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NEW AND RARE CHRYSOPHYCEAN STOMATOCYSTS FROM THE BRYOPHYTE SPRING IN THE TATRA NATIONAL PARK, POLAND

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Abstract. During investigation of a soft-water bryophyte spring on the western slope of Mały Kościelec Mt. in the Tatra National Park in Poland, eleven chrysophycean stomatocysts were found. Three morphotypes are new to science, one is new to Europe, three are new to Poland, and the remaining four have already been reported from other Polish locations. The stomatocysts are illustrated with SEM micrographs and described according to International Statospore Working Group (ISWG) guidelines.

Key words: Stomatocysts, chrysophytes, new morphotypes, taxonomy, spring vegetation, Tatra National Park, Poland

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INTRODUCTION

Extensive studies on chrysophycean stomatocysts in the Tatra National Park in Poland started in 2003 (Cabała & Piątek 2004). They have concentrated on the many lakes in the area, and to a lesser extent on the peat bog habitats. Within the park there are also a variety of habitats such as springs, areas of moss and liverwort vegetation, and snowmelt areas, presumably suitable for chrysophytes and their siliceous resting stages called stomatocysts. To verify this assumption, samples from various habitats have been collected and examined. Previous observations of samples collected in Źródło Lodowe spring and in moss vegetation growing in a flowing stream in the Dolina Kościeliska valley showed no stomatocysts (Cabała 2005b). Samples collected in a soft-water bryophyte spring on the western slope of Mały Kościelec Mt. revealed the presence of stomatocysts. They are described, illustrated and discussed in the present paper.

MATERIAL AND METHODS

The material comprised water squeezed from mosses collected on 7 August 2004 from a soft-water bryophyte spring on the western slope of Mały Kościelec Mt. SEM preparation and studies proceeded as described by Cabała and Piątek (2004). SEM micrographs were taken in the Laboratory of Field Emission Scanning Electron Microscopy and Microanalysis at the Institute of Geological Sciences of the Jagiellonian University. The stomatocysts were measured and described from SEM micrographs according to International Statospore Working Group (ISWG) guidelines (Cronberg & Sandgren 1986).

New stomatocysts not previously published were assigned numbers by Piątek J. beginning with stomatocyst #33, Piątek J., and referred to as 'this paper'. This numbering system continues the numbering of stomatocysts 1–30 under the name Cabała J., and is introduced due to her change of name to Piątek J. In a previous paper, two stomatocysts (stomatocysts 31 and 32, Piątek J.) are already described under this latter name (Piątek & Piątek 2005). This procedure was followed at the suggestion of Professors John P. Smol and Barbara A. Zeeb, who proposed some guidelines for descriptions of stomatocysts, concluding that it is better to continue a numbering sequence if the author remains the same, instead of starting a new numbering scheme with the author's new name. 'Number of specimens' refers to the number of SEM micrographs used for the stomatocyst description. Negatives are deposited in the Iconotheca of Algae (KRAM) in the Department of Phycology of the W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Fig. 1. Soft-water bryophyte spring on the western slope of Mały Kościelec Mt., dominated by *Philonotis seriata* Mitt. and *Scapania undulata* (L.) Dum.

Description of study area

The samples were collected in an area on the western slope of Mały Kościelec Mt., by the blue hiking trail from Dolina Gąsienicowa valley to Przełęcz Karb pass, at 1740 m a.s.l. and with a local N-S inclination of *ca* 10°. The habitat consists of vegetation around the spring dominated by a bryophyte turf community formed by *Philonotis seriata* Mitt. and *Scapania undulata* (L.) Dum. (Fig. 1). This community is sparsely covered by vascular plants typical of subalpine or alpine areas, such as *Aconitum firmum* Rchb., *Caltha laeta* Schott, Nym. & Kotschy, *Luzula alpinopilosa* (Chaix) Breistr., *Mutellina purpurea* (Poir.) Reduron, Charpin & Pimenov and *Viola biflora* L. The bryophyte spring covers granitic soil in the subalpine belt and is surrounded by shrubs of *Pinus mugo* Turra and subalpine meadows. The physical and chemical characteristics of the water

Table 1. Chemical and physical data of the soft-water bryophyte spring on the western slope of Mały Kościelec Mt. in the Tatra National Park.

