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CHRYSOPHYTE STOMATOCYSTS FROM GYPSUM DAMP VEGETATION IN SOUTHERN POLAND

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Abstract. The Góry Wschodnie Reserve is a steppe reserve situated in the Wyżyna Małopolska upland in southern Poland. Two small patches of damp vegetation, periodically wet, are located within predominantly xerothermic vegetation overgrowing gypsum-rich soils. Water samples collected there in 2005 and 2006 contained many specimens of chrysophyte stomatocysts. SEM studies revealed an unusual diversity of stomatocysts, which were classified under 25 morphotypes. One morphotype is described as new to science, one morphotype is new to Europe, five morphotypes are recorded from continental Europe for the first time, and two morphotypes are new to Poland. The stomatocyst assemblage was dominated by one morphotype, stomatocyst 135 Duff & Smol, and the remaining 24 morphotypes occurred less abundantly. The variability of this morphotype is described, illustrated and discussed in detail. Nine notable stomatocysts are also described and illustrated with SEM micrographs.

Key words: chrysophytes, stomatocysts, new morphotype, morphology, taxonomy, Poland

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INTRODUCTION

The Góry Wschodnie Reserve is one of several steppe reserves situated in the Wyżyna Małopolska upland in southern Poland. The reserve, established in 1959, covers a total area of 1.78 ha, most of which is overgrown by xerothermic grasslands belonging to communities of *Adonido-Brachypodietum pinnati*, *Thalictro-Salvietum pratensis* and *Sisymbrio-Stipetum capillatae*. These communities harbor numerous vascular plants, including such remarkable species as *Adonis vernalis* L., *Erysimum odoratum* Ehrh., *Sesleria uliginosa* Opiz, *Stipa capillata* L., *Oxytropis pilosa* (L.) DC. and others. A long gypsum ravine runs from north to south through the middle of the reserve (Fig. 1). In two places at the north end of the ravine there are small patches of damp vegetation next to gypsum rock. The patches, each covering a few square meters, are overgrown by various sedges, including *Carex riparia* Curt. and *C. acuta* L., and are filled with stagnant water only periodically, mostly in springtime and after rainy periods. During our visits in the Góry Wschodnie Reserve in May 2005 and June 2006 these damp places were filled with water. The first author's ongoing studies focusing on the taxonomic diversity of chrysophyte stomatocysts have included a number of different bodies of water (Cabała 2002, 2003a, b, 2005a, b; Cabała & Piątek 2004; Piątek 2005, 2006, 2007; Piątek & Piątek 2005), but none of them were as ephemeral as the ones studied in the Góry Wschodnie Reserve. There we collected some water samples, made detailed SEM observations, and identified the stomatocysts in the material. Following are the results of this study, including illustrative descriptions of the ten most remarkable morphotypes found.

MATERIAL AND METHODS

The location of the study site is as follows: Poland, Wyżyna Małopolska upland, Góry Wschodnie Reserve, *ca* 70 km NE of Kraków, *ca* 10 km S of Busko Zdrój, 50°22′22.5″N, 20°43′40.5″E, elev. *ca* 185 m a.s.l.

Figs 1–3. 1 – General view of the Góry Wschodnie Reserve, 2 – Station A, 3 – Station B.

The material was collected in May 2005 and June 2006 from two places near to each other (stations A and B) with damp vegetation next to gypsum rock (Figs 1–3). The material includes samples from different microhabitats: (*i*) mats of algae, (*ii*) water squeezed from *Carex* spp., and (*iii*) bottom sediment.

The chemical and physical characteristics of the water were determined on the two collection days. Water temperature (°C), conductivity ($\mu S \cdot cm^{-1}$) and pH were measured immediately upon collection. Temperature and conductivity were measured with a CC-102 conductivity meter (Elmetron IP67), and pH was measured with a CP-103 waterproof pH meter (Elmetron IP67). The chemical and physical characteristics of the water are presented in Table 1.

Samples for scanning electron microscopy (SEM) were prepared as described by Piątek (2006). SEM micrographs were taken in the Laboratory of Field Emission Scanning Electron Microscopy and Microanalysis at the Institute of Geological Sciences, Jagiellonian University. The stomatocysts were measured and described from SEM micrographs according to International Statospore Working Group (ISWG) guidelines (Cronberg & Sandgren 1986; Duff *et al.* 1995; Wilkinson *et al.* 2001). The new stomatocyst is designated stomatocyst #43, Piątek J., and cited as 'this paper.'

