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RHAETIAN FORAMINIFERS FROM THE WESTERN BLACK SEA SHELF: NEW EVIDENCE FOR HETEROZOAN CARBONATE FACTORIES IN THE PALAEOTETHYS

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Abstract. The North Dobrogean Orogen (NDO) is a NW-SE trending fold-and-thrust belt in the eastern foreland of the Alpine Carpathian Orogen, palaeogeographically representing the westernmost segment of the Palaeotethys-issued Cimmeride Orogenic System. Eastwards, the NDO structurally extends into the Romanian sector of the western Black Sea continental shelf. The Triassic development of North Dobrogea is well known for its Tethyan-type facies and richness in various groups of fossils, but little attention has been paid to microfacies and fossil content of the offshore Triassic. The drill hole 817 LV of the Lebăda Vest oilfield, offshore Romania, ends in the Rhaetian (Upper Triassic) limestone olistolith, from which a rich association of foraminifers and ostracods was recovered. The limestone also contains sponge spicules, mollusc fragments, echinoderm ossicles, bryozoans, and brachiopods. Foraminiferal assemblage from the residue consists of agglutinated species only. Tolypamminids, *Gaudryinopsis triadica* (Kristan-Tollmann), *G. triassica* (Trifonova), *G. kelleri* (Tappan), *Ammobaculites tzankovi* (Trifonova), *A. zlambachensis* Kristan-Tollmann, *Verneuilinoides racema* (Trifonova), and *Trochammina* spp. predominate. Non-agglutinated species, determined from thin sections include *Ophthalmidium* spp., and rare involutinids *Trocholina* ex gr. *intermedia/umbo* and "*Involutina turgida*" (*Involutina* ex gr. *liassica*). The rich ostracod assemblage is dominated by Bairdiidae. Species of the Paracyprididae and Sigilliidae families are rather common. The conodont *Norigondolella steinbergensis* (Mosher) was also found. The deposition is suggested to take place in a relatively deep setting (outer shelf) offshore heterozoan-dominated platform in relatively cool waters.

Introduction

Following a drastic decline in the diversity of calcareous taxa at the end of the Permian (Groves et al. 2007; Payne & Clapham 2012; Rego et al. 2012), foraminifers exhibited a delayed recovery during the Middle Triassic, and only reached pre-extinction levels of generic diversity during the Late Triassic, more than 20 million years later (Groves & Altiner 2005; Payne et al. 2011). Many Norian and Rhaetian foraminiferal species and genera display facies dependencies and may thus be used as indicators of relative position along the carbonate platform–basin transects (e.g., Hoheneg-

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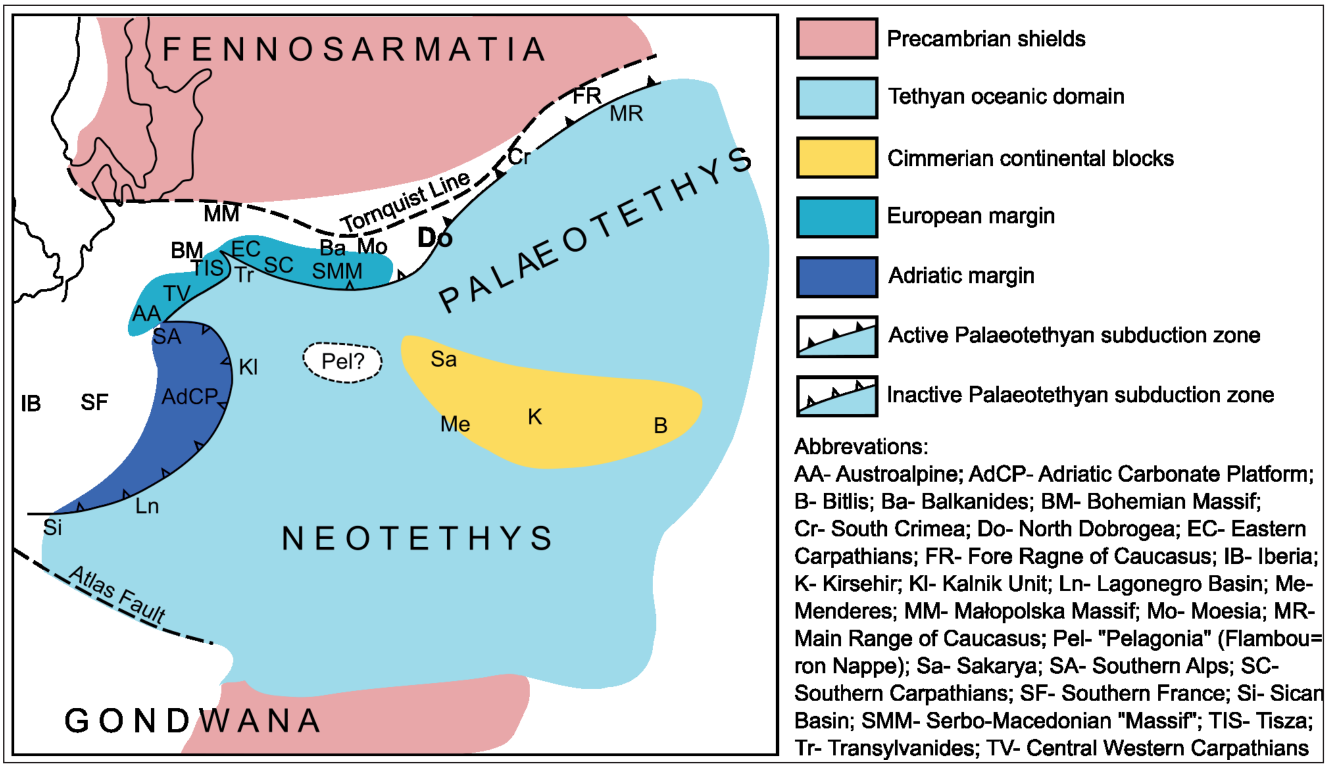

Fig. 1 - Palaeogeography of the western Tethys domain during the Late Triassic (Norian). Modified after Kovács et al. (2011).

ger & Lobitzer 1971; Hohenegger & Piller 1975; Senowbari-Daryan 1980; Chablais et al. 2011). Relations between foraminiferal species and relative palaeodepth, however, are only established for tropical and subtropical carbonate platforms of the Dachstein type, while the composition of foraminiferal assemblages in heterozoan carbonates outside the western Neotethys and Panthalassa Oceans remains poorly known and understudied (Gale et al. 2020). New cases of foraminiferal assemblages from heterozoan carbonates are thus important for setting up a model of the foraminiferal palaeodepth distribution along heterozoan-dominated platforms and ramps.

