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RESEARCH ARTICLE

A review of the genus *Anatoma* in the Eurasian Arctic seas (Gastropoda: Vetigastropoda: Anatomidae)

Обзор рода *Anatoma* арктических морей Евразии (Gastropoda: Vetigastropoda: Anatomidae)

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Abstract. A taxonomic review of the genus *Anatoma* Woodward, 1859 in the Eurasian Arctic seas is presented. The new species *A. golikovi* **sp. nov.** is described from the northwestern part of the Barents Sea. The species differs from all other Arctic and North Atlantic *Anatoma* in having a flat spire. We consider *Anatoma schioettei* Høisæter et Geiger, 2011, **syn. nov.**, a junior synonym of *A. crispata* (Fleming, 1828). *Anatoma schanderi* Høisæter et Geiger, 2011 is recorded for the first time from the Siberian seas.

Резюме. Выполнен таксономический обзор видов рода *Anatoma* Woodward, 1859, обитающих в евразийских арктических морях России. *Anatoma golikovi* **sp. nov.** описан из северо-западной части Баренцева моря. Новый вид отличается от остальных арктических и североатлантических представителей рода плоским завитком раковины. *Anatoma schioettei* Høisæter et Geiger, 2011, **syn. nov.**, предложено считать младшим синонимом *A. crispata* (Fleming, 1828). *Anatoma schanderi* Høisæter et Geiger, 2011 впервые отмечен в сибирских морях.

Key words: Arctic, Barents Sea, Vetigastropoda, Anatomidae, *Anatoma*, new synonymy, new species

Ключевые слова: Арктика, Баренцево море, Vetigastropoda, Anatomidae, *Anatoma*, новая синонимия, новый вид

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Introduction

Anatomidae is a family of minute marine vetigastropods distributed all over the World. For a long time, all Arctic and northern Atlantic representatives of the family were attributed to a single species, *Anatoma crispata* (Fleming, 1828) (Sars, 1878; Herzenstein, 1885; Gorbunov, 1946; Golikov, 1995; Golikov et al., 2001; Kantor & Sysoev, 2006; Nekhaev, 2014). Høisæter & Geiger (2011) revised the genus *Anatoma* from the northern Atlantic and suggested the presence of at least five species in the region. These authors designated a neotype for *A. crispata* and, thus, specified the application of this name, previously used for a group of species distributed throughout the Northern Hemisphere (e.g. Fretter & Graham, 1976). Høisæter & Geiger (2011) described two species, *A. schioettei* Høisæter et Geiger, 2011 and *A. schanderi* Høisæter et Geiger, 2011, based on

few samples from the waters around Greenland and North America and redescribed two more species, *A. aspera* (Philippi, 1844) and *A. tenuisculpta* (Seguenza, 1877).

However, little is known about the composition of the genus *Anatoma* in the Arctic waters east of the Norwegian Sea. Nekhaev (2014) confirmed the presence of *A. crispata* s. str. in the southwestern Barents Sea and noted that no more representatives of the genus had been found in the region. However, a careful reexamination of his material and study of the molluscan collections from the other parts of the Russian Arctic provided us with new data on the taxonomy and distribution of *Anatoma* species.

The present paper is aimed to overview the species of the genus *Anatoma*, currently known from the Eurasian Arctic seas, based on the shell and radula morphology.

Materials and methods

The following abbreviations are used for shell measurements: NW – whorl number; SH – shell height; BWH – body whorl height; AH – aperture height; SW – shell width; AW – aperture width. The institutional abbreviations are as follows: ZIN – Zoological Institute of the Russian Academy of Sciences, St Petersburg, Russia; SMNH – Stockholm Museum of Natural History. The abbreviation spm(s) is used for the ethanol-preserved specimen(s).

For the present study, we used the collections of ZIN and SMNH and the materials collected during the recent (2006–2015) expeditions to the Barents Sea. The studied area covers the Eurasian Arctic seas: the Barents Sea, the Kara Sea, the Laptev Sea, and the East Siberian Sea. The collections examined did not contain any material of *Anatoma* from the White Sea and the Chukchi Sea.

Snails were examined under a stereomicroscope and a Zeiss Merlin scanning electronic microscope. All examined specimens were measured, and the number of ribs on different parts of shells was counted. The following measurements were taken: shell height, body whorl height, aperture height, aperture width, shell width, diameter of protoconch, width of the nucleus (width of embryonic cap), and numbers of whorls for protoconch, shell, teleoconch I and teleoconch II. The shells were measured according to the scheme suggested by Nekhaev (2019). Radulae were cleaned from tissues with an aqueous solution of sodium hypochlorite and then washed with distilled water. The radulae of seven specimens of *Anatoma crispata* (including *A. schioettei*) were examined.

The higher classification follows that of Bouchet et al. (2017).

