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Three new *Gomphonema* Ehrenberg (Bacillariophyta, Gomphonemataceae) species from the lower reaches of Yangtze River, China

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Abstract: In this study, three new species of the genus *Gomphonema* from freshwater lakes of the lower reaches of Yangtze River, China. They include *G. qii* sp. nov. from Yangcheng Lake, *G. poyangense* sp. nov. from Poyang Lake, and *G. longganense* sp. nov. from Longgan Lake, and all of these new species were collected on stone. We detailed morphological features of these new species are described based on light microscopy (LM) and scanning electron microscopy (SEM), and the LM and SEM photographs illustrate the size ranges and particular ultrastructure of these new species. *G. qii* sp. nov. with clavate–lanceolate valves, bluntly rounded headpole and narrowly–rounded footpole, narrowly axial area, uniseriate striae. *G. poyangense* sp. nov. with clavate–lanceolate valves, rounded headpole and narrowly–rounded footpole, broadly rhombic–lanceolate axial area, short uniseriate striae, c–shaped to irregularly shaped areolae. *G. longganense* sp. nov. with slightly heteropolar, linear–lanceolate valves, protruded headpole and rounded footpole, narrowly axial area, variously–shaped areolae. Additionally, three new species only have one stigma per valve. We compare these new species with other similar species of *Gomphonema* based on valve outline, shape of the axial and center areas, and striae density. While their valve features and symmetry easily assign them to *Gomphonema*, their differences with 'core' species of the genus are discussed.

Key words: diatom, Longgan Lake, new species, Poyang Lake, taxonomy, Yangcheng Lake

Introduction

Species of the freshwater diatom genus *Gomphonema* Ehrenberg (Ehrenberg 1832, p. 87) are well known worldwide, and they occur over a wide range of environment conditions. *Gomphonema* is a large genus of over 2400 species (Kociolek et al. 2019; Liu et al. 2020), and those species are found from oligotrophic to eurtrophic or organically polluted freshwater (Fore & Grafe 2002; Jiang et al. 2018). Moreover, *Gomphonema* species can be found in waters of low to high conductivity, and occur at neutral to slightly alkaline pH (Van Dam et al. 1994; Potapova et al. 2003; Gong et al. 2012).

The primary characteristic of this genus includes the valves are asymmetric to the transpapical axis. Valves are linear to linear–lanceolate and headpole wider than footpole (Round et al. 1990). The raphe is straight or slightly lateral, and with straight or slightly curved and expanded proximal endings and slightly curved distal endings (Ludwig & Tremarin 2006; Mederios et al. 2018). An apical pore fields is position and bisected by the terminal raphe. Stigamata is presence or absence. Striae uniseriate or biseriate, and have highly variability areolar (Almeida et al. 2020), and most species possess both septa and pseudosepta at the apices (Kociolek & Stoermer 1993).

In China, studies on the genus *Gomphonema* have been carried out by Skvortzow (1928, 1929, 1930 a, b, 1935, 1937, 1938, 1946), who documented many new gomphonemoid species from the eastern part of China (Liu et al. 2021). Later, some species of *Gomphonema* were described from the Tibet Region and South–Western China (Jao et al. 1964, 1973; Li 1983; Zhu & Chen 1994, 2000; Shi 1994). Additional species of *Gomphonema* have been reported from Northeast China (Bao et al. 1992; Bao & Reimer 1992; Kociolek 1992; Fan 1998, 2004). A review of the gomphonemoid diatoms of China was published by Shi (2004). Recently, some new species of this genus have been described from eastern China (Zhang et al. 2016, 2018 a, b; Zhang LX et al. 2020), North–Eastern China (Bao & Reimer 1992; Fan 2004; Liu et al. 2013; Lei et al. 2014), Southwest China (Li

et al. 2006, 2010; Gong & Li 2012; Jiang et al. 2018; Liao et al. 2018; Liu et al. 2020), Western–Southwestern China (You et al. 2015), and from Henan province (Liu et al. 2021).

In this paper, we described three new freshwater diatoms species of the genus *Gomphonema*. The first species *G. qii* sp. nov. is from Yangcheng Lake, the second species *G. poyangense* sp. nov. is from Poyang Lake, and the third species *G. longganense* sp. nov. is from Longan Lake, All of these are located at the lower reaches of Yangtze River, China. We documented those new species valve morphology with light (LM) and scanning electron microscopy (SEM), and compared them with similar species in this genus.

Material and Methods

For this study we used diatom samples that were collected from three lakes of the lower reaches of Yangtze River, collected in August, 2019. Poyang Lake (28º22'–29º45'N, 115º47'–116º45'E) is located at the junction of the middle and lower reaches of Yangtze River, it is the largest freshwater lake in China. Yangcheng Lake (31º21'–31º30'N, 120º39'–120º51'E) is located in Northeast Suzhou, Jiangsu Province, and this lake consists of three parts, west–lake, east–lake and mid–lake. The sample on which our observations have been made is from the west–lake. Longgan Lake (29º52'–30º05'N, 115º35'–116º17'E) is located on the border between Hubei and Anhui provinces, which is consists of two sub lakes, Long Lake and Gan Lake, and the material studied herein came from Long Lake (Fig. 1). In the field, several water chemistry characteristics were recorded, including: pH, temperature, dissolved oxygen, total dissolved solids (TDS), and conductivity (EC). These were all measured using a YSIPro Plus multiparameter meter (YSI, Ohio, USA). Diatom samples were collected from natural substrates, including stones, or from navigation buoys, by brushing with clean toothbrushes. Samples were placed in sample bottles and preserved with formalin (4% final concentration).

In the laboratory, diatom samples were cleaned with concentrated nitric acid using the Microwave Accelerated Reaction System (Model MARS, CEM Corporation, Charlotte, USA) (Parr et al. 2004), with a pre–programmed digestion scheme (temperature, 180°C) (Yu et al. 2019). Next, samples were alternately centrifuged for 8 min at 3000 rpm (TDZ5–WS, Luyi Corporation, Shanghai, China) and washed five times using distilled water. The resulting diatom samples were preserved with 95% ethanol. Permanent diatom slides were made with Naphrax for light microscopy (LM), and the cleaned diatom samples were air–dried onto cover slips and mounted onto alloy stubs for observation with the scanning electron microscope (SEM). LM studies were made with an ZEISS AXIO Imager A2

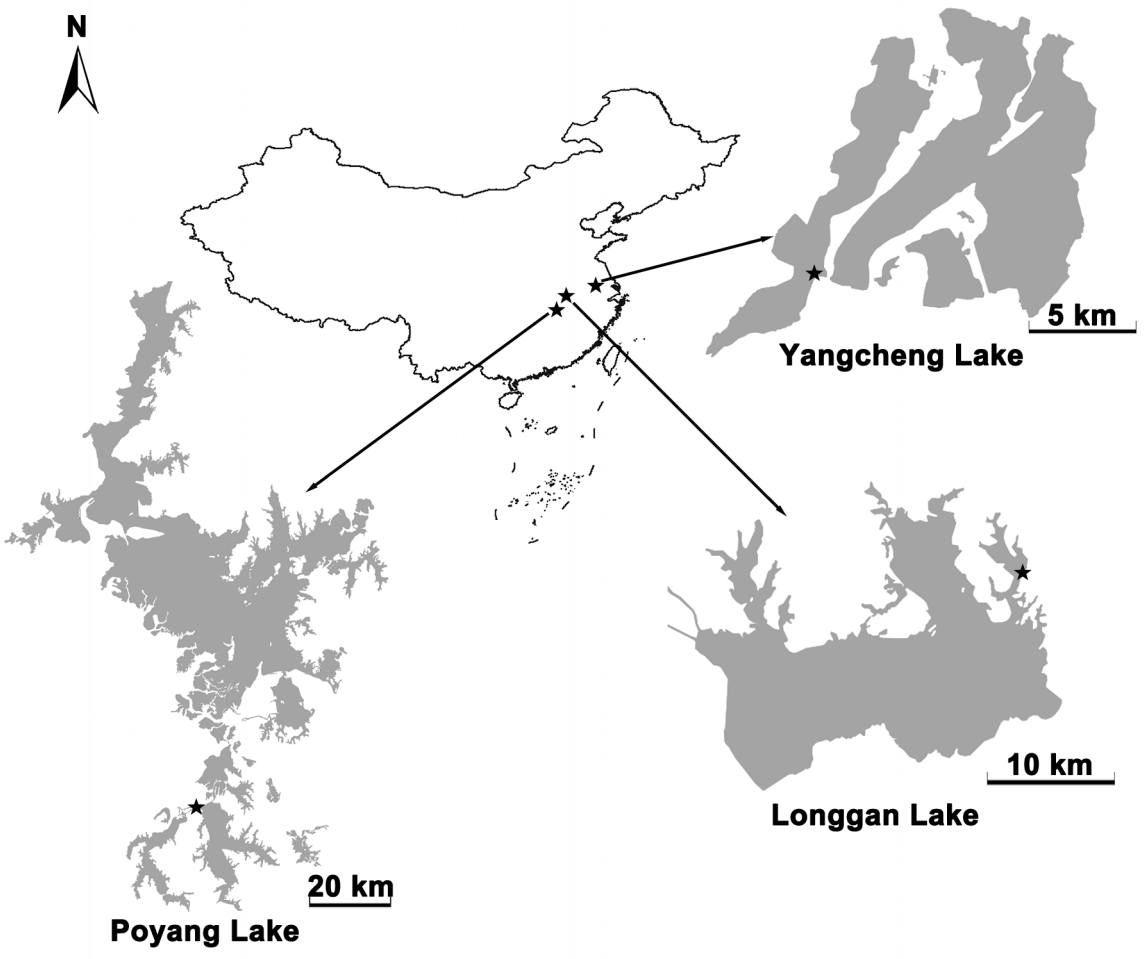


Fig. 1. Map of the study area.

