

Late Devonian radiolarians from the Rudny Altai (SW Siberia)

OLGA T. OBUT & TATYANA A. SHCHERBANENKO



Four well-preserved radiolarian associations recovered from the uppermost Givetian–upper Frasnian siliceous strata of the Zolotukha and Gryaznukha formations near Gornyak Settlement in the Altai-Sayan Folded Area (ASFA) in the South West Rudny Altai, southwestern Siberia, eastern Russia, are represented by 26 species assigned to 11 genera including a new taxon, *Cancellientactinia acifera* gen. et sp. nov. The validity of the genera *Entactinia* Foreman and *Stigmatosphaerostylus* Rüst is discussed and the diagnosis of the genus *Trilonche* Hinde is emended. The main Frasnian fauna is dominated by spherical entactiniids whereas spiny ceratohiscids and palaeoscenids possess more diversity in the later transitional Frasnian-Famennian association. • Key words: Mid-Upper Devonian, Frasnian, radiolarians, taxonomy, SW Siberia.

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Upper Devonian sediments crop out along the southwestern part of the Rudny Altai (Fig. 1). According to paleogeographic reconstructions for the Late Devonian of West Siberia, Rudny Altai is believed to have occupied an ocean marginal sea environment in the Paleo-Asian Ocean (Yolkin *et al.* 2003, 2005). Deep-water fine-grained terrigenous-siliciclastic rocks, which accumulated on the slopes of the oceanic highs, occur in combination with shallow-water reefal carbonates, including numerous corals and other benthic fauna (Yolkin *et al.* 2005). The former are represented by siliceous mudstones, shales, siltstones and cherts with subordinate tuffaceous material, and tuffs associated with acid volcanics (mainly rhyolites and dacites). The first report of Upper Devonian radiolarians from the Rudny Altai was made by Lyakhnitsky & Gutak (1998). Succeeding studies (during 2000–2003) were organized by a joint Russian-Japanese team including radiolarian workers from Hokkaido and Tokyo universities (K. Iwata and M. Umeda) and the Institute of Petroleum Geology SB RAS (O.T. Obut, guided by N.V. Sennikov).

Well-preserved radiolarians were reported from two sections exposed along the Zolotukha and Gryaznukha brooks, near Gornyak Settlement, in the SW Rudny Altai (Umeda *et al.* 2004). Further detailed sampling of the volcano-siliceous sequences revealed the presence of abundant radiolarian faunas in four successive sections covering the uppermost

Givetian–upper Frasnian interval (Obut *et al.* 2005, Obut 2006, present study). Four well-preserved radiolarian associations were recovered. Three Frasnian radiolarian assemblages are dominated by spherical entactiniids whereas one transitional to the Famennian includes various palaeoscenids, ceratohiscids and palacantholithids.

Locality and stratigraphy

New generation regional stratigraphic charts for the Middle–Upper Devonian of the Altai-Sayan Folded Area (ASFA) are based on identification of stratigraphic units for the NE Kuznetsk Basin (Fig. 1) that are well studied and characterized by fauna, particularly by conodonts. They can be correlated with local stratigraphic units previously recognized in the Rudny Altai sections (Yolkin *et al.* 2005, 2006; Fig. 2).

Radiolarians were recovered from four sections SB-031, S-033, S-0210, S-0011 exposed along the right banks of the Zolotukha and Gryaznukha brooks, near the former Razdol'noe Village (see Fig. 1). Detailed descriptions of the sections showing ranges of key taxa and data on regional stratigraphy were presented in Bakharev *et al.* (2004). Strata are dated using conodonts and ammonoids (Yolkin *et al.* 2005, Obut *et al.* 2007). The radiolarian

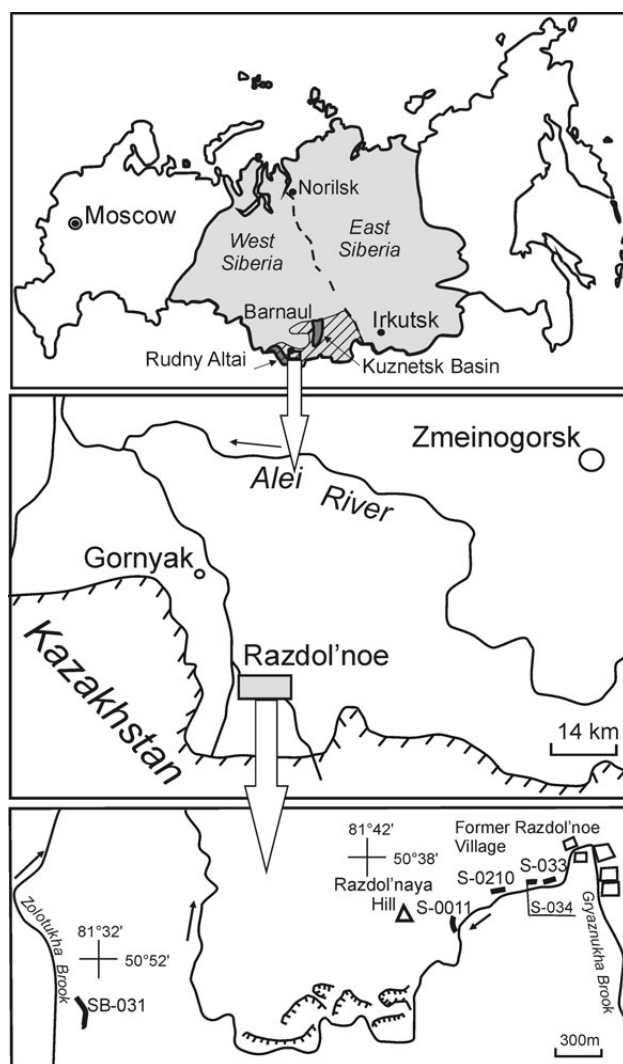


Figure 1. Sketch map showing location of the Middle and Upper Devonian sections exposed along Zolotukha and Gryaznukha brooks, SW Rudny Altai, Altai-Sayan Folded Area (ASFA), southwestern Siberia.

associations come from fine-grained pale-gray, greenish-gray, and black siliceous mudstones, shales and cherts from four stratigraphic intervals: uppermost Givetian–lower Frasnian, middle Frasnian, and upper Frasnian.