Taxonomy

Class **Gastropoda** Cuvier, 1795

Subclass **Vetigastropoda** Salvini-Plawen, 1980

Order **Lepetellida** Moskalev, 1971

Superfamily **Scissurelloidea** Gray, 1847

Family **Anatomidae** McLean, 1989

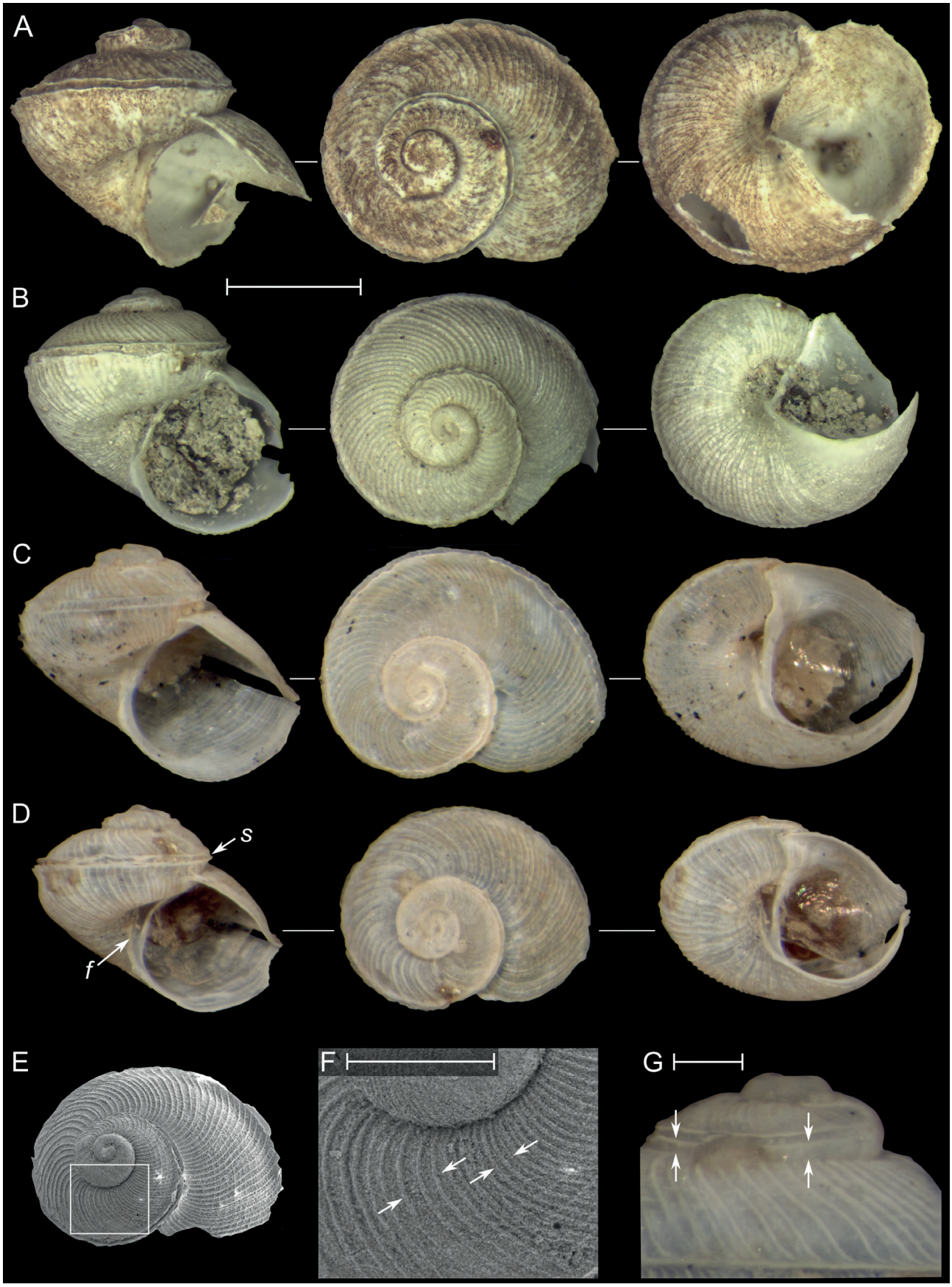
Genus ***Anatoma*** Woodward, 1859

Type species: *Scissurella crispata* Fleming, 1828, subsequently designated by Geiger (2012).

Anatoma crispata (Fleming, 1828)
(Figs 1A–G; 2A–F; 3A–F; 4C)

Scissurella crispata Fleming, 1828: 385, pl. 6, fig. 3.
Scissurella angulata Lovén, 1846: 20.
Anatoma schioettei Høisæter et Geiger, 2011: 103–105, figs 48–60; Geiger, 2012: 1086–1089, figs 886–889, **syn. nov.**
Scisurella crispata: Herzenstein, 1885: 67; Thiele, 1928: 565.
Anatoma crispata: Golikov et al., 2001: 104 (partim); Kantor & Sysoev, 2006: 24, fig. 9A (partim); Høisæter & Geiger, 2011: 90–94, figs 1–18; Nekhaev, 2014: 78; Geiger, 2012: 832–847, figs 674–680.
Anatoma sp.: Nekhaev & Krol, 2017: 2283.

