ALGAE — ВОДОРОСЛИ

A new species of *Navicula* (Bacillariophyta) from the Niger River (Mali, West Africa)

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Abstract. *Navicula suturata* sp. nov. is described on the base of light and scanning electron microscopy observations of a sample, collected from the Niger River at Bamako, Mali. The species resembles four previously described taxa. *Navicula suturata* is morphologically most similar to *N. nielsfogedii*, but differs from it by larger valve dimensions and coarser areolae. The new species differs from *N. venezuelensis* by more convex valve margins, wider central area and higher striae density; from *N. babeiensis* by absence of external apical grooves, wider valves with coarser striation and finer areolation; from *N. delicatilineolata* by larger valve dimensions. A new morphological term, rimulae, is introduced for small shallow transapical cracks on the external surface of virgae and axial area.

Keywords: Naviculaceae, diatoms, freshwaters, morphology, taxonomy, terminology, West Africa.

Новый вид *Navicula* (Bacillariophyta) из реки Нигер (Мали, Западная Африка)

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Резюме. Новый вид, *Navicula suturata* sp. nov., описан на основании данных световой и сканирующей электронной микроскопии из образца, собранного в реке Нигер у г. Бамако, Мали. Данный вид сходен с четырьмя ранее описанными таксонами. Он морфологически наиболее близок к *N. nielsfogedii*, но отличается от последнего более крупными створками и редкими ареолами. Новый вид отличается от *N. venezuelensis* выпуклыми краями створки, широким средним полем и большей частотой штрихов; от *N. babeiensis* — отсутствием апикальных углублений на наружной поверхности створки, более широкими створками, с более редкими штрихами и частыми ареолами; от *N. delicatilineolata* — более крупными створками. Введен новый морфологический термин — римулы, обозначающий неглубокие трансапикальные «трещинки» на наружной поверхности вирг и осевого поля.

Ключевые слова: Naviculaceae, диатомовые, морфология, пресные воды, таксономия, терминология, Западная Африка.

The diatom genus *Navicula* Bory includes both freshwater and marine species. For the long time it was a “catch-all” taxon for biraphid diatoms with isopolar and isobilateral valves, lacking distinctive features in the light microscope, such as stauros, longitudinal canals, etc. After the wide application of SEM-microscopy in diatom taxonomy many new ultrastructural characters were revealed and the genus was split into many new genera. The current concept of *Navicula* sensu stricto embraces species with lineolate areolae with internal hymenes and peculiar structure of the raphe-system, with internal raphe fissures that open obliquely and accompanied by so-called accessory rib in majority of taxa. The diversity of ultrastructural features within the genus was highlighted by Cox (1999). Though several hundreds of *Navicula* species are known from freshwaters, the diversity of the genus still remains underestimated. New taxa are regularly described from different world region, including those considered well-studied, such as central Europe.

Though some diatoms groups from the African continent were recently partially revised taxonomically (e. g., Cocquyt, Jahn, 2007; Taylor *et al.*, 2010, 2024; Fofana *et al.*, 2014), little attention was paid to the genus *Navicula* sensu stricto in the last decades (Taylor *et al.*, 2016). Interpretation of taxa, introduced in historical publications, is often problematic since records are confirmed by line-drawings only. Modern taxonomical papers on African *Navicula*, containing series of LM-micrographs accompanied with SEM images, are scarce (e.g., Taylor *et al.*, 2007, 2016). Floristic-taxonomical diatom monographs exist for East (Gasse, 1986) and South Africa (Taylor *et al.*, 2007), but in the West Africa mainly (paleo-)ecological works were conducted (e. g., Gasse, 1987; Gasse *et al.*, 1989; Badiane *et al.*, 2016). The single taxonomic treatment of diatoms from Mali

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part of the Niger River was conducted by Maillard (1977), who listed 140 taxa, including eight new to science and among them one new *Navicula* species. The research interest was mainly paid to the Niger River Delta (Ziller, Economou-Amilli, 1998; Arimoro *et al*., 2008; Effiong *et al*., 2018).

The aim of this paper is morphological (LM and SEM) investigation of a population of unknown *Navicula* species found in an occasional sample from the Niger River. Because of the difference from the other taxa we describe it as a new species.

Material and Methods

The material for the present study was collected by S. N. Elansky from the Niger River in Bamako (Mali, West Africa). A sample of bottom sediment was taken near the bank of the river on 5 II 2024. Geographical coordinates of the sampling point are 12.62710°N, 7.98516°W.