The first association is found in section SB-031, in the Zolotukha Formation, exposed on the right bank of Zolotukha Brook (Fig. 3, beds 8, 10, 13, 15, 17, 18, 45). Conodonts *Klapperina disparilis* (Ziegler & Klapper) and *Polygnathus ovinodorus* Ziegler & Klapper obtained from bed 9 (Bakharev *et al.* 2004) indicate an uppermost Givetian–lower Frasnian (*disparilis-falsiovalis* zones) age. The radiolarian fauna is dominated by spherical entactiniids and includes *Trilonche davidi* (Hinde), *Tr. minax* (Hinde), *Tr. palimbola* (Foreman), *Tr. cf. inusitata* (Foreman), *Astroentactinia stellata* Nazarov, *A. paronae*

Global Stratigraphic Scale				Conodont Zone	North-East Kuznetsk Basin		Rudny Altai		
System	Series	Stage	Substage		Horizon, Beds		Formation		
Devonian	Upper	Famennian	L ₁	<i>rhomboidea</i>	Pestchanka	Mitikhka Beds	Gryaznukha		
				<i>crepida</i>		Kosoy Utyos Beds			
				<i>triangularis</i>					
		Frasnian	M ₁	<i>linguiformis</i>	Solomino				Razdol'noe
				<i>rhenana</i>			Gerikhovskoe		
				<i>jamieae</i>					
				<i>hassi</i>					
				<i>punctata</i>					
				L ₂	<i>transitans</i>				
					<i>falsiovalis</i>				
	Middle	Givetian	U ₁	<i>disparilis</i>		Mazalovskiy Kitat	Davydovka		
				<i>hermanni-cristatus</i>					

Figure 2. Regional stratigraphic charts for the Middle-Upper Devonian of the Rudny Altai (after Yolkin *et al.* 2005, Weddige 2006).

(Hinde), and *Palaeoscenidium cladophorum* Deflandre (Fig. 4A, E, F).

A second association was revealed from section S-033 (Fig. 3, beds 6, 8, 12, 14, 18) of the Zolotukha Formation, provisionally dated as middle Frasnian (?*hassi* conodont zone), because overlying strata of section S-034 (see Fig. 1) yielded conodonts *Polygnathus uchtensis* Ovnanova & Kuzmin, *Palmatolepis hassi* Müller & Müller and *Pal. rhenana* Müller. The radiolarian fauna is characterized by spherical *Trilonche davidi* (Hinde), *Tr. minax* (Hinde), *Tr. hindea* (Hinde), *Tr. echinata* (Hinde), *Tr. vetusta* Hinde, *Astroentactinia stellata* Nazarov, and *Palaeoscenidium cladophorum* Deflandre (Fig. 4G).

A third association is from section S-0210 (Fig. 3) in the Gryaznukha Formation. Conodonts *Palmatolepis rhenana* Bischoff, *Pal. jameiae* Ziegler & Sandberg, *Pal. gigas* Müller & Youngquist and ammonoids in this part of the section are dated as upper Frasnian (*rhenana-linguiformis* zones and *Manticoceras* Stufen). Radiolarians are represented by a few specimens of *Trilonche hindea* (Hinde), *Astroentactinia stellata* Nazarov, *Palaeoscenidium cladophorum* Deflandre, and *Palaeoscenidium* sp.

The fourth association is the most diverse. It was recovered from section S-0011 (Fig. 5, beds 10–27) of the upper Frasnian Gryaznukha Formation. It is characterized by *Trilonche guangxiensis* (Li & Wang), *Tr. vetusta* Hinde, *Tr. echinata* (Hinde), *Tr. davidi* (Hinde), *Tr. minax* (Hinde), *Tr. tanheensis* Luo, Aitchison & Wang, *Astroentactinia stellata* Nazarov, *A. vishnevskayae* Afanasieva, *Stigmosphaerostylus* sp. A; *Borisella* cf. *maksimovae* Afanasieva, *Moscovistella* cf. *allbororum* Afanasieva, *Haplentactinia rhinophyusa* Foreman, *Palaeoscenidium cladophorum* Deflandre, *Pal. delicatum* Aitchison, *Pal. tabernaculum* Aitchison, *Ceratoikiscum avimexpectans* Deflandre, *Cer. mirum* Cheng, *Cer. labyrinthum* Cheng,

Cer. delicatum Cheng, *Cer. spinosum* Cheng, *Nazarovites bioculus* Afanasieva, *N. pinnula* Afanasieva, *Cancellientactinia acifera* gen. et sp. nov., and *Palaethalomnus* sp. (Figs 4B–D, H–T, 6A–T). The age of the strata as Upper *rhenana*-*linguiformis* zones has been established by recent findings of conodonts *Palmatolepis* gr. *Pa. delicatula* Branson & Mehl (beds 10, 25), *Pa. cf. Pa. rotunda* Ziegler & Sandberg (beds 18, 27), *Palmatolepis* ssp. (beds 10, 18, 25, 27) and *Polygnathus* sp. (beds 10, 18, 25) (Obut *et al.* 2007). It should be mentioned that in previous reports (Obut 2006), the stratigraphic position of this radiolarian association, was regarded as transitional uppermost Frasnian–Lower Famennian, based on *Cer. avimexpectans* Deflandre, *Cer. mirum* Cheng, *Cer. spinosum* Cheng and *Circuliforma robusta* Cheng, which range into the Famennian–Lower Carboniferous (Cheng 1986, Schwartzapfel & Holdsworth 1996). The other radiolarians present occur in Middle–Upper Devonian sequences worldwide. We also emphasize here that the ranges of many genera and species of Devonian radiolarians require more precise specification.