Material examined. **Norway**, *Norwegian Sea*, *Finnmark*, S. Lovén leg., 1 shell (SMNH 4394, lectotype of *Scissurella angulata*). **Russia**: *Barents Sea*: 60 m, 71°54.26′N, 47°51.52′E, 18 Aug. 2006, R/V Dal'nie Zelentsy, 2 spms, 1 shell; Motovskiy Bay, 197 m, 69°36.87′N, 32°16.43′E, 26 May 1996, M/S GS-440, 4 shells (ZIN 62141/36); Murman Coast, 42 m, 69°40.82′N, 31°37.00′E, 6 July 2005, R/V Dal'nie Zelentsy, 1 shell; Murman Coast, 18–20 m, 69°36.5′N, 32°29.5′E, 29 May 1901, R/V Andrey Pervozvannyy, 3 shells (ZIN 1607/7); Ura Inlet, 17 m, 69°22.70′N, 32°54.88′E, 6 Oct. 2006, 4 shells; Ura Inlet, 158 m,


A
B
C
D
s
f
E
F
G

69°27′N, 33°08′E, 2 Oct. 2006, 1 spm; Ura Inlet, mouth of Shalimskaya Bay, 24–40 m, 13 Aug. 1887, 1 shell (ZIN 1602/1); Ivanovskaya Inlet, 54 m, 68°22.46′N, 38°32.30′E, 30 July 2008, R/V Dal'nie Zelentsy, 1 spm; Kola Inlet, 22 m, 69°16.81′N, 33°32.99′E, 28 May 2013, Yu.A. Zuev & S.V. Goldin leg., 4 shells (ZIN 32142/37); off Teriberka, 150–170 m, 6 Aug. 1884, 1 shell (ZIN 1603/2); Dal'ne-Zelenetskaya Bay, 66 m, 69°08.41′N, 36°04.54′E, 4 June 2009, R/V Dal'nie Zelentsy, 2 spms; Franz Joseph Land: 251 m, 80°44.19′N, 53°36.85′E, 23 Aug. 2006, R/V Dal'nie Zelentsy, 2 shells (ZIN 62140/35), 76 m, 80°31.60′N, 52°34.12′E, 29 Aug. 2007, R/V Dal'nie Zelentsy, 1 shell, 102 m, 79°52.05′N, 51°49.13′E, 24 Aug. 2006, R/V Dal'nie Zelentsy, 3 spms, 53 m, 80°14.5′N, 73°51′E, 14 Sept. 1936, R/V Sadko, 4 spms (ZIN 1615/15), Hooker I., Tikhaya Bay, 120 m, 25 Aug. 1992, R/V Pomor, 2 spms (ZIN 58716/34); Novaya Zemlya, Chernaya Inlet, 46 m, 70°35′N, 54°55′E, 8 Oct. 2000, R/V Dal'nie Zelentsy, 2 spms.; *Kara Sea*: 446 m, 80°58.5′N, 73°32′E, 9 Sept. 1936, R/V Sadko, 4 shells (ZIN 1614/14); 41 m, 80°11′N, 75°02′E, 18 Aug. 1934, R/V Sedov, 21 shells (ZIN 37030/20).

Redescription. Shell small, globular, fragile, matt or slightly shiny, from white to yellowish, semitransparent or opaque. Spire low; upper whorls from rounded to stepped; body whorl relatively large, lenticular; shell base convex. Protoconch of 0.75–1.0 whorls, with sculpture of coarse flocculae which usually tending to form two or three spiral riblets. Diameter of protoconch from 210 to 320 μm, nucleus 70–180 μm wide. Teleoconch I of 0.25–1.0 whorls. Teleoconch II of 0.7–2.0 whorls. Upper parts of body whorl with 3–14 thin spirals riblets, shell base with 7–21 ones. Teleoconch I with 13–25 axial riblets, sometimes weak spiral cord present in position of selenizone (Fig. 2C). First whorl of teleoconch II with 33–65 axial riblets. Body whorl with 43–80 axials. Axials irregularly spaced (Fig. 1F). Spirals weaker than axials. Spirals and axials on base forming reticulate pattern. Aperture rounded; outer lip above selenizone arciform or almost straight, outer lip under selenizone and columellar lip rounded. Umbilicus open, deep with distinct funiculus. Space between selinizone (Fig. 1D, *s*) and suture of subsequent whorl variable (Fig. 1G).

Mean values of measurements of 34 specimens: NW 2.9 ± 0.04, SH 1.38 ± 0.06 mm, BWH 1.25 ± 0.05 mm, AH 0.93 ± 0.03 mm, SW 1.73 ± 0.06 mm, AW 0.90 ± 0.03 mm. Measurements of the largest specimen (Franz Josef Land, 76 m): NW 3, SH 2.05 mm, BWH 1.82 mm, AH 1.30 mm, SW 2.34 mm, AW 1.17 mm.

Radula (Fig. 3A–F): rachidian tooth trapezoidal, with prominent central denticle and 3–6 narrow pointed denticles on either side. Five lateral teeth with narrow pointed denticles. Lateral teeth 1–3 usually with 5–8 denticles. Fourth lateral tooth reduced, with distinct terminal denticle. Fifth lateral tooth with approximately 7–9 denticles. Tips of lateral teeth directed towards inner margin, rachidian and lateral teeth with slightly serrate edges. Inner marginal teeth with triangular tips directed towards outer margin, bearing approximately 7–9 narrow denticles. Outer marginal teeth spoon-shaped, with approximately 15–20 thin sharp denticles.