The North Dobrogean Orogen (NDO) represents the westernmost segment of the Palaeotethys-issued Cimmeride Orogenic System (Fig. 1). Triassic sedimentary series, unconformably overlying the Variscan basement, generally show transitions from the shallow-marine carbonate platform in the east to the deep-marine basinal facies in the west (Grădinaru 1995, 2000). According to Stampfli and Kozur (2006), and Kovács et al. (2011), sedimentation took place at the active margin of the Laurasian part of the Pangea during the Late Triassic situated between 35° (early Norian) and 50° (latest Rhaetian) of the northern palaeolatitude (Stampfli & Kozur 2006). Data on Upper Triassic foraminiferal assemblages from the North Dobrogea is scarce. Mirăuţă and Gheorghian (1975) determined foraminifers from the upper Carnian to upper Norian hemipelagic limestones in the Cilic Valley south of Rîndunica and in the Muchea Verde Hill. The assemblage largely consists of agglutinated taxa and Lagenida, and a single species of *Variostoma*. From the Carnian – Norian of Dobrogea, Salaj et al. (1988) described two contrasting foraminiferal assemblages. The first type mostly consists of Variostomatidae and *Spiroplectammina dobrudziana* Trifonova, while the second type of the assemblage is characterised by Nubeculariidae and Miliolidae. From the Norian part of the Cataloi Formation, Mirăuţă et al. (1993) described *Hyperammina stabilis* Blumenstengel, *Endothyranella* sp., *Ophthalmidium lucidum* Trifonova, *Ophthalmidium* sp., *Gheorghianina vujisici* (Urošević & Gaździcki), *Textularia jurassica* (Gümbel), *Variostoma helicta* (Tappan), *Paraophthalmidium* sp., and "*Vidalina*" sp. Lower Carnian beds from the same locality contained an assemblage composed of "*Vidalina*" sp., *Gheorghianina anae* (Gheorghian), *G. vujisici* (Urošević & Gaździcki), *Turriglomina meso-*

triassica (Koehn-Zaninetti), *Ammobaculites tzankovi* (Trifonova), "*Glomospira*" sp., and *Ophthalmidium lucidum* Trifonova. The topmost Triassic foraminiferal assemblage reported by Mirăuţă et al. (1993) comes from the Teliţa Formation, which was later dated by Grădinaru (1984) as Rhaetian in age due the occurrence of the bivalve *Otapiria marshalli alpina* Zapfe. The assemblage includes "*Vidalina*" sp., *Ophthalmidium fusiforme* (Trifonova), *Ophthalmidium* sp., and frequently Tolypamminidae.

Eastwards, the North Dobrogean Orogen extends structurally into the Romanian sector of the western Black Sea continental shelf, where Triassic rocks have been observed and sampled in a few boreholes (Grădinaru et al. 1989), including the 817 LV borehole, from which Gheorghian (in Grădinaru et al. 1989) described, but not depicted, a moderately diverse Late Triassic foraminiferal assemblage. The assemblage was originally described as consisting of *Jaculella* sp. cf. *expansa* (Plummer), *Glomospira charoides* (Jones & Parker), *Ammobaculites tzankovi* (Trifonova), *Gaudryinella kotlensis* Trifonova, *G. kelleri* Tappan, *Trochammina alpina* Kristan-Tollmann, *Reophax rudis* Kristan-Tollmann, *Tetrataxis* sp., *Cyclogyra* sp. cf. *pachygyra* (Gümbel), *Oberhauserella norica* Fuchs and several other specimens belonging to Oberhauserellidae, *Plagioraphe tornata* Kristan-Tollmann, and *Pseudobolivina tornata* Kristan-Tollmann. The conodonts *Norigondolella steinbergensis* (Mosher) and *Oncodella paucidentata* (Mostler) were also documented (Mirăuţă in Grădinaru et al. 1989).

In the present contribution, we reinvestigated the Upper Triassic limestone sampled from the drill hole 817 LV of the Lebăda Vest oilfield. The core is important from the standpoint of its microfacies, and especially for its outstanding content of Rhaetian microfossils. A rich assemblage of ostracods and foraminifers, and a few conodonts were collected from the residue after cold and hot acetolysis. Whereas the ostracod assemblage is here only briefly mentioned (see Forel & Grădinaru 2020 for full study), the focus of the present work is on foraminifers. New determinations of foraminifers revise previous determinations done by Gheorghian (in Grădinaru et al. 1989). We highlight the specific composition of the described foraminiferal assemblage as an example of foraminiferal assemblage from the non-tropical heterozoan-dominated carbonate platform.

Structural setting and stratigraphic data

The North Dobrogean Orogen (NDO) is a NW-SE trending fold-and-thrust belt located south of the Danube Delta in the eastern foreland of the Alpine Carpathian Orogen (Săndulescu 1984, 1995). The NDO (Fig. 2) palaeogeographically represents the westernmost segment of the Palaeotethys-issued Cimmeride Orogenic System (Săndulescu 1984, 1994), which extends further eastwards into the Mountainous Crimea, the Greater Caucasus, and into the Asian Cimmerides (Şengör 1984, 1986). The NDO is separated from the Scythian Platform to the north by the Sfântu Gheorghe Fault, and from the Moesian Platform to the south by the Peceneaga-Camena Fault.

Whereas in the Scythian and Moesian platforms the Triassic is of Germanic type (Paraschiv 1979; Pătruţ et al. 1983), the Triassic of the North Dobrogean Orogen is of Tethyan type (Peters 1867; Arthaber 1906; Kittl 1908; Simionescu 1925, 1927). The NDO is a pile of NE-verging imbricated thrust sheets encompassing the Variscan basement and its Cimmerian sedimentary cover. The thrust sheets are grouped into Măcin, Consul, Niculiţel, and Tulcea nappes (Visarion et al. 1990). The Măcin nappe comprises mostly Proterozoic and Palaeozoic formations, the Variscan basement (Seghedi 2001, 2012; Balintoni et al. 2010, Balintoni & Balica 2016), and a narrow strip of Triassic and Jurassic sedimentary and volcanic rocks along the northern side of the Peceneaga-Camena Fault (Grădinaru 1988, 2006). Instead, the Triassic and Jurassic sedimentary and volcanic rocks, representing the Cimmerian cover, dominate the exposed parts of the remaining three nappes (Grădinaru 1995, 2000). The Consul Unit has Early and Middle Triassic carbonate rocks intruded or interlayered by rhyolitic lavas (Seghedi et al. 1990). The Niculiţel Unit, which has a median position, is characterized by Early-Middle Triassic sub-oceanic deep-water cherty-carbonate sediments interlayered or intruded by ophiolitic rocks with intra-continental geochemistry (Savu 1986; Seghedi 2001; Saccani et al. 2004). The succession is then followed by Upper Triassic to (possibly) Lower Jurassic siliciclastic turbidites (Grădinaru 1995, 2000). In the Tulcea Unit, the Palaeozoic arc- and fore-arc sedimentary and magmatic rocks of the Variscan basement (Seghedi & Oaie 1995; Seghedi 2012) are