Results and discussion

Examination of freshly collected samples by light microscopy revealed numerous stomatocysts as well as taxa of diatoms and chlorophytes. Cyanophytes (e.g., *Nostoc* sp.), euglenophytes (e.g., *Entosiphon* spp.), dinophytes (e.g., *Gymnodinium* sp.) and cryptophytes (e.g., *Cryptomonas* sp.) occurred less frequently. The stomatocyst assemblage was composed of virtually one dominant morphotype, identified as stomatocyst 135 Duff & Smol *in* Duff *et al.* 1992, which was very abundant. SEM studies revealed many more morphotypes in this assemblage, occurring at lower frequency. We identified a total 25 morphotypes in the damp vegetation of the Góry Wschodnie Reserve. This is a large number of stomatocysts. In previous studies of stomatocyst diversity in water bodies in the Wyżyna Małopolska upland the number of morphotypes was much lower: for example, 16 stomatocysts in a karstic sinkhole near Staszów (Wołowski *et al.* 2004), 11 in sulphur-saline habitats in the Owczary Reserve (Piątek & Piątek 2005) and 12 in an artificial reservoir in Wymysłów (Piątek 2007). The assemblages of chrysophyte stomatocysts in various places in the subalpine zone of the Tatra Mts were also usually much smaller: 8 stomatocysts in Morskie Oko lake (Cabała 2005b), 13 in Żabie Oko lake (Cabała 2005b), 11 in a bryophyte spring on the western slopes of Mały Kościelec Mt. (Piątek 2005), 4 in

Table 1. Chemical and physical data of the water from the Góry Wschodnie Reserve.

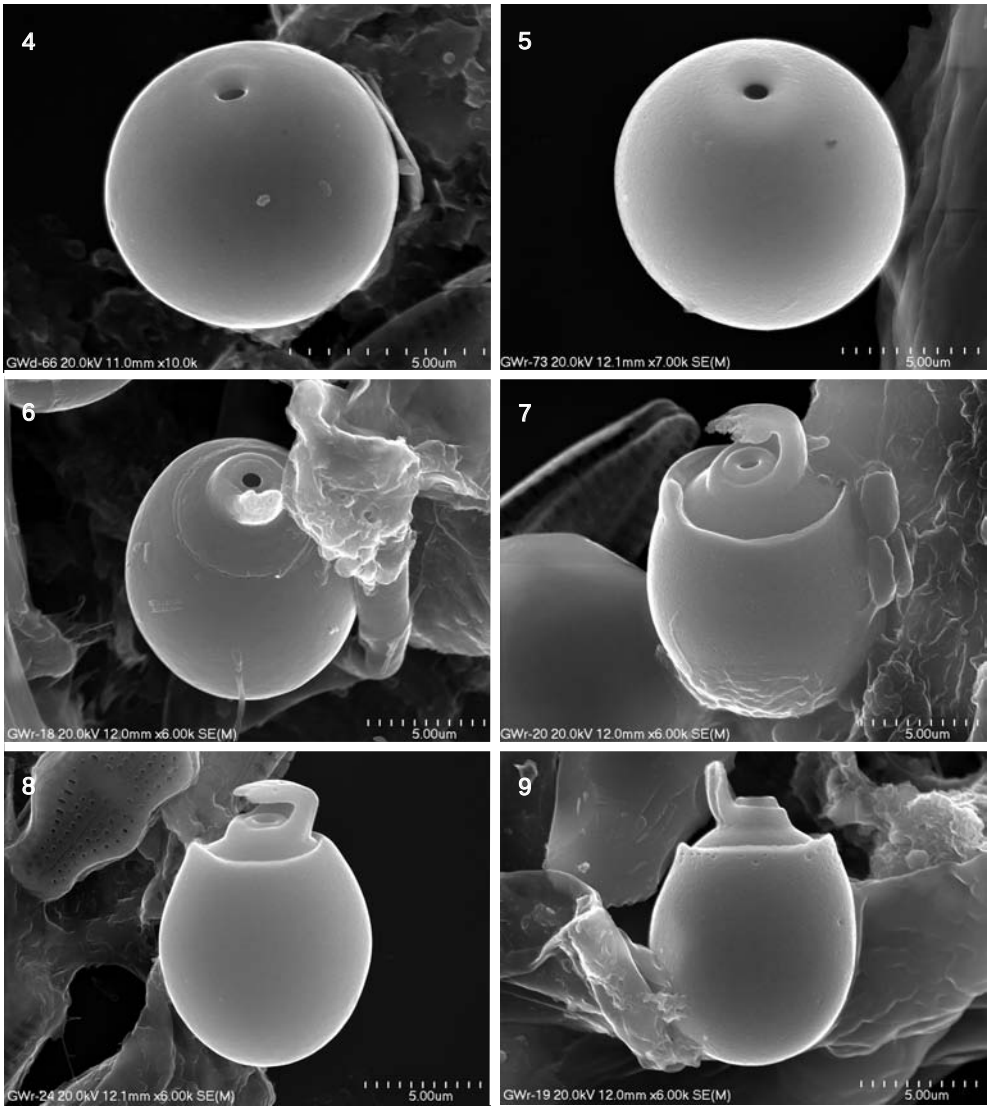
Chemical and physical parameters	Góry Wschodnie Reserve			
Date	11 May 2005		2 June 2006	
	station A	station B	station A	station B
Water temperature (°C)	14.0	12.5	17.5	15.5
Conductivity ($\mu S \cdot cm^{-1}$)	no data	no data	2000	2043
pH	no data	no data	7.1	6.5
Number of collected samples	2	2	9	4

