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Two new *Cymatopleura* taxa (Bacillariophyta) from Xinjiang, China with slightly twisted frustules

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Abstract: Two new species of the diatom genus *Cymatopleura*, *Cymatopleura aquastudia* and *Cymatopleura xinjiangiana*, that have torsion about the apical axis of the valves, are reported from Xinjiang Region, China, using light and scanning electron microscopy. The valves of *Cymatopleura aquastudia* sp. nov. exhibit torsion about the apical axis, are heteropolar, and are slightly constricted at the margin in the middle of the valves. These characters differentiate it from morphologically similar taxa in the genus, e.g. *C. solea* (Brébisson) W. Smith and *C. spiralis* Behning in Rauschenbach et Behning. The valves of *Cymatopleura xinjiangiana* sp. nov. also exhibit torsion about the apical axis, but are small and have curved ridges at both ends and rounded apices that are protracted at the wider ends. These features distinguish *C. xinjiangiana* from *C. cochlea* Brun and *C. elliptica* f. *spiralis* Boyer. These two new taxa help to demonstrate the unique nature of the freshwater diatom flora from Xinjiang Region, China.

Key words: Bacillariophyta, China, *Cymatopleura*, new species, Xinjiang

Introduction

Cymatopleura W. Smith (1851) frustules are generally large in size (Spaulding & Edlund 2008) and more abundant in high–conductivity (alkaline) waters (Round et al. 1990). There are over 150 described taxa (Fourtanier & Kociolek 2011), most of them were described before the middle of the last century. A few new species have been described recently, for example, from the Balkan Peninsula (Levkov et al. 2007), western North America (Bahls 2013), and East Africa (Cocquyt & Jahn 2014). Due to the large size of their cells, *Cymatopleura* taxa have been easy to isolate and they are reported to be relatively easy to culture, making them useful for the study of ontogeny, meiosis, and auxospore formation (e.g. Pfitzer 1871; Karsten 1900, 1928; Thaler 1972; Mann 1987; Chang & Steinberg 1988).

As in the closely related genus *Surirella* Turpin (Ruck & Kociolek 2004; Ruck & Theriot 2011), some species of *Cymatopleura* have been described to have a slight degree of torsion about the apical axis. Examples in *Cymatopleura* include *C. cochlea* Brun (1891), *C. spiralis* Behning (in Rauschenbach & Behning 1912) and *C. elliptica* f. *spiralis* Boyer (1916). And like many other areas (e.g. Ross 1983; Cocquyt & Jahn 2005, 2007), in the Xinjiang Uygur Autonomous Region (shorter name: Xinjiang Region) of China, the number of *Cymatopleura* taxa reported are fewer than those of the genus *Surirella* Turpin (You 2009). You (2009) reported 25 species and 3 varieties of *Surirella* species and 3 species and 5 varieties of *Cymatopleura* species from this region.

We have begun to review the species occur--ring in Xinjiang Region, and many new species have already been described from this little–explored area in the northwest of China (Kociolek et al. 2015; You et al. 2008, 2009, 2013, 2015a, b). The purpose of the present study is to re–examine the *Cymatopleura* taxa from Xinjiang Region based on observations from light and scanning electron microscopy, and to describe two new species of the genus (*C. aquastudia and C. xinjiangiana*) that are twisted about the apical axis.

Material and Methods

Diatom samples were collected in various habitats from the Xinjiang Region in July 2001 and July 2007 (Table 1). In these samples, the new *Cymatopleura* species described here

Table 1. Locality data and habitat for samples studied.

No.	Locations	Habibat	Water Tempera-ture (°C)	pH	Collecting Data	Collectors
XJ010105	Bachu	Temporary water on the road-side	18	-	7.8. 2001	Wang Q.X,& Li H.L.
XJ010112	Akesu	Temporary water near the river	13	-	7.25.2001	Wang Q.X,& Li H.L.
XJ010117	Akesu	Little ditch	14	-	7.25.2001	Wang Q.X,& Li H.L.
XJ010128	Bohu	Attached aquatic plants on the lakeside	15	8.5	7.25.2001	Wang Q.X,& Li H.L.
XJ010183	Chabuchaer	Temporary water on the road-side, with *Chara*	20	8.2	8.8.2001	Wang Q.X,& Li H.L.
XJ010192	Chabuchaer	Temporary water on the road-side, with *Chara*	20	8.2	8.8.2001	Wang Q.X,& Li H.L.
XJ071055	Yecheng	Little ditch, clean, with aquatic plants	24	8.5	7.17.2007	Wang Q.X,& You Q.M.

were found in both northern and southern Xinjiang; the specific localities are shown in Fig. 1. Samples were field–fixed in 4% formaldehyde, water temperature and pH were measured with a HANNA HI 98128 (HANNA instruments, Ann Arbor, MI) pH meter on site. In the laboratory, samples were treated with concentrated nitric acid using the Microwave Accelerated Reaction System (Model MARS, CEM Corporation, Charlotte, USA) (Parr et al. 2004) and a pre–programmed digestion scheme (temperature: 180 °C, ramping up to the desired temperature in 15 min, then maintain that temperature for 15 min) (You et al. 2015a). After digestion, samples were alternatively centrifuged for 5 minutes at 3500 rpm (TDZ5–WS, Luyi Corporation, Shanghai, China), washed with distilled water and decanted, ca. five times, until the pH of the sample was approximately neutral. The cleaned material was kept in 95% ethanol.

