

## Distribution of Triassic Foraminifers in the Limestone Massifs of the Dalnegorsk District, Primorsky Krai

V. Ja. Vuks<sup>a, \*</sup> and T. A. Punina<sup>b, \*\*</sup>

<sup>a</sup>Karpinsky Russian Geological Research Institute, St. Petersburg, 199106 Russia

<sup>b</sup>Far Eastern Geological Institute, Far Eastern Branch, Russian Academy of Sciences, Vladivostok, 690022 Russia

\*e-mail: Valery\_Vuks@vsegei.ru

\*\*e-mail: pounta@mail.ru

Received August 1, 2018; revised October 15, 2018; accepted November 28, 2018

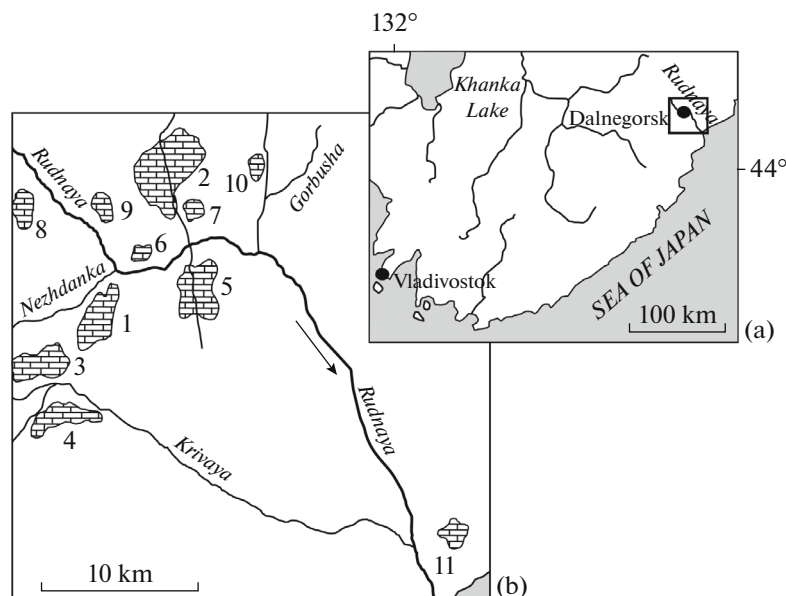
**Abstract**—Foraminifer assemblages from five massifs of the Triassic limestones of the Dalnegorsk District have been described for the first time, and images of these foraminifers are provided. Foraminifer associations are found here on all the known stratigraphic levels, except for the Rhaetian. In the massif of Mount Verkhni Rudnik, four foraminifer assemblages have been recorded within the interval from the Carnian to the top of the Norian. The foraminifer assemblages in the Dalnegorsk limestones are comparable to the coeval foraminifer associations of the Carpathians and the Alps. The research results make it possible, for the first time, to compare the foraminifer assemblage composition between various limestone massifs and different stratigraphic levels.

**Keywords:** Far East, Triassic, foraminifers

**DOI:** 10.1134/S0031030119090181

The Triassic limestones in the vicinity of the city of Dalnegorsk, Primorsky Krai, have been known since the early 20th century, and various groups of the organic world are studied in them (Punina, 1999)

(Fig. 1). The first mention of foraminifers, without identifying their species and genera, was made by O. Weigel (1914). To date, there are no dedicated publications on foraminifer research, although, a number



**Fig. 1.** Triassic limestone massifs in the city of Dalnegorsk and its vicinity, Primorsky Krai: (a) Study area in Primorsky Krai; (b) location of the Triassic carbonate massifs in the Dalnegorsk District: (1) Mount Sakharnaya, (2) Mount Verkhni Rudnik, (3) Mount Bol'nichnaya, (4) Mount Kamennye Vorota, (5) Mount Partizanskaya, (6) area of Podstantsiya, (7) Mount Vokzal'naya, (8) Mount Gorelaya, (9) Mount Primorskaya, (10) Mount Nikolaevskaya, and (11) Mount Kar'ernaya (Punina, 1999, with amendments).

