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Six new species of *Gomphonema* Ehrenberg (Bacillariophyceae) species from the Great Xing'an Mountains, Northeastern China

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Abstract – Six new species of the diatom genus *Gomphonema* Ehrenberg are described from lakes, swamps, bogs and streams from the Great Xing'an Mountains region of Northeastern China. Descriptions are based on light and scanning electron microscope observations of valve shape, size and ultrastructure. Of the six new species, four are known from the Great Xing'an Mountains only, while two others have been recognized in nearby Mongolia. All six species are known from habitats that are circumneutral to alkaline. Each species is described and compared with similar taxa. These new species descriptions, in addition to the recognition of other new species in the region, suggest aquatic habitats in the Great Xing'an Mountains may support an endemic diatom flora.

Bacillariophyta / China / diatom / *Gomphonema* / new species / Great Xing'an Mountains

INTRODUCTION

Until recently, there have been relatively few studies on the freshwater diatoms of the Asian continent. Classical works include those of Hustedt (1922), Gandhi (e.g. 1959, 1999) and Skvortzow (e.g. 1928, 1930 among many) as well as Skuja (1937), Meister (1932), Voigt (1942, 1969), Hirano (1967), and Amossé (1969). More recent studies have been floristic in nature, compiling the distribution of known taxa that were mostly described from Europe (e.g. Zhu & Chen, 2000; Shi, 2004; though see Bao & Reimer, 1992). Tyler (1996) has documented the shortcomings of "shoe-horning" specimens from Auastralasia into European names. Only recently, attempts were made to better characterize the diatom flora with the description of several new taxa, both at the genus and species levels (Metzeltin *et al*., 2009; Kulikovsky *et al*., 2009, 2010; Li *et al*., 2010; Liu *et al*., 2010a, b).

One group of diatoms from this region that has received significant attention is the genus *Gomphonema* Ehrenberg, resulting in the description of several new species from Nepal (Jüttner *et al*., 2000; 2004), Russia (Lange-Bertalot & Genkal, 1999; Kulikovskiy *et al*., 2012; Kociolek *et al.*, in press a), China

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(Fan *et al*., 2004; Li *et al*., 2003a, b, 2004, 2006, 2010; You *et al.*, 2013; Kociolek *et al*., in press b) and India (Karthick *et al*., 2011). Many of the species described from the Himalayan region have a similar morphology suggesting that they may be closely related (e.g. Karthick *et al*., 2011).

A floristic study of the Great Xing'an Mountains in northeastern China resulted already in the description of several new species (e.g. Liu *et al*., 2010a, b), as well as in observations on taxa with interesting aspects on their morphogenesis and biology (Kociolek *et al*., 2011). In this study we report light and scanning electron microscope observations on the valves of six new species of the diatom genus *Gomphonema* from the Great Xing'an Mountains, and discuss their distribution relative to ecological conditions of the habitats from which they are derived.

MATERIALS AND METHODS

Samples were collected from Great Xing'an Mts. region of China, located at ca. 46°39'- 47°39', North latitude, 119°28'-121°23' East longitude. More than 500 samples were collected from lakes, rivers, swamps and ponds from July 2004 to July 2007. Collection sites include Azalea Lake, Crane Lake, Daerbin Lake, Wusulangzi Lake, Tianchi Lake, Halaha River, Santan Gorge, and Stone ponds and swamps scattered in the mountains (Fig. 1). Samples were fixed in the field with 4% formaldehyde. Field samples were treated with hydrogen peroxide and hydrochloric acid to remove organic materials. Following oxidation, samples were alternately settled, decanted and rinsed 5-7 times with distilled water. Cleaned materials were mounted in Naphrax. Slides were examined with an Olympus BX 51 microscope equipped with DIC optics and an Olympus DP71 digital camera. For scanning electron microscope (SEM) observations, cleaned samples were mounted on stubs, sputter-coated with palladium (4 minute) and observed under JEOL JSM-6480LV scanning electron microscope at 15kv. Both LM and SEM observations were made at the Museum of Natural History in University of Colorado (Boulder, U.S.A.). For the morphological descriptions, more than 30 valves of each species were observed and measured. For morphological terms related to gomphonemoid diatoms, we follow the characters and charater state data described by Kociolek and Stoermer (1993).

RESULTS

Gomphonema rexlowei* Liu *et* Kociolek, *sp. nov. **Figs 2-15**

Fig. 3 represents the holotype.

Description: Valves clavate, lanceolate, slightly asymmetrical to the apical axis, with small, capitate headpole and a narrower footpole, Length 15-35 μm, breadth 4.6-6.2 μm. Raphe lateral, almost straight externally. Axial area parallel, narrow, nearly straight. Central area rectangular, asymmetric, approximately half the

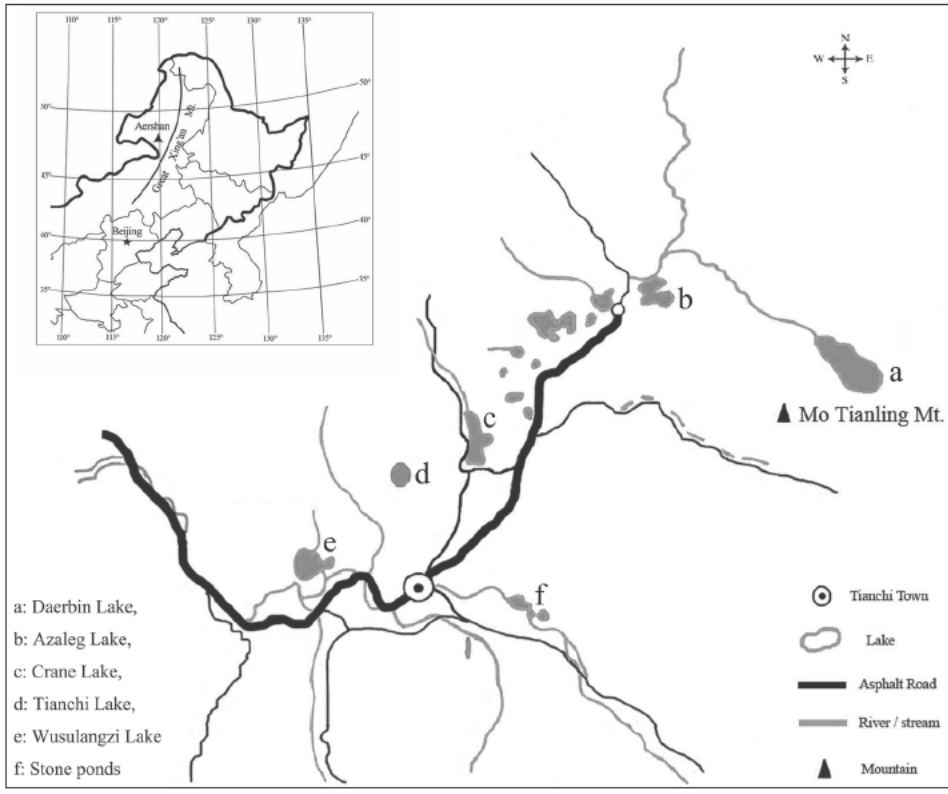


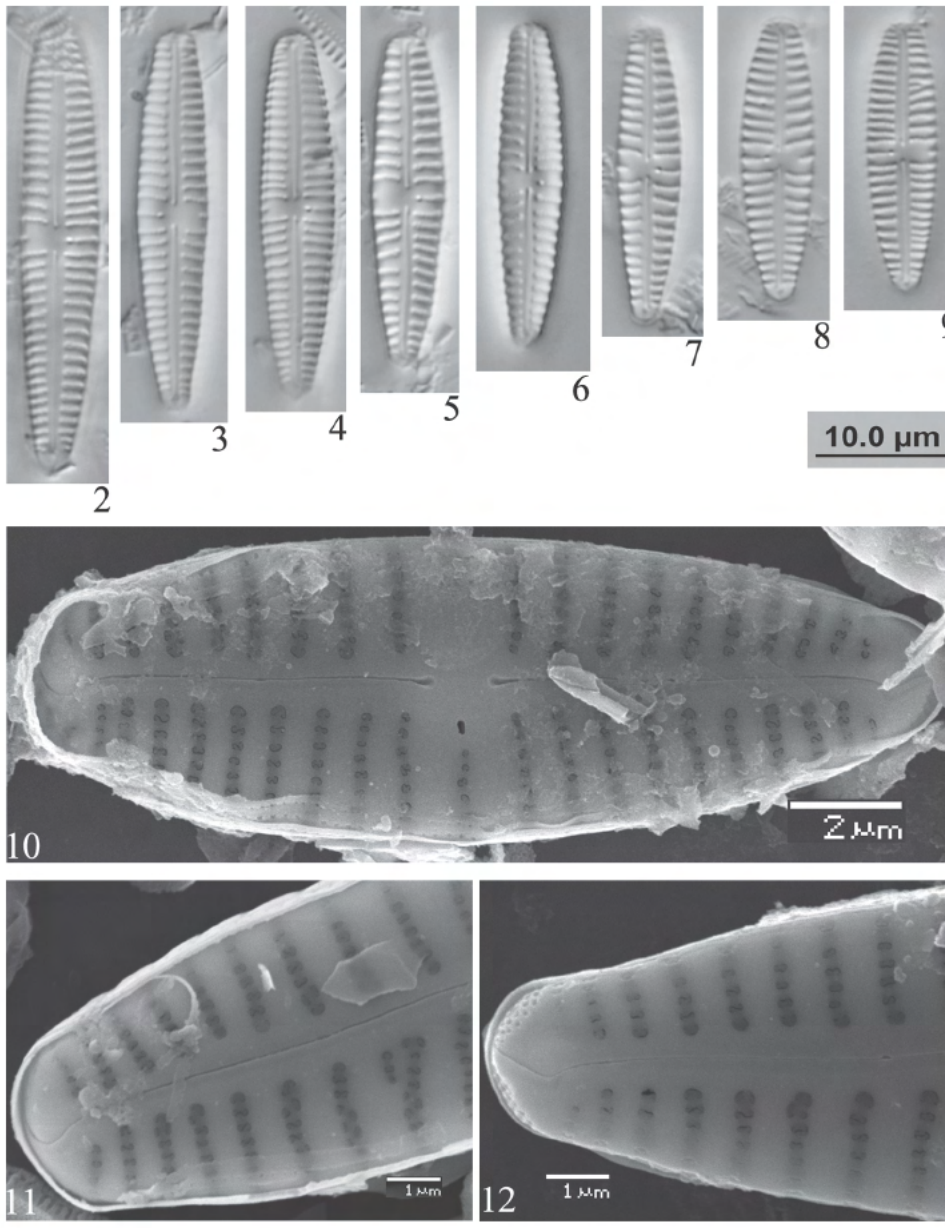
Fig. 1. Location of the sampling sites.

breadth of the valve. One stigma present at the end of a stria on the primary side of the central nodule. One short stria located on the opposite side of central area. Striae parallel to slightly radiate throughout, 8-12 in 10 μm at the center, denser towards the apices, 10-14 in 10 μm.

