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Three new species of the genus *Stauroneis* Ehrenberg (Bacillariophyceae: Stauroneidaceae) from the Northern Western Ghats, India

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Abstract: Three new species of the genus *Stauroneis* Ehrenberg are discovered from the Northern Western Ghats of India – *Stauroneis datarii* sp. nov., *Stauroneis bahlsii* sp. nov., and *Stauroneis hamiltonii* sp. nov. Based on light microscopy (LM) and scanning electron microscopy (SEM) observations, detailed morphological features are presented and each taxon is discussed in comparison with similar species within the genus. Features of linear–lanceolate valves with median constriction, rounded apices, bow–tie shaped stauros, and radiating striae characterize *Stauroneis datarii*. *Stauroneis bahlsii* has large, lanceolate valves, with obtusely–rounded apices, a bow–tie shaped stauros that may have isolated areolae in some valves. *Stauroneis hamiltonii* possesses linear–lanceolate valves, broadly rostrate apices, characteristic bow–tie shaped stauros, and radiate striae. All of the taxa share a characteristic pseudoseptum at the apices. The recent discoveries of many novel taxa from the terrestrial and semi–aquatic environments of the Northern Western Ghats highlight the role of non–aquatic habitats in unmasking the diatom diversity of the Indian subcontinent.

Key words: Bacillariophyta, Kaas plateau, new species, *Stauroneis*, taxonomy, Western Ghats

Introduction

The Western Ghats is a mountain range parallel to the west coast of peninsular India and represents one of the world's most biologically diverse regions. This mountain range, combined with Sri Lanka, is recognized as one of the world's 8th 'hottest hotspots' of biological diversity (Menon & Bawa 1997). The chain of mountains runs about 1600 km extending South from the Tapti River (21°N) to Kanyakumari (8 °N), interrupted by the 30 km Palghat Gap at around 11 °N (Menon & Bawa 1997). The Western Ghats can be divided into three regions: northern, central, and southern Western Ghats. The Northern area extends from Tapti in the north, running through Maharashtra and Goa's states, to the River Kali in Karnataka about 700 km South (Shigwan et al. 2020). The diverse topography and climate create a wide range of habitats supporting a rich and unique flora and fauna. Thus, the Western Ghats is characterized by an exceptionally high biological diversity level and endemism (Groomebridge 1992). Based on the present level of understanding (Gunawardene et al. 2007), endemism is highest in amphibians (78% of species reported), followed by molluscs (76%), reptiles (62%), evergreen trees (56%), fish (53%), lianas (40%), ants (20%), mammals (11%) and birds (4%). However, studies on this region's microbial diversity are few and have only started relatively recently (Gandhi 1959, 1966, 1970; Karthick & Kociolek 2011, 2012; Suryanarayana et al. 2011; Alakananda et al. 2012; Radhakrishnan et al. 2018).

The northern parts of the Western Ghats are composed mostly of Deccan flood basalts, an igneous rock formed from the cooling of the Deccan Volcanic lava flows, which includes the bedrock of the western part of Maharashtra State. The Deccan Traps are mostly arranged in flat layers, giving rise to the Deccan plateau's flat plains and the Western Ghats hills' layered aspect characteristic in Maharashtra (Watve 2013). This unique geological history resulted in abundant rocky crevices. Thus, many unique aquatic habitats such as ephemeral pools on the lateritic rocky outcrop, small waterfalls, and wet walls along the mountain pass across the Northern region of the Western Ghats. These habitats are covered with algal biofilms during the southwest monsoon period (June – September). Our initial surveys in these habitats confirmed unique diatom assemblages even at the genus level, and our ongoing work has resulted in descriptions of many new taxa (Roy et al. 2019; Radhakrishnan

et al. 2020).
The current report describes three new species of the genus *Stauroneis* from the northern Western Ghats (Fig. 1), based on light (LM) and scanning electron microscopic (SEM) observations along with comparisons of similar *Stauroneis* taxa.

Materials and Methods

Study Site. The present study was conducted at two mountain passes (Kaas and Varandha Ghat sections) of India's Northern Western Ghats.

Sample Collection and Treatment. Benthic diatom samples were collected by scraping substrates with spoons, transferring the algal biofilms into Whirl–Pak® storage bags, and then returning them to the lab in Pune. Water quality variables such as water temperature, pH, and electrical conductivity were measured in the field using an HQ40D portable multiparameter meter (Hach, Loveland, Colorado, USA). Nitrate and phosphate were also measured in the field, using a portable spectrophotometer DR1900 (Hach, Loveland, Colorado, USA) using Hach made chemicals (NitraVer® 3 Nitrate and NitraVer® 6; PhosVer® 3 Phosphate). Geographical coordinates and elevation readings were taken using eTrex® 30x (Garmin®, Kansas, USA) instrument. For cleaning, a portion of each sample was mixed with equal volumes of concentrated HNO_3 and boiled to oxidize the organic matter for 90 minutes. Subsequently, the material then was alternately centrifuged at 3000 rpm and rinsed with distilled water several times until it attains a neutral pH. The cleaned material was air–dried onto glass coverslips, and the coverslips were subsequently mounted onto glass slides using Naphrax as a mounting medium (Refractive Index 1.73) for LM analysis. The slides were studied at 1000× magnification under oil immersion using an Olympus BX53 (Tokyo, Japan) microscope equipped with Differential Interference Contrast (Nomarski) optics, and images were captured with an Olympus DP 74 camera. Morphometric measurements (length, breadth, number of striae/10 µm at the centre, and apices) were noted for each species. For SEM analysis, the cleaned samples were dried onto glass coverslips (5mm × 5mm), affixed to aluminium stubs with double–sided carbon tape. Stubs were sputter–coated with gold–palladium with an Emitech K57SX sputter coater (Quorum Technologies, United Kingdom). SEM observations were performed with a Zeiss EVO MA 15 (Oberkochen, Germany) microscope with LaB6 filament. LM and SEM images were processed in GIMP (version 2.10.24) and plates were compiled in Inkscape (version 0.92). For some LM images (Figs 25–32 and 44–51) to maintain the uniformity of the image size, cloned parts were created. Cleaned materials and slides are archived in the Diatom collection at Agharkar Research Institute Herbarium (AHMA), Pune, India. Morphological terminology follows Ross et al. (1979) and Barber & Haworth (1981).

Results

***Stauroneis datarii* Wadmare, Kociolek et B.Karthick sp. nov. (Figs 2–23)**

LM Description (Figs 2–13): Valves linear–lanceolate with median area appearing very slightly constricted and apices rounded. Length 16.5–34.5 µm, breadth 3.7–5.5 µm. Axial area narrow at apices widening towards the centre to form a bow–tie shaped stauros. Raphe lateral, proximal raphe ends deflected, and distal raphe ends straight. Striae strongly radiate throughout 24–30/10 µm. Areolae distinct and dash–like. Pseudosepta evident in LM. For measurements, n= 47 valves.
SEM Description (Figs 14–23): Externally, valves linear–lanceolate with a narrow axial area wider at the centre (Figs 14, 15). Central stauros bow–tie–shaped without any striation (Fig. 16). Proximal raphe ends teardrop–shaped and bent slightly in the same direction (Fig. 16). Distal raphe ends sickle–shaped, continuing onto the mantle (Figs 17, 18). Striae composed of dash or hyphen–shaped areolae (Figs 14, 15).
Internally, valve mantle constricted at the central stauros (Figs 19, 20). Proximal raphe ends slightly deflected and terminating onto a well–developed, broad stauros (Fig. 21). Centre of stauros with distinct ridge present (Figs 20, 21). Distinct pseudoseptum present at each valve apex obscuring the distal raphe ends (Figs 22, 23). Hymenate occlusions bacilliform (Figs 21, 22).