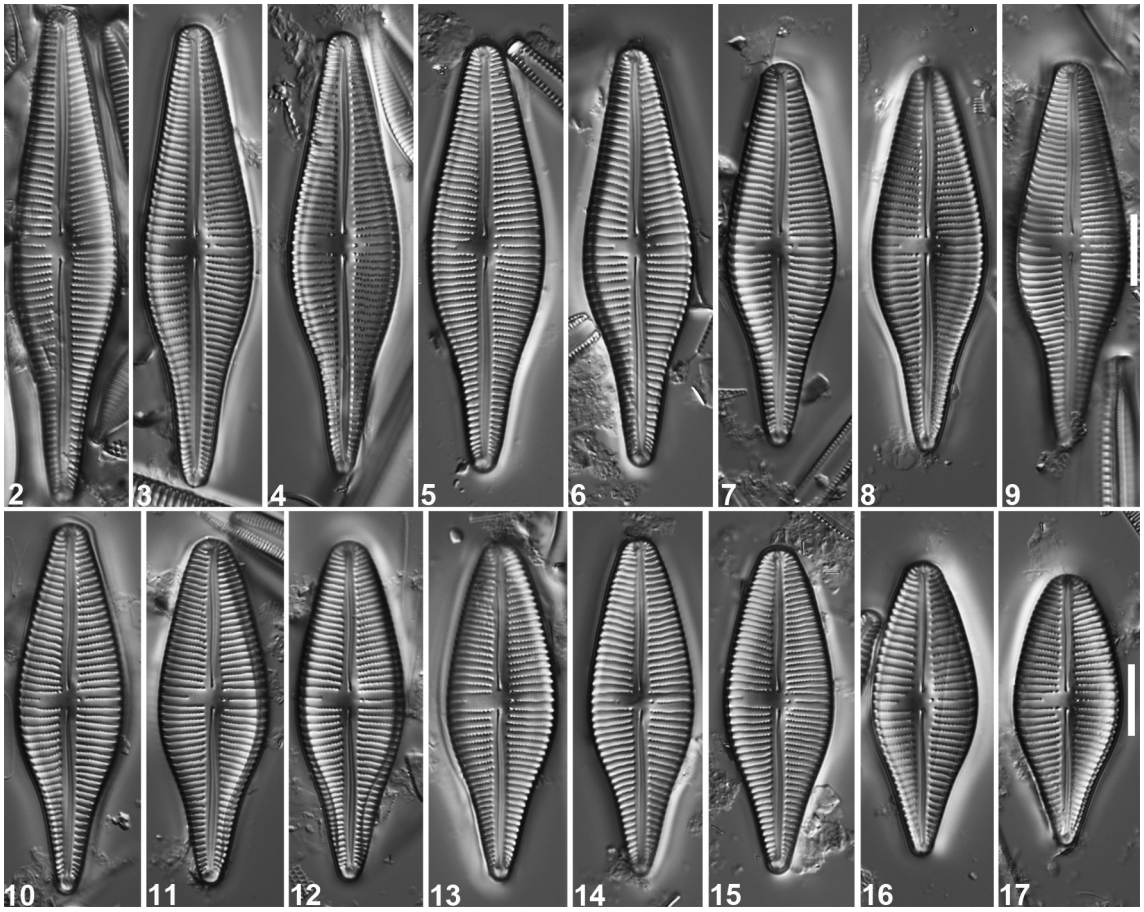
microscope fitted with DIC optics and at 1000× magnification (1.4 numerical aperture). SEM examination was made using a SU8010 (Hitachi High–Technologies Corp., Tokyo, Japan) at 2 kV, and at a working distance of less than 6 mm. Images were compiled with Adobe Photoshop CS6 (Adobe Systems Inc., San Jose, C.A., U.S.A.). Morphological terminology follows Round et al. (1990). All of the diatom samples and permanent slides are housed in Lab of Algae and Environment, College of Life Sciences, Shanghai Normal University (SHTU). Isotype material and slides have been deposited in the Kociolek Collection at the University of Colorado, Boulder (COLO).

Results

Class Bacillariophyceae Haeckel emend. Medlin et Kaczmarska 2004
Subclass Bacillariophycideae Mann in Round et al. 1990
Order Cymbellales Mann in Round et al. 1990
Family Gomphonemataceae Mann in Round et al. 1990

***Gomphonema qii* Yu, You, Kociolek et Wang sp. nov. (Figs 2–30)**
Description: LM observations (Figs 2–17), valves clavate–lanceolate, gradually tapering towards the headpole with bluntly rounded, but more abruptly tapering from the valve central towards the footpole with narrowly–rounded. Length 40–73 μm, breadth 15–17 μm (n = 100). Axial area narrow, linear. Central area small, with one or two shortened central striae on one side, and an isolated stigma site on other side at the end of the central stria. Raphe is lateral, and slightly undulate. Transapical striae punctate, nearly parallel to slightly radiate at the central, becoming strongly radiate towards the headpole and footpole. Striae number is 7–12/10 μm at the center, 9–12/10 μm at the headpole and 10–12/10 μm at the footpole. Footpole with a distinct and bilobed apical pore field.

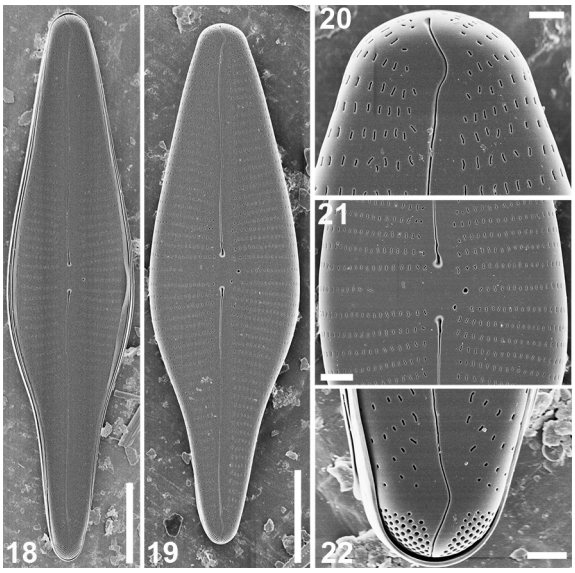
SEM observations (Figs 18–30), externally, raphe with proximal ends tear–drop shaped and stigma opening circular in outline (Fig. 21). The distal raphe ends bend slightly towards the primary valve side and continue as terminal raphe fissures bending towards the secondary side and extending onto the mantle (Figs 20, 22). Striae are uniseriate, and extend onto the mantle (Figs 18–22, 29). Areolae are slit–like, shorter or slightly undulate or, near the axial area, c–shaped (Figs 20–22). At the footpole the distal raphe end bisects the porelli of the apical pore field, and the porelli are small, round and clearly separated from the areolae, porelli number is 50/10 μm (Figs 22, 30). Internally, in the central area, proximal raphe ends are distinctly deflected and positioned on the elongated central nodule, and the long, slit–like stigma opening is distinctly separated from the last areola in



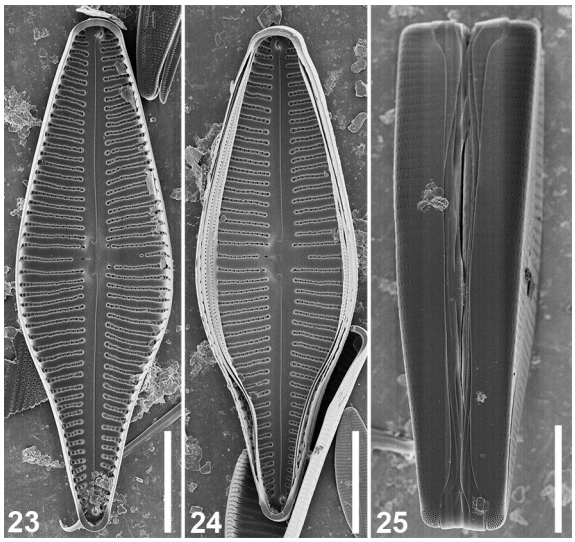
Figs 2–17. LM valve views of *Gomphonema qii* sp. nov., Scale bar 10 μm.

the central striae (Figs 23–24). Headpole distal raphe end deflected opposite or towards the stigma side (Figs 23–24, 26–27), and footpole distal raphe end deflected opposite the stigma side (Figs 23–24, 28). In the striae, there are small tooth–like projections from each side suggesting the presence of tectullae, the areolae are circular or slit–like, without occlusions (Figs 26–28). The helictoglossa and pseudoseptum are visible at both poles (Figs 26, 28), and the septum appears at the headpole and footpole (Figs 27–28). Girdle composed of several open, smooth bands, at least two bands with a row of small slit–like or irregular oval poroids near the edge away from the valve (Figs 25, 29–30).

Holotype (designated here): SHTU! Slide YCXH201908–Z1 in Lab of Algae and Environment, College of Life Sciences, Shanghai Normal University, Shanghai, China. Holotype illustrated in Fig. 5.
Isotype (designated here): COLO! 650045, Kociolek Collection, University of Colorado, Museum of Natural History Diatom Herbarium, Boulder, USA.
Type locality: CHINA. Yangcheng Lake, Jiangsu Province, 31º21'–31º30'N, 120º39'–120º51'E. collected by Pan Yu, 25th August 2019.
Etymology: The species is named for Prof. Yuzao Qi, Jinan University, China, for his pioneering work on the diatoms of China, and for his continued support of diatom research.
Ecology: Collected in one sample (YCXH201908–Z1) on stones. water temperature (T) (°C) – 30.9, pH – 9.15, Salinity (‰) – 0.16, Total Dissolved Solids (TDS) ($mg.l^{-1}$) – 218.4, EC ($\mu S.cm^{-1}$) – 374.2, Total Nitrogen (TN) ($mg.l^{-1}$) – 1, Total Phosphorus (TP) ($mg.l^{-1}$) – 0.22, Chemical Oxygen Demand (COD) ($mg.l^{-1}$) – 21.
Distribution: So far, the new species is known only from the type locality.



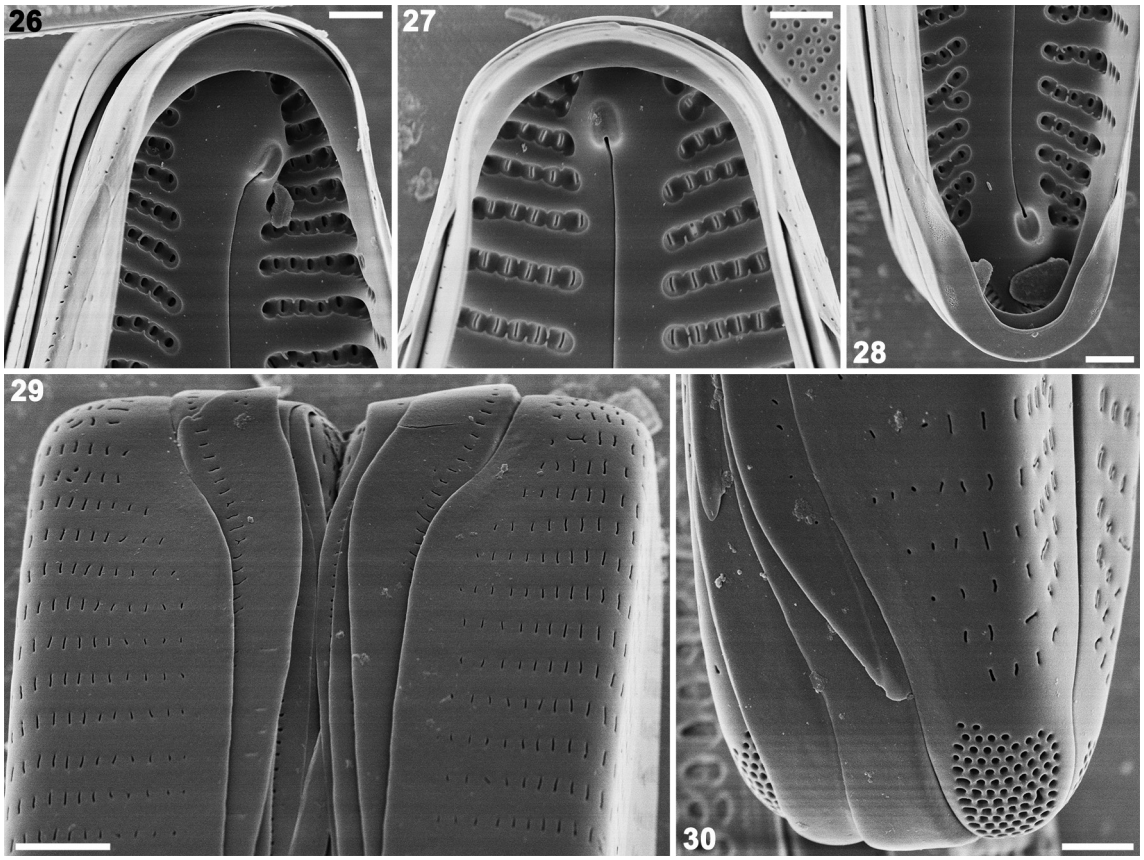
Figs 18–22. *Gomphonema qii* sp. nov., SEM, external views: (18–19) entire valve view; (20) details of the headpole with distal raphe end curved on the mantle; (21) central portion of the valve showing proximal raphe ends and rounded stigma opening; (22) details of the footpole with distal raphe end curved on the mantle and apical filed porelli are small round and clearly separated from the areolae. Scale bars 10 μm (18–19), 2 μm (21), 1 μm (20, 22).