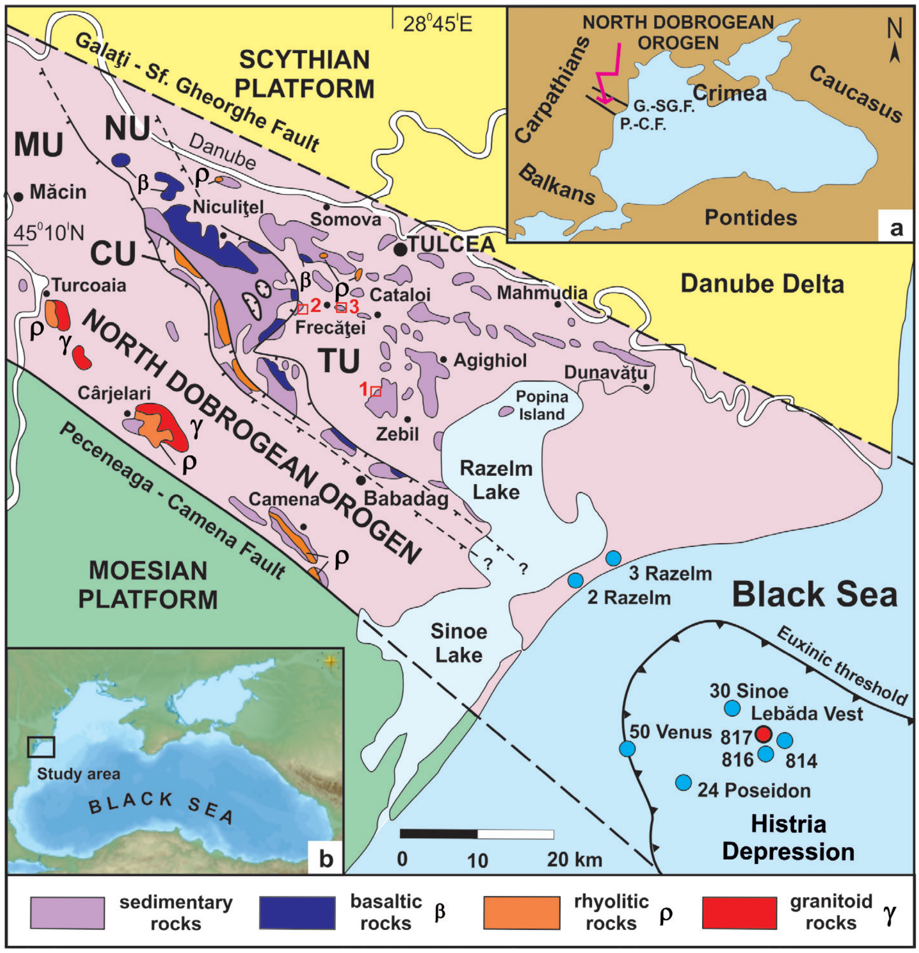

Fig. 2 - Tectonostratigraphic map of the North Dobrogean Orogen, showing the distribution of Triassic rocks and the location of the boreholes on the western Black Sea shelf that drilled into the Triassic. MU: Măcin Unit, CU: Consul Unit, NU: Niculiţel Unit, TU: Tulcea Unit (modified and completed after Grădinaru 2000). 1-3: onshore occurrences of the Upper Triassic at Rândunica, Muchea Verde and Frecăţei. Inset map (a) shows the location of the North Dobrogean Orogen. Inset map (b) shows the location of the study area on the Western Black Sea shelf. After Forel and Grădinaru (2020).

unconformably overlain by a thick succession of Triassic and Jurassic sedimentary series (Grădinaru 1984, 1995, 2000).

The Triassic sedimentary series has the largest and the most representative development in the Tulcea Unit, where it starts with the lower Spathian transgressive terrigenous deposits. Upwards, the upper Spathian to Rhaetian carbonate facies show transitions from the shallow-marine carbonate platform in the east to the deep-marine basinal carbonate facies in the west, the latter locally bearing Upper Triassic siliciclastic turbidites (Grădinaru 1995, 2000).

Eastwards, the North Dobrogean Orogen structurally extends into the Romanian sector of the western Black Sea continental shelf, where the Triassic rocks have been met and sampled in a few boreholes (Grădinaru et al. 1989; Cătuneanu & Maftei 1994; Ţambrea et al. 2002; Dinu et al. 2005). The lithofacies of the Triassic rocks drilled on the Romanian western shelf of the Black Sea, such as those sampled in the boreholes 2 Razelm, 3 Razelm, 50 Venus or 24 Poseidon, are comparable to facies known in the onshore North Dobrogean Triassic successions. In other cases, such as for boreholes 814, 816 and 817 Lebăda Vest, and 30 Sinoe, the lithofacies of the sampled Triassic rocks do not match any of the known onshore North Dobrogean Triassic successions (Grădinaru et al. 1989). Except for the boreholes 2 Razelm and 3 Razelm that were drilled on the shore of the Black Sea, all other boreholes are located in the area of the Histria Depression rimmed by the so-called Euxinic threshold, i.e. the outer margin of the Paleogene shelf (e.g. Dinu et al. 1989, 2005) (Fig. 2).

The Triassic limestone in the studied 817 LV (Lebăda Vest) borehole was reached at a depth of 2620 m after drilling through a thick series of Middle Jurassic argillites (Fig. 3). The drilling continued for 5 m more into the limestone and was then stopped. The limestone (a 2-m thick drill core from depths 2623 m to 2625 m, labelled CM31) is light grey-cream in colour, compact and hard, with splintery cracking and thin veins of calcite or black clay. The limestone is macroscopically homogenous throughout the core's length and does not display

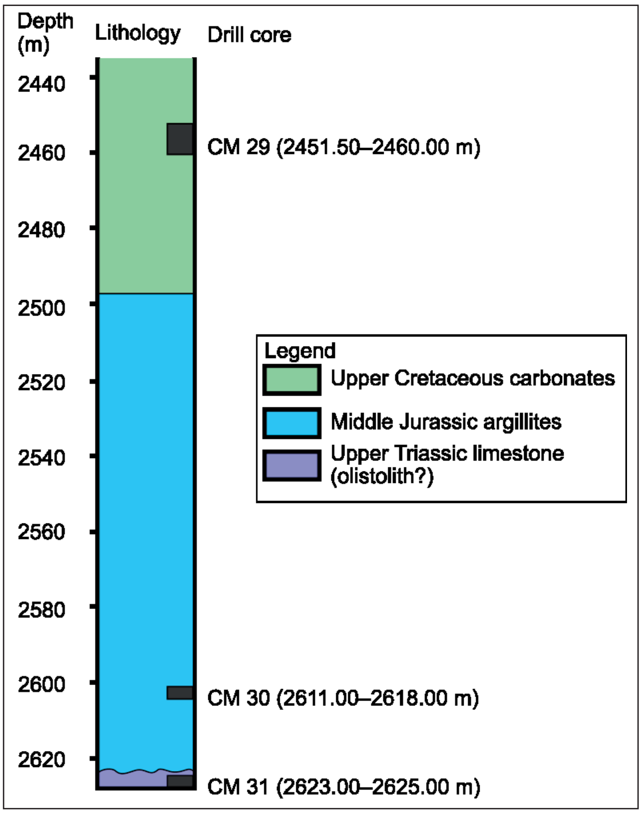

Fig. 3 - Stratigraphic log of the borehole 817 Lebăda Vest, Romanian Western Black Sea continental shelf.

any sedimentary structure, implying that it was drilled more or less along bedding. Numerous limestone clasts, some cm to dm in size, together with clasts of a volcanic origin, packed in slickensided Middle Jurassic black argillites, were encountered in the last two meters of the core sample CM30 (2611 to 2618 m). This implies that the drill core CM31 (2623 to 2625 m) also comes from an olistolith. The rich and diverse ostracod assemblage extracted from the drill core CM31 limestone by Forel and Grădinaru (2020) constrains the Rhaetian age. This is also supported by the brachiopod fauna, which includes *Euxinella anatolica* (Bittner), *Fissirhynchia fissicostata* (Suess), and *Rhaetina pyriformis* (Suess), and is thus similar to that of the allochthonous Rhaetian limestone in the Mountainous Crimea as recorded by Dagys (1974).