Holotype: Specimen circled on microscope slide marked 03–67 accession #134 illustrated in Fig. 5, deposited at the Agharkar Herbarium of Maharashtra Association (AHMA) located at Agharkar Research Institute, Pune, India.
Type Locality: High altitude waterfall site, a cave located at Varandha Ghat road, (18.11281°N, 73.6077°E, altitude 691 meters above sea level), Maharashtra, India.
Habitat: Epilithic composite sample collected around the waterfall.
Etymology: This taxon is dedicated to Dr. Mandar Datar, Agharkar Research Institute, Pune, for his contributions in understanding the flowering plants in the Northern Western Ghats.
Ecology: pH– 7.17, EC ($\mu S.cm^{-1}$) – 37.33, DO ($mg.l^{-1}$) – 7.9, T (°C) – 24.10, N ($mg.l^{-1}$) – 1.4, P ($mg.l^{-1}$) – 0.24. The values mentioned above of the ecological parameters are single measurements corresponding to the time of collection. Various associated taxa dominate the sample belongs to *Gomphonema, Navicula*, *Frustulia* and *Pinnularia*.

The species that most closely resemble *Stauroneis datarii* is *Stauroneis sikkimensis* N.Wadmare, S.Roy, Kociolek et B.Karthick described from moss habitats of Sikkim, India (Wadmare et al. 2019). It is differentiated from *S. datarii* by having bluntly or obtusely–rounded, non–protracted, apices, and the shape of the stauros, which is broad, and H–shaped. *Stauroneis lundii* Hustedt, a freshwater species described from Europe, overlap valve dimensions (12–32 µm long and 4–5.5 µm broad) but has a more linear–lanceolate outline, subrostrate apices and straight, non–inflated proximal raphe endings (Hustedt 1959). Valves of *S. atacamae* var. *fuegensis* Cleve–Euler, a freshwater species from Tierra del Fuego, Argentina, South America, are wider (7.0–7.5 µm), and they lack pseudosepta (Cleve–Euler 1948). *S. distinguenda* Hustedt, described from moss habitats

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of Sumatra Island, Indonesia, is larger (42–57 µm long and 6 µm broad; Hustedt 1937; Simonsen 1987) than the new species described here. A striae density of 30–36 in 10 µm distinguishes *S. datarii* from *S. cataractae* Moser, Lange–Bertalot et Metzeltin, a freshwater species known from river habitats of New Caledonia (Moser et al. 1998). *S. sphagnophila* Krasske, also described from moss habitats, differs from the obtusely rounded apices as well as the stauros, which is broad, widened, and truncated towards the margin (Krasske 1948). Features used to distinguish *Stauroneis datarii* from a group of morphologically similar *Stauroneis* species are given in Table 1.

***Stauroneis bahlsii* Wadmare, Kociolek et B.Karthick sp. nov. (Figs 24–42)**

LM description (Figs 24–32): Valves large, lanceolate, with blunt, obtusely–rounded apices. Length 63.5–124.5 µm, Breadth 12.0–19.5 µm. Axial area widens gradually towards the central area. Central stauros shaped like a bow–tie, widening towards the valve margin, possessing isolated areolae in some valves. Raphe filiform in the

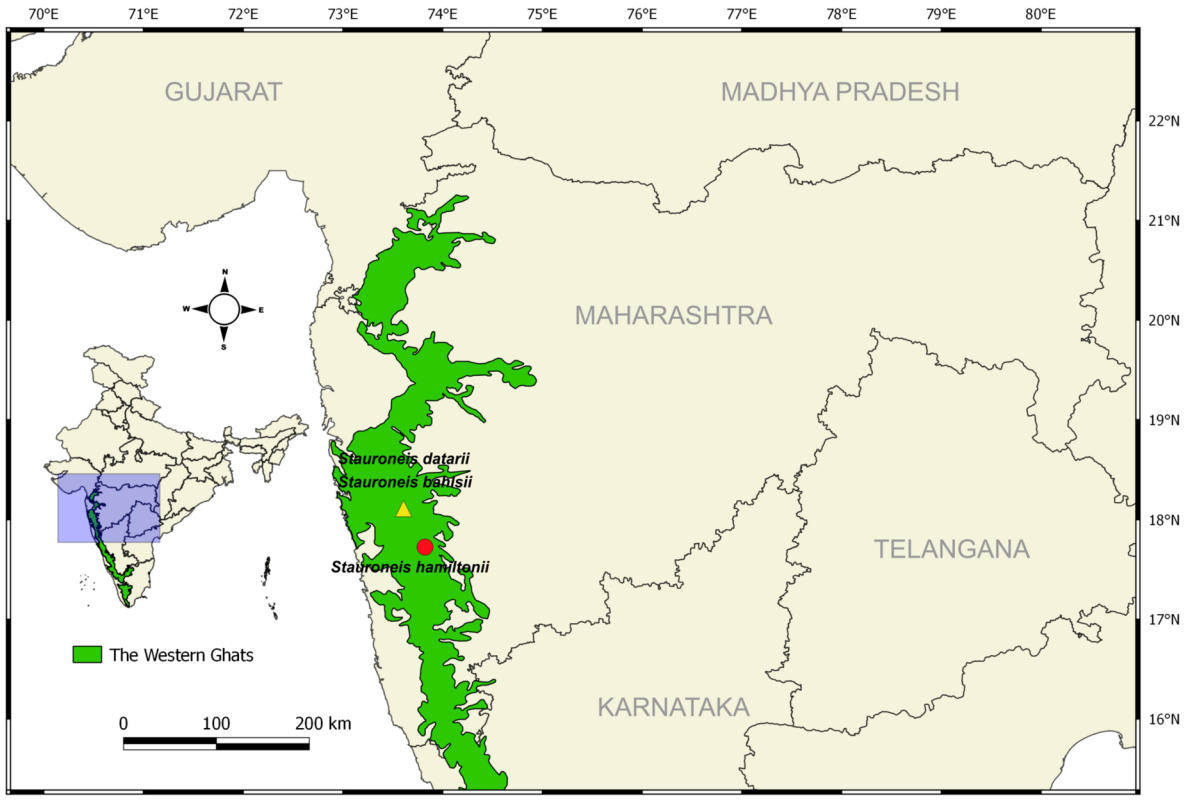
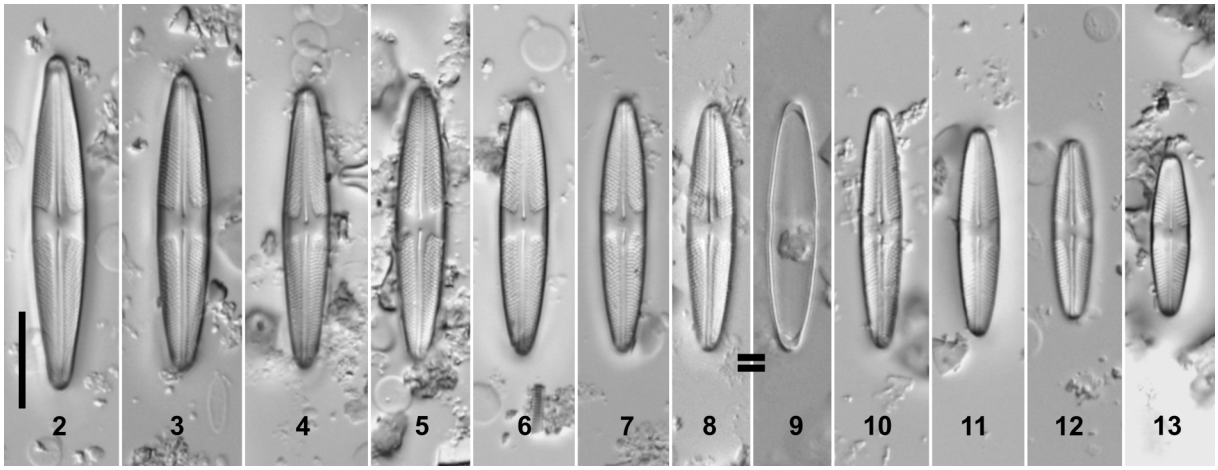


Fig. 1. Map showing the sampling sites of three new *Stauroneis* species described from the India. "Triangle" represents species from the Varandha Ghat and "Circle" from the Kass plateau region of the northern Western Ghats.