Figs 23–25. *Gomphonema qii* sp. nov., SEM, internal and girdle views: (23–24) pseudosepta are evident at the poles, and in the central area, proximal ends are distinctly deflected and positioned on the elongated central nodule, and the stigma opening long slit–like; (25) frustule in girdle view. Scale bars 10 μm.

***Gomphonema poyangense* Yu, You, Kociolek et Wang sp. nov. (Figs 31–71)**
Description: LM observations (Figs 31–59), valves clavate–lanceolate, the headpole rounded and the footpole narrowly–rounded. Distance from central nodule to footpole is greater than the distance from central nodule to headpole. Length 35.0–41.5 μm, breadth 6.5–8.0 μm (n = 80). Axial area broad, rhombic–lanceolate. A single, isolated stigma located near the proximal raphe ends. Raphe lateral, and slightly undulate. Transapical striae nearly parallel at the headpole, slightly radiate at the center, becoming strongly radiate towards the footpole. Striae number 13–16/10 μm at the center and footpole, and up to 16–17/10 μm at the headpole. Footpole with a distinct and bilobed apical pore field.

SEM observations (Figs 60–71), externally, raphe with proximal ends tear–drop shaped, curved toward the stigma. Stigma opening small, circular (Figs 60–61, 65). Distal raphe ends bend slightly towards the primary valve side and continue as terminal raphe fissures bending towards the secondary side and extending onto the mantle (Figs 60–63). Striae are uniseriate, composed of c–shaped to irregularly shaped areolae, which extend onto the mantle (Figs 60–65, 68). Areolae adjacent to the axial area are c–shaped (Figs 63–65). On some valves, there are some irregular, round shallow depressions distributed in the region near the axial area at the footpole (Fig. 64). At the footpole, the distal raphe end bisects the porelli of the apical pore field. Porelli are small round and clearly separated from the areolae, porelli number is 70/10 μm



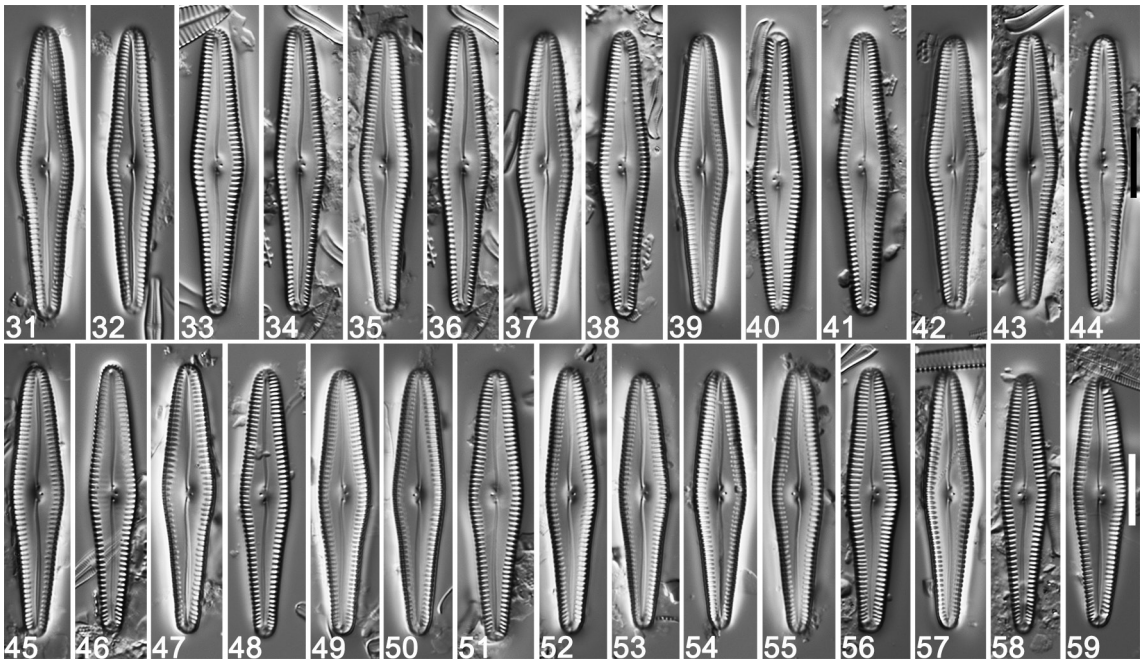
Figs 26–30. *Gomphonema qii* sp. nov., SEM: (26–27) headpole, with pseudoseptum obscures the helictoglossa, and septum appears at the headpole; (28) footpole, with pseudoseptum and helictoglossa evident, and septum appears at the footpole; (29–30) girdle views. Bands are open and smooth, at least two bands with a row of small slit–like or irregular oval areolae near the edge away from the valve. Scale bars 2 μm (29), 1 μm (26–28, 30).

(Fig. 64). Internally, the alveoli have straight edges without struts and the areolae have irregularly–shaped internal openings (Figs 69–71). In the central area, the proximal raphe fissures are hooked, and curved to the opposite side of stigma. The stigma opening is long slit–like, and the axial plate covers approximately 1/3 to 2/3 of the striae length on the valve face (Figs 66–67). The helictoglossa and pseudoseptum are visible at both poles (Figs 66–67, 69–71). At the pseudoseptum, a few small round pores may be present (Figs 69, 71). The septum appears at the headpole and footpole (Figs 69–71). Striae are composed of 3–6 areolae on the mantle (Fig. 68). Girdle composed of several open, smooth bands, at least one band with a row of irregular oval poroids near the edge away from the valve (Figs 63–64, 68).

Holotype (designated here): SHTU! Slide PYH201908–Z38 in Lab of Algae and Environment, College of Life Sciences, Shanghai Normal University, Shanghai, China. Holotype illustrated in Fig. 33.
Isotype (designated here): COLO! 650046, Kociolek Collection, University of Colorado, Museum of Natural History Diatom Herbarium, Boulder, USA.
Type locality: CHINA. Poyang Lake, Jiangxi Province, 28º22'–29º45'N, 115º47'–116º45'E. collected by Quanxi Wang, 21th August 2019.
Etymology: The species is named for Poyang Lake, where it was discovered.
Ecology: Collected in one sample (PYH201908–Z38) on stone. T (℃) – 32.79 ℃, pH – 8.06, Salinity (‰) – 0.049, TDS (mg.l^{-1}) – 66, EC (μS.cm^{-1}) – 99.
Distribution: The new species is known only from the type locality.

***Gomphonema longganense* You, Yu, Kociolek etWang sp. nov. (Figs 72–126)**
Description: LM observations (Figs 72–116), frustules slightly wedge–shaped in girdle view. Valves slightly heteropolar, linear–lanceolate with its greatest breadth near midvalve, headpole protruded, and the footpole rounded. Length 13.5–26.0 μm, breadth 4–5 μm (n = 100). Axial area narrow, linear. A single, pronounced isolated stigma located one side at the central area. Raphe laterally expanded and slightly undulate. Striae weakly radiate at the central area to headpole, becoming strongly radiate at the footpole. Striae number 12–16/10 μm.

SEM observations (Figs 117–126), externally, raphe with proximal ends tear–drop shaped and stigma opening is a circular (Figs 117–119). The distal raphe ends bend slightly towards the primary valve side and extend onto the mantle (Figs 117–118, 120–121). Striae are uniseriate, and extending onto the mantle; some striae



Figs 31–59. LM valve views of *Gomphonema poyangense* sp. nov. Scale bar 10 μm.

