Morphology and taxonomy of selected cymbelloid diatoms from a Mongolian Sphagnum ecosystem with a description of three species new to science

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Abstract: The present paper focuses on selected cymbelloid diatom taxa inhabiting Nur Sphagnum bog in northern Mongolia. Samples collected in this area contained numerous species of Encyonema KÜTZING and Cymbopleura (KRAMMER) KRAMMER, that are together acidobiontic, oligotraphentic taxa. Cymbopleura pernaviculiformis, Cymbopleura deviatkinii and Encyonema marvanii are described as species new to science. Furthermore, for two other species we suggest new nomenclatural combinations. The characteristics of Cymbopleura naviculiformis (AUERSWALD) KRAMMER sensu stricto are discussed in order to compare it with other species mentioned in this paper. The autecological characteristics of the new species found in Nur bog are presented.

Key words: Mongolia, Sphagnum bogs, cymbelloid diatoms, new taxa

Introduction

Diatom assemblages associated with mosses (e.g. Sphagnum spp.) and liverworts have been studied for some time (ANDO 1977, 1978); however, scientific interest in such assemblages was intensified as late as the 1990s. The studies were mainly focused on the Arctic, Antarctic and the Southern Ocean islands, e.g. Kerguelen Islands (VAN DE VĲVER et al. 2001, GREM MEN et al. 2007), Crozet Islands (VAN DE VĲVER et al. 2002), Southern Shetland Islands (TEMNISKOVA-TOPALOVA & CHIPEV 2001), Southern Georgia (VAN DE VĲVER & BEYENS 1996). In the northern hemisphere, the Canadian Arctic was the site of studies conducted by DOUGLAS & SMOL (1995, 1999) and ANTONIADES et al. (2008). A series of papers concerning diatom flora of European moss habitats were also published (Central Europe: WOTJAL et al. 1999, POULÍČKOVÁ et al. 2002, BUCZKÓ 2006; European part of Russia: KULIKOVSKY 2007, 2008, 2009). As emphasized by BUCZKÓ (2006), diatomists tend to reduce the role of mosses and consider them only as substrate, thus inferring that their taxonomy has no significance. However, the studies by POULÍČKOVÁ et al. (2004) and BUCZKÓ (2006) indicate that the relationship between moss species and diatom community structure is highly significant. This is reflected not only by their taxonomic composition, but also by the number of taxa, and furthermore biodiversity.

During the last decade a significant increase in studies of the diatom flora from different ecosystems and habitats from Mongolia has been observed. The reason for discovering this area for broad diatomological audience is that some of these habitats e.g. Lake Hovsgol, belong in the Lake Baikal rift zone and represents one of the oldest habitats existing in the world (e.g. POPOVSKAYA et al. 2002; EIDLUND et al. 2003, 2006b). Within last few years diatom assemblages of the province of Hentei were floristically studied by METZELTIN et al. (2009). All these studies, however, considered well developed, species rich lacustrine habitats.
The questions raised in these studies were either evolutionary (Edlund et al. 2003, 2006a) or floristic (Metzeltin et al. 2009).

A few studies on Sphagnum ecosystems of Mongolia have been completed, since they are not typical for the arid zone of Mongolia. Sphagnum ecosystems world wide play a very important role in the water balance of the regions in which they occur. In this particular case, Sphagnum bogs support the stability of the water level and surface flows in the Selenga, Yenisei and Amur basins (Gunin & Vostokova 2005, Minaeva et al. 2005).

Mongolian Sphagnum bogs have historically been virtually unstudied, hence very little data exist about the vegetation of these ecosystems. Most data on their vegetation and diversity originated long time ago and are summarized by Pavlov (1929) and Yanatov (1950). Exceptionally comprehensive results of studies on higher plant assemblages are given by Lavrenko (2000).