Czarny Staw Gąsienicowy lake (Piątek 2006) and 16 in Zmarzły Staw Gąsienicowy lake (Piątek 2006). Notable exceptions were Staw Toporowy Niżni lake (36 stomatocysts; Cabała & Piątek 2004) and the Staw Toporowy Wyżni peat bog (31; Cabała 2005a), both in the upper montane zone of Tatra National Park. In light of these data, the diversity of stomatocysts found in the Góry Wschodnie Reserve can be considered high and unusual.

Fifteen stomatocysts that have been recorded previously from Poland are given in Table 2 with references, the number of observed specimens and their distribution in Poland. The remaining ten most remarkable ones are described, illustrated and discussed in greater detail.

Table 2. Stomatocysts already reported from Poland, identified in the gypsum damp in the Góry Wschodnie Reserve.

Stomatocyst no.	Reference	Number of observed specimens	Distribution in Poland
9	Duff & Smol 1988 *emend.* Zeeb & Smol 1993	2	Five records (Wołowski *et al.* 2004; Cabała & Piątek 2004; Cabała 2005a, b; Piątek 2006)
15	Duff & Smol 1988 *emend.* Zeeb & Smol 1993	1	Four records (Wołowski *et al.* 2004; Cabała 2005a; Piątek & Piątek 2005; Piątek 2007)
40	Piątek J. 2007	2	One record (Piątek 2007)
41	Piątek J. 2007	1	One record (Piątek 2007)
42	Duff & Smol 1989	1	Four records (Rybak 1987; Wołowski *et al.* 2004; Piątek & Piątek 2005; Piątek 2007)
46	Duff & Smol 1991	1	One record (Cabała 2002)
49	Duff & Smol 1991 *emend.* Zeeb & Smol 1993	1	Five records (Rybak 1986; Cabała 2002; Piątek 2005, 2007; Piątek & Piątek 2005)
118	Zeeb *et al.* 1990	3	One record (Cabała & Piątek 2004)
120	Duff & Smol *in* Duff *et al.* 1992 *emend.* Zeeb & Smol 1993	5	Five records (Cabała 2002; Cabała & Piątek 2004; Wołowski *et al.* 2004; Piątek & Piątek 2005; Piątek 2006)
134	Duff & Smol *in* Duff *et al.* 1992	1	One record (Cabała 2002)
150	Zeeb & Smol 1993	6	One record (Piątek & Piątek 2005)
181	Brown & Smol *in* Brown *et al.* 1994 *emend.* Taylor & Smol *in* Wilkinson *et al.* 2001	1	Four records (Cabała 2002; Cabała & Piątek 2004; Piątek 2006, 2007)
183	Brown & Smol *in* Brown *et al.* 1994	2	Four records (Cabała 2003b, 2005a; Cabała & Piątek 2004; Piątek 2006)
188	Brown & Smol *in* Brown *et al.* 1994	1	One record (Cabała & Piątek 2004)
189	Zeeb & Smol *in* Zeeb *et al.* 1996	4	Four records (Cabała 2002; Wołowski *et al.* 2004; Piątek & Piątek 2005; Piątek 2006)



Figs 4–9. 4 – Stomatocyst 123, 5 – Stomatocyst 358, 6–9 – Stomatocyst 135 (with broken projection).