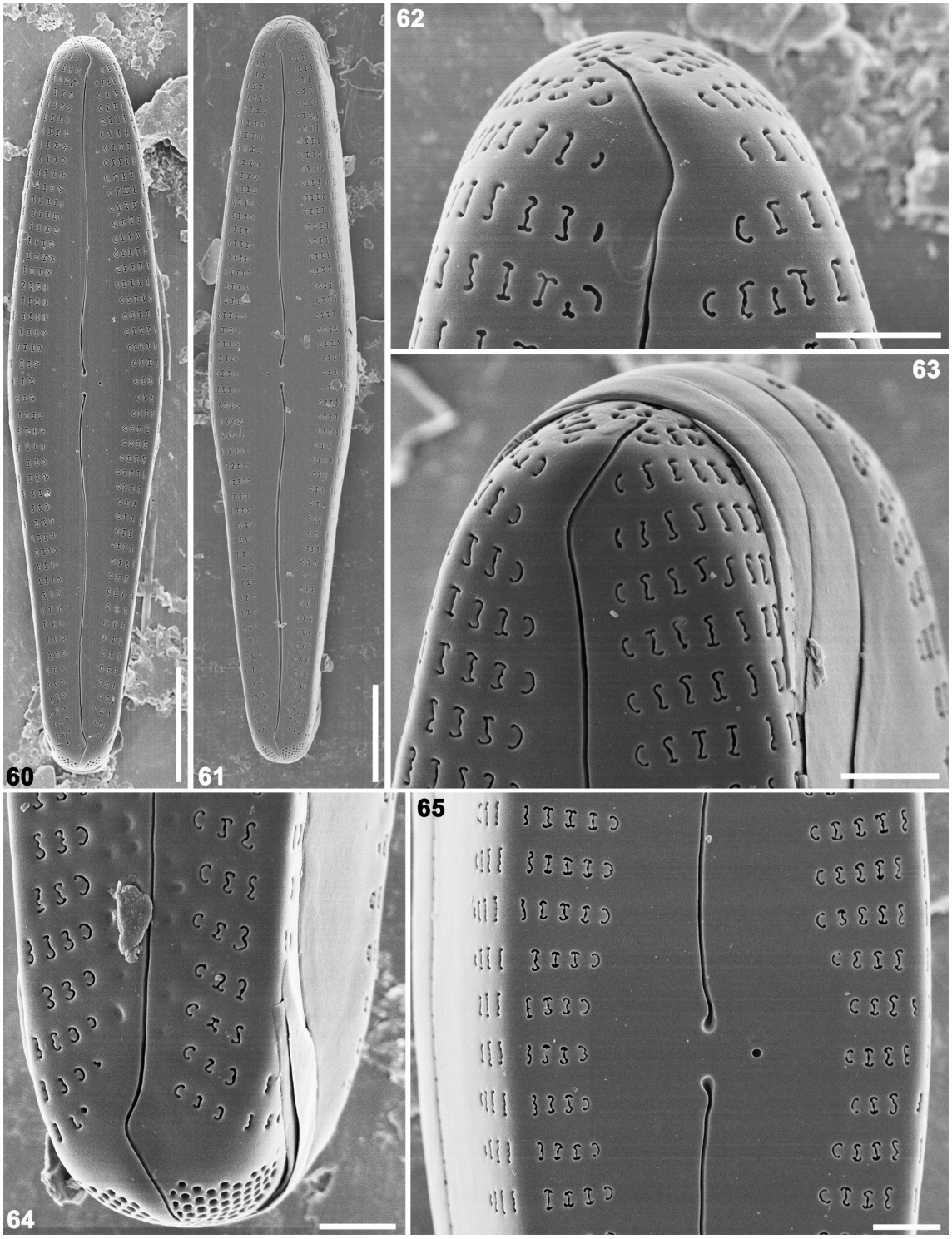
are biseriate on the valve margin (Figs 117–118, 124). Areolae are variously–shaped, including small circular, irregular oval, long slit–like, or irregular c–shaped (Figs 118–121). Striae are composed of 2–3 rows of small circular and 2–5 rows slit–like areolae on the mantle (Fig. 124). At the footpole the distal raphe end bisects the porelli of the apical pore field, and the porelli are small round and clearly separated from the areolae, porelli number is 60/10 μm (Fig. 121). There are notches or faint depressions on the valve face of around the raphe and areolae (Fig. 119). Internally, the areolae are irregular oval, long slit–like, or irregularly c–shaped (Figs 122–123, 126). In the central area, proximal raphe ends are distinctly deflected and positioned on the elongated central nodule, and the stigma opening is long, slit–like and distinctly separated from the last areola in the central striae (Fig. 126). The helictoglossae and pseudosepta are visible at both poles (Figs 122–123). Girdle composed of several open, smooth bands, at least two bands with a row of small irregular oval poroids near the edge away from the valve (Fig. 124).

Holotype (designated here): SHTU! Slide LGH201908–Z1 in Lab of Algae and Environment, College of Life Sciences, Shanghai Normal University, Shanghai, China. Holotype illustrated in Fig. 75.
Isotype (designated here): COLO! 650047, Kociolek Collection, University of Colorado, Museum of Natural History Diatom Herbarium, Boulder, USA.
Type locality: CHINA. Longgan Lake, Anhui Province, 29º52'–30º05'N, 115º35'–116º17'E. collected by Pan Yu, 22th August 2019.
Etymology: The species is named for the place where it was found, namely Longgan Lake.
Ecology: Collected in one sample (LGH201908–Z1) on stone. T (℃) – 31.2 ℃, pH – 8.12, Salinity (‰) – 0.12, TDS ($mg.l^{-1}$) – 163.15, EC ($\mu S.cm^{-1}$) – 280.6, TN ($mg.l^{-1}$) – 2.1, TP ($mg.l^{-1}$) – 0.1, COD ($mg.l^{-1}$) – 13.2.
Distribution: So far, the new species is known only from the type locality.

Discussion

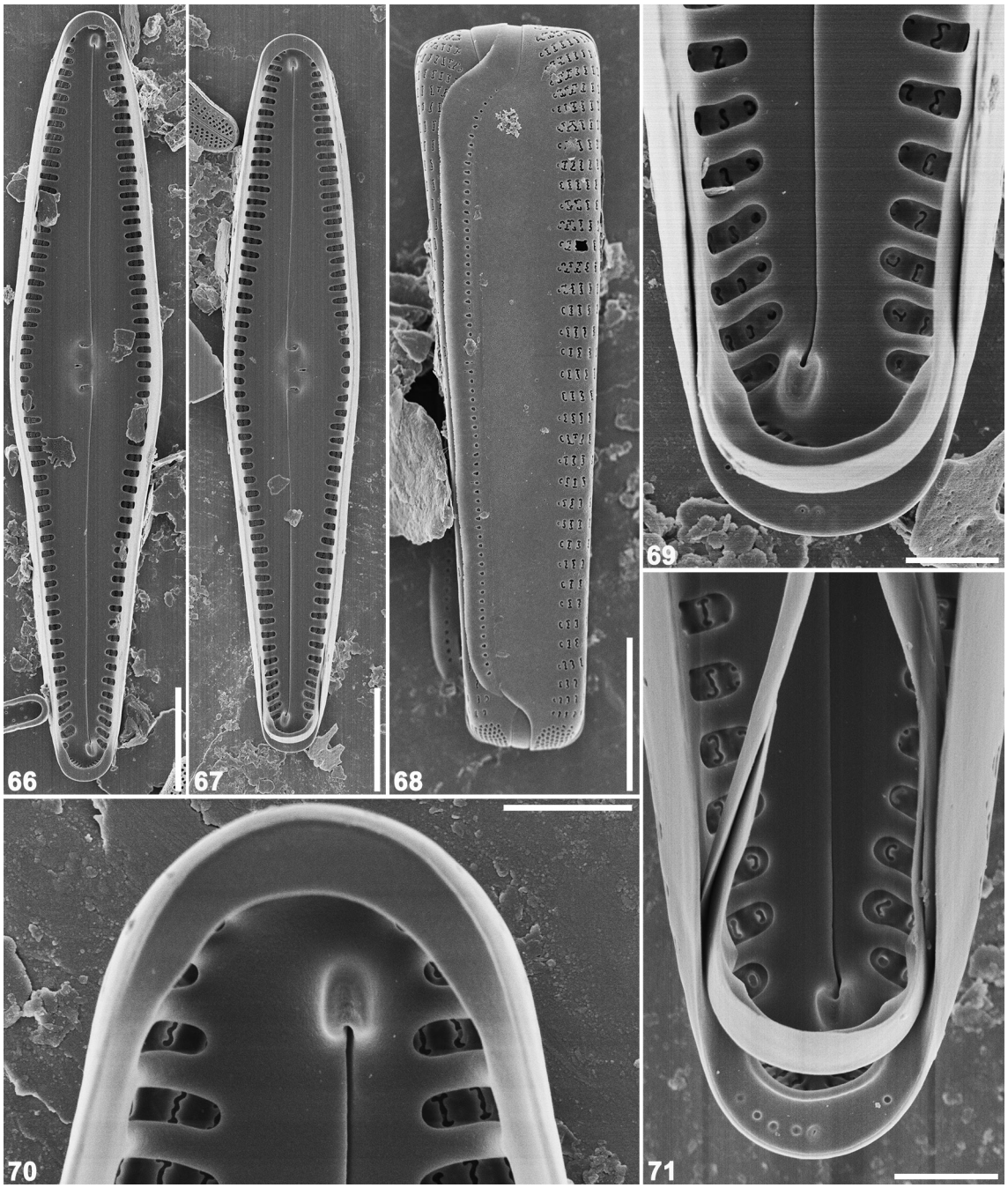
Gomphonema qii, *G. poyangense*, and *G. longganense* are new species that possess certain characteristics that support their classification in the genus *Gomphonema*, including: asymmetry about the transapical axis, clavate frustules in girdle view, a stigma present on one side of the central area, presence of pseudosepta and when visible septa on the girdle bands, and an apical pore field present and bisected by the terminal raphe on the footpole. The structure of the areolae in these species are variable, with most examples being slit–like to rounded. This is quite different from the classical or 'core' species of the genus (e.g. *G. parvulum* (Kützing) Kützing*, G. acuminatum* Ehrenberg, etc. – see Abarca et al. 2020), which predominantly have c–shaped areolae (Reichardt 1999, 2001; Kulikovskiy et al. 2015). Species currently assigned to the genus *Gomphonema* that differ from the classical taxa in this regard can be found in many parts of the globe (e.g. Metzeltin & Lange–Bertalot 1998; Reichardt 2005b; Kociolek et al. 2016), but are particularly common in freshwaters of Asia (Kociolek 1992; Liu et al. 2013; Kociolek et al. 2015; You et al. 2015; Liu et al. 2020, Liu et al. 2021).

The new taxa described herein can be compared



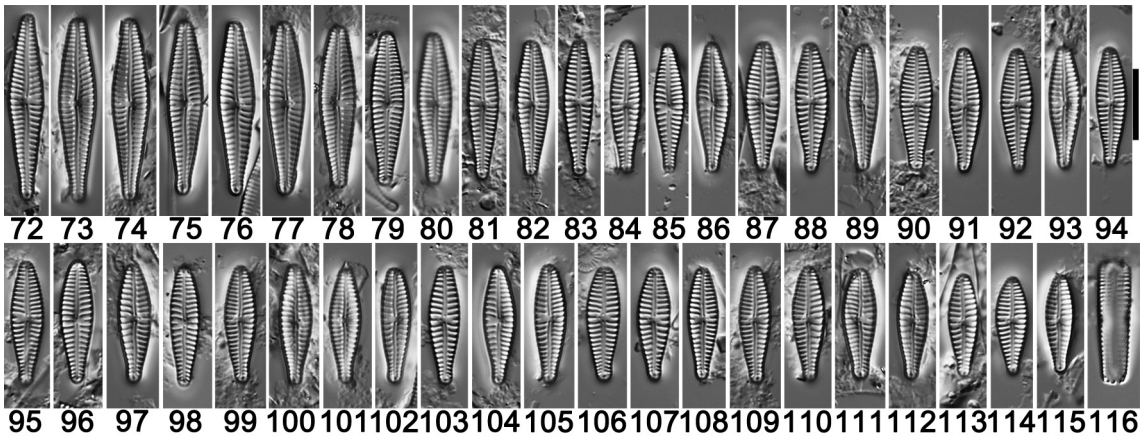
Figs 60–65. *Gomphonema poyangense* sp. nov., SEM, external views: (60–61) valve with a broadly rhombic–lanceolate axial; (62–63) details of the headpole with distal raphe end curved on the mantle; (64) details of the footpole with distal raphe end curved on the mantle and apical filed porelli are small round and clearly separated from the areolae. Some irregular round shallow depressions distributed at near the axial area of footpole. (65) central portion of the valve showing proximal raphe ends and rounded stigma opening. Scale bars 5 μm (60–61), 1 μm (62–65).