Published information regarding the algal flora of Nur bog is lacking, and diatoms have received no attention at all. Thus this paper presents the first data on some aspects of diatom assemblages of Nur bog. Though the diatom assemblage is rich in species number in this paper we only focus on a few cymbelloid species occurring in Nur bog. Based on Kramer (1982, 1997a, 1997b, 2003) we have made an attempt to establish their taxonomic position. Some of them were found in literature as various infraspecific categories (e.g. Foged 1953, Lange–Bertalot & Genkal 1999, Kramer 2003). Sometimes a single taxonomic entity was recorded under several names (e.g. Encyonema marvanii = Cymbella affinis var. semicircularis Lagerstedt sensu Cleve–Euler, 1955 and Encyonema (?) nov.) spec. in Lange–Bertalot & Genkal (1999: Figs 61, 9). Their relatively abundant occurrence in the material from Nur bog in Mongolia enabled us to carry out detailed ultrastructural studies by means of electron microscopy. This in turn helped us in their taxonomic revision.

Material and methods

The material used in the present study was collected from different parts of the Nur bog (Northern Mongolia) on September the 5th 2005. Altogether 12 samples were collected from Sphagnum spp. Water temperature at the studied localities varied from 11 to 13 °C and the pH from 5.5 to 5.6.

The Nur Sphagnum bog (N 49°38'; E107°48') represents the largest wetland area in Mongolia (Fig. 1). It is situated in the mountain taiga forest (1348–1351 m a.s.l) in the northern part of the Hentei highlands that include the Huder sum. It is a system of peatlands, consisting of several groups, situated on the flat terraces of the mountain saddle. There are more than 10 species of the Sphagnum genus there. Herb layer is dominated by Carex rostrata with co-dominance of Eriophorum polystachion, Scheuchzeria...
*Cymbopleura laticapitata* (Krammer)

**Kulikovskiy et Lange-Bertalot, stat. nov.**

(Fig. 2: a–d, x)


Description: Valves slightly dorsiventral and more linear in comparison to *C. naviculiformis* (Fig. 2: a–d, x). Ventral margins are straight and dorsal margins are weakly convex (Fig. 2: a–d, x) with abruptly capitulate protracted ends (Fig. 2: a–d, x). Valve length 41–43.3 µm, breadth 9.3–10.3 µm, length/breadth ratio 4.1–4.7. Axial area narrow, linear becoming slightly broader towards the central area, almost in the median line of valve. Central area round, slightly rhomboid and expanding abruptly from the central nodule up to 1/2–2/3 of the valve breadth (Fig. 2: a–d, x). Raphe typical for the *C. naviculiformis*-group, lateral, becoming filiform towards the proximal and distal ends. Outer raphe fissures ventrally displaced in the proximal part for about 1/4 of the raphe branch length. Proximal raphe ends very slightly expanded as central pores and ventrally tipped. Terminal fissures somewhat undulate comma-shaped and dorsally deflected (Fig. 2: a–d, x). Striae radiate throughout, 15–17/10 µm, areolae in LM barely resolvable, 32/10 µm (Fig. 2: a–d, x).

Distribution: This species is known so far from its type locality in Vittangi, Swedish Lapland and gytta from a moor bog (Krammer 2003).

**Cymbopleura pernaviculiformis** Kulikovskiy, Lange-Bertalot et Dorofeyuk, sp. nov.

(Fig. 2: e–h, y)


Description: Diagnosis differens versus *Cymbopleura naviculiformis* (Auerswald) Krammer 2003 sensu stricto


Description: Differential diagnosis versus *Cymbopleura naviculiformis* (Auerswald) Krammer 2003 s. str.

Valve outlines and size dimensions of both taxa similar with exception of the ratio of length/breadth that is consistently lower in all cell cycle stages of *C. pernaviculiformis* populations from Mongolia and from Yugorsky–Shar Strait tundra, 2.9–3.4 (instead of 3.3–4.4). Length 28.7–34.4 µm, breadth 10–10.7 µm (i.e. on average more than 8.7–9.3 of the type population of *C. naviculiformis*). Raphe, axial– and central area are not significantly differentiated. Transapical striae 14–17 in 10 µm becoming denser
Fig. 2. (a–d, x) *Cymbopleura laticapitata* stat. nov.; (e–h, y) *Cymbopleura pernaviculiformis* sp. nov.; (i, j) *Cymbopleura naviculiformis* (Auerswald) Krammer, note the difference in the raphe fissures shape; (t–w, aa) *Cymbopleura deviatkini* sp. nov.; (p–s, bb) *Encyonema groenlandica* stat. nov. et comb. nov.; (k–o, cc, dd) *Encyonema marvanii* sp. nov. LM: a–w; SEM: x, aa, cc - external valve view; y, bb, dd - internal valve view. Scale bar 10 µm.
the ends, c. 20 in 10 µm. Areolae 27–33 in 10 µm. SEM internal view (Fig. 2: y). The pattern of striae ultrastructure is not significantly differentiated when compared with *C. naviculiformis*.

