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Articles

Aulacoseira capitalina sp. nov. (Bacillariophyta) from the Middle Miocene sediments of the Barguzin Valley, Baikal Rift Zone (Russia)

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Using light and scanning electron microscopy, a new species *Aulacoseira capitalina* Titova et Usoltseva from the Middle Miocene deposits of the Barguzin Valley is described. It is shown that the new species is similar to other elliptical species in terms of elliptical valve face profile, diameter, deep ringleist, but differs in the shape of separating spines, the absence of ridge structure and the shape of rimoportulae. The finding of *A. capitalina* in the Middle Miocene deposits of the Barguzin Valley expands the range of distribution of elliptical species.

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Keywords

Aulacoseira capitalina, elliptical valves, fossil diatoms, Middle Miocene

Introduction

The Barguzin Valley is the largest intermountain depression located between the Barguzin and Ikat ridges to the northeast of the Svyatoy Nos peninsula and the Barguzin Bay of Lake Baikal (Fig. 1). It is one of the axial structures of the Baikal Rift Zone.

We started the study of diatoms from the Miocene–Pliocene deposits of the Barguzin Valley in 2012. Since then, diatoms from cores 532, 531 and 545 have been studied (Usoltseva et al. 2019; Hassan et al. 2019; Usoltseva et al. 2020).

It was shown that *Aulacoseira* Thwaites species dominated in all cores. Only one core (532) contained *Aulacoseira* with an elliptical valve. Previously, diatoms with an elliptical valve shape were not mentioned in the fossil deposits of the Baikal Region. Their findings are known from freshwater Miocene deposits of the submarine Yamato Rise, Japan Sea (Akiba et al. 1996; Burckle and Akiba 1978; Tsoy et al. 1985; Tsoy and Shastina 1999; Usoltseva and Tsoy 2010; Tsoy and Usoltseva 2016), North Korea (Iwahashi 1935), Oregon, USA (Van Landingham 1967), Japan (Morita et al. 1996; Tanaka et al. 2008; Tanaka and Nagumo 2011), and Primorye (Pushkar et al. 2019). The purpose of this work was to study elliptical *Aulacoseira* using light and scanning microscopy, to compare them with other species with elliptic valves and to describe a new species.