Methods and material

Fifteen thin sections of 28 × 47 mm- size were made from different parts of the drill core CM31 for the investigation of microfacies and foraminifers. Thin sections were photographed under a polarising optical microscope. Descriptions of microfacies follow classification by Dunham (1962) modified by Embry and Klovan (1971). The proportion of clasts in wackestone was estimated semi-quantitatively using comparison charts by Baccelle and Bosellini (1965). For the quantitative analysis of packstone we used random point-counting of 300 points per image in JMicroVision v1.2.7 (© 2002–2008 Nicolas Roduit).

For the preparation of microfossils, 0.6 kg of limestone was dissolved in buffered 5% acetic acid in the Laboratory of Palaeontology, University of Bucharest. At the Sorbonne University, the rock was also dissolved using hot acetolysis. The latter method proved suitable for the preparation of ostracods, but was too aggressive for foraminifers. Foraminifers, ostracods and conodonts were hand-picked from the residue and preliminarily determined using a stereoscope with under ×5 magnification. Selected foraminifers and conodont specimens were photographed with the JEOL JSM 6490LV Scanning Electron Microscope at the Geological Survey of Slovenia. Ostracods were photographed with the Hitachi TM3000 Scanning Electron Microscope at the Sorbonne University (Paris, France).

Results

Microfacies description

On the microscopic level, the samples show irregular transitions between sparse and dense bioclastic wackestone, packstone, and floatstone. The composition of the bioclasts is basically the same in each of these varieties, but the proportions of the main components differ locally. Sponge spicules and recrystallized mollusc fragments are usually the main bioclasts. Less abundant, but regularly present, are echinoderm ossicles, bryozoans, benthic foraminifers, ostracods and brachiopod shells. The latter are fragmented or complete, and locally even among the most common bioclasts. The matrix is micrite, with up to 10% of silt to sand-sized terrigenous grains (mostly quartz). Irregular dissolution voids are filled with an elongated rim calcite cement and clear blocky calcite. Some varieties of the limestone are described in Table 1. Sparse and dense bioclastic wackestone are shown in Figure 4.

Foraminiferal assemblage

Even though a highly diluted acid was used for the dissolution of limestone matrix, it seems that acetolysis was still too aggressive for non-agglutinated foraminifers, and only agglutinated tests survived the procedure. These are mostly composed of quartz grains. In thin sections also species with porcelaneous and hyaline walls were observed. Their diversity and abundance, however, seem rather low compared to the agglutinates. The exception is *Ophthalmidium*, which is relatively common in thin sections.

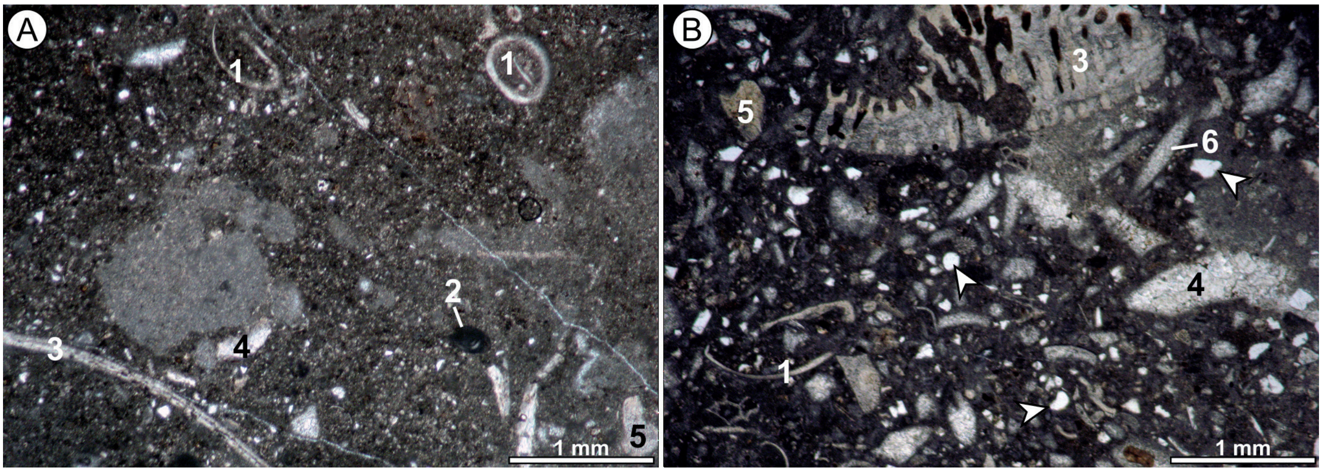

Fig. 4 - Microfacies of the Rhaetian limestone olistolith, sample CM31 of borehole 817 LV offshore Romania. a: Sparse bioclastic wackestone. b: Bioclastic packstone. Numbers indicate: ostracods (1), foraminifers (2), brachiopods (3), mollusc fragments (4), echinoderm plates (5), and sponge spicules (6). Arrowheads point to sand grains.

Foraminiferal assemblage, as determined from the residue after cold acetolysis (Figs. 5–6), is dominated by *Verneuilinoides racema* (Trifonova) (40%), Tolypamminidae (18.5%), *Ammobaculites zlambachensis* Kristan-Tollmann (14%), and *Ammobaculites tzankovi* (Trifonova) (8%). Several other species are present (see Table 2), but represent a smaller part of the assemblage. From thin sections, *Ophthalmidium* cf. *triadicum* (Kristan-Tollmann), *Ophthalmidium* spp., *Trocholina* ex gr. *intermedia/umbo* Frentzen, and "*Involutina turgida* Kristan" (i.e. *Involutina* ex gr. *liassica* (Jones) sensu Blau, 1987) were additionally determined (Fig. 7). Whereas *Ophthalmidium* spp. is represented by many specimens, *Trocholina* and *Involutina* are rare.

Compared to the previous determinations by Gheorghian (in Grădinaru et al 1989), we did not confirm the presence of *Jaculella*, *Gaudryinella kotlensis* Trifonova, *Reophax rudis* Kristan-Tollmann (the *Rheophax* observed by us has more numerous, more globular, and gradually increasing chambers than *R. rudis*), *Cyclogyra* sp. cf. *pachygyra* (Gümbel) (could be in fact *Ammodiscus* or *Glomospirella*, since *Cyclogyra* has porcelaneous wall), Oberhauserellidae, *Plagioraphe* and *Pseudobolivina*. Unfortunately, Gheorghian did not show any photographs or drawing of her specimens, so we cannot properly compare her results with this study or evaluate her determinations.

Conodont assemblage

The conodont fauna is characterized by the presence of a single species *Norigondolella steinbergensis* (Mosher) in different ontogenetic stages (Fig. 8). The preservation of juvenile conodonts is good, whereas adult specimens and very few ramiform

Microfacies variety	Description
Mudstone	Mudstone contains rare ostracods.
Sponge spicule wackestone	Sponge spicules represent approximately 10% of the area. Most of the rock is composed of slightly silty and fine-sandy micritic matrix.
Sparse sponge spicule-mollusc wackestone	Sponge spicules and recrystallized fragments of molluscs each represent 10% of the area. Subordinate are echinoderm plates, benthic foraminifers, fragments of brachiopods, and ostracods. Micritic matrix is in places silty.
Sparse bioclastic wackestone	Bioclasts barely represent 10% of the area. Mollusc fragments are the most common (5%). Fragments of brachiopods, encrusting bryozoans, foraminifers and echinoderm plates are the other types of bioclasts present. The matrix is in places silty and contains some small peloids.
Dense bioclastic wackestone to packstone	Grains represent 40% of the area: 30% belongs to bioclasts, and 10% to the siliciclastic component. Bioclasts are poorly sorted, ranging in size from 0.08 mm to 2.18 mm (the main size is 0.25 mm). Mollusc fragments account for 16% of the area. Less abundant are echinoderm plates (5%), bryozoans (5%), ostracods (2%), brachiopods (1%), and foraminifers. Sponge spicules and brachiopods are locally more abundant. Sand grains (mostly quartz) represent 10% of the area.
Bioclastic floatstone	Several mm large brachiopod and bivalve shells represent approximately 30% of the area. Shells are bored by endoliths. Additional components are sponge spicules, microgastropods, echinoderm plates, bryozoans, smaller mollusc fragments, and ostracods.