Figs 2–13. *Stauroneis datarii* sp. nov., light micrograph valve views showing size diminution series: (5) holotype specimen. Scale bar 10 µm.

Table 1. Comparison of morphological characteristics of taxa similar to *Stauroneis datarii* sp. nov.

Features	***Stauroneis datarii* sp. nov.**	***S. lundii***	***S. atacamae* var. *fuegensis***	***S. distinguenda***	***S. cataractae***	***S. sphagnophila***	***S. sikkimensis***
Length (µm)	16.5– 34.4	12–32	33–40	42–57	22–28	16–26	17.9–37.6
Breadth (µm)	3.7– 5.3	4–5	7.0–7.5	6	4.8–5.2	4–5	4.1–5.8
Valve shape	lanceolate with median depression	linear to linear–lanceolate	linear, with median depression	linear lanceolate, with median depression	linear elliptical, with slight median depression	linear lanceolate with median depression	lanceolate with median depression
Apex	acutely rounded	subrostrate	bluntly rounded	bluntly rounded	broadly rounded and tapered	obtusely rounded	bluntly or obtusely rounded, non–protracted
Central area (Stauros)	bow– tie shaped	bow–tie shaped, expanded	broad, expanded	broad, strongly expanded	broad, strongly expanded	broad, widened and truncate outwards	broad, expanded or H–shaped
Central raphe endings, central pore	slightly curved	straight, not inflated	curved, small pin–point–like	curved, weakly expanded	slightly curved, small pin–point–like	straight, not inflated, small pin– point–like	slightly curved, expanded small pin–point–like
Striae (in 10 µm)	24–30	30	20	20–28	30–36	25	24–28
Striation pattern	radiate throughout	slightly curved, radiating	radiate throughout	radiate throughout	radiate throughout	radiate throughout	radiate throughout
Shape of the areolae	rounded	rounded	rounded to slightly elongated	slightly elongated	rounded to slightly elongated	rounded	rounded to elongated
Presence/absence of pseudosepta	present	-	absent	present	present	present	present
References	current study	HUSTEDT (1959)	CLEVE– EULER (1948)	HUSTEDT (1937), SIMONSEN (1987)	MOSER et al. (1998)	KRASSKE (1948)	WADMARE et al. (2019)

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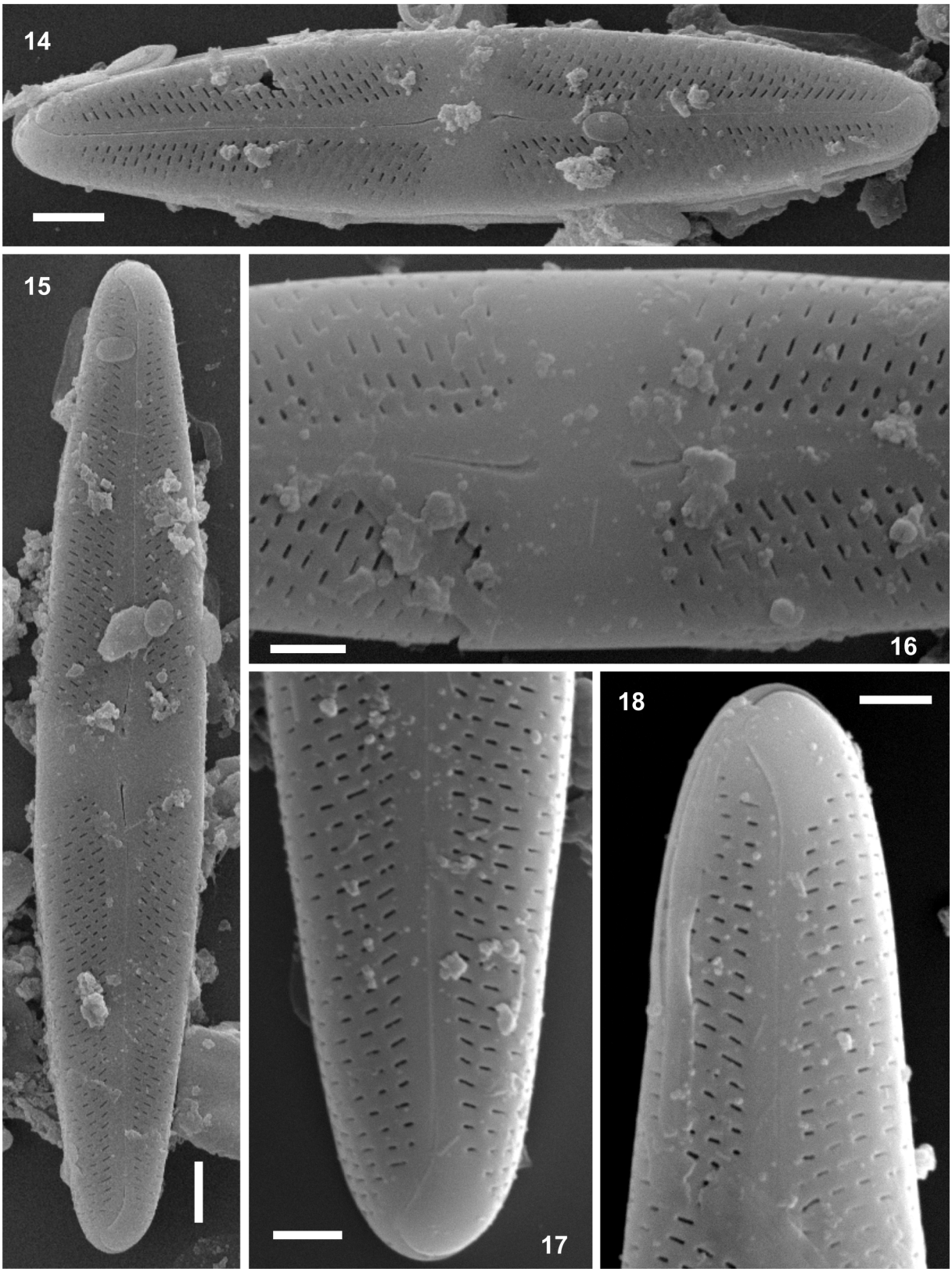
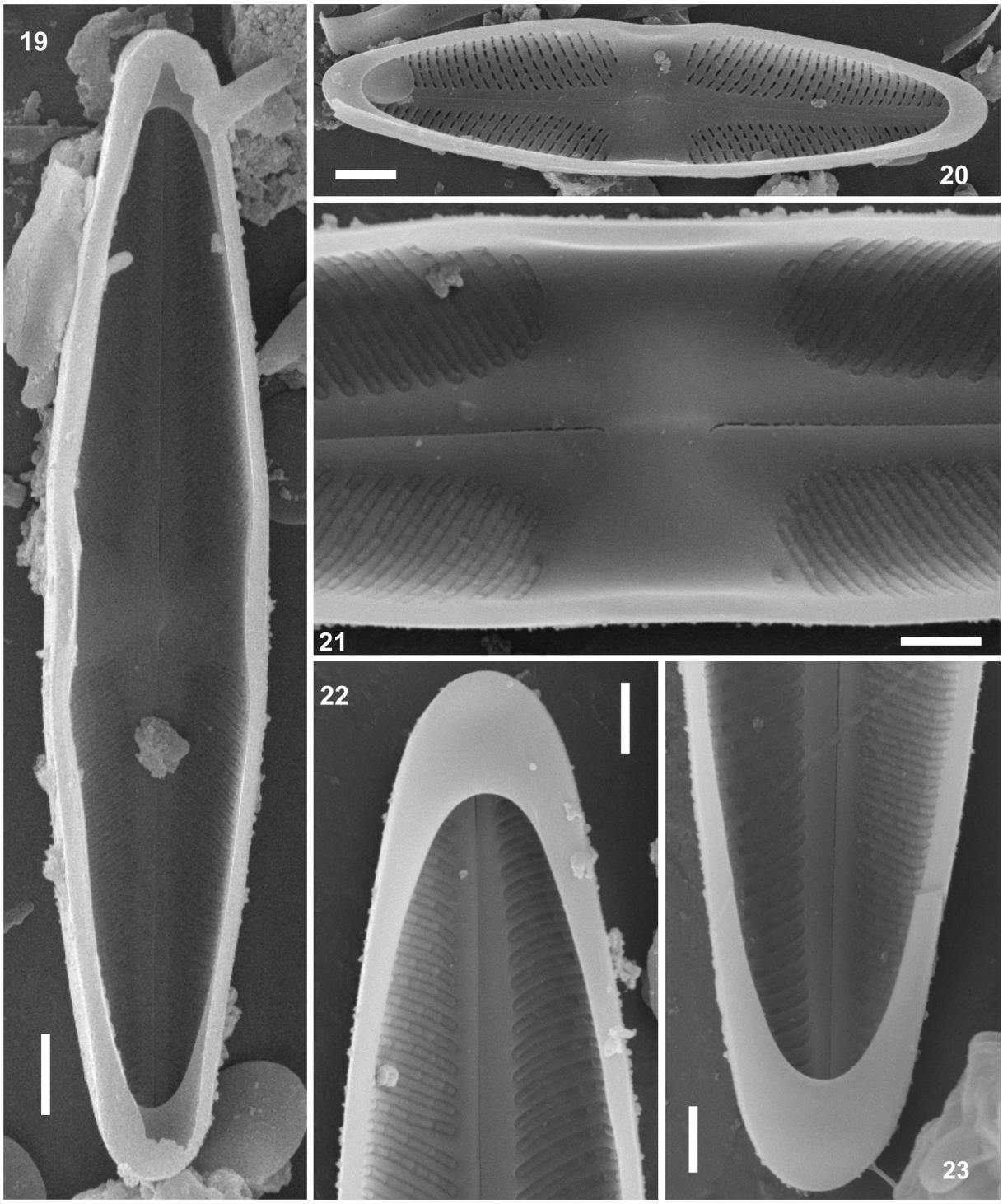