General stratigraphical scale				Coral beds (Punina, 1999)	Foraminifer assemblages (in present paper)	
System	Series	Stage	Substage			
Triassic	Upper	Rhaetian		<i>Retiophyllia buonamici</i> beds		
		Norian	Upper	<i>Meandrostylis tener</i> beds	<i>Trochammina</i> sp., <i>Endotebanella</i> ex gr. <i>bicamerata</i> (Salaj), <i>Calcitornella</i> (?) sp.	
			Middle	<i>Gablonzeria kiparisovae</i> beds	<i>Trochammina almtalensis</i> Koehn-Zaninetti	
			Lower	<i>Margarosmia melnikovae</i> beds	<i>Pilammina</i> ex gr. <i>begani</i> (Salaj), <i>Pseudobolivina</i> (?) <i>globosa</i> Kristan-Tollmann, <i>Trochammina almtalensis</i> Koehn-Zaninetti, <i>Palaeolituonella meridionalis</i> (Luperto), <i>Textularia</i> ex gr. <i>haeusleri</i> Kaptarenko, “ <i>Permodiscus</i> ” <i>planidiscoides</i> Oberhauser, <i>Nodosinella</i> ex gr. <i>siliqua</i> Trifonova, <i>Agathammina austroalpina</i> Kristan-Tollmann et Tollmann, <i>Dentalina</i> sp., <i>Diploremmina</i> ex gr. <i>astrofimbriata</i> Kristan-Tollmann, <i>Duostomina turboidea</i> Kristan-Tollmann	
		Carnian	Upper	<i>Volzeia badiotica</i> beds	<i>Tolypamma gregaria</i> Wendt, <i>Glomospirella</i> sp., <i>Trochammina almtalensis</i> Koehn-Zaninetti, <i>Gaudryinella</i> (?) sp., “ <i>Permodiscus</i> ” <i>planidiscoides</i> Oberhauser, <i>Parvalamella friedli</i> (Kristan-Tollmann), <i>A. oscillens</i> (Oberhauser), <i>Triasina</i> (?) sp., <i>Agathammina austroalpina</i> Kristan-Tollmann et Tollmann, <i>Nodosaria</i> ex gr. <i>ordinata</i> Trifonova, <i>Diploremmina</i> ex gr. <i>astrofimbriata</i> Kristan-Tollmann	
			Lower			
		Middle	Ladinian	Upper	<i>Coryphyllia moisseevi</i> beds	<i>Pilammina gmerica</i> (Salaj), <i>Trochammina almtalensis</i> Koehn-Zaninetti, <i>Nodosaria</i> (?) sp.