with others in the genus that appear similar. For example, *Gomphonema qii* is similar to several species, including *G. aciforme* Kociolek, Spaulding, Sabbe et Vyverman (Kociolek et al. 2004), *G. matanoense* Kapustin, Kociolek et Kulikovskiy (Kociolek et al. 2018), *G. yaominae* Li (Gong et al. 2012), *G. krammeri* (Reichardt 2005a), and *G. affine* var. *rhombicum* Reichardt (Reichardt 1999). There are also additional features that distinguish this new species from other, similar species (Table 1). Valve shape is clavate–lanceolate in *G. qii*, but rhomboid–clavate in *G. matanoense*, and rhombic–lanceolate in *G. krammeri* and *G. affine* var. *rhombicum*. The headpole is bluntly

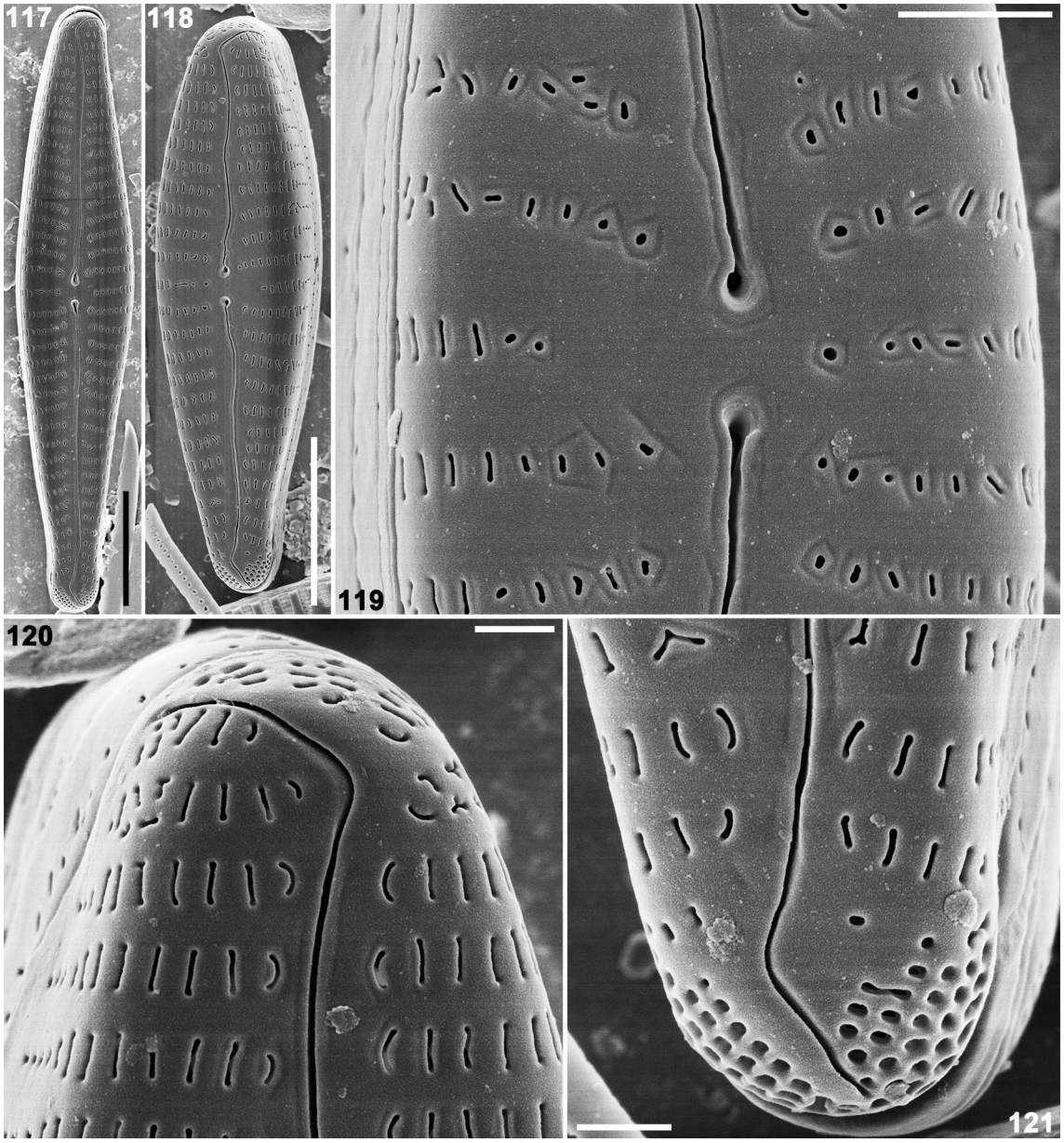


Figs 66–71. *Gomphonema poyangense* sp. nov., SEM, internal and girdle views: (66–67) pseudosepta are evident at the poles, and in the central area, proximal raphe fissures are hooked, and curved to the opposite side of stigma, the stigma opening long slit–like; (68) frustule in girdle view; (69,71) footpole, with pseudoseptum and helictoglossa evident, and septum appears at the footpole. At the pseudoseptum, have a few small round psuedopore. (70) headpole, with pseudoseptum obscures the helictoglossa. Scale bars 5 μm (66–68), 1 μm (69–71).

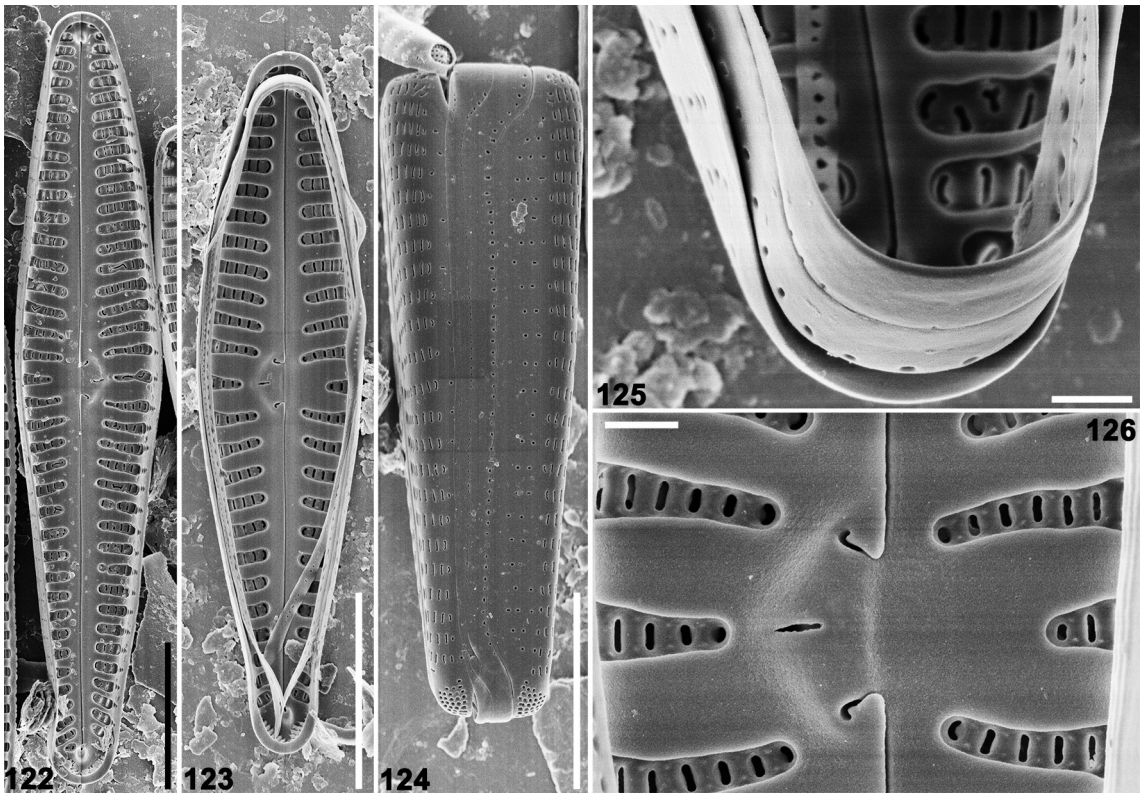
rounded in *G. qii*, while very narrow in *G. aciforme* at the headpole, and narrowly rounded in *G. krammeri* and *G. affine* var. *rhombicum*. Additionally, valves of *G. qii* are longer (40–73 μm) than *G. affine* var. *rhombicum* (35–62 μm), shorter than *G. matanoense* (92.5–108.1 μm) and *G. yaominae* (72–97 μm). Valves of *G. qii* are wider (15–17 μm), as compared to *G. aciforme* (6.5–12.0 μm), *G. krammeri* (10.5–14.7 μm), *G. yaominae* (13.0–14.5 μm) and *G. affine* var. *rhombicum* (10.0–12.8 μm), and narrower than *G. matanoense* (26.7–30.0 μm). The striae density at mid–valve in *G. qii* (7–12/10 μm) is higher than *G. matanoense* (6–7/10 μm). In the SEM, the areolae shape is slit–like, shorter or slightly undulate or c–shaped in *G. qii*, but ovoid in *G. matanoense*, c–shaped or elongate in *G. yaominae*, round or slit–like in *G. krammeri* and c–shaped in *G. affine* var. *rhombicum*. Moreover, *G. yaominae* and *G. krammeri* have irregular, round shallow depressions distributed in the axial area, but *G. qii* is without this character. Finally, the *G. krammeri* has 3–5 stigma, while *G. qii* has only a single stigma.



Figs 72–116. LM valve views of *Gomphonema longganense* sp. nov. Scale bar 10 µm.



Figs 117–121. *Gomphonema longganense* sp. nov., SEM, external views: (117–119) central portion of the valve showing proximal raphe ends and small rounded stigma opening; (120) details of the headpole with distal raphe end curved on the mantle; (121) details of the footpole with distal raphe end curved on the mantle and apical filed porelli are small round and clearly separated from the areolae. Scale bars 5 µm (117–118), 1 µm (119), 0.5 µm (120–121).



Figs 122–126. *Gomphonema longganense* sp. nov., SEM: (122–123) entire internal valve view; (124) girdle view. with several open, smooth bands, at least two bands with a row of small irregular oval areolae near the edge away from the valve; (125) footpole, with helictoglossa evident; (126) central area, proximal raphe ends is recurved and stigma opening long slit–like and distinctly separated from the last areola in the central striae. Scale bars 5 μm (122–124), 0.5 μm (125–126).