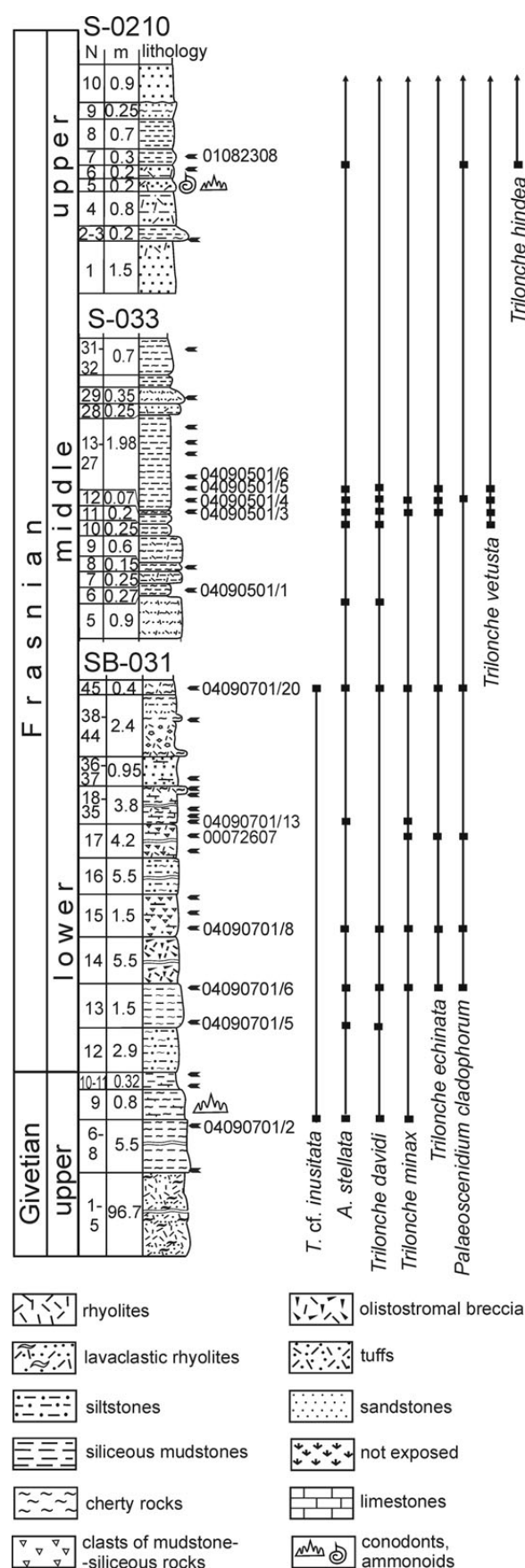
Material and methods

Radiolarians were extracted from siliceous argillites and cherts of the field area by standard methods using 5–15% hydrofluoric acid, with samples repeatedly washed, and specimens picked under a binocular lens. Detailed observation and photography were made using a Leo 1430 VP SEM. More than 600 specimens in total, mostly slightly broken, were studied. The described collection (registered as # 1099) is stored in the Central Siberian Geological Museum (CGSM) in the Institute of Geology and Mineralogy, Siberian Branch of Russian Academy of Sciences, Novosibirsk, Russia. All figured and described radiolarians come from samples collected from sections SB-031, S-033, S-0210 and S-0011, which crop out in the SW Rudny Altai, near Gornyak Settlement, in the watershed of the Gryaznukha and Zolotukha brooks (Fig. 1).

Systematic palaeontology

Radiolarians described below include a new genus and species, as well as some abundant taxa that were not found previously in the sequences examined earlier in this study.

Figure 3. Upper Devonian sections exposed along the Zolotukha and Gryaznukha Brooks, near former Razdol'noe Village, SW Rudny Altai and ranges of key radiolarian taxa. Abbreviation: A – Astroentactinia, T – Trilonche.



Family Polyentactiniidae Nazarov, 1974

Genus *Cancellientactinia* gen. nov.

Etymology. – From *cancelli* lat. – lattice and *Entactinia*.

Type species. – *Cancellientactinia acifera* sp. nov., Upper Devonian, upper Frasnian Gryaznukha Formation, Rudny Altai, south of West Siberia, Russia.

Diagnosis. – One spherical latticed shell, constructed by a meshwork of short bars. Inner skeleton represented by an 8-rayed spicule, all eight rays originating from a central point. Eight main more robust spines develop from rays of the internal spicule.

Remarks. – The described genus differs from *Polyentactinia* Foreman (Foreman 1963, p. 281) in having a single internal spicule (without central bar) and the presence of only rod-like spines, and from *Magnisphaera* Won (Won 1997, p. 366) by one latticed shell and an internal spicule.

Occurrence. – Late Devonian, late Frasnian; right bank of Gryaznukha Brook, section S-0011, Rudny Altai, SW Siberia, Russia.

***Cancellientactinia acifera* sp. nov.**

Figure 6A–D

1997 *Polyentactinia* sp.; Aitchison & Stratford, figs 2–12.

Etymology. – From *acifera* lat. – process, thorn.

Holotype. – Complete shell with internal spicule specimen CSGM 1099/1 (Fig. 6A).

Paratypes. – Shells with internal spicule, possessing cross section (specimens CSGM 1099/2, 1099/3).

Type horizon and locality. – Upper Devonian, upper Frasnian Gryaznukha Formation: right bank of Gryaznukha

Brook, section S-0011, bed 25, SW Rudny Altai, SW Siberia, Russia.

Material. – About 20 specimens in CSGM: 2 well preserved shells, 5 damaged shells, more than 10 broken specimens.

Diagnosis. – One robust latticed shell constructed from a meshwork of short bars. Broad rod-like bars enmeshed with fine short thorns and spinules. Eight main spines developed from rays of an internal spicule are rod-like and conical. Test a regular hexagon in cross-section.

Description. – One large sturdy latticed shell is formed from a regular meshwork of short robust rod-like bars. Occurring on the broad bars are specific sculptural elements, fine thorn-like projections of various lengths, sometimes as long as the main spines (Fig. 6B, D). The inner spicule is robust with eight rays developed from a central point. The main spines are rod-like, slightly conical, long, and sometimes equal in length to the test radius. They are decorated with short curved spinules that can sometimes intersect with each other or with the thorns developed on the bars.

Dimensions. – Test diameter 120–180 µm; inner spicule ray diameter 7–10 µm; main spine length 70–90 µm, with base diameter 20 µm; diameter of bars 7–10 µm; by-spine length 10–55 µm.