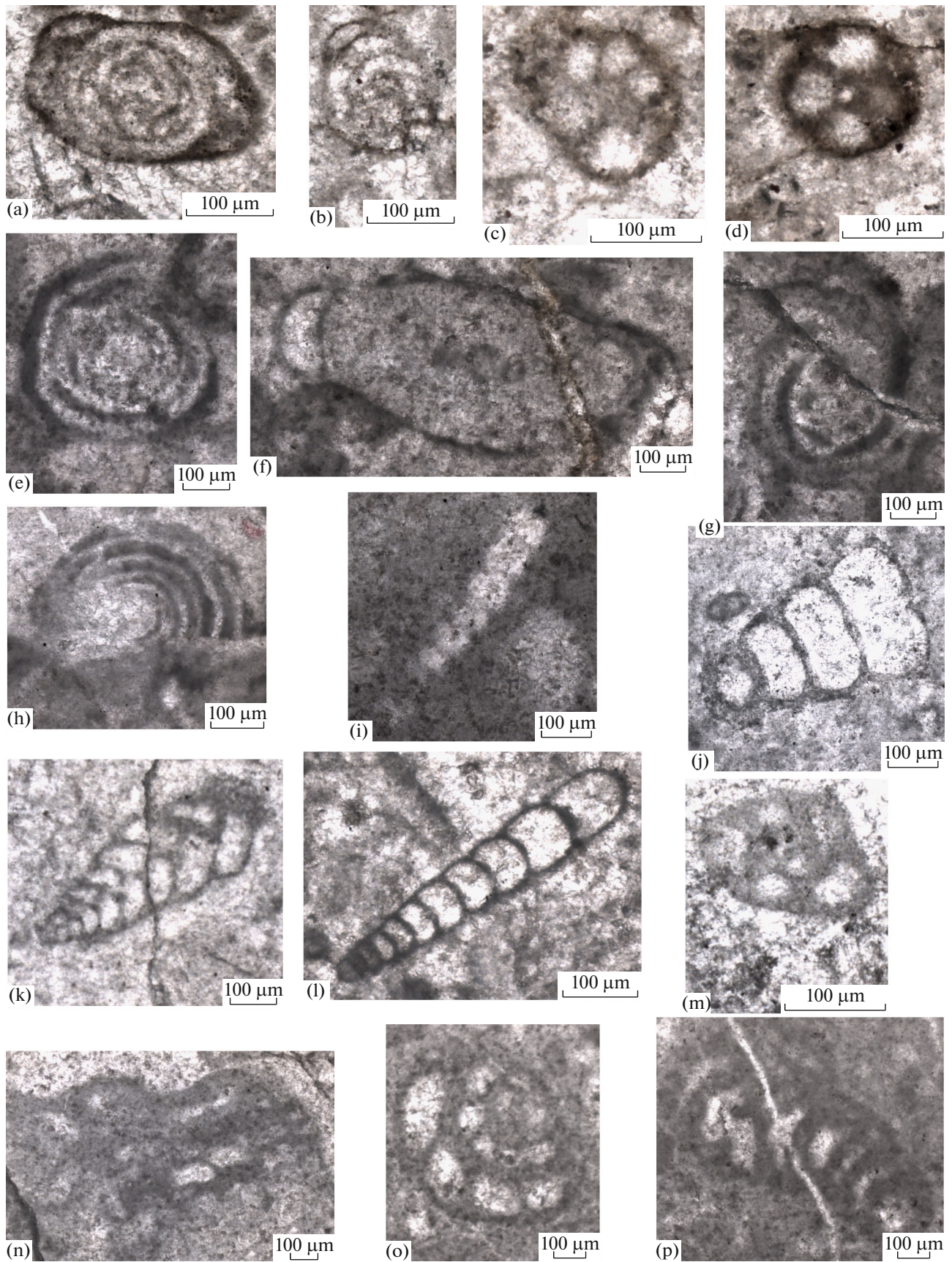
Fig. 2. Comparison of the distribution of Triassic foraminifers with the biozone scale by corals in the limestone massifs of the Dalnegorsk District, Primorsky Krai.

of works consider some species or genera without providing their images. The only work where images of members of three foraminifer genera are published,

and the presence of foraminifer is noted for almost each described bed of the Triassic limestones, is the book by T.A. Punina (1999).

Fig. 3. Triassic foraminifers from the limestone massifs of Mount Bol'nichnaya, Mount Kamennye Vorota, Mount Sakharnaya, and Mount Verkhni Rudnik, Dalnegorsk District, Primorsky Krai: (a, b) *Pilammina gmerica* (Salaj, 1969), (a) no. 13331/4, (b) 13331/5, Mount Bol'nichnaya, trench 1558, t.s. GB-16; (c, d) *Trochammina almtalensis* Koehn-Zaninetti, 1968, (c) no. 13331/8, (d) no. 13331/9, Mount Bol'nichnaya, trench 1558, t.s. GB-16; (e) *Glomospirella* sp., no. 13331/2, Mount Kamennye Vorota, t.s. 87; (f) “*Permodiscus*” *planidiscoides* Oberhauser, 1964, no. 13331/19, Mount Kamennye Vorota, t.s. 87; (g) *Parvalamella friedli* (Kristan-Tollmann, 1962), no. 13331/20, Mount Kamennye Vorota, t.s. 87; (h) *Triasina* ? sp., no. 13331/23, Mount Kamennye Vorota, t.s. 87; (i) *Nodosaria* ex gr. *ordinata* Trifonova, 1965, no. 13331/28, Mount Kamennye Vorota, t.s. 87-20; (j) *Palaeolituonella meridionalis* (Luperto, 1965), no. 13331/12, Mount Sakharnaya, t.s. S-58-2; (k) *Textularia* ex gr. *haeusleri* Kaptarenko, 1959, no. 13331/13, Mount Sakharnaya, t.s. S-58-2; (l) *Nodosinella* ex gr. *siliqua* Trifonova, 1972, no. 13331/14, Mount Sakharnaya, t.s. S-58-1; (m) *Agathammina austroalpina* Kristan-Tollmann et Tollmann, 1964, no. 13331/26, Mount Sakharnaya, t.s. S-58-2; (n) *Tolypamma gregaria* Wendt, 1969, no. 13331/1, Mount Verkhni Rudnik, t.s. 172; (o) *Trochammina almtalensis* Koehn-Zaninetti, 1968, no. 13331/7, Mount Verkhni Rudnik, t.s. 101; (p) *Gaudryinella* ? sp., no. 13331/11, Mount Verkhni Rudnik, t.s. 101.