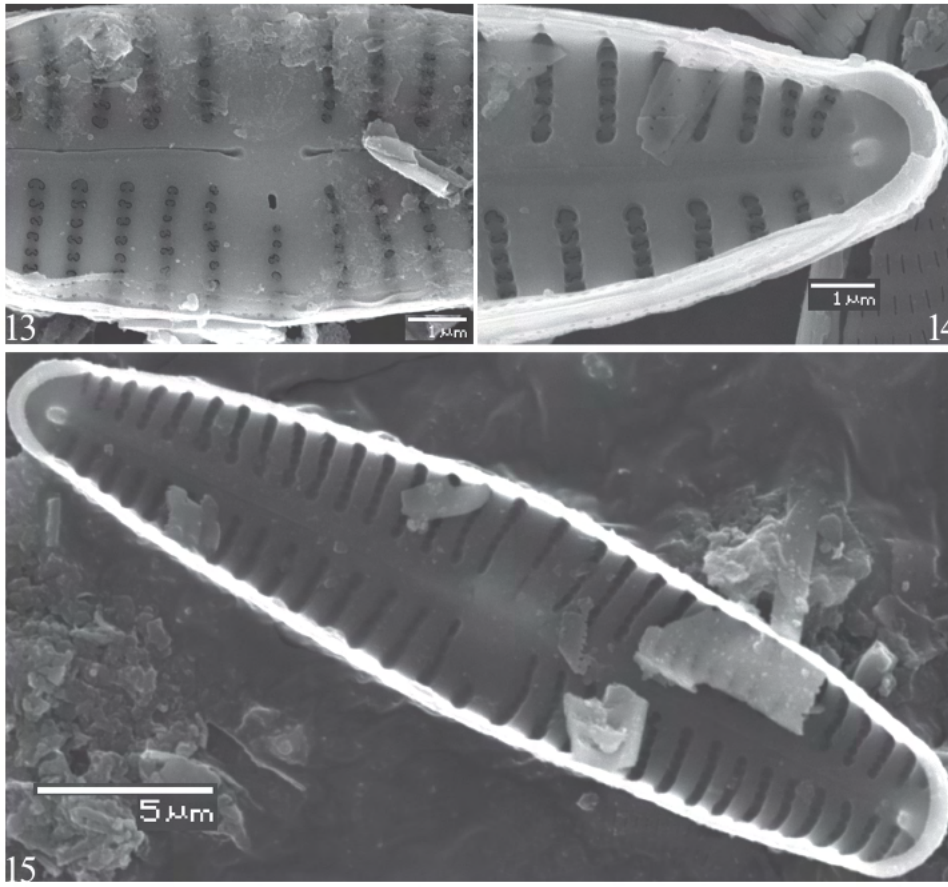
SEM observations: Externally, the raphe is slightly undulate with proximal raphe endings straight to slightly expanded, distal raphe endings hooked to the same side, opposite the stigma. At the headpole, the distal raphe endings are "?"shaped (Fig. 11) and deflected onto the mantle. At the footpole, distal raphe endings are sickle-shaped. Apical pore fields are present on the mantle only (Fig. 12), comprised of a few rows of round porelli. Striae consist of one row of "C" or "S" -shaped areolae (Fig. 10), some of them are irregular in shape, continuing onto the mantle. One stigma is positioned in the central area, with an elliptic to rectangular opening (Figs 10, 13).

Internally, the raphe fissures are straight. The proximal raphe endings are hooked in the same direction towards the stigma. The stigmal opening is slit-like (Fig. 15). Areolar openings "C" or "S" -shaped , depressed on the internal valve. Helictoglossae and the small but distinct pseudosepta are obvious at each pole (Figs 14, 15).

Holotype: COLO, Kociolek Collection, Slide 043146.



Figs 2-12. *Gomphonema rexlowei*. **2-9.** LM. Valve views showing size diminution series. Fig. 3 is of the holotype. Scale bar = 10 µm. **10-12.** SEM. External views. **10.** Whole valve view with prominent elliptical stigmal opening. Striae are C- or S- shaped. Proximal raphe endings are dilated. Scale bar = 2 µm. **11.** Headpole, showing distal raphe ending curved onto mantle. Scale bar = 1 µm. **12.** Footpole, with apical pore fields restricted to the valve mantle. Scale bar = 1 µm.



Figs 13-15. *Gomphonema rexlowei*. SEM. **13.** External view of the valve center showing prominent stigmal opening and dilated proximal raphe endings. Scale bar = 1 µm. **14-15.** Internal views. **14.** Footpole showing small septum on the girdle band at the footpole and prominent helictoglossa. Striae occur in grooves. Scale bar = 1 µm. **15.** Entire valve view with helictoglossae evident. Scale bar = 5 µm.

Isotype: Slide 043146, in Shanghai Normal University, Shanghai, China.
Type locality: Collected from moss on stones in the Halaha River. pH 6.9, altitude 1100 m.
Etymology: Named in honor of our friend and colleague Dr. Rex L. Lowe, formerly of Bowling Green State University, Ohio, USA.
Remarks: *Gomphonema punae* Lange-Bertalot *et* Rumrich shares some characters with this species in having a linear outline and small size, and the shape of the axial and central areas. But *G. punae* is smaller and the headpole is described as "head-ends shortly and more preferred to less broad and wide, flat to almost rounded" (Rumrich *et al.*, 2000), which is different from our species. External views with SEM show both species have "C-", "S-" or irregularly-shaped areolae (Figs 10-13; Rumrich *et al.*, 2000, Taf. 129, Figs 2, 3). *Gomphonema punae* valves have sickle-shaped distal raphe endings and a small rounded stigma

(Rumrich *et al*., 2000, Taf. 129, Figs 2, 3, 5). In contrast, *G. rexlowei* has "?"shaped distal raphe endings at the headpole (Fig. 11), and stigmata with elliptic to rectangular openings (Fig. 13). Internally, the opening of the stigma is rectangular (Rumrich *et al.,* 2000, Taf. 129, Fig. 4) in *G. punae* versus slit-like (Fig. 15) in *G. rexlowei*. *Gomphonema pedrerense* Metzeltin, Lange-Bertalot & García-Rodríguez may be closely related to our species, as suggested by their similar size, outline and number of striae. A feature used to distinguish them is the shape of the headpole. Metzeltin *et al*. (2005) described and illustrated *G. pedrerense* with a short, protracted, subcapitate and broadly rounded headpole. In *G. rexlowei* there is a small, capitate headpole and the valves are much narrower than *G. pedrerense* (4.6-6.2 μm vs 6.6-7.3μm).

Gomphonema chinense* Liu *et* Kociolek, *sp. nov. **Figs 16-31**

Fig. 20 is of the holotype.

Description: Valves clavate, elliptic-lanceolate, with a slightly rostrate headpole and narrower footpole. Length 24.4-31.8 μm, breadth 4.6-5.1 μm. Raphe lateral, external raphe fissure slightly undulate. Axial area broadly lanceolate, narrower towards the apices. Central area almost absent, only slightly wider than axial area, lanceolate to oval. One isolated stigma present in the central area, close to the central nodule. Striae slightly shorter at the center of the valve, almost parallel in the center, slightly radiate towards the poles, 10-13 in 10 μm.

SEM observations: Externally, the raphe is curved slightly, has distal raphe endings deflected to the same side, and central raphe endings deflected slightly to the side opposite the stigma. At the headpole, the distal raphe endings are sickle-shaped (Fig. 26). At the footpole, the raphe ending is slightly curved, creating an asymmetrical pore field (Fig. 27). Striae are uniseriate, with "C"shaped areolae, which extend onto the mantle (Fig. 26). A small rounded stigma is present in the central area (Figs 25, 26).

Internally, the proximal raphe endings are hooked to one side and recurved (Fig. 30). The stigmal opening is an elongated slit. At each pole, a helictoglossa and pseudoseptum are obvious (Figs 28, 29). Both helictoglossae are slightly offset from the main axis of the raphe. The pseudoseptum is small, but distinct (Figs 28, 29, 31).