Using cleaned material, permanent slides were made by mounting in Naphrax for light microscope (LM) observations. For scanning electron microscope (SEM) observations, cleaned material was air–dried onto coverslips and mounted onto Cu stubs. LM observations were made with an Olympus BX–51 microscope (Olympus America Inc., Center Valley, Pennsylvania, USA) fitted with DIC optics (100× objective, numerical aperture 1.4). Light micrographs were taken with an Olympus DP–71 digital camera. SEM examination was conducted using a JEOL JSM–6380LV (15 kV). Diatom images were compiled with Photoshop CS3.

Morphometry statistics for *Cymatopleura aquastudia* sp. nov. and *C. xinjiangiana* sp. nov. are provided. We measured a total of 30 valves for each species with respect to length, breadth, and ratio of length / breadth, and calculated the mean and standard deviation for these variables (Table 3). The measurements of length and width were made from LM and SEM images, terminology for the morphological description follows Cocquyt & Jahn (2005, 2007, 2014), Round et al. (1990) and Ruck & Kociolek (2004).

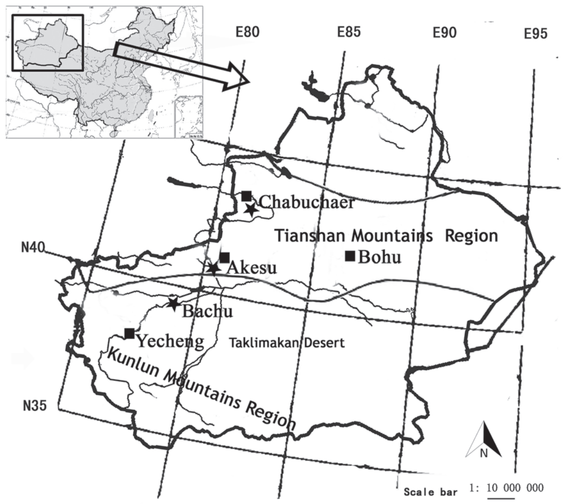


Fig. 1. Distribution of two new species in Xinjiang. "■" means *Cymatopleura aquastudia*, "★" means *Cymatopleura xinjiangiana*.