Chemical and physical parameters	Bryophyte spring of Mały Kościelec Mt.
Water temperature °C	2.3
pH	6.0
Conductivity µS ·cm^{-1}	15
Ammonium (NH_4^+) mg ·l^{-1}	not detected
Nitrite (NO_2^-) mg ·l^{-1}	0.025
Nitrate (NO_3^-) mg ·l^{-1}	not detected
Oxygen (O_2) mg ·l^{-1}	8.9
Phosphate (PO_4^{3-}) mg ·l^{-1}	not detected
Total hardness °d	2.8
Carbonate hardness (acid-binding capacity) °d	1.4
Residual hardness °d	0.5

from this location were determined on one occasion and are presented in Table 1.

Results

The abundance of stomatocysts was lower than at other locations already investigated in the Tatra National Park (Cabała 2005a, b; Cabała & Piątek 2004), and they could not be observed by light microscopy. However, SEM studies revealed a few dozen specimens, which were classified under eleven morphotypes enumerated below. The recorded cysts are grouped by common morphological characteristics following Duff *et al.* (1995), Pla (2001) and Wilkinson *et al.* (2001).

Unornamented stomatocysts

spherical, no collar, no ornamentation

Stomatocyst 1, Duff & Smol 1988 *emend.* Zeeb & Smol 1993 (Fig. 2)

Negative number. Mr-08.

Number of specimens. 1.

Biological affinity. Probably this cyst is produced by several species, including two species of *Paraphysomonas* (according to Duff *et al.* 1995).

Description. This is a small, smooth, spherical stomatocyst, 5.8 μm in diameter. The pore is regular, 0.4 μm in diameter. No collar is present.

Distribution in Poland. Stomatocyst 1 was found in the peat bogs in Budzyń (Cabała 2002) and Staw Toporowy Wyżni (Cabała 2005a).

General distribution. This stomatocyst has been found in Canada, the U.S.A. (Duff *et al.* 1995) and Central Europe (Facher & Schmidt 1996a, b), moss vegetation from the Strømness Bay area, Antarctica (van de Vijver & Beyens 1997), the alpine lake Gossenköllesee, Austria (Kamenik *et al.* 2001), the Spanish Pyrenees (Pla 2001), and the high arctic Svalbard lakes (Betts-Piper *et al.* 2004).

Stomatocyst 29, Duff & Smol 1989 *emend.* Zeeb & Smol 1993 (Fig. 3)

Negative number. M/r-01.

Number of specimens. 2.

Biological affinity. Probably this cyst is produced by more than one species (according to Duff *et al.* 1995).

Description. This is a small, smooth, spherical stomatocyst, 4.2–4.8 μm in diameter. The pore is concave, 0.3 μm in diameter. No collar is present.

Distribution in Poland. Stomatocyst 29 was previously found in the Budzyń peat bog (Cabała 2002) and Żabie Oko lake in the Tatra National Park (Cabała 2005b).

General distribution. This stomatocyst has been found in Canada, the U.S.A. (Duff *et al.* 1995), Central Europe (Facher & Schmidt 1996a), the alpine lake Gossenköllesee, Austria (Kamenik *et al.* 2001), the Spanish Pyrenees (Pla 2001) and the high arctic Svalbard lakes (Betts-Piper *et al.* 2004).

Stomatocyst 49, Duff & Smol 1991 *emend.* Zeeb & Smol 1993 (Fig. 4)

Negative number. Mr-25.

Number of specimens. 2.

Biological affinity. It is not well known, and probably is produced by more than one species (Duff *et al.* 1995).

Description. This is a small, smooth, spherical stomatocyst, 5.4 μm in diameter. The pore is concave, inner diameter 0.3 μm, outer diameter 0.6 μm, with a swollen pseudoannulus. No collar is present.