Occurrence. – The same as for genus.

Family Entactiniidae Riedel, 1967,
emend. Afanasieva, 1999

**Genus *Stigmatosphaerostylus* Rüst, 1892,
emend. Foreman, 1963**

1892 *Stigmatosphaerostylus* Rüst; Rüst, p. 142.

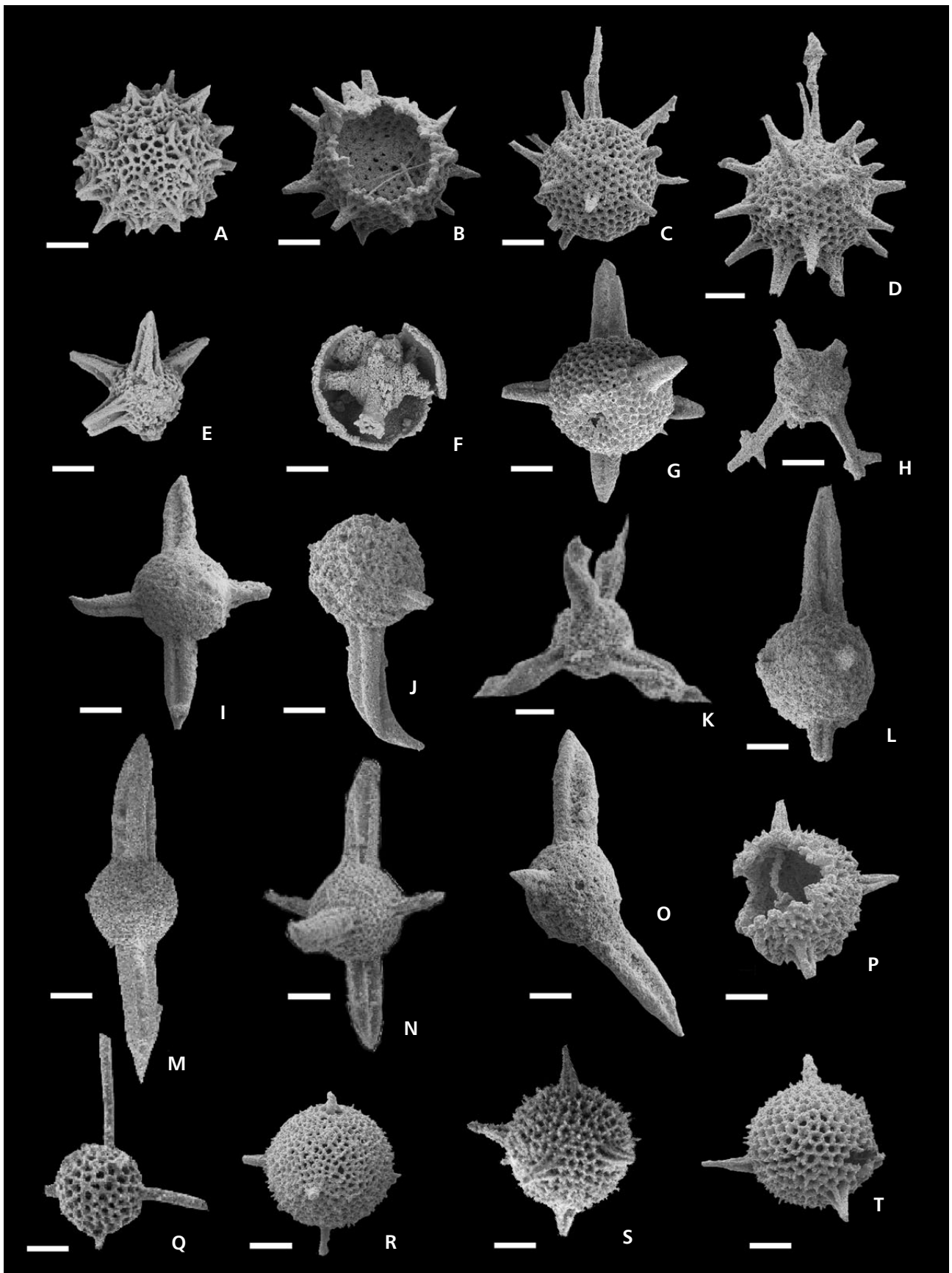
1963 *Entactinia* Foreman; Foreman, p. 271.

1988 *Entactinia* Foreman. – Nazarov, pp. 58, 59.

1999 *Stigmatosphaerostylus* Rüst. – Braun & Budil, p. 584.

2000a *Entactinia* Foreman. – Afanasieva, p. 41.

Figure 4. Radiolarians from the Zolotukha and Gryaznukha brooks sections, Upper Devonian, Frasnian, SW Rudny Altai. Scale 50 µm. • A, B – *Astroentactinia stellata* Nazarov; A – section SB-031 (loc. 04090701/20), 1099/10; B – section S-0011 (loc. 00072603/8), 1099/11. • C, D – *Astroentactinia vishnevskayae* Afanasieva, section S-0011 (loc. 00072603/8); C – 1099/12, D – 1099/13. • E–G – *Trilonche davidi* (Hinde); E, F – section SB-031 (loc. 04090701/20), 1099/20, 1099/21; G – section S-033 (loc. 04090501/4), 1099/22. • H – *Moscovistella allbororum* Afanasieva, section S-0011 (loc. S-0011-10), 1099/56. • I, J – *Trilonche guanxiensis* (Li & Wang), section S-0011 (loc. S-0011-25); I – 1099/31; J – 1099/32. • K – *Trilonche tangheensis* Luo, Aitchison & Wang, section S-0011 (loc. S-0011-27), 1099/34. • L – *Trilonche echinata* Hinde, section S-0011 (loc. S-0011-10), 1099/25. • M – *Trilonche minax* (Hinde), section S-0011 (loc. S-0011-27), 1099/23. N – *Trilonche hindea* (Hinde), section S-0011 (loc. S-0011-25), 1099/27. • O – *Trilonche vetusta* Hinde, section S-0011 (loc. 00072603/8), 1099/29. • P, S, T – *Stigmatosphaerostylus* sp. A, section S-0011 (loc. 00072603/8); P – 1099/41; S – 1099/40; T – 1099/42. • Q, R – *Borisella* cf. *maksimovae* Afanasieva, section S-0011 (loc. 00072603/8); Q – 1099/50; R – 1099/51.