The Niger River is the third river in Africa according to the total length. The river has increased (wet season) and decreased (dry season) flow periods. The ranges of the main hydrochemical parameters of the river's water at Bamako may be found in the paper of Sangare *et al*. (2023).

Material was cleaned from the organic substances by heating in concentrated (37%) hydrogen peroxide for an hour with subsequent adding of a few drops of concentrated hydrochloric acid for removing of carbonates. Then the valves were rinsed with distilled water by repeated centrifugation (four times, 10 minutes at 2000 rpm). Cleaned valves were air-dried onto coverslips. For LM investigation material was embedded in Naphrax, the slides were studied under Levenhuk Med25t microscope, equipped with Zeiss 100× achromatic oil-immersion objective (NA = 1.25) and Levenhuk M1000 (China) digital camera. For SEM the coverslips were mounted on aluminum stubs with nail polish, coated with aurum-palladium in Eiko IB3 ion coater and studied under JEOL JSM6380LA (Japan) microscope. Digital images were processed with ImageJ 1.45s and GIMP 2.10.10 computer programs. Striae density was measured on the primary valve side along the proximal parts of raphe branches. The length of a segment containing 10 striae was measured with subsequent calculation of the number of striae in 10 μm. The samples and slides used in this study are stored in the diatom collection of the Department of Mycology and Algology of Lomonosov Moscow State University (acronym MW-D).

Results

Navicula suturata Chudaev, sp. nov. (Figs. 1–4)

LM (Fig. 1). Valves narrowly lanceolate with widely rounded apices. Valve length 43.5–48.0 μm, width 7.5–8.5 μm (n = 37). Axial area narrow, gradually widening proximally, asymmetric in relation to raphe position. At secondary valve side axial area conspicuously wider than at primary side, where it is almost absent. Central area asymmetric, occupying about one half of valve width, semicircular to semi-lanceolate at secondary valve side to trapezoid at primary side. Striae strongly radial in valve centre, becoming strongly convergent towards apices, 14.0–16.5 in 10 μm. Lineolae barely visible in LM. Raphe filiform or slightly lateral, terminal fissures unilaterally hooked towards

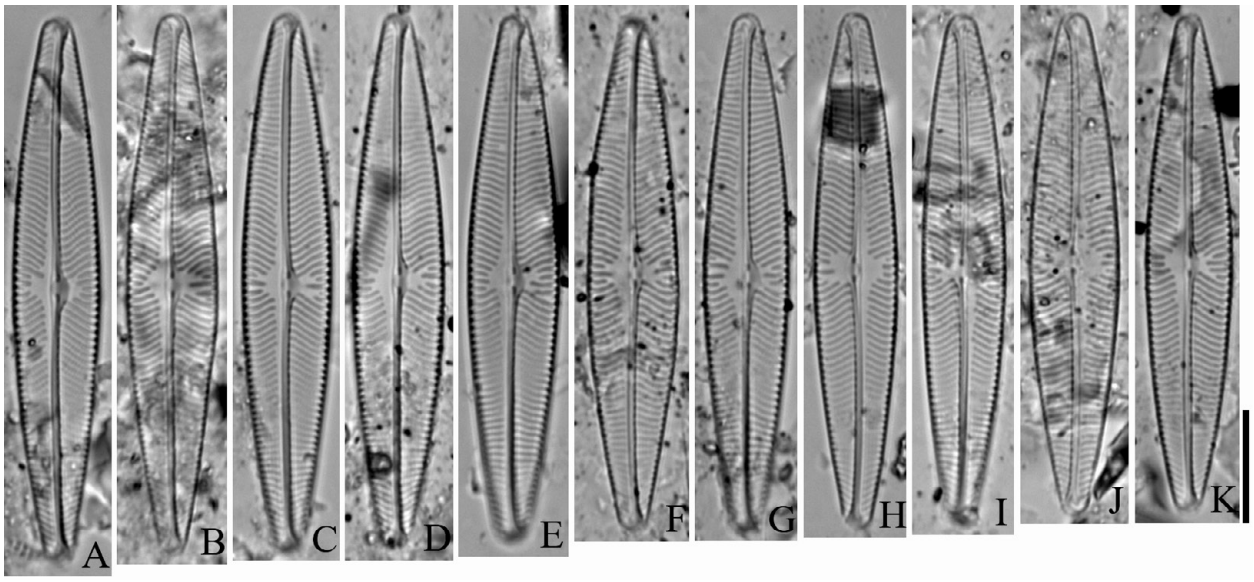

Fig. 1. A–K. *Navicula suturata* sp. nov., LM images from the type material (slide MW-D 1244s1) (C represents the holotype specimen). Scale bar: 10 μm.

secondary side, central pores slightly deflected towards primary side, central nodule asymmetric, widened towards primary side.

