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A new *Rhabdammina* species (Foraminifera: Textulariina) with an unusual distribution pattern from Cretaceous (Germany) and Recent (Greece: Aegina) localities

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Abstract: A new species of agglutinated encrusting Foraminifera, *Rhabdammina voigti* n. sp., is described based upon the test morphology, primarily the number of tubes and the proloculus size. *R. voigti* n. sp. generally occurs attached on molluscs, brachiopods and echinoderm tests. The area of distribution includes continental shelves of the temperate climate zone. Fossils of *R. voigti* n. sp. have been recovered from the Upper Turonian to Upper Campanian of the "Münsterländer Kreidemulde" and the Lower Maastrichtian to Upper Maastrichtian of the "Norddeutsche Senke", North Germany. Recent material has been collected from Aegina, Greece. All recently known species of the genus are typical deep sea forms. In contrast, the new species *R. voigti* n. sp. inhabited shallow marine waters in the North Sea Basin during the Upper Cretaceous, and in the Aegean Sea at present. Probably *R. voigti* n. sp. occupied the same habitats during the Cenozoic, but is unrecorded up to now or migrated into deep sea after the Cretaceous-Tertiary boundary for a long time.

Zusammenfassung: Eine neue Art von agglutinierenden Foraminiferen, *Rhabdammina voigti* n. sp. wird anhand der Gehäusemorphologie, vor allem der Anzahl der Röhren und der Größe des Proloculus, beschrieben. *R. voigti* n.sp. ist generell an Mollusken, Brachiopoden und Seeigelgehäusen angeheftet. Das Verbreitungsgebiet umfasst kontinentale Schelfe der gemäßigten Klimazonen. Fossile Vertreter von *R. voigti* n. sp. stammen aus dem Oberturonium bis Obercampanium der Münsterländer Kreidemulde und aus dem Maastrichtium der Norddeutschen Senke (Norddeutschland). Rezentes Material stammt von der Insel Aegina (Griechenland). Alle bekannten Arten dieser Gattung sind typische Tiefwasserformen. Im Gegensatz dazu besiedelt *R. voigti* n. sp. flachmarine Räume der oberkretazischen Nordseebecken und rezent die Aegäische See. Vielleicht besiedelte *R. voigti* n. sp. im Känozoikum ähnliche Habitate, ohne bisher beobachtet worden zu sein oder wanderte nach der Kreide-Tertiär-Grenze für lange Zeit in die Tiefsee.

Keywords: *Rhabdammina*, Textulariina, Foraminifera, Cretaceous, recent, North Germany, Greece

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Introduction

Actually, Foraminifera are the most commonly and diverse monophyletic marine Protista (Pawlowski et al. 1997) characterised through organic, agglutinated, or calcareous tests (Lee 1990). Following Nuglisch (1985), encrusting species appear within the Allogromiidae Rhumbler, Astrorhizidae Brady, Ammodiscidae Reuss, Lituolidae de Blainville, Ptychocladiidae Elias, Nubeculariidae Jones, Polymorphinidae d´Orbigny, Cibicididae Cushman, Acervulinidae Schultze, and Homotrematidae Cushman.

Thorough study of the morphology of the published evidence on encrusting foraminifera led us to the genus *Rhabdammina* within the Astrorhizidae. By contrast, most species of this genus have been recovered from deep marine water sediments. This association was termed the "*Rhabdammina*-Fauna" by Winkler (1984). In the present paper we show the first record of shallow marine water *Rhabdammina* species. The here presented recent findings sheds new light on the distribution and ecology of the still poorly known genus.

Geological and stratigraphical setting

Greece: Aegina: The site of Aegina, where we have recovered the only recent material, is one of the largest Saronic Islands, located 40 km southwest of the Greece capitol city of Athens. It is the only record outside of Germany, is located between Attika and Argolis in the Saronic Golf, and is a part of the Aegean Sea in the Mediterranean basin (Fig. 1). The average depositional depth oscillates between 200-300 m.