To study foraminifers, T.A. Punina provided 72 thin-sections from the collection of corals collected in the 1980s and 1990s from five localities: Mount Verkhni Rudnik and its right shoulder, Mount Sakharnaya, Mount Nikolaevskaya, Mount Kamennye Vorota (trench 1005), and Mount Bol'nichnaya (Fig. 1). Foraminifers were found and examined in 20 thin-sections. The thin-sections from the Rhaetian limestones were not available for the research. The studied collection of foraminifers in thin-sections is deposited at the Chernyshev Central Scientific Research Geological Survey Museum (TsNIGR Museum) under no. 13331.

In thin-sections from the carbonate deposits of Mount Bol'nichnaya, which, judging by corals, correspond to beds with *Coryphyllia moissevi* (Upper Ladinian?–Lower Carnian) (Punina, 1999), the following foraminifer association was identified: *Pilaminella gemerica*, *Trochammina almtalensis*, and *Nodosaria* ? sp. (Figs. 2, 3a–3d). The species *Pilaminella gemerica* is typical of the Anisian–Lower Carnian of the Carpathians and Bulgaria, while the species *Trochammina almtalensis* was recorded from sediments of the Anisian in China and the Caucasus, the Anisian–Carnian (probably Norian) in Europe, and the Norian in the Pamirs (Salaj et al., 1983; Oravec-Scheffer, 1987; Vuks, 1988; Efimova, 1991; Trifonova, 1992; Pronina and Vuks, 1996; Vuks, 1996; Velleditis et al., 2003; Gale et al., 2015). This stratigraphic level is known only from the limestone massif of Mount Bol'nichnaya (Punina, 1999).

In the thin-sections from the limestone massif of Mount Nikolaevskaya, on the stratigraphic level of beds with *Volzeia badiotica* (Carnian) (Punina, 1999), the poorest assemblage of foraminifers was found, *Endotabanella* sp., which occur in deposits of the Lower Triassic–Carnian in Europe and Asia (Rettori, 1995).

In the limestone massif of Mount Kamennye Vorota, from the stratigraphic level of beds with *Volzeia badiotica* (Carnian) (Punina, 1999), the following foraminifer association was recorded: *Glomospirella* sp., “*Permodiscus*” *planidiscoides*, *Parvalamella friedli*, *Nodosaria* ex gr. *ordinata*, *Triasina* (?) sp. (Figs. 2, 3e–3i). From this foraminifer assemblage, in one of the thin-section we found one section of *Triasina* (?) sp., iden-