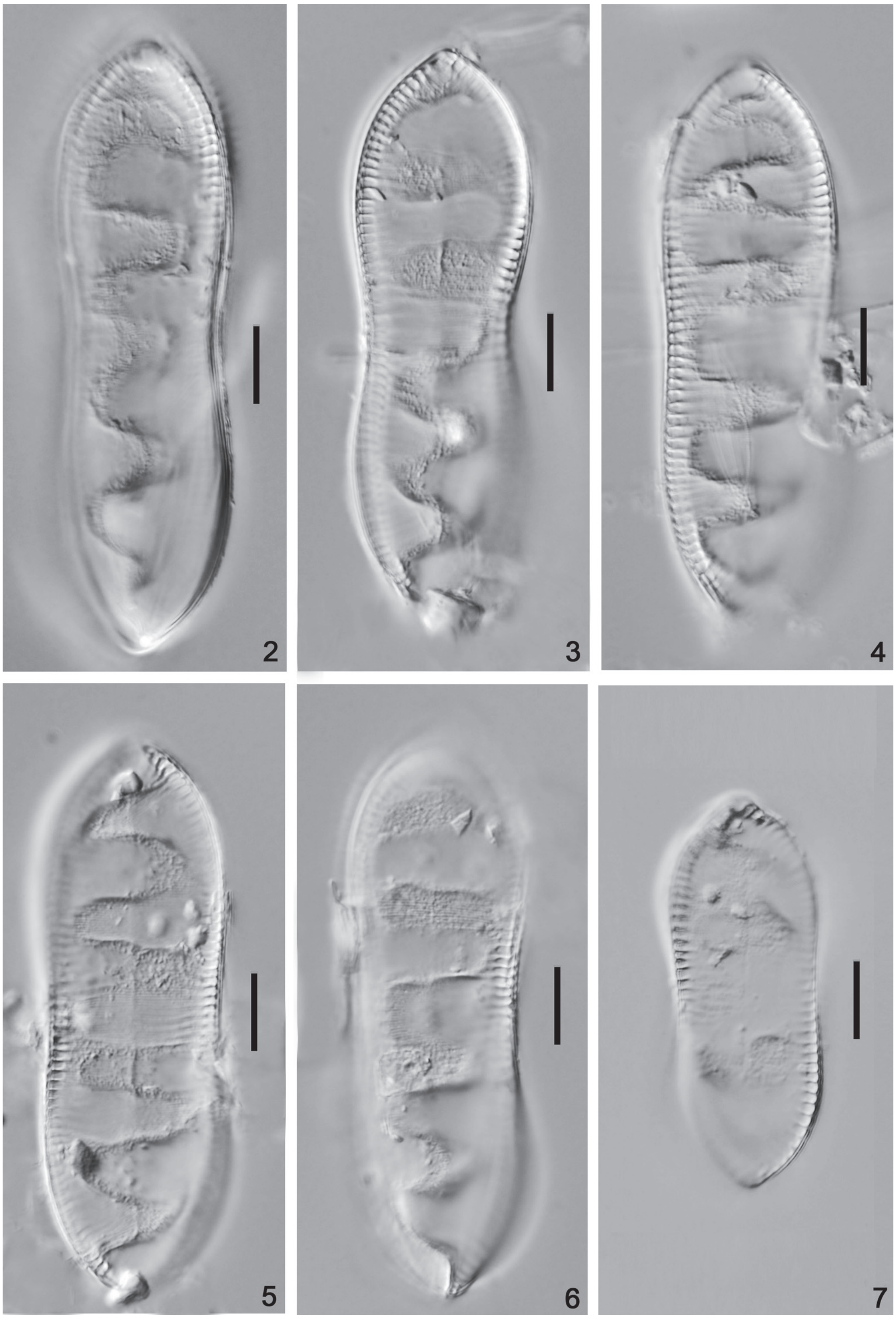
Results

Formal descriptions of new species

Cymatopleura aquastudia **Kociolek et You sp. nov. (Figs 2–17)**

Description

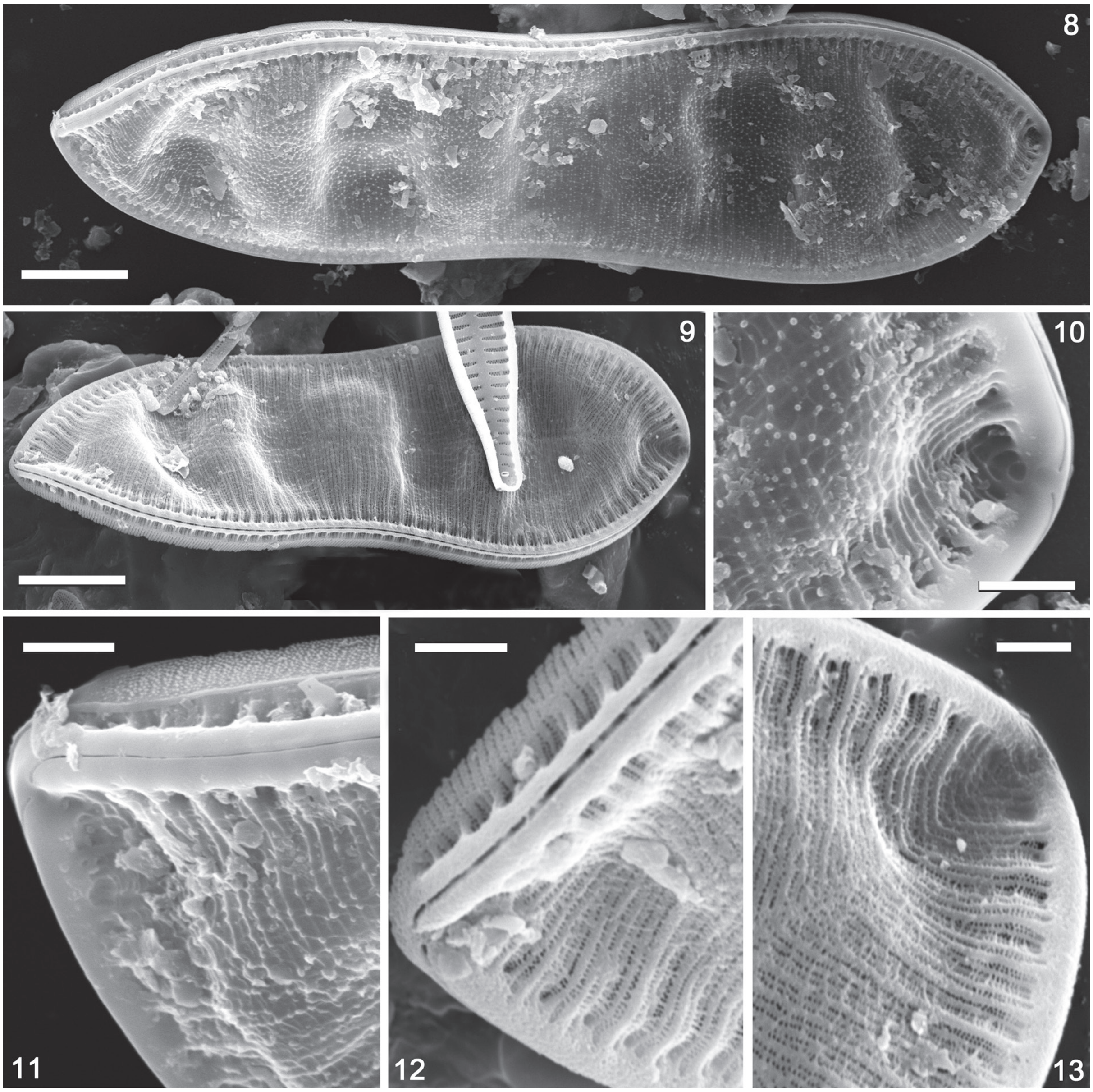
Light microscopy (Figs 2–7): Frustules with a slight degree of torsion about the apical axis. Valves panduriform and slightly asymmetrical to the transapical axis, broadly rounded and wider at the head pole, slightly protracted and narrower at the foot pole, with constrict-