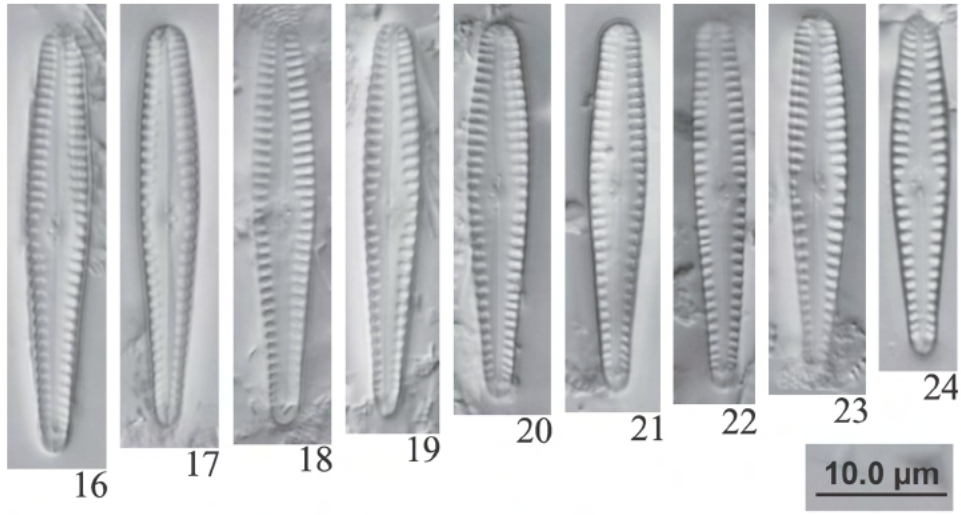
Holotype: COLO, Kociolek Collection, Slide 043146.

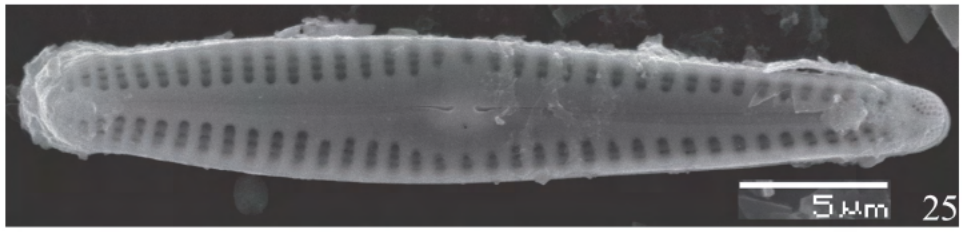
Isotype: Slide 043146, in Shanghai Normal University, Shanghai, China.

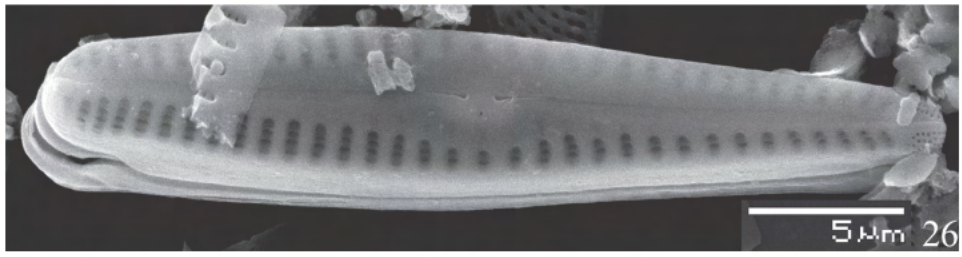
Type locality: Collected from moss growing on a stone in the Halaha River. pH 6.9, altitude 1100 m.

Etymology: This species is known only from China.

Remarks: Metzeltin *et al*. (2009) reported "*G*. cf. spec.3 Julma Ölkky Lange-Bertalot & Metzeltin" from Mongolia. They provided no description for their specimens. Examination of the images of "*G*. (?nov.) spec. Nr. 3" in Lange-Bertalot & Metzeltin (1996, plate 173, figs. 11-22), suggest the Mongolian specimens and our new species are quite similar in terms of valve outline. However, these diatoms differ in the shape of headpole (more pronounced in the Mongolian specimens) and in striae pattern (striae are shorter and more radiate in the Mongolian specimens). It would appear *G. chinense* is more widely distributed beyond the Great Xing'an Mountains.





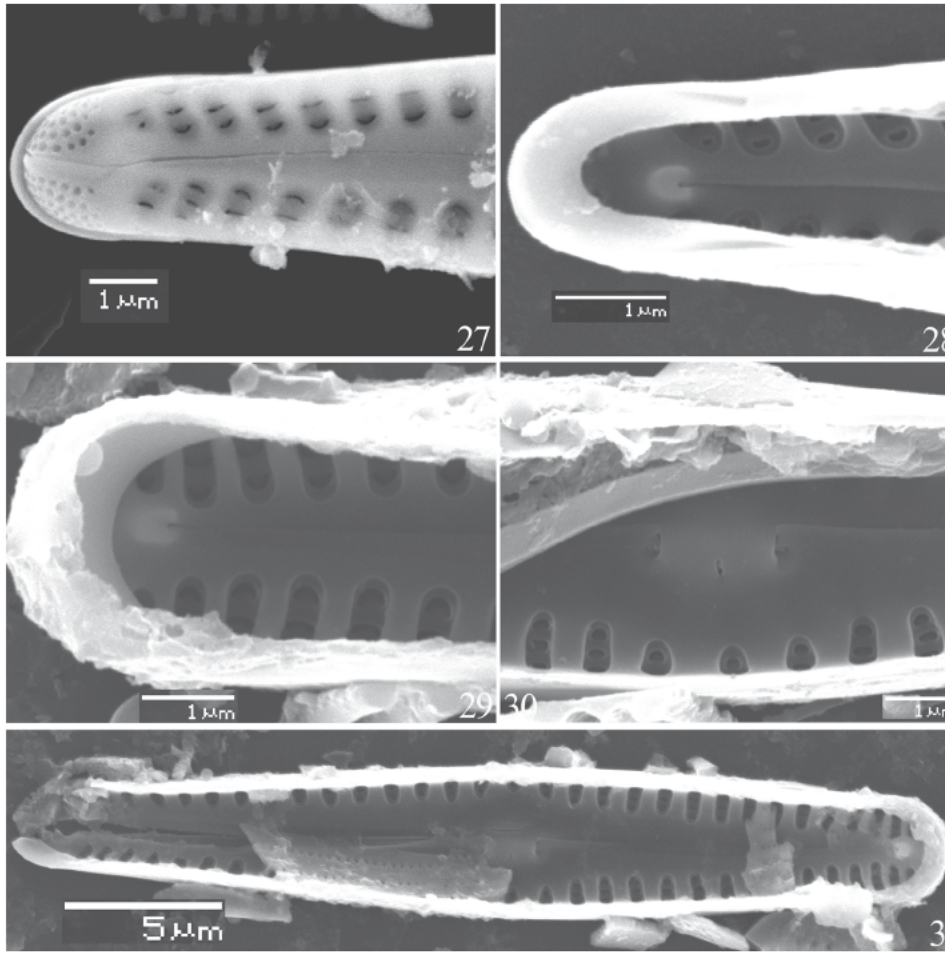


Figs 16-26. *Gomphonema chinense*. **16-24.** LM. Valve views showing size diminution series. Fig. 20 is of the holotype. Scale bar = 10 µm. **25, 26.** SEM. External views. Showing rounded stigmal opening, sickle-shaped distal raphe endings and dilated proximal raphe endings and wide axial area. Scale bars = 5 µm.

Gomphonema genestoermeri* Liu *et* Kociolek, *sp. nov. **Figs 32-44**

Fig. 34 is of the holotype.

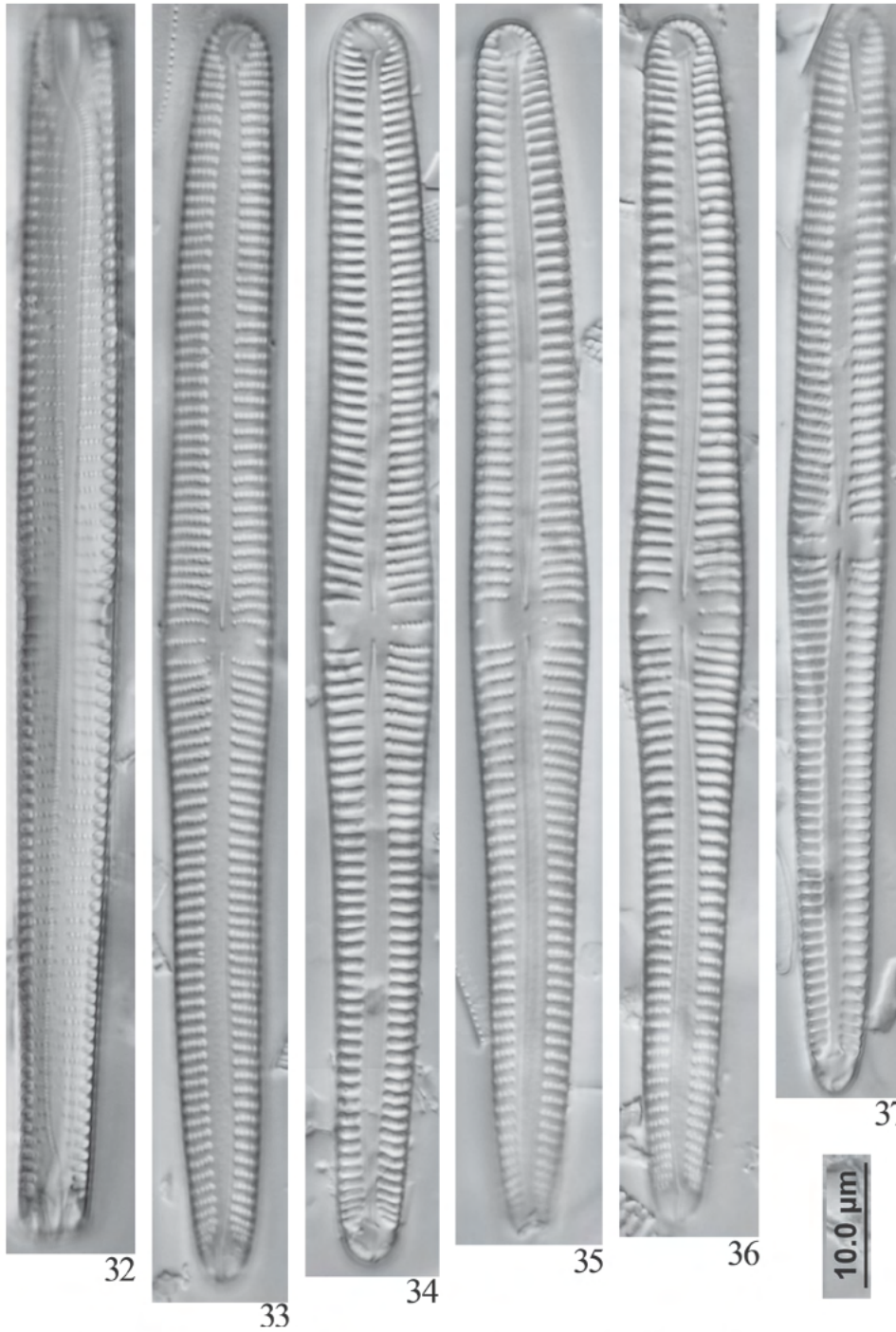
Description: Frustules almost rectangular in girdle view (Fig. 32). Valves linear, clavate, slightly cymbelloid, with weakly triundulate margins, a rounded headpole and a narrower, more acutely rounded footpole. Valve center slightly inflated. Length 86.0-102.9 µm, breath 7.8-9.7 µm. Raphe undulate, expanded laterally, with dilated external raphe endings which unilaterally deflected towards the same side



