

FIRST RECORD OF THE RECENTLY DESCRIBED
GOMPHONEMA SANCTI-NAUMII (BACILLARIOPHYTA)
FROM LAKE SEDIMENT IN ROMANIA

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Abstract: Here we report the first occurrence of the diatom *Gomphonema sancti-naumii* D. Metzeltin & Z. Levkov beside the type locality, during the Last Glacial Maximum. The species presented here with its morphological characteristics demonstrated on detailed scanning electron microscope (SEM) pictures and its palaeolimnological significance in diatom-based pH reconstruction is proclaimed. The species was observed in the material collected from a borecore obtained from a lake sediment core of Lake St. Anne (Romania) between 16 and 15 kyr cal BP. *Gomphonema sancti-naumii* occurred in low abundance with other narrow valved (< 5 µm) gomphonemoid taxa.

Key words: diatoms, *Gomphonema*, Lake St. Anne, palaeolimnology, taxonomy

INTRODUCTION

The genus *Gomphonema* is one of the most frequently reported benthic diatoms in freshwater assemblages. *Gomphonema* frustules are typically heteropolar, wedge-shaped in girdle view, with a wider head pole and a narrower foot pole. Valve views are more or less clavate (club-shaped) and symmetrical about the apical axis (ROUND *et al.* 1990, CANTONATI *et al.* 2017, LEVKOV *et al.* 2016). Cells often form colonies and branched mucilage stalks, attached to solid substrates.

Beside the most commonly reported taxa, the detailed ultrastructural studies recently revealed the high taxonomic diversity of the genus and resulted in many new species (REICHARDT 1997, 1999, 2001, 2007, 2015*a, b*, REICHARDT & LANGE-BERTALOT 1991, LEVKOV *et al.* 2016), so more than 1,500 species names belonging to the genus *Gomphonema* are listed in the relevant database (GUIRY & GUIRY 2018, KOCIOLEK *et al.* 2018). Though the growing number of diatom taxa complicates determination, the precise taxonomical identification is the key for reliable environmental assessment and palaeolimnological reconstruction (BIRKS 1994, JÜTTNER *et al.* 2013). Our aim is to apply the highest attainable taxonomical resolution to diatom assemblages in order to understand better the palaeoecology of the last crater lake of the Eastern Carpathians: Lake St. Anne. The present paper is the first noteworthy result in refining taxonomy for our purposes. It was during the on-going palaeoecological survey of the diatom flora of Lake St. Anne, when the subject of our present paper, some narrow (< 5 µm) diatom valves came to our attention. The aim of the present paper is to clarify the identity of these taxa.

Algological background

Algological studies on Lake St. Anne are surprisingly scarce, in spite of being one of the most visited tourist attractions in Romania. Merely seven papers have been published before the launching of the project on the palaeoecology of the lake in 2001 (MAGYARI *et al.* 2009, CARAUS 2017). Moreover, no diatom record was available before 2007 (BUCZKÓ & MAGYARI 2007). Following the contributions on the taxonomy and distribution of representatives of the *Kobayasiella* genus in the lake (BUCZKÓ & WOJTAL 2007, BUCZKÓ *et al.* 2009), a detailed, well-illustrated study was published presenting the entire Holocene diatom flora (BUCZKÓ & MAGYARI 2007). In the Holocene sequence only 74 taxa were distinguished, and based on the diatom assemblages oligo-dystrophic conditions were reconstructed with low pH values for the lake. The diatom flora was found to be rather unique with several rare species, and 30 of them were first reported from Romania.

MATERIAL AND METHODS

Study site

Lake St. Anne, as the last open crater lake of the Eastern Carpathians has been in the focus of palaeoenvironmental survey for the last decades (MAGYARI *et al.* 2009, 2014). The lake (946 m a.s.l.; 46.126388° N, 25.888055° E) is situated

in the Ciomadul Massif of the Harghita Mts; it has no outlet and it is fed mainly by rain-water (PÁL 2001). This locality has witnessed the latest eruptive volcanic activity in East-Central Europe, thus there is still ongoing postvolcanic activity of CO₂ degassing and fumaroles in the St. Anne crater (SZAKÁCS *et al.* 2002). The area of the lake is ~189,900 m²; maximum water depth is ~6 m, mean depth is ~3.1 m, and mean width is ~310 m (PANDI 2008). The lake water is usually neutral in summer (pH = 7), and acidic in winter (pH = 4), where summer pH has increased considerably in recent years probably due to human impact (PÁL 2001, MAGYARI *et al.* 2009).

Drilling and dating

A 1200 cm long sediment core was obtained from Lake St. Anne during the winter of 2010 using a 7-cm-diameter Livingstone piston corer (core SZA-2010). A chronological framework of the sediment was established using 10 AMS radiocarbon dates, and the radiocarbon ages were calibrated into calendar years before present (cal yr BP). For more details see MAGYARI *et al.* (2014).