Figs 2–7. *Cymatopleura aquastudia* LM micrographs of valve views showing size diminution series. Fig. 4 is of the holotype. Scale bars 10 µm.

ed margins in the middle and rounded, slightly protracted apices. Valve face with 3–6 transapical undulations. Length 50.5–125.0 µm, breadth 17.0–25.0 µm in the middle (constricted), 18.0–28.0 µm at the widest points. Length–to–breadth ratio 2.9–5.8 at the widest part. Costae 7–9 in 10 µm, more developed near the margin than on the rest of the valve face, and almost reaching the axial area. Axial area narrow, forming a nearly straight line. Striae fine, difficult to observe in LM.

Scanning electron microscopy (Figs 8–17): External view of valve (Figs 8–13). Valve face with obvious transapical undulations. Narrow costae elevated above the valve face, and evident from valve margin to the

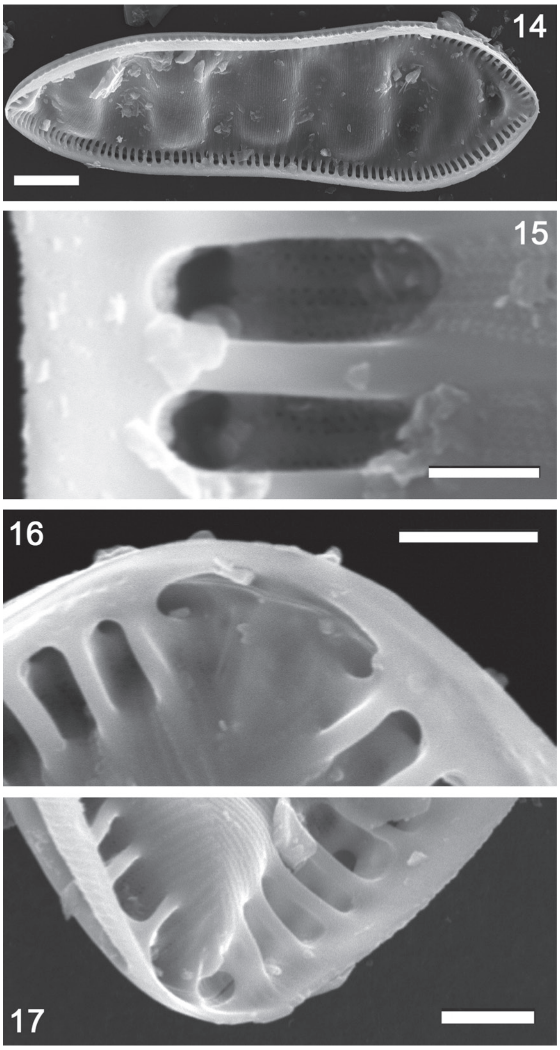


Figs 8–13. *Cymatopleura aquastudia* SEM, entire external views: (8–9) valve view showing entire valve. Note undulations in the center of the valve, with keel extending around the periphery; (10) wider end of the valve showing valve surface and terminal raphe endings; (11) narrower end of the valve showing valve surface and terminal raphe ending; (12) narrower end showing areolae arrangement, raphe slit and terminal raphe endings; (13) wider end showing striae and thickened ribs. Scale bars 10 µm (8–9); 2 µm (10–13).

narrow axial area. Transapical costae are parallel in the middle of the valve and converge at the ends. Scattered silica granules are present on the valve face. There is a siliceous layer on the valve surface covering the areolae of the striae, obscuring the striae externally. Striae are doubly–punctate at the margin, becoming uniseriate in the middle of the valve. Areolae 80–95 in 10 µm, denser towards the raphe. Raphe positioned on a shallow keel, simple. Raphe with terminal raphe endings near both poles. Raphe fissures are not enlarged, but slightly curved towards the valve face.

Internal view of valve (Figs 14–17). Striae are uniseriate, composed of small, round areolae, possessing rims on the internal surface, 80–95 areolae per 10 µm. Within the interfibular space, striae are biseriate, and the areolae lack rims. Fibulae are rib–like, 8–9 per 10 µm, evenly spaced to connect valve face and narrow mantle. Raphe is simple, and continuous at both poles, without terminal raphe ends.

Holotype: Slide and material numbered XJ010192, deposited at Shanghai Normal University (SHTU).
Iconotype: Fig. 4.
Type locality: Temporary pond on the roadside, with *Chara*, sample XJ010192, Chabuchaer, Xinjiang. Water temperature 20 °C, pH 8.2. Coll. date 8. 8. 2001.
Etymology: The specific epithet in Latin, “aquastudia” means “intermittent water” referring that the new species is found in small ponds and ditches.