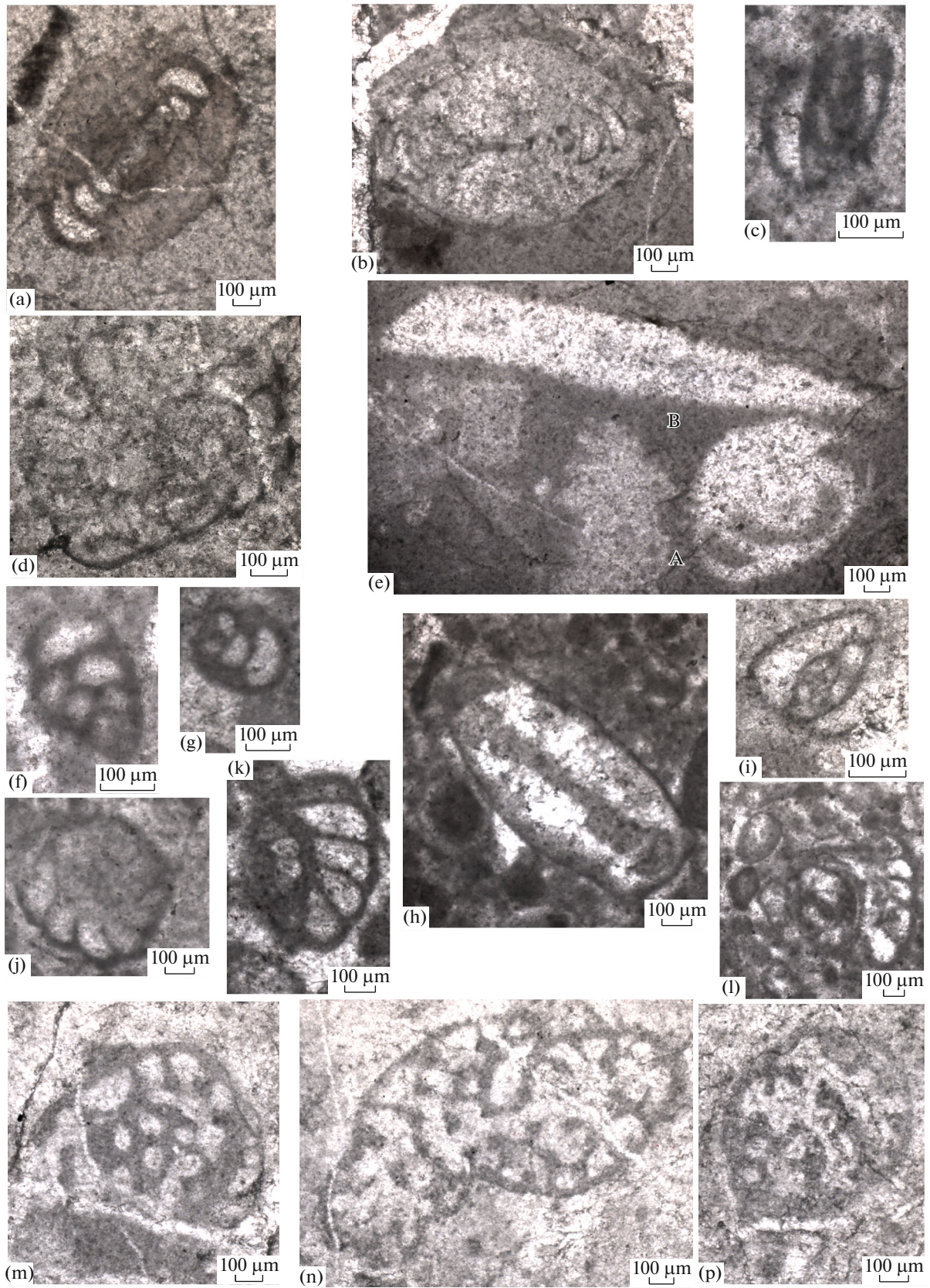
tified rather conditionally because of the poor preservation of its test. The species *Parvalamella friedli* occurs in sediments from the Anisian to the Rhaetian in Europe and Asia, the Upper Triassic in America, and is also an index species for zones determined based on foraminifers of the Rhaetian in the Carpathians and the Norian in the Caucasus (Zaninetti, 1976; Salaj et al., 1983; Efimova, 1991; Trifonova, 1993; Vuks, 1996; Rigaud et al., 2012). The species “*Permodiscus*” *planidiscoides* is typical of Ladinian–Rhaetian deposits in Europe (Salaj et al., 1983).

In the limestone of Mount Sakharnaya, foraminifers were found in the thin-sections from a stratigraphic level which corresponds to the beds with *Margarosmia melnikovae* (Lower Norian) (Punina, 1999). This foraminifer assemblage is represented by *Palaeolituonella meridionalis*, *Textularia* ex gr. *haeusleri*, *Nodosinella* ex gr. *siliqua*, and *Agathammina austroalpina* (Figs. 2, 3j–3m). The species *Palaeolituonella meridionalis* and *Agathammina austroalpina* occur in the Middle–Upper Triassic in Europe and Asia (Salaj et al., 1983; Trifonova, 1993; Rettori, 1995; Vuks, 1996). Both species, *Palaeolituonella meridionalis* and *Agathammina austroalpina*, are known from sediments of the Middle–Upper Triassic in Europe and Asia (Salaj et al., 1983; Trifonova, 1992, 1993; Rettori, 1995; Pronina and Vuks, 1996; Vuks, 1996; Martini et al., 2009; Senowbari-Daryan and Link, 2017).