In *G. poyangense*, which has a wide axial area, some species that are similar include *G. hawaiiense* Reichardt (Reichardt 2005b), *G. caperatum* Ponader et Potapova (Ponader et al. 2017), *G.obstipum* Potapova, Ponader et Desianti (Ponader et al. 2017), *G. amerhombicum* Reichardt (Reichardt 2007), and *G. medioasiae* Metzeltin, Lange–Bertalot et Soninkhishig (Metzeltin et al. 2009). The main characters found in the new species and similar species are summarized in Table 2. Valve shape is clavate–lanceolate in *G. poyangense*, but rhomboid–lanceolate in *G. hawaiiense*. The headpole is rounded in *G. poyangense*, while *G. hawaiiense* and *G. amerhombicum* have subacute, rounded headpoles and in *G. caperatum* the headpole is acutely rounded. The axial area is rhomboid–lanceolate in *G. poyangense*, but linear–lanceolate in *G. amerhombicum*. Valves of *G. poyangense* are longer (35.0–41.5 μm) than *G. caperatum* (18–31 μm), *G. obstipum* (23–29 μm), and *G. amerhombicum* (22.0–58.7 μm), while shorter than *G. medioasiae* (47–52 μm). valves of *G. poyangense* are wider (6.5–8.0 μm) than *G. caperatum* (3.7–5.0 μm), *G.obstipum* (5–6 μm), *G.* andd *amerhombicum* (5.5–7.6 μm). Additionally, the shape of the areolae is c–shaped to irregularly shaped in *G. poyangense*, but small circular in *G. amerhombicum*, c–shaped, ε–shaped or I–shape in *G.obstipum*, andd c–shaped or small circular in *G. caperatum*. Moreover, *G. caperatum* has shallow grooves or wrinkles on external valve suface often aligned with the striae, but *G. poyangense* is without this character. *G.obstipum* has shallow circular depressions in the axial area, but a similar feature is only distributed in the region near the axial area of footpole in *G. poyangense*. The striae are biseriate in *G. amerhombicum*, while they are uniseriate in *G. poyangense*.

G. longganense can be compared to several *Gomphonema* species, based on similarities in outline and structure of the valve including *G. cholnokyi* Passy, Kociolek et Lowe (Passy et al. 1997), *G. alfinitoanum* Metzeltin et Lange–Bertalot (Metzeltin & Lange–Bertalot 2007), *G. andinum* Morales et Vis (Morales & Vis 2007), and *G. subbulbosum* Reichardt (Reichardt 2008). The morphological characteristics of *G. longganense* and these similar species are summarized in Table 3. Valve shape is linear–lanceolate in *G. longganense*, but in *G. alfinitoanum* valves are curved elongated pear–shaped, in *G. andinum* it is clavatae, and in *G. subbulbosum* it is clavatae–lanceolate to elliptical. The headpole is protruded in *G. longganense*, while in *G. andinum* the headpole is broadly rounded. The footpole is rounded in *G. longganense*, but in *G. alfinitoanum* the footpole is acutely rounded, and in *G. subbulbosum* it is narrowly rounded. Valves of *G. longganense* are shorter (13.5–26.0 μm) than *G. cholnokyi* (29–44 μm), *G. alfinitoanum* (27–35 μm), and *G. subbulbosum* (23.5–57.0 μm). Additionally, the number of striae of in *G. longganense* (12–16/10 μm) is higher than in *G. cholnokyi*

Table 1. Comparison of morphological characteristics of *Gomphonema qii* sp. nov. and closely related taxa.

Species/Feature	***G. qii***	***G. aciforme***	***G. matanoense***	***G. yaominae***	***G. krammeri***	***G. affine* var. *rhombicum***
Valve length (μm)	40–73	36–80	92.5–108.1	72–97	44–75	35–62
Valve width (μm)	15–17	6.5–12	26.7–30	13–14.5	10.5–14.7	10–12.8
Valve outline	Clavate–lanceolate	Lanceolate–clavate	Broadly rhomboid–clavate	Lanceolate	Minime clavatae, rhombic–lanceolate	Rhombic–lanceolate
Headpole	Bluntly rounded	Narrow	Bluntly rounded	Broadly rounded	Narrowly rounded	Narrowly rounded
Footpole	Narrowly–rounded	Narrow	Rounded	Narrowly rounded	Narrowly rounded	Narrow
Axial area	Narrow, linear	Narrow linear	Lanceolate	Narrow, lanceolate	Lanceolate to linear–lanceolate	Narrow linear
Central area	Small	Absent	Not distinct	Not distinct	Not distinct	Absent
Striae	Nearly paralleled to slightly radiate, becoming strongly radiate towards the poles	Nearly paralleled	Distinctly punctate and paralleled (middle), paralleled and condensed (headpole), less or more paralleled (footpole)	Slightly radiate, becoming radiate towards the poles	Radiate on middle, becoming paralleled towards the poles	Nearly paralleled, becoming radiate towards the poles
Areolae	Slit–like, shorter or slightly undulate or c–shaped	Straight slits	Ovoid	C–shape or long strip shape	Round or slits	C–shape
Density of striae (10 μm)	7–12 (middle), 9–12 (headpole), 10–12 (footpole)	10–12	6–7 (middle), 10–12 (poles)	7–14	7–9	8–10
References	Current study	Kociolek et al. (2004)	Kociolek et al. (2018)	Gong et al. (2012)	Reichardt (2005a)	Reichardt (1999)

Table 2. Comparison of morphological characteristics of *Gomphonema poyangense* sp. nov. and closely related taxa.

Species/Feature	***G. poyangense***	***G. hawaiiense***	***G. caperatum***	***G.obstipum***	***G. amerhombicum***	***G. medioasiae***
Valve length (μm)	35–41.5	28–48	18–31	23–29	22–58.7	47–52
Valve width (μm)	6.5–8	6.4–7.5	3.7–5	5–6	5.5–7.6	6–8
Valve outline	Clavate–lanceolate	Rhombic–lanceolate	Linear to linear–lanceolate	Lanceolate	Clavate–lanceolate	Slightly clavate–lanceolate
Headpole	Rounded	Subacute rounded	Acutely rounded	Rounded	Subacute rounded	Obtuse rounded
Footpole	Narrowly–rounded	Narrow–rounded	Narrow	Rounded	Narrow–rounded	Acute rounded
Axial area	Rhombic–lanceolate	Rhombic–lanceolate	Lanceolate	Rhombic	Linear–lanceolate	Lanceolate
Central area	Not distinct	Not distinct	Not distinct	Not distinct	Not distinct	Not distinct
Striae	Nearly paralleled (headpole), slightly radiate (central), strongly radiate (footpole)	Radiate	Slightly radiate	Slightly radiate, becoming radiate towards the poles	Radiate, becoming nearly paralleled towards the poles	Radiate
Areolae	C–shaped to irregularly shaped	Slits or c–shaped	C–shaped or small circular	C–shape, ε–shaped or I–shape	Small circular	No data
Density of striae (10 μm)	13–16 (middle and footpole), 16–17 (headpole)	14–16	13–16	13–16	14–16 (middle), 16–18 (poles)	16–18
References	Current study	Reichardt (2005b)	Ponader et al. (2017)	Ponader et al. (2017)	Reichardt (2007)	Metzeltin et al. (2009)

Table 3. Comparison of morphological characteristics of *Gomphonema longganense* sp. nov. and closely related taxa.

Species/Feature	***G. longganense***	***G. cholnokyi***	***G. alfinitoanum***	***G. andinum***	***G. subbulbosum***
Valve length (μm)	13.5–26	29–44	27–35	14–31.6	23.5–57.6
Valve width (μm)	4–5	5.5–7	6–6.6	4.8–7.2	7.5–10.6
Valve outline	Linear–lanceolate	Linear–lanceolate	Curved elongated pear–shaped	Clavatae	Clavatae lanceolate to elliptical
Headpole	Protruded	Rounded	Obtusely rounded	Broadly rounded	Obtusely rounded
Footpole	Rounded	Rounded	Acutely rounded	Blunt rounded	Narrowly rounded
Axial area	Narrow, linear	Narrow, linear	Narrow, linear	Narrow, linear	Narrow, linear
Central area	Absent	Rectangular	Not distinct	Absent	Not distinct
Striae	weakly radiate at the middle to headpole, becoming strongly radiate at the footpole	Radiate, becoming weakly radiate to paralleled (headpole) , strongly radiate (footpole)	Radiate, becoming nearlly paralleled towards the poles	weakly radiate at the middle, becoming nearlly paralleled (headpole) and strongly radiate (footpole)	Radiate on middle to footpole, becoming paralleled towards the headpole
Areolae	Circular, slit–like, irregular oval or c–shaped	C–shape or indented	No data	Reniform	C–shape or slit–like
Density of striae (10 μm)	12–16	10–12	14–15	10–15 (middle), 15–20 (poles)	10–12
References	Current study	Passy et al. (1997)	Metzeltin & Lange–Bertalot (2007)	Morales & Vis (2007)	Reichardt (2008)

(10–12/10 μm) and *G. subbulbosum* (10–12/10 μm). The shape of the areolae is circular, slit–like, irregular oval or c–shaped in *G. longganense*, but reniform in *G. andinum*, and c–shaped or indented in *G. cholnokyi*. Moreover, *G. alfinitoanum* has two stigmata, but in *G. longganense* only a single stigma is presentt. The internal stigma opening is long and slit–like in *G. longganense*, while it is small and round in *G. cholnokyi*. The striae are biseriate in *G. amerhombicum*, but uniseriate in *G. longganense*. And the striae are biseriate with pores on mantle of *G. subbulbosum*, but in *G. longganense* theis feature in uniseriate.

In our study, these three new *Gomphonema* species were only been found their respective type localities. *G. qii* is known only from Yangcheng Lake, which has low TN (1 mg.l^{-1}) and TP (0.22 mg.l^{-1}), high COD (21 mg.l^{-1}). In addition, our data show this species is a common species in type locality, and the main accompanying diatom taxa in the flora include *Ulnaria ulna* (Nitzsch) Compère (Compère 2001), *Fragilaria pararumpens* Lange–Bertalot, Hofmann et Werum (Hofmann et al. 2011), *Cocconeis placentula* Ehrenberg (Ehrenberg 1838), *Gomphonema turris* Ehrenberg (Ehrenberg 1843), *G. lagenula* Kützing (Kützing 1844), *Lemnicola hungarica* (Grunow) Round & Basson (Round & Basson 1997), *Nitzschia amphibia* Grunow (Grunow 1862) and *N. palea* (Kützing) Smith (Smith 1856). *G. poyangense* is described from Poyang Lake, and the water in this lake has low TDS (66 mg.l^{-1}) and low EC (99 μS.cm^{-1}). In our data, *G. poyangense* is abundant in the type locality, and the main co–occurring diatom species include, *Achnanthidium minutissimum* (Kützing) Czarnecki (Czarnecki et al. 1994), *G. graciledictum* Reichardt (Reichardt 2015) and *Ulnaria ulna* (Nitzsch) Compère (Compère 2001). *G. poyangense* is abundant in the type locality of Longgan Lake, and this lake has low TN (2.1 mg.l^{-1}) and TP (0.1 mg.l^{-1}), and high COD (13.2 mg.l^{-1}). In the type locality, the main co–occurring diatom species include, *Tabularia fasciculata* (Agardh) Williams et Round (Williams & Round 1986), *Gomphonema lagenula* Kützing (Kützing 1844), *G. minutum* (Agardh) Agardh (Agardh 1831), A*ctinocyclus normanii* (Gregory) Hustedt (Hustedt 1957), S*tephanodiscus hantzschii* Grunow (Cleve & Grunow 1880) and *Craticula subminuscula* (Manguin) Wetzel et Ector (Wetzel & Ector 2015).