Figs 14–17. *Cymatopleura aquastudia* SEM, entire internal views: (14) valve view showing entire valve. Undulations are prominent; (15) valve margin showing fibular structure and details of areolae in the valve surface and between fibulae; (16) wider end of the valve showing valve surface and continuous raphe fissure; (17) more narrow end of the valve showing fibulae and raphe end. Scale bars 10 µm (14); 1 µm (15); 2 µm (16, 17) .

Ecology and Distribution: *Cymatopleura aquastudia* was widely distributed in the Xinjiang Region, and observed in samples collected in Akesu (XJ010112, XJ010117), Bohu (XJ010128), Chabuchaer (XJ010183, XJ010192) and Yecheng (XJ071055). These sites are distributed in & south of Tianshan Mountains Region, near the Kunlun Mountains Region; specific locations are given in figure 1. The type population of *C. aquastudia* was observed in an alkaline, temporary pond on the roadside. This new species was also found in small, clean ditch, with aquatic plants, and alkaline pH (see Table 1).

Remarks: *Cymatopleura aquastudia* resembles *C. solea* (Brébisson) W. Smith (1851), by its panduriform valve outline. *Cymatopleura aquastudia* differs from *C. solea* by being twisted about the apical axis, and being slightly asymmetrical to the transapical axis. This new species is morphologically similar to *C. spiralis* Behning (in Rauschenbach & Behning 1912), a species described from a plankton sample taken in the Winter from the Volga River in Russia. While both taxa have panduriform outlines, they differ in that the new species described here is heteropolar, with slightly constricted middle margins. *Cymatopleura spiralis* is isopolar, similar to *C. solea*, and with obviously constricted margins in the middle (Rauschenbach & Behning 1912, figure II: 1–2). The difference between this new species and other *Cymatopleura* possessing valves with torsion is summarized in Table 2.

***Cymatopleura xinjiangiana* You et Kociolek sp. nov. (Figs 18–33)**

Description

Light microscopy (Figs 18–23): Frustules with a more or less slight torsion about the apical axis. Valves broadly wedge–shaped and asymmetrical to the transapical axis, without a median constriction, with apices rounded and protracted at the wider end, narrowly rounded and more cuneate at the narrower end. Valve face with 3–5 transapical undulations. Valve length 45.0–75.0 µm, breadth 18.0–21.0 µm. Length–to–breadth ratio 2.4–3.5. Costae 7–9 in 10 µm, more developed near the margin than on the rest of the valve face, and almost reaching the axial area. Axial area narrow, forming a nearly straight line. Striae fine, difficult to observe in LM.

Scanning electron microscopy (Figs 24–33): External view of valve (Figs 24–28). Valve face with obvious transapical undulations. Narrow costae raised just above the valve face, and elevated from the valve margin to the axial area. Transapical costae oriented parallel in the most part of the middle valve, convergent at the ends. Irregular siliceous elements between costae give the valve surface a reticulate appearance, with scattered siliceous granules present on the valve face. There is a silica layer on the valve surface covering the areolae, obscuring the striae externally. Raphe located in a short keel and simple, with terminal raphe ends evident near the two poles. Raphe fissures not enlarged and slightly curved onto the valve surface.

Internal view of valve (Figs 29–33). Valve face with obvious transapical undulations. Striae are uniseriate, composed of small, round areolae, each areola is rimmed by a narrow outline of silica. Areolae 75–85 per 10 µm. Striae are biseriate, and areolae are without rims within the interfibular space. Fibulae are rib–like, 9–11 per 10 µm, evenly spaced connecting valve face and narrow mantle. Raphe is simple, continuous to the apices, without terminal ends.