In the massif of Mount Verkhni Rudnik and its right shoulder, foraminifers were recorded from different levels of carbonate sediments. In the limestone beds with *Volzeia badiotica* (Carnian) (Punina, 1999), the following foraminifers were identified: *Tolypammmina gregaria*, *Trochammina almtalensis*, *Gaudryinella* (?) sp., *Aulotortus oscillens*, *Agathammina austroalpina*, and *Diplostromina* ex gr. *astrofimbriata* (Figs. 2, 3n–3p, 4a–4d). The species *Tolypammmina gregaria* Wendt is found in the Olenekian–Rhaetian of Europe, Turkey, and the Mangyshlak (Zaninetti, 1976; Salaj et al., 1983; Trifonova, 1992; Pronina and Vuks, 1996; Vuks, 1996, 2007), and *Aulotortus oscillens* occurs in the Ladinian–Rhaetian of Europe (Oberhauser, 1964; Salaj et al., 1983). The species *Trochammina almtalensis* and *Agathammina austroalpina* are known from sediments of the Middle–Upper Triassic of Europe and Asia, as noted above. Higher, on the level of the

**Fig. 4.** Triassic foraminifers from the massifs of Mount Verkhni Rudnik, Dalnegorsk District, Primorsky Krai: (a, b) *Aulotortus oscillens* (Oberhauser, 1957), (a) no. 13331/21, (b) no. 13331/22, Mount Verkhni Rudnik, right shoulder, t.s. VP-12; (c) *Agathammina austroalpina* Kristan-Tollmann et Tollmann, 1964, no. 13331/24, Mount Verkhni Rudnik, right shoulder, t.s. VP-12; (d) *Diplostromina* ex gr. *astrofimbriata* Kristan-Tollmann, 1960, no. 13331/28, Mount Verkhni Rudnik, t.s. 198; (e): (A) *Pilaminella* ex gr. *begani* (Salaj, 1969), no. 13331/3, (B) *Dentalina* sp., no. 13331/27, Mount Verkhni Rudnik, t.s. 233; (f) *Pseudobolivina* ? *globosa* Kristan-Tollmann, 1973, no. 13331/6, Mount Verkhni Rudnik, t.s. 236; (g) *Trochammina almtalensis* Koehn-Zaninetti, 1968, no. 13331/10, Mount Verkhni Rudnik, t.s. 236; (h) “*Permodiscus*” *planidiscoides* Oberhauser, 1964, no. 13331/18, Mount Verkhni Rudnik, t.s. 236; (i) *Agathammina austroalpina* Kristan-Tollmann et Tollmann, 1964, no. 13331/25, Mount Verkhni Rudnik, t.s. 236; (j) *Diplostromina* ex gr. *astrofimbriata* Kristan-Tollmann, 1960, no. 13331/29, Mount Verkhni Rudnik, t.s. 239; (k, l) *Duostomina turboidea* Kristan-Tollmann, 1960, (k) no. 13331/31, (l) no. 13331/30, Mount Verkhni Rudnik, t.s. 236; (m–o) *Endotabanella* ex gr. *bicamerata* (Salaj, 1967), (m) no. 13331/15, (n) no. 13331/16, (o) no. 13331/17, Mount Verkhni Rudnik, t.s. VR-200.