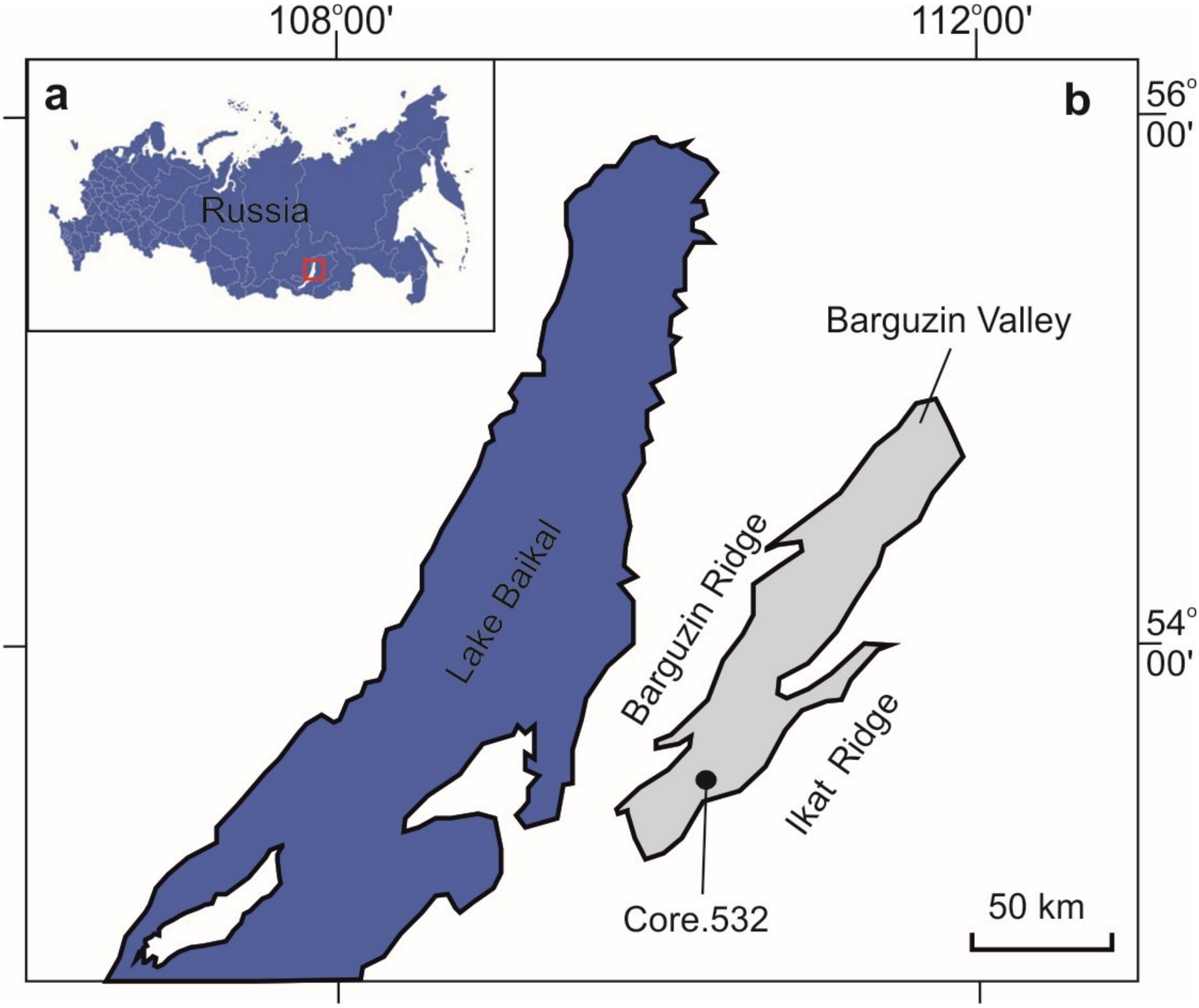

Figure 1. *Location of the core 532.*

Material and methods

The new species was found in the sample 94 m from core 532 taken on the southeast of Barguzin Valley by Baikal branch of Sosnovgeology "Urangeologorazvedka".

Preparation of samples for light microscopy and quantitative accounting was carried out according to the method described in [Grachev et al. 1998]. Cleaned valves were dried on cover slips and mounted in Naphrax (Naphrax Ltd., United Kingdom, refractive index = 1.74) and counted using light microscopy Axiovert 200 ZEISS LM (Carl Zeiss, Jena, Germany) equipped with a Pixera

Penguin 600CL camera. Diatom frustules were broken by crushing a drop of the material between two cover glasses. The material was then placed on the stub for mounted on and coated with gold using a SDC 004 (BALZERS) ion sputter for 150 seconds at 10–15 mA. The sample was analysed using a SEM Quanta 200 (FEI Company, USA) at 21.5 kV and 10 mm working distance.

Results

Aulacoseira capitalina **Titova et Usoltseva sp. nov.** (Figures 2–5).

Type locality: Russia, Barguzin Valley

Material examined: Middle Miocene sediments in Barguzin valley, core 532 (53°44'28.1"N; 110°11'31.3"E).

Holotype: NS0046231 (Central Siberian Botanical Garden, Novosibirsk, Russia, Herbarium of Vascular Plants) Holotype specimen is illustrated in Figure 2D.

Isotypes: Slide № 532–94, SEM stubs 14047, 15818, 17547, 17162, 17164 deposited at Limnological Institute of SB RAS, Irkutsk, Russia.

Habitat: collected from sample 94 m, 532 core.

Etymology: New species is dedicated to the mother of one of the author Titova Kapitalina Anatolyevna.

Description: Valves cylindrical, elliptical valve face 9–18 µm in diameter in the apical axis and 9–16 µm in diameter in the transapical axis, 4.4–15 µm in height. The height/diameter ratio varies within 0.31–0.85. The ratio of diameter to apical and transapical axes is 1–1.3.

Mantle striae straight, 8–12 in 10 µm. Each stria comprises a single row of areolae, 8–10 in 10 µm. Linking spines wide spathulate. Separating spines short or elongated pointed with rounded ends. Ringleist deep. Ringleist aperture 3–6.7 µm wide. Rimoportulae (4–8) with straight stalk are embedded in the ringleist. The channels of rimoportulae penetrate through the ringleist and open into the first areola of the row.