Descriptions of notable morphotypes

Unornamented stomatocysts

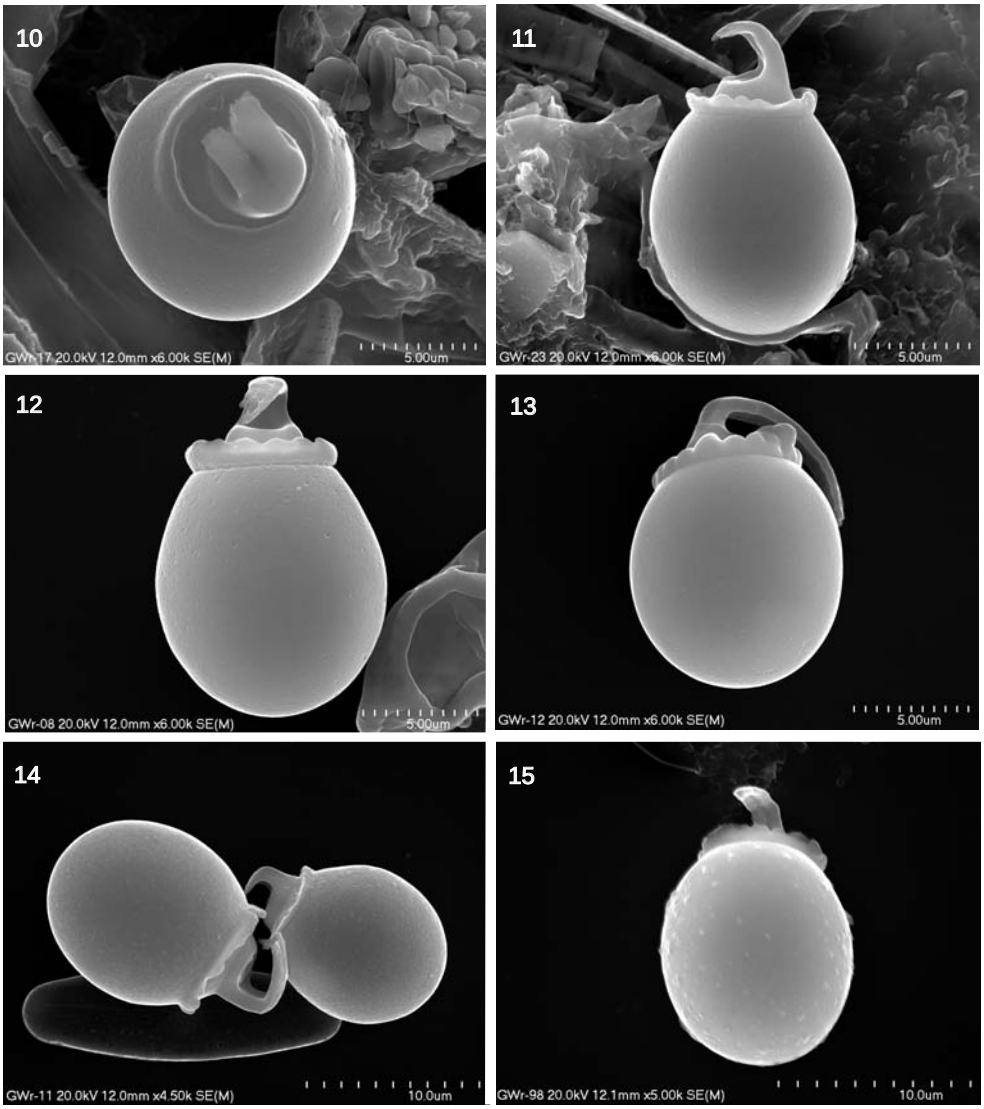
with conical collar

Stomatocyst 123, Duff & Smol *in* Duff *et al.* 1992 Fig. 4

Number of observed specimens: 1.
Picture-file number: GWd–66.

SEM description. Smooth and spherical, 7.5 μm in diameter. Collar small and conical, pore regular, 0.7 μm in diameter.

Notes. Stomatocyst 123 has been reported from several places, mostly in arctic North America (Duff *et al.* 1995), the high-arctic Svalbard lakes (Betts-Piper *et al.* 2004) and the subantarctic island of South Georgia (van de Vijver & Beyens 1997). The observation of stomatocyst 123 in the Góry



Figs 10–15. Stomatocyst 135 (in Figs 10–12, stomatocysts with broken projection; in Figs 14–15, stomatocysts with broken projection and ornamented with scabrae; in Fig. 13, stomatocyst with long, unbroken projection).

Wschodnie Reserve is the first in Poland and the first in continental Europe.

WITH CYLINDRICAL COLLAR

Stomatocyst 358, Taylor & Smol (*in* Wilkinson *et al.* 2001) Fig. 5

Number of observed specimens: 1.
Picture-file number: GWr–73.

SEM DESCRIPTION. Smooth and spherical, 10.4 µm in diameter. Collar cylindrical and very low, 2.0 µm in diameter, 0.4 µm high. Pore regular, 0.9 µm in diameter.

NOTES. This stomatocyst has been reported from only a few places in North America and Europe, and probably as stomatocysts 31, 32 and 33 van de Vijver & Beyens 1997 from the subantarctic island of South Georgia (Wilkinson

et al. 2001). It is reported here from Poland for the first time.

WITH TRUE OR FALSE COMPLEX COLLAR

Stomatocyst 135, Duff & Smol *in* Duff *et al.* 1992 Figs 6–15

Number of observed specimens: very numerous.
Picture-file number: GWr–18 and GWr–20.