Type species. – *Stigmosphaerostylus notabilis* Rüst, 1892; Lower Carboniferous, Harz Mountains, Germany.

Discussion. – Aitchison & Stratford (1997) regarded the widely-used name *Entactinia* introduced by Foreman (1963) as a junior synonym of *Stigmosphaerostylus* Rüst and proposed Foreman's diagnosis as an amendment. According to the original diagnosis of the genus *Stigmosphaerostylus* by Rüst (1892, p. 142), representatives that possessed one latticed shell with radial spines and an internal spicule constructed of radial rays were assigned to this genus. The description of the only recognized species *St. notabilis* defines the inner structure of this taxon: the inner spicule is constructed of six rays combined in one center (Rüst 1892, taf. X, fig. 2). Foreman's (1963, p. 271) original diagnosis for *Entactinia* is: "A single well-developed latticed or spongy shell (sometimes with external spongy material) and an internal six-rayed double spicule more delicate than the main spines." It should be noted that most of described species in recent literature assigned to *Stigmosphaerostylus* Rüst (*St. ornata* (Hinde), *St. pussila* (Hinde), *St. etheridgei* (Hinde), *St. hystricuosa* (Aitchison), *St. variospina* (Won) are characterized by a six-rayed double internal spicule and one latticed shell (Aitchison & Stratford 1997, Aitchison *et al.* 1999, Braun & Budil 1999, Wang *et al.* 2000, Luo *et al.* 2002).

***Stigmosphaerostylus* sp. A**

Figure 4P, S–T

2004 *Stigmosphaerostylus* sp. A; Umeda *et al.*, pl. III, figs 3, 4.

Type horizon and locality. – Upper Devonian Gryaznukha Formation, right bank of Gryaznukha Brook, section S-0011, loc. S-0011/10, 25, 27, SW Rudny Altai, southwestern Siberia, Russia.

Material. – 10 specimens.

Description. – The one spherical porous shell has six approximately equal main spines that are strongly three-bladed, grooved and tapered at the tip. The shell possesses subcircular pores and a wide interporous area, decorated with fine short thorns. The inner spicule is observed in broken specimens.

Dimensions. – Shell diameter 100–130 µm; main spine length 25–40 µm, with base diameter 15–20 µm.

Remarks. – This form differs from *Stigmosphaerostylus additiva* (Foreman), described from Upper Devonian Hu-

ron Member, Ohio Shale of Ohio, USA (Foreman 1963) and the Frasnian of the South Urals, Russia (Nazarov 1975) in having more delicate main spines, which are smaller in the diameter of their base and length. It resembles *Stigmosphaerostylus bogdanovi* (Afanasieva) reported from the Frasnian and Famennian of the Timan-Pechora region, Russian Platform (Afanasieva 2000a). The form we report has in comparison a larger shell diameter and considerably shorter main spines. Our form possibly represents a new species.

Occurrence. – Upper Devonian, upper Frasnian, Gryaznukha Formation: right bank of Gryaznukha Brook, section S-0011, beds 10, 18, 25, 27, Rudny Altai, southwestern Siberia, Russia.

Genus *Borisella* Afanasieva, 2000

Type species. – *Borisella maksimovae* Afanasieva, 2000; Upper Devonian, Frasnian, Domanic Formation, Timan-Pechora Province, northern Russia.

Diagnosis. – See Afanasieva (2000b, p. 31).

***Borisella* cf. *maksimovae* Afanasieva, 2000**

Figure 4Q, R

2004 *Stigmosphaerostylus* sp. B; Umeda *et al.*, pl. III, fig. 5.

Material. – 5 specimens.

Description. – The one spherical thick porous shell has six rod-like, conical main spines with Y-shape cross-section at the base and a small cavity. The shell possesses subcircular to subangular pores divided by a wide interporous area, framed with fine short thorns, sometimes with additional very short thorns. An inner spicule is observed in broken specimens.

Dimensions. – Shell diameter 100–160 µm; main spine length up to 200 µm, with base diameter 8–10 µm.

Remarks. – Afanasieva (2000b) reported the presence of massive by-spines (sometimes absent) and very long, thin main spines in the material from the Upper Devonian, Frasnian, Domanic Formation of Timan-Pechora Province. The specimens in our collection lack by-spines and the main spines are almost always broken.

Occurrence. – Upper Devonian, upper Frasnian Gryaznukha Formation; right bank of Gryaznukha Brook, section S-0011, beds 10, 25, 27, Rudny Altai, southwestern Siberia, Russia.