Distribution in Poland. Stomatocyst 49 was found in paleocyst flora of bottom sediments of Jezioro Kortowskie lake (Rybak 1986), in freshwater material in the Budzyń peat bog (Cabała 2002) and in the Owczary Reserve in sulphuric saline habitats with *Vaucheria dichotoma* (L.) C. Agardh (Piątek & Piątek 2005).

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada, the U.S.A. (Duff *et al.* 1995) and Central Europe (Facher & Schmidt 1996a), moss vegetation and freshwater habitats in the Strømness Bay area, Antarctica (van de Vijver & Beyens 1997, 2000), the alpine lake Gossenköllesee, Austria (Kamenik *et al.* 2001) and the Spanish Pyrenees (Pla 2001).

SPHERICAL, SIMPLE CONICAL COLLAR, NO ORNAMENTATION

Stomatocyst 51, Duff & Smol 1991 *emend.* Duff *et al*. 1995 (Fig. 5)

NEGATIVE NUMBER. Mr-28.

NUMBER OF SPECIMENS. 3.

BIOLOGICAL AFFINITY. Unknown.

DESCRIPTION. This is a smooth, spherical stomatocyst, 6.1–6.6 μm in diameter. The pore is not visible. The collar is conical, 1.5 μm in diameter and 0.2 μm high.

DISTRIBUTION IN POLAND. Stomatocyst 51 is new to Poland and Europe.

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada and the U.S.A. (Duff *et al.* 1995).

COMMENTS. This cyst is similar to stomatocyst 308 Brown & Smol, except that it is generally smaller and the pore is regular. Although the pore was not visible, the present species most likely represents stomatocyst 51 and not stomatocyst 308, because the former has a diameter size range of 6.1 to 6.6 μm (always 6.6 μm), while stomatocyst 308 exhibits diameter sizes from 4.5 to 10.5 μm.

SPHERICAL, SIMPLE CYLINDRICAL COLLAR, NO ORNAMENTATION

Stomatocyst 125, Duff & Smol 1991 in Duff *et al.* 1992 (Fig. 6)

NEGATIVE NUMBER. Mr-24.

NUMBER OF SPECIMENS. 1.

BIOLOGICAL AFFINITY. Produced by *Paraphysomonas antarctica* Takahashi (according to Duff *et al.* 1995).

DESCRIPTION. This is a smooth, spherical stomatocyst, 6.5 μm in diameter. The pore is regular, 0.4 μm in diameter. The collar is low, 1.4 μm in diameter and 0.2 μm high.

DISTRIBUTION IN POLAND. Stomatocyst 125 was previously found in the Staw Toporowy Niżni peat bog (Cabała & Piątek 2004).

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada (Duff *et al.* 1995), the Spanish Pyrenees (Pla 2001) and the high arctic Svalbard lakes (Betts-Piper *et al.* 2004).

COMMENTS. This cyst is similar to stomatocyst 26 Hansen. The latter is distinguished on the basis of ornamentation. It has a few short struts radiating from the collar into the anterior surface of the cyst body, but as Hansen (2001) suggested they may be artefacts caused by uneven gold vapor adhesion.

NON-SPHERICAL, SIMPLE COLLAR, NO ORNAMENTATION

Stomatocyst #33, Piątek J., this paper (Figs 7–9)