Figs 14–18. *Stauroneis datarii* sp. nov., SEM, external valve views: (14, 15) external view of an entire valve with distal raphe ends deflecting to the same side; (16) central stauros with teardrop–like raphe ends; (17, 18) details of apical area with sickle–shaped raphe ends. Scale bars 2 μm (14, 15), 1 μm (16–18).



Figs 19–23. *Stauroneis datarii* sp. nov., SEM, internal valve views: (19, 20) internal view of an entire valve; (21) central stauros with median constriction and silica ridge; (22, 23) pseudosepta evident at the apices obscuring distal raphe ends. Scale bars 2 µm (19, 20), 1 µm (21–23).

centre, becoming lateral and remaining so to the distal raphe ends. Proximal raphe ends slightly dilated and curved in the same direction. Distal raphe ends curved in a direction opposite to proximal ends. Striae strongly radiate throughout, 19–23/10 µm. Areolae elongated to dash–like, distinct. Pseudosepta evident in LM. For measurements, n= 57 valves.

SEM Description (Figs 33–42): Externally, valves lanceolate with a narrow axial area that widens near the centre (Fig. 33). Central stauros broad, expanded (Fig. 34). Raphe expanded at the stauros (Fig. 34). Proximal raphe ends deflected (Fig. 34). Distal raphe ends sickle–shaped, continuing onto the mantle (Figs 35, 36). Striae composed of rounded to variously elongated areolae (Fig. 37).

Internally, the stauros is bow–tie–shaped and

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expanded towards the margin (Figs 38, 40). Proximal raphe ends are slightly deflected and terminate on a well–developed, broad stauros (Fig. 40). Silica ridge present in the centre of stauros (Figs 38, 40). Distinct pseudoseptum present at each valve apex obscuring the distal raphe end (Figs 41, 42). Areolae distinct, dash– or hyphen–shaped (Fig. 39).

Holotype: Specimen circled on microscope slide marked 03–67 accession #134 illustrated in Fig. 28, deposited at the Agharkar Herbarium of Maharashtra Association (AHMA) located at Agharkar Research Institute, Pune, India.
Type Locality: High altitude waterfall site, a cave located at Varandha Ghat road, (18.11281°N, 73.6077°E, altitude 691 meters above sea level), Maharashtra, India.
Habitat: Epilithic composite sample collected around the waterfall.
Etymology: The species honours Dr. Loren Bahls from (Montana, USA) for his significant contribution to the genus *Stauroneis* in the Northern Rockies of North America.
Ecology: pH– 7.17, EC ($\mu S.cm^{-1}$) – 37.33, DO ($mg.l^{-1}$) – 7.9, T (°C) – 24.10, N ($mg.l^{-1}$) – 1.4, P ($mg.l^{-1}$)– 0.24. The values mentioned above of ecological parameters are single measurements corresponding to the time of collection. The sample is dominated by various associated taxa of *Gomphonema, Navicula*, *Frustulia* and *Pinnularia*.

Stauroneis bahlsii resembles *Stauroneis charrua* Metzeltin, Lange–Bertalot et Garcia–Rodriguez, described from Uruguay, in valve outline, but the latter taxon is broader (22–23 µm) and lacks pseudosepta (Metzeltin et al. 2005). *S. thompsonii* Bahls, a freshwater species described from rocks and sediments from Montana, USA, can be distinguished by having broader valves, (16.3–23.5 µm), rounded, non–protracted apices, and straight to weakly inflated central raphe endings (Bahls 2012). Furthermore, the valves of *S. kishinena* Bahls, another species described from Montana, are larger (122–182 µm), broader (26.33 µm), and have rounded areolae, all of which distinguish this species from *S. bahlsii* (Bahls 2010). *S. americana* Heiden differs from our species by having larger valves (136–214 µm long, 32–46 µm broad; Bahls 2010). Features used to distinguish *Stauroneis bahlsii* from a group of morphologically similar *Stauroneis* species are given in Table 2.

Table 2. Comparison of morphological characteristics of taxa similar to *Stauroneis bahlsii* sp. nov.

Features	***Stauroneis bahlsii* sp. nov.**	***S. charrua***	***S. thompsonii***	***S. kishinena***	***S. americana***
Length (µm)	63.5– 124.4	84–110	81–124	122–182	136–214
Breadth (µm)	12.0– 19.5	22–23	16.3–23.5	26.33	32–46
Valve shape	broadly lanceolate	lanceolate	lanceolate	broadly lanceolate	broadly lanceolate
Apex	blunt, obtusely rounded	bluntly rounded	rounded, non–protracted	rounded, subtly protracted	blunt, broadly rounded, non–protracted
Central area (Stauros)	bow–tie shaped	broad, expanding towards margin	nearly rectangular	rectangular	rectangular
Central raphe endings,	slightly curved, deflected	slightly curved	straight, weakly inflated	strongly hooked	straight, deflected
Striae (in 10 µm)	19–23	15–16	15–18	11–12	11–14
Striation pattern	radiate throughout	radiate throughout	radiate throughout	radiate throughout	radiate throughout
Shape of the areolae	elongated	elongated	coarse, elongated	rounded	rounded
Presence/absence of pseudosepta	present	absent	present	present	present
References	current study	Metzeltin et al. (2005)	Bahls (2012)	Bahls (2010)	Bahls (2010)

Stauroneis hamiltonii Wadmare, Kociolek et B.Karthick sp. nov. (Figs 43–59)

LM description (Figs 43–51): Valves linear–lanceolate with broadly rostrate ends. Length 30–61 µm, breadth 7.0–9.5 µm. Axial area linear, widening at the centre, forming a small stauros, usually bow–tie

shaped, rarely rectangular. Raphe filiform at the ends, lateral between the ends, with proximal raphe, ends teardrop–shaped, deflected in the same direction. Distal raphe ends deflected in the same direction. Striae strongly radiate throughout, 11–12/10 μm. Areolae are punctate to elongated, distinct in LM. Pseudosepta evident in LM. For measurements, n= 46 valves.