Holotypus: slide no. 12519 (see Fig. 2, f) in collection of A. WITKOWSKI, Institute of Marine Sciences, University of Szczecin (SZCZ), leg. N. DOROGEFYUK.

Isotypus: Slide no. 3 in collection of M. KULIKOVSKY, Institute for Biology of Inland Waters (IBIW), Borok, Russia.

Locus typicus: Nur Sphagnum bog, northern Hentei highlands (N49°38'; E107°48', 1348–1351 m a.s.l), Mongolia, 05.09.2005.

Etymology: “Per” in Latin means in this context similar but not identical.

Distribution: As yet only observed in Central Asia and a tundra lake of the Yugorsky Shar Strait area at the coast of the Arctic Ocean.

*Cymbopleura deviatkinii* KULIKOVSKY, LANGÉ-BERTALOT et DOROGEFYUK, sp. nov. (Fig. 2: t–w, aa)

**Descrip**tio: Diagnosis differens versus *Cymbopleura declivis* Metzeltin et Kramm er in Kramm er 2003.


*Cymbopleura fluminea* (PATRICK et FREESE) LANGE-BERTALOT et KRAMMER proprie differt valvis angustioribus lineari-ellipticis cum marginibus paene aequaliter curvatis utrimque.

Description: Differential diagnosis versus *Cymbopleura declivis* Metzeltin et Krammer in Krammer 2003.

Valves moderately to more distinctly dorsiventral, elliptic-lanceolate with occasionally weakly triundulate dorsal margins and more variable ventral margins. Ends abruptly short-protracted, rostrate. Length 31.3–35.3 µm, breadth 8.7–10 µm.

### Table 1. Morphometric data from different populations of *Cymbopleura* species.

<table>
<thead>
<tr>
<th>Species</th>
<th>References</th>
<th>Length (µm)</th>
<th>Breadth (µm)</th>
<th>Length/Breadth ratio</th>
<th>Striae 10-1 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. pernaviculiformis</em></td>
<td>This study</td>
<td>28.7–34.3</td>
<td>10–10.7</td>
<td>2.9–3.4</td>
<td>14–17</td>
</tr>
<tr>
<td><em>C. pernaviculiformis</em></td>
<td>Krämer 2003 (Pl. 79: 13)</td>
<td>10–10.7</td>
<td>2.9–3.4</td>
<td>14–17</td>
<td></td>
</tr>
<tr>
<td><em>C. naviculiformis</em></td>
<td>Krämer 2003 (Pl. 76: 1–10)</td>
<td>35.3–36.7*</td>
<td>8.7–9.3*</td>
<td>3.4–3.6*</td>
<td>15–17</td>
</tr>
<tr>
<td><em>C. naviculiformis</em></td>
<td>Krämer 2003 (Pl. 77: 1–12)</td>
<td>31.3–41*</td>
<td>8.0–10.3*</td>
<td>3.4–4.3*</td>
<td>15–17</td>
</tr>
<tr>
<td><em>C. naviculiformis</em></td>
<td>Siwe et al. 2005 (Pl. 72: 22–26)</td>
<td>24.6–34.2*</td>
<td>7.4–8.4*</td>
<td>3.6–4.4*</td>
<td>15–17</td>
</tr>
<tr>
<td><em>C. naviculiformis</em></td>
<td>Krämer 2007 (Pl. 79: 1–12)</td>
<td>36.4–44.4</td>
<td>9.3–10.7*</td>
<td>3.7–4.7*</td>
<td>15–17</td>
</tr>
<tr>
<td><em>C. laticapitata</em></td>
<td>This study</td>
<td>41–43.3</td>
<td>9.3–10.3</td>
<td>4.1–4.7</td>
<td>15–17</td>
</tr>
</tbody>
</table>