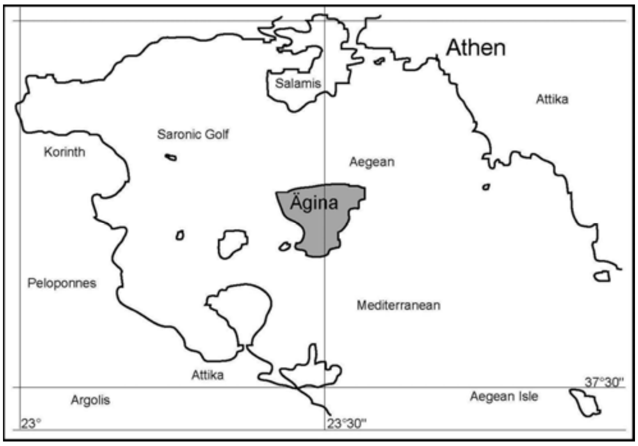

Fig. 1: Locality of the recent sample from Aegina (Greece)

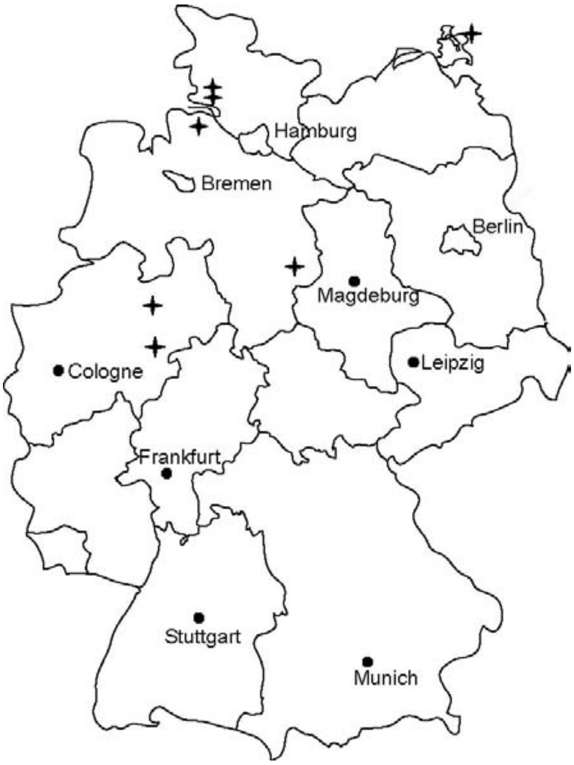

Fig. 2: Map of Germany showing location of fossil sites where the Cretaceous samples have been collected (cross symbols)

The sediments are rich in organic matter. In the central Aegean Sea, the temperature is ca. 18°C, and the salinity is 39.2 ‰ (Meier 2001). Aegina is, like Santorin, part of the still active Hellenic Arc. A minute description of the original site is not available. Our guess is that the recent specimens were collected near the coastline.

Germany: Specimens of the new rhabdamminid species were also collected at two Upper Cretaceous localities in the “Münsterländer Kreidemulde” (Beckum, Mülheim) and at five sites in the “Norddeutsche Senke” (Hemmoor, Kronsmoor, Rügen, Lägerdorf, Vallstedt), all located in northern Germany (Fig. 2). In the “Münsterländer Kreidemulde”, sandstones, marls, and limestones of Lower Cenomanian to Campanian age represent a transgressive phase coming from the northwest (cf. Tröger et al. 1996). During the Turonian, two greensand layers were deposited in the southern parts of “Münsterländer Kreidemulde” as offshore formations between primarily marly and later limy rocks and pure limestones (Seibertz 1979a, b). After reaching the peak level of transgression in the Lower Santonian, only limesandstones and fine sandstones were deposited in the Middle and Upper Santonian. The latest deposits, documenting a regression in the Campanian, are located in central parts of the basin near the mountain ranges of Baumbergen and Beckumer Berge (Kaplan et al. 2005, Wolf 1995).The other five sites are located in the North German Basin and in the central part of the Middle German Basin. The main morphologic characters are the “Niedersächsisches Tektogen” and the “Pompeckjsche Scholle” in the northwestern part. The “Niedersächsische Becken” was influenced by a Subherzynic and Laramic tectonic inversion in the Upper Cretaceous (Horna 1996), whereas it forms an independent area of sedimentation in the Upper Jurassic and Lower Cretaceous, with 2000-3000 m thick sediments. In this setting, we have the Santonian site of Vallstedt near the city of Braunschweig.

The habitats remaining are all located at the “Pompeckjsche Scholle”, which is characterised by many salt deposits with Rheinic orientation. The last site is the isle of Rügen. A detailed description of the habitat, probably the coastline, is missing. The recovered material is of Maastrichtian age (Hemmoor, Kronsmoor, Isle of Rügen), except Lägerdorf, which is of Campanian age (Tab. 1). A continuous sequence was deposited in the Rügen Basin up to the Lower Maastrichtian which crops out as white chalk at the clifflines of Rügen, Jasmund and Arkona. While still in the Upper Maastrichtian, after shallowing and restriction of the Upper Cretaceous Ocean, the whole North German former subsidence area was exposed (Ernst & Wood 1995).