Distribution and habitat. *Anatoma crispata* is known from Baffin Bay, Greenland, Shetland Islands, Scandinavian coast, Barents Sea and northwestern Kara Sea; the depth range is from 10 to 1083 m (Høisæter & Geiger, 2011; Geiger, 2012). The records of *A. crispata* from the northeastern Pacific (Sirenko et al., 2013) probably refer to another species and need confirmation. Also, we did not find any specimens identified as *A. crispata* in ZIN collection. The findings of *A. crispata* in the Laptev Sea and East Siberian Sea (e.g. Gorbunov, 1946; Golikov et al., 2001) actually belong to *A. schanderi*. *Anatoma crispata* was found on different substrates. The minimum observed temperature at the collection site of living specimens was −0.8°C (Franz Josef Land).

Fig. 1. *Anatoma crispata* (Fleming, 1828), shells with the data on the number of axials on teleoconch I (T1) and the first whorl of teleoconch II (T2). **A**, Barents Sea, Franz Josef Land, 251 m, 80°44.19′N, 53°36.85′E, ZIN 62140/35 (axials: T1 – 11, T2 – 45); **B**, Barents Sea, Murman Coast, Ura Inlet, 17 m, 69°22.70′N, 32°54.88′E (axials: T1 – 21, T2 – 49); **C**, Barents Sea, Murman Coast, Ura Inlet, 158 m, 69°27′N, 33°08′E (axials: T1 – 20, T2 – 51); **D–G**, Barents Sea, Murman Coast, Dal'ne-Zelenetskaya Bay, 66 m, 69°08.41′N, 36°04.54′E (axials: T1 – 8, T2 – 55). Shells (A–E); shell fragment with irregular axial riblets (magnified part of E) (F); fragment of spire with variable position of selenizone (G); *f*, funiculus; *s*, selenizone. Scale bars: A–E, 1 mm; F–G, 300 μm.