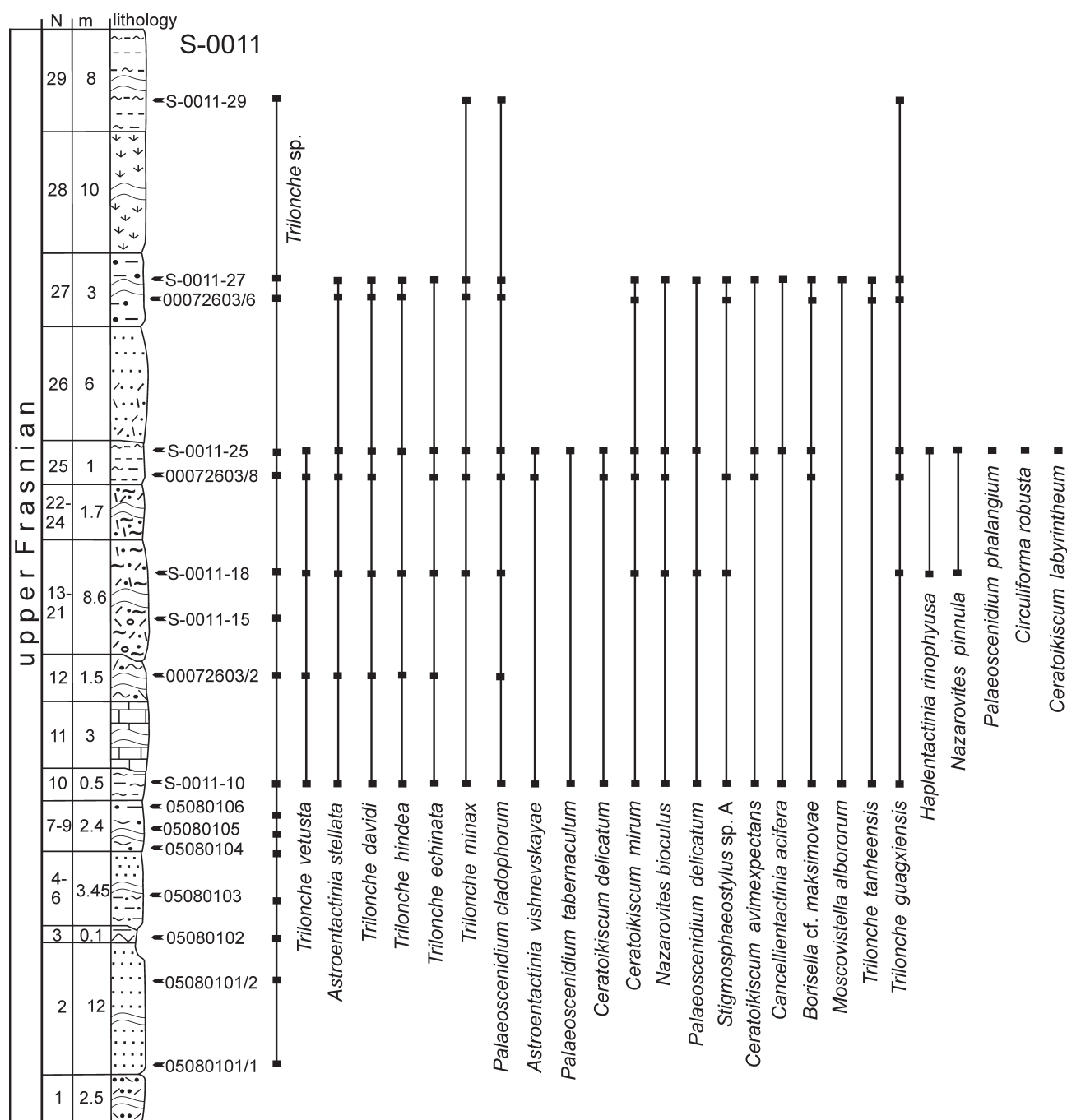


Figure 5. Upper Devonian sections exposed along the right bank of Gryaznukha Brook, near former Razdol'noe Village, SW Rudny Altai and ranges of key radiolarian taxa (for legend see Fig. 3).

Genus *Trilonche* Hinde, 1899, emend. Aitchison & Stratford, 1997, emend. herein

- 1899 *Trilonche* Hinde; Hinde, p. 48.
 1899 *Staurodruppa* Hinde; Hinde, p. 51.
 1963 *Entactinosphaera* Foreman; Foreman, p. 274.
 1988 *Entactinosphaera* Foreman. – Nazarov, p. 60.
 1999 *Trilonche* Hinde. – Braun & Budil, p. 586.

2000c *Bientactinosphaera* Afanasieva; Afanasieva, pp. 13, 14.

Type species. – *Trilonche vetusta* Hinde, 1899; Upper Devonian, volcanic tuff from Tamworth, New South Wales, Australia.

Original diagnosis. – The test consists of two concentric latticed spheres, with three radial spines at equal or unequal

distances apart. Secondary surface-spines are also sometimes present.

Emended diagnosis. – Further emendment herein after Aitchison & Stratford (1997). Two well-developed spherical or sub-spherical porous or latticed shells and an internal six-rayed double spicule. Six main radial spines developed from rays of the internal spicule. Up to six main spines can be present.

Remarks. – On the basis of thin-section observation of the material, the diagnosis of Hinde (1899, p. 47) restricted the genus to specimens with three radial spines. We agree with Aitchison & Stratford (1997, p. 374) that the genus *Entactinosphaera* reported by Foreman (1963, p. 274) is a junior synonym of *Trilonche* Hinde because the former encompasses material described by Hinde (1899). However, revision of *Entactinosphaera* Foreman made by Nazarov (1975) showed that the mentioned genus is basically composite, including species with two or three shells and a different structure of skeletal sphere. These facts allowed Nazarov to distinguish three different taxa: *Entactinosphaera* Foreman for species with two porous shells; *Spongentactinia* Nazarov for species with one spongy and one porous shell; and *Tecentactinia* Nazarov for species with three shells (Nazarov 1975). Thus, Foreman's (1963) diagnosis can be used as a basis for *Trilonche* but it should be corrected by restricting the number of shells strictly to two and including only representatives with porous or latticed structure of the skeletal sphere. Radiolarians with three or more shells and spongy structure should be assigned to other genera.

***Trilonche tanheensis* Luo, Aitchison & Wang, 2002**
Figure 4 K

Holotype. – Figured by Luo, Aitchison & Wang (2002, p. 119, pl. 3, fig. 8), Middle Devonian, Givetian, Tanhe Formation, Wuxiangling Section, Nanning, Guangxi. Collection is deposited in the Department of the Earth Sciences, University of Hong Kong (NKU-WXL128c_14).

Material. – 4 specimens.

Description. – A spherical latticed shell with six three-bladed main spines that are almost equal and robust, disposed at approximately 90° to each other, with 1.25–1.5 torsion, and coiling sinistrally when looking towards the tip. The spines taper rapidly near the tip. By-spines are not developed. The internal structure is not clear.

Dimensions. – Shell diameter 95–105 µm; main spine length 90–110 µm, with base diameter 20–30 µm.

Occurrence. – Upper Devonian, upper Frasnian Gryaznukha Formation; right bank of Gryaznukha Brook, section S-0011, beds 10, 18, 25, 27, SW Rudny Altai, southwestern Siberia, Russia.

Family Haplentactiniidae Nazarov, 1980

Genus *Haplentactinia* Foreman, 1963

Type species. – *Haplentactinia rhinophyusa* Foreman, 1963; Upper Devonian, Frasnian, Huron Member, Ohio, USA.

