEM) at the King Fahd University of Petroleum and Minerals College of Petroleum and Geosciences. The holotype and paratype specimens were placed in separate microslides and deposited in the collections of the European Micropaleontological Reference Centre in Kraków, Poland.

SAMPLE LOCATION

The Contessa Highway Section (43°22'47"N; 13°33'49"E) is located in the Umbria–Marche basin of Central Italy (Fig. 1). It is part of the pelagic limestone sequence that extends from the Cenomanian to upper Eocene with some interbedded marls in the lower Paleocene. Alvarez & Montanari (1988) described the Scaglia Rossa Formation as consisting of reddish-pinkish pelagic micritic limestones with some cherty horizons. For this study, the lower part of the Danian (0.0–5.0 m above the K/Pg boundary) of the Scaglia Rossa Formation R3 member was sampled (Fig. 2).

RESULTS

Our lowermost samples collected from the Danian in the Contessa Highway Section contain numerous specimens of *Nodulina* spp. with continuous occurrence and a varying proportion of specimens. The abundance of *Nodulina* generally decreases upsection from the boundary. All specimens are well preserved. We recovered 518 specimens of *Nodulina kuhntei* n.

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FIGURE 1. Location of the Contessa Highway outcrop sampled for this study.

sp. and 196 specimens of *Nodulina eugubina* n. sp. from the 44 samples collected from the lower 5 m of the Paleocene.

SYSTEMATIC PALEONTOLOGY

Subclass GLOBOTHALAMANA Pawlowski, Holzmann & Tyszk, 2013

Order LITUOLIDA Lankester, 1885

Suborder HORMOSININA Mikhalevich, 1980

Superfamily HORMOSINOIDEA Haeckel, 1894

Family REOPHACIDAE Cushman, 1927

Genus *Nodulina* Rhumbler, 1895

Remarks. We use the definition of the genus given by Loeblich & Tappan (1987), which we consider to be the emendation of the description of Rhumbler (1895). Loeblich & Tappan (1987) designated the specimen figured by Brady (1881, p. 49) as the lectotype of the type species, *Reophax dentaliniformis*. Kaminski & Cetean (2008) re-illustrated the lectotype.

Nodulina kuhnti n. sp.

Figs. 3.1a–b, 3.2a–b, 3.3a–b, 3.4a–b, 3.5a–b, 3.6a–b, 3.7a–b
Reophax sp. 2 Kaminski et al., 1988, p. 187, pl. 3, figs. 2–3.

Reophax sp. 2 Kuhnt, 1990, p. 324, pl. 3, figs. 7–9.

Reophax sp. Kuhnt et al., 1998, pl. 2, fig. 4.

Derivation of name. Patronymic, named after Prof. Wolfgang Kuhnt (CAU, Kiel) who first reported the species from Gubbio.

Material. 518 specimens.

Dimensions/Dimensions of holotype. Length horizontal = 140–190 μm , Length vertical = 370–630 μm .

Type level. Danian, lower Paleocene, at a stratigraphic height 0.1 m above the K/Pg boundary continuous occurrence up to +4.8 m, absent only at +3.6 m.

Type locality. R3 member of the Scaglia Rossa Formation, Contessa Highway, Gubbio, Italy.

Geographic distribution. This species was first reported from the Danian Lizard Springs Formation of Trinidad (Kaminski et al., 1988), and in the Upper Campanian and Upper Maastrichtian of

the Gubbio sections (Kuhnt, 1990). It was later reported from the Danian at ODP Site 959, Ivory Coast–Ghana margin (Kuhnt et al., 1998).

Description. The test is elongated, slightly compressed, and composed of three to five chambers that are partially elongated and increase very slowly in size. Horizontal sutures, wall moderately coarse, with a rough surface. Aperture terminal.

Remarks. *Nodulina kuhnti* n. sp. is a common species at Contessa, considered as an opportunistic species, and found in nearly every lower Paleocene sample. The species was first found in the nearby Bottacione section by Kuhnt (1990). Based on Kuhnt's (1990) description, the number of chambers is reported to be 4–5, the test is elongated, often compressed, with chambers gradually increasing in size. Kuhnt pointed out similarity with the modern species *Reophax dentaliniformis* Brady, which is the type species of the genus *Nodulina*. Of the three subspecies of *Reophax dentaliniformis* described by Rhumbler (1936, figs. 136–138, p. 184), the subspecies *Reophax dentaliniformis* Brady forma *compactilis* is the most similar. However, the specimens of Rhumbler (1936) differ in their larger dimensions and in possessing chambers that are more elongated.