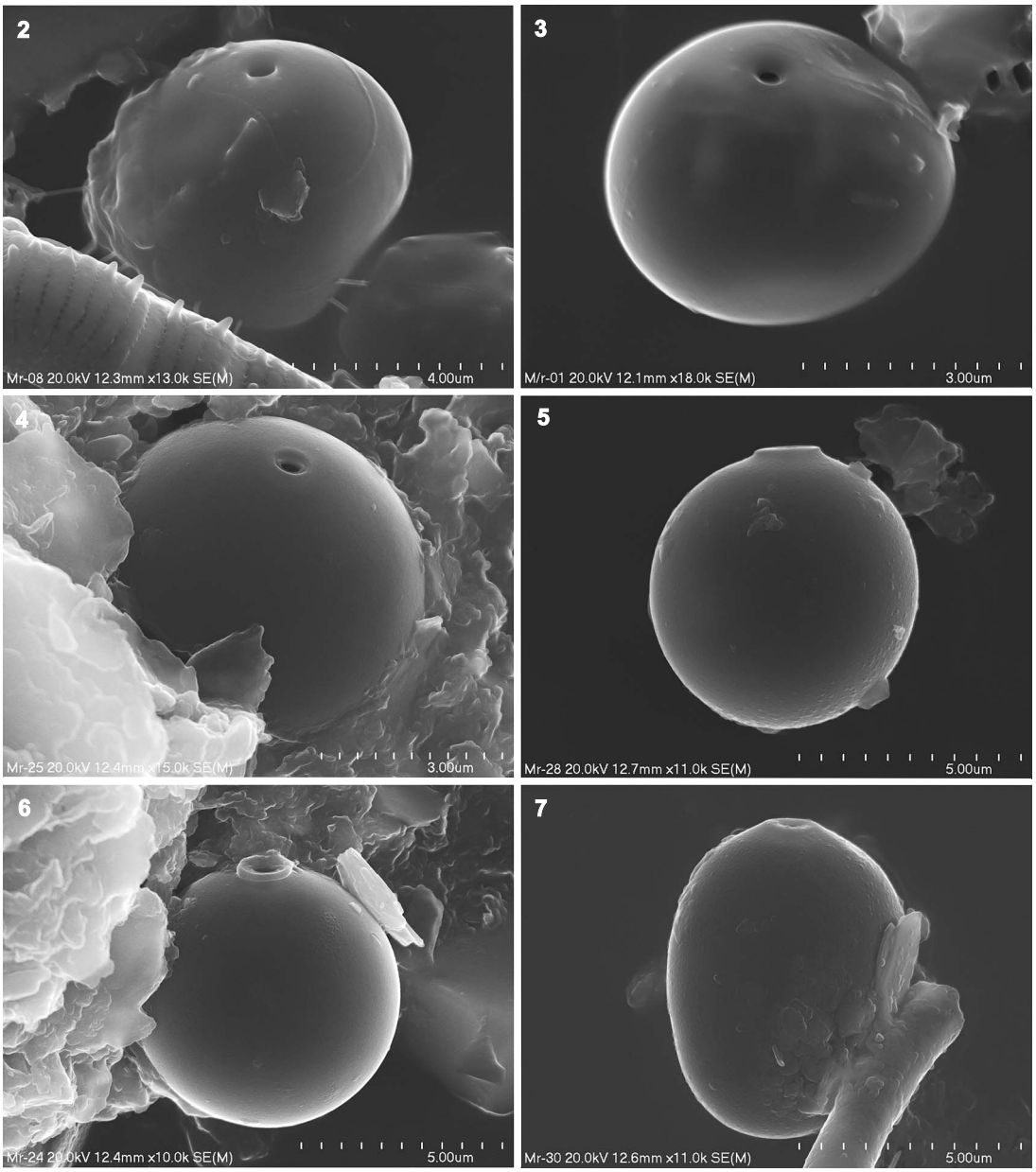
NEGATIVE NUMBER. Piątek J., negative Mr-30, Fig. 7.

NUMBER OF SPECIMENS. 4.

BIOLOGICAL AFFINITY. Unknown.

DESCRIPTION. This is a smooth, oval to obovate stomatocyst, 6.7–7.3 μm long and 5.3–6.5 μm wide. The pore is slightly concave, 0.3 μm in diameter. The collar is conical and low, 1.2–1.5 μm in diameter and 0.1–0.3 μm high.

COMMENTS. This stomatocyst is similar to stomatocyst 8 Facher & Schmidt, stomatocyst 197 Duff & Smol, stomatocyst 199 Duff & Smol and stomatocyst 269 Gilbert & Smol. However, all these stomatocysts have sets of characters that differentiate them from the new stomatocyst.



Figs 2–7. 2 – Stomatocyst 1; 3 – Stomatocyst 29; 4 – Stomatocyst 49; 5 – Stomatocyst 51; 6 – Stomatocyst 125; 7 – Stomatocyst #33.