SEM, external valve surface (Figs. 2, 4). Areolae lineolate, apically elongate. External areolar openings not connected by longitudinal furrows, except near valve face-mantle junction. Areola density 31.6–33.6 in 10 μm. Apical areola pattern is following. Four obliquely oriented areolae placed at primary apex side and two — at secondary. Proximal apical areolae at both sides of terminal raphe fissure are connected to areolae of striae, forming inverted V-shaped structures. Raphe-sternum not elevated above valve surface. External raphe fissures are displaced towards secondary side of axial area except in proximal parts, where they are deflected towards primary side. Central pores drop-like, with tongue-like internal projections. Terminal fissures geniculate, unilaterally curved towards secondary side. Structures remaining cranial sutures (rimulae, see below) extend from the raphe fissures towards valve margins on external surface of virgae.

SEM, internal valve surface (Fig. 3). Areolae closed with elliptical hymenes. Striae lie in transapical depressions, almost of the same width as virgae. Raphe straight, opens obliquely towards secondary valve side. Raphe rib accompanied by prominent accessory rib, both ribs separated by distinct longitudinal groove. Accessory rib widens unilaterally towards primary side at centre and apices. Proximal raphe endings simple, straight,

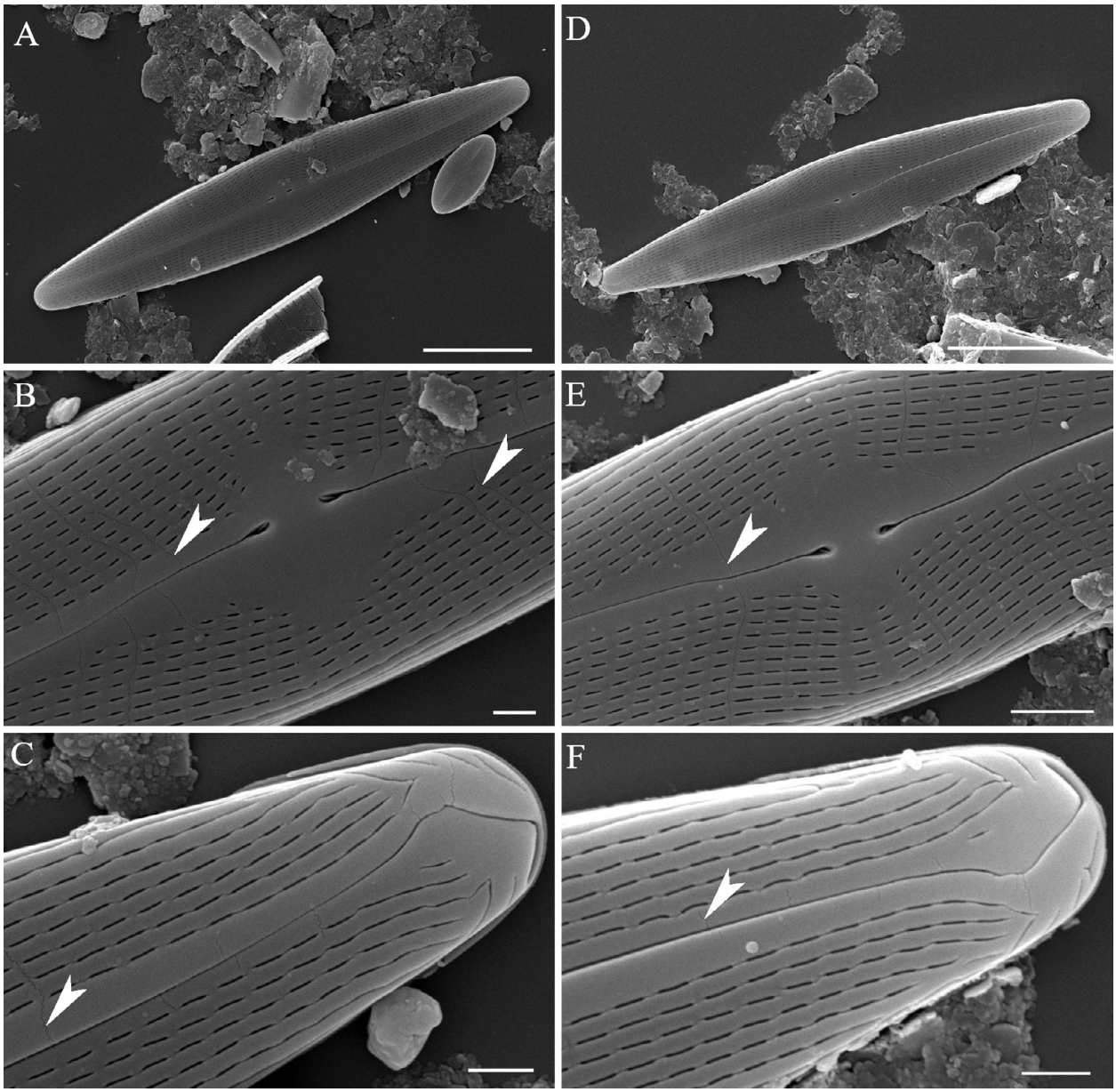

Fig. 2. *Navicula suturata* sp. nov., external valve view, SEM images of the type material. A, D — whole valve; B, E — central valve part; C, F — valve apex. Arrowheads mark rimulae. Scale bars: A, D — 10 μm, B, C, F — 1 μm, E — 2 μm.