Tab. 1 - Description of the most common microfacies varieties from the Rhaetian olistolith offshore Romania (sample CM31, borehole 817 LV).

Fig. 5 - Foraminifers from the Rhaetian limestone from the 817 LV borehole, sample CM31. a: *Tolypammina*? sp. A. b: *Tolypammina*? sp. B. c: ?*Neotolypammina discoidea* (Trifonova). d: *Neotolypammina* sp. A. (cf. *Tolypammina continuus* Gutschnik). e: *Neotolypammina* sp. B. f: *Ammodiscus* sp. A. g: *Glomospira charoides* (Jones & Parker). h: *Duotaxis* cf. *birmanica* Zaninetti & Brönnimann. i: *Duotaxis* sp. j: "*Tetrataxis*" cf. *inflata* Kristan. k: *Gaudryinopsis triadica* (Kristan-Tollmann). l: *Gaudryinopsis triassica* (Trifonova). m: *Gaudryinopsis kelleri* (Tappan). n–p: *Gaudryinopsis* spp. q: *Reophax* sp. Scale is 400 µm, and for specimens marked with an asterisk 800 µm.

elements are fragmented. The colour of the obtained conodont elements is white, corresponding to the Colour Alteration Index 1 (Epstein et al. 1977).

Ostracod assemblage

The ostracods, described in more detail by Forel and Grădinaru (2020), are relatively well preserved, abundant, and diverse. Seventy-two species were recovered, including seven newly described species and the oldest representative of *Pokornyopsis* Kozur, considered a forerunner of the recent anchialine and submarine cave taxa (Fig. 9) (see Tóth & Cséfán 2018; and discussion in Forel & Grădinaru 2020). The assemblage is characterized by the overwhelming dominance of Bairdiidae and the relative importance of Paracyprididae and Sigilliidae. Accessory components are Polycopidae, Cylindroleberididae, Cytherellidae, Pontocyprididae, Thaumathocyprididae, Bythocytheridae, Macrocyprididae and Rectonariidae. For several of the species, juveniles and adults are present, allowing for the characterization of their ontogenetic development (e.g. *Bairdiacypris multidentata* Bolz, *Carinobairdia alpina* Kollmann).

Discussion

Depositional setting

According to the interpretation of the ostracod assemblage, deposition of the investigated sample took place in relatively well-oxygenated

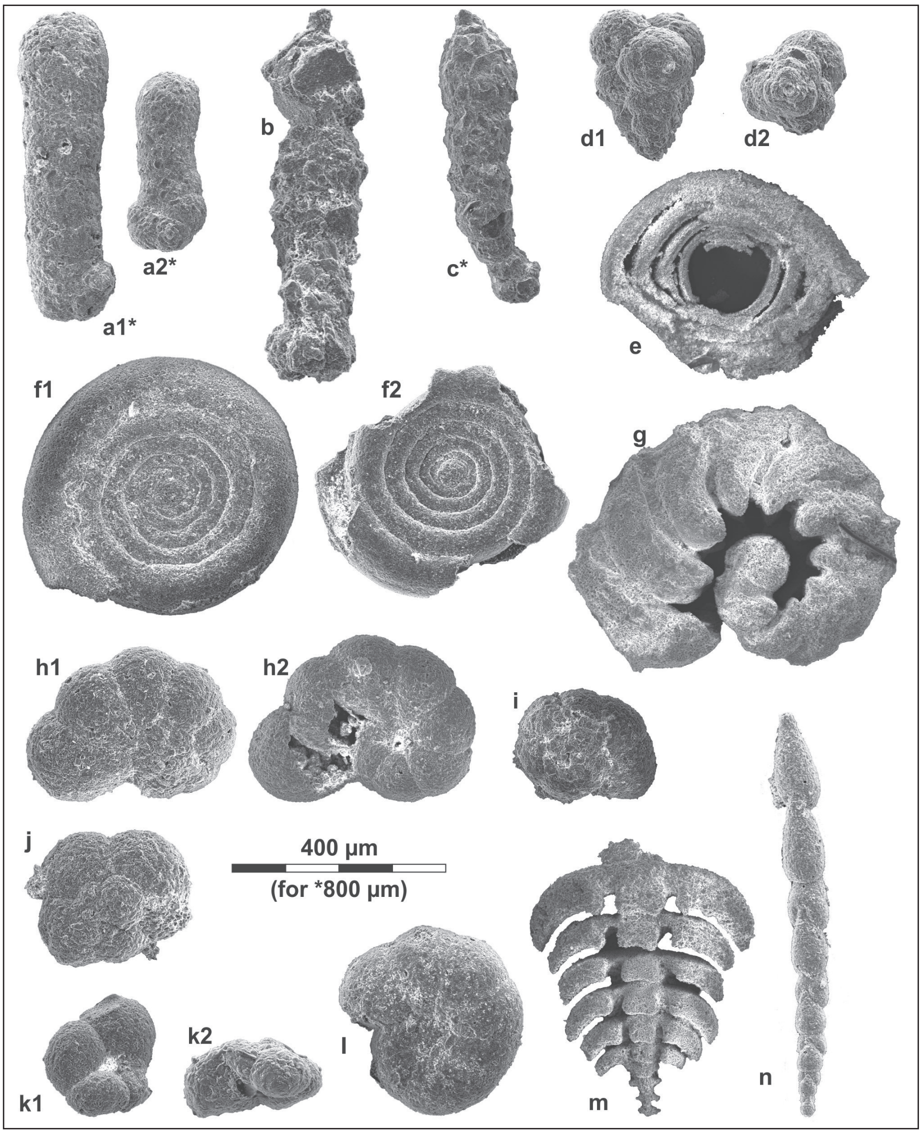

Fig. 6 - Foraminifers from the Rhaetian limestone from the 817 LV borehole, sample CM31. a: *Ammobaculites zlambachensis* Kristan-Tollmann. b: *Ammobaculites tzankovi* (Trifonova). c: *Ammobaculites* sp. (?*A.* cf. *wallalensis* Crespin). d: *Verneuilinoides racema* (Trifonova). e: Ophthalmidiidae. f: *Ammodiscus* sp. B. g: Duostominidae? h: Undetermined species A (?*Endothyra* sp.; low trochospiral, the wall is agglutinated). i: Undetermined species B (low trochospiral with agglutinated wall). j: *Trochammina* sp.; apical view. k: *Trochammina* sp.; umbilical and lateral view, respectively. l: Undetermined species C (the wall is agglutinated). m: ?*Lingulina plackensis* Kristan-Tollmann. n: *Dentalina* sp. or *Laevidentalina* sp. Scale is 400 µm, and for specimens marked with an asterisk 800 µm.

conditions of an outer shelf environment (Forel & Grădinaru 2020). The composition of sample CM31 stands out in the dominance of heterozoan components. Heterotrophic-dominated carbonates are largely considered characteristic of temperate to cool-water areas lacking significant terrigenous sediment input (Schlager 2003). The heterotrophic-dominated associations, however, may also result from increased nutrient levels, high water energy, oscillating oceanographic conditions, type of substrate, and other environmental factors that supress the growth of auto- and mixotrophic organisms (Hallock 2001; Westphal et al. 2010; Michel et al. 2011). According to Stampfli and Kozur (2006), the Triassic rocks of the Dobrogea deposited at around 35° northern latitude in the early Norian, and at almost 50° northern latitude in the latest Rhaetian. The relatively high-latitude (out-of-tropical belt) position, and not some other factors, probably explains the heterozoan character of the investigated limestone. The idea of relatively cooler water conditions is also supported by the presence of facies-controlled conodont *Norigondolella steinbergensis* (Mosher) (Kozur & Mock 1991; Krystyn et al. 2007a, 2007b; Muttoni et al. 2010; Trotter et al. 2015; Rigo et al. 2018).