Tab. 1: Left column with original sample number, second column with number of observed textulariid specimens per sample, other three columns with additional information about the listed material

Sample number	Number of Individuals	Stratigraphy	Attached on	Location
8305	8	recent	Algal mat with serpulids	Aegina (Greece)
11521	2	Upper Maastrichtian	Terebratulids	Hemmoor (Germany)
02	2	Maastrichtian	Terebratulids	Hemmoor (Germany)
11654	11	Lower Maastrichtian	Terebratulids with Bryozoa	Quarry Saturn / Kronsmoor (Germany)
11741	7	Lower Maastrichtian	Terebratulids	Quarry Saturn/Kronsmoor (Germany)
4220	1	Lower Maastrichtian	Echinoids	Isle of Rügen
4221	1	Lower Maastrichtian	Echinoids	Isle of Rügen
4222	1	Lower Maastrichtian	Echinoids	Isle of Rügen
4223	1	Lower Maastrichtian	Echinoids	Isle of Rügen
01	0	Upper Campanian	Echinoids	Beckum/Wephalia (Germany)
04	2	Upper Campanian	? Echinoids	Beckum/Wephalia (Germany)
4218	1	Upper Campanian	Echinoids	Beckum/Wephalia (Germany)
5885	1	Upper Campanian	Echinoids	Beckum/Wephalia (Germany)
5886	0	Upper Campanian	Echinoids	Beckum/Wephalia (Germany)
5889	0	Upper Campanian	Echinoids	Beckum/Wephalia (Germany)
5890	0	Upper Campanian	Echinoids	Beckum/Wephalia (Germany)
5891	1	Upper Campanian	Echinoids	Beckum/Wephalia (Germany)
11475	1	Upper Campanian	Echinoids	Beckum/Wephalia (Germany)
06	1	Campanian	Echinoids	Lägerdorf (Germany)
11473	1	Santonian	indeterminable	Vallstedt (Germany)
03	1	Upper Turonian	Indeterminable	Mülheim-Broich/Ruhr (Germany)
05	7	Upper Turonian	Oyster	Mülheim-Broich/Ruhr (Germany)
5883	6	Upper Turonian	Oyster	Mülheim-Broich/Ruhr (Germany)
11476	3	Upper Turonian	Indeterminable	Mülheim-Broich/Ruhr (Germany)
11520	1	Upper Turonian	Indeterminable	Mülheim-Broich/Ruhr (Germany)
11526	1	Upper Turonian	Indeterminable	Mülheim-Broich/Ruhr (Germany)

Material and methods

The systematic order of Loeblich & Tappan (1988) is used in this paper. The material consists of 26 samples, including 61 specimens collected by Prof. Dr. E. Voigt (1905-2004). Tab. 1 lists the locations where rhabdamminid specimens were discovered, the stratigraphic position, and the number of observed specimens. It includes the whole type series. Most of the tests are broken, altered by diagenetic processes, partly preserved only with basal test layer which, as a consequence, gives little detailed morphological information. Few specimens are completely preserved, and only the eight specimens collected from Aegina offer an unmodified wall texture used for classification.

Illustrations were prepared with the aid of a scanning electron microscope (Cambridge S 360) equipped with a Nikon F 301 camera. Exclusive samples were embedded in Reckli Injektionsharz for precision cuts.

The type material will be deposited at the Museum für Naturkunde in Berlin. Institutional abbreviations: MfN, Museum of Natural History.

Systematics

Order Foraminifera Eichwald, 1830
Suborder Textulariina Delage & Hérouard, 1896
Superfamily Astrorhizacea Brady, 1881
Family Rhabdamminidae Brady, 1884
Subfamily Rhabdammininae Brady, 1884
Genus *Rhabdammina* M.Sars, 1869

Type species: *Rhabdammina abyssorum* Sars, 1868

Included species: *R. abyssorum*, *R. discreta, R. major*, *R. neglecta, R. scabra*

Rhabdammina voigti n. sp.

Fig. 3 A-D, Fig. 4

Etymology: *Rhabdammina voigti* is named in honour of Prof. Dr. Ehrhard Voigt (1905-2004).

Holotype: Number will be given after acception MfN, original collectors number 8305 (Fig. 3A-B), deposited at the Museum of Natural History, Berlin, Germany.