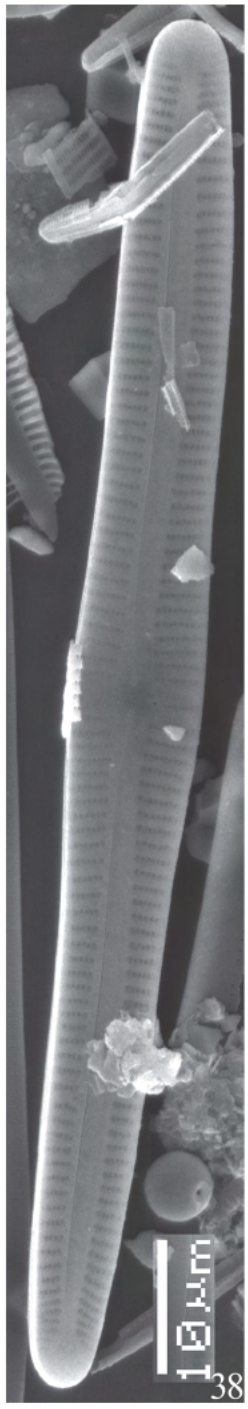
Figs 27-31. *Gomphonema chinense*. SEM. **27.** External view. Footpole showing bilobed apical pore field composed of round porelli and bisected by distal raphe ending. Scale bar = 1 µm. **28-31.** Internal views. **28.** Footpole showing distinct pseudoseptum and thickened helictoglossa. Scale bar = 1 µm. **29.** Headpole showing pseudoseptum and distinct helictoglossa. Scale bar = 1 µm. **30.** Central nodule is raised internally. Located on the periphery of the central nodule are distinctly hooked proximal raphe endings and a small, slit-like stigmal opening. Scale bar = 1 µm. **31.** Entire valve view with pseudoseptum. Scale bar = 5 µm.

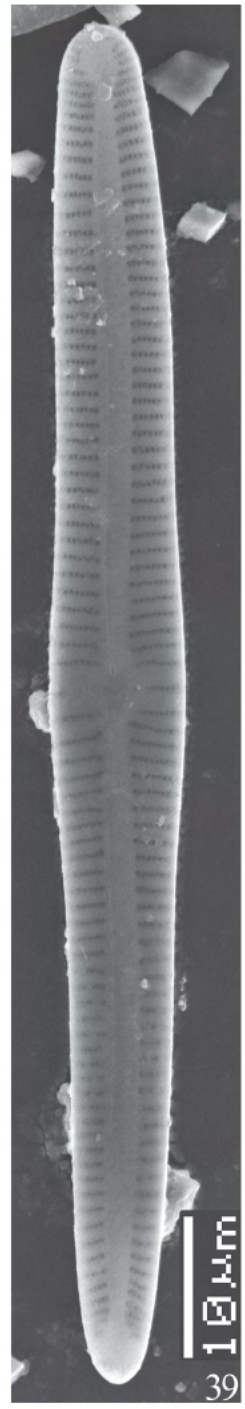
to the expanded central area. Axial area linear and narrow. Central area rectangular, unilaterally expanded with a shortened stria. A stigma present at the end of stria on the opposite side of the expanded central area. Striae almost parallel in the center of the valve, 7-9/10 µm, slightly radiate towards the apices, 8-10/10 µm, 2-3 rows rounded areolae visible continuing on the mantle.

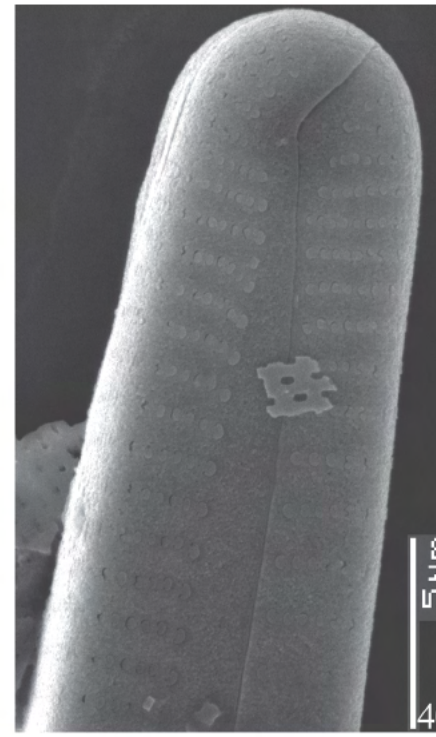
SEM observations: External views show the raphe is undulate. Distal raphe endings are curved towards the same side (Figs 38, 39). The proximal raphe endings are almost straight, slightly dilated. At the headpole, the raphe ending is sickle-shaped (Fig. 40). At the footpole, the raphe ending is slightly curved. An apical pore field is present at the footpole, comprised of rows of round porelli. The

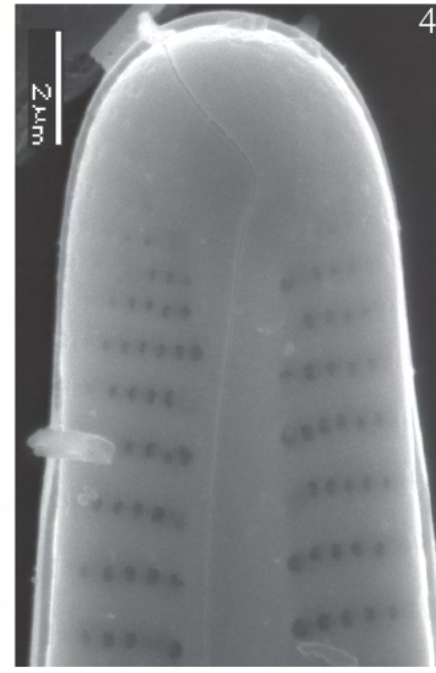


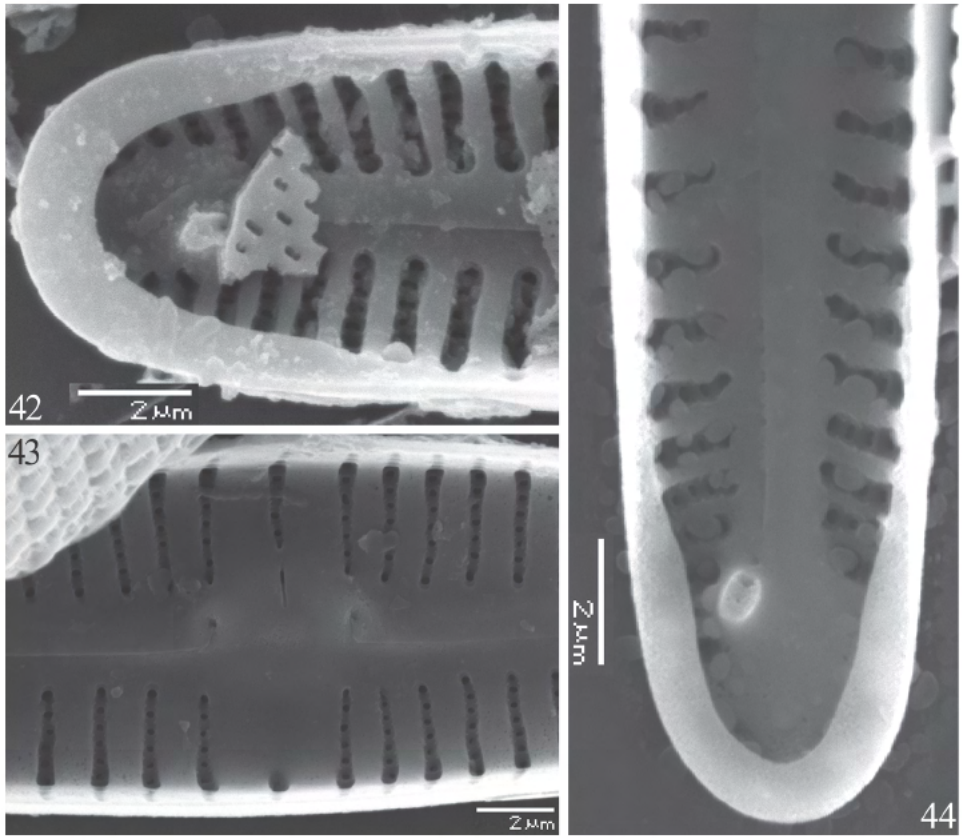
Figs 32-37. *Gomphonema genestoermeri*. LM. **32.** Girdle view. Figs **33-37.** Valve views showing size range. Figure 34 is of the holotype. Scale bar = 10 µm.