Peculiarities of the fossil assemblage

Foraminiferal assemblages from heterozoan carbonate factories are poorly known compared to those from the tropical and subtropical carbonate factories of the Neotethys and Panthalassa Oceans. The described assemblage thus adds an important dimension to our knowledge of assemblages from such settings, which we do not yet fully understand. The general composition of the assemblage from sample CM31 is very similar to some of the assem-

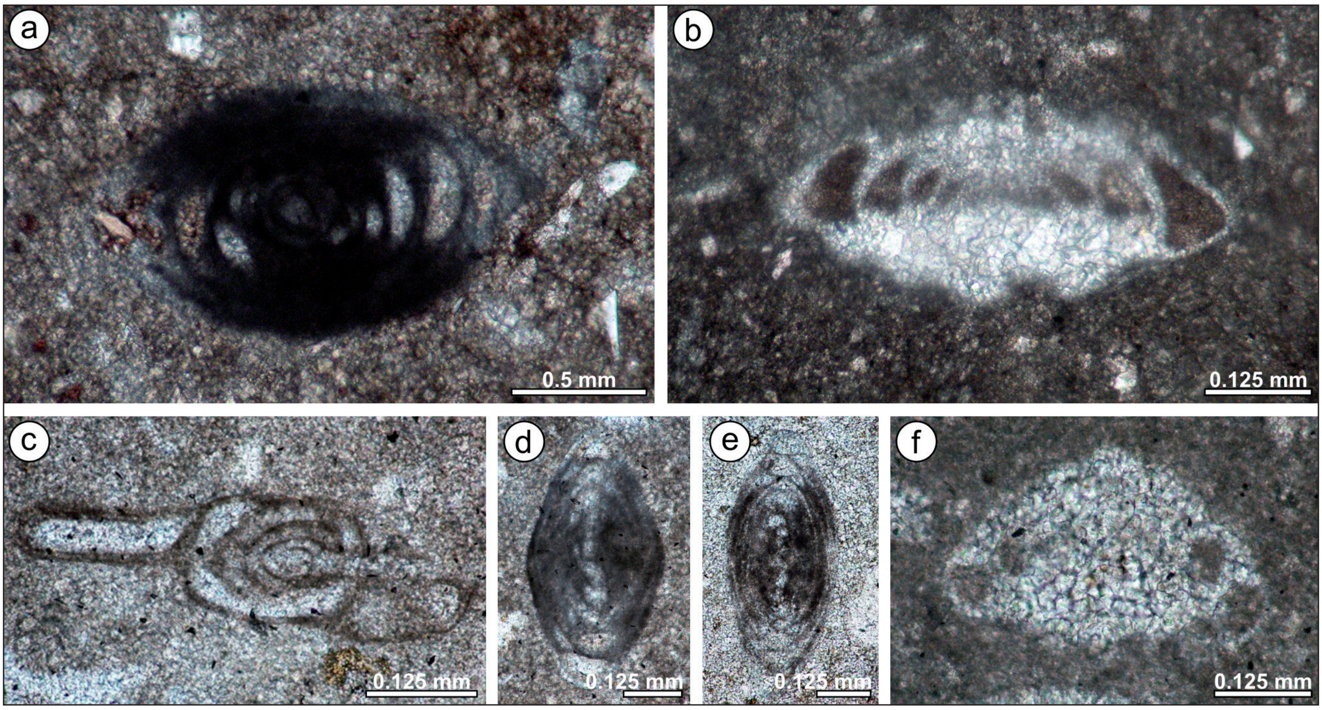

Fig. 7 - Foraminifers from the Rhaetian limestone from the 817 LV borehole, sample CM31. Specimens determined in thin sections. a: *Ophthalmidium* cf. *triadicum* (Kristan-Tollmann). b: "*Involutina turgida* Kristan" (i.e. *Involutina* ex gr. *liassica* (Jones) sensu Blau, 1987), subaxial section. c: Tolypamminidae. d–e: *Ophthalmidium* sp. f: *Trocholina* ex gr. *intermedia/umbo* Frentzen.

blages previously reported from the region, even though they are reportedly not of the same age (Table 2). We attribute this to the fact that the majority of the species from the assemblage have long stratigraphic ranges, except for "*Involutina turgida* Kristan". The similarity with the assemblages mentioned below thus lies in some feature of the palaeoenvironment and does not imply the same age.

Marly limestone of the Teliţa Formation from North Dobrogea is dated by Grădinaru (1984) as Rhaetian in age by the occurrence of the bivalve *Otapiria marshalli alpina* Zapfe. The foraminiferal assemblage includes "*Vidalina*" sp., *Ophthalmidium fusiforme* (Trifonova), *Ophthalmidium* sp., and frequently Tolypamminidae (Mirăuţă et al. 1993). Unfortunately, no detailed description of the microfacies was provided by Mirăuţă et al. (1993), but the Teliţa Formation probably deposited in deeper water (Grădinaru, pers. data).

The upper Carnian – lower Norian Hallstatt-type limestones from the Cilic Valley and the Muchea Verde Hill in the North Dobrogea contain ostracods, echinoderms, brachiopods, bivalves, ammonites, "calcispheres" (radiolarians or recrystallized pellets), and foraminifers. Agglutinated taxa and lagenids predominate. The former comprise genera *Hyperammina*, *Ammodiscus*, *Glomospira*, *Glomospirella*, *Tolypammina* (incl. *Neotolypammina*), *Haplophragmoides*, *Gaudryina* (i.e., *Gaudryinopsis*) *Gaudryinella*, *Ammobaculites*, and *Verneuilinoides* (Mirăuţă & Gheorghian 1975). A similar assemblage has also been reported by Trifonova (1962, 1967) from the lower Carnian limestone from the surroundings of Kotel in Bulgaria (see also Trifonova 1984). The Norian beds bearing the bivalve *Monotis salinaria* Bronn additionally contain "*Involutina*" *rara* Trifonova [the generic attribution is herein considered to be wrong; it is probably a tolypamminid], "*Trochammina*" *helicta* Tappan, "*T.*"? *angulata* Trifonova, *Spirophthalmidium lucidum* Trifonova, *S. fusiformis* Trifonova, and *Discorbis*? *pristina* Tappan (Trifonova 1962). However, we do not have information on the microfacies composition of these limestones.