Type specimens. The holotype (Fig. 3.5) and figured paratypes are deposited in the collections of the European Micropaleontological Reference Centre in Kraków, Poland, in Cabinet 7, drawer 27c.

Nodulina eugubina n. sp.

Figs. 3.8a–b and 3.9a–b

Reophax sp. 4 Kuhnt, 1990, p. 324, pl. 3, fig. 12.

Derivation of Name. From the Roman name of the city of Gubbio.

Material. 196 specimens.

Dimensions/Dimensions of holotype. Length horizontal = 130–180 μm , Length vertical = 450–730 μm .

Type level. Danian, lower Paleocene, at a stratigraphic height 0.1 m up to 0.5 m above the K/Pg boundary, abundance drops significantly from 0.6 m up to 4.8 m.

Type locality. R3 member of the Scaglia Rossa Formation, Contessa Highway, Gubbio, Italy.

Geographic distribution. This species has been found in the Paleocene R3 member of the Scaglia Rossa Formation at Gubbio, Italy. The species was reported as “*Reophax* sp. 4” from the Santonian of the Gubbio sections (Kuhnt, 1990).

Description. The test is elongated, flattened, thin walled, with very clearly visible horizontal suture between the chambers, formed by 4–5 elongated chambers. Wall thin, finely agglutinated, aperture terminal.

Remarks. *Nodulina eugubina* n. sp. is a common species in Contessa. This opportunistic species occurs in almost every sample in the lower Paleocene, and its stratigraphic distribution is generally continuous. The specimens decrease in abundance upsection from the K/Pg boundary. Kuhnt (1990) discovered the species in the Santonian in the Gubbio area and named it “*Reophax* sp. 4.” According to his description, the test has five chambers, is elongated, strongly compressed, the test wall is very finely agglutinated, and the sutures between the chambers are visible.

Type specimens. The holotype (Fig. 3.8) and figured paratype are deposited in the collections of the European

