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Algae, Cyanobacteria and Chytridiales of Černé Lake in the Bohemian Forest (Šumava, Czech Republic) †

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Abstract
Algae of Černé Lake, in the Bohemian Forest, were studied through the period 1988–2004. The results are compared with records of algae of the lake in 1897, 1935–1937, 1941, and also with some paleolimnological records from sediment cores. The lake was acidified and its hydrochemistry, phytoplankton and zooplankton have seriously changed since the 1870s. The Secchi depth increased from ca. 2 m in 1898 to ca. 15 m in 1960–1980 as a result of atmospheric acidification and dropped back to ca. 7 m by 2000. There were 422 taxa of cyanobacteria and algae found together in the lake, including the lake corrie; 260 were recent, 43 species were plankton, 143 species benthic, 77 taxa were growing on rocks on the lake wall, and 157 species of Bacillariophyceae were determined from the cores. A few taxa are new for the Czech Republic: Stomatocyst 35 Duff & Smol (1989) and Stomatocyst 73 Duff & Smol (1991) were known only from cores, until now. *Coelastrum pascheri* Lukavský (2006) is a new species for science. Some algae, mentioned by Frič & Vávra in the 1890s, had disappeared from the littoral, such as *Oedogonium cryptophorum*, *O. crispum* and *O. tenuissimum*; and these were substituted for by the genera *Binuclearia, Microspora, Microthamnion, Ulothix*, and primarily by *Mougeotia*. Eighty new taxa of Bacillariophyceae were determined, and 18 taxa from the first list are now missing. The differences could be also the result of progress made in collecting and concentration methods, determination keys, and the changes in the taxonomy of the individual genera and species.

Key words: acidification, species richness, long-term changes

Introduction

Černé Lake (Černé jezero / Schwarzer See) in the Bohemian Forest (Šumava / Böhmerwald) has attracted people from early times. As the largest lake in the Bohemian Forest, it is a prominent natural reserve with rare glacial relicts – e.g., *Soldanella montana* Wild., *Sparganium angustifolium* Michaux fil. (*S. affine* Schnitzl.), and *Isöetes lacustris* L. have there their exclusive localities, within the Czech Republic (Husák et al. 2000).

The first, preliminary, limnological research of the lake was done by Frič (1872) and followed by Frič & Vávra (1897). The lake was the third locality where “a portable zoological station” was in operation, 1892–1896. Since that time, other Czech hydrobiologists and phycologists have collected in the lake and its corrie. Reviews of research on Czech lakes were published by Veselý (1994), Váňa (1996), Vrba et al. (2000), Nedbalová et al. (2006); a bibliography of all lakes in this area was compiled by Vrba (2000), as well.

This long history in research has given us a unique chance to use the lake for the monitoring of long-term changes of the environment. Remote mountain lakes are ideal for such

† Dedicated to memory of Prof. Dr. B. Fott (1908–1976)

evaluations because they are not directly influenced by big towns or industrial areas and, consequently, are controlled by the mean changes of the general environment (Morales--Baquero et al. 1992, Mosello et al. 1992, Straškrabová 1995, Sommaruga & Psenner 2001, Grabherr et al. 2005). Lakes with a comparably long history of monitoring, to that of Černé Lake, are not common, e.g. Lake Erie has been phycologically investigated since 1898 (Downing 1970). Weiser (1947) compiled the history of the explorations of Černé Lake and deduced the succession of zooplankton and limnological classification of the lake. He stated that the lake was oligotrophic, at least for the past half century. The present sharp decline of air pollution, following its maximum in 1980, gave us a unique chance to study the reaction of the lake to acidification and its subsequent recovery; utilizing the monitoring background of over a century (Vrba et al. 2003).

Phytoplankton research, unfortunately, had been limited by the technique of concentration. In the period of Frič & Vávra (1897), phytoplakton were not evaluated, Steinich (in Frič & Vávra 1897) worked-up Bacillariophyceae from mud, collected from a depth of 20–35 m, and Hansgirg (in Frič & Vávra 1897) determined littoral algae from periphyton and stones. B. Fott (1936, 1938, unpubl. data) was the first who introduced centrifugation and the Utermöhl's chamber; and the author of this paper also introduced membrane filtration, for the concentration of phytoplankton. This, unfortunately, limits the comparison of planktonic algae now and of century ago. Fott (1937, 1938) described 3 new species from Černé Lake to the science (*Bitrichia ollula*, syn. *Diceras ollula*; *Katodinium bohemicum* syn. *Gymnodinium bohemicum*, and *Katodinium planum* syn. *Massartia plana*), but other algae, lists of species, and vertical stratification and drawings are only from his unpublished field notebook (Fig. 1; all Figs except one are placed at the end of the contribution). Rosa (1941) found there 11 new species for Bohemia. Nedbalová & Vrtiška (2000) found 24 species of phytoplankton in the lake.

Species richness is also dependent upon progress in taxonomy, e.g., Steinich in Frič & Vávra (1897) determined 28 taxa in the lake, Řeháková in Schmidt et al. (1993) determined from a core 157 species of Bacillariophyceae.

The first hydrochemical analysis was carried out by Hannamann in 1895 (in Frič & Vávra 1897), next by Jírovec & Jírovcová (1937); followed by the historical development of the lake being compiled by Schmidt et al. (1993), Veselý (1994, 1996), Vrba et al. (1996, 2000).

Several sediment cores were taken from Černé Lake. This technique allows for the reconstruction of the history of the lake since its origin, unfortunately with some limitations: only organisms with solid remains are preserved, such as pollen grains, Cladocera, Bacillariophyceae, some Chlorococcales, scales of Chrysophyta, some Dinophyceae, Stomatocysts, etc. (Schmidt et al. 1993, Břízová 1996, Veselý 1998).

The aim of this study is to prepare the list of species of algae for quantitative evaluation of phytoplankton, for the evaluation of algae in cores and preserved samples; and for evaluations of long-term monitoring of the environment. Stress should also be placed upon detailed documentation, including common species, which are usually overlooked.

Material and Methods

Site description

Černé Lake is situated 1007 m a.s.l., 49°11