10 µm
38


10 µm
39


5 µm
40


41
2 µm



Figs 42-44. *Gomphonema genestoermeri*. SEM. Internal views. **42.** Headpole, showing helictoglossa offset from sternum and evident pseudoseptum. Scale bar = 2 µm. **43.** Central nodule has recurved proximal raphe endings and slit-like stigmal opening. Scale bar = 2 µm. **44.** Footpole, showing prominent pseudoseptum and helictoglossa offset from the main sternum axis. Scale bar = 2 µm.

stigmal opening is elliptical. Striae are uniseriate, with "C" shaped openings in the outside, and extend from the valve face onto the mantle.

Internally the proximal raphe endings are curved towards the slit-like stigmal openings and recurved (Fig. 43). Areolar openings are round or elliptical. Helictoglossae and pesudosepta are obvious at both poles (Figs 42, 44). The helictoglossa at the headpole is slightly offset from the main axis of the raphe and deflected to one side of the valve (Fig. 42). The pseudosepta are small, but distinct.

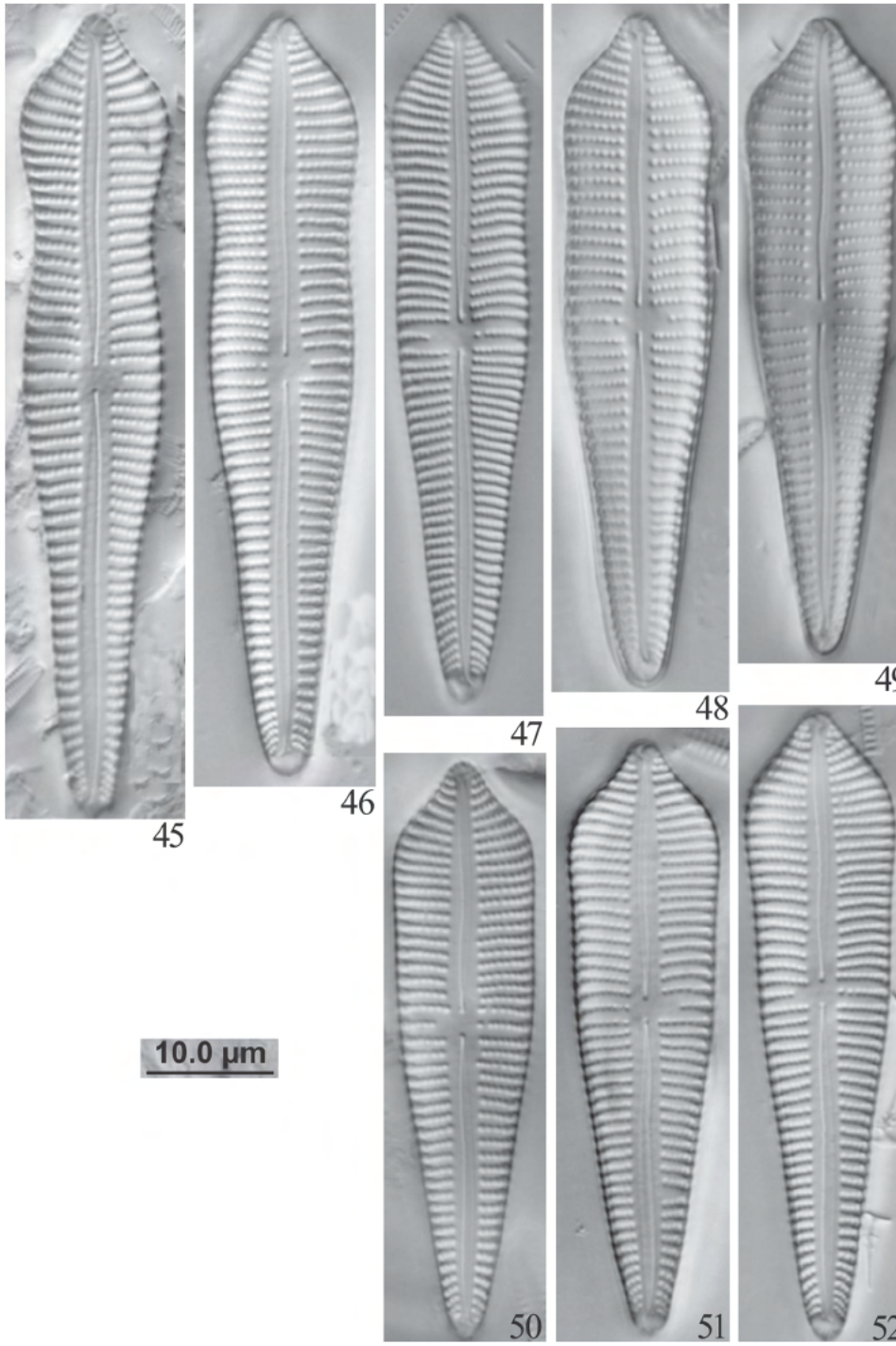
◀ Figs 38-41. *Gomphonema genestoermeri*. SEM. External views. **38, 39.** Entire valve views showing valve shape, including slight asymmetry about the apical axis. Striae appear compressed at the headpole. Scale bars = 10 µm. **40.** Headpole, showing deflected distal raphe ending curving onto the mantle. Striae appear disorganized around the headpole. Scale bar = 5 µm. **41.** Footpole with bilobed apical pore field more or less constrained to the mantle. The distal raphe ending bisects the pore field. Scale bar = 2 µm.

Holotype: COLO, Kociolek Collection, Slide 053190.
Isotype: Slide 053190, in Shanghai Normal University, Shanghai, China.
Type locality: Stream near Crane Lake. The samples attach on the filamentous algae which floating in the stream. pH 6.1, altitude 1148 m.
Etymology: Named in the memory of our good friend, colleague and mentor, Dr. Eugene F. Stoermer of the University of Michigan, Ann Arbor.
Remarks: Of the previously described *Gomphonema* species, the only species that is similar to *G. genestoerermi* is *G. pratense* Lange-Bertalot *et* Reichardt. Both have long and slightly cymbelloid valves (Reichardt, 1999). *Gomphonema pratense* has a linear- lanceolate to sublinear outline and slightly subcapitate headpole, as compared to our species which has a linear outline, shorter and a much narrower valve with a broadly rounded headpole. In the SEM, the character that easily distinguishes these two species is the external distal raphe endings. *Gomphonema pratense* has almost straight distal raphe endings that curve onto the mantle (Reichardt, 1999, Taf. 15, Fig. 7; Levkov *et al*., 2007, Pl. 168, Figs 3, 5), while *G. genestoermeri* has distinct, sickle-shaped distal raphe endings (Figs 40, 41).

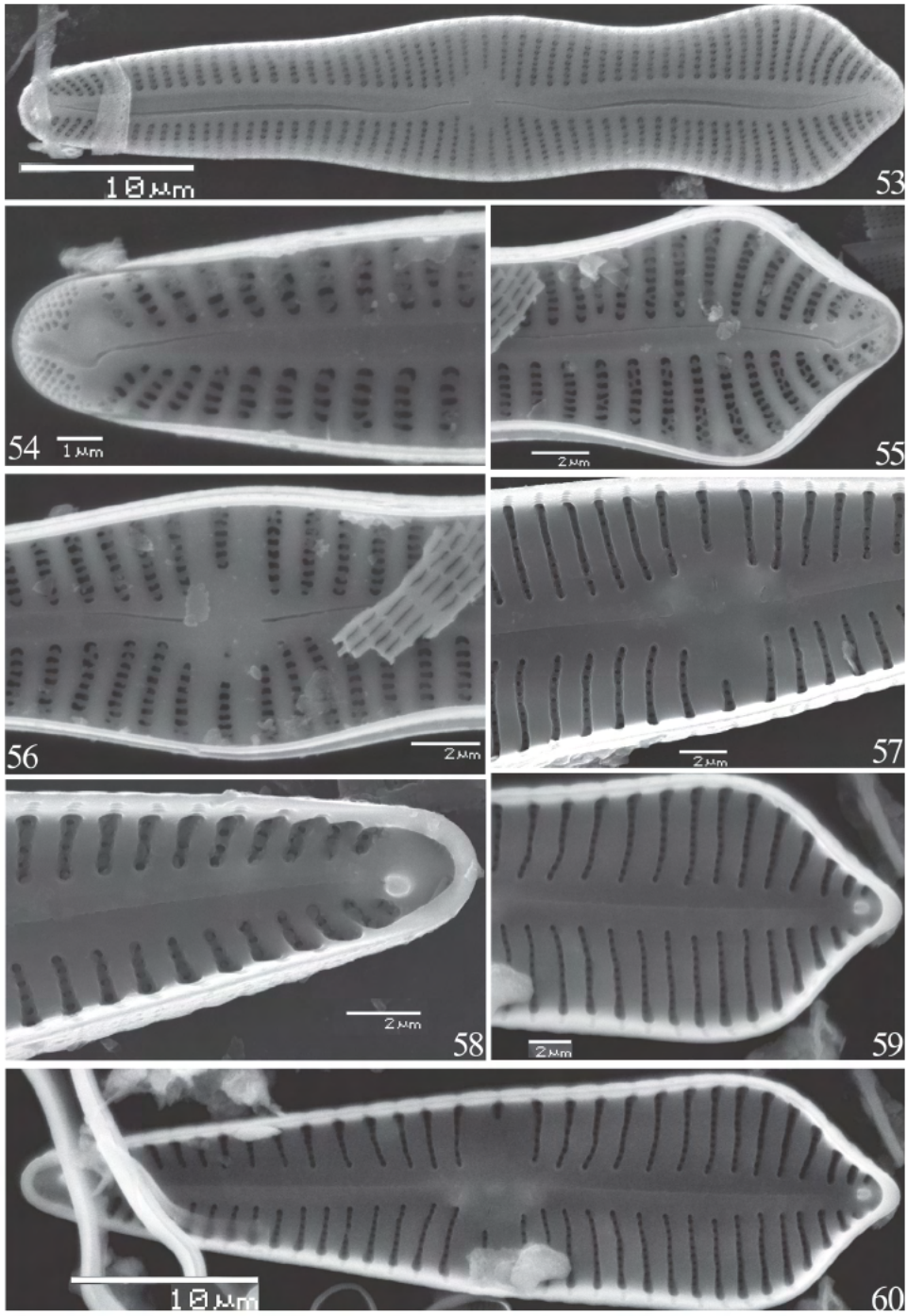
Gomphonema asiaticum* Liu *et* Kociolek, *sp. nov. **Figs 45-60**

