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REGULAR PAPER

# Morphology of *Actinocyclus* and *Lobodiscus* species (Bacillariophyta) from the Miocene deposits of the Vitim Plateau, Russia

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**Background and aims** – In 2006, during a field expedition in the Amalat (Southern) paleovalley of the Vitim Plateau, 85 samples were taken from sediments of a new key hole 7236. The composition and distribution of siliceous microfossils were studied with light microscope (Usoltseva et al. 2008). The prevailence of species of the planktonic genera of *Actinocyclus* Ehr. and *Aulacoseira* Thwaites was recorded. The aims of this paper were electron-microscopic investigations of fossil freshwater species *Actinocyclus* and *Lobodiscus* from the Miocene lacustrine sediments of a new key hole 7236, and the comparison of our morphological data with formerly published descriptions of known freshwater taxa of these genera.
**Methods** – Samples from the section 7236 were examined using LM and SEM. Abundance was calculated based on the LM slides.
**Key results** – Valve ultrastructure of dominant biostratigraphically valuable species of *Actinocyclus* and *Lobodiscus* from the Miocene freshwater sediments of the Vitim Plateau was for the first time studied with SEM. The comparison of results of carried out investigations with formerly published descriptions of known freshwater taxa of *Actinocyclus* and *Lobodiscus* permits to belong the studied species to *Actinocyclus gorbunovii* (Sheshukova) Moisseeva & Sheshukova and *A. krasskei* (Krasske) Bradbury & Krebs, to expand their certain morphometric data, as well as to describe *A. vitimicus* Usoltseva & Khursevich sp. nov., *A. intermedius* Usoltseva & Khursevich sp. nov. and *Lobodiscus peculiaris* Usoltseva & Khursevich sp. nov., with definite diagnostic features.
**Conclusion** – Freshwater extinct species of *Actinocyclus* can be used as stratigraphic markers. Thus, occurred planktonic taxa of *Actinocyclus*, including the new species of *A. vitimicus* and *A. intermedius*, described above, as well as *Lobodiscus peculiaris* together with dominant accompanying planktonic representatives of *Aulacoseira* represent the characteristic diatom complex in lacustrine sediments of the Upper Dzhilinda subformation recovered from key hole 7236 within the Amalat paleovalley (the Vitim Plateau). The Middle-Late Miocene age of studied lacustrine deposits agrees with K-Ar dating of lavas in this part of section.

**Key words** – Miocene, Vitim Plateau, freshwater *Actinocyclus*, *Lobodiscus*, new species, morphology, SEM, valves.

## INTRODUCTION

The Vitim Plateau is situated eastward from the Baikal Depression (fig. 1). Its tectonic and magmatic activity is presented by Mezozoic and Cenozoic sedimentary and volcanogenic beds. During a geological survey and drilling by the "Sosnovgeologiya" team, the borders of three main paleovalleys (Khoigot or Northern, Atalanga or Central, Amalat or Southern) buried by basalts were outlined (Rasskazov et al. 2000). Volcanosedimentary rocks of the Middle-Upper Miocene Dzhilinda Formation with general age range of lavas dating 15–9 My were widespread within these paleovalleys (Rasskazov et al. 2007). Lacustrine sediments of this formation, and especially of the Upper Dzhilinda subformation, often contained numerous valves of diatoms.

The study of the fossil diatom flora in this area started in 1970. More than fifty taxa were found in the deposits from

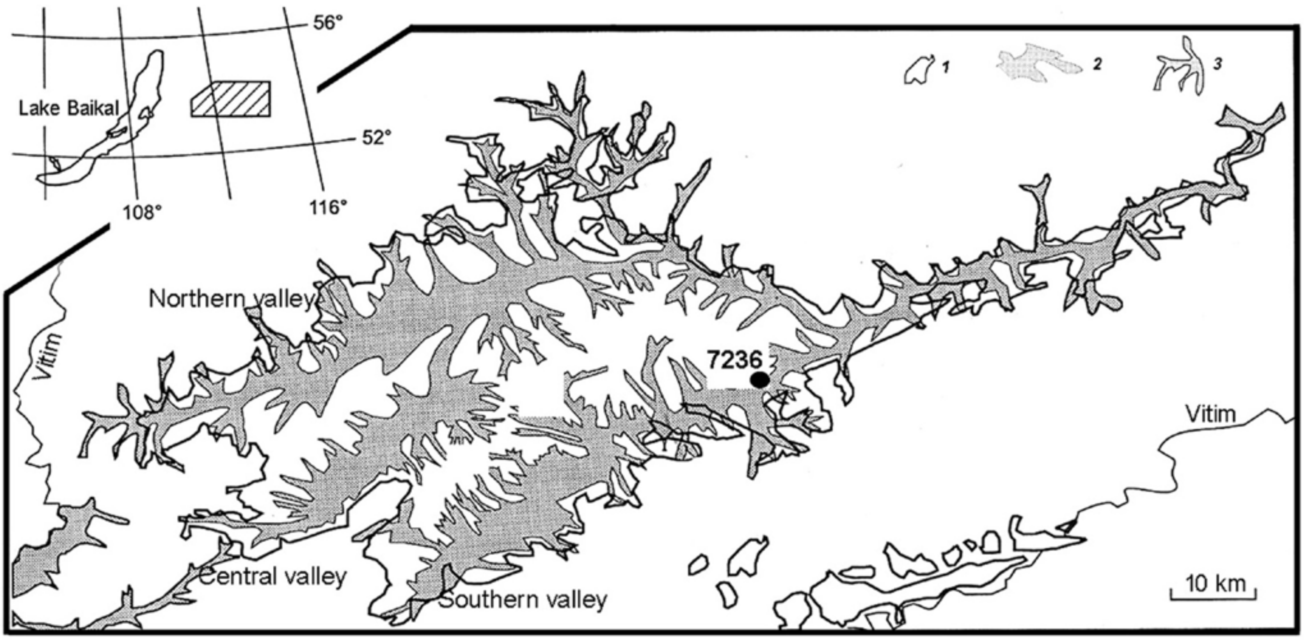


**Figure 1** – Configuration of paleovalleys buried by basaltic lavas from the Vitim volcanic field after data by Peshkov (Luchinin et al. 1992), and the position of the borehole 7236. The location of the Vitim Plateau is shown in the insertion. Shadings: basaltic lavas (1), paleovalleys buried (2) or unburied (3) by basaltic lavas.

the western part of the Northern paleovalley (Yendrikhinsky & Cheremisinova 1970). Among them, *Miosira* (= *Melosira*, *Aulacoseira*, *Alveolophora*) *jouseana* (Moisseeva) Krammer, Lange-Bertalot & Schiller and various *Aulacoseira* species dominated in the plankton. *Actinocyclus* species are represented by single specimens of *A. krasskei* (Krasske) Bradbury & Krebs (= *Coscinodiscus miocaenicus* Krasske) and *Actinocyclus* (= *Coscinodiscus*) sp. Later, Moisseeva (1984) identified fifteen diatom taxa in sediments from the eastern part of the Northern paleovalley. *Miosira jouseana*, some ancient taxa of *Aulacoseira* and *Actinocyclus* (= *Coscinodiscus*) *gorbunovii* (Sheshukova) Moisseeva & Sheshukova occurred with a rather high abundance in the diatom flora.

The diatom flora from the Miocene deposits of three main paleovalleys in the Vitim Plateau was studied by Chernyaeva (Rasskazov et al. 2001, 2007, Chernyaeva et al. 2007). Miocene lacustrine sediments of the Northern and Southern paleovalleys were characterized by different diatom dominants. The Miocene complex of diatoms from the Northern paleovalley was distinguished by the prevailence of *Miosira* (= *Alveolophora*) *areolata* (Moisseeva) Khursevich, *M. jouseana*, several coarsely ornamented species of *Aulacoseira*, *Concentrodiscus variabilis* Khursevich & Chernyaeva and *Actinocyclus* aff. *tunkaensis* Khursevich. The Miocene diatom complex from the Southern paleovalley differed by the dominance in many sections of ancient *Aulacoseira*, diverse *Actinocyclus* (*A. tubulosus* Khursevich, *A.* aff. *tunkaensis*, *A.* g*orbunovii*, *A. krasskei*), *Lobodiscus sibericus* (Tscheremissinova) Lupikina & Khursevich, *Pseudoaulacosira moisseeviae* (Lupikina) Lupikina & Khursevich, and *Miosira* (=*Alveolophora*) *tscheremissinovae* Khursevich. These dominant planktonic diatom complexes were clearly formed in a deep-water environment (Rasskazov et al. 2001, 2007, Chernyaeva et al. 2007).

In 2006 during the field expedition in the Amalat (Southern) paleovalley, 85 samples were taken from sediments of a new key hole 7236 drilled by the *Sosnovgeologiya* Geological Survey Corporation. The composition and distribution of siliceous microfossils (diatom valves, chrysophycean cysts and spicule sponges) were studied with light microscope (Usoltseva et al. 2008). The prevailence of species of the planktonic genera of *Actinocyclus* Ehr. and *Aulacoseira* Thwaites was recorded. *A.* g*orbunovii*, *A. krasskei* and *Actinocyclus* sp. were marked among the taxa of *Actinocyclus.*

The aims of this paper included scanning electron microscopy investigations of fossil freshwater species *Actinocyclus* and *Lobodiscus* from the Miocene lacustrine sediments of a new key hole 7236 recovered in the Amalat (Southern) main paleovalley, and the comparison of our morphological data with formerly published descriptions of known freshwater taxa of these genera.

## MATERIAL AND METHODS

Key section 7236 stripped lacustrine sediments, including two intervals of basaltic injections (sills), at the depth interval of 249–126 m**.** The lower sill (222–200 m) has a K-Ar dating 9.8 ± 0.5 My, the upper sill (165–157.5 m) – 12.6 ± 0.8 My, according to the method of Rasskazov et al. (2000). The sedimentary stratum is overlain by massive basalts (above 128 m) formed at about 10.8 ± 0.3 My. In the section, the studied lacustrine deposits represented by aleurolites and argillites belong to the Upper Dzhilinda subformation that agrees with the age inferred from the isotope dating of basaltic lavas noted above. Generally, 38 samples with various species of *Actinocyclus*, and only one sample with *Lobodiscus* species from the section 7236 were studied in SEM.

For LM, aliquots of the clean material were air-dried on individual coverslips that were mounted onto glass slides with Naphrax. Observations were made with LM Axiovert 200 ZEISS with camera Pixera Penguin 600CL at a magnification of × 1000. The abundance of diatom valves was calculated, according to the method described in Grachev et al. (1997).

For SEM, raw material was preliminarily treated with 30% hydrogen peroxide at 75°C for three hours, rinsed with distilled water three times and centrifuged. Then, diatom frustules were broken crushing a drop of the material between two cover glasses. Then the material was placed on the stub, dried, coated with gold in the vacuum SDC 004 (BALZERS), and examined with Philips SEM 525M. Terminology follows Ross et al. (1979) and Karayeva et al (1988).

## OBSERVATIONS

The results of diatom investigations showed a high abundance for species from the genera *Actinocyclus* and *Aulacoseira* in Miocene deposits of the key section 7236 recovered within the Amalat (Southern) main paleovalley.

The genus *Actinocyclus* is represented by the known extinct taxa *A. gorbunovii* and *A. krasskei*, and by the new species *A. vitimicus* and *A. intermedius.* Moreover, *Lobodiscus*

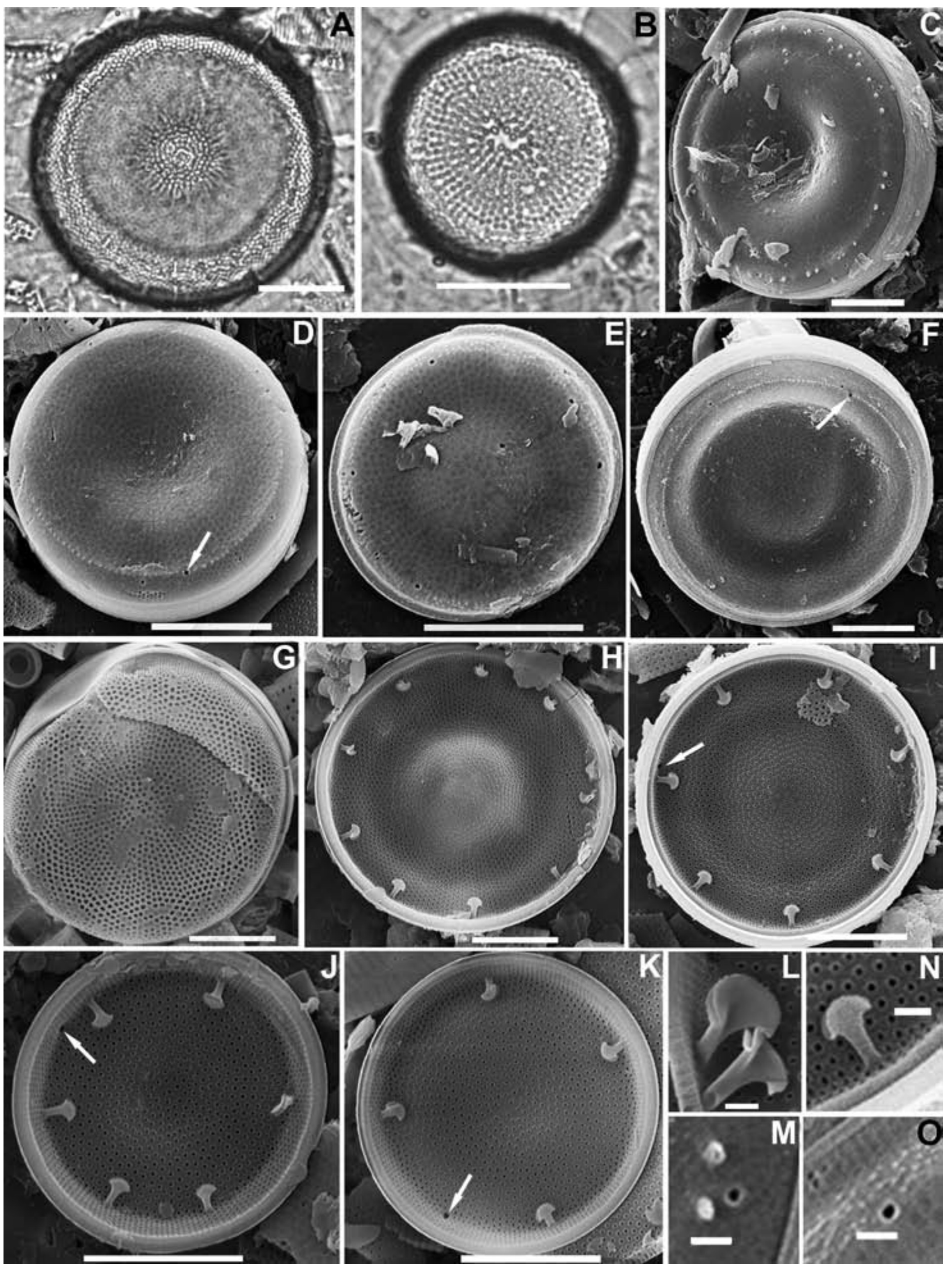


**Figure 2** – Morphology of the valves of *Actinocyclus gorbunovii*. A & B, LM, valve view; C–O, SEM. C–G, external valve view, note pseudonodulus (arrow); H–K, internal valve view showing a marginal ring of rimoportulae and pseudonodulus (arrow); L & N, internal expression of rimoportulae; M & O, external opening of rimoportula. Scale bars = 10 µm (A–K) or 1 µm (L–O).

**Table 1 – Chosen morphological characters of *Actinocyclus* and *Lobodiscus* species based on this paper and references.**
*: data obtained from published micrographs.

| Taxon | Height of valve mantle (µm) | Rows of areolae on valve mantle in 10 µm | Valve diameter (µm) | Areolae in 10 µm | Rows of areolae in 10 µm | Rimoportulae | | | Spines on valve face/ mantle junction | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Number | Internal expression | External expression | | |
| *A. gorbunovii* | 1–3.8 | 26–30 | 17–46.5 | 16–20 | 16–20 | 4–9 | high tube with arc-shaped slit in apical part | small round opening | present | present data |
| *A. gorbunovii* (= *Coscinidiscus gorbunovii* Sheshuk.) | - | - | 35–70 | - | 13–18 | - | - | - | present | Sheshukova-Poretskaya & Moisseeva 1964 (original description) |
| *A. gorbunovii* | 2–4 | 22–26 | 22–70 | 14–18 | 16–18 | 3–8 | high tube with arc-shaped slit in apical part | small round opening | present | Khursevich et al. 1990 |
| *A. krasskei* | 1.3–4.2 | 24–26 | 17.6–37.5 | 14–16 | 14–16 | 4–9 | not high tube with more or less straight or arc-shaped slit in apical part | small round opening | absent | present data |
| *A. krasskei* (= *Coscinodiscus miocenicus* Krasske) | - | about 20 rows of areolae | 11–47 | about 13 | - | - | - | - | absent | Krasske 1934 (original description) |
| *A. krasskei* (= *Coscinodiscus miocenicus* Krasske) | - | 20 | 11–47 | about 13 | - | - | - | - | absent | Lange-Bertalot (ed.) 1996 (Lectotypus A VII 25) |
| A. *krasskei* | - | - | 11–47 | 12–13 | - | - | relatively high narrow tube | very small opening | absent | Bradbury & Krebs 1995 |
| *A. krasskei* | up to 4 | 20–24 | 11–47 | 11–14 | 12–14 | 4–6 | not high tube with arc-shaped slit in apical part | small round opening | absent | Kozyrenko et al. 2008 |
| *A. vitimicus* sp. nov. | 0.8–2.2 | 26–28 | 17.7–36.5 | 16–18 | 16–20 | 3–4 (seldom 7) | not high tube with curved or arc- shaped slit in apical part | short protruding tube | absent | present data |
| *A. tubulosus* | 1–2 | 26–32 | 11–34 | 16–22 | 15–24 | 3–6 (seldom 9) | narrow tube with lateral straight slit in apical part | relatively not high protruding tube | present | Khursevich et al. 1990 (original description) |
| *A. theleus* | - | about 25 в 10 мкм | 11–35 | 13–18 | - | 4–5* | narrow, round tube having spade-shaped labiae with curved, slit-like opening in apical part | low nipple-like protrusion | absent | Bradbury & Krebs 1995 (original description) |
| *A. intermedius* sp. nov. | - | 26–30 | 19–34 | 20–26 (more often 20) | 18–28 (more often 20) | 4–5 | not high tube with arc-shaped slit in apical part | small round opening | absent | present data |

**Table 1 (continued) – Chosen morphological characters of *Actinocyclus* and *Lobodiscus* species based on this paper and references.** *: data obtained from published micrographs.

| Taxon | Height of valve mantle (µm) | Rows of areolae on valve mantle in 10 µm | Valve diameter (µm) | Areolae in 10 µm | Rows of areolae in 10 µm | Rimoportulae | | | Spines on valve face/ mantle junction | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Number | Internal expression | External expression | | |
| *Actinocyclus claviolus* | - | - | 17–60, typically about 27–30 | 13–14 | - | 4–6 * | presumably narrow, round tube; apical part broken | short, blunt, rather thick-walled tube with a narrow opening | absent | Bradbury & Krebs 1995 (original description) |
| *Lobodiscus peculiaris* sp. nov. | 1,7–5,5 | 26–30 | 26.5–64.8 | 14–18 | 14–18 | 6–7 | long narrow tube with a shoe-shaped slit in the apical part; this forms a right angle with the tube axis | small round opening | absent | present data |
| *Lobodiscus sibericus* | - | - | 40–147 | 12–16 | 14–18 | - | long narrow tube with a shoe-shaped slit in the apical part; this forms a right angle with the tube axis | very short tube, expressed directly under the lobed spine, or long tube penetrating the lobed spine | present | Lupikina & Khursevich 1991 (original description) |

*peculiaris* sp. nov. was revealed in the section 7236. The descriptions of these taxa occurred in the studied section are given below.

***Actinocyclus gorbunovii*** (Sheshukova) Moisseeva & Sheshukova (in Khursevich et al. 1990: 1439, pl. I, figs 1–5). – *Coscinodiscus gorbunovii* Sheshukova (in Sheshukova-Poretskaya & Moisseeva 1964: 94, pl. II, figs 1–5). – *Pontodiscus gorbunovii* (Sheshukova) Moisseeva & Sheshukova (in Temniskova-Topalova et al. 1981: 1310).

Frustule short, cylindrical, with intercalary bands; valvocopula wide and hyaline. Valves circular in outline (fig. 2A–K), with concave or convex centre (fig. 2C–E), or concentrically undulate (fig. 2A & F), 17–46.5 µm in diameter. Central area small, structureless (fig. 2B, J & K) or with one–several isolated areolae (fig. 2H & I). Areolae loculate with cribra on the external valve surface (fig. 2D &E) and foramina on the interior (fig. 2H–K), 16–20 in 10 µm; areolae arranged in radial rows, 16–20 in 10 µm, not forming fascicles. Hyaline ring with scattered areolae and more or less densely located spinules usually present on the valve face/ mantle junction (fig. 2C, D & F), with pseudonodulus (fig. 2D & F). Valve mantle from 1 to 3.8 µm high, perforated by fine areolae in vertical rows (26–30 in 10 µm). Marginal ring of rimoportulae (from 4 to 9) located at the base of short hyaline strips near the upper boundary of the mantle (fig. 2A & H–K); rimoportula internally with a comparatively high tube with arc-shaped slit in apical part (fig. 2H–L & N); externally terminating by a small round opening (fig. 2M & O).

Freshwater extinct species.

Middle Miocene: Primorsky region, Russia. Late Miocene: West Siberia, Transbaikalia, Primorsky region, Russia, and the Sofia and Karlovo Basins, Bulgaria.

In the studied section 7236, this species occurred in the Upper Miocene sediments in mass.

***Actinocyclus krasskei*** (Krasske) Bradbury & Krebs (Bradbury & Krebs 1995: 9, pl. 8, figs 2–6, 8–11, pl. 9, figs 1–3). – *Coscinodiscus miocaenicus* Krasske (Krasske 1934: 23, figs 5–7).

Frustule short, cylindrical, with intercalary bands; valvocopula wide and hyaline. Valves circular, from flat to concentrically undulate (fig. 3A–E & G), 17.6–37.5 µm in diameter. Central area absent (fig. 3J–K) or small with one-two isolated areolae (fig. 3F & H). Areolae loculate, having cribra externally (fig. 3E & L) and foramina internally (fig. 3H–K), 14–16 in 10 µm, located in radial rows, 14–16 in 10 µm, forming unclear fascicles. A narrow hyaline ring present on the boundary of the valve face and mantle (fig. 3C, D & G) or it lacks (fig. 3B). Pseudonodulus absent. Valve mantle 1.3–4.2 µm high, with vertical rows of small areolae (24–26 in 10 µm). Marginal ring of rimoportulae (from 4 to 9) located in upper part of mantle (fig. 3D, F & H–K); rimoportula internally with a relatively not high tube with arc-shaped slit (fig. 3N) or with a more or less straight slit (fig. 3M) in the apical part; externally terminating by a small round opening (fig. 3O).

Freshwater extinct species.

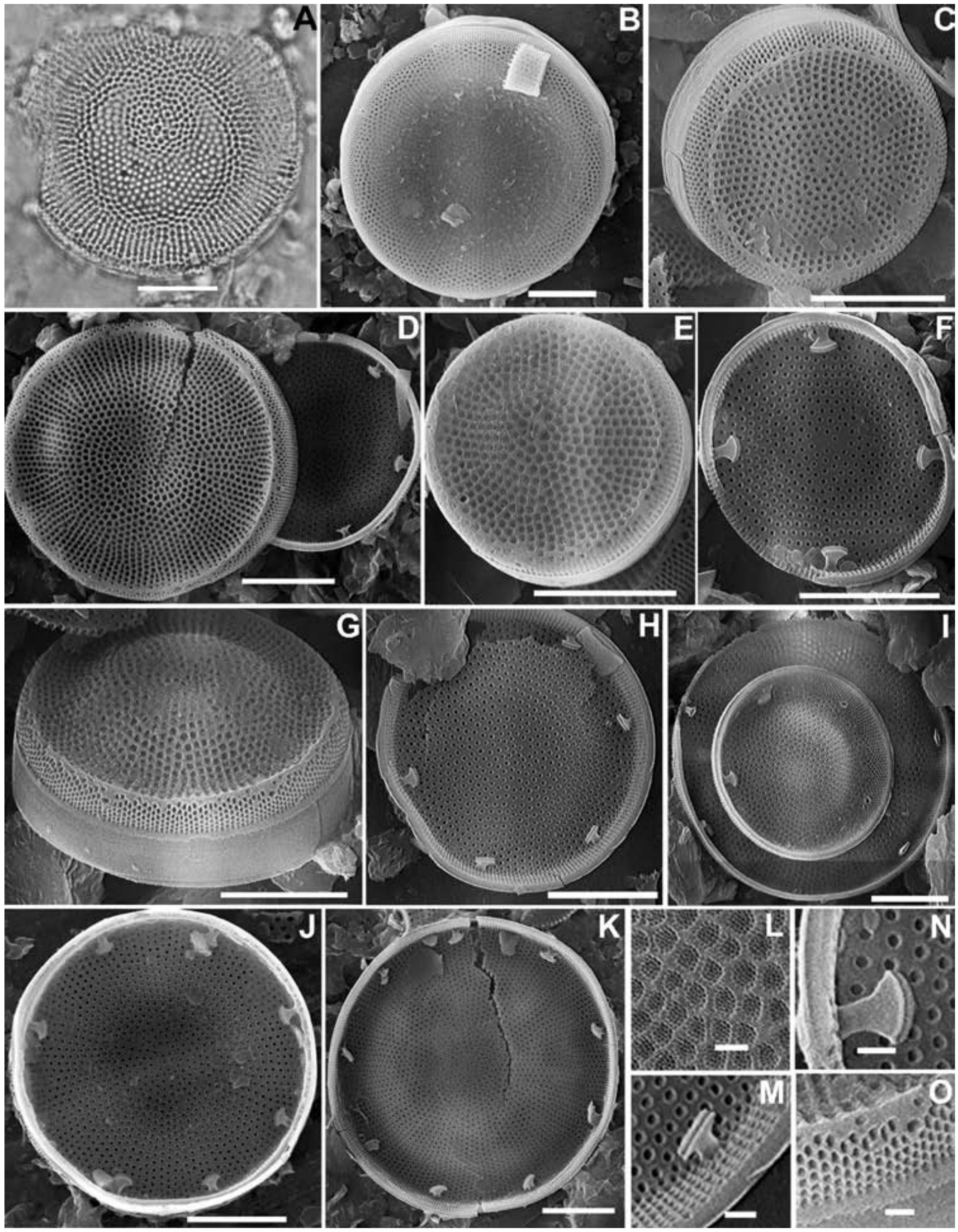


**Figure 3** – Morphology of valves of *Actinocyclus krasskei*. A, LM, valve view; B–O, SEM. B–E & G, external valve view showing openings of rimoportulae on the mantle; F & H–K, internal valve view showing a marginal ring of rimoportulae; L, external cribra in areolae; M & N, internal expression of rimoportula; O, external opening of rimoportula on the mantle. Scale bars = 10 µm (A–K) or 1 µm (L–O).

Early Miocene: West Siberia, Primorsky region, Russia. Middle Miocene: Western U.S.A. Middle–Late Miocene: Transbaikalia, Primorsky region, Russia. Late Miocene: Germany, Bulgaria, Russia (Lake Baikal, bottom sediments).

In the studied section 7236 this species was found in the Middle Miocene deposits in mass.

***Actinocyclus vitimicus*** Usoltseva & Khursevich, **sp. nov.**

Frustule short, cylindrical (fig. 4 A, B, F–J, O & P), with intercalary bands with ligula (fig. 4B & C). Valve circular, with concave or convex centre (fig. 4F & G), sometimes concentrically undulate (fig. 4B), 17.7–36.5 µm in diameter. Central area small, structureless (fig. 4H–J, O & P). Areolae loculate, with external cribra and internal foramina covered with half-spherical thin membranes (fig. 4Q), 16–18 in 10 µm; areolae arranged in radial rows, 16–20 in 10 µm, not forming fascicles. Pseudonodulus on the valve face/mantle junction (fig. 4H–J & P). Three-four, rarely seven, narrow, short hyaline strips in the submarginal zone of the valve face. Valve mantle 0.8–2.2 µm high, perforated by small areolae in vertical rows (26–28 in 10 µm). Marginal ring of rimoportulae located at the base of these strips on the boundary with valve mantle (fig. 4H–J, O & P); rimoportula internally with a low tube with a curved (fig. 4M & Q) or arc-shaped slit (fig. 4K, L & N) in the apical part; externally terminating by a short protruding tube (fig. 4B–G). – Type: holo-: slide 7236/177 (Limnological Institute of SB RAS, Irkutsk, Rus-

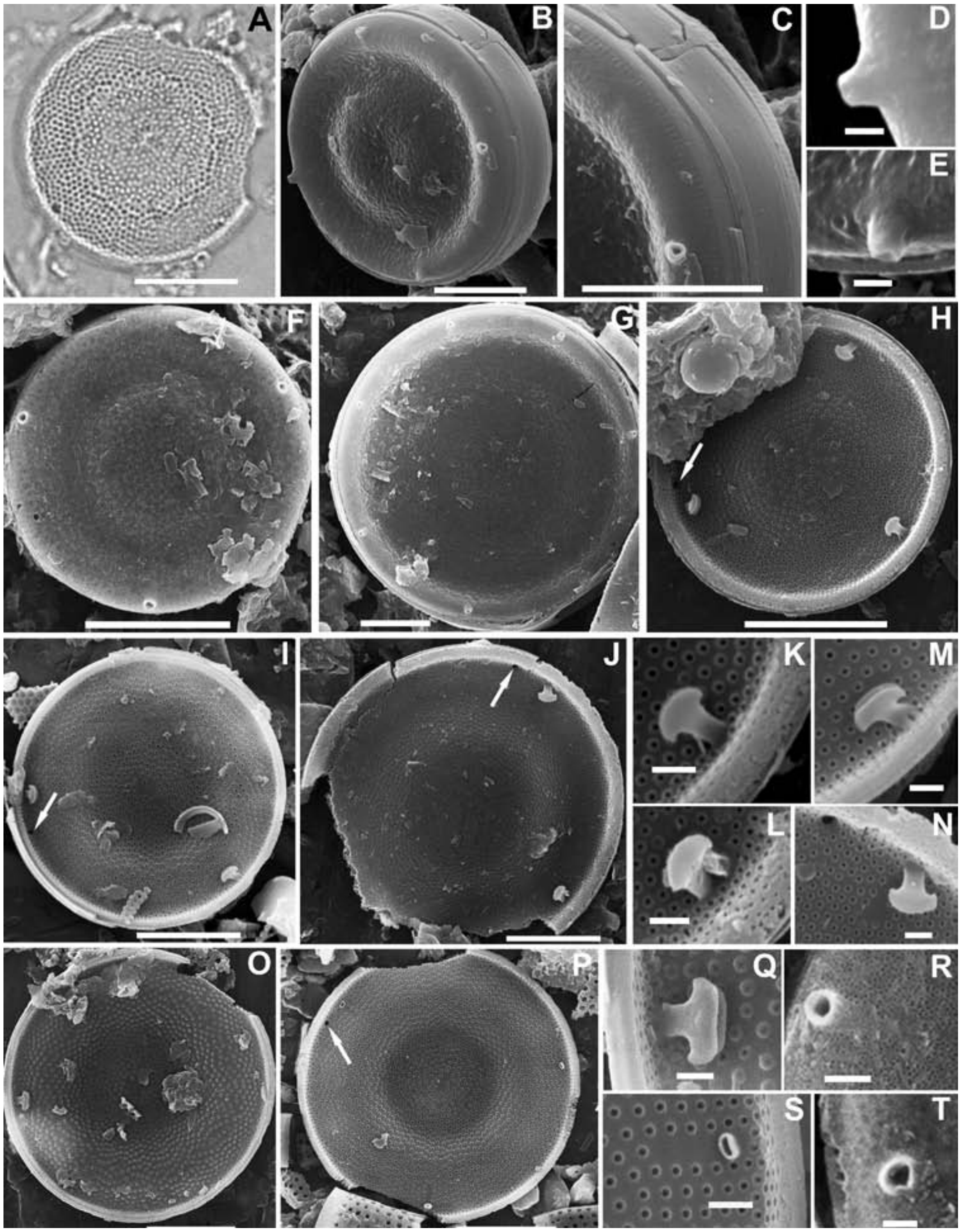


**Figure 4** – Morphology of valves of *Actinocyclus vitimicus*: A, LM, valve view; B–T, SEM. B, F & G, external valve view; C–E, fragments of valve (B) showing external short protruding tube of rimoportula; H–J, O & P, internal valve view showing a marginal ring of rimoportulae and pseudonodulus (arrow); K–N & Q, internal expression of rimoportula; R, external cribra in areolae and external short tube of rimoportula; S, fragment of valve (P) showing the location of broken rimoportula at the base of hyaline strip; T, external short protruding tube of rimoportula. Scale bars = 10 µm (A–C, F–J, O & P) or 1 µm (D, E, K–N & Q–T).

sia); iso-: slide 7236/172; stubs 9174, 0320, 0411 (Limnological Institute of SB RAS, Irkutsk, Russia). – Type locality: Russia, East Siberia, Vitim Plateau, Amalat (Southern) paleovalley, the borehole 7236, the depth of 177 and 172 m; lacustrine sediments of Middle Miocene age, common.

**Etymology** – Named after Vitim, the name of plateau in Transbaikalia where the type locality is situated.

**Comments** – This species differs from *Actinocyclus tubulosus* Khursevich (Khursevich et al. 1990: 1440, pl. I, figs 7 & 8, pl. II, figs 1–3), in having another expression of the rimoportula on the internal valve surface (in particular, in the presence of a relatively low tube with a curved or arc-shaped slit in the apical part), as well as in the absence of spines (table 1). The new species is distinguished from *Actinocyclus theleus* Bradbury & Krebs (Bradbury & Krebs 1995: 12, pl. 13, fig. 7; pl. 14, figs 1–4) by the different expression of the rimoportula not only internally, but also externally (table 1).

***Actinocyclus intermedius*** Usoltseva & Khursevich, **sp. nov.**

Frustule short, cylindrical. Valve circular, with slightly concave or convex centre (fig. 5A–E), sometimes with slightly radial undulation in the periphery of the valve face (fig.

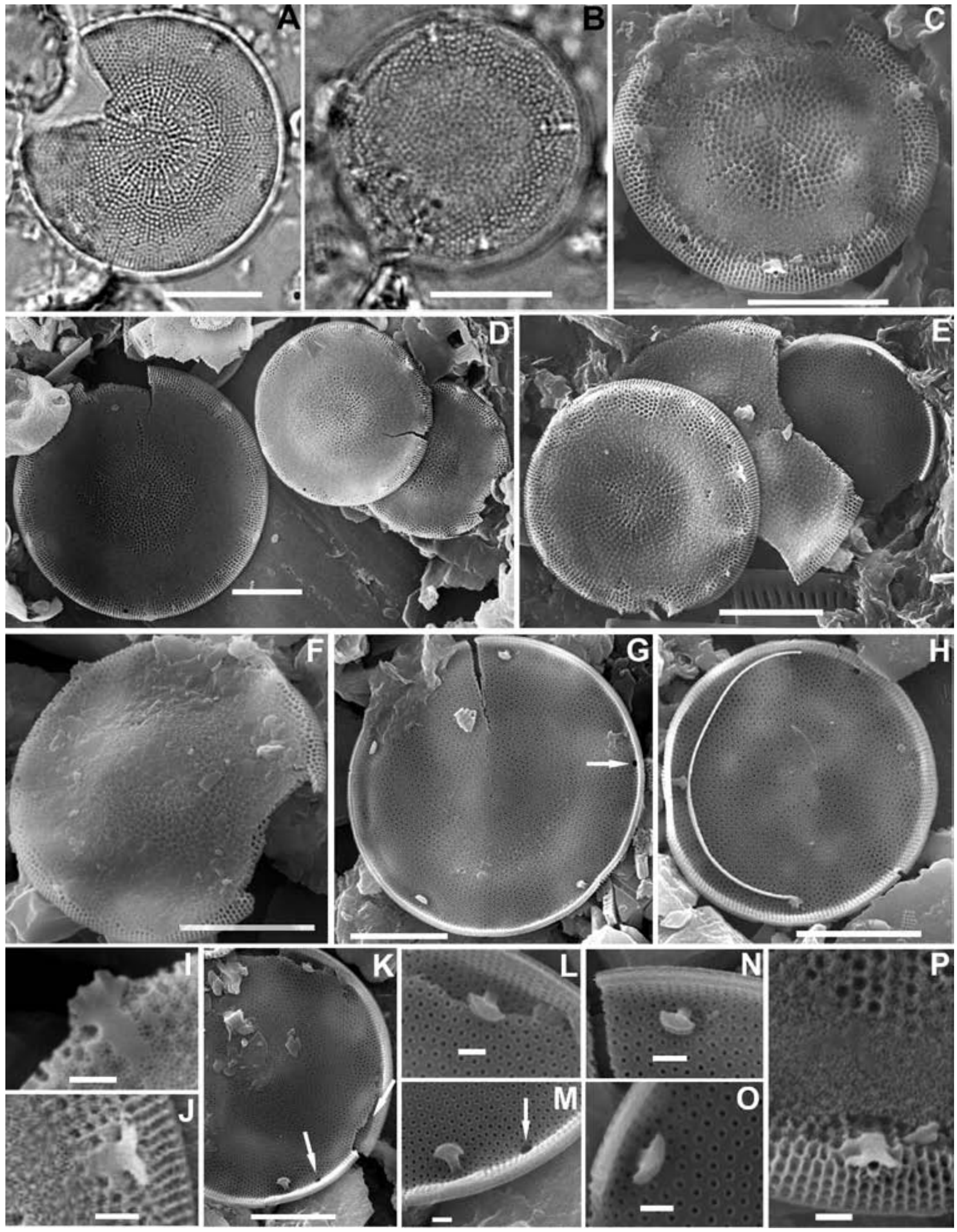

**Figure 5** – Morphology of valves of *Actinocyclus intermedius*: A & B, LM, valve view; C–P, SEM. C–E, external valve view; F, external valve view showing slightly radial undulation in the periphery of the valve face; G, H & K, internal valve view showing the location of rimoportulae and pseudonodulus (arrow); I & J, fragments of valves (F and E, respectively) showing external cribra in areolae and shapes of hyaline strips at the valve face/mantle junction; L, N & O, internal expression of rimoportula; M, fragment of valve (K) showing the location of rimoportula and pseudonodulus (arrow); P, fragment of valve (C) showing external opening of rimoportula at the base of hyaline strip. Scale bars = 10 µm (A–H & K) or 1 µm (I, J & L–P).

5F), 19–34 µm in diameter. Central area absent (fig. 5H) or small, with one-several isolated areolae (fig. 5G). Areolae loculate, having cribra externally (fig. 5E & F) and foramina internally (fig. 5G, H & K), 20–26 (more often 20) in 10 µm; areolae arranged in radial rows, 18–28 (more often 20) in 10 µm forming vague fascicles. Pseudonodulus seen on the valve face/mantle junction (fig. 5G, H & K). Valve mantle 1–2 µm high, with vertical rows of fine areolae, 26–30 in 10 µm. Marginal ring of rimoportulae (4–5) located at the base of short, but prominent hyaline strips expanded distally to form irregular, somewhat diminutive nail-, fin- or clove-shaped areas near the boundary of the valve face and mantle (fig. 5I & J); rimoportula internally with a comparatively not high tube with arc-shaped slit in apical part (fig. 5K–O); externally terminating by a small round opening (fig. 5P). – Type: holo-: slide 7236/181 (Limnological Institute of SB RAS, Irkutsk, Russia); iso-: slide 7236/182; stubs 9197, 9263 deposited at Limnological Institute of SB RAS, Irkutsk, Russia). – Type locality: Russia, East Siberia, Vitim Plateau, Amalat (South-

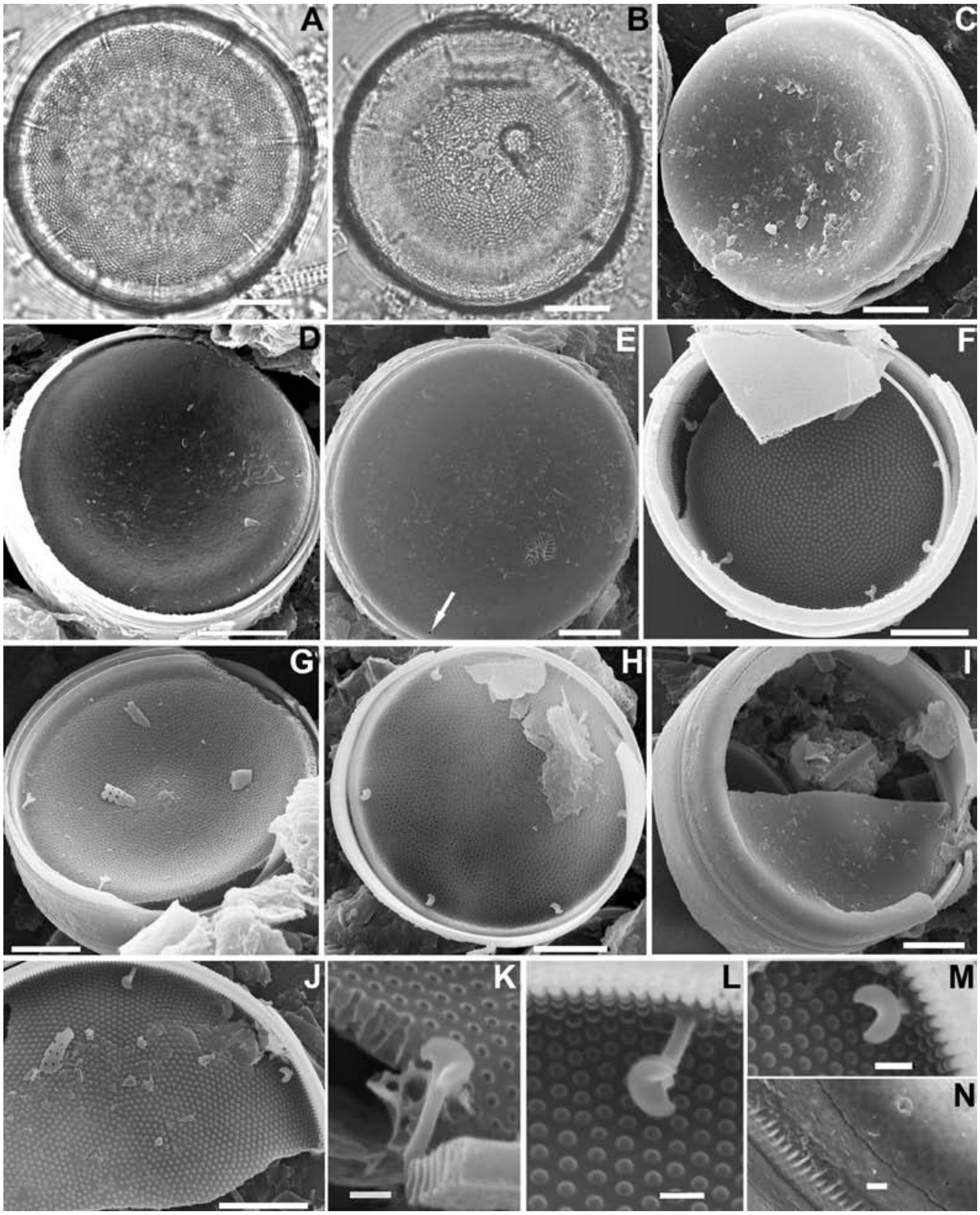


**Figure 6** – Morphology of valves of *Lobodiscus peculiaris*: A & B, LM, valve view; C–N, SEM. C–E & I, external valve view; E, probably pseudonodulus (arrow); F–H & J, internal valve view showing the location of rimoportulae; K, loculate areolae with broken internal domed velum; L & M, fragments of valve (J) showing internal domed velum in areolae and the internal expression of rimoportula; N, fragment of valve showing probably the external opening of rimoportula. Scale bars = 10 µm (A–J) or 1 µm (K–N).

ern) paleovalley, the borehole 7236, the depth of 181 and 182 m; lacustrine sediments of Middle Miocene age, common.

**Etymology** – Named after *intermedius* (Latin) = intermediate.

**Comments** – This species differs from *Actinocyclus claviolus* Bradbury & Krebs (Bradbury & Krebs 1995: 5–6, pl. 4, fig. 7, pl. 5, figs 1–5) by having a thinner areolation of the valve face surface (20–26 areolae in 10 µm in *A. intermedius* against 13–14 areolae in *A. claviolus*), a different structure of the rimoportula (table 1), as well as by the presence of a slightly radial undulation in the periphery of the valve face in some specimens.

***Lobodiscus peculiaris*** Usoltseva & Khursevich, **sp. nov.**

Frustule short, cylindrical (fig. 6A–I), with intercalary bands. Valve circular, 26.5–64.8 µm in diameter, with almost flat (fig. 6E) and concave (fig. 6C & D) or convex (fig. 6A & B) middle zone. Central area irregular, with several isolated areolae (fig. 6F–H & J). Areolae loculate (fig. 6K) with two-side velum: domed on the internal valve surface (fig. 6L & M) and probably flat continuous cribrum on the external one (fig. 6I); areolae 16–18 in 10 µm, arranged in radial rows, 16–18 in 10 µm, forming vague fascicles. Pseudonodulus on the boundary of the valve face surface and mantle (fig. 6E). Valve mantle 1.7–5.5 µm high, perforated by fine areolae in

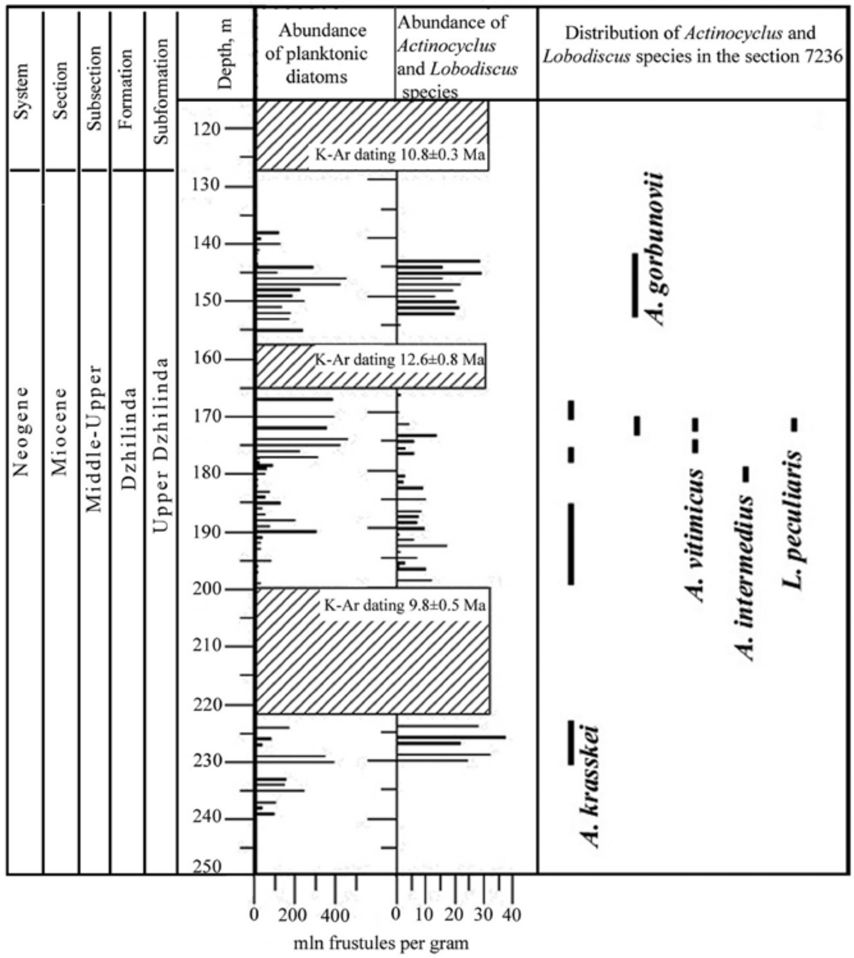


**Figure 7** – Abundance of planktonic diatoms and the distribution of species from genera of *Actinocyclus* and *Lobodiscus* in the key section 7236 within the Vitim Plateau. Oblique shading shows intervals of basaltic injections (sills) in the lacustrine sedimentary stratum of the section 7236.

vertical rows (26–30 in 10 µm). Small densely located spines sometimes observed on the valve face/mantle juncture (fig. 6D–E). Marginal ring of rimoportulae (6–7) located at the base of relatively long hyaline strips (fig. 6A) on the valve mantle (fig. 6F–H & J). Rimoportula internally with a long narrow tube (fig. 6K–L) with a shoe-shaped slit expressed in the apical part (fig. 6M) forming a right angle with the tube axis (fig. 6F–H & J–M). Externally, rimoportula terminating by a small round opening (fig. 6N). – Type: holo-: slide 7236/172 (Limnological Institute of SB RAS, Irkutsk, Russia); iso-: stubs 9166, 0810, 0696, 0695 (Limnological Institute of SB RAS, Irkutsk, Russia).

**Type locality** – Russia, East Siberia, Vitim Plateau, Amalat (Southern) paleovalley, borehole 7236, depth of 172 m; lacustrine sediments of Middle Miocene age, common.

**Etymology** – From *peculiaris* (Latin) = peculiar.

**Comments** – This species differs from *Lobodiscus sibericus* (Tscheremissinova) Lupikina & Khursevich (Lupikina & Khursevich 1991: 69, figs 1–9) by a lesser valve size (26.5–64.8 µm in diameter in *L. peculiaris* against 40–147 µm in *L. sibericus*), the absence of solid lobed spines at the valve mantle and by a different location of the rimoportulae. Their position is not connected with these lobed spines.

## DISCUSSION

The comparison of the detailed morphological investigations of *Actinocyclus* and *Lobodiscus* species, present in the Miocene lacustrine deposits from a new key section 7236 (the Amalat main paleovalley), with descriptions of the known freshwater taxa *Actinocyclus gorbunovii*, *A. krasskei*, *A. tubulosus*, *A. claviolus* and *Lobodiscus sibericus* published earlier (Krasske 1934, Sheshukova-Poretskaya & Moisseeva 1964, Khursevich et al. 1990, Lupikina & Khursevich 1991, Bradbury & Krebs 1995, Kozyrenko et al. 2008), allows to make a conclusion.

In general, the fossil population of *Actinocyclus gorbunovii* from the Miocene basins present in the Amalat paleovalley is characterized by a lesser valve size as compared to what is known from the type material of West Siberia (Sheshukova-Poretskaya & Moisseeva 1964) (table 1), as well as from the fossil material of other regions (Kozyrenko et al. 2008). As far as *Actinocyclus krasskei* is concerned, the range of valve size of specimens, observed in the Miocene sediments from the Amalat paleovalley, and of those originally described from Germany (Krasske 1934, Lange-Bertalot 1996) and reported from other localities of the world (Bradbury & Krebs 1995, Kozyrenko et al. 2008) overlap. However, the *A. krasskei* specimens are distinguished by a thinner areolation of the valve face surface and by a larger number of rimoportulae (table 1).

*Actinocyclus vitimicus* revealed from the new key hole 7236, is more similar to *A. tubulosus* in almost all morphometric data and in the external expression of rimoportula, represented by a short tube (table 1). At first, using only LM observations, this newly described species was identified in the hole 7236 as *Actinocyclus* sp. (Usoltseva et al. 2008), and probably as *A. tubulosus* in boreholes 4053, 4170, 4387 and 2917, located also within the Vitim Plateau (Rasskazov et al. 2007). However, *A. vitimicus* differs from *A. tubulosus* in having a different expression of the rimoportula internally (see above). In addition, *A. vitimicus* resembles *A. theleus* in the light microscope. But the latter is distinguished by the presence of a nipple-like protrusion of the rimoportula on the external valve surface, and of a narrow, round tube having spade-shaped labiae with a curved, slit-like opening in the apical part on the internal one (table 1).

*Actinocyclus intermedius* is more similar to *A. claviolus* in the presence of distinct laterally expanded hyaline strips marking positions of rimoportulae at the valve face/mantle junction. But the structure of the rimoportula is different in both species mentioned above (table 1). On the other hand, certain specimens of *A. intermedius* are characterized by the presence of slightly radial undulation in the periphery of the valve face. That is typical for taxa of *Undatodiscus* (Lupikina et al. 1991: 743).

*Lobodiscus peculiaris* and its closely related species *L. sibericus* have similar loculate areolae with two-side velum (internal domed and external flat cribrum) on the valve surface and specific structure of rimoportula (table 1). The rimoportula of both taxa has a long narrow internal tube with a shoe-shaped slit expressed in the apical part, and this slit has a right angle with the tube axis. But the external expression of the rimoportula in both species is different (table 1). It should be mentioned, that the slit of the rimoportula in *Actinocyclus* and *Undatodiscus* species occurs usually in the same plane with the tube on the internal valve surface, as compared with *Lobodiscus.* The location of rimoportulae in *L. sibericus* is associated with lobed spines, while *L. peculiaris* does not possess these solid spines.

Species of *Actinocyclus* and *Lobodicus* described above, are found in the key hole 7236 in the depth interval between 230 and 138 m (fig. 7). *A. krasskei* is the most abundant in the lower depth interval of 230–222 m reaching as high as 37 million frustules per gram at a depth of 226 m. This species occurs with the planktonic taxa *Aulacoseira spiralis*, *A. valida* and *A.* sp. The next sediment interval from 198 to 185 m is distinguished by a notable decrease in concentration of *A. krasskei* (12–0.02 million frustules per gram), and here this species associates with *Aulacoseira ambigua*, *A. italica* and benthic taxa of *Ellerbeckia*, *Tetracyclus*, *Eunotia* and *Gomphonema.* The short core depth interval of 182–181 m is clearly recognized by appearance of the new species *Actinocyclus intermedius* in number 2–2.8 million frustules per gram; it is present together with *Aulacoseira spiralis* and certain taxa of *Tetracyclus.* The overlying interval (177–172 m) is marked by the occurrence of the new species *Actinocyclus vitimicus*. The latter is associated with not numerous *A. krasskei* at the depth of 177 m, where the quantity of both *Actinocyclus* does not exceed 2.6 million frustules per gram. At the depth of 172 m *A. vitimicus* occurs with the new species *Lobodiscus peculiaris* (this species is present only at this depth), as well as with *A. spiralis* and some benthic taxa. The total number of *Actinocyclus* and *Lobodiscus* species makes up 4 million frustules per gram at the level of 172 m. All taxa of *Actinocyclus* and *Lobodiscus* described as a new, are absent above the depth of 172 m.

The first appearance of *A. gorbunovii* was registered in the studied section at the depth of 174 m. But this species is characterized by a high abundance in the depth interval of 153–144 m, reaching 28.9 million frustules per gram at the depth of 146 m. The associated diatom flora is dominated mainly by elliptical forms of *Aulacoseira*, as well as at some levels by *A. canadensis*, *A. spiralis* and some other ancient species of this genus. Lacustrine sediments of this interval were formed apparently at the beginning of the Late Miocene, because they are stripped under massive basalts having a K-Ar dating 10.8 ± 0.3 My.

Thus, the planktonic *Actinocyclus* taxa, including the new species of *A. vitimicus* and *A. intermedius* described above, as well as *Lobodiscus peculiaris*, together with the dominant accompanying planktonic *Aulacoseira* representatives, represent the characteristic diatom complex in the lacustrine sediments of the Upper Dzhilinda subformation recovered from key hole 7236 within the Amalat paleovalley (the Vitim Plateau). The Middle-Late Miocene age of the studied lacustrine deposits agrees with the K-Ar dating of lavas in this part of the section.

The freshwater extinct *Actinocyclus* taxa (29 species and three varieties) appear to have a longer geologic range (from Late Oligocene to Early Pliocene). The most ancient freshwater species of *Actinocyclus* are known from the Late Oligocene of Russia, West Siberia (Rubina & Khursevich 1990) and from the Early Miocene of Russia, the Ukraine and the U.S.A. (Khursevich & Rubina 1991, Olshtynskaya 1993, 1994, Bradbury & Krebs 1995, Kozyrenko et al. 2008). The maximum diversity of *Actinocyclus* (thirteen species) occurred during the Middle-Late Miocene in various regions within the Eurasian continent (Gersonde & Velitzelos 1977, Bradbury 1984, Servant-Vildary et al. 1988, Khursevich et al. 1990, Khursevich & Lupikina 1992, Temniskova-Topalova et al. 1993, Khursevich 1994, Khursevich & Řeháková 1994, Temniskova-Topalova & Ognjanova-Rumenova 1997, Ognjanova-Rumenova 2000, 2001, 2005, Khursevich & Fedenya 2006). The maximum development of the freshwater *Actinocyclus* representatives in the western United States (eleven species and one variety) was characteristic for the Middle Miocene (Krebs et al. 1987, Bradbury & Krebs 1995). The freshwater extinct *Actinocyclus* species can be used as stratigraphic markers. At present, non-marine extinct *Actinocyclus* species were reported only for the northern hemisphere.

Recently, the genus *Lobodiscus* (Lupikina & Khursevich 1991: 67) was represented by one species *L. sibericus* first described from the Middle-Late Miocene of the Tunka Depression. The finding of the new taxon *L. peculiaris* in the key hole 7236 expanded the composition of this genus.

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REFERENCES

Bradbury J.P. (1984) Fossil Actinocyclus species from freshwater Miocene deposits in China and the United States. In: Mann D.G. (ed.) Proceedings of the 7th International Diatom Symposium, Philadelphia, August 22–27: 157–171. Koenigstein, Koeltz Scientific Books.

Bradbury J.P., Krebs W.N. (1995) The diatom genus Actinocyclus in the Western United States. U.S. Geological Survey Professional Paper 1543 A–B. Washington, United State Government Printing Office.

Chernyaeva G.P., Lyamina N.A., Rasskazov S.V., Rezanov I.N., Savinova V.V. (2007) Biostratigraphy and deposition environments of the Middle-Late Miocene volcanosedimentary section in the Dzhilinda basin, Western Transbaikalia. Russian Geology and Geophysics 48: 460–471. (In Russian)

Gersonde R., Velitzelos E. (1977) Diatomeenpaläoökologie im Neogen-Becken von Vegora N-W Mazenoiden. Annales Géologiques des Pays Helléniques 29: 373–382.

Grachev M.A., Likhoshway Ye.V., Vorobyova S.S., et al. (1997) Signals of the paleoclimates of the Upper Pleistocene in the sediments of Lake Baikal. Geology and Geophysics 38: 957–980. (In Russian)

Karayeva N.I., Makarova I.V., Nikolayev V.A. (1988) Morphology of frustule of diatom algae. In: Makarova I.V. (ed.) The Diatoms of the USSR. Fossil and Recent: 7–22. Leningrad, Nauka. (In Russian)

Khursevich G.K. (1994) Morphology and taxonomy of some centric diatom species from the Miocene sediments of the Dzhilinda and Tunkin hollows. Memoirs of the California Academy of Science 17: 269–280.

Khursevich G.K., Fedenya S.A. (2006) Morphology of new freshwater species of Actinocyclus (Bacillariophyta) from the upper Miocene sediments of Lake Baikal, Siberia. Algologia 16: 384–394. (In Russian)

Khursevich G.K., Lupikina Ye.G. (1992) New freshwater species of the genus Actinocyclus Ehr. (Bacillariophyta) from the upper Miocene sediments of Kamchatka. Algologia 2: 71–73. (In Russian)

Khursevich G.K., Moisseeva A.I., Kozyrenko T.F., Rubina N.V. (1990) New taxa of the genus Actinocyclus (Bacillariophyta) from the Neogene freshwater sediments of the USSR. Botanicheski Zhurnal 75: 1439–1442. (In Russian)

Khursevich G.K., Řeháková Z. (1994) A new species Actinocyclus muticus (Bacillariophyta) from the Miocene deposits of Southern Bohemia. Botanicheski Zhurnal 79: 133–134. (In Russian)

Khursevich G.K., Rubina N.V. (1991) A new taxonomic combination in the genus Actinocyclus (Bacillariophyta). Botanicheski Zhurnal 76: 1151–1152. (In Russian)

Kozyrenko T.F., Strelnikova N.I., Khursevich G.K., Tsoy I.B., Jakovschikova T.K., Mukhina V.V., Olshtynskaya A.P., Semina G.I. (2008) The Diatoms of Russia and adjacent countries. Fossil and recent. St. Petersburg, St. Petersburg University Press. (In Russian)

Krasske G. (1934) Die Diatomeenflora der hessischen Kieselgurlager. Sitzungsberichte der Heidelberger Akademie der Wissenschaften 5: 1–26.

Krebs W.N., Bradbury J.P., Theriot E.C. (1987) Neogene and Quaternary lacustrine diatom biochronology, western USA. Palaios 2: 505–513.

Lange-Bertalot H. (1996) Iconographia Diatomologica, vol. 3. Koenigstein, Koeltz Scientific Books.

Luchinin I.I., Peshkov P.A., Dement'ev P.K, Kochenov A.V., Khaldei A.E., Khalezov A.B. (1992) Deposits of uran in paleovalleys of Transuralia and Transbaikalia. Razvedka and okhrana nedr 5: 12–15. (In Russian)

Lupikina E.G., Khursevich G.K. (1991) Lobodiscus (Tscher.) Lupik. & Khurs. – new genus of class Centrophyceae (Bacillariophyta). Algologia 1: 67–70. (In Russian)

Lupikina E.G., Khursevich G.K., Rubina N.V. (1991) The taxonomic status of the genus Undatodiscus (Bacillariophyta). Botanicheski Zhurnal 76: 743–746. (In Russian)

Moisseeva A.I. (1984) Role of diatom algae in stratigraphy and paleogeography of the Neogene of East Siberia. Volume abstracts: Problem of the age of geological formations from East Siberia: 70–71. Irkutsk. (In Russian)

Ognjanova-Rumenova N.G. (2000) Lacustrine diatom flora from Neogene basins on the Balkan Peninsula: preliminary biostratigraphical data. In: Witkowski A., Siemińska J. (eds) The origin and early evolution of the diatoms: fossil, molecular and biogeographical approaches: 137–143. Kraków, W. Shafer Institute of Botany, Polish Academy of Sciences.

Ognjanova-Rumenova N. (2001) Neogene diatom assemblages from lacustrine sediments of F.Y.R.O.M. (Macedonia) and their distribution in collelative formations of south-western Bulgaria. In: Economou-Amilli A. (ed.) Proceedings of the 16th International Diatom Symposium, Athens and Aegean Islands, Greece, 27 August–1 September 2000: 423–432. Athens, Amvrosiou Press.

Ognjanova-Rumenova N. (2005) Upper Neogene siliceous microfossils from Pelagonia Basin (Balkan Peninsula). Geologica Carpatica 56: 347–358.

Olshtynskaya A.P. (1993) New species of the genus Actinocyclus Ehr. (Bacillariophyta). Algologia 3: 57–59. (In Russian)

Olshtynskaya A.P. (1994) Morphological peculiarities of some diatoms of the genus Actinocyclus Ehr. from the freshwater Neogene of the Ukraine. Geologicheskij Zhurnal 1: 122–130.

Rasskazov S.V., Logachev N.A., Brandt I.S., Brandt S.B., Ivanov A.V. (2000) Geochronology and geodynamics of Late Cenozoic (the Southern Siberia – the Southern and Eastern Asia). Novosibirsk, Nauka. (In Russian)

Rasskazov S.V., Logachev N.A., Ivanov A.V., Misharina V.A., Chernyaeva G.P., Brandt I.S., Brandt S.B., Skoblo V.M., Lyamina N.A. (2001) Palynological and diatom analyses of sediments from the Late Cenozoic pra-Amalat valley (Western Transbaikalia). Russian Geology and Geophysics 42: 773–785. (In Russian)

Rasskazov S.V., Lyamina N.A., Chernyaeva G.P., Lusina I.V., Rudnev A.F., Resanov I.N. (2007) Cenozoic stratigraphy of the Vitim Plateau: phenomenon of long rifting in the south of East Siberia. Novosibirsk, Academic Publishing House "Geo". (In Russian)

Ross R., Cox E.J., Karayeva N.I., Mann D.G., Paddock T.B.B., Simonsen R., Sims P.A. (1979) An emended terminology for the siliceous component of the diatom cell. Nova Hedwigia 64: 513–533.

Rubina N.V., Khursevich G.K. (1990) New representatives of the genus Actinocyclus (Bacillariophyta) from the late Oligocene of the Western Siberia. Botanicheski Zhurnal 75: 1565–1567. (In Russian)

Servant-Vildary S., Paicheler J.C., Semelin B. (1988) Miocene Lacustrine Diatoms from Turkey. In: Round F.E. (ed.) Proceedings of the 9th International Diatom Symposium, Bristol, 1986: 165–180. Koenigstein, Koeltz Scientific Books.

Sheshukova-Poretskaya V.S., Moisseeva A.I. (1964) New and interesting freshwater diatom algae from the Neogene of West Siberia and Far East. News of Systematics of Lower Plants: 92–103. Leningrad, Nauka. (In Russian)

Temniskova-Topalova D.N., Khursevich G.K., Valeva M.T. (1993) A new freshwater species of the genus Actinocyclus (Bacillariophyta). Botanicheski Zhurnal 78: 138–139. (In Russian)

Temniskova-Topalova D.N., Kozyrenko T.F., Moisseeva A.I., Sheshukova-Poretskaya V.S. (1981) The new genus Pontodiscus (Bacillariophyta). Botanicheski Zhurnal 66: 1308–1311. (In Russian)

Temniskova-Topalova D., Ognjanova-Rumenova N. (1997) Description, comparison and biostratigraphy of the nonmarine Neogene diatom floras from Southern Bulgaria. Geologica Balcanica 27: 57–81.

Usoltseva M.V., Vorobyova S.S., Firsova A.D., Maslennikova M.M., Rasskazov S.V., Brandt I.B., Brandt S.B. (2008) Siliceous microfossils in the upper Miocene sediments of Transbaikalia. Novosti paleontologii i stratigragii. Supplement to Russian Geology and Geophysics 49: 360–362. (In Russian)

Yendrichinsky A.S., Cheremisinova Ye.A. (1970) On finding of Miocene deposits in the Vitim plateau. Doklady Akademii Nauk SSSR 191: 885–888. (In Russian)

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