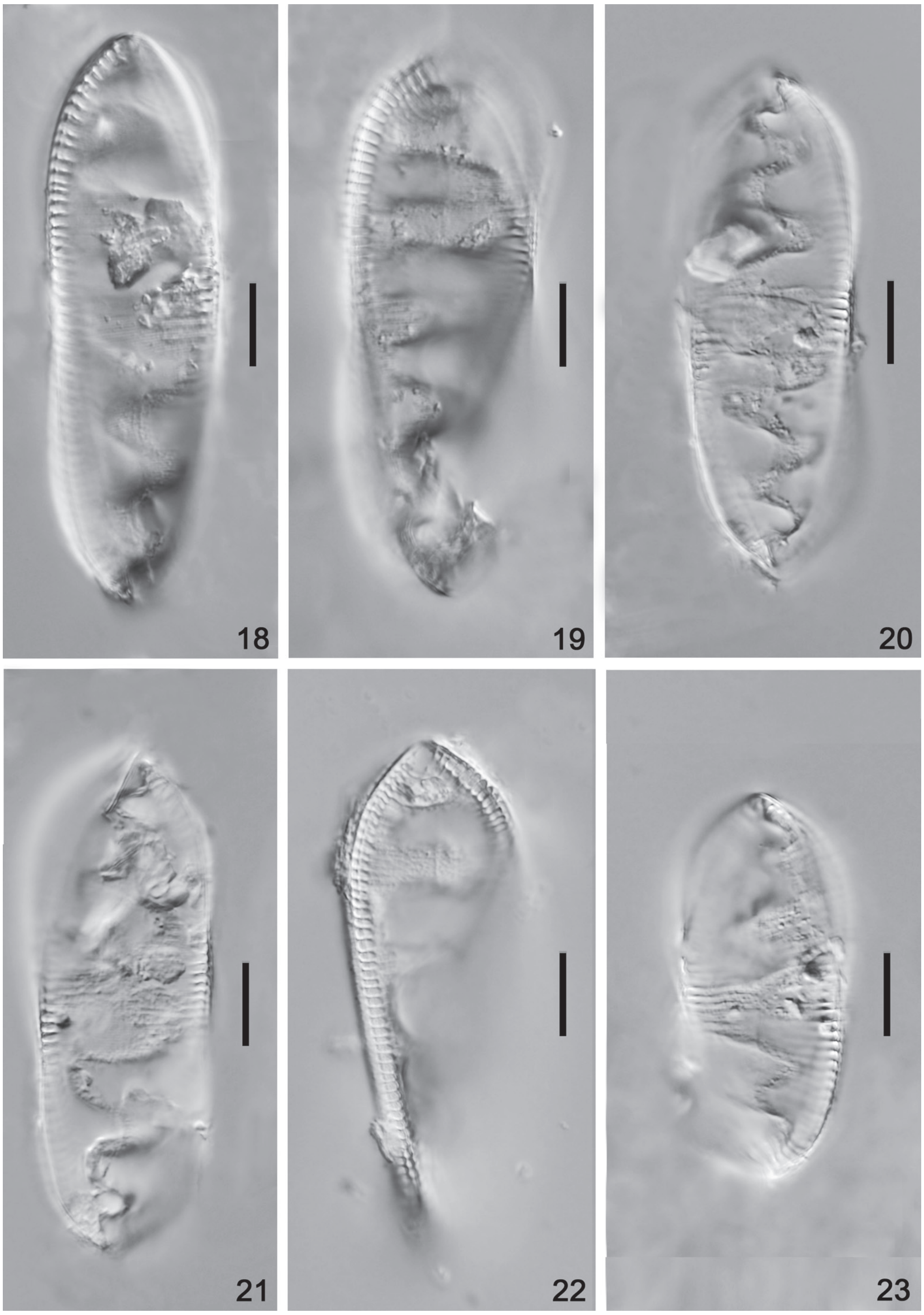
Holotype: Slide and material numbered XJ010183, deposited at Shanghai Normal University (SHTU).
Iconotype: Fig. 20.

Table 2. Comparison of valve features between two new spiral *Cymatopleura* species and other similar *Cymatopleura* species.

Species	Outline	Spiral status	Length (µm)	Breadth (µm)	Costae /10µm	Sources
C. *aquastudia*	Panduriform and heteropolar, with slightly constricted middle margins and rounded, slightly protracted ends	Spiral along the apical axis, curved ridges existed at both ends	50.5 –94	17 –21	7–9	This study
C. *xinjiangiana*	Wedge–shaped and heteropolar, without constricted margins and rounded, protracted ends at the wider ends	Spiral along the apical axis, curved ridges existed at both ends	45.5 –70	18.5 –20.5	7–9	This study
C. solea	Panduriform, isopolar,with constricted middle margins and rounded, protracted ends	Without spiral	51–254	1/10 of length	–	Smith 1851
C. cochlea	Wedge–shaped and heteropolar, without constricted margins and rounded at the wider ends	Spiral, curved ridge only existed at narrow ends	120 –150	55–65	5–8	Brun 1891
C. elliptica f. *spiralis*	Wedge–shaped and heteropolar, without constricted margins and rounded at the wider ends	Spiral, curved ridge only existed at narrow ends	70 –140	–	3	Boyer 1916
C. spiralis	Panduriform, isopolar, with obviously constricted middle margins and rounded, protracted ends	Spiral along the apical axis	129.43	19.3–38.6	–	Rauschenbach, & Behning 1912

Table 3. Morphometry statistic of *Cymatopleura aquastudia* and *Cymatopleura xinjiangania.*

	C. aquastudia	***C. xinjiangania***
Number of cells measured	**30**	**30**
Length		
Range	50.5–125.0	45.0–75.0
Mean	85.2	61.5
Standard Deviation	17.4	7.9
Breadth (widest)		
Range	18.0–28.0	18.0–21.0
Mean	24.1	20.2
Standard Deviation	2.5	1.0
Length / Breadth (widest)		
Range	2.9–5.8	2.4–3.5
Mean	4.1	3.0
Standard Deviation	0.6	0.3