* - countings from microphotographs given in literature.
(not 10.7–12.7) µm. Ratio length/breadth 3.4–3.5. Raphe lateral with distinctly undulating external fissures (not almost filiform). Axial and central areas vary considerably in shape. Transapical striae radiate throughout, 15–16 (not 10–12) in 10 µm, proximally becoming c. 18 near the ends. Areolae 32–34 in 10 µm.

*Cympleura fluminea* (Patrick et Freese) Lange–Bertalot et Krammer differs mainly in that it has narrower, linear-elliptical valves with almost equally curved dorsal and ventral margins.

Holotypus: slide no. 12529 (see fig. 2, u) in collection A. Witkowski, Institute of Marine Sciences, University of Szczecin (SZCZ), leg. N. Dorofeyuk.

Isotypus: Slide no. 4 in collection M. Kulikovskiy, Institute for Biology of Inland Waters (IBIW), Borok, Russia.

Locus typicus: *Sphagnum* bog Nur, northen part of Hentei highlands (49°38′; 107°48′, 1348 m a.s.l.), Mongolia, 05.09.2005.

Etymology: The species is dedicated to our colleague Dr. Vladimir Deviatkin who is currently studying the diatom flora from different ecosystems of Mongolia.

*Encyonema groenlandica* (Foged) Kulikovskiy et Lange–Bertalot, stat. nov. et comb. nov. (Fig. 2: p–s, bb)


Description: Valves weakly dorsiventral, dorsal margins convex, ventral margins straight, ends rounded (Fig. 2: r–o, bb). Length 25.3–32 µm, breadth 5.2–6 µm, length/breadth ratio 4.8–5.3. Axial area moderately narrow, central area absent (Fig. 2: r–o). Raphe filiform, curved, proximally turned to the dorsal side, terminal fissures ventrally bent. On the inside of valve, the proximal raphe endings are widely spaced with a wide intermissio between the two raphe branches and the raphe fissures possess an intermissio (Fig. 2: r–o, bb). Transapical striae parallel, on the ventral side the two central striae are longer than the other ones. The striae become more closely spaced towards the apices of the valve (Fig. 2: r–o, bb). Striae in the valve centre, 5–6 in 10 µm. Each stria is composed of relatively small round areolae (Fig. 2: bb).

Distribution: This species is known from Nur *Sphagnum* bog in Mongolia (this study), West Greenland and Iceland (Foged 1953, 1974).

*Encyonema marvanii* Kulikovskiy, Lange–Bertalot, Witkowski et Dorofeyuk, sp. nov. (Fig. 2: k–o, cc, dd)

*Synonyms:* *Cymbella affinis* var. *semicircularis* Lagerstedt sensu Cleve–Euler, 1955: 1178, p; *Encyonema* (? nov.) spec. in Lange–Bertalot & Genkal (1999: Fig. 61, 9).


Raphe et area axialis conformantes in speciebus duobus. Area centralis vacans. Striae transapicales subparallelae in media parte valvae tum modice radiantes ad latera dorsalia ventraliaque, 7.5–8.5 in 10 µm sed paucis striae circiter ventraliter subapicibus distincte densius sitis, ibi 13–15 in 10 µm. Areolae difficulter discernendae microscopio photonico, circiter 18–19 ultramicroscopio (vide Fig. 2: cc, dd).

Holotypus: slide no. 12524 (see Fig. 2, l) in collection A. Witkowski, Institute of Marine Sciences, University of Szczecin (SZCZ), leg. N.
DOROFEYUK.
Isotypos: Slide no. 5 in collection M. KULIKOVSKYIY, Institute for Biology of Inland Waters (IBIW), Borok, Russia.
Etymology: this taxon is dedicated Dr. PETR MARVAN in recognition of his contribution to the development of algalogical studies.
Distribution: So far found in Mongolia, Yugorsky–Shar Strait and Swedish Lapland (see CLEVE–EULER 1955, Fig. 1177).