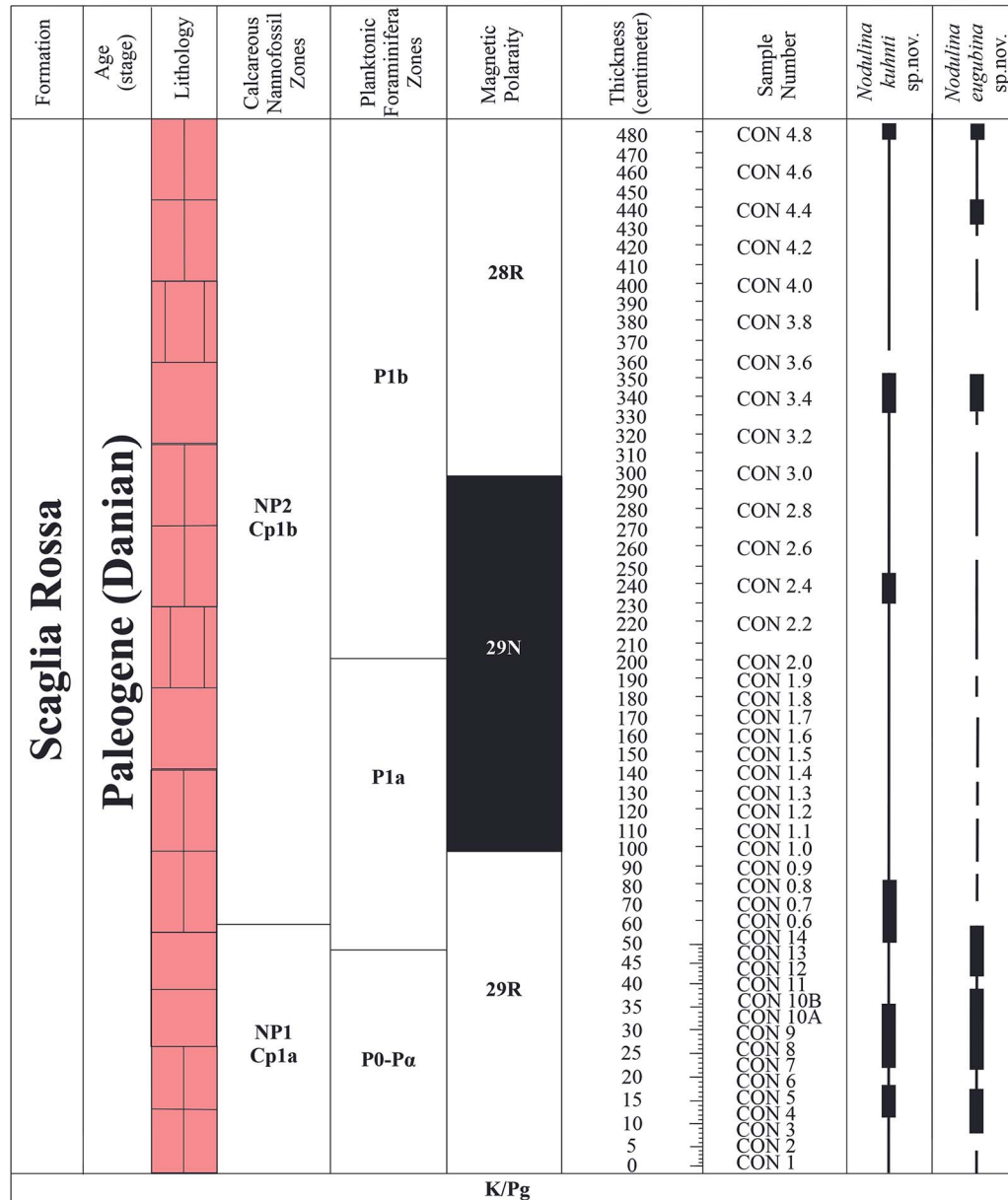


FIGURE 2. Lithostratigraphic column of the studied section showing the position of the samples with *Nodulina*. Calcareous nannofossil zones and magnetostratigraphy are from Monechi & Thierstein (1985), and planktonic foraminiferal zones are from Premoli Silva & Sliter (1995).

Micropaleontological Reference Centre in Kraków, Poland, in Cabinet 7, drawer 27c.

DISCUSSION

Kuhnt (1990) conducted the first taxonomic study of the DWAF from Tethyan Upper Cretaceous pelagic limestones sampled at Gubbio and in the Hacho de Montejaque section of southern Spain. Kuhnt illustrated five species of "*Reophax*," four of which were left in open nomenclature. Of these, Kuhnt's *Reophax* sp. 2 and *Reophax* sp. 4 are common in the lower Paleocene in the Scaglia Rossa at Contessa (see Kuhnt & Kaminski, 1996).

This study describes the new species *Nodulina kuhnti* n. sp. and *Nodulina eugubina* n. sp. as the formal species names

now assigned to *Reophax* sp. 2 and *Reophax* sp. 4 of Kuhnt (1990) (Fig. 4). Kuhnt (1990) described *Reophax* sp. 2 as possessing an elongated test with mainly four to five compressed chambers and increasing in size and *Reophax* sp. 4 as possessing elongated chambers, a flattened thin-walled test, and distinct sutures between the chambers. The species we recovered in the Lower Paleocene at Contessa mostly have three to four chambers, making Paleocene specimens somewhat smaller than the Cretaceous specimens.

Both species, originally placed in the genus *Reophax*, are now assigned to *Nodulina*, owing to their primarily straight tests and horizontal sutures. The difference between the two species lies in the shape of the final chambers and the wall structure. In *Nodulina kuhnti* n. sp., the chamber shape tends



FIGURE 3. *Nodulina kuhnti* n. sp. and *Nodulina eugubina* n. sp. from the Danian of Contessa Highway section, near Gubbio, Italy. 1–7 *Nodulina kuhnti* n. sp. 1 Sample CON-4.4. 2 Sample CON-3.8. 3 Sample CON-4.4. 4 Sample CON-3.9. 5 Holotype, Sample CON-3.8. 6 Sample CON-0.7. 7 Sample CON-4.8. 8–9 *Nodulina eugubina* n. sp. 8 Holotype, Sample CON-0.8. 9 Sample CON-1.0. All scale bars = 100 μ m.

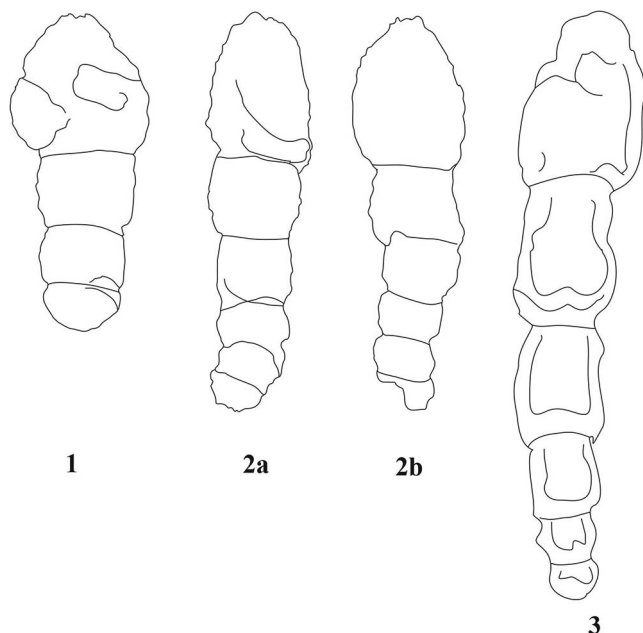


FIGURE 4. Specimens sketched from Kuhnt, 1990. **1, 2a–b** *Reophax* sp. 2; **1** Length = 289 μm , **2a** Length = 484 μm . **3** *Reophax* sp. 4, length = 667 μm .

to be more spherical, and chambers increase in dimensions more slowly than in *Nodulina eugubina* n. sp. *Nodulina eugubina* n. sp. also differs in its finely agglutinated wall and more pyriform chambers.