SEM Description (Figs 52–59): Externally, valves linear–lanceolate with a narrow axial area, which is wider at the centre (Fig. 52). Central stauros small, bow–tie shaped (Fig. 53). Proximal raphe ends teardrop–shaped and bent slightly in the same direction (Fig. 53). Distal raphe ends sickle–shaped, continuing onto the mantle (Figs 54, 55). Striae composed of dash–like to elongated areolae (Fig. 55).

Internally, central stauros small, thickened and expanded (Fig. 57). Proximal raphe ends slightly deflected and terminating onto a well–developed broad stauros, a distinct, longitudinally–oriented ridge present in the centre of stauros (Fig. 57). Distinct pseudoseptum present at each valve apex concealing the distal raphe end (Figs 56, 58, 59). Areolae hyphen–shaped with hymen occlusions (Figs 58, 59).

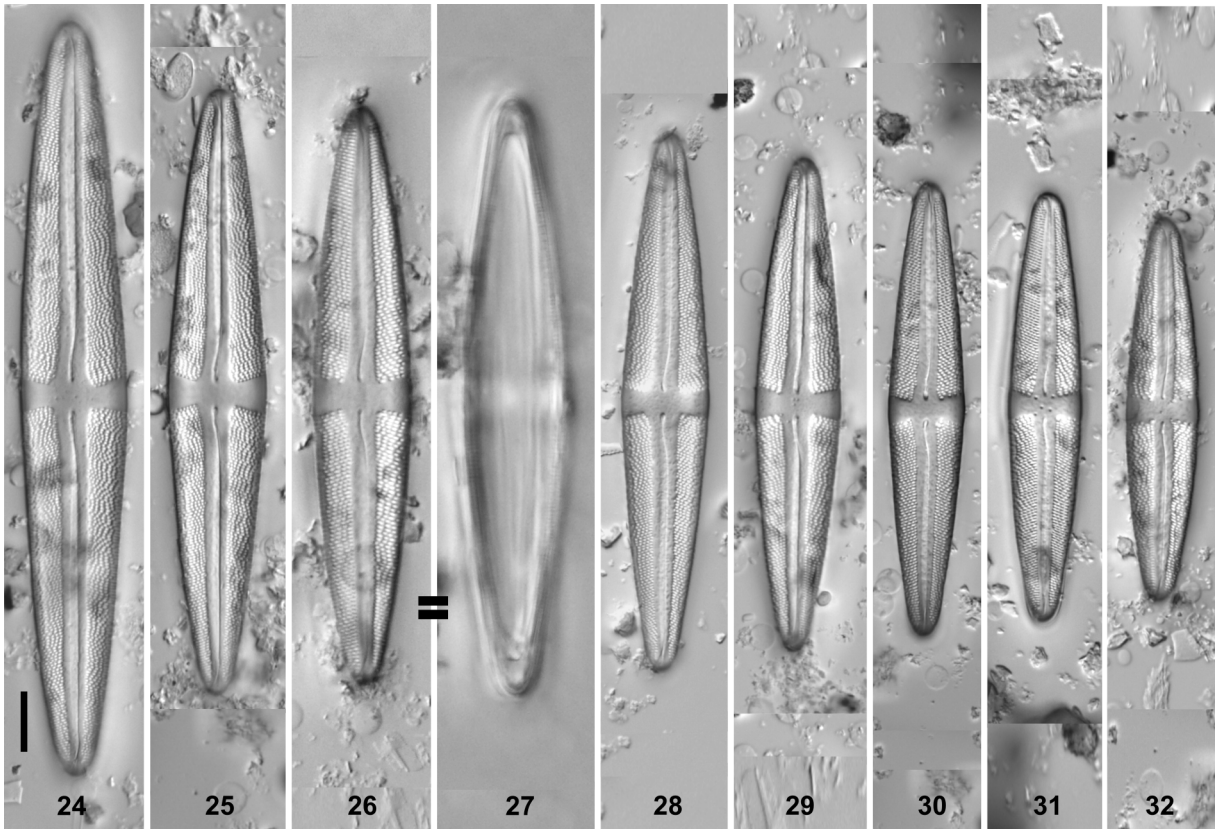
Holotype: Specimen circled on microscope slide marked 02–89 accession #95 illustrated in Fig. 45, deposited at the Agharkar Herbarium of Maharashtra Association (AHMA) Agharkar Research Institute, Pune, India.

Type Locality: Kaas plateau protected area, near Satara, (17.72635°N, 73.82249°E, altitude 1224 above mean sea level), Maharashtra, India.

Habitat: Benthic sample collected from a pool.

Etymology: The species is dedicated to Dr. Paul Hamilton (Museum of Nature, Ottawa, Canada) to acknowledge his work in diatom taxonomy.

Ecology: No water quality parameter observed during the collection. *Stauroneis hamiltonii* sp. nov. co–occurred with taxa of *Pinnularia*, *Navicula*, *Sellaphora* and *Adlafia*. *Stauroneis saprophila* M. Rybak, Noga et Ector, a saprobic species described from Poland's anthropogenic environments, Europe, resembles *Stauroneis hamiltonii* sp. nov. in having a lanceolate outline, bow–tie shaped stauros, and a pseudoseptum. But *S. saprophila* differs in having straight central raphe endings with rounded to teardrop–shaped central pores (Noga et al. 2017). *S. pseudoschimanskii* Van de Vijver et Lange–Bertalot was found in semi–dry moss samples from South Georgia, in the sub–Antarctic region, and it resembles *S. hamiltonii* is the overall shape. This species from high southern latitudes differs, however, by having smaller valves (length 24–30 μm, breadth 6–7 μm), and much finer striae (23–24 in 10 μm) nearly twice the density as compared to the new species (Van de Vijver et al. 2004, p. 58). *S. intricans* Van de Vijver et Lange–Bertalot was described from an inland pool from Kvarossbukta, Jan Mayen, an island in the Arctic. This species is differentiated from *S. hamiltonii* by having central raphe endings that are straight and inconspicuous and much finer striae (23–27 in 10 μm; Van de Vijver et al. 2004, p. 43). *S. acidoclinata*



Figs 24–32. *Stauroneis bahlsii* sp. nov., Light micrograph valve views showing size diminution series. (28) holotype specimen. Scale bar 10 μm.