A. capitalina f. *capitalina* Titova et Usoltseva. Valves are straight along the central axis.

A. capitalina f. *curvata* Titova et Usoltseva. Valves are curved along the central axis.

Differential diagnosis. *A. capitalina* is similar to other elliptical species in terms of elliptical valve face profile, diameter, deep ringleist, but differs in the shape of separating spines, the absence of ridge structure, and the shape of rimoportulae.

LM and SEM observation. LM observation shows that *A. capitalina* has an elliptical flat valve face without areolae (Figs 2A, 4B, 4C) or with areolar ring at the periphery (Figs 2B, 4A). The valves are variable in size (Fig. 2B–E) and in shape from narrow (Figs 2 A, D–H, J–P, 4 B–J) to broadly elliptical, almost round (Figs 2B, C, I, 4 A).

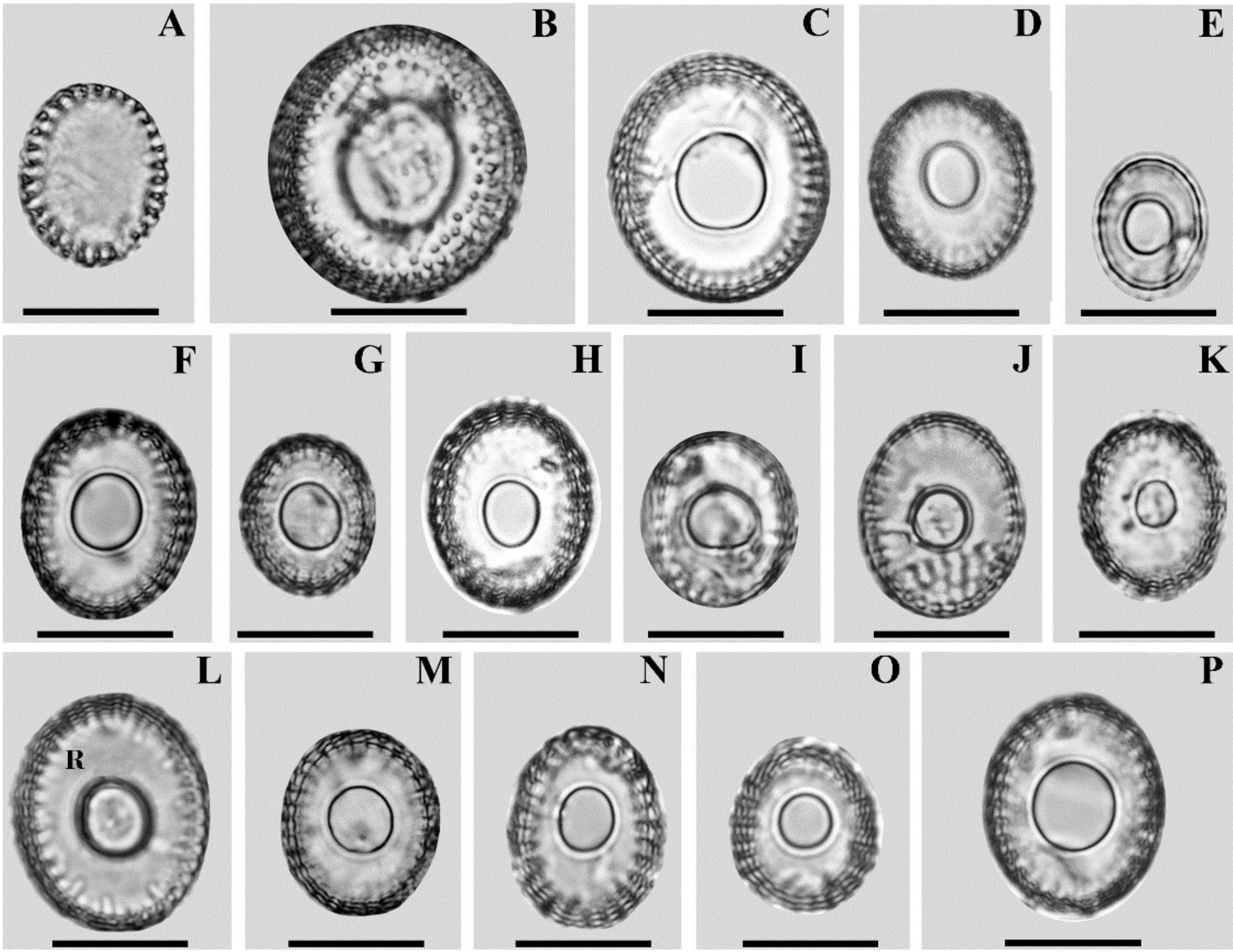

Figure 2. *Aulacoseira capitalina sp. nov.: **A**, **B** – external views; **C**–**P** – internal views showing a ringleist (R), variability of aperture of ringleist in their shape. **D** – holotype. LM. Scale bar: 10 µm.*