The similarity of the assemblages does not extend to assemblages documented from the Crimea and the Pre-Caucasus, even though heterotrophic carbonates were documented also from these localities. Norian – Rhaetian limestone olistoliths from the Crimea, embedded within Jurassic clastic Eskiorda (also Eskiordin) Formation were described as wackestones and packstones with echinoderms, brachiopods, foraminifers and bryozoans, and intraclastic-bioclastic grainstones with sponges and gastropods in addition to the previously mentioned

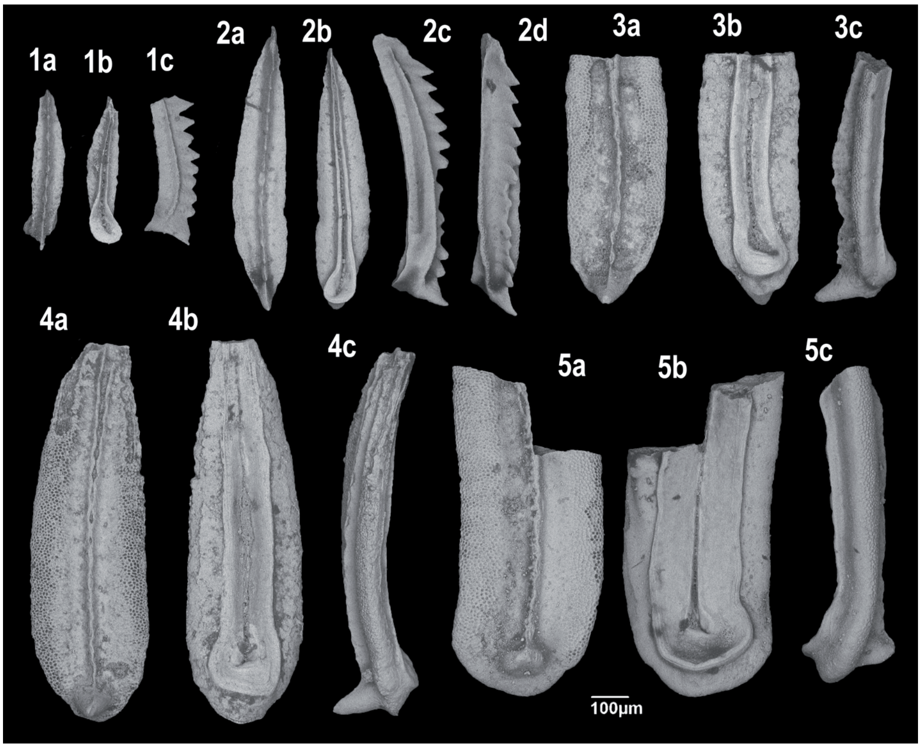

Fig. 8 - *Norigondolella steinbergensis* (Mosher). Sample CM31. 1: juvenile; 2: intermediate; 3–5: adult; a: upper view, b: lower view, c: lateral view.

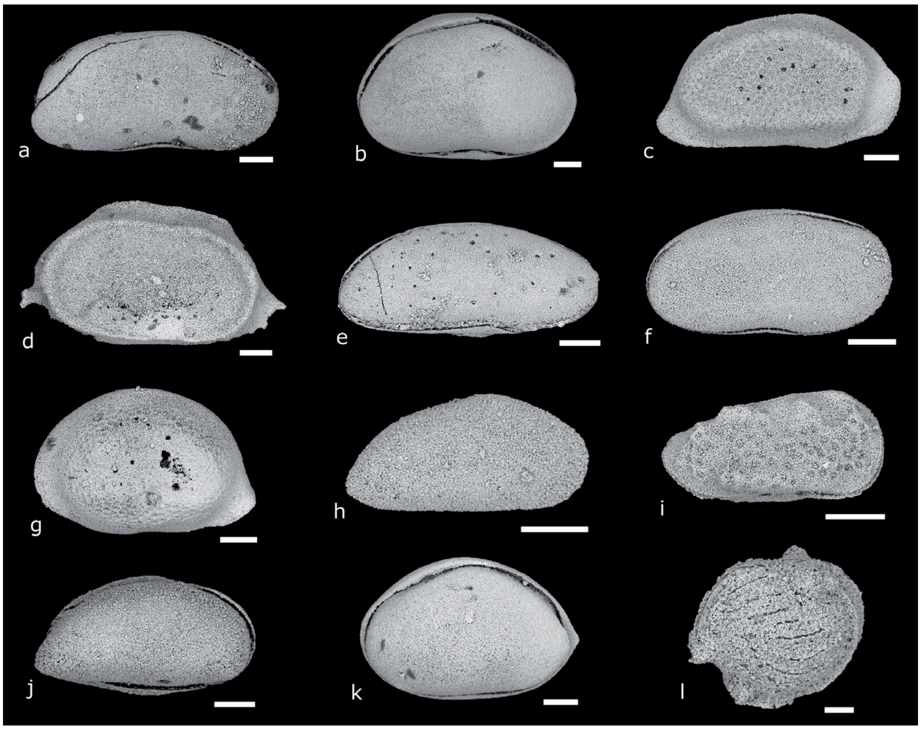

Fig. 9 - Ostracods from the Rhaetian limestone from the 817 LV borehole, sample CM31. a: *Bairdiacypris multidentata* Bolz, right lateral view of a carapace. b: *Bairdiacypris argonautaii* Forel *in* Forel & Grădinaru 2020, right lateral view of a carapace. c: *Carinobairdia triassica triassica* Kollmann, external view of a right valve. d: *Carinobairdia alpina* Kollmann, emend. Kristan-Tollmann, external view of a right valve. e: *Fabalicypris* cf. *triassica* Bolz, right lateral view of a carapace. f: *Isobythocypris atalantella* Forel *in* Forel & Grădinaru 2020, right lateral view of a carapace. g: *Lobobairdia salinara* Kollmann, external view of a left valve. h: *Paracypris ovidi* Forel *in* Forel & Grădinaru 2020, right lateral view of a carapace. i: *Judahella andrusovi* Kozur & Bolz *in* Bunza & Kozur, right lateral view of a carapace. j: *Cardobairdia* sp. 1, right lateral view of a carapace. k: *Hungarella koessenensis* (Mette & Mohtat-Aghai), right lateral view of a carapace. l: *Pokornyopsis* sp. 1, left lateral view of a carapace. All scale bars are 100 µm.