SEM DESCRIPTION. Highly variable in shape, from spherical, oval and ovate to oblate, 8.5–12.1 μm long, 8.8–10.8 μm wide. Pore regular, 0.9 μm in diameter. Primary collar conical, 1.5–2.3 μm in diameter, 0.4–0.6 μm high. Secondary collar conical, 2.7–3.8 μm in diameter, 0.9–1.4 μm high, with inwardly hooked projection 3.8–9.0 μm long, 1.5–6.2 μm wide. Tertiary collar cylindrical to obconical, 5.2–7.8 μm in diameter, 0.2–1.2 μm high, sometimes with irregular apex. Cyst body usually smooth but sometimes ornamented with scabrae 0.1–0.2 μm in diameter.

NOTES. Stomatocyst 135 occurred very abundantly in the samples collected in the Góry Wschodnie Reserve, allowing its morphological variability to be observed. The shape of the cyst body, the shape and size of the tertiary collar, and the size of the hooked projection of the secondary collar vary greatly in this morphotype. In the original description the height of the projection above the collar was given as 0.7 to 3.0 μm. In the present study some specimens had hooked projections up to 9.0 μm long. The cyst bodies of most specimens are smooth but occasionally are minutely ornamented with scabrae scattered over the entire cyst surface. The SEM micrographs in Figures 6–15 show the main trends of variability of stomatocyst 135 from the samples in the Góry Wschodnie Reserve.

Stomatocyst 135 is very similar to stomatocyst 46 Hansen 2001, and they very likely represent the same morphotype: their shape, size and complex collar morphology is the same. The length of the projection, 6–12 μm long in stomatocyst 46, is the only difference. The reason for this difference may be that many specimens of stomatocyst 135 have broken projections, for example the Góry Wschodnie Reserve specimens in Figures 6–12 and 14–15, or the specimen in Plate E3 in Pla (2001). Coradeghini and Vigna (2001) reported specimens from Argentina with short and long projections. It is therefore clear that the length of the projection is variable in various specimens of stomatocyst 135 and that many specimens have broken projections.

Stomatocyst 135 is a widespread morphotype, reported from many places in North America and Europe in the Northern Hemisphere (Duff *et al.* 1995; Hansen 2001; Pla 2001) and in South America and the Kerguelen Islands in the Southern Hemisphere (Duff *et al.* 1995; Coradeghini & Vigna 2001). Stancheva and Temniskova (2004) reported three morphotypes of chrysophyte stomatocysts from fossil material collected in Bulgaria as 'Chrysophycean stomatocysts.' The included LM micrographs give grounds to identify one of these stomatocysts as stomatocyst 135. In Poland this morphotype was previously found only three times: in the Modlniczka peat bog in the Wyżyna Krakowsko-Częstochowska upland (Cabała 2002, as 'unidentified stomatocyst = Type 160') and in two places in the Tatra National Park (Cabała & Piątek 2004; Cabała 2005a). Only single specimens were observed in these places.