Frustules are short cylinders, straight (Figs 3A, B, F, 4I, J, L) or curved (Figs 3C–E, 4G, H, K, M) along the central axis. The longest chain found had eleven valves (Fig. 3C). The ringleist is very deep, 3.5–4.6 µm (Figs 2 C–P, 4 D–F). The shape of the ringleist aperture (3–6,7 µm) varies and may be oval (Figs 2D, E, H, N, 4F), wide and round (Figs 2B, C, F, M, O, P, 4D), small and round (Figs 2J, K, 4E) or uneven (Fig. 2D, G, I).

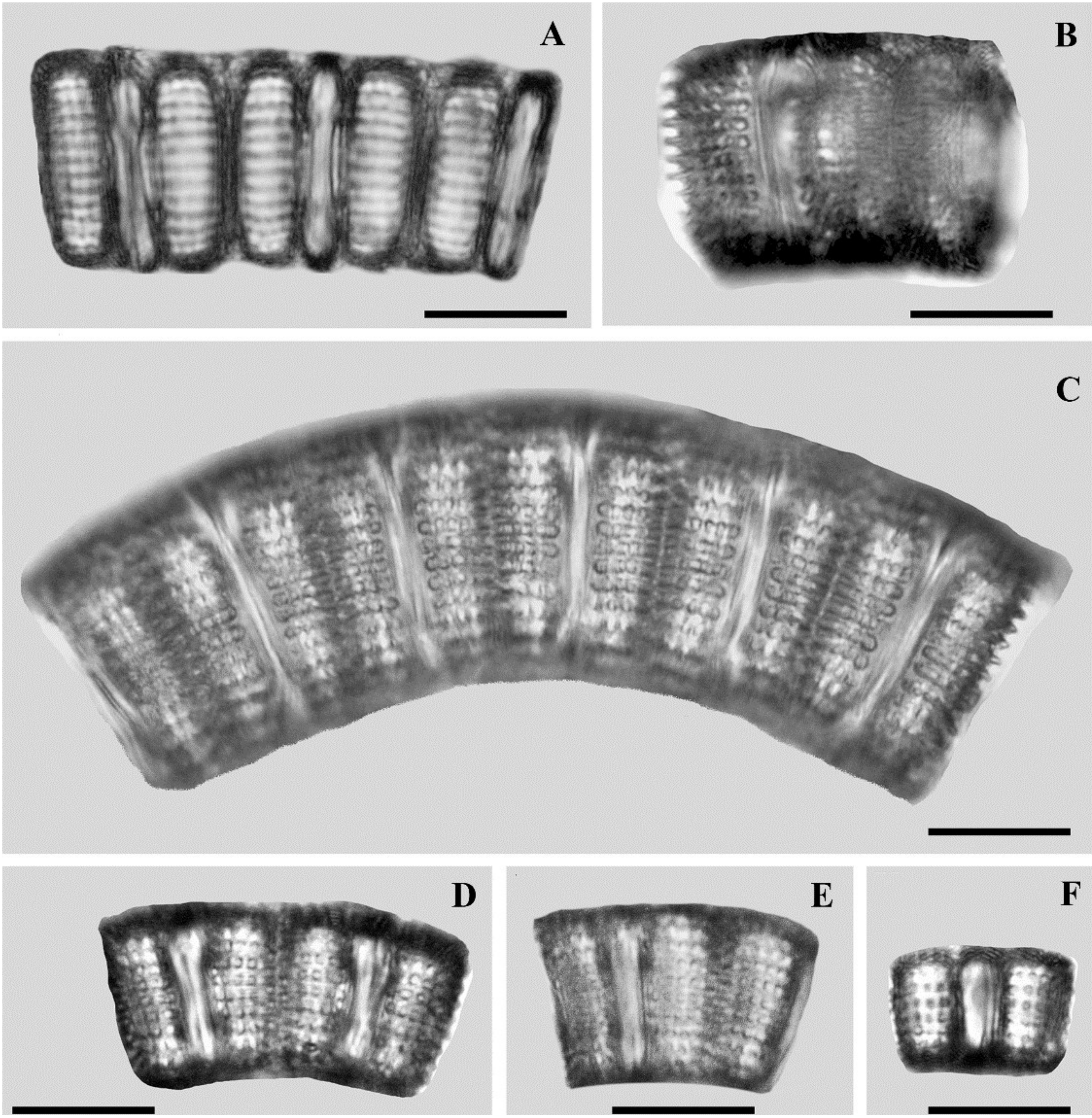

Figure 3. *Aulacoseira capitalina sp. nov.: **A** – internal views; **B**–**F** – external views, showing different size of the valves. LM. Scale bar: 10 µm.*

The collar is not broad but ribbed, 1.1–2.8 µm (Fig. 4G–M). Linking spines are broadly spathulate (Fig. 4H–L, O, Q), located between the rows of areoles, with a frequency of one spine per one row. Separating spines short or elongated pointed with rounded ends (Figs 3B, C, 4J, L–N, P). Round areolae located on the mantle in straight rows (Figs 3A–F, 4G–M).