beds with *Margarosmia melnikovae* (Lower Norian) (Punina, 1999), the following foraminifers were present: *Pilammina* ex gr. *begani*, *Pseudobolivina* (?) *globosa*, *Trochammina almtalensis*, “*Permodiscus*” *planidiscoides*, *Agathammina austroalpina*, *Dentalina* sp., *Diploremmina* ex gr. *astrofimbriata*, and *Duostomina turboidea* (Figs. 2, 4e–4l). The species *Pseudobolivina* (?) *globosa* was found in Europe from the Anisian to the Rhaetian (Zaninetti, 1976; Salaj et al., 1983; Vuks, 1988; Trifonova, 1992); the species *Duostomina turboidea*, in the Upper Ladinian–Carnian of the Alps and Hungary, the Rhaetian of the Carpathians, the Upper Triassic of Cyprus, and the Norian of Afghanistan (Zaninetti, 1976; Salaj et al., 1983; Oravec-Scheffer, 1987; Martini et al., 2009). The species *Trochammina almtalensis*, *Agathammina austroalpina*, and “*Permodiscus*” *planidiscoides* were recorded from the Middle–Upper Triassic of Europe and Asia, as noted above, except for the latter species that appears in the Ladinian. At the level of beds with *Gablonzeria kiparisovae* (Middle Norian) (Punina, 1999), the only species identified from limestones was *Trochammina almtalensis*, typical of the Middle–Upper Triassic of Europe and Asia, as already mentioned above. In the limestones corresponding to beds with *Meandrostylis tener* (Upper Norian) (Punina, 1999), the following foraminifers were found: *Endotebanella* ex gr. *bicamerata* (Salaj), *Trochammina* sp., and *Calcitornella* (?) sp. (Figs. 2, 4m–4o). The species *Endotebanella bicamerata* (Salaj) is typical of the Anisian–Norian of Europe and Asia (Salaj et al., 1983; Trifonova, 1993; Pronina and Vuks, 1996), although our specimens were determined with an open nomenclature. Thus, in the carbonate Triassic sediments of Mount Verkhni Rudnik, foraminifer assemblages have been found, according to the division of the Triassic by corals (Punina, 1999), in four beds with corals, within the stratigraphic interval from the Carnian to the Upper Norian.

In 2017, Prof. Rossana Martini and her PhD student Giovan Peyrotty from the department of Earth Sciences at the University of Geneva started an official collaboration with Dr Valery Vuks (Russian Geological Research Institute, Saint Petersburg) and Drs Tatiana Punina and Igor Kemkin (Far East Geological Institute, Vladivostok). In the same year, they carried out a field mission in the Dalnegorsk area to visit and accurately sample some of the localities reported in this work, and many others. The purpose of their project is to perform an accurate sedimentological, biostratigraphical and diagenetic study of the Upper Triassic limestones from the Panthalassa Ocean (REEFCAD project to R.M.). For this reason, we expect further joint integrated research on the above-considered limestones.

Thus, it can be stated that foraminifer assemblages with different degrees of representation, both very poor and quite diverse, have been first described from five carbonate limestone massifs in the city of Dalne-

gorsk and its vicinities. Images of most of the listed foraminifers, with some of them identified to species, are provided for the first time. In these carbonate massifs, foraminifer associations are found on different stratigraphic levels, while in the massif of Mount Verkhni Rudnik four foraminifer assemblages have been recorded within the interval from the Carnian to the top of the Norian. The identified foraminifer assemblages in the Dalnegorsk limestones are most comparable with the coeval foraminifer assemblages of the Carpathians and the Alps. The results of the study, for the first time, make it possible to understand the composition of assemblages in different limestone massifs and at different stratigraphic levels, as well as to consider the diversity of the foraminifer association in the Triassic limestones located in the vicinity of Dalnegorsk.