ORNAMENTED STOMATOCYSTS

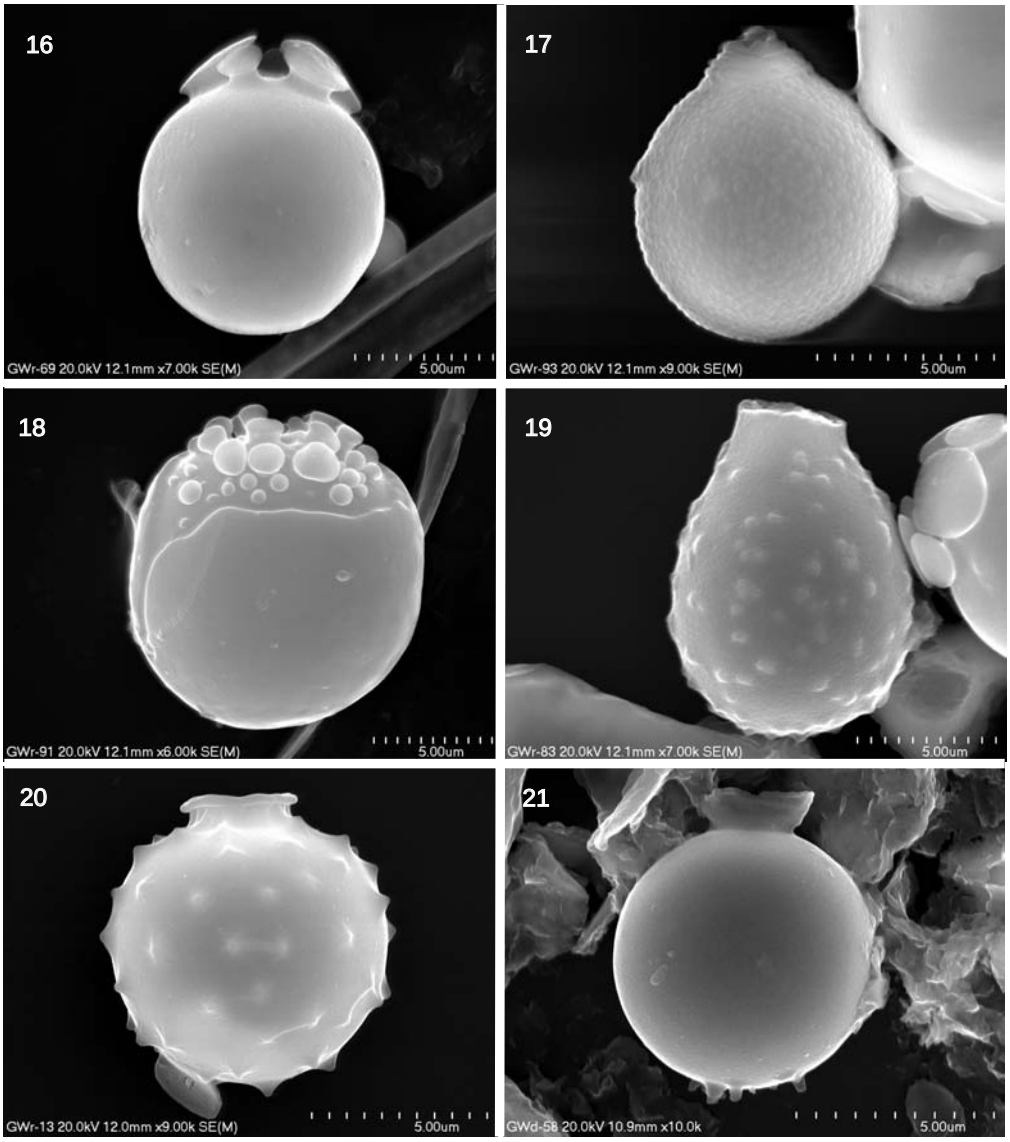
WITH OR WITHOUT COLLAR, ORNAMENTATION CONSISTS OF ANTERIOR PROJECTIONS SIMULATING SIMPLE/COMPLEX COLLAR

Stomatocyst 136 forma A, Duff & Smol *in* Duff *et al.* 1992 *emend.* Gilbert & Smol *in* Gilbert *et al.* 1997 Fig. 16

Number of observed specimens: 11.
Picture-file number: GWr–69.

SEM DESCRIPTION. Spherical to oval, 8.7–9.6 μm wide, 8.8–10.2 μm long, usually with six inwardly flexed projections, 0.5–0.6 μm high, with flattened, circular apices, 1.1–3.2 μm in diameter. Pore not visible.

NOTES. Wilkinson *et al.* (2001) divided stomatocyst 136 into two forms on the basis of differences in morphology and the height of projections.



Figs 16–21. 16 – Stomatocyst 136 forma A, 17 – Stomatocyst 60, 18 – Stomatocyst 260 forma A, 19 – Stomatocyst 133 forma A, 20 – Stomatocyst 284, 21 – Stomatocyst 185 forma A.

Forma A was illustrated and discussed by Duff *et al.* (1995, as stomatocyst 136). Stomatocyst 136 forma A has been observed in numerous places in North America, South America, Europe and the subantarctic Kerguelen Islands (Duff *et al.* 1995; Hansen 2001; Pla 2001; Coradeghini & Vigna 2001; Kamenik *et al.* 2001). It is reported here from Poland for the first time.

WITH SCABRAE

Stomatocyst 60, Hansen 2001 Fig. 17

Number of observed specimens: 1.
Picture-file number: GWr–93.

SEM DESCRIPTION. Spherical to slightly ovate, 7.4 µm in diameter. Pore and primary collar morphology not visible. Collar (?secondary) conical,

1.4–2.9 μm in diameter. Cyst body ornamented with scabrae 0.1–0.3 μm in diameter.

NOTES. Stomatocyst 60 Hansen 2001 is distinguished from stomatocyst 68 van de Vijver B. & Beyens L. 2000 on the basis of size and ornamentation. Stomatocyst 68 is larger, 8.8–13.3 μm in diameter, and has ornamentation usually with baculate spines, which are sometimes bifurcated. Stomatocyst 60 was originally described from the Azores (Hansen 2001), and is reported here for the first time from continental Europe and Poland.

WITH VERRUCAE

Stomatocyst 260 forma A, Zeeb *et al.* 1996 *emend.* Gilbert *et al.* 1997 Fig. 18

Number of observed specimens: 1.
Picture-file number: GWr–91.

SEM DESCRIPTION. Spherical, 12.1 μm in diameter. Anterior hemisphere ornamented with verrucae of different shapes and sizes 0.4–2.0 μm in diameter, up to 1.1 μm high. Posterior hemisphere unornamented.