Diagnosis. – See Foreman (1963, p. 270).

***Haplentactinia rhinophyusa* Foreman, 1963**
Figure 6K, L

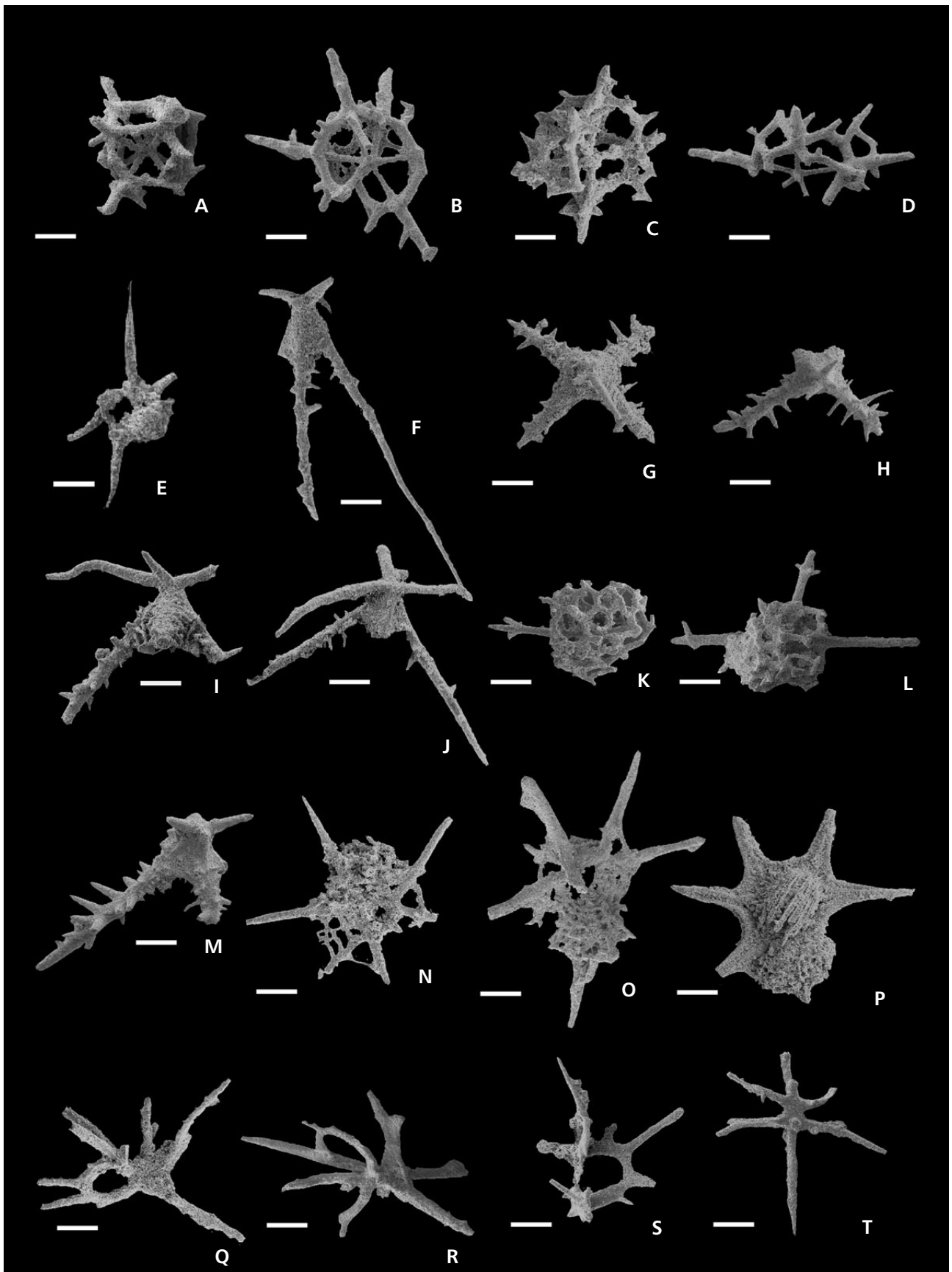
- 1963 *Haplentactinia rhinophyusa* Foreman; Foreman, pl. 1, fig. 2; pl. 3, fig. 7.
- 2000a *Haplentactinia rhinophyusa* Foreman. – Afanasieva, pl. 25, figs 5, 6.

Holotype. – USNM 640392 figured by Foreman (1963, p. 270, pl. 1, fig. 2), from concretions Norwalk 1, Upper Devonian, Huron Member, Ohio, USA. The holotype and associated collection are deposited in the United States National Museum, Washington D.C.

Material. – 5 specimens.

Description. – The skeletal framework consists of six

Figure 6. Radiolarians from the Gryaznukha Brook sections, Upper Devonian, upper Frasnian, SW Rudny Altai. Scale 50 µm. • A–D – *Canellientactinia acifera* sp. nov., section S-0011; A – holotype, loc. S-0011-25, 1099/1; B – paratype, loc. S-0011-10, 1099/2; C – paratype, loc. S-0011-27, 1099/3; D – paratype, loc. S-0011-10, 1099/4. • E – *Circuliforma robusta* Cheng, section S-0011 (loc. 0011/25), 1099/106. • F – *Palaeoscenidium delicatum* Aitchison, section S-0011 (loc. S-0011-10), 1099/76. • G, H – *Palaeoscenidium cladophorum* Deflandre, section S-0011; G – loc. 00072603/8, 1099/70; H – loc. S-0011-10, 1099/71. • I, J – *Palaeoscenidium tabernaculum* Aitchison, section S-0011 (loc. 00072603/8); I – 1099/77; J – 1099/78. • K, L – *Haplentactinia rhinophyusa* Foreman, section S-0011; K – loc. S-0011-27, 1099/58; L – loc. S-0011-25, 1099/57. • M – *Palaeoscenidium phalagium* Aitchison, section S-0011 (loc. S-0011-25), 1099/79. • N, O – *Ceratoikiscum delicatum* Cheng, section S-0011; N – loc. 00072603/8, 1099/96; O – loc. S-0011-10, 1099/97. • P – *Ceratoikiscum avimexpectans* Deflandre, section S-0011 (loc. 00072603/8), 1099/90. • Q–S – *Nazarovites bioculus* Afanasieva, section S-0011; Q – loc. 00072603/8, 1099/60; R – loc. S-0011-25, 1099/61; S – loc. 00072603/8, 1099/62. • T – *Nazarovites pinnula* Afanasieva, section S-0011 (loc. 00072603/8), 1099/66.



rod-like, slightly tapering spines (rays) that arise from a short medial bar. The internal framework is constructed of one or two groups of branched spinules or apophysis on the spines uniting in a meshwork and creating an isometric latticed shell. The meshwork openings are of angular forms. The distal part of the spines carries a short curved apophysis.