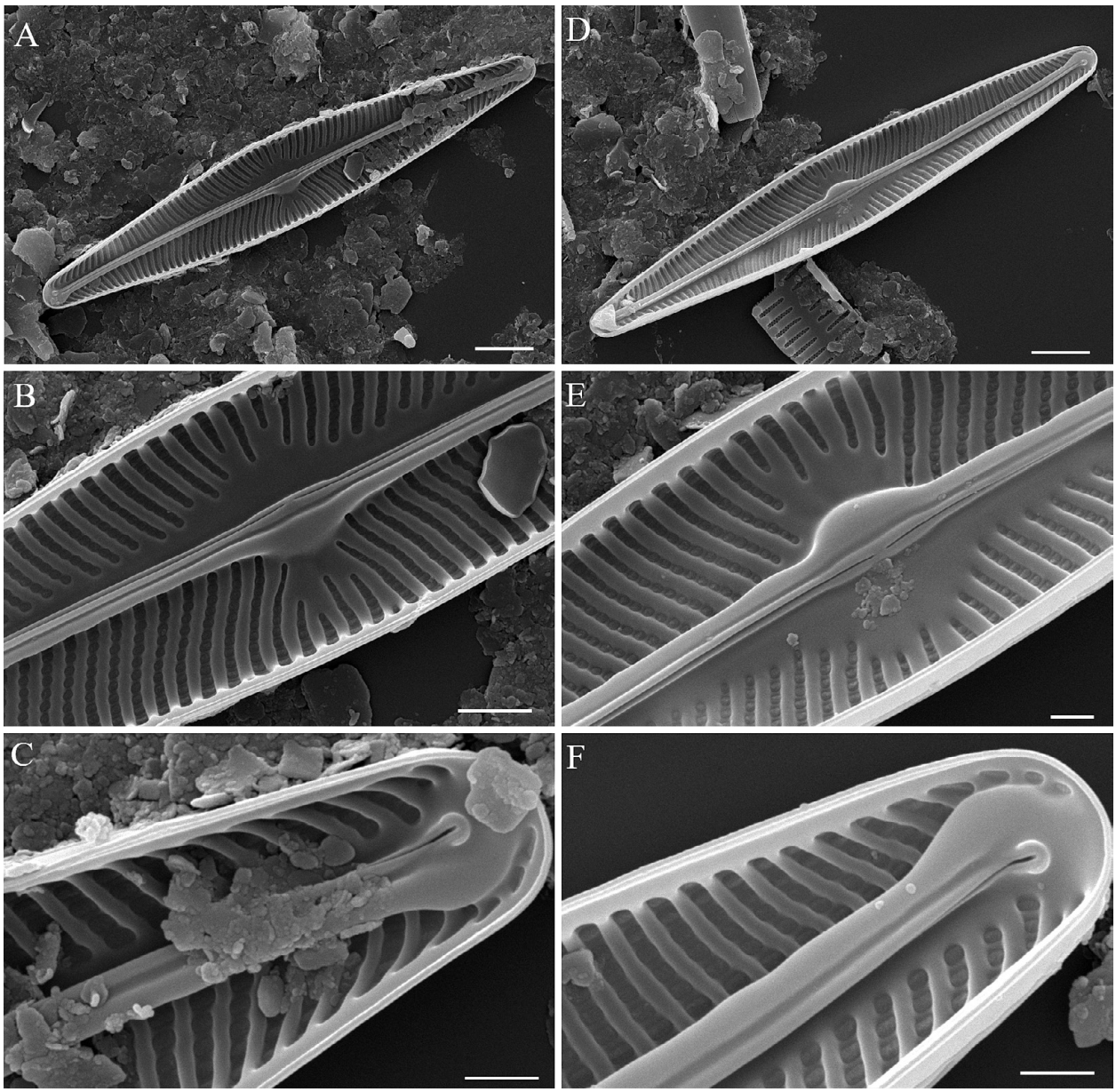

Fig. 3. *Navicula suturata* sp. nov., internal valve view, SEM images of the type material. A, D — whole valve; B, E — central valve part; C, F — valve apex. Scale bars: A, D — 5 μm, B — 2 μm, C, E, F — 1 μm.

coaxial. Distal raphe endings are well-developed, straight or slightly deflected helictoglossae.

Diagnosis. *Navicula suturata* differs from *N. venezuelensis* Hust. by more convex valve margins, wider central area and higher striae density; from *N. nielsfogedii* J. C. Taylor et Cocquyt by larger valve dimensions and coarser areolae; from *N. babeiensis* Chudaev et al. by absence of external apical grooves, wider valves with coarser striation and finer areolation; from *N. delicatilineolata* H. Kobayasi et Mayama by larger valve dimensions (see Discussion).

Holotype: specimen represented in Fig. 1C from slide MW-D 1244s1 (Diatom collection of the Department of Mycology and Algology, Faculty of Biology, Lomonosov MSU, Moscow, Russia).