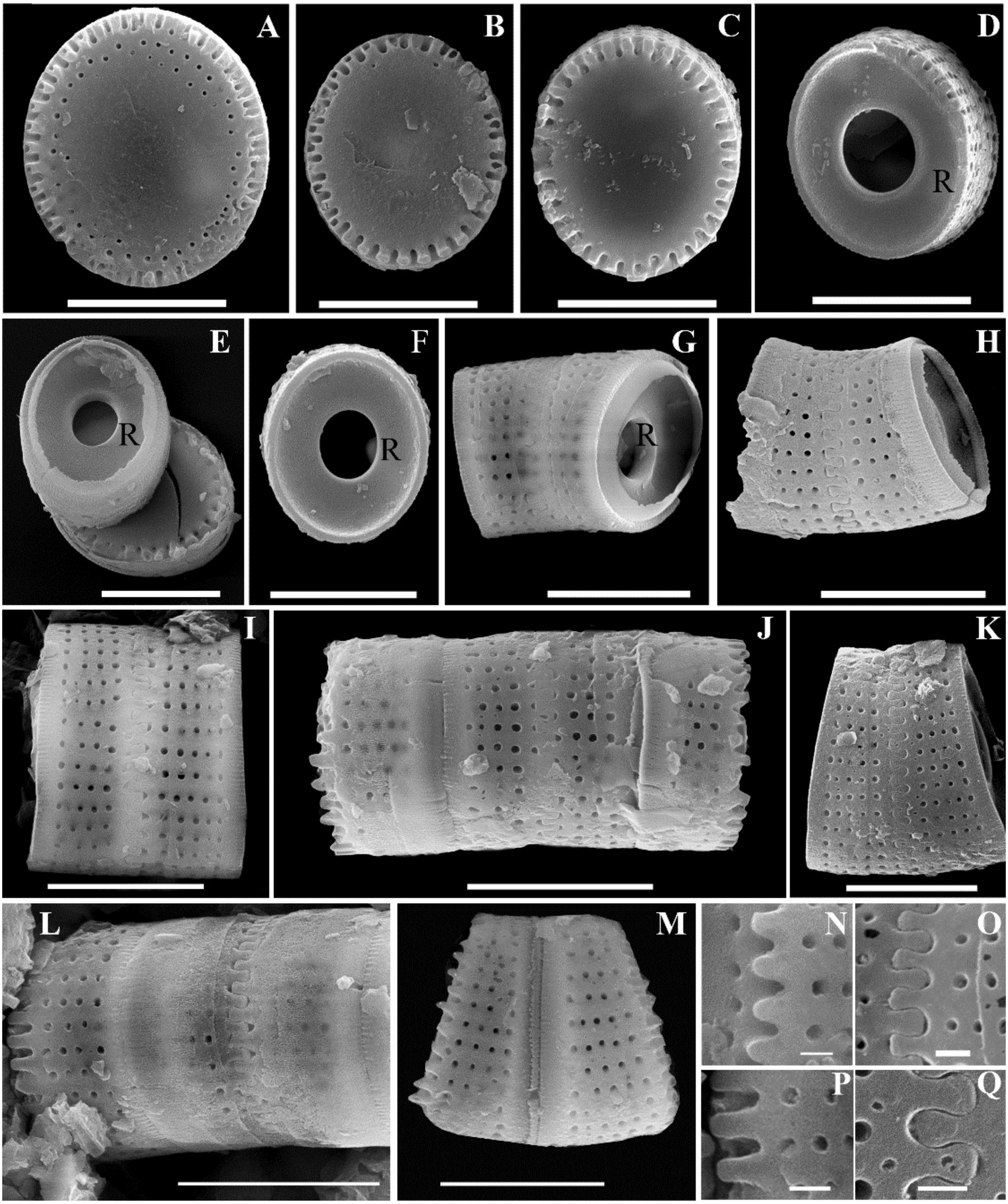

Figure 4. *Aulacoseira capitalina sp. nov.*: ***A–Q*** *– external views;* ***A*** *– valve face with areolar ring at the periphery;* ***B***, ***C*** *– valve face without areolae;* ***D–F*** *– variability of aperture of ringleist in their shape;* ***H–M*** *– girdle view, showing valves with spines;* ***N***, ***P*** *– separating spines;* ***O***, ***Q*** *– linking spines.* ***R*** *– ringleist. SEM. Scale bar:* ***A–M*** *– 10 μm;* ***N–Q*** *– 1 μm.*

Areolae of thick–walled cells seen from outside have 4–5 volae running to the centre (Fig. 5A), from inside – a bell–like plate (Fig. 5B, C, F) with radial perforations attaches to them. On some valves, you can see that they are completely covered inside with a plate (Fig. 5E) or the remains of this plate are visible (Fig. 5F, H, L). Rimopurtulae with straight stalk are embedded in the ringleist (Fig. 5C, D, G–L, O). The channels of rimoportulae straight or curved penetrate through the ringleist and open into the first areola of the row (Fig. 5F–H, M, N, P).

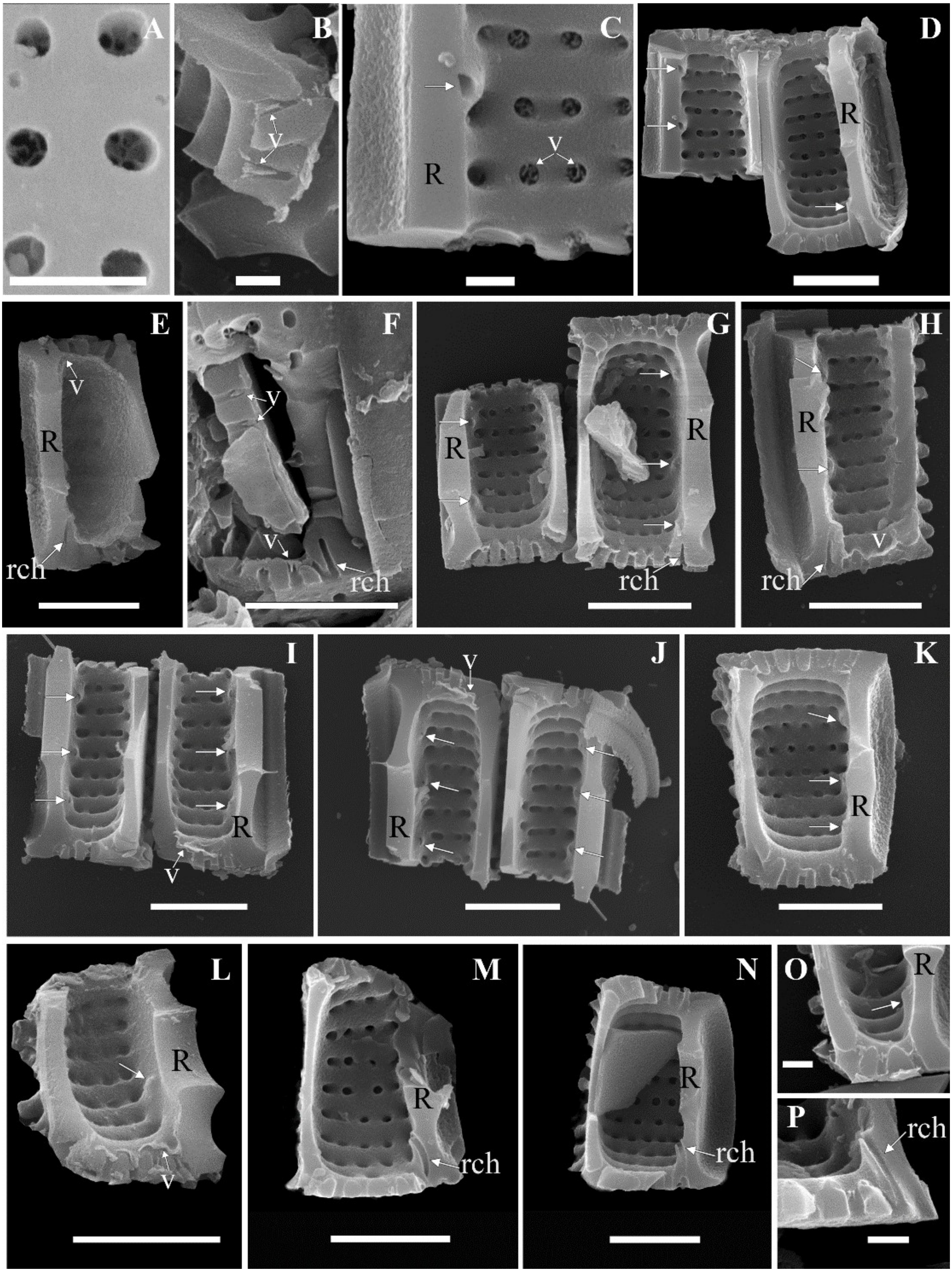
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Figure 5. *Aulacoseira capitalina sp. nov.: **A** – external view showing areolae velum; **B–P** – internal views showing areolae velum (**B**, **C**, **E**, **F**), rimoportulae position (**C–P**) and channel of rimoportula (**E–H**, **M**, **N**, **P**). **V** – velum, rch – rimoportulae channel, arrows – rimoportulae. SEM. Scale bar: **D–N** – 5 µm; **A–C**, **O**, **P** – 1 µm.*