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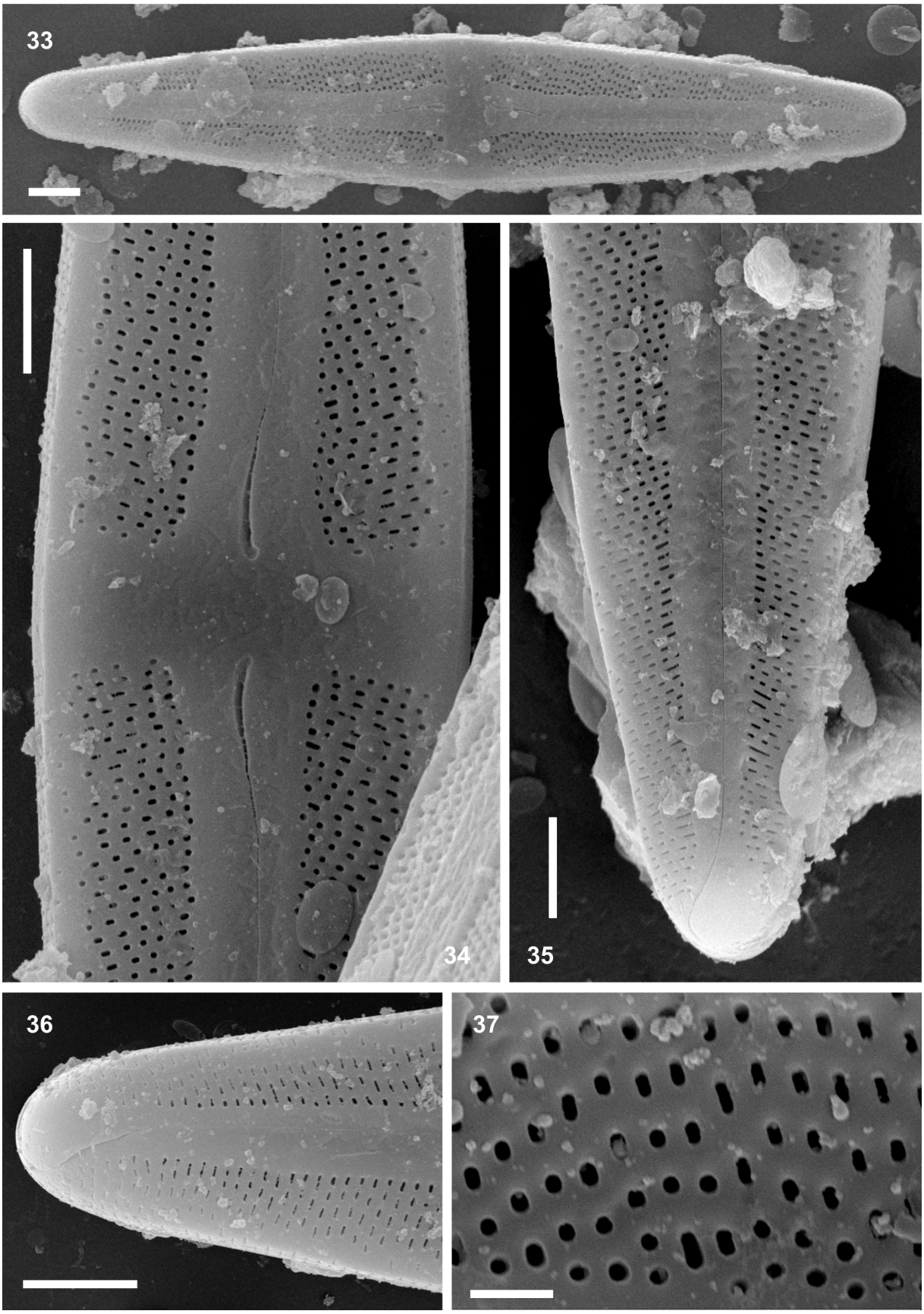
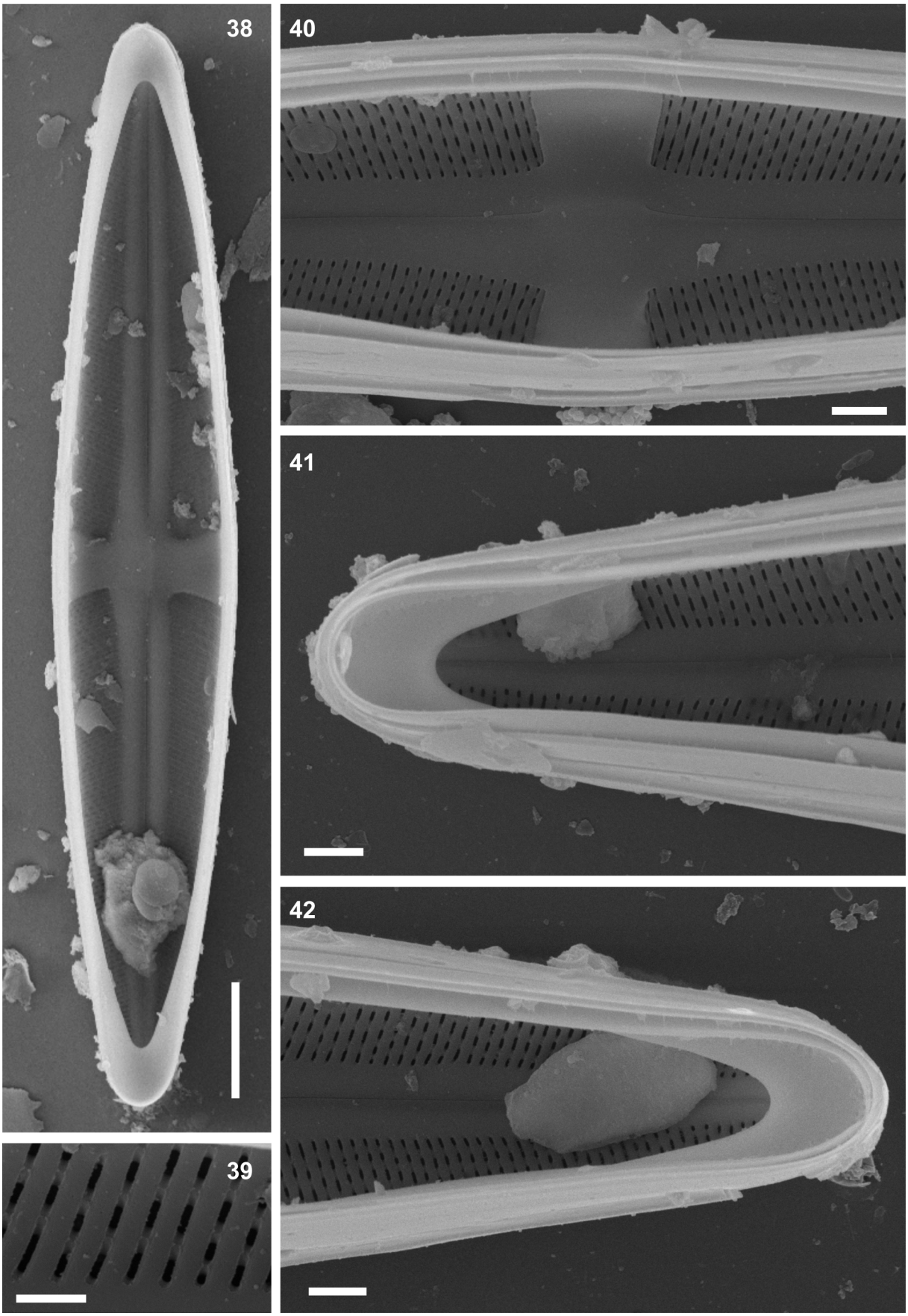


Figs 33–37. *Stauroneis bahlsii* sp. nov., SEM, external valve views: (33) external view of an entire valve; (34) broad stauros with deflected proximal raphe; (35, 36) sickle–shaped raphe continuing onto mantle; (37) view of rounded to variously elongated areolae. Scale bars 4 μm (33–36), 1 μm (37).



Figs 38–42. *Stauroneis bahlsii* sp. nov., SEM, internal valve views: (38) internal view of an entire valve; (39) hyphen–shaped areolae; (40) central area with broad stauros and silica ridge; (41, 42) Distal raphe ends obscured by distinct pseudoseptum. Scale bars 10 µm (38), 2 µm (40–42), 1 µm (39).