Paratypes: Numbers will be given after acception MfN, original collectors numbers 11521, 02, 11654, 11741, 4220, 4221, 4222, 4223, 01, 04, 4218, 5885, 5886, 5889, 5890, 5891, 11475, 06, 11473, 03, 05, 5883, 11476, 11520, 11526, (Fig. 3C-D).

Type locality and horizon: Aegina in the Saronic Gulf, about 40 km west of the town of Athens; recent.

Referred material: Several localities from North-West Germany, Upper Cretaceous.

Diagnosis: Proloculus size in combination with the habitat are unique for this new species. The heterogene agglutinated test consists of calcite particles of two to five µm in size.

Description: The typical imperforate test consisting of fine agglutinated material causes a heterogenic test surface. Main components are calcite particles varying in size from 2-5 µm. A variable number of chambered tubes originate from the hemispheric proloculus. The test morphology is adapted to the subsurface and therefore variform. Test size varies from 200 µm to 1250 µm. The holotype proloculus is 78 µm in size. The lower side is flat, whereas the top side is convex globular. Three uniserial chambered tubes spring directly from the proloculus. One of these tubes shows dichotomous secession of two secondary tubes. All observed tubes are completely attached to the ground without any evidence of erection (Fig. 3A, C). Therefore the lower side is flat and the top side is convex. All tubes are regularly chambered, but chambers are not visible from the outside. Tube splitting takes place without swelling. Tube width varies between 70 µm and 80 µm. The foramen is simple rotund and located in the central region of the tube septum with 6.7 µm in diameter. The terminal aperture is also simple and located centrally at the open end of the tubes. Maximum individual size measured from the central proloculus along the longest tube is 476 µm.

Paratypes: The main agglutinated components are calcite particles. Agglutinated sand grains, other organisms, sulfide minerals or similar components have not been observed. The proloculus size of the paratypes varies from 44-110 µm.

The majority of cases possess three or more primary tubes originating from the proloculus. Secondary lateral processes can branch off from these primary tubes. This has been documented for twelve cases. Secondary tubes can branch off in a distinct angle or parallel to primary tubes. All observed tubes are completely attached to the ground, without any evidence of overlapping or erection of the tubes. Tube width varies from 41-100 µm, with the majority between 60-85 µm. Observed foramina and aperture correspond with the recent material in shape and position. All researched specimens have been assigned to one species, because of the consistent proloculus size, individual size, position of the aperture and agglutinated test material in fossil and recent specimens. The similar test morphology, their fixosessile lifestyle, and the observed distribution pattern support this view. Ornamentation, perforation, and potential organic matrix are absent.