Locality	**817 Lebăda Vest borehole (this work); Rhaetian**	**Teliţa Formation, North Dobrogea (Mirăuţă et al. 1993); Rhaetian**	**Cilic Valley & Muchea Verde Hill, North Dobrogea (Mirăuţă & Gheorghian 1975); upper Carnian – lower Norian**	**Kotel, Bulgaria Trifonova (1962, 1967); lower Carnian**
Agglutinated	*Neotolypammina discoidea* (Trifonova)	Tolypamminidae	*Hyperammina* spp.	*Ammobaculites tzankovi* Trifonova
	Tolypammina and/or *Neotolypammina* spp.	"*Vidalina*" sp.	*Ammodiscus* sp. cf. *tenuissimus* (Gümbel)	*Glomospira articulosa* Plummer
	Ammodiscus sp. A	*Ophthalmidium fusiforme* (Trifonova)	*Ammodiscus* sp. cf. *planus* (Moeller)	*Glomospira gordialis* Jones & Parker
	Ammodiscus sp. B			
	Glomospira charoides (Jones & Parker)	*Ophthalmidium* sp.	*Glomospira gordialis* (Jones & Parker)	*Glomospirella* sp.
	Duotaxis cf. *birmanica* Zaninetti & Brönnimann		*Glomospirella* cf. *spirillinoides* (Grozdilova & Glebovskaia)	*Neotolypammina* and/or *Tolypammina* spp.
	Duotaxis sp.		*Neotolypammina discoidea* (Trifonova)	*Ammovertella bulbosa* Gutschick & Treckman
	"*Tetrataxis*" cf. *inflata* Kristan		*Tolypammina indistincta* Trifonova	*Ammobaculites* cf. *inconspicua* Cushman & Waters
	Gaudryinopsis triadica (Kristan-Tollmann)		*Tolypammina* aff. *labyrinthica* Trifonova	*Ammobaculites delicatus* Trifonova
	Gaudryinopsis triassica (Trifonova)		*Ammosphaeroidina* sp.	*Verneuilinoides mauritii* (Terquem) (i.e., *V. triserialis* Ziegler; see Trifonova 1992)
	Gaudryinopsis kelleri (Tappan)		*Haplophragmoides* spp.	*Gaudryinopsis racema* (Trifonova)
	Gaudryinopsis sp.		*Gaudryinella kotlaensis* Trifonova	*Gaudryinopsis adoxa* (Tappan)
	Reophax sp.		*Gaudryinopsis adoxa* (Tappan)	*Gaudryinopsis triassica* (Trifonova)
	Ammobaculites zlambachensis Kristan-Tollmann		*Gaudryinopsis triassica* (Trifonova)	*Gaudryinella clavuliniformis* Trifonova
	Ammobaculites tzankovi (Trifonova)		*Ammobaculites* cf. *radstadtensis* Kristan-Tollmann	*Gaudryinella kotlensis* Trifonova
	Ammobaculites sp.		*Verneuilinoides mauritii* (Terquem)	"*Trochammina*" *balcanica* Trifonova
	Verneuilinoides racema (Trifonova)		?*Endotriadella* sp.	"*Trochammina*" aff. *contornata* Tappan
	Trochammina spp.		*Endothyranella* sp.	*Cornuspira liasina* Terquem
	Undetermined species A (Fig. 6h)		*Vinelloidea* cf. *parasitica* (Dain)	nodosariid lagenids
	Undetermined species B (Fig. 6i)		*Variostoma* cf. *spinosa* Kristan	*Placopsilina florae* Trifonova
	Undetermined species C (Fig. 6l)		?*Geinitzina* sp.	*P. lacera* Trifonova
porcelaneous	*Ophthalmidium* cf. *triadicum* (Kristan-Tollmann)		?*Nodosinella libera* Trifonova	*Spirillina gurgitata* Tappan
	Ophthalmidium spp.		*Pseudonodosaria obconica* (Reuss)	*Astacolus* cf. *connudatus* Tappan
Hyaline aragonitic	?Duostominidae		*Pseudonodosaria* sp.	
	Trocholina ex gr. *intermedia/umbo* Frentzen		*Dentalina* sp.	
	"*Involutina turgida* Kristan" (i.e. *Involutina* ex gr. *liassica* (Jones) sensu Blau, 1987)		*Frondicularia* sp.	
Hyaline calcitic	?*Lingulina placklesensis* Kristan-Tollmann		*Lenticulina* sp.	
	Dentalina sp.			
	Lenticulina sp.			

Tab. 2 - A complete list of foraminifers determined in sample CM31 and similar assemblages from the region. The wall composition is indicated by different shading. Note that the wall composition of *Endotriadella* and *Endothyranella* is not indicated. Both genera are placed into Fusulinina, but the microstructure of these Triassic genera has not yet been investigated.

bioclasts (Kotlyar et al. 1999). Their foraminiferal assemblages include some of the same genera as the assemblage from CM31 (i.e. *Tolypammina*, *Gaudryinopsis* and *Ophthalmidium* in most samples), as well as a great variety of non-agglutinates, including *Decapoalina*, *Galeanella* and *Miliolipora* (Pronina & Vuks 1996; Kotlyar et al. 1999; Vuks 2000; Korchagin et al. 2003). Bioclastic limestone of the Norian and Rhaetian Khodz Group in the Caucasian Fore Range is wackestone and packstone, locally floatstone to rudstone with variable amounts of sponges, solenoporacean algae, bryozoans, brachiopods, echinoderms, bivalves, small benthic foraminifers, juvenile ammonoids, and less abundant agglutinated worm tubes, gastropods, ostracods, and corals (Gale et al. 2020). Sedimentation was interpreted to take place in relatively shallow water. This facies passes laterally and vertically into deeper marine *Monotis*-rich limestone (Gaetani et al. 2005). Foraminiferal assemblages from the Khodz Group were described by Efimova (1975, 1991), Vuks (1996, 2000, 2004), Gaetani et al. (2005), and Gale et al. (2020). The most intriguing feature of the bioclastic limestone is the large proportion and diversity of trocholinids (Gale et al. 2020). Compared to the sample CM31, the proportion of agglutinates is low.

The differences between the assemblages recorded from the Crimea and the Pre-Caucasus on one side, and the assemblages described from the NDO (and its offshore continuation) and the Kotel area on the other, can probably not be attributed to the palaeolatitude. The Upper Triassic rock from the first two localities were palaeogeographically even further north than deposits from the NDO and Kotel, yet nevertheless contain *Galeanella*, *Miliolipora*, and *Decapoalina*, which are common elements of the equatorial carbonates (e.g. Schäfer and Senowbari-Daryan 1978; Schäfer 1979; Senowbari-Daryan 1980; Martini et al. 2007, 2009; Chablais et al. 2011; Gale 2012). Perhaps the main difference is in the depositional depth, since the deposition of the investigated sample, as well as of the other formations with similar assemblages, was in a somewhat deeper environment, and the Khodz Group has at least been interpreted as a shallow marine unit. However, other, completely local sets of characters could direct the specific composition of faunas. More attention should be given to assemblages from heterozoan carbonate systems to further elaborate on these hypotheses.

Conclusions

Rhaetian limestone, reached in the drill hole 817 LV of the Lebăda Vest oilfield, offshore Romania, is dominated by sponge spicules and mollusc fragments, with smaller amounts of echinoderm ossicles, bryozoans, benthic foraminifers, ostracods and brachiopod shells. The relative abundance of ostracods belonging to Bairdiidae, Paracyprididae, and Sigilliidae points to a well oxygenated environment of the outer shelf. The foraminiferal assemblage from the residue is dominated by agglutinated species and ophthalmidiids. Similar assemblages have been reported from the Rhaetian Teliţa Formation (Mirăuţă et al. 1993), and from the upper Carnian – lower Norian Hallstatt-type limestones from the Cilic Valley and the Muchea Verde Hill in the North Dobrogea (Mirăuţă & Gheorghian 1975), and from the lower Carnian limestone from the surroundings of Kotel in Bulgaria (Trifonova 1962, 1967). In contrast, heterozoan-dominated limestone from the Norian-Rhaetian of Crimea and the Precaucasus contains a large number and variety of non-agglutinated foraminifers, such as Trocholinidae, *Galeanella*, *Miliolipora*, and *Decapoalina* (Gale et al. 2020 and references therein). The differences among assemblages could be due to their different depositional depths. Agglutinated foraminifers might represent the bulk of the species diversity and numbers in the more distal parts of the heterozoan-type carbonate platforms, while the miliolids and the trocholinid involutinids may characterise the proximal parts of such systems.

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