Isotype: slide LE A0004254 (Herbarium of Komarov Botanical Institute RAS, St. Petersburg, Russia).

Type locality: Mali, Bamako, Niger River, 12.627097°N, 7.985164°W, bottom surface sediment, 5 II 2024, *Elansky*.

Etymology: Specific epithet reflects the presence of structures resembling cranial sutures (lat. suturatus — possessing sutures) on the external valve surface.

Distribution: The species is known so far from the type locality only.

Discussion

During the study of the sample from the Niger River, a new *Navicula* species, *N. suturata*, was found and described. The combination of morphological

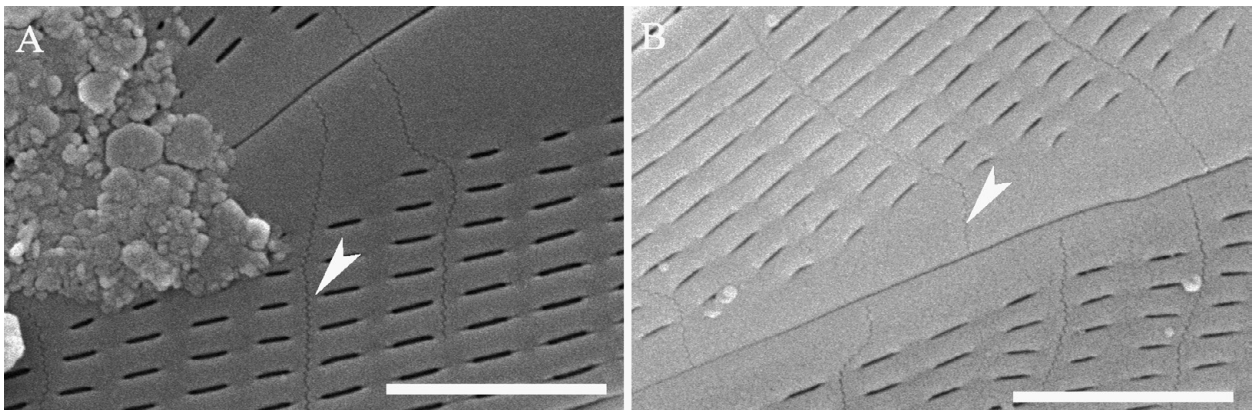

Fig. 4. *Navicula suturata* sp. nov., rimulae (marked by arrowheads), external view, SEM images of the type material. Scale bars: 2 μm.

features, such as presence of lineolate areolae with internal hymenes and median raphe with internal accessory rib and unilaterally curved external terminal fissures, indicates that the species should be placed within the genus *Navicula*.