Fig. 46 is of the holotype.
Description: Valve outline clavate to weakly linear. Margins clearly triundulate, constricted above the valve middle, headpole broadly rhomboid to even quadrangular with a protracted and rostrate apex. Footpole acutely rounded. The triundulate nature of the margins in smaller valves not very obvious, as they are less constricted above the valve center. The breadth of the headpole is wider than at mid-valve. Length 41.3-70.0 μm, breadth at the valve middle 10.3-13.5 μm, breadth of the headpole 11.5-13.8 μm. Raphe lateral, external fissures undulate. Axial area linear to linear-lanceolate, narrow. Central area small, rectangular, unilaterally expanded with a shortened stria. One stigma present at the end of the central transpical stria. Striae almost parallel in the middle 6-10/10 μm, slightly radiate towards the apices 9-12/10 μm. Areolae clearly visible with LM.
SEM observations: Externally the raphe is undulate (Fig. 53). A small round stigma is present in the central area (Fig. 56). The proximal raphe endings are straight, and the distal raphe endings curve towards the side of the stigma. At the headpole, the external distal raphe ending is deflected onto the valve mantle (Fig. 53). At the footpole, the apical pore field is present on both the valve face and the mantle, comprised of a few rows of round porelli (Fig. 54). The apical pore field is slightly asymmetrical due to the position of the terminal raphe ending. Striae consist of one row of "C"-shaped areolae, continuing onto the mantle. In the valves which were not well developed, the areolae are bigger, slit-like, towards the margins, with striae tending to be irregularly biseriate (Fig. 55).

Internally, the raphe fissures are straight, and the proximal raphe endings are deflected onto the central nodule. The central nodule appears to be asymmetrically placed in the central area. The stigmal opening is slit-like (Fig. 57). At each pole, a helictoglossa and pseudoseptum are evident (Figs 58, 59, 60). Both helictoglossae are slightly offset from the main axis of the raphe.
Holotype: COLO, Kociolek Collection, Slide 063183.
Isotype: Slide 063183, in Shanghai Normal University, Shanghai, China.
Type locality: Swamp near Wusulangzi Lake, pH 6.8, altitude 1044 m.
Remarks: This species is very similar to "*G.* spec. cf. *brebissonii* Kützing", which was reported in Metzeltin *et al.* (2009). This name has no nomenclatural status, as



Figs 45-52. *Gomphonema asiaticum*, LM. Valve views showing size diminution series. 46 is of the holotype. Scale bar = 10 µm.


10 µm
53
54
1 µm
2 µm
55
56
2 µm
2 µm
57
2 µm
58
2 µm
59
10 µm
60

no description was given, and only two LM images were presented for this species. Based on the images of "*G*. spec. cf. *brebissonii* ", it shares the same outline, raphe and striae patterns with our new species. Although it was named "cf. *brebissonii*", it is clear that the two illustrated valves, and our species, are different from *G. brebissonii* Kützing in outline, shape of the headpole, and the valve breadth. Another discriminating feature between our species and *G. brebissonii* seen with the SEM, is the internal proximal raphe endings are recurved in *G. brebissonii* (Reichardt, 1999, Taf. 56, Fig. 14), but only curved in our new species (Fig. 57).

The combination of valve outline, areolae structure and raphe system, suggests *G. asiaticum* belongs to the *G. acuminatum* Ehrenberg group of taxa. Van de Vijver and McBride (2006, Table 2), compared the main discriminating features of this group. Within the group, *G. coronatum* Ehrenberg, *G. acuminatum* and *G. isabellae* Van de Vijver share a similar outline, but only *G. coronatum* and *G. acumintum* have broad "shoulders" near the headpole, and *G. isabellae* has a cuneate headpole without shoulders. In *G. isabellae,* the valve breadth at the headpole is narrower than the middle valve; in our species the opposite is true. Together with *G. coronatum*, *G. brebissonii* and *G. isabellae*, *G. asiaticum* is one of the largest species in this group with a maximum valve length of 70 µm. Based on the larger size, the triundulate outline, the rostrate apex and coarse striae, *G. asiaticum* can be separated as an independent species in this group.

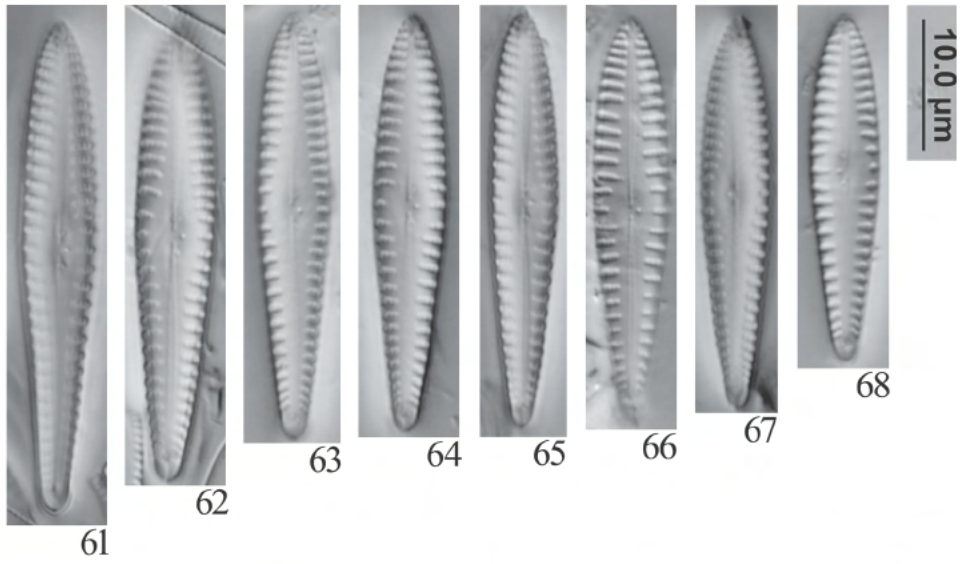
Gomphonema williamsii* Kociolek *et* Liu, *sp. nov. **Figs 61-72**

Fig. 63 is of the holotype.

Description: Valves rhombic-lanceolate, clavate with a cuneate headpole and a narrow footpole. Length 26.4-37.1 µm, breadth 5.5-6.4 µm. Raphe lateral, external raphe fissure slightly undulate. Axial area broadly lanceolate, narrower towards the apices. A single isolated stigma present in the central area, close to the proximal raphe endings. Striae slightly shorter at the center of the valve, almost parallel around the center, slightly radiate towards the poles, 7-11 in 10 µm.

SEM observations: Externally the raphe is curved slightly (Fig. 69). The distal raphe endings are deflected to the same side. Proximal raphe endings are straight and dilated slightly. The stigma is positioned in the central area and has a small, round opening. An apical pore field is present at the footpole (Figs 69, 71). Striae are uniseriate, consisting of "C" shaped areolae that extend onto the mantle (Fig. 71).

◀ Figs 53-60. *Gomphonema asiaticum*, SEM. **53-56.** External views. **53.** Entire valve view showing undulate raphe fissures. Scale bar = 10 µm. **54.** Footpole, showing apical pore field bisected by distal raphe endings. Pore field is restricted to valve mantle. Scale bar = 1 µm. **55.** Headpole with distal raphe ending deflected in the direction opposite the stigmal opening. Scale bar = 2 µm. **56.** Central area, showing deflected proximal raphe endings and small, round stigmal opening. Areolae are C-shaped. Scale bar = 2 µm. **57-60.** Internal views. **57.** Central nodule with broadly hooked proximal raphe endings and small, slit-like stigma present. Areolae appear rounded and unoccluded. Scale bar = 2 µm. **58.** Footpole, showing the prominent helictoglossa offset from the raphe fissure. A small pseudoseptum is present. Scale bar = 2 µm. **59.** Headpole, with septum and pseudospetum evident. Helictoglossae are offset from the main branch of the raphe. Scale bars = 2 µm. **60.** Entire valve view. Helictoglossae are offset from the raphe branches, the central nodule is prominent and septa are evident at the poles. Scale bars = 10 µm.