Discussion

Aulacoseira is a freshwater planktonic genus that has been widely distributed from the Eocene to nowadays. In most *Aulacoseira* species, the frustule is circular in valve view (Simonsen 1979). Elliptical valves have 5 taxa: *Aulacoseira ovata* Usoltseva et Tsoy, *A. elliptica* Tsoy et Usoltseva, *A. hachiyaensis* Tanaka, *A. iwakiensis* Tanaka et Nagumo and *Melosira distans* var. *ovata*. The features of the proposednew species *A. capitalina* and the other elliptical *Aulacoseira* taxa are shown in Table 1.

Taxon	*M. distansvar. ovata*	*A. ovata*	*A. elliptica*	*A. hachiyaensis*	*A. iwakiensis*	*A. capitalina*
Height of valves	5–7	2.2–9.8	2.4–11.3	6–11	3–6	4.4–15
Diameter of valve (µm)	8–21	9–15 a.a 5.9–10 t.a	6–16.8 a.a 5.8–13 t.a	11–19 a.a 8.5–12 t.a	8–15 a.a 6.5–13 t.a	9–18 a.a 9–16 t.a
Number of areolar rows in 10 µm	–	6–16	8–14	8–10	14	8–12
Number of areolae in 10 µm of a row	10–13	8–20	9–15	10–12	16	8–10
Areolae on the valve face	over the entire valve face	with areolae over the entire valve face, without areolae or only on the periphery	without areolae or only on the periphery	with areolae over the entire valve face or without areolae	over the entire valve face dense or rare	without areolae or only on the periphery
Linking spines	–	spatulated	hastate	spatulated	spatulated	wide spatulated 1.2–1.6 µm
Separating spines	–	finely tapered	pointed	pointed	pointed	short or elongated pointed with rounded ends
Ringleist (R)	deep	deep	deep	middle or deep	shallow–middle	deep 3.5–4.6 µm
Aperture of ringleist , d (µm) and shape	medium or big round	2.2–9.1 square or rectangular with rounded angles, round or oval	2.2–6.9 small round or seldom oval	round, square with rounded angles* or transapically stretched*	round or square with rounded angles* or transapically stretched*	4–6.7 a.a3–6.5 t.a oval, seldom round
Ridge	absent	1, flat shallow	1, flat shallow	1–2, from well round to flat shallow	absent	absent
Rimoportulae (rp)	–	3–4 stalks lying diagonal on the R, external opening of rp are open into areola	4–5 sessil on the R, external opening of rp are associated with areola	6–8 sessil* on the R or slightly removed from the R	5–6 stalks lying straight or diagonal on the R, external opening of rp are associated with areola	4–8 stalks lying straight on the R, external opening of rp are open into areola
Location	Korea, Ranan	Takuyo Bank, Japan Sea	Yamato Bank, Japan Sea	Japan, Hachiya Formation	Japan, Shichiku Formation	Russia, Barguzin valley, core 532
Age	–	Early Miocene	Early Miocene	Early Miocene	Early Miocene	Middle Miocene
References	Iwahashi 1935	Usoltseva and Tsoy 2010	Usoltseva and Tsoy 2010	Tanaka et al. 2008	Tanaka and Nagumo 2011	present data