Ecology and associated flora
The discovery of the above mentioned species in a large oligotrophic bog as well as in other holarctic ecosystems allows us to consider them as characteristic elements of diatom assemblages of the arctic-alpine diatom flora. These species prefer oligotrophic, humic habitats with low pH. Samples containing these species were prefer oligotrophic, humic habitats with low pH. Samples containing these species were dominated by Eolimna vekhovii (LANGE–BERTALOT et GENKAL) LANGE–BERTALOT et KULIKOVSKYIY, Nupela impexiformis (LANGE–BERTALOT) LANGE–BERTALOT, Stenopterobia aniceps (LEWIS) BRÉBISSON, Tabellaria flocculosa (ROTH) KÜTZING, Kobayasiella parasubtilissima (KOBAYASI et NAGUMO) LANGE–BERTALOT, Gomphonema montanum SCHUMANN, Frustulia crassinervia (BRÉBISSON) LANGE–BERTALOT et KRAMMER, Chamaepinnularia mediocris (KRASSKE) LANGE–BERTALOT et KRAMMER and Adlafia suchlandtii (HUSTEDT) LANGE–BERTALOT. These species are found in abundance in oligotrophic lakes of Finland, Novaya Zemlya Island (LANGE–BERTALOT & METZLITIN 1996, LANGE–BERTALOT & GENKAL 1999, GENKAL & YEKHOV 2007). Aulacoseira spp. abundant in Nur bog is distinctive for the diatom flora of Sphagnum bogs in the European part of Russia (GENKAL & KULIKOVSKYIY 2006; KULIKOVSKYIY 2007). Aulacoseira alpigena (GRUNOW) KRAMMER, A. lirata (EIHRENBerg) ROSS and A. septentrionalis (CABMURN et CHARLES) GENKAL et KULIKOVSKYIY found in Nur bog are known from low–alkalinity lakes of North America and holarctic ecosystems in the European and Asian part of Russia (e.g. CABMURN & KINGSTON 1986, CABMURN & CHARLES 2000, GENKAL & KULIKOVSKYIY 2006, YARUSHINA & GENKAL 2006).

Discussion
KRAMMER (1997a,b, 2002, 2003) discussed the problems with identification and groupings of cymbelloid diatoms. The principal size characteristics e.g. valve length, breadth and length/breadth ratio as well as the shape of the ends are very important for identification. However, valve shape can be also important KRAMMER (2003), for example into the Cymbopleura naviculiformis-group for distinguishing taxa such as Cymbopleura sublanesolata KRAMMER, Cymbopleura naviculiformis var. laticapitata KRAMMER and Cymbopleura amphicephala (NAEGELI) KRAMMER.

Cymbopleura naviculiformis (AUERSWALD) KRAMMER was frequently misidentified in the past. The morphological variability of this taxon from the type material together with specimens from other habitats have been illustrated by KRAMMER (2003). Illustrations of the type material delivered by KRAMMER (2003) served as comparison for other authors in their studies. This was specially important for ultrastructural studies which involved SEM examination of the valves. Such attempts were undertaken by e.g. SIVER et al. (2005) in Lakes of Cape Code in the United States and KULIKOVSKYIY (2007) in a population from a Sphagnum bog in the European Russia. SEM investigations of C. naviculiformis from a Russian bog revealed that the valves are characterised by absence of intermissio and the smaller extended raised central nodule in internal view, smaller helictoglossae that agree with KRAMMER’s figures (2003: Pl. 78, 1) but not with KRAMMER (1982) where a heterogeneous collection of valves is presented. The central area of C. naviculiformis is fairly variable and may extend for about 1/2–2/3 of the valve breadth (KRAMMER 2003) or can be very small, almost lacking (cf. SIVER et al. 2005, KULIKOVSKYIY 2007). In Figure 2: i, j C. naviculiformis from Russian bog are illustrated for comparison with other species.