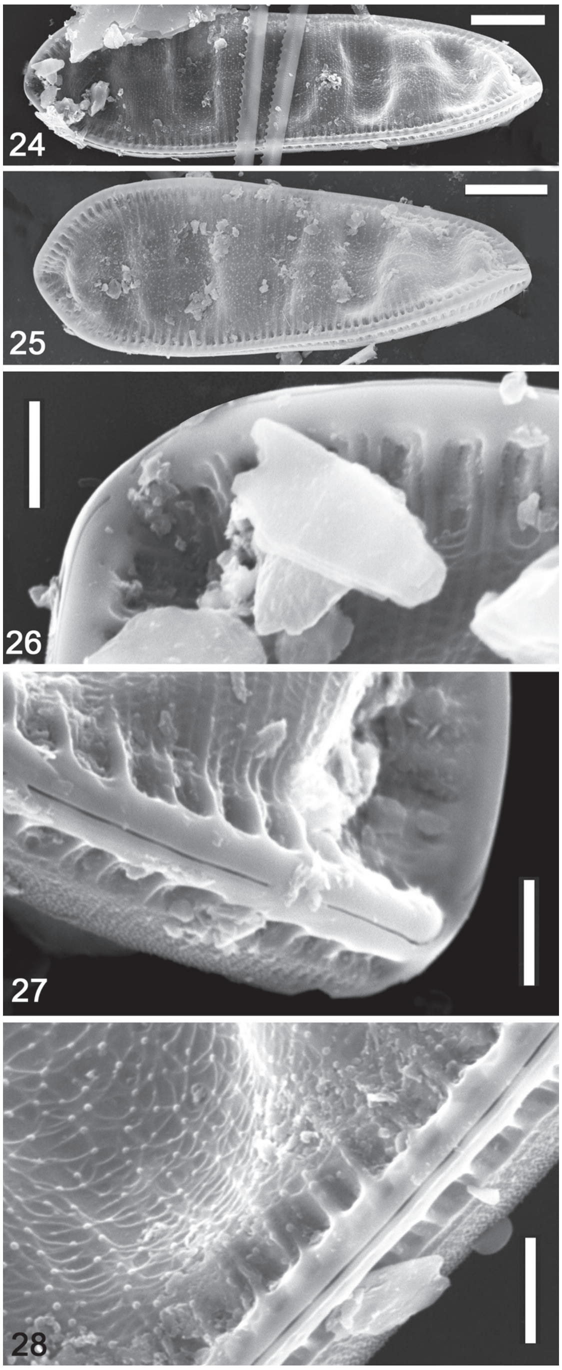


Figs 18–23. *Cymatopleura xinjiangiana* LM micrographs of valve views showing size diminution series. Fig. 20 is of the holotype. Scale bars 10 µm.

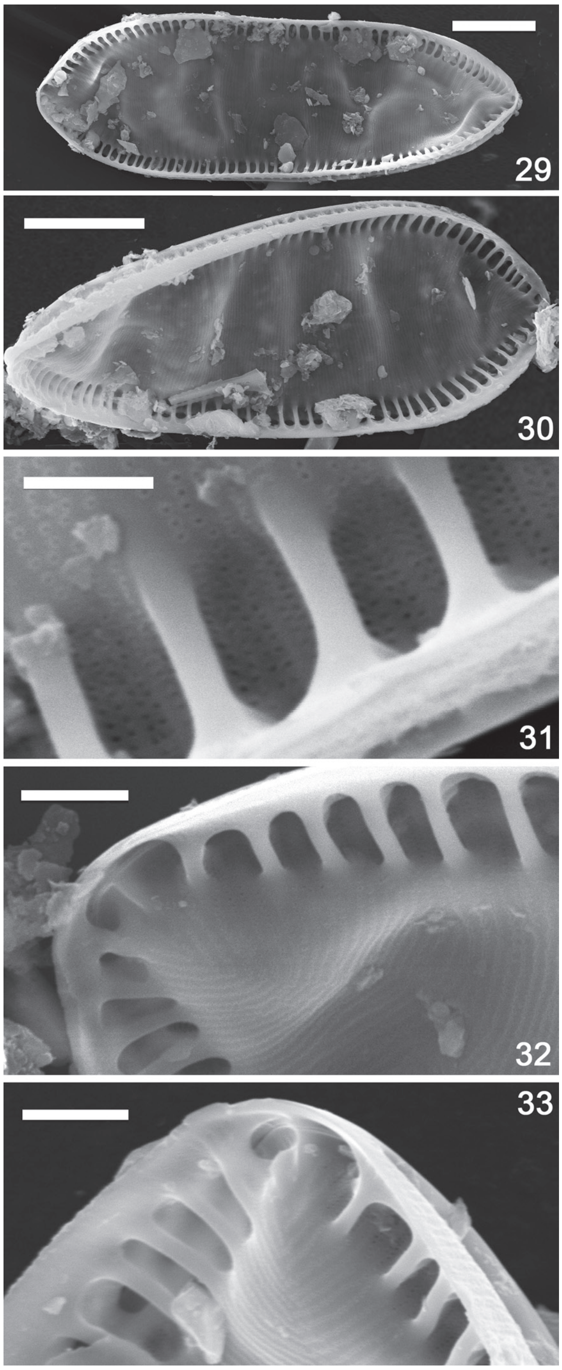
Type locality: Temporary pond on the roadside, with *Chara*, sample XJ010183, Chabuchaer, Xinjiang. Temperature 20 °C, pH 8.2. Coll. date 8. 8. 2001.
Etymology: The species is named for the Xinjiang Region, where it was found.