Stomatocyst 8 Facher & Schmidt has a cyst body 8.0–12.5 μm wide and 10.0–15.0 μm long, and a pore about 1 μm in diameter. Stomatocyst 197 Duff & Smol is large (15.6–20.1 μm in diameter) and spherical, with a large collar (basal diameter 3.7–6.5 μm, apical diameter 3.2–3.6 μm, height 0.5–2.1 μm) and pore (0.7–1.6 μm in diameter). Stomatocyst 199 Duff & Smol is also large (6.8–10.3 × 7.7–12.2 μm) and almost spherical, with a large collar (1.5–2.6 μm in

diameter, height *ca* 0.7–1.1 μm). Stomatocyst 269 Gilbert & Smol has a large collar (basal diameter 2.2–3.9 μm, apical diameter 1.6–2.1 μm, height 0.5–1.1 μm) and a regular pore (diameter 0.6–0.8 μm). In summary, these stomatocysts have a larger cyst body and larger collars than in the newly described stomatocyst. In particular, they have collars wider than 1.5 μm and higher than 0.3 μm, while the newly described stomatocyst is small and has a very low collar, typically *ca* 0.3 μm.

Ornamented stomatocysts

with scabrae/verrucae

Stomatocyst #34, Piątek J., this paper (Figs 10–12)

Negative number. Piątek J., negative M/r-03, Fig. 10.

Number of specimens. 6.

Biological affinity. Unknown.

Description. This stomatocyst is spherical, sometimes slightly irregular, 4.4–6.5 μm in diameter. The pore is regular with a planar pseudoannulus, inner diameter 0.3–0.5 μm, outer diameter 0.6 μm. It has a characteristic depression forming a circulus, 2.7–3.5 μm in diameter, originating next to the low collar. The cyst body is partly smooth and partly ornamented with scabrae and verrucae, 0.2–0.3 μm in diameter, covering the entire cyst body, except in the depression.

Comments. This stomatocyst is distinguished from stomatocyst 92 Facher & Schmidt on the basis of ornamentation, pore and collar morphology, and from stomatocyst 310 Pla on the basis of ornamentation and collar morphology. Stomatocyst 92 Facher & Schmidt has a smooth surface with one circulus originating from the pore, while stomatocyst 310 Pla has a smooth to psilate surface and a low, cylindrical, off-center collar.

with ridges

Stomatocyst 345, Forma C, Pla 2001 (Fig. 13)

Negative number. Mr-21.

Number of specimens. 2.

Biological affinity. Unknown.

Description. This is an ovate, slightly irregular stomatocyst, 5.6–6.2 μm wide and 6.5–6.9 μm long. The pore is concave, 0.3 μm in diameter. The collar is very low, 1.3 μm in diameter, with a fossa surrounding the pore, and a variable number of longitudinal ridges (*ca* 0.1–0.15 μm wide) originating from the collar.

Distribution in Poland. Stomatocyst 345 forma C is new to Poland.

General distribution. This stomatocyst has been found in the Spanish Pyrenees (Pla 2001).

Comments. This cyst is similar to stomatocyst 345 Pla except that it has a concave pore.

Stomatocyst #35, Piątek J., this paper (Fig. 14)