NOTES. This morphotype was originally described from Siberia in Russia, and is also known from North America, where it was recorded in the U.S.A. and Costa Rica (Wilkinson *et al.* 2001). The specimens from the Azores designated stomatocyst 281 Gilbert *et al.* 1997 (Hansen 2001) probably also belong here. The specimens from Argentina described by Coradeghini and Vigna (2001) as stomatocyst 11 also are very similar morphologically and most probably represent stomatocyst 260 forma A. Thus, stomatocyst 260 forma A is reported here from continental Europe and Poland for the first time.

WITH CONULA

Stomatocyst 133 forma A, Duff *et al.* 1992 *emend.* Wilkinson & Smol *in* Wilkinson *et al.* 1997 Fig. 19

Number of observed specimens: 3.
Picture-file number: GWr–83.

SEM DESCRIPTION. Spherical to oval, 8.9–10.2 μm long, 7.1–8.3 μm wide. Collar conical, 4.1 μm in diameter, 1.3 μm high. Primary collar and pore not visible. Stomatocyst ornamented with conulae 0.5–0.9 μm in diameter.

NOTES. This morphotype is known from places in North America (Wilkinson *et al.* 2001) and in Svalbard (Betts-Piper *et al.* 2004), which geographically belongs to Europe. It is reported here as new to continental Europe and Poland.

Stomatocyst 284, Gilbert & Smol *in* Gilbert *et al.* 1997 Fig. 20

Number of observed specimens: 2.
Picture-file number: GWr–13.

SEM DESCRIPTION. Spherical, 7.8 μm in diameter. Collar obconical, 2.9–3.3 μm in diameter, 0.8 μm high. Collar apex may flex towards cyst body. Pore not visible. Stomatocyst ornamented with conulae 0.2–0.4 μm in diameter, 0.4 μm high, scattered over cyst body.

NOTES. This stomatocyst is very similar to stomatocyst 70 Duff & Smol 1991, whose cyst body, however, is smaller, 3.4–5.5 μm in diameter. Stomatocyst 284 was originally described from Siberia in Russia (Wilkinson *et al.* 2001) and was not found anywhere else before the present finding. It is reported here for the second time in the world, as new to both Europe and Poland.

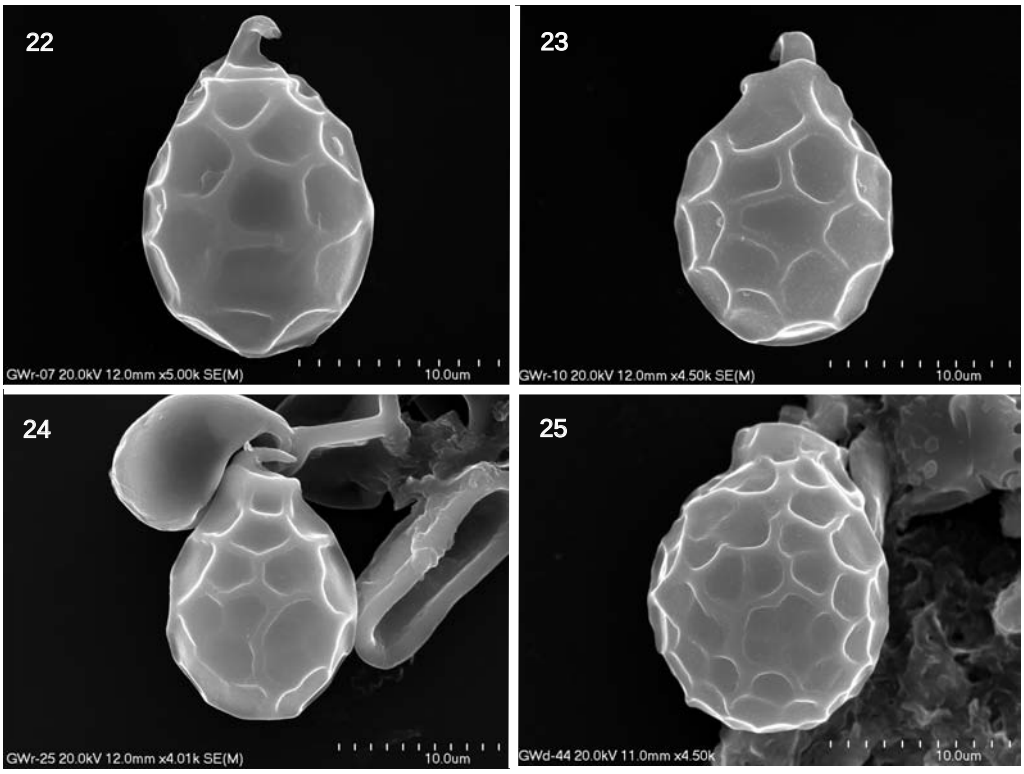
WITH SPINES

Stomatocyst 185 forma A, Brown & Smol *in* Brown *et al.* 1994 Fig. 21

Number of observed specimens: 1.
Picture-file number: GWd–58.