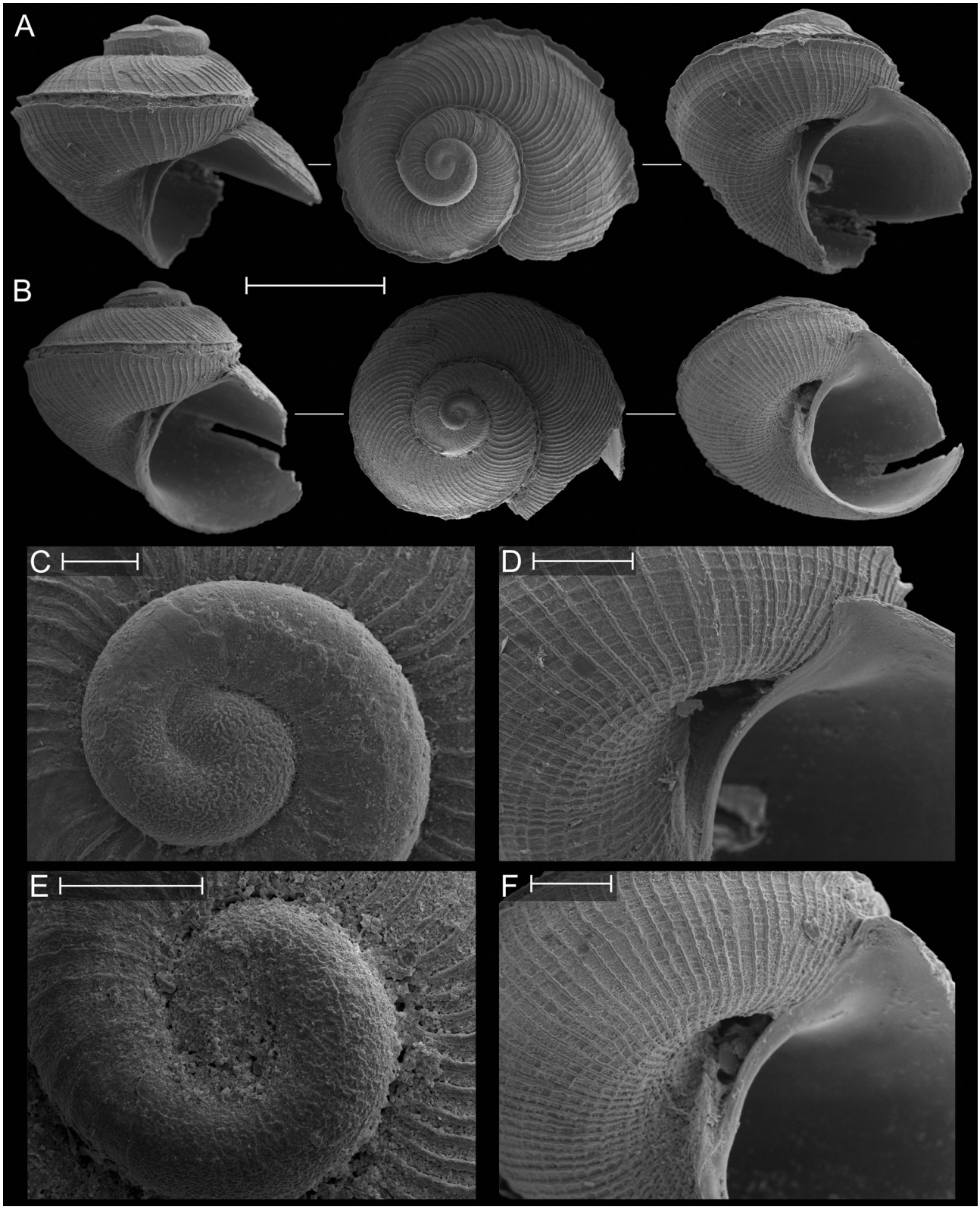


Fig. 2. *Anatoma crispata* (Fleming, 1828), shells. **A**, **C**–**D**, Barents Sea, Franz Josef Land, 251 m, 80°44.19′N, 53°36.85′E, ZIN (same specimen as in Fig. 1A); **B**, **E**–**F**, Barents Sea, Murman Coast, Ura Inlet, 17 m, 69°22.70′N, 32°54.88′E (same specimen as in Fig. 1B). Shells (A–B); protoconch details (C, E); funiculus details (D, F). Scale bars: A–B, 1 mm; C, E, 100 μm; D–F, 300 μm.

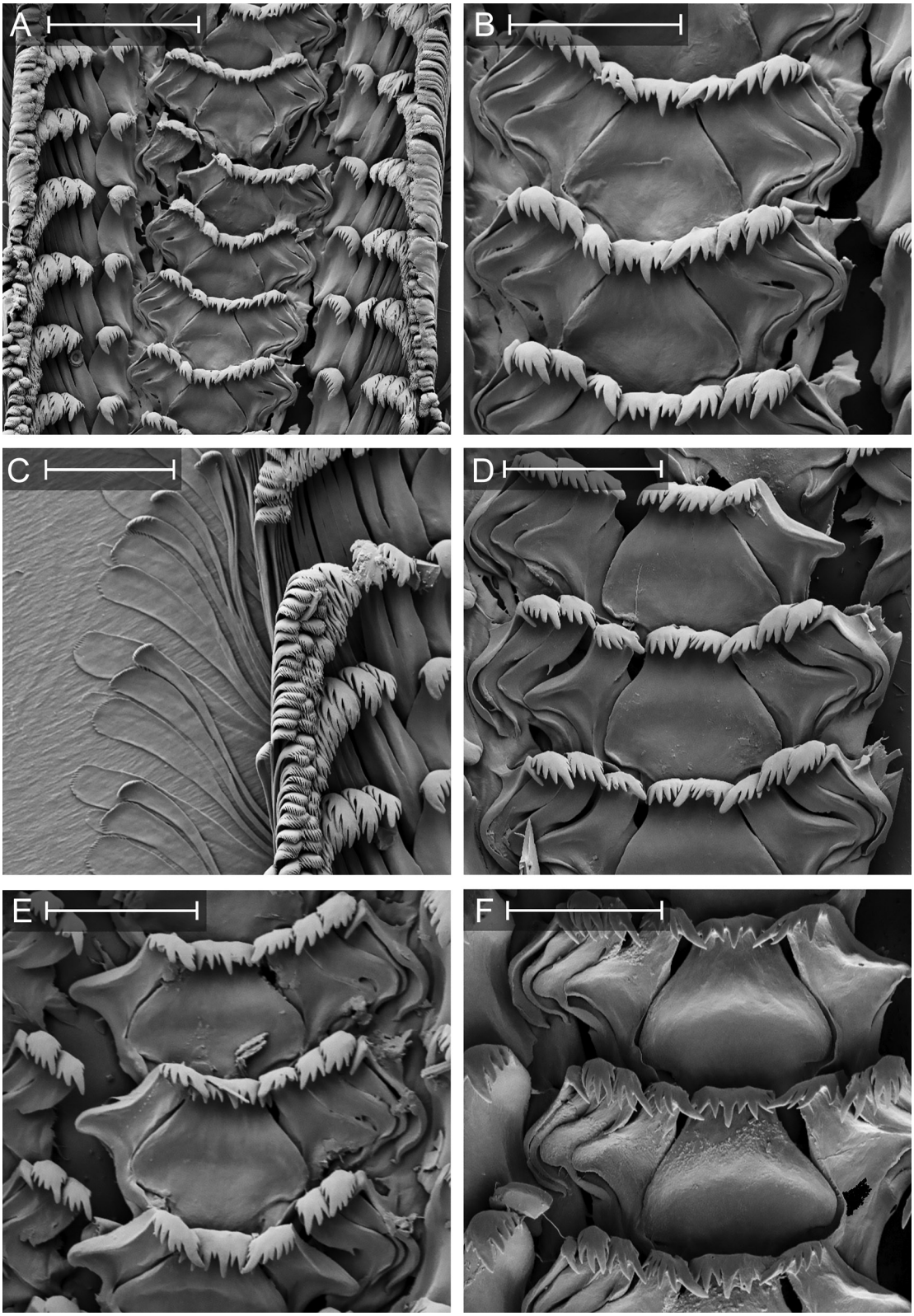


Fig. 3. *Anatoma crispata* (Fleming, 1828), radulae. **A**–**D**, Barents Sea, Murman Coast, Dal'ne-Zelenetskaya Bay, 66 m, 69°08.41′N, 36°04.54′E (A–C and D were taken from two different specimens); **E**, Barents Sea, Murman Coast, Ura Inlet, 158 m, 69°27′N, 33°08′E. **F**, Barents Sea, Franz Josef Land, 102 m, 79°52.05′N, 51°49.13′E. Scale bars: A, 40 μm; B–F, 20 μm.