The type species of *Nodulina* (*Reophax dentaliniformis* Brady, 1881; Figs. 5.3A–B) differs in its larger dimensions, coarsely agglutinated wall, in the more rapid rate of chamber enlargement, and in possessing an aperture on a distinct neck. Also, the final chamber is more elongated. The modern species *Nodulina gracilis* Kiaer (1900) differs in having a more elongated test with more than five chambers, reaching ten or even twelve, a thin and flexible test wall, and younger chambers with pyriform shape.

The elongate test of *Pseudonodosinella nodulosa* (Brady; Figs. 5.1A–C) has ovate to subpyriform chambers that are arranged uniserially. Each chamber overlaps the apertural face and a significant part of the preceding chamber. In the megalosphaeric form, the proloculus may be more elongated than the subsequent chambers. The exterior and interior finish of the test wall is smooth; the wall itself is thin, but consists of many grains, and it is firmly agglutinated. The wall is constructed with an undifferentiated organic cement, featuring both inner and outer organic layers. The center of the thickened wall of the apertural face has the terminal aperture, which is on a neck. *Nodulina eugubina* n. sp. has smaller dimensions, a flattened elongated test, no sign of overlapping chambers (Figs. 5.4a–b).

Both species appear to be restricted to the western Tethys and possibly Atlantic–Caribbean area. The post K/Pg bloom in “*Reophax*” has been observed at ODP Site 959 (Kuhnt et al., 1998), and a very similar form reported as “*Reophax* sp. 2” has been reported in the Danian “fysch-type” assemblages of Trinidad (Kaminski et al., 1988). However, the new species have not been observed in the Danian of Site U1511 in the Tasman Sea (Kaminski et al., 2021).

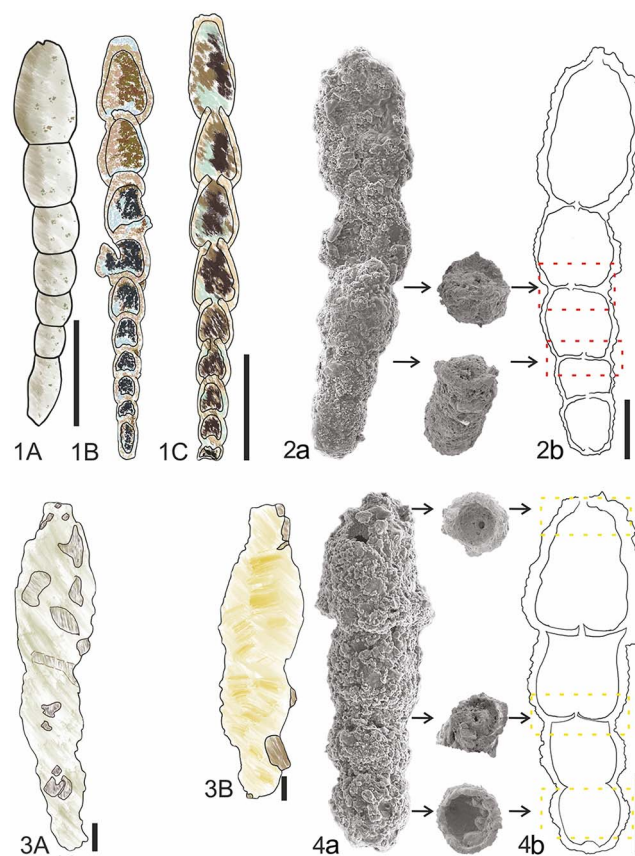


FIGURE 5. Specimens sketched from Kaminski & Cetea (2008). **1A–C** *Pseudonodosinella nodulosa* (Brady). **2a–b** SEM image and reconstruction of *Nodulina kuhnti* n. sp. **3A–B** Specimens sketched from Kaminski & Cetea (2008), *Nodulina dentaliniformis* (Brady). **4a–b** SEM image and reconstruction of *Nodulina eugubina* n. sp. Scale bars = 100 μm , except **1A–C** (1 mm).

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