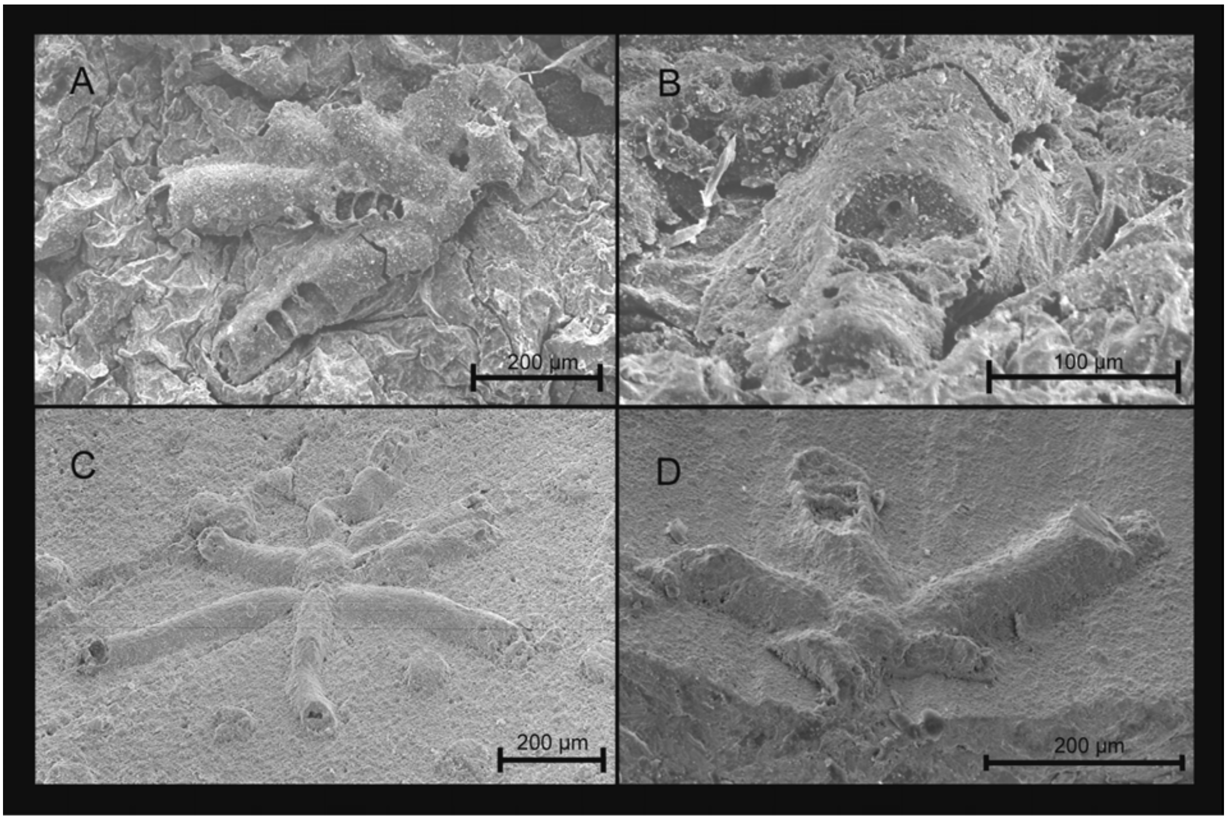

Fig. 3 A-D. *Rhabdammina voigti* n. sp. **A-B:** Holotype from the Aegaean Sea, Greece. Collection E.Voigt, original number 8305. **C-D:** Paratype from the Isle of Rügen, Germany, Lower Maastrichtian, original number 4223.

Discussion: Most of the members of the genus *Rhabdammina* that live in depths between 3000-6000 m are becoming clearly larger, up to 22.5 mm in size, and use silica grains for building their tests (Gooday 1986). *R. abyssorum,* unlike *R. voigti,* agglutinates particles of the size from 1-180 µm and of 25 µm average, mostly quartz, and reaches a maximum individual size of 20 mm (Mendelson 1982). *R. scabra* is characterised by a free test with a swirl test consisting of coarse grains of sand and sponge spicules or tests of other foraminifera. The tubes are straight or sinuously curved with an aperture at the end. Specimens only known from the Skagerrak grow up to 6 mm with a tube diameter of 0.3-0.5 mm, tubes unbranched. *R. neglecta* possesses three dimensional branching tubes not attached to the substrate and an oval proloculus. The tubes originate from the oval ending of the proloculus. Tube sections between dichotomous branches are sinuously curved. Thin tests are composed of agglutinated quartz grains and sponge spicules. Only fragments are known whereof the largest unbranched tube measures more than 10 mm (Gooday 1986). Finally, *R. major* differs from *R. voigti* by sinuous tube segments and slight ballooning before branching. Tests consist of agglutinated quartz grains. Tubes could branch up to four times with constant intervals, 3.2 to 5.2 mm on average, between each branching point. The proloculus is unknown. Individual size is 8-14 mm, maximum 22.5 mm (Gooday 1986).

Palaeoecologcal interpretatiton

A detailed depiction of ecology and palaeoecology of benthic and agglutinated Foraminifera is provided by Murray (1991), Brasier (1980), Haynes (1981), Buzas & Culver (1982) and Hemleben (1990). Eco-parameters like salinity, pressure, temperature, light, water depth, water energy, substrate and turbidity affect morphological parameters of the Foraminifera test, for example, shape and size (Racey 1992). Only the proloculus is independent from ecologic parameters. Bosellini & Papazzoni (2003) report that a positive correlation between the ratio of flat and globular forms in encrusting Foraminifera exists with rising water energy in coral reefs. Thus the plano-convex test indicates a low water energy milieu. Associations of epizoic Foraminifera and invertebrates are very common and known from polar to tropical regions in shallow and bathyal areas (Zumwalt & DeLaca 1980).