Recently, have four new species of the genus *Gomphonema* from eastern China, these three new species are sufficiently different from these four species based on valve outline, shape of the axial and center areas, and striae density. *G. shanghaiensis* Zhang et Kociolek (Zhang et al. 2016) collected from river in from Shujiawan River, Shanghai City, *G. bicepiformis* Zhang et Kociolek (Zhang et al. 2018 a) collected from stream in the Xianju County, Zhejiang Province, *G. wuyiensis* Zhang et Kociolek (Zhang et al. 2018 b) collected from river in Wuyi Mountains, Jiangxi Province, and *G. qingyiensis* Zhang, Yu et You (Zhang et al. 2020) collected from river in Qingyi River, Anhui Province, and all of these four species occurs in low conductivity, slightly alkaline water and relatively clean water. Although in our study, these new species were collected from lake, but they also mainly occurs in slightly alkaline and relatively clean water, *G. poyangense* sp. nov. occurs in low conductivity (99 μS.cm^{-1}) water, but *G. qii* sp. nov. and *G. longganense* sp. nov. occurs in slightly high conductivity (374.2 μS.cm^{-1} and 280.6 μS.cm^{-1}) water. So far, these species have been described only from the type locality, and further research is needed to determine whether they are geographically unique.

Further studies are needed to fully document the diatom flora of the Yangtze River, and in China generally. We will continue to study relationship between diatom diversity and ecology from this region, which will be useful in applying diatoms to gain an understanding of water quality in the region.

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References

Agardh, C.A. (1831): Conspectus criticus diatomacearum. Part 3. – pp. 33–48, Lundae [Lund]: Literis Berlingianus.

Abarca, N.; Zimmerrman, J.; Kusber, W–H.; Mora, D.; Van, A.T.; Skibbe, O. & Jahn, R. (2020): Defining the core group of the genus *Gomphonema* Ehrenberg with molecular and morphological methods. – Botany Letters 167: 114–159.

Almeida, F.; Ector, L.; Silva, E.S. & Wetzel, C.E. (2020): *Gomphonema frequentiformis* (Metzeltin & Krammer) comb. nov. (Bacillariophyta): ecology and taxonomy of a Neotropical diatom. – Phytotaxa 439: 265–275.

Bao, W.M.; Wang, Q.X. & Reimer, C.W. (1992): Diatoms from the Changbaishan Mountain area. – Bulletin of botanical research 12:125–143.

Bao, W.M. & Reimer, C.W. (1992): New taxa of the diatoms from Changbaishan Mountain, China. – Bulletin of botanical research 12:357–361.

Cleve, P.T. & Grunow, A. (1880): Beiträge zur Kenntniss der Arktischen Diatomeen. – Kongliga Svenska–Vetenskaps Akademiens Handlingar 17: 121 pp.

Compère, P. (2001): *Ulnaria* (Kützing) Compère, a new genus name for *Fragilaria* subgen. Alterasynedra Lange–Bertalot with comments on the typification of *Synedra* Ehrenberg. –In: Jahn, R.; Kociolek, J.P.; Witkowski, A. & Compère, P. (eds): Lange–Bertalot Festschrift. Studies on diatoms dedicated to Prof. Dr. Dr. h.c. Horst Lange–Bertalot on the occasion of his 65th birthday. – pp. 97–101, A.R.G. Gantner Verlag K.G, Ruggell.

Czarnecki, D.B. (1994): The freshwater diatoms culture collection at Loras College, Dubuque, Iowa. – In: Kockiolek, J.P. (ed.): Proceedings of the 11th International Diatom Symposium. – Memoirs of the California Academy of Sciences 17: 155–174.

Ehrenberg, C.G. (1832): Über die Entwicklung und Lebensdauer

der Infusionsthiere; nebst ferneren Beiträgen zu einer Vergleichung ihrer organischen Systeme. – 154 pp., Abhandlungen der Königlichen Akademie der Wissenschaften zu – Berlin.

Ehrenberg, C.G. (1838): Atlas von Vier und Sechzig Kupfertafeln ze Christian Gottfried Ehrenberg über Infusionsthierchen. – 548 pp., Leipzig: Verlag von Leopold Voss.

Ehrenberg, C.G. (1843): Verbreitung und Einfluss des mikroskopischen Lebens in Süd–und Nord–Amerika. – pp. 291–445, Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin.

Fan, Y.W.; Bao, W.M. & Wang, Q.X. (1998): Investigation on Gomophonemaceae from Heilongjiang Province in China. – Bulletin of Botanical Research 18: 243–251.

Fan, Y.W.; Shi, Z.X.; Bao, W.M. & Wang, Q.X. (2004): A new combination and two varieties of polystigmate *Gomphonema* (Gomphonemaceae Bacillariophyta) from Heilongjiang Province, China. – Chinese Journal of Oceanology and Limnology 22: 198–203.

Fore, L.S. & Grafe, C. (2002): Using diatoms to assess the biological condition of large rivers in Idaho (U.S.A.). – Freshwater Biology 47: 2015–2037.

Gong, Z. & Li, Y.L. (2012): *Gomphonema yaominae* sp. nov. Li, a new species of diatom (Bacillariophyta) from lakes near Yangtze River, China. – Phytotaxa 54: 59–64.

Grunow, A. (1862): Die österreichischen Diatomaceen nebst Anschluss einiger neuen Arten von andern Lokalitäten und einer kritischen Uebersicht der bisher bekannten Gattungen und Arten. – p. 574, Verhandlungen der kaiserlich–königlichen zoologisch–botanischen Gesellschaft – Wien.

Hofmann, G.; Werum, M. & Lange–Bertalot, H. (2013): Diatomeen im Süßwasser—Benthos von Mitteleuropa. Bestimmungsflora Kieselalgen für die ökologische Praxis. – 908 pp., Koeltz Scientific Books, Königstein.

Hustedt, F. (1957): Die Diatomeenflora des Flußsystems der Weser im Gebiet der Hansestadt Bremen. – Abhandlungen des Naturwissenschaftlichen Verein zu Bremen 34:181–440.

Jao, C.C. (1964) Some freshwater algae from Southern Tibet. – Oceanography and Limnology Sinica 6: 169–192.

Jao, C.C.; Zhu, H.Z. & Li, Y.Y. (1973): Notes on the freshwater algae of the Mt. JolmoLungma Region in Southern Tibet. – Chinese Science Bulletin 18: 30–32.

Jiang, Z.; Liu, Y.; Kociolek, J.P. & Fan, Y.W. (2018): One new *Gomphonema* (Bacillariophyta) species from Yunnan Province, China. – Phytotaxa 349: 257–264.

Kociolek, J.P. (1992): Valve ultrastructure and systematic position of *Gomphonema kaznakowi* Mereschkowsky. – Diatom Research 7: 259–265.

Kociolek, J.P.; Balasubramanian, K.; Blanco, S.; Coste, M.; Ector, L.; Liu, Y.; Kulikovskiy, M.; Lundholm, N.; Ludwig, T.; Potapova, M.; Rimet, F.; Sabbe, K.; Sala, S.; Sar, E.; Taylor, J.; Van De Vijver, B.; Wetzel, C.E.; Williams, D.M.; Witkowski, A. & Witkowski, J. (2019): DiatomBase. – Accessed at http://www.diatombase.org on 2021–04–12.

Kociolek, J.P.; Glushchenko, A. & Kulikovskiy, M.S. (2015): Typification, valve ultrastructure, and systematic position of *Gomphonema goomphopleuroiddes* Amossé ex Kociolek, Glushchenko and Kulikovskiy, an endemic diatom from Southeast Asia. – Diatom Research 30: 247–255.

Kociolek, J.P.; Kapustin, D. & Kulikovskiy, M. (2018): A new, large species of *Gomphonema* Ehrenberg from ancient Lake Matano, Indonesia. – Diatom Research 33: 241–250.

Kociolek, J.P.; Spaulding, S.A.; Sabbe, K. & Vyverman, W. (2004): New *Gomphonema* (Bacillariophyta) species from Tasmania. – Phycologia 43: 427–444.

Kociolek, J.P. & Stoermer, E.F. (1993): Freshwater gomphonemoid diatom phylogeny: preliminary results. – Hydrobiologia 269: 31–38.

Kociolek J.P.; Woodward, J. & Graeff, C. (2016): New and endemic *Gomphonema* C. G. Ehrenberg (Bacillariophyceae) species from Hawaii. – Nova Hedwigia 102: 141–171.

Kulikovskiy, M.S.; Kociolek, J.P.; Solak, C. & Kuznetsova, I. (2015): The diatom genus *Gomphonema* Ehrenberg in Lake Baikal. II. Revision of taxa from *Gomphonema acuminatum* and *Gomphonema truncatum–capitatum* complexes. – Phytotaxa 223: 251–272.

Kützing, F.T. (1844): Die Kieselschaligen Bacillarien oder Diatomeen. – 152 pp., Nordhausen: zu finden bei W. Köhne.

Lei, G.; Liu, Y.; Kociolek, J.P. & Fan, Y.W. (2014): New *Gomphonema* (Bacillariophyta) species from Xingkai Lake, China. – Phytotaxa 175: 249–255.

Li, J.Y. (1983): The diatom fossils from Diatomaceous Earth of Sipangul Lake, Region Xizang. – In: Contribution to the Geology of Qinghai–Xizang (Tibet) Plateau. No. 4. – 309 pp., Geological Publishing House, Beijing.

Li, Y.L.; Gong, Z.; Xie, P. & Shen, J. (2006): Distribution and morphology of two endemic gomphonemoid species, *Gomphonema kaznakowi* Mereschkowsky and *G. yangtzensis* Li nov. sp. in China. – Diatom research 21: 313–324.

Li, Y.; Kociolek, J.P. & Metzeltin, D. (2010): *Gomphonema sichuanensis* Li and Kociolek sp. nov. and *Gomphonema laojunshanensis* Li, Kociolek and Metzeltin sp. nov. from two high mountain lakes, China. – Diatom Research 25: 87–98.