When the two species are compared, Cymbopleura pernaviculiformis is distinguished from C. naviculiformis by the pronounced intermissio, more raised helictoglossae and a large circular central nodule. Ends of C. pernaviculiformis are always broadly rostrate, whereas in C. naviculiformis they are longer, narrow–rostrate to capitate. Of importance in this group of species is the valve width. When this feature is considered, C. pernaviculiformis is
always broader than the latter taxon. The ventral margin is always straight and more parallel to the axial area whereas in *C. naviculiformis* the ventral margin is slightly arched, straight or slightly convex in the central part (cf. Krämer 2003, Silver et al. 2005).

For comparative analysis of size ranges, morphometric data were taken from micrographs of the type population of *C. naviculiformis* and a population from a pond in southern Germany, illustrated in Krämer (2003), and in addition the range of variation recorded by Silver et al. (2005) (Table 1). *C. pernaviculiformis* has a length/breadth ratio that separates this species from *C. naviculiformis* (Table 1). Using these data, the valve that was documented by Lange–Bertalot & Genkal (1999: Pl. 56: 11) and later transferred to *C. naviculiformis* by Krämer (2003: Pl. 79: 13), we should identify as *C. pernaviculiformis*.

Krämer (2003) also described *Cymbella naviculiformis* var. *laticapitata*. Our observations of valve outline and other parameters show that this entity deserves a separate status at the species rank. It differs from *C. naviculiformis* with respect to valve outline (distinctly lower variability) and a higher length/breadth ratio than *C. naviculiformis* (Table 1). In this paper a formal transfer of *Cymbopleura naviculiformis* var. *laticapitata* into *Cymbopleura laticapitata* is proposed.

Likewise *Cymbopleura deviatkinii* is related to the *C. naviculiformis*–group. The major character shared between the two taxa is raphe morphology. Even if the raphe is crucial for distinguishing its phylogeny, *C. deviatkinii* is very easily distinguished from other similar taxa, i.e. *Cymbella naviculiformis* and *C. pernaviculiformis*, by shape, denser striaation on the dorsal valve side, and length/breadth ratio (Table 1). *C. naviculiformis* and *C. pernaviculiformis* have irregularly arranged striae in the central area of the dorsal side, whereas *C. deviatkinii* shows some similarity to *Cymbopleura fluminea* (Patrick et Freese) Lange–Bertalot et Krämer, but can be distinguished by wider valves and indistinctly punctate–lineate striae (Krämer 2003).

In the material studied we have found several species of *Encyonema*. Two taxa under study (*Encyonema groenlandica, E. marvanii*) were previously described as infraspecific taxa. Both are small–celled species.

Our new species *Encyonema marvanii* has been confused with *Cymbella affinis* var. *semicircularis* Lagerstedt (syn. *Encyonema latens* (Krasske) D.G. Mann sensu Krämer 1997). This misidentification resulted from a mistake in “matches” the drawing of this taxon by Cleve–Euler; Cleve–Euler illustrated a single valve from Lapland (Cleve–Euler 1955, Fig. 1178p) as *Cymbella affinis* var. *semicircularis*. Independently, Lange–Bertalot & Genkal (1999) depicted a single valve of this taxon as “Encyonema (? nov.)” from Yugorsky–Shar Strait in the Arctic Ocean. This image corresponds with *Encyonema marvanii* as illustrated here and matches very well with the characteristics of this species. Hence the distribution of *E. marvanii*, so far as is known is limited to northern Scandinavia, Mongolian Sphagnum bog and Yugorski Shar area in the Arctic.

Similarly, *E. groenlandica* was described as *Cymbella ventricosa* var. *groenlandica* Foged from West Greenland (Foged 1953). Later, this variety was also identified from Iceland (Foged 1974). The morphological features of this species are distinct from *Cymbella (Encyonema) ventricosa*, therefore we suggest a new taxonomic status and make its transfer to *Encyonema*. *E. groenlandica* is characterized by the long ventral terminal fissures, proximal raphe ends which are bent dorsally and the outer raphe fissure which is bent to the ventral margin. The latter character is an important characteristic in the delimitation of the genus *Encyonema* sensu Krämer (Krämer 1997a, b, 2002).

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