10.0 µm
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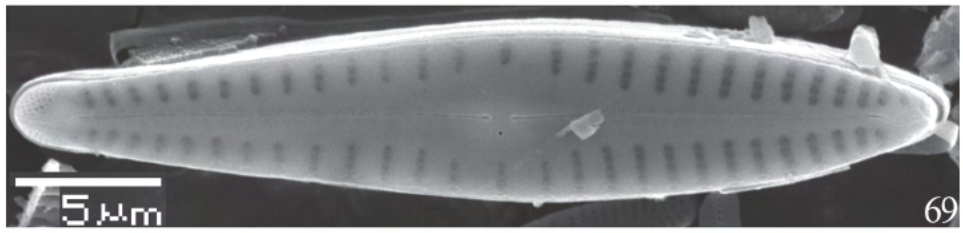
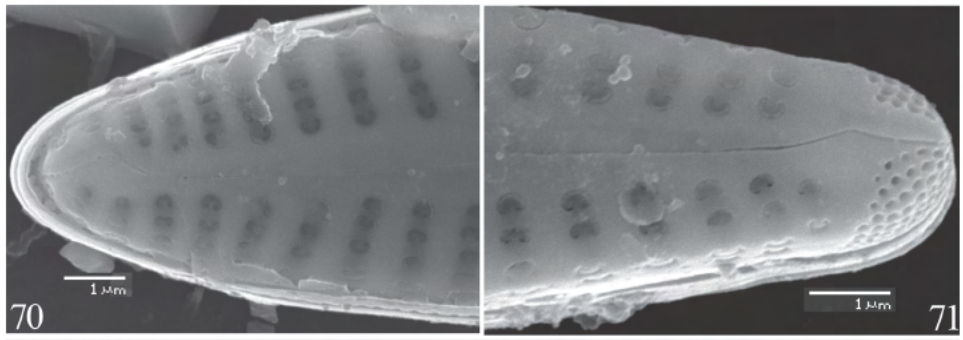

5 µm
69


1 µm
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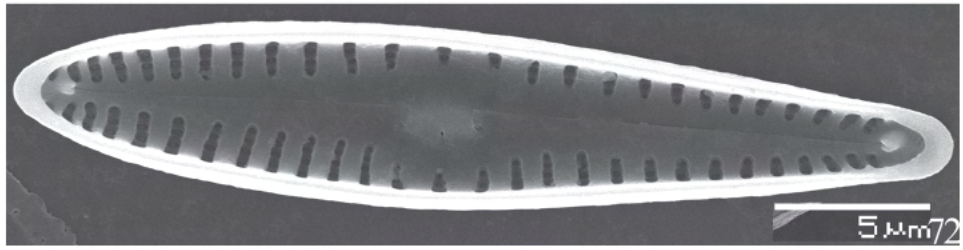
1 µm
71


5 µm
72

Internally, the raphe branches are straight, while the proximal raphe endings are deflected to one side and recurved (Fig. 72). The stigmal opening is an elongated slit. A helictoglossa and small pseudoseptum are present at the headpole and footpole. The helictoglossae are slightly offset from the main axis of the raphe.

Holotype: COLO, Kociolek Collection, Slide 053344.

Isotype*:* Slide 053344, in Shanghai Normal University, Shanghai, China.

Type locality: Azalea Lake. Epiphytic on aquatic plants in the lake. pH 7.1, altitude 1188 m.

Etymology: Named in honor of our colleague and friend, Dr. David Williams, of The Natural History Museum, London.

Remarks: Based on the characters in both LM and SEM, we do not know of a similar taxon. Our species is sufficiently different from other taxa and can be easily recognized as new.

Gomphonema witkowskii* Kociolek *et* Liu, *sp. nov. **Figs 73-89**

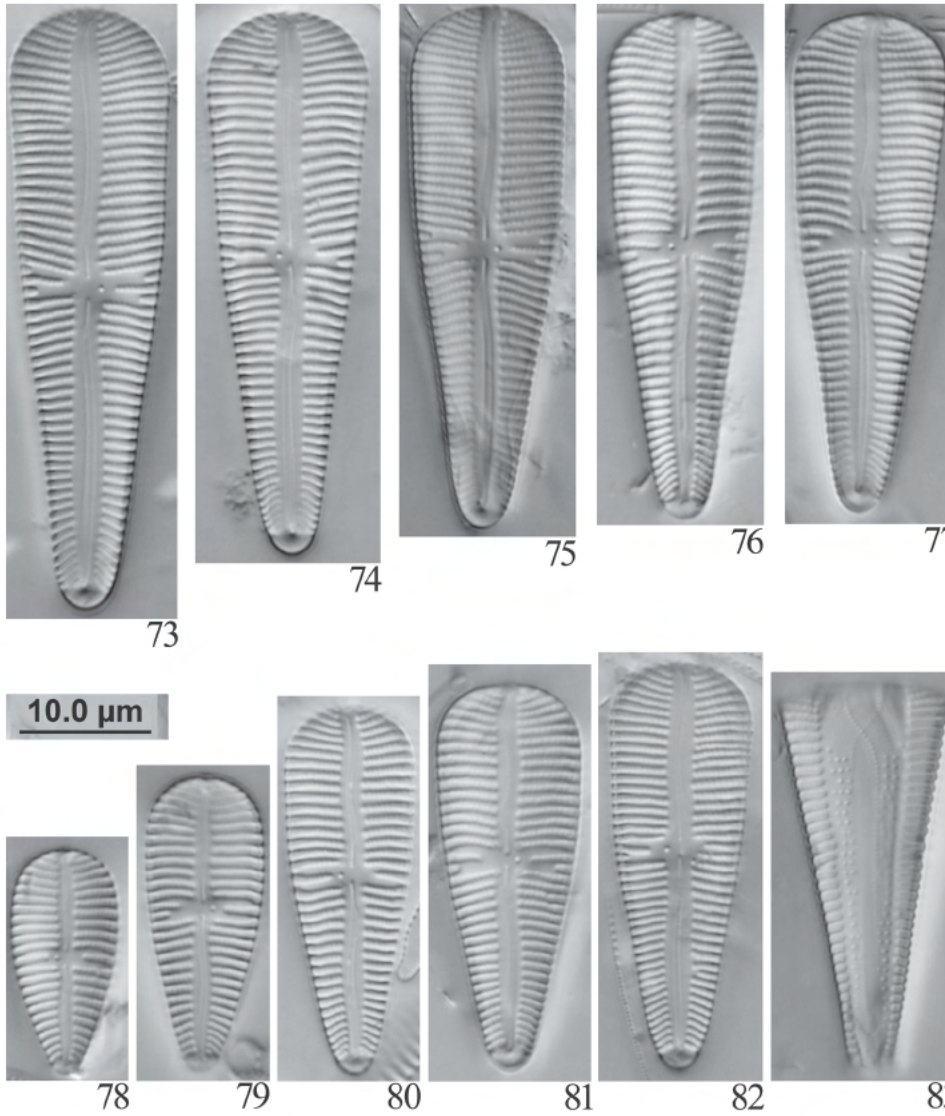
Fig. 74 is of the holotype.

Description: Valves are clavate with broadly rounded headpole and narrower footpole. Length 17.0-44.9 µm, breadth 10.5-14.5 µm. Headpole usually wider than the middle of the valve. Axial area linear, narrow. Central area small, rectangular. Alternating shorter and longer striae delimit the central area, commonly 1-2 at each side. A stigma is present in the central area close to the proximal raphe endings. Raphe lateral. Striae parallel in the middle of the valve, radiate towards the ends, 10-14 in 10 µm. In girdle view, frustules are clearly clavate. Several series of areolae are visible continuing from the striae onto the mantle.

SEM observations: Externally, the raphe is undulate. Distal raphe endings are deflected to the same side, opposite the stigma. The proximal raphe endings are round, dilated slightly, and the raphe fissures are nearly straight (Fig. 86). At the headpole, the distal raphe endings are deflected onto the mantle (Fig. 85). At the footpole, the raphe ending hooks onto the mantle, forming an asymmetrical apical pore field with densely packed, round porelli located on the valve mantle. The stigmal opening is round and small. Striae consist of one row of "C" shaped areolae that extend onto the mantle (Fig. 84). On some valves, striae are interrupted from the valve face to the mantle by a small siliceous elevation along the margin (Fig. 85).

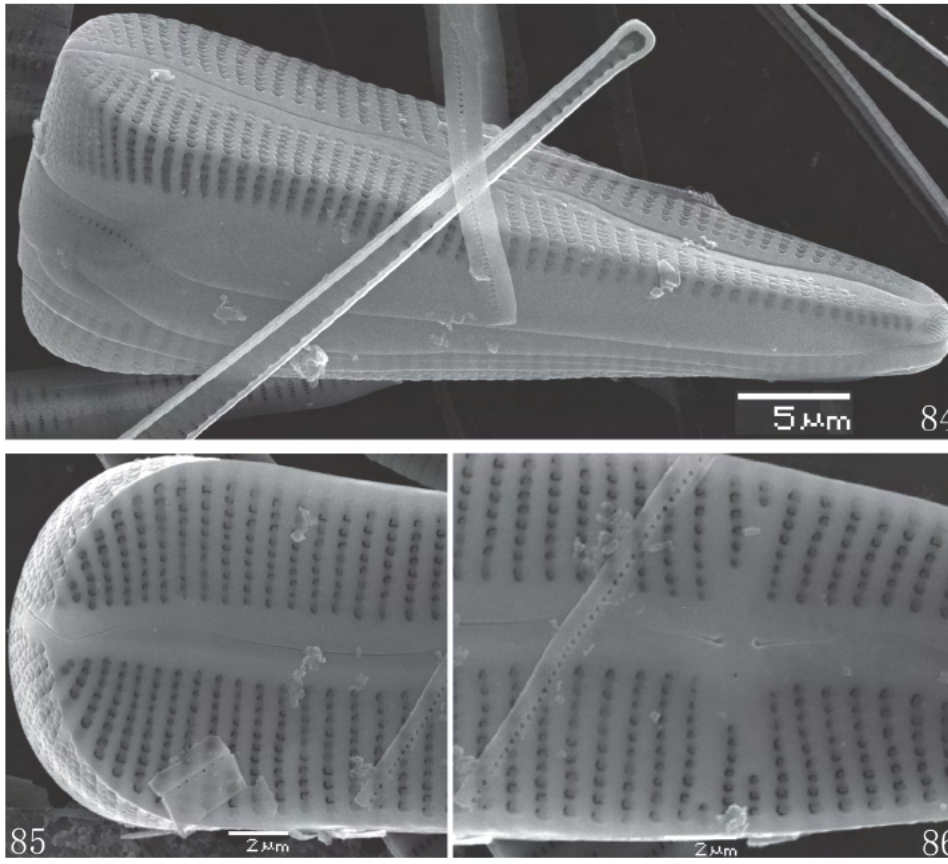
Internally, the raphe fissures are straight. The proximal raphe endings are hooked to the same side and recurved. The stigmal opening is slit-like (Fig. 88). Areolae have "C" shaped openings (Fig. 88). Helictoglossae and

◀ Figs 61-72. *Gomphonema williamsii*. **61-68.** LM. Valve views showing size diminution series. Fig. 63 is of the holotype. Scale bar = 10 µm. **69-71.** External SEM. **69.** Entire valve view showing wide axial area, central area with round, small stigmal opening and dilated proximal raphe endings. Scale bar = 5 µm. **70.** Headpole, with distal raphe endings gently deflected and extending onto the valve mantle. Areolae appear to be nearly totally occluded with a slight appearance of C-shaped openings. Scale bar = 1 µm. **71.** Footpole, with deflected distal raphe ending bisecting the apical pore field, which extends from the valve face onto the mantle. Scale bar = 1 µm. **72.** Internal view. Entire valve view showing areolae to be in deep troughs or grooves. Central nodule with broadly recurved proximal raphe endings and a small, rounded stigmal opening. Helictoglossa prominent at both poles. Pseudoseptum small. Scale bar = 5 µm.