Liao, M.N. & Li, Y.L. (2018): One new *Gomphonema* Ehrenberg (Bacillariophyta) species from a high mountain lake in Yunnan Province, China. – Phytotaxa 361: 123–130.

Liu, Y.; Kociolek, J.P. & Wang, Q.X. (2013): Six new species of *Gomphonema* Ehrenberg (Bacillariophyceae) species from the Great Xing'an Mountains, Northeastern China. – Cryptogamie, Algologie 34: 301–324.

Liu, Y.; Kociolek, J.P.; Lu, X.X. & Fan, Y.W. (2020): Valve ultrastructure of two species of the diatom genus *Gomphonema* Ehrenberg (Bacillariophyta) from Yunnan Province, China. – Fottea 20: 25–35.

Liu, Q.; Cui, N.N.; Feng, J.; Lü, J.P.; Nan, F.R.; Liu, X.D.; Xie, S.L. & Kociolek, J.P. (2021): *Gomphonema* Ehrenberg species from the Yuntai Mountains, Henan Province, China. – Journal of Oceanology and Limnology 4:1–21.

Ludwig, T.A.V. & Tremarin, P. I. (2006): Bacillariophyta. – In: Bicudo, C. & Menezes, M. (eds): Gêneros de Algas de águas continentais do Brasil, Vol. 2. – pp. 391–439, Rima, São Paulo.

Medeiros, G.; Amaral, M.; Ferreira, P.C.; Ludwig, T.V. & Bueno, N.C. (2018): *Gomphonema* Ehrenberg (Bacillariophyceae, Gomphonemataceae) of the São Francisco Falso River, Paraná, Brazil. – Biota Neotropica 18: e20170495.

Medlin, L.K & Kaczmarska, I. (2004): Evolution of the diatoms: V. Morphological and cytological support for the major clades and a taxonomic revision. – Phycologia 43: 245–270.

Metzeltin, D. & Lange–Bertalot, H. (1998): Tropical diatoms from South America I. About 700 predominantly rarely known or new taxa representative of the neotropical flora. – In: Lange–Bertalot, H. (ed.): Iconographia Diatomologica. Annotated Diatom Micrographs, Vol. 5. – 695 pp., Koeltz Scientific Books, Königstein.

Metzeltin, D. & Lange–Bertalot, H. (2007): Tropical diatoms of South America II. Special remarks on biogeography disjunction. – In: Lange–Bertalot, H. (ed.): Iconographia diatomologica. Annotated diatom micrographs. Diversity–Taxonomy–Biogeography, Vol. 18. – 877 pp., A.R.G. Gantner, Ruggell, Liechtenstein.

Metzeltin, D.; Lange–Bertalot, H. & Soninkhishig, N. (2009): Diatoms in Mongolia. – In: Lange–Bertalot, H. (ed.): Iconographia diatomologica. Annotated diatom micrographs. Diversity–Taxonomy–Biogeography, Vol. 20. – 691 pp., A.R.G. Gantner, Ruggell, Liechtenstein.

Morales, E.A. & Vis, M.L. (2007): Epilithic diatoms (Bacillariophyceae) from cloud forest and alpine streams in Bolivia, South America. – Proceedings of the Academy of Natural Sciences of Philadelphia 156: 123–155.

Parr, J.F.; Taffs, K.H. & Lane, C. M. (2004): A microwave digestion technique for the extraction of fossil diatoms from coastal lake and swamp sediments. – Journal of Paleolimnology 31: 383–390.

Passy, J.P.; Kociolek, J.P. & Lowe, R.L. (1997): Five new *Gomphonema* species (Bacillariophyceae) from rivers in South Africa and Swaziland. – Journal of Phycology 33: 455–474.

Ponader, K.C.; Potapova, M.G.; Desianti, N.; Hamilton, P.B. & Campeau, S. (2017): *Gomphonema caperatum* sp. nov., *G. obstipum* sp. nov. and similar taxa from rivers of North America. – Diatom Research 32: 59–73.

Potapova, M. & Charles, D.F. (2003): Distribution of benthic diatoms in U.S. rivers in relation to conductivity and ionic composition. – Freshwater Biology 48: 1311–1328.

Reichardt, E. (1999): Zur Revision der Gattung *Gomphonema*. – In: Lange–Bertalot, H. (ed.): Iconographia diatomologica. Annotated diatom micrographs. Diversity–Taxonomy–Biogeography, Vol. 8. – 203 pp., A.R.G. Gantner, Ruggell, Liechtenstein.

Reichardt, E. (2001): Revision der Arten um *Gomphonema truncatum* und *G. capitatum.* – In: Jahn, R.; Kociolek, J.P.; Witkowski, A. & Compere, P. (eds): Festschrift Honoring H. Lange–Bertalot. A.R.G. – pp. 187–224, A.R.G. Gantner, Ruggell, Liechtenstein.

Reichardt, E. (2005a): *Gomphonema dubravicense* Pantocsek eine taxonomische revision. – Diatom Research 20: 335–349.

Reichardt, E. (2005b): Die identität von *Gomphonema entolejum* Østrup (Bacillariophyceae) sowie Revision ähnlicher Arten mit weiter Axial area. – Nova Hedwigia 81: 115–144.

Reichardt, E. (2007): Neue und wenig bekannte *Gomphonema*–Arten (Bacillariophyceae) mit Areolen in Doppelreihen. – Nova Hedwigia 85: 103–137.

Reichardt, E. (2008): *Gomphonema intermedium* Hustedt sowie drei neue, ähnliche Arten. – Diatom Research 23: 105–115.

Reichardt, E. (2015): *Gomphonema gracile* Ehrenberg sensu stricto et sensu auct. (Bacillariophyceae): A taxonomic revision. – Nova Hedwigia 101: 367–393.

Round, F.E.; Crawford, R.M. & Mann, D.G. (1990): The Diatoms. Biology and morphology of the genera. – 747 pp., Cambridge University Press, Cambridge.

Round, F.E. & Basson, P.W. (1997): A new monoraphid diatom genus (*Pogoneis*) from Bahrain and the transfer of previously described species *A. hungarica* and *A. taeniata* to new genera. – Diatom Research 12: 71–81.

Shi, Z.X. (1994): Compilation of reports on the survey of algal resources in South–Western China. – 130 pp., Science Press, Beijing.

Shi, Z.X. (2004): Flora Algarum Sinicarum Aquae Dulcis. Tomus XII. Bacillariophyta. Gomphonemaceae. – 147 pp., Science Press, Beijing.

Skvortzow, B.W. (1929): Freshwater Diatoms from Amoy, South China. – The China Journal Shanghai 2: 40–44.

Skvortzow, B.W. (1930a): Diatoms from Dalai–Nor Lake, Eastern Mongolia. – Philippine Journal of Science 41: 31–37.

Skvortzow, B.W. (1930b): Alpine diatom from Fukien Province, South China. – Philippine Journal of Science 41: 39–49.

Skvortzow, B.W. (1935): Diatomées récoltées par le Père E. Licent au cours de ses voyages dans le Nord de la Chine. au bas Tibet, en Mongolie et en Mandjourie. – Publications du Musée Hoangho Paiho de Tien Tsin. Tienstsin 36 :1–43.

Skvortzow, B.W. (1937): Neogene diatoms from eastern Shantung. – Bulletin of the Geological Society of China 17: 193–208.

Skvortzow, B.W. (1938): Diatoms from Chengtu, Szechwan, western China. – Philippine Journal of Science 66: 479–496.

Skvortzow, B.W. (1946): Species novae et minus cognitae Algarum, Flagellatarum et Phycomicetarum Asiae, Africae, Ameriae et Japoniae nec non Ceylon anno 1931–1945, descripto et illustrato per tab. 1–18. Proceedings of the Harbin Society of Natural History and Ethnography. – Botany. Harbin 2: 1–34.

Skvortzow, B.W. & Meyer, C.I. (1928): A contribution to the diatoms of Baikal Lake. – Proceedings of the Sungaree River Biological Station 1: 1–55.

Smith, W. (1856): Synopsis of British Diatomaceae. – 107 pp., John Van Voorst, London.

Van Dam, H.; Mertens, A. & Sinkeldam, J. (1994): A code checklist and ecological indicator values of freshwater diatoms from the Netherlands. – *Netherlands* Journal of Aquatic Ecology 28: 117–133.

Wetzel, C.E.; Ector, L.; Van de Vijver, B.; Compère, P. & Mann, D.G. (2015): Morphology, typification and critical analysis of some ecologically important small naviculoid species (Bacillariophyta). – Fottea 15: 203–234.

Williams, D.M. & Round, F.E. (1986): Revision of the genus *Synedra* Ehrenb. – Diatom Research 1: 313–339.

You, Q.M.; Wang, Q.X. & Kociolek, J.P. (2015): New *Gomphonema* Ehrenberg (Bacillariophyceae: Gomphonemataceae) species from Xinjiang province, China. – Diatom Research 30: 1–12.

Yu, P.; Kociolek, J.P.; You, Q.M. & Wang, Q.X. (2019): Three new freshwater species of the genus *Achnanthidium* (Bacillariophyta, Achnanthidiaceae) from Taiping Lake, China. – Fottea 19: 33–49.

Zhang, L.X.; Yu, P.; Kociolek, J.P.; Pang, W.T.; Wang, Q.X. & You, Q.M. (2020): *Gomphonema qingyiensis* sp. nov., a new freshwater species (Bacillariophyceae) from Qingyi River, China. – Phytotaxa 474: 040–050.

Zhang, W.; Xu, X.Y.; Kociolek, J.P. & Wang, L.Q. (2016): *Gomphonema shanghaiensis* sp. nov., a new diatom

species (Bacillariophyta) from a river in Shanghai, China. – Phytotaxa 278: 29–38.

Zhang, W.; Shang, G.X.; Kociolek, J.P.; Wang, L.Q. & Tan, H.X. (2018a): *Gomphonema bicepiformis* sp. nov., a new diatom species (Bacillariophyta) from a stream in Zhejiang, China. – Phytotaxa 375: 274–282.

Zhang, W.; Du, C.L.; Kociolek, J.P.; Zhao, T.T. & Wang, L.Q. (2018b): *Gomphonema wuyiensis* sp. nov., a new freshwater species (Bacillariophyceae) from Wuyi Mountains, China. – Phytotaxa 375: 113–120.

Zhu, H.Z. & Chen, J.Y. (1994): Study on the Diatom of the Wuling Mountain Region. – In: Shi, Z.; Wei, Y.; Chen, J.; Li, Y.; Zhu, H.; Li, R. & Yao, Y. (eds): Compilation of Report on Survey of Algal Resources in the Southwestern China. – pp. 79–130, Science Press, Beijing.

Zhu, H.Z. & Chen, J.Y. (2000): Bacillariophyta of the Xizang (Tibet) Plateau. – 353 pp., Science Press, Beijing.

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