Ecology and Distribution: *Cymatopleura xinjiangiana* was observed in samples collected at Bachu (XJ010105), Akesu (XJ010117) and Chabuchaer (XJ010183). These sites are mainly distributed around the Tianshan Mountains Region, specific locations are seen in figure 1. The type population of *C. xinjiangiana* was observed in an alkaline temporary pond on the roadside, with *Chara*. This new species was also found in similar ecological conditions in the region but populations were very small (see Table 1).

Remarks: This new species is morphologically similar to *Cymatopleura cochlea* Brun (1891) and *C. elliptica* f. *spiralis* Boyer (1916), in that all three taxa are het-



Figs 24–28. *Cymatopleura xinjiangiana* SEM, entire external views: (24–25) valve view showing entire valve. Undulations in the center of the valve are evident, degree of torsion is slight; (26) wider end of the valve showing valve surface and terminal raphe endings, close together but separate; (27) narrower end of the valve showing valve surface, keel and terminal raphe ending; (28) margin of valve showing fine costae, raphe fissure and narrow mantle. Scale bars 10 µm (24–25); 2 µm (26–28).



Figs 29–33. *Cymatopleura xinjiangiana* SEM, entire internal views: (29–30) valve views of entire cell. Undulations and fibulae are evident; (31) fibulae structure and details of areolae in the valve surface and between fibulae; (32) wider end of the valve showing valve surface, fibulae and continuous raphe fissure; (33) narrower end of the valve showing valve surface, fibulae and continuous raphe fissure. Scale bars 10 µm (29–30); 1 µm (31); 2 µm (32–33).

eropolar and have twisted frustules. There are, however, obvious differences in outline and valve characters between the three taxa. The valves of the new species found in Xinjiang have rounded apices and are protracted at the wider ends. Frustules are twisted along the apical axis, and curved ridges can exist at both ends. In *C. elliptica* f. *spiralis* and *C. cochlea*, there are no protracted wider ends and the apices are rounded, the frustules are twisted slightly, and curved ridges only occur at the narrower ends. Moreover, *C. cochlea* has larger frustules, with length 120–150 µm and breadth 55–65 µm (Brun 1891); it is larger than

Xinjiang species (length 45–75 µm, breadth 18–21 µm). According to the description of Boyer (1916), *C. elliptica* f. *spiralis* is the same size as nominate species (*C. elliptica* (Brébisson et Kützing) W. Smith; length 70–140 µm), thus it also larger than the new species from Xinjiang Region. Detailed differences about outline, length, width and costae of these species are compiled in Table 2.

Discussion

The only *Cymatopleura* species previously described from China is *C. sinensis* Skvortzow, known only from ponds in Tianjin ("Tientsin" Skvortzow 1927). The species described by Skvortzow is long and slender, 52.7–74.5 µm long, 5.1 µm wide, with broadly rounded apices and has 5–6 undulations on the valve face (Skvortzow 1927; fig. 27). You (2009) and You & Wang (2011) reported *Cymatopleura cochlea* from the Xinjiang Region, however recently we re–examined these samples with LM and SEM and the *Cymatopleura* taxa present with twisted valves can be separated into two distinct morphologies, one with a median constriction similar to *C. solea* and one asymmetrical to the transapical axis. These two morphologies represent the new taxa described here. Since neither of these morphologies are similar to *C. cochlea*, we cannot verify the occurrence of *C. cochlea* in Xinjiang as reported by You (2009) and You & Wang (2011).

Previously described *Cymatopleura* taxa with twisted valves, including *C. cochlea* (Brun 1891), *C. spiralis* (Rauschenbach & Behning 1912) and *C. elliptica* f. *spiralis* (Boyer 1916) were described before the early part of last century, and the frustules are large in size and easy to distinguish. They were only originally recorded in several locations, and based on very few specimens. In the original description of *C. cochlea,* the species was reported to be found in Cabenda (in present day Angola, Africa), in the port of New York City and Port–au–Prince, Haiti (Brun 1891). It has, more recently been reported from the Laurentian Great Lakes (Stoermer et al. 1978, 1999; Kociolek 2005), Iowa (Ohl 1965; Begres 1971) and Taiwan (Shao 2003–2014). *Cymatopleura spiralis* has only been reported from the type locality, the Volga River near Saratov, Russia (Rauschenbach & Behning 1912). *Cymatopleura elliptica* f. *spiralis* was originally reported from the Delaware River (Port Penn), and subsequently reported from the Laurentian Great Lakes (Stoermer 1978, 1999) and lakes in Nebraska (Eberle 2008). So far, the two, new species described herein are known only from Xinjiang Region.

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