Preparation

In order to analyse diatoms, samples were prepared by standard digestion procedures (BATTARBEE 1986). Aliquot-evaporated suspensions were embedded in Zrax. From each sample at least 300 valves were counted using a light microscope (Leica DM LB2 equipped with 100 HCX PLAN APO objective and VSI-3.OM(H) digital camera). For SEM cleaned samples were air-dried on an aluminium stub. Specimens were coated with gold-palladium using a XC7620 Mini Sputter Coater for 120 s at 16 mA, and studied with a Hitachi S-2600N scanning electron microscope operated at 20 kV and 5–8 mm distance.

RESULTS

The *Gomphonema* genus was present with great variability at the species level, but low abundance in the sediment samples of Lake St. Anne throughout the lake history. While the detailed comprehensive overview of the genus is in progress, it is worthwhile to describe in the present study separately the species *Gomphonema acuminatum* Ehrenberg, *G. brebissonii* Kützing, *G. exilissimum* (Grunow) Lange-Bertalot & E. Reichardt in Lange-Bertalot & Metzeltin, *G. italicum* Kützing, and *G. truncatum* Ehrenberg, that were found frequent and common before the Holocene (> 11,700 cal yr BP).

Between 1091–1085 cm (ca. 15,650–15,320 cal yr BP) in the SZA2010 core section some narrow (< 5 µm) diatom valves were found. During the examina-

tion of the ultrastructure of these gomphonemoid taxa by SEM mono- and biseriate areola structures were found. The morphometric features of the valves revealed that several similar representatives of the genus co-occur in these layers. One of these species shows great agreement with *Gomphonema sancti-naumii*.

Gomphonema sancti-naumii D. Metzeltin & Z. Levkov 2007
(LEVKOV *et al.* 2007, pp. 67–68; pl. 171, Figs 1–15)

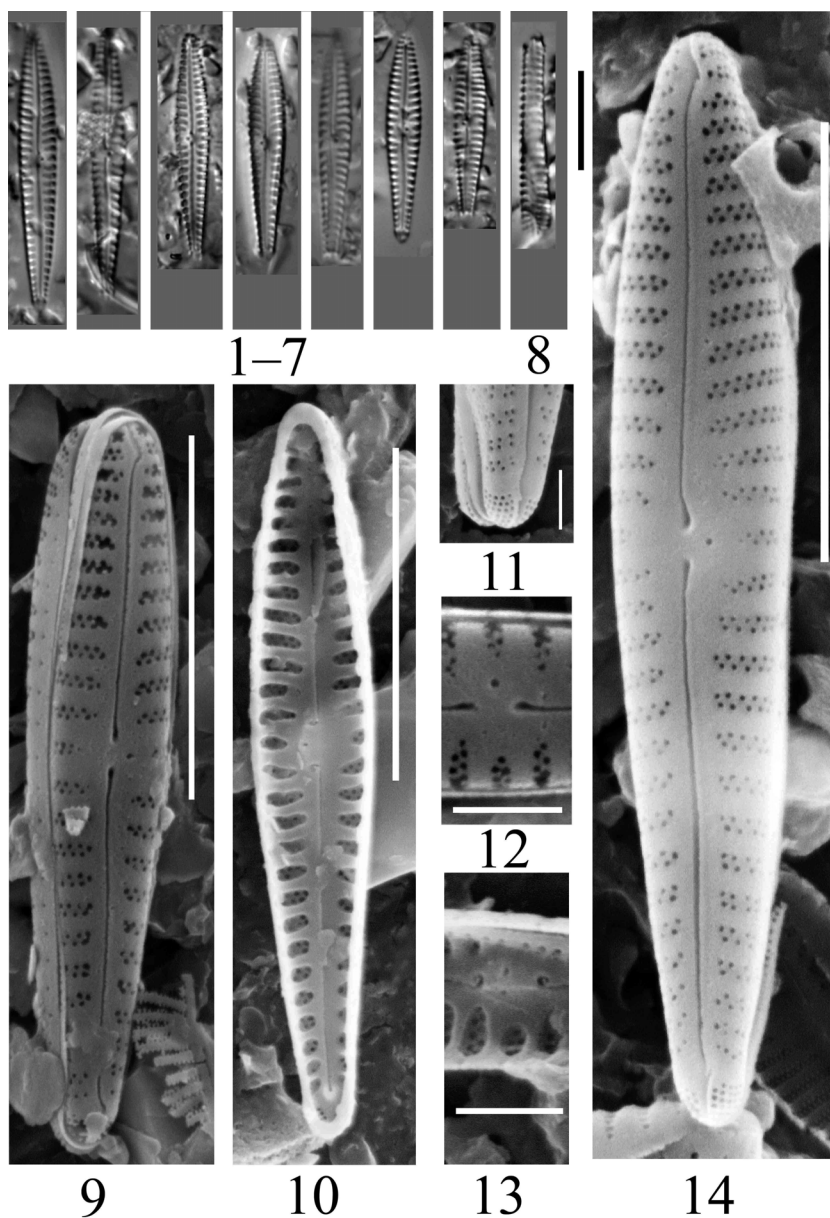
Description: Valves narrowly clavate to linear-lanceolate, with weakly obtusely rounded head pole and non-protracted, narrowly rounded foot pole (Figs 1–7). Length 19–42 μm , valve breadth 3.5–6 μm . Axial area narrow, gradually widening towards the transversally expanded central area where one central stria shortened. One isolated stigma present in the central area near the proximal raphe ends. Raphe lateral becoming filiform near the proximal raphe ends. Frustule slightly cuneate to almost rectangular in girdle view (Fig. 8). Striae radiate throughout, 12–14/10 μm in the middle of the valve, becoming 14–16/10 μm at the ends.