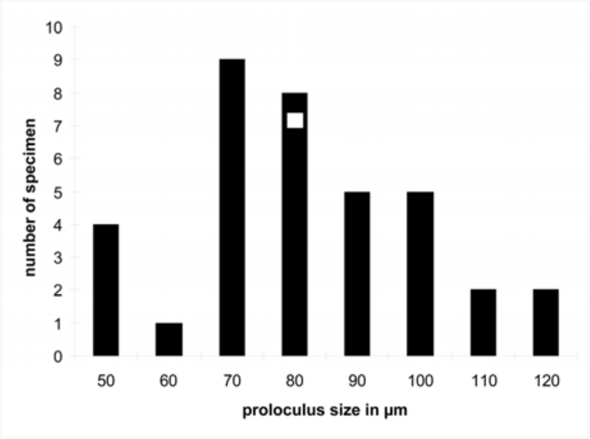

Fig. 4: Prolocolus size histogram of all measureable specimen, recent specimen diagrammed with a quadrangle symbol

The strong preference for filter feeding hosts indicates the advantage for epizoic Foraminifera due to increased food supply in this special microhabitat without producing a food water current on their own (Langer & Long 1994). Most of the researched Foraminifera lived attached to such filter feeding organisms as serpulids, oysters, terebratulids, or echinoids (cf. Tab. 1). Therefore, following Langer & Long (1994), a filter feeding life style is suggested for this newly presented species. For interpretation of palaeoecology of the locations Lägerdorf, Kronsmoor and Hemmoor, we used data given by Schönfeld (1990), and for the locations Beckum and Mülheim data given by Lommerzheim (1991). The appraisal of water depth took place on actualistic analogy of Foraminifera genera as the generic composition of recent fauna established in the middle Cretaceous (Lommerzheim 1991).

The faunal assemblage of the Cretaceous "Münsterländer Becken" is referred to the "foramol-association" (Lommerzheim 1991). This faunal association is characterised by dominance of benthic foraminifers, molluscs, bryozoans, echinoders, and ostracods, and indicates moderate temperature water. Foramol-associations are typically located in mid-latitudes and tolerate thermal fluctuations between 0°C and 25°C and salinity fluctuations between 31-38 ‰. Benthos-Foraminifera-Index and the occurrence of typical planctonic Foraminifera indicate a decrease of water temperature from warm-moderate in the Lower Campanian to cold-moderate in the Upper Campanian. Moderate water temperature that varies from 6° to 20°C, is the temperature range of main distribution for the new *Rhabdammina* species.

Recent distribution patterns of the "foramol-association" between 30 to 50 degrees northern latitude correlates with results of palaeomagnetic measurements. As a result, the "Münsterländer Becken" was probably located at a latitude of 40 degrees in the Upper Campanian (Lommerzheim 1991). As the occurrence of Echinodermata, Mollusca, Brachiopoda, Bryozoa and Polychaeta already indicates a shallow marine sedimentation space, the quantitative analysis after Stehli (1966) suggests a water depth oscillating between 60-120 m, for the Campanian. Echinodermata are dominant organisms in the Upper Campanian shallow water facies (cf. Ernst 1972). Today, ophiuroids and heart urchins find optimal living conditions below storm wave base (Lommerzheim 1991). The bathymetric range of the echinoderm belt is at 20-40 m for minor seas. Sea level changes in the Campanian range from 230 m to 180 m near Lägerdorf (Schönfeld 1990). The typical chalk facies also implies a moderate water temperature like in the "Münsterländer Becken".

Lommerzheim (1991) and Schönfeld (1990) provide the first clues for the distribution of the new species with ecologic implications, as we found similar ecological conditions in northern Germany, where most of our findings come from (Ziegler 1990). All sedimentation conditions described for the Upper Cretaceous of northwestern Germany, for example, water temperature and geographical location, are conspicuously like the recent conditions in the Saronic Golf (Aegina). Holotype material was found together with serpulids and algal mats which banishes the possibility of the new species as shallow water inhabitant. The material belongs to the sand fraction with calcite elements and high rate of organic matter. Therefore we adopt approximately 20 m as the possible bathymetric range for living space. For exact logging of distribution patterns, more recent records from different locations are needed. Despite observations on fossil and recent material defining the new species as shelf inhabitants, most *Rhabdammina* species are almost exclusively known from bathyal and abyssal sediments. Most deep water Foraminifera that show simple morphologies are combined under the term "*Rhabdammina*-fauna", for example, *Bathysiphon*, *Rhizammina*, *Saccamina* and *Rhabdammina* (Valchev 2003, Winkler 1984). Consequently the new *Rhabdammina* species lived and lives in a shallow water habitat, in contrast to all other known species of this genus. This is probably also true for all Cenozoic specimens which are, however, unrecorded up to now. Moreover, it is conceivable that after the Cretaceous/Tertiary-Boundary *R. voigti* n. sp. migrated into the deep sea for a long time.

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