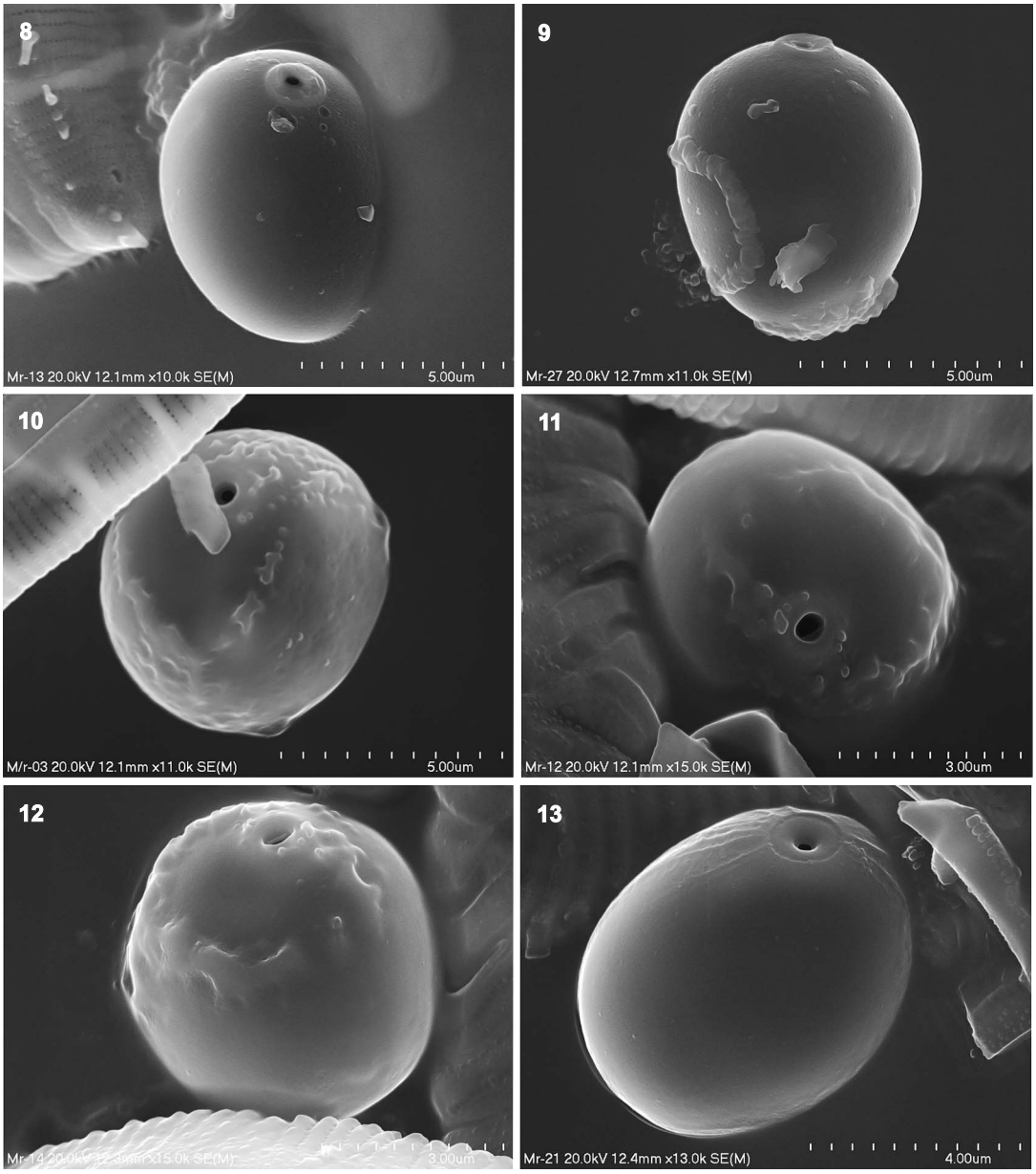
Negative number. Piątek J., negative M/r-04, Fig. 14.

Number of specimens. 3.

Biological affinity. Unknown.

Description. This stomatocyst is spherical, 4.9–5.9 μm in diameter. The pore is regular with a planar pseudoannulus, inner diameter 0.4 μm, outer diameter 0.7 μm. No collar is present. The stomatocyst surface is ornamented with very thin, long ridges, 0.1 μm high and 0.1–0.14 μm wide. These ridges start from the outer part of the pore and run from its anterior toward but not reaching its posterior pole.

Comments. This stomatocyst is described as a new morphotype because of its unique characteristic ornamentation, easily seen by SEM. In the available literature, no reports of similar stomatocysts with ornamentation in the form of very thin and low ridges were found.



Figs 8–13. 8–9 – Stomatocyst #33; 10–12 – Stomatocyst #34; 13 – Stomatocyst 345 Forma C.

WITH RETICULUM

Stomatocyst cf. 6, Duff & Smol 1988 (Fig. 15)

NEGATIVE NUMBER. Mr-10.