SEM: proximal external raphe fissures widened, slightly unilaterally deflected (Figs 9, 12, 14). Internal raphe ends recurved unilaterally (Figs 10, 13) proximal raphe ends deflected unilaterally from exterior as well as from the interior of the valve, where crochet-shaped (Fig. 13). The stigma has an oval external opening (Fig. 12) and a small elliptical internal opening (Fig. 13). Striae biseriate, composed of oval or irregularly shaped areolae (Figs 9, 14). The foot pole has a typical differentiated apical pore field with porelli, separated from striae by a hyaline area, and divided into two parts by the raphe (Fig. 11).

Distribution: Apart from this second record from Lake St. Anne, *Gomphonema sancti-naumii* was known only from the type locality, St. Naum springs, close to Lake Ohrid in Macedonia (LEVKOV *et al.* 2007)

Ecology: There is no detailed information on the ecology of the species. According to LEVKOV *et al.* (2007), it was found in slightly alkaline water the pH varied between 7.6–8.8 in the St. Naum springs, Macedonia.

Dominant, co-occurring taxa: mainly small fragilaroid taxa, like *Staurosira venter* (Ehrenberg) Cleve & J. D. Möller, *Staurosirella pinnata* (Ehrenberg) D. M. Williams & Round, *Stauroforma exiguiformis* (Lange-Bertalot) R. J. Flower, V. J. Jones & Round were the most abundant in the sediment of Lake St. Anne sediment samples between 1091–1085 cm (*ca.* 15,650–15,320 cal yr BP) in the SZA2010 core (MAGYARI *et al.* 2014). *Cavinula pseudoscutiformis* (Hustedt) D. G. Mann & A. J. Stickle, *Rossethidium pusillum* (Grunow) Round & Bukhtiyarova, *Cymbopleura subaequalis* (Grunow) Krammer, *Cymbopleura naviculiformis* (Auerswald ex Heiberg) Krammer were subdominant in these layers.



Figs 1–14. *Gomphonema sancti-naumii*. **Figs 1–7:** Valve face in LM. **Fig. 8:** Griddle view in LM. **Fig. 9:** Partially oblique valve. Note the biseriate striae and mantle. Outside view, SEM. **Fig. 10:** Inside view, SEM. **Fig. 11:** The foot pole with apical pore field with porelli, outside view, SEM. **Fig. 12:** Central area with oval stigma. Outside view, SEM. **Fig. 13:** Central area with stigma. Note the unilaterally curved internal raphe ends. Inside view, SEM. **Fig. 14:** Valve view with biseriate striae.

Outside view, SEM. Scale bars = 10 μm (Figs 1–9, 10, 14) Scale bars = 2 μm (Figs 11–13)

DISCUSSION

The alga flora of Romania is quite up-to-date thanks to the detailed compilation of CARAUS (2017) who refreshes the Romanian algae list regularly. According to this summary, during the last decades of the 20th century, our knowledge on the algal flora of Romania has multiplied. Many species of *Gomphonema* are known from Romania, but there is no record of the species *G. sancti-naumii* CARAUS (2017).

In spite of the intensive search in both off-line and on-line resources (GUIRY & GUIRY 2018, KOCIOLEK *et al.* 2018) we also failed to find any record of *G. sancti-naumii*, so our data seems to be the second occurrence of this taxon beside the type locality. It is worthwhile to mention here that the taxon was part of the diatom flora flourishing between *ca* 15,650–15,320 cal yr BP in Lake St. Anne, so it cannot be regarded as the member of the recent flora of Romania.