Lange–Bertalot et Werum, as the name suggests, is associated with acidic environments described from Bunter Sandstein, Germany. This species can be differentiated from *S. hamiltonii* in having acutely–protracted apices, non–deflected, central raphe endings, and finer striae (21–22/10 µm; Werum & Lange–Bertalot 2004). Features used to distinguish *Stauroneis hamiltonii* from a group of morphologically similar *Stauroneis* species are given in Table 3.

Table 3. Comparison of morphological characteristics of taxa similar to *Stauroneis hamiltonii* sp. nov.

Features	***Stauroneis hamiltonii* sp. nov.**	***S. saprophila***	***S. pseudoschimanskii***	***S. intricans***	***S. acidoclinata***
Length (µm)	30–61	29.3–50.8	24–30	23–44	35–60
Breadth (µm)	7.0–9.5	7.9–11.4	6–7	6.0–7.5	8.5–10.5
Valve shape	lanceolate	linear lanceolate	lanceolate to linear lanceolate	elliptic lanceolate to linear lanceolate	linear lanceolate
Apex	broadly subrostrate	rostrate	broadly subrostrate	protracted subrostrate to sub capitate	acutely protracted
Central area (Stauros)	small, bow–tie shaped	bow–tie shaped	distinctly widened towards the margins	broad, expanding towards valve margins	widening towards margin
Central raphe endings, central pore	tear drop, deflected	straight, rounded to tear drop shaped	weakly curved, somewhat deflected	straight, inconspicuous	filiform, non– deflected
Striae (in 10 µm)	20–21	13–16	23–24	23–27	21–22
Striation pattern	radiate throughout	moderately radiate throughout	moderately radiate throughout	radiate throughout	strongly radiate
Shape of the areolae	rounded to elongated	bacilliform	coarse	no discernible	trans apically elongated
Presence/absence of pseudosepta	present	present	present	absent	–
References	current study	Noga et al. (2017)	Van de Vijver et al. (2004: 58)	Van de Vijver et al. (2004: 43)	Werum & Lange– Bertalot (2004)

Discussion

The diatom genus *Stauroneis* has been assigned over 1100 taxa and, in terms of several species and subspecific taxa, is one of the largest freshwater genera of diatoms (Kociolek et al. 2020). All of the species in *Stauroneis* have thickened, an internally–elevated siliceous feature of a stauros, which lends its name to the genus and family in which these taxa occur. In terms of phylogenetic relationships, Hustedt (1952, 1962) noted several groups within the genus based on morphological and ecological differences. Some of these groups have been recognized as distinct genera, including *Capartogramma* with X–shaped central area (Ross 1963), *Schizostauron,* which includes monoraphid taxa (Grunow 1867), *Parlibellus* which includes estuarine and marine taxa (Cox 1988), taxa possessing pseudosepta, as well as *Prestauroneis*, where there is a small thickening at the central area (Bruder & Medlin 2008; Liu et al. 2015). These taxa and groups of species and the genus *Craticula*, species of which do not have a stauros (Spaulding et al. 2021), have been included in the family Stauroneidaceae, based on formal analyses of relationships using molecular data (Ashworth et al. 2017; Kulikovskiy et al. 2019).

The material from the Northern Western Ghats reported here confirm that we observe species from several morphological groups of *Stauroneis* present in the region. The three new species described here, *S. datarii*, *S. bahlsii,* and *S. hamiltonii,* all possess pseudosepta. Pseudosepta are found in a wide range of taxa within *Stauroneis*, including some very large taxa (e.g., *S. acuta* W. Smith, *S. obtusa* Lagerstedt) and some relatively small taxa, such as the distinctive *S. smithii* Grunow group (Spaulding et al. 2021). Assuming *Stauroneis* is a monophyletic group, this diversity of forms within a genus found in the northern Western Ghats suggests different dispersal events of *Stauroneis* taxa to the region. Alternatively, it may seem that several different lineages of diatoms have independently evolved a stauros (and thus *Stauroneis* is not monophyletic;

see Kociolek et al. 2019), and some of these different lineages are present in the northern Western Ghats. To date, the few taxa of *Stauroneis* investigated in formal phylogenetic analyses confirm the genus to be monophyletic (Ashworth et al. 2017; Kulikovskiy et al. 2019; Wadmare et al., accepted). However, only a few species of the genus have been considered to date, and they do not reflect the tremendous range of morphological variation currently included in the genus. Our results attest to the diversity of unique taxa and forms present in India's the Western Ghats. Finally, all of the taxa described here and previously (Radhakrishnan et al. 2018; Karthick & Kociolek 2011) from the Northern region of the Western Ghats originate from the semi–aquatic to terrestrial habitats, which signifies the role of the non–aquatic ecosystems in supporting the endemic biodiversity of this region.

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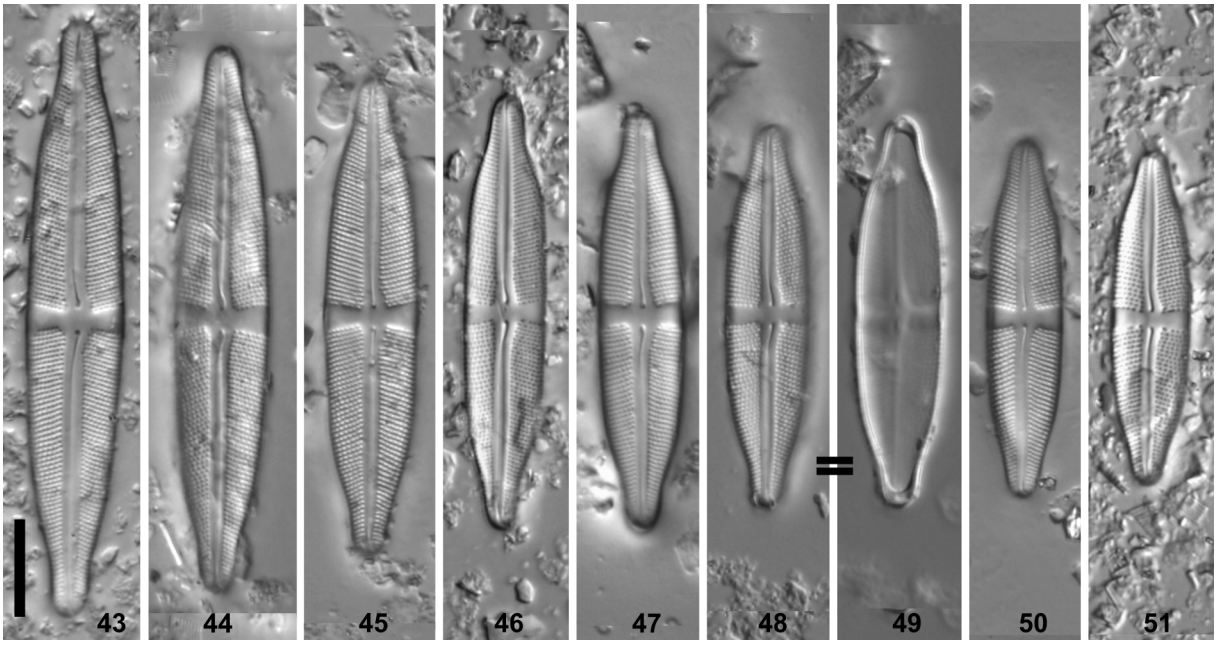

Figs 43–51. *Stauroneis hamiltonii* sp. nov., light micrograph valve views showing size diminution series: (45) holotype specimen. Scale bar 10 μm.