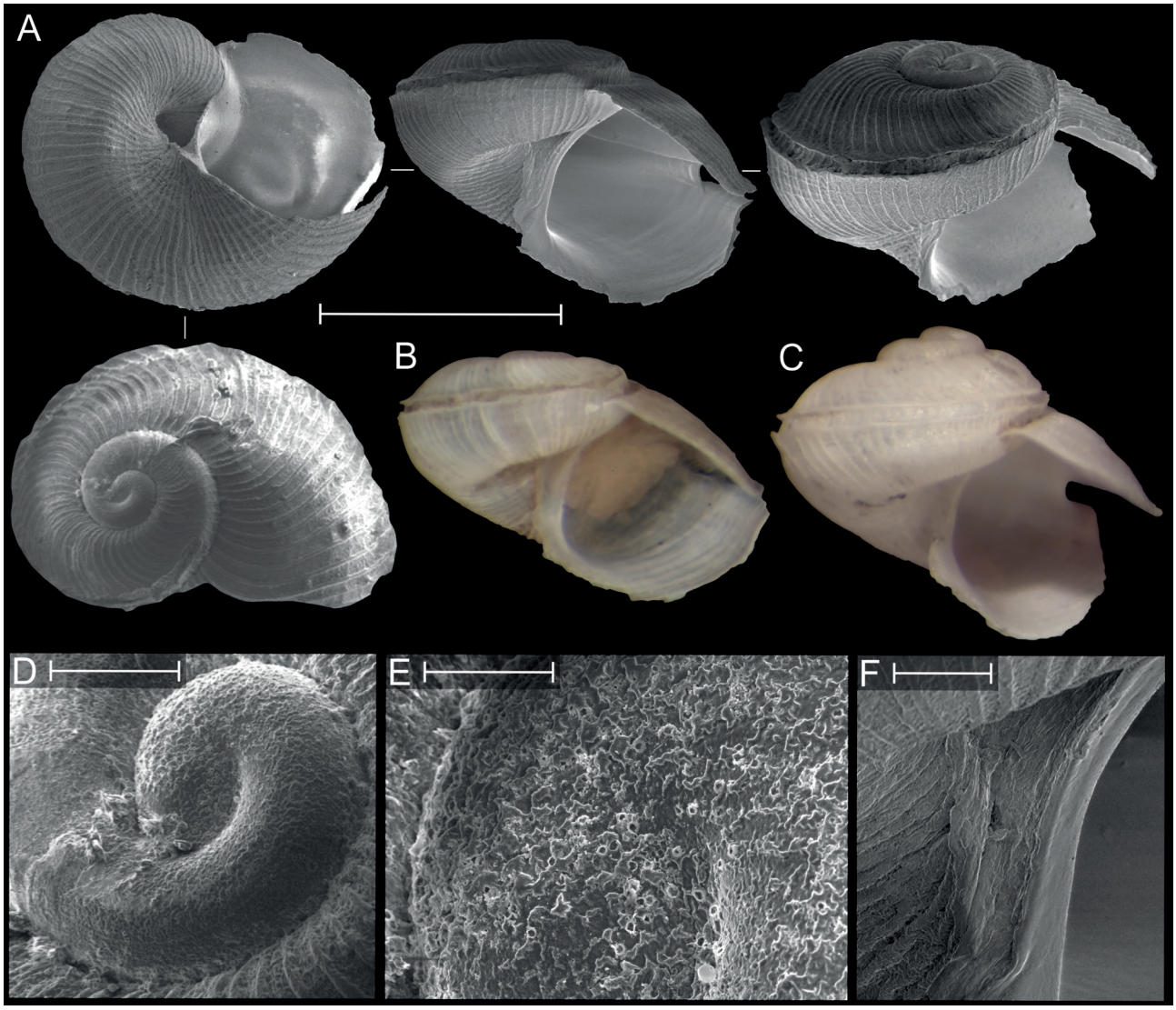


Fig. 4. *Anatoma golikovi* **sp. nov.**, holotype (A–B, D–F) and *A. crispata* (C, Barents Sea, 60 m, 71°54.26′N, 47°51.52′E). **A–C**, shell; **D–E**, protoconch details; **F**, funiculus details. Scale bars: A–C, 1 mm; D–F, 100 μm; E, 20 μm.

Remarks. Høisæter & Geiger (2011) described *A. schioettei* from the upper slope of Greenland. This species differs from *A. crispata* in having a wider sutsel (space between the beginning of selenizone and the suture of the subsequent whorl) and in having about 1.5 times as many or more distinct axials (e.g. 22 *vs* 15 on teleoconch I) (Høisæter & Geiger, 2011). However, these characters were variable in our material and numerous specimens displayed significant non-discrete variation: they differed in the position of selenizone (Fig. 1G), in the number of axial riblets and in the distance between them (Fig. 1F); the variability occurred even between the different parts of the same shell.