Dimensions. – Shell diameter 100–120 µm; main spine length 90–130 µm, with base diameter 5–10 µm.

Occurrence. – Upper Devonian, upper Frasnian Gryaznukha Formation; right bank of Gryaznukha Brook, section S-0011, beds 18, 25, SW Rudny Altai, southwestern Siberia, Russia.

Family Palacantholithidae Kozur & Mostler, 1981, emend. Afanasieva & Amon, 2005

Genus *Nazarovites* Afanasieva, 2000

Type species. – *Nazarovites bioculus* Afanasieva, 2000; Upper Devonian, middle and upper Frasnian, Domanic Formation, Timan-Pechora Province, northern Russia.

Diagnosis. – See Afanasieva (2000c, p. 4).

Nazarovites bioculus Afanasieva, 2000

Figure 6Q–S

- 1983 *Ceratoikiscum* cf. *spinosiarcuratum* Foreman. – Nazarov & Ormiston, pl. 2, fig. 1.
- 1997 *Nazarovites bioculus* (nomen nudum); Afanasieva, figs 2–19.
- 2000a *Nazarovites bioculus* Afanasieva; Afanasieva, pl. 111, figs 1–11.
- 2000c *Nazarovites bioculus* Afanasieva; Afanasieva, pl. 1, figs 4, 5.

Holotype. – FF-POO1/092-09834 figured by Afanasieva (1997, pp. 7, 8, pl. 1, fig. 5), borehole Shuga-Yag-1003, Middle Frasnian, Domanic Formation, Timan-Pechora Province, Russia. The holotype and associated collection are deposited in the Federal Fund for boring-cores, paleontological and lithological collections, Aprel' Division of All-Russian Research Institute of Petroleum Geology (VNIGNI), Moscow.

Material. – 35 specimens.

Description. – The skeleton is constructed of three main rod-like thin spines intersected in one center at 90°, conditionally vertical (*vL*), horizontal (*gL*) and medial (*mL*). The

apical part of the *vL* spine carries two accessory arch-shaped by-spines (*l*) forming ring structures and situated at the same level. The main and by-spines possess a relatively long, robust, conical apophysis.

Dimensions. – Length of the *mL* spine 280–300 µm; length of the *gL* spine 270–280 µm, with diameter 20 µm; by-spine diameter 17–20 µm; ring structure radius 60 µm; length of the apophysis 10–80 µm, with diameter 5–10 µm.

Occurrence. – Upper Devonian, upper Frasnian Gryaznukha Formation; right bank of Gryaznukha Brook, section S-0011, beds 10, 18, 25, 27, SW Rudny Altai, southwestern Siberia, Russia.

Nazarovites pinnula Afanasieva, 2000

Figure 6T

- 1999 *Ceratoikiscum* sp.; Boundy-Sanders *et al.*, pl. 1, fig. H.
- 2000a *Nazarovites pinnula* Afanasieva; Afanasieva, pl. 112, figs 1–9.
- 2000c *Nazarovites pinnula* Afanasieva; Afanasieva, pl. 1, figs 7, 8.

Holotype. – FF-POO1/093-09508 figured by Afanasieva (2000c, pl. 1, fig. 7), Lyayol' River, middle Frasnian, Domanic Formation, Timan-Pechora Province. The holotype and associated collection are deposited in the Federal Fund for boring-cores, paleontological and lithological collections, Aprel' Division of All-Russian Research Institute of Petroleum Geology (VNIGNI), Moscow.

Material. – 35 specimens.

Description. – The skeleton is constructed of three main rod-like thin spines intersected in one center: conditionally, vertical (*vL*) is the most long and thin, horizontal (*gL*) and medial (*mL*) spines are short, and can be thin or robust. Several additional arch-shaped by-spines (*l*) are robust and situated on two levels: the lower spines are slightly curved, and the upper ones are strongly curved forming ¼ ring structures. Main and by-spines possess a short, robust conical apophysis.

Dimensions. – Length of the *vL* spine 200–210 µm; length of the *gL* spine 130–150 µm, with diameter 10–12 µm; length of *l* spine 160–210 µm; by-spine diameter 10 µm.

Occurrence. – Upper Devonian, upper Frasnian Gryaznukha Formation; right bank of Gryaznukha Brook, section S-0011, SW Rudny Altai, southwestern Siberia, Russia.

Conclusions

Advanced studies of radiolarian faunas from Upper Devonian strata of the Rudny Altai reveals the domination of spherical entactiniids in the Frasnian. This coincides completely with data known from their global distribution (Nazarov 1988, Braun 1990, Nazarov & Ormiston 1993, Aitchison 1993, Won 1997, Aitchison & Stratford 1997, Aitchison *et al.* 1999, Boundy-Sanders *et al.* 1999, Afanasieva 2000a, Wang *et al.* 2000, Luo *et al.* 2002, Umeda *et al.* 2004). Increasing diversity of ceratohyalids in the upper Frasnian fauna from the Rudny Altai has already been mentioned in previous reports (Umeda *et al.* 2004, Obut *et al.* 2007). Further detailed study also reveals an abundance of spiny palaeosconids and palacantholithids in the upper Frasnian association.

Continuing radiolarian findings embrace the stratigraphical interval from the top of Givetian to uppermost Frasnian. This data might be used to establish a radiolarian zonation for the Frasnian Stage of SW Siberia.

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