Navicula suturata resembles four species of the genus, and the differences are discussed below. The species *N. nielsfogedii* (Taylor *et al.*, 2016: 202, figs. 1–22, 34–51) is morphologically very closed to *N. suturata* in aspects of valve ultrastructure (central pores with tongue-like projections, presence of "cranial sutures", inverted V-shaped subapical structures, well-developed accessory rib with central and terminal thickenings). However, the metrical values of *N. nielsfogedii* differ. This species has smaller valve dimensions (length 22–43 μm, width 5.3–6.7 μm) and higher areolae density (40 in 10 μm). The other species *N. venezuelensis* (Hustedt, 1956: 115, figs. 33–36) differs from *N. suturata* by valve outline (valve margins are less convex, almost parallel in *N. venezuelensis*), lower striae density (12.1–12.4 in 10 μm, values for *N. venezuelensis* are measured from the type material images in Simonsen (1987: pl. 653, figs. 15–19). Axial area of *N. venezuelensis* is narrower in comparison to *N. suturata*, and asymmetry of central area is absent or much less pronounced. *Navicula babeiensis* (Kulikovskiy *et al.*, 2021: 62, figs. 1–24) is similar to *N. suturata* by asymmetric area and raphe structure, but differs by the presence of prominent longitudinal external grooves containing apical rows of areolae. *Navicula babeiensis* also has narrower valves (width 5.4–6.8 μm) with more densely spaced striae (17.0–19.1 in 10 μm), but much coarser areolae (23.1–28.2 in 10 μm). *Navicula delicatilineolata* (Mayama, 2003: 19, figs. 11–20) is similar to *N. suturata* in valve ultrastructure, but differs in metric characters. Valves of *N. delicatilineolata* are shorter (29–42 μm) and slightly narrower (6.5–7.5 μm). "Cranial sutures" were not observed in *N. delicatilineolata*. Characters of *N. suturata* and mentioned morphologically similar species are summarized in Table 1.

Interesting morphological features observed in *Navicula suturata* are suture-like structures on the external valve surface (Fig. 4). We have observed them in each valve of the species, studied under SEM. These structures were firstly recently described in populations of *N. nielsfogedii* (Taylor *et al.*, 2016), the authors indicated that "such structures were not reported in other diatoms and their value as taxonomic characteristics is unknown" (Taylor *et al.*, 2016: p. 202). Later, "irregular grooves on the external valve surface" were described in *N. eileeniae* Potapova et Ciugulea (Potapova *et al.*, 2019: p. 375). Investigation of published SEM-micrographs shows that the same or similar sutures occur in other species of *Navicula*. For example, similar structures, but appearing straight rather than sinuous, were noticed in *N. sparsilineolata* Chudaev et al. (Kulikovskiy *et al.*, 2022: figs. 4B–C) and can be observed in published SEM-images of *N. praeterita* Hust. (Lange-Bertalot, 2001: pl. 72, fig. 1). The existence of taxa with and without sutures and with sutures of different morphology indicates that a taxonomic value of these features needs to be more thoroughly investigated. According to our opinion these structures deserve to be named. Since, here we introduce a new term (rimulae) for them. The definition is following:

Rimula, *pl.* rimulae (*English* small crack, *Russian* римула) — a very narrow transapically elongated sinuous (e. g., in *Navicula suturata*) or straight (e. g., in *N. sparsilineolata*) sutures on the external surface of virgae or axial area (Figs. 2B, C, E, F; 4A, B arrowheads).

Table 1

Morphological features of *Navicula suturata* and similar species

Taxon	Valve length, μm	Valve width, μm	Striae in 10 μm	Areolae in 10 μm	Geographical distribution	Other diagnostic features	References
N. suturata sp. nov.	43.5–48.0	7.5–8.5	14.0–16.5	31.6–33.6	Mali	—	This study
N. nielsfogedii	22–43	5.3–6.7	16–18	40	tropics and sub-tropics of southern and central Africa; tropical south-east Asia	—	Taylor *et al.*, 2016; Chudaev *et al.*, 2020
*N. venezuelensis**	38.9–44.5	7.0–7.7	12.1–12.4	28.9–32.5	Venezuela	valve margins less convex, almost parallel; axial area narrower; asymmetry of central area absent or much less pronounced	Simonsen, 1987
N. babeiensis	31.1–59.7	5.4–6.8	17.0–19.1	23.1–28.2	Vietnam	longitudinal external grooves containing apical rows of areolae	Kulikovskiy *et al.*, 2021
N. delicatilineolata	29–42	6.5–7.5	15–16	30–35	Japan	rimulae not observed	Mayama, 2003

* Values of metric characters for the species are measured from the images.

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Conflicts of Interest. The authors declare no conflict of interest.

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