SEM DESCRIPTION. Spherical, 6.4 μm in diameter. Collar obconical, basal diameter 2.1 μm, apical diameter 3.1 μm, 1.0 μm high. Pore not visible. Baculate spines located over posterior hemisphere.

NOTES. Stomatocyst 185 is divided into two formae (forma A and forma B), distinguished on the basis of collar morphology and cyst body ornamentation. The collar morphology of the specimen from the Góry Wschodnie Reserve is not fully visible, but the spines on the cyst body are located in the posterior hemisphere only, well matching the



Figs 22–25. Stomatocyst #43, newly described, with characteristic ornamentation and complex collar.

description of stomatocyst 185 forma A. Forma B has spines over the entire cyst surface. Stomatocyst 185 forma A is known from North America, where it was found in Canada and Greenland (Duff *et al.* 1995), and from Europe, where it was recorded in Svalbard (Betts-Piper *et al.* 2004). It is reported here for the first time from continental Europe and from Poland.

WITH RETICULUM

Stomatocyst #43, Piątek J., this paper
Figs 22–25

Number of observed specimens: 14.
Picture-file number: Piątek J., GWr–07, Fig. 22.

SEM DESCRIPTION. Ovate, 11.1–17.0 µm long, 8.9–13.9 µm wide. Primary collar conical, 2.0–2.9 µm in diameter, 0.5–0.6 µm high, with hooked projection up to 4.5 µm long, 0.9–1.4 µm wide. Secondary collar cylindrical, 4.9–5.6 µm in diameter, 0.6–1.8 µm high. Pore not observed. Cyst body reticulate, with lacunae 2.2–3.8 µm in diameter, varying in shape from roughly circular to more irregular. Reticular ridges very wide, adjoining secondary collar.

NOTES. This morphotype is equivalent to cyst 46 Sandgren & Carney 1983 recorded from fossil samples from Frains Lake, Michigan, U.S.A. Because cyst 46 was described prior to the ISWG guidelines (Cronberg & Sandgren 1986), we describe this morphotype as new, following the approach of Duff *et al.* (1995).

Stomatocyst #43 is a characteristic morphotype because of its collar morphology and the peculiar ornamentation of the cyst body surface. Stomatocyst 135 Duff & Smol *in* Duff *et al.* 1992 is similar in shape and has a secondary collar with a characteristic hooked projection, but differs by having a smooth cyst body surface and being slightly smaller (7.3–15.0 × 5.7–12.6 µm). Sto-

matocyst 255 Wilkinson & Smol *in* Wilkinson *et al.* 1997 has similar ornamentation and cyst body size but differs by having no hooked projection on any collar.

Summary

Of the 25 stomatocysts we found in the material collected in the Góry Wschodnie Reserve, 18 morphotypes were unornamented and seven were ornamented. One is described as new: stomatocyst #43 Piątek J. One was recorded in Europe for the first time: stomatocyst 284 Gilbert & Smol (references given above). Five were recorded in continental Europe for the first time: stomatocysts 123 Duff & Smol, 60 Hansen, 260 forma A Zeeb *et al.*, 133 forma A Duff *et al.*, and 185 forma A Brown & Smol. Two were recorded in Poland for the first time: stomatocysts 358 Taylor & Smol and 136 forma A Duff & Smol.

Two stomatocysts, 40 and 41 Piątek J., are known only from Poland. They were described recently as new from material collected from artificial reservoir in Wymysłów in the Wyżyna Małopolska upland (Piątek 2007). The locality in the Góry Wschodnie Reserve is the second known station for both. The two localities are in the same region of Poland.

The two other stomatocysts, 60 Hansen and 284 Gilbert & Smol, are reliably reported for the second time in the world. The first stomatocyst was known only from the Azores, from where it was described as new to science (Hansen 2001). In the Azores, stomatocyst 60 was observed in four ponds. In connection with stomatocyst 60 it should be pointed out that according to Hansen (2001) the picture of this morphotype from the U.S.A. was also included by Adam and Mahood (1981). Stomatocyst 284 was known only from one locality in Siberia in Russia.

The majority of stomatocysts occurred in very low numbers (1–3 specimens of each morphotype). Others were more common (4–6 specimens) and two were very abundant: 136 forma A Duff & Smol (11 specimens) and #43 Piątek J. (14 specimens). One morphotype was dominant: stomatocyst 135 Duff & Smol. Because of its mass occurrence, the morphological variability of this morphotype could be observed, described and illustrated. The three morphotypes observed most abundantly, stomatocysts 135, 136 forma A and #43, have a characteristic hooked projection or projections located at the anterior pole, usually close to the collar and pore.

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