Figs 73-83. *Gomphonema witkowskii*, LM. **73-82.** Valve views showing size diminution series. Fig. 74 is of the holotype. **83.** Girdle view. Scale bar = 10 µm.

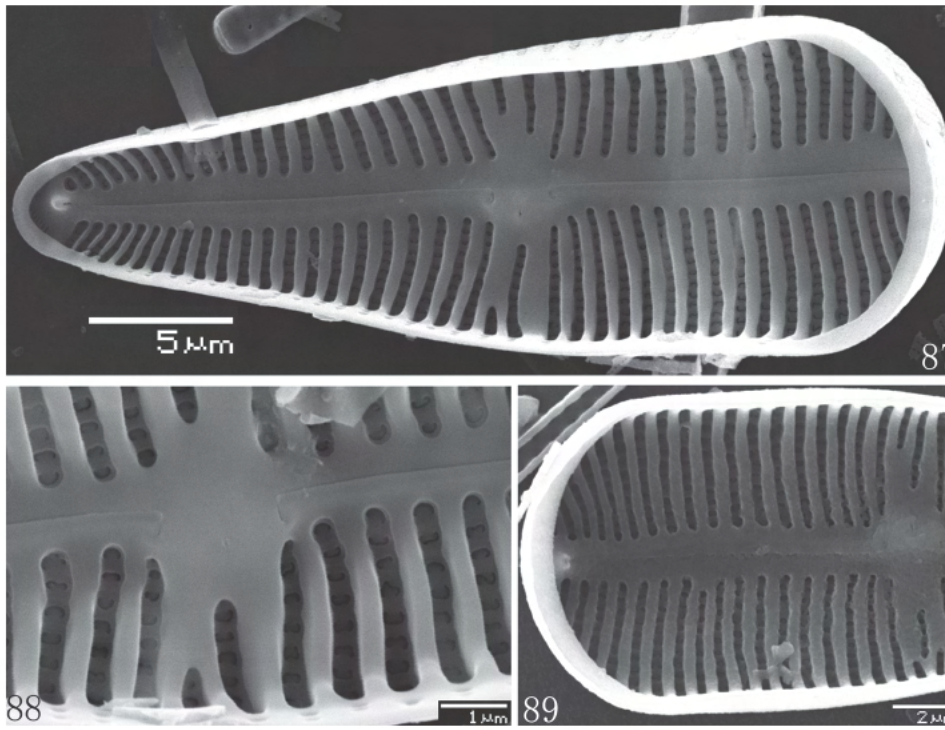
pesudosepta are evident. Both helictoglossae are slightly offset from the main axis of the raphe. The pseudosepta are small, but distinct, at each pole (Fig. 87, 89).
Holotype: COLO, Kociolek Collection, Slide 053158.
Isotype: Slide 053158, in Shanghai Normal University, Shanghai, China.
Type locality: Azalea Lake. Attached on aquatic plants in the lake. pH 6.8, altitude 1197 m.



Figs 84-86. *Gomphonema witkowskii*, SEM. External view. **84.** Wedge-shaped frustule, with areolae extending from the valve face onto the mantle. Scale bar = 5 µm. **85.** Headpole with undulate raphe fissure evident and distal raphe ending deflected onto the mantle. Scale bar = 2 µm. **86.** Central area with proximal raphe endings situated close to one another. The small, round stigmal opening is evident. Scale bar = 2 µm.

Etymology: Named in honor of our friend and colleague, Dr. Andrzej Witkowski, University of Szczecin, Poland.

Remarks: This species belongs to the group of taxa related to *G. truncatum* Ehrenberg, having the typical "C" shaped, uniseriate areolae. Reichardt (2001) made a detailed study of this group, and other workers suggest it can be easily divided into two subgroups, based on the uniseriate/biseriate character of the striae (Van de Vijver & Gremmen, 2006). Our taxon is part of the uniseriate subgroup. Species in this subgroup, such as *G. truncatum*, *G. laticollum* Reichardt and *G. italicum* Kützing, all resemble *G. witkowskii*, but our species has a wider headpole, and it has only a slightly developed marginal crest, as compared to it being more developed in the other taxa (Van de Vijver & Gremmen, 2006).



Figs 87-89. *Gomphonema witkowskii*, SEM. Internal view. **87.** Entire valve view showing central nodule and helctoglossa offset from raphe fissure at the footpole. Scale bar = 5 µm. **88.** Central nodule with recurved proximal raphe endings and a small stimgal opening. The C-shaped areolae appear to be in curved trough-like depressions. Scale bar = 1 µm. **89.** Headpole, with a narrow pseudoseptum and helictoglossa present. Scale bar = 2 µm.

DISCUSSION

These six new species clearly belong to the genus *Gomphonema* based on their valve shape and symmetry, as well as their raphe and areolar characteristics. Although *G. rexlowei* and *G. genestoermeri* have slightly cymbelloid valves, they also share with other species the characteristic generic features of heteropolar valves, apical pore fields at the footpole, typical "C" shaped areolae and small septa and pseudosepta. Within *Gomphonema*, these species are part of the common, widely distributed group of species that includes the generitype, *G. acuminatum*, as well as *G. parvulum* (Kützing) Kützing, *G. truncatum* and many other species that share the feature of external "C" or "S" shaped occlusions.

All six new species grow epiphytically and occur in low relative abundances in the samples. Some of the species have a very limited distribution whereas others are more widely distributed. *G. rexlowei* and *G. williamsii*, for

example, have only been observed in the type localities. *Gomphonema chinense* co-occurred with *G. rexlowei* in the type locality, but it also occurred in Santan Gorge and other slower flowing, small rivers with circumneutral pH. *Gomphonema genestoermeri* was also observed in other collections near the type locality, in habitats with pH values from 7.8 to 8.0. *G. asiaticum* and *G. witkowskii* on the other hand, were distributed widely. *Gomphonema asiaticum* was observed in Wusulangzi Lake, Crane Lake, and swamps scattered in the mountains. Apparently, the species prefers habitats on lake shores or swamps nearby large lakes, in collections with pH from 6.4 to 9.8. *G. witkowskii* was observed in Azalea Lake, Crane Lake, Wusulangzi Lake, stone ponds, and swamps scattered in the Great Xing'an Mountains region. It co-occurred with *G. chinense* or *G. asiaticum* and found in higher relative abundances on lake shores, ponds or swamps with pH from 6.4 to 9.8. Although overall the samples from the Great Xing'an Mountains were collected from water bodies with pH from 4.5 to 10.2, these new species only occurred in circumneutral to alkaline habitats. In the absence of environmental data and additional distributional records, their ecological requirements remain unclear.

The new *Gomphonema* presented herein, and other new species found in this area (Liu *et al*. 2010a, b), support the idea that the diatom flora in the Great Xing'an Mountains has unique or endemic elements. Of the six new species described here, four are known only from this area. Three of these four of them are endemic to Aer Mountain, including *G. rexlowei, G. genestoermeri* and *G. williamsii*. Conversely, *G. asiaticum* and *G. witkowskii* are more broadly distributed across Great Xing'an Mountains, and *G. asiaticum* and *G. chinense* appear to be more broadly distributed. Moser *et al*. (1998) suggested that oligotrophic conditions might favour the development of endemic taxa. Aer Mountain, located in the middle part of Great Xing'an Mountain region, is still relatively unaffected by human activity and pollution.

With regard to the distribution of freshwater diatoms, it is clear that some genera and species are limited geographically, whereas others are more widely distributed. There are species that occur in single habitats, others limited to particular regions or restricted to either the Northern or Southern Hemisphere (Kociolek *et al*., 2004). In total, 22 *Gomphonema* taxa were found in the diatom flora of the Great Xing'an Moutains (Liu, unpublished dissertation). When species from this mountain region are compared with floras of Europe (Krammer & Lange-Bertalot, 1986; Lange-Bertalot & Metzeltin, 1996; Lange-Bertalot & Genkal, 1999; Lange-Bertalot *et al*., 2003; Werum & Lange-Bertalot, 2004), North America (Siver *et al*., 2005; Antoniades *et al*., 2008), South America (Reichardt, 1995; Metzeltin & Lange-Bertalot, 1998; Rumrich *et al*., 2000; Metzeltin *et al*., 2005; Antoniades *et al*., 2008) and Africa (Metzeltin & Lange-Bertalot, 2002) the *Gomphonema* species in Great Xing'an Mountains are clearly more similar to those from Asia, versus those from South America or Africa. In Asia, Metzeltin *et al*. (2009) reported the diatom flora of Mongolia, and this region shares some *Gomphonema* species with the Great Xing'an Mountains, such as *G. khentiiense* Metzeltin, Lange-Bertalot & Nergui, *G. lagerheimii* Cleve, *G. pala* Reichardt, and *G. truncatum* . Some new species which were reported from Mongolia were also found in Great Xing'an Mountains. And *G. chinense* and *G. asiaticum* for example, were also found in Mongolia. Although the diatom flora of this region shares similarities with other northern hemisphere areas, these new species help to make the Great Xing'an Mountains a distinctive region for diatom research.

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