Gomphonema sancti-naumii was described from the springs of St. Naum, created after the establishment of the present Lake Ohrid. The bottom of the springs is covered with organic sediments, with an average water depth of 3.5 m (LEVKOV *et al.* 2007). This habitat is believed to be ideal to a *Gomphonema* species, allowing it to attach to the different kind of surfaces with its well-developed apical pore fields.

Crater lakes provide unparalleled opportunities to investigate the impact of climate change in aquatic ecosystems over their ontogenies (MAGYARI *et al.* 2014). Recently the lake water of Lake St. Anne is slightly acidic, with low pH. The varying intensity of degassing due to the postvolcanic activity (PANDI 2008) controls pH of the water, but the geographic position of the lake is also predicting non-alkaline water chemistry. The lake was formed in a crater of dacitic lava and pyroclasts with low calcium content.

As the species *G. sancti-naumii* is rather rare, we have limited data on its environmental preferences. However, it is noteworthy that at the type locality of St. Naum the spring water was found slightly alkaline with a pH varying between 7.6 and 8.8.

The diatom-based palaeoecological reconstruction is in progress for Lake St. Anne. To infer changes in pH based on a sedimentary sequence, it is essential to have a robust knowledge on the autoecology of the diatom taxa. The fact that the species of *G. sancti-naumii* is found in the studied sediments can become a valuable contribution to the diatom-based pH reconstruction on. The other, co-occurring taxa of the diatom assemblages from these layers are also known from circumneutral or slightly alkaline waters. Disentangling all drivers of the diatom assemblage changes in Lake St. Anne is in progress.

Increasing knowledge generally on the taxonomy and ecology of diatoms at species level is crucial if we want to use them in palaeoecological studies (JÜTTNER *et al.* 2013). This new record of *G. sancti-naumii* can contribute to the better understanding of the palaeolimnological changes taking place in Lake St. Anne, especially the variable lake water chemistry that can be connected to the postvolcanic activity of the dormant volcano.

CONCLUSIONS

This paper reports a new record of *Gomphonema sancti-naumii*, a diatom species described originally from the slightly alkaline springs of St Naumi in Macedonia. The first appearance of gomphonemoid taxa with narrow valves ($< 5 \mu\text{m}$) in the sediments of Lake St. Anne can be dated to ca. 15,650 cal yr BP, and after a short flourishing they disappeared at ca 15,320 cal yr BP. In order to identify these diatom taxa SEM was used, which unexpectedly revealed the variable ultrastructure of the valves, proving the presence of several, closely related taxa. One of these taxa is *G. sancti-naumii*, which was known as an endemic diatom until finding it in Lake St. Anne. Further studies on the diatom assemblages of this lake during the Last Glacial Maximum are in progress.

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Összefoglaló: A *Gomphonema sancti-naumii* kovaalgát Macedóniából, a Sveti Naum forrásból írta le D. Metzeltin és Z. Levkov, 2007-ben, közel az Ohridi-tóhoz. Releváns adatbázisok szerint (Algaebase, Diatombase) leírása óta más élőhelyről eddig még nem közölték. A Szent Anna-tó üledékének paleoökológiai vizsgálata során, 16–15 ezer évvel ezelőtti mintákból mutattuk ki a fajt, ahol kis gyakorisággal, más hasonló, keskeny vázú ($< 5 \mu\text{m}$) gomphonemoid fajokkal fordult elő. Ez az adat a típus leírása utáni első előfordulás, és mint ilyen, új adat Románia flórájára. Fontos megjegyezni, hogy eddigi adataink szerint nem tagja a tó jelenlegi diatómaflórájának. Részletes, pásztázó elektronmikroszkópos morfológiai leírását is megadjuk, kiemelve, hogy a striák kettős areolákból állnak, ami a faj egyik fő bélyege. A Szent Anna-tó napjainkban alacsony pH-val jellemezhető savanyú víz, lápgyűrűvel a szélén. Korábbi vizsgálatok szerint a holocén során is főleg acidofil kovaalgák éltek a vízben. A Sveti Naum forrás vízének pH-ja 7,6–8,8 között változik, vagyis inkább a lúgos tartományban van. Ugyancsak magasabb pH-t jeleznek a Szent Anna-tavi mintában előforduló domináns taxonok (*Staurosira venter* (Ehrenberg) Cleve & J. D. Möller, *Staurosirella pinnata* (Ehrenberg) D. M. Williams & Round, *Stauroforma exiguiiformis* (Lange-Bertalot) R. J. Flower, V. J. Jones & Round). A Szent Anna-tó paleolimnológiai vizsgálata keretében jelenleg történő pH rekonstrukció készítésénél fontos adat a *Gomphonema sancti-naumii* jelenléte az Utolsó Eljegesedési Maximum (Last Glacial Maximum) idején.

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