The number of axial ribs varied from 8 to 25 (mean 14.64 ± 0.74, n = 22) on teleoconch I and from 33 to 65 (mean 46.86 ± 1.09, n = 36) on the first whorl of teleoconch II. The hypothesis of normal distribution cannot be statistically rejected for both values (teleoconch I: Shapiro-Wilk test = 0.919, p = 0.073; first whorl of teleoconch II: Shapiro–Wilk test = 0.971, p = 0.45).

Both the forms also do not substantially differ from each other by other characters such as shell shape, sculpture and size of protoconch, and

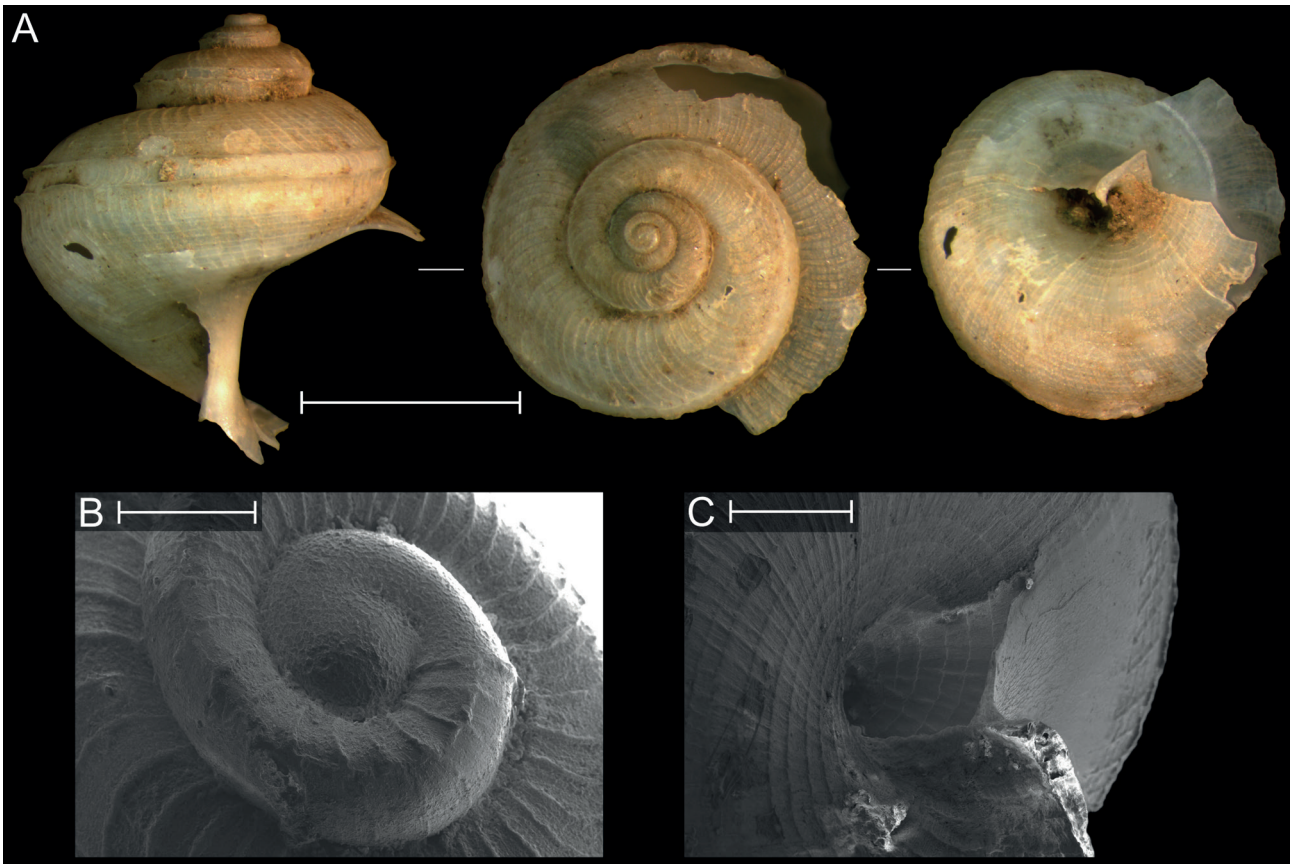


Fig. 5. *Anatoma schanderi* Høisæter et Geiger, 2011, shell (Laptev Sea, 68 m, 76°48′N, 129°41′E, ZIN 37031). **A**, shell; **B**, protoconch details; **C**, funiculus details. Scale bars: A, 2 mm; B, 100 μm; C, 400 μm.

radular morphology (see Figs 1B, 2B, 2E, 2F, 3D for typical *A. crispata*; Figs 1A, 2A, 2C, 2D, 3A–C, 3E, 3F for typical *A. schioettei*; and Figs 1C–D for transitional forms). Therefore, we consider *A. schioettei* as a synonym of *A. crispata*.

Anatoma golikovi sp. nov.
(Fig. 4A–B, D–F)

Holotype. **Norway**, *Barents Sea*, Svalbard, near Hopen I., 49 m, 76°11.04′N, 23°11.78′E, 21 Aug. 2008, R/V Dal'nie Zelentsy (ZIN 62138/1).