NUMBER OF SPECIMENS. 1.

BIOLOGICAL AFFINITY. Unknown.

DESCRIPTION. This is a spherical stomatocyst, 6.8 μm in diameter. In the SEM micrograph the pore and collar are not visible. The surface is covered by a low reticulum varying in shape,

with fairly large, polygonal lacunae, 0.6 μm in diameter.

DISTRIBUTION IN POLAND. Stomatocyst cf. 6 is new to Poland.

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada, the U.S.A, Denmark (Duff *et al.* 1995), freshwater habitats in the Strømness Bay area, Antarctica (van de Vijver & Beyens 2000) and the high arctic Svalbard lakes (Betts-Piper *et al.* 2004).

COMMENTS. Although the pore and collar are not visible in the SEM micrograph, this morphotype seems most similar to stomatocyst 6 Duff & Smol, because of its size and ornamentation. The ornamentation is lower than in the illustration of Duff *et al.* (1995: Fig. 127A–B), but it matches well with the variability of stomatocysts 6, especially with respect to the description of this morphotype (Duff *et al.* 1995: 127).

Stomatocyst 372, Pla 2001 (Figs 16 & 17)

NEGATIVE NUMBER. Mr-18.

NUMBER OF SPECIMENS. 4.

BIOLOGICAL AFFINITY. Unknown.

DESCRIPTION. This is a spherical to slightly oblate stomatocyst, 6.0–7.6 μm in diameter. The pore is not very clearly visible but has a swollen pseudoannulus. The collar is conical, 1.4–1.8 μm in diameter and 0.2–0.4 μm high. The stomatocyst surface and collar are ornamented with net-like reticulum forming irregular lacunae.

DISTRIBUTION IN POLAND. Stomatocyst 372 is new to Poland.

GENERAL DISTRIBUTION. This stomatocyst has been found in the Spanish Pyrenees (Pla 2001).

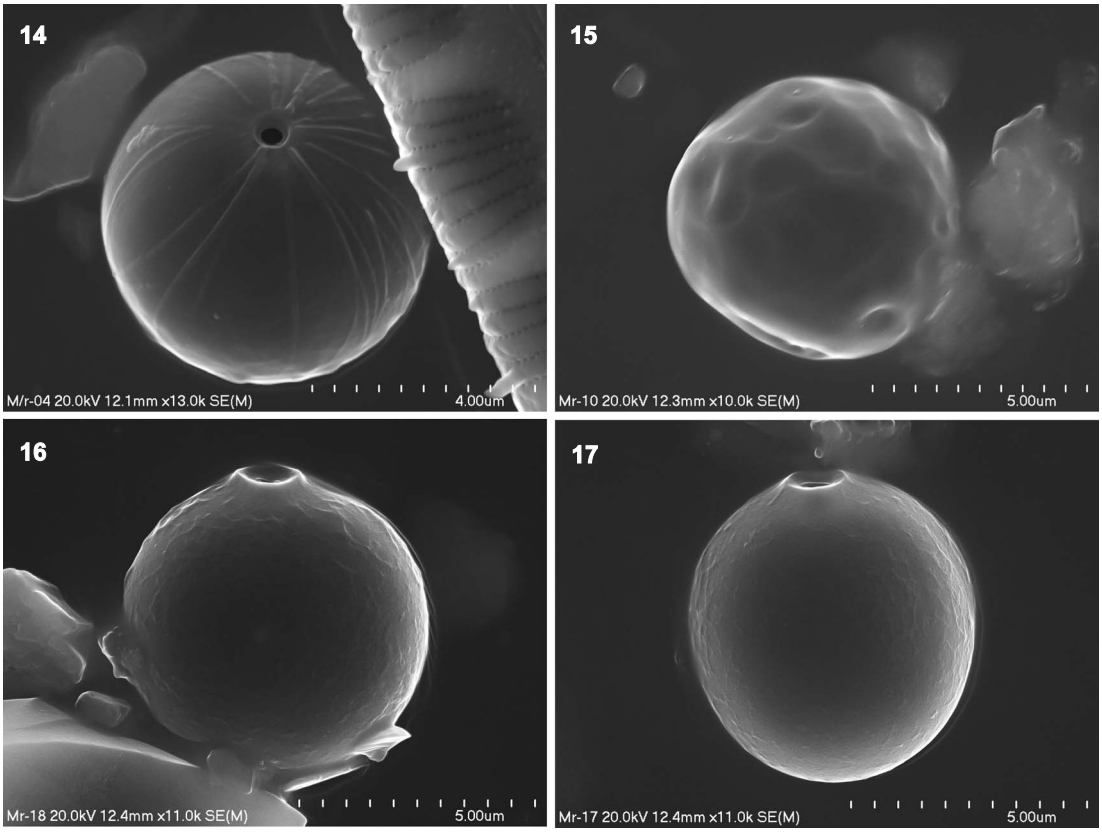
COMMENTS. This cyst is similar to stomatocyst 372 Pla, except that it is generally spherical and larger, with a larger collar as well. The present specimens have a cyst body 6.0 to 7.6 μm in diameter and a collar 1.4–1.8 μm in diameter. Stomatocyst 372 has a cyst body 5.5 to 5.7 μm in diameter and a collar 1.3–1.5 μm in diameter. Pla (2001) described the new morphotype on the basis of three specimens, but he did not report their pore morphology. The ornamentation of stomatocyst 372 is lower than in the illustration of Pla (2001: Plate S1), but it matches well with the variability of stomatocyst 372, especially in respect of ornamentation and the shape and size of the cyst body and collar (Pla 2001: 118).