Table 1. *Morphological characters of elliptical Aulacoseira (Melosira)*

*data was given from published figures. a.a. – apical axis, t.a. – transapical axis, – no information.

Aulacoseira capitalina is similar to *Melosira distans* var. ovata in the valve face profile, in diameter and in deep ringleist, but differs in height, in number of areolae in 10 µm of a row and in the absence of areolae on the valve face. It is obvious that it is impossible to carry out complete comparison of these species as there is no information on elements of the frustules fine structure. We have seen only three schematic drawing in Iwahashi (1935).

A. capitalina is similar to *A. ovata* in the valve face profile, in linking spines, in deep ringleist, in absence of areolae on the some valve face or their location along the ring, in external opening of rimoportulae, but differs in greater variability in height and diameter, in lower density of areolae, in shape of separating spines, in ringleist aperture, in absence of ridge, in number and shape of rimoportulae.

A. capitalina is similar to *A. elliptica* in the valve face profile, in height and diameter, in areolae location on the valve face, in deep ringleist and aperture of the ringleist, but differs in lower density of areolae, in shape of separating spines, in absence of ridge, in number and shape of rimoportulae.

A. capitalina is similar to A. *hachiyaensis* in the valve face profile, in height and diameter, in number of areolae in 10 µm of a row, but differs in number of areolae in 10 µm of a row, in areolae location on the valve face, in shape of spines, in absence of ridge, aperture of the ringleist and in shape of rimoportulae.

A. capitalina is similar to *A. iwakiensis* in diameter, in absence of ridge, in shape of rimoportulae, but differs in height, in lower density of areolae, in areolae location on the valve face, in shape of spines, in ringleist aperture.

Thus, the elliptical valve face profile, diameter, deep ringleist, and thick valve walls are common to all elliptical *Aulacoseira*. These characters are probably ancient, since they are found in representatives of *Aulacoseira* from the Early Miocene deposits. The ridge structure found in *A. ovata, A. elliptica, A. hachiyaensis* can also be attributed to ancient characters.

The unique features of *A. capitalina* are the shape of the separating spines and the shape of the rimoportulae. Other characters are similar to other species that have a round valve face profile. For example, the velum in *A. capitalina* is similar to that of *Aulacoseira baicalensis* (K. Meyer) Simonsen and *A. nyassensis* (O. Müll) Simonsen. It is known that these species are endemic to Lakes Baikal and Nyasa. Previously, it was assumed that the characters of the velum in this species may have an adaptive function suited to the conditions in deep water (Crawford, Likhoshway, 2001).

Rimoportulae of *A. capitalina* are similar to that of *Melosira californica* (Ehrenbeg) Ralfs from Oregon (Fig. 23 in Likhoshway and Crawford 2001). They are represented by straight stalks that open into the first areola of the row. One more species, *A. canadensis* (Hustedt) Simonsen has rimoportulae such as stalk lying on ringleist. But, unlike the above species, the channels are diagonal and open below the first areola of the row with a small round opening. This type of rimoportulae is regarded as a feature of ancient *Aulacoseira* species (Likhoshway and Crawford 2001).

Species of *Aulacoseira* with an elliptical valve surface have been found in Early Miocene deposits of Japan and Japan Sea (Usolteva and Tsoy 2010). Thus, the elliptical *Aulacoseira* in this region may be Early Miocene markers. The age of the Korea deposits where *Melosira distans* var. ovata is still not well defined. The finding of *A. capitalina* in the Middle Miocene deposits of the Barguzin Valley expands the range of distribution of elliptical species.

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