## REFERENCES

- Efimova, N.A., The Triassic system, in *Prakticheskoe rukovodstvo po mikrofaune SSSR. T. 5. Foraminifery mezozoya* (A Practical Guide to the Microfauna of the USSR, vol. 5: Foraminifera of the Mesozoic), Leningrad: Nedra, 1991, pp. 16–25.
- Gale, L., Celarc, B., Caggiati, M., Kolar-Jurkovšek, T., Jurkovšek, B., and Gianolla, P., Paleogeographic significance of Upper Triassic basinal succession of the Tamar Valley, northern Julian Alps (Slovenia), *Geol. Carpath.*, 2015, vol. 66, no. 4, pp. 269–283.
- Martini, R., Peybernes, B., and Moix, P., Late Triassic foraminifera in reefal limestones of SW Cyprus, *J. Foraminiferal Res.*, 2009, vol. 39, no. 3, pp. 218–230.
- Oberhauser, R., Zur Kenntnis der Foraminiferengattungen *Permodiscus*, *Trocholina* und *Triasina* in der alpinen Trias und ihre Einordnung zu den Archaeodisciden, *Verh. Geol. Bundesanst.*, 1964, no. 2, pp. 196–210.
- Oravec-Scheffer, A., *Triassic foraminifers of the Transdanubian Central Range*, *Geol. Hung., Ser. Palaeontol.*, 1987, vol. 50.
- Pronina, G.P. and Vuks, V.Ja., New data on the Triassic foraminifers of the Crimea, *Suppl. Ann. Mus. Civ. Rovereto, Sez. Archeol., Stor. Sci. Nat.*, 1996 (1995), vol. 11, pp. 215–228.
- Punina, T.A., *Triasovye skleraktinii v organogennykh postroikakh Dal'negorskogo raiona (Sikhote-Alin')* (Triassic Scleractinian Corals in Organogenic Constructions of the Dalnegorsk District, Sikhote-Alin), Vladivostok: Dal'nauka, 1999.
- Rettori, R., Foraminiferi del Trias Inferiore e Medio della Tetide: revisione tassonomica, stratigrafia ed interpretazione filogenetica, *Publ. Dep. Geol. Paleontol., Univ. Geneve*, 1995, no. 18, pp. 1–150.
- Rigaud, S., Martini, R., and Rettori, R., Parvalamellinae, a new subfamily for Triassic glomospiroid Involutinidae, *J. Foraminiferal Res.*, 2012, vol. 42, no. 3, pp. 245–256.
- Salaj, J., Borza, K., and Samuel, O., *Triassic Foraminifers of the West Carpathians*, Bratislava: Geol. Ústav Dionýza Štúra, 1983.
- Senowbari-Daryan, B. and Link, M., Foraminifera from the Norian–Rhaetian reef carbonates of the Taurus Moun-

- tains (Saklikent, Turkey), *Geol. Carpath.*, 2017, vol. 68, no. 4, pp. 303–317.
- Trifonova, E., Taxonomy of Bulgarian Triassic foraminifera. I. Families Psammosphaeridae to Nodosinellidae, *Geol. Balc.*, 1992, vol. 22, no. 1, pp. 3–50.
- Trifonova, E., Taxonomy of Bulgarian Triassic foraminifera. II. Families Endothyriidae to Ophthalmiidae, *Geol. Balc.*, 1993, vol. 23, no. 2, pp. 19–66.
- Velleditis, F., Forian-Szabo, M., Berczi-Makk, A., Piros, O., and Jozsa, S., Stratigraphy and origin of the Kiszénis Nappe (Bukk Mountains, NE Hungary). Is the silica unit really present in the Bukk Mountains?, *Geol. Carpath.*, 2003, vol. 54, no. 3, pp. 189–198.
- Vuks, V.Ja., Late Triassic foraminifera from the pebbles in the Dobridol Formation, SW Bulgaria, *Geol. Balc.*, 1988, vol. 18.3, pp. 47–50.
- Vuks, V.Ja., Late Triassic Foraminifera of Caucasus and Pamirs, *Suppl. Ann. Mus. Civ. Rovereto, Sez. Archeol., Stor. Sci. Nat.*, 1996 (1995), vol. 11, pp. 199–206.
- Vuks, V.Ja., Olenekian (Early Triassic) foraminifera of the Gorny Mangyshlak, Eastern Precaucasus and Western Caucasus, *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 2007, vol. 252, pp. 82–92.
- Weigel, O., Ueber einige Erzlagerstätten am Sichota-Alin in Ostsibirien, *Neues Jahrb. Mineral., Geol. Palaeontol.*, 1914, vol. 37, pp. 653–738.
- Zaninetti, L., Les Foraminifères du Trias. Essai de synthèse et corrélation entre les domaines mésogéens européen et asiatique, *Riv. Ital. Paleontol. Stratigr.*, 1976, vol. 82, no. 1, pp. 1–258.

*Translated by E. Shvetsov*