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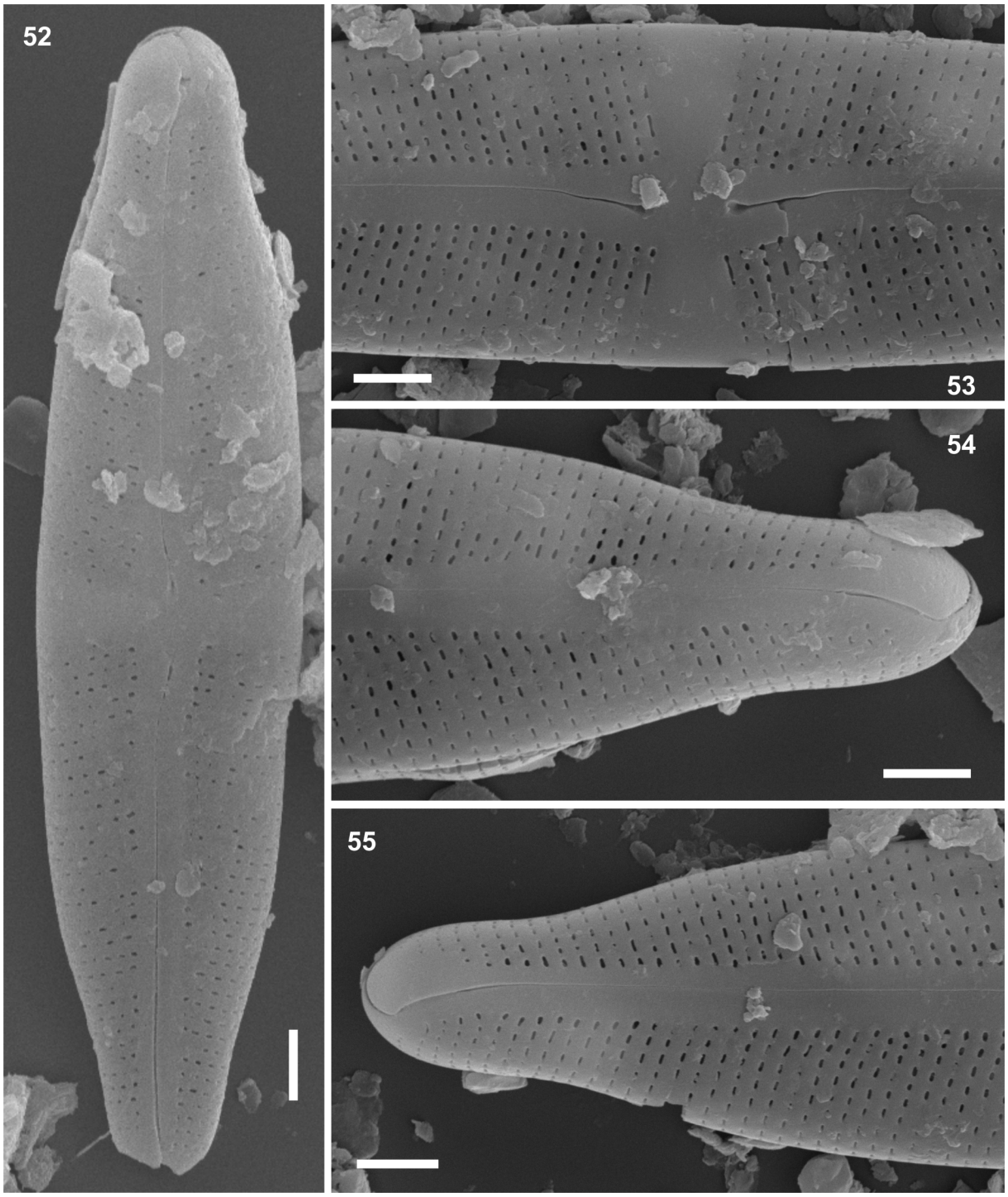
DOI: 10.5507/fot.2021.007



Figs 52–55. *Stauroneis hamiltonii* sp. nov., SEM, external valve views: (52) external view of an entire valve; (53) small stauros with teardrop–like proximal raphe ends (54, 55) apices with sickle–shaped raphe. Scale bar 2 μm (52–55).

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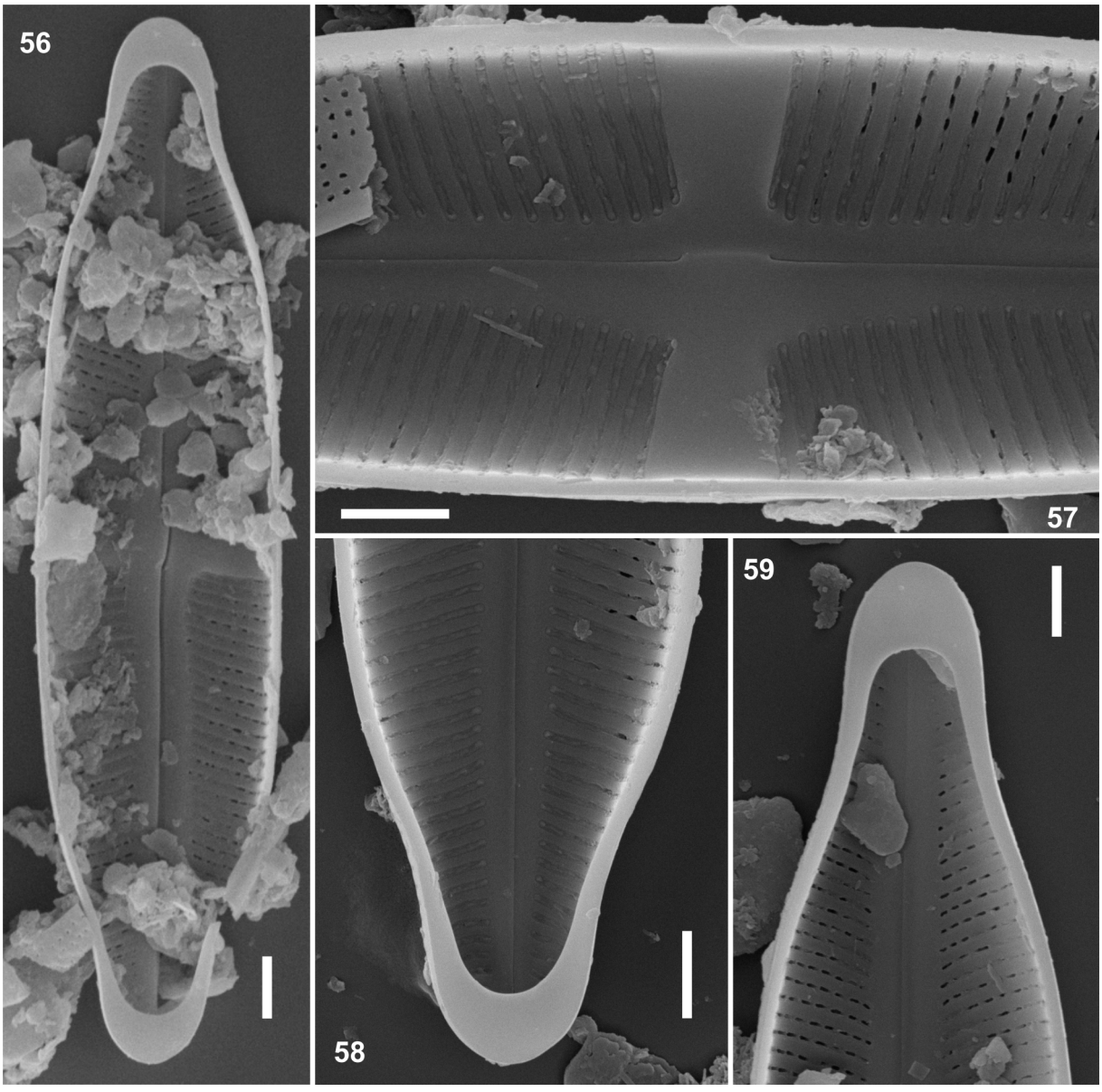

Figs 56–59. *Stauroneis hamiltonii* sp. nov., SEM, internal valve views: (56) internal view of an entire valve; (57) central stauros small with distinct silica ridge; (58, 59) pseudosepta evident at the apices. Scale bar 2 µm (56–59).

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