CONCLUSIONS

In this study, eleven different stomatocysts were recorded from the soft-water bryophyte spring on the western slope of Mały Kościelec Mt. in the Tatra National Park. Of these, three are new to science, including one unornamented (#33) and two ornamented (#34, #35) stomatocysts. The newly described morphotypes are unique for their cyst body and collar size (#33), ornamentation, pore and collar morphology (#34), and highly unique characteristic ornamentation (#35).

One of the eleven mentioned stomatocysts is new to Europe: 51 Duff & Smol. Three others are new to Poland: stomatocysts cf. 6 Duff & Smol, 345 Forma C Pla and 372 Pla. Pla (2001) found these stomatocysts for the first time in Llauset lake and Baiau Superior lake in the Pyrenees. Stomatocyst cf. 6 Duff & Smol has been found several times in Europe, including the arctic Svalbard lake, and in North America (Canada, U.S.A.) and Antarctica, but it is recorded for the first time in Poland.

These investigations of stomatocysts in the Tatra National Park began in 2003. This paper continues research on chrysophycean stomatocysts occurring in various water bodies in this area. Some of the cysts were recorded from the Park earlier. Stomatocyst 1 Duff & Smol was previously found in the Staw Toporowy Wyżni peat bog (Cabała 2005a), stomatocyst 29 Duff & Smol was reported from Żabie Oko lake (Cabała 2005b), and stomatocyst 125 Duff & Smol was collected in the Staw Toporowy Niżni peat bog (Cabała & Piątek 2004). In Poland, Stomatocyst 1 Duff & Smol has been found previously only in two peat bogs – Budzyń and Staw Toporowy Wyżni (Cabała 2002, 2005a). The wide ecological spec-



Figs 14–17. 14 – Stomatocyst #35; 15 – Stomatocyst cf. 6; 16–17 – Stomatocyst 372.

trum of this stomatocyst (Duff *et al.* 1995; Facher & Schmidt 1996a, b; van de Vijver & Beyens 1997; Kamenik *et al.* 2001; Pla 2001; Cabała 2002, 2005a; Betts-Piper *et al.* 2004) suggests that it may be found in other localities in the Tatra Mts and Poland. Other morphotypes may also exhibit a wide ecological spectrum, such as stomatocyst 49 Duff & Smol, which has been found in various habitats in Poland (peat bog, sulphuric salt marsh), suggesting that this morphotype is cosmopolitan and has a broad range of occurrence.

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