Diagnosis. *Anatoma golikovi* **sp. nov.** differs from all Arctic species of the genus in its planispiral shell with a depressed spire, the presence of distinct funiculus, and embryonic shell with sculpture of loose flocculae.

Description. Shell small, fragile, slightly shiny, cream, semitransparent. Spire flat; body whorl relatively large, lenticular; shell base convex. Protoconch of 0.8 whorls, with sculpture of loose flocculae, which tending to form irregular spiral riblets. Diameter of protoconch 240 μm, nucleus 70 μm wide. Teleoconch I of 0.7 whorls. Teleoconch II of 1.1 whorls. Six thin spirals riblets on upper parts of body whorls and 17 on shell base. Teleoconch I with 16 axial riblets. Teleoconch II with 51 strong axial ribs. Shell base with 60 axial riblets. Spirals and axials forming reticulate sculpture around umbilicus.

Aperture rounded; outer lip almost straight above selenizone and rounded under selenizone and columellar lip. Umbilicus open, deep, with distinct funiculus. Space between selinizone and suture of subsequent whorl almost equal to width of selenizone.

Measurements of holotype: NW 2.6, SH 0.93 mm, AH 0.86 mm, SW 1.50 mm, AW 0.79 mm.

Distribution. Known only from the type locality.

Habitat. The holotype was collected from the sea bottom with sand, shellrock and pebbles. The temperature at the collecting site was +2.17°C, salinity 33.84‰.

Remarks. *Anatoma crispata* differs from *A. golikovi* **sp. nov.** in having an elevated spire (see Fig. 4B–C for comparison) which is visible even in young specimens (with less than one whorl on teleoconch II). *Anatoma schanderi* can be distinguished from the new species by its larger size, elevated spire and reticulate pattern on the embryonic shell. *Anatoma tenuisclupta* (Seguenza, 1880) which is known from the Norwegian coast differs in the lacking funiculus and elevated spire.

Etymology. The species is named after Alexander Golikov, a prominent malacologist and benthic ecologist.

Anatoma schanderi Høisæter et Geiger, 2011
(Fig. 5A–C)

Scissurella crispata: Gorbunov, 1946: 45.
Anatoma crispata: Golikov et al., 2001: 104 (partim).
Anatoma schanderi Høisæter et Geiger, 2011: 106–109, figs 68–83; Geiger, 2012: 1081–1085, figs 881–885.

Material examined. **Russia**: *East Siberian Sea*, 57 m, 78°13′N, 142°13′E, 19 Dec. 1937, R/V Sadko, 1 shell (ZIN 37032); *Laptev Sea*, 68 m, 76°48′N, 129°41′E, 8 Nov. 1937, R/V Sadko, 1 shell (ZIN 37031).

Redescription. Shell large, towering, fragile, slightly shiny, semitransparent. Spire high; whorls stepped; shell base convex. Protoconch of 0.75 whorls, with reticulate sculpture. Diameter of protoconch 190 μm, nucleus have 100 μm width. Teleoconch I of 1.0 whorl. Teleoconch II of 3.2 whorls. Upper parts of body whorls with 14 thin spirals riblets, shell base with 31 ones. Teleoconch I with 30 axial riblets; strong spiral cord present in position of selenizone. First whorl of teleoconch II with 41 axial riblets. Body whorl with 81 axials. Axials irregularly spaced. Spirals and axials of same size, forming reticulate sculpture. Aperture rounded. Umbilicus open, deep, with small funiculus. Space between selinizone and suture of subsequent whorl as wide as selenizone.

Measurements of largest specimen examined: NW 4.9, SH 4.20 mm, BWH 3.70 mm, AH 2.30 mm, SW 4.25 mm, AW 2.70 mm.

Remarks. The two empty shells collected from the waters around the New Siberian Islands (the Laptev Sea and the East Siberian Sea) clearly correspond to the description of *A. schanderi*, which was previously known only from the extreme North of the Atlantic: from Nova Scotia to the Norwegian Sea. The examined specimens are the only representatives of the genus known from the region, and apparently all the records of *A. crispata* from the Laptev Sea and the East Siberian Sea by the Russian authors (e.g. Gorbunov, 1946; Golikov, 1995; Golikov et al., 2001; Kantor & Sysoev, 2006) in fact refer to these specimens of *A. schanderi*.

Discussion

According to our data, the genus *Anatoma* includes three species in the Eurasian Arctic seas: *A. crispata*, *A. golikovi* **sp. nov.** and *A. schanderi*. The representatives of the family Anatomidae are relatively rare in the recent samples and in the examined museum collections from the region. Therefore, the data about the species distribution are rather fragmentary, especially for the regions east of the Kara Sea, from which only two samples with *A. schanderi* are available. The representatives of the genus *Anatoma* have not been found from the Central Arctic Basin as well as from the White Sea. Species delimitation within the group is still based mainly on the shell morphology, while the anatomical characters (except for the radula) and gene sequences were not used in the species-level systematics of the family Anatomidae so far (Geiger, 2012). Accordingly, it can be assumed that a greater number of species live in the Arctic. However, their identification will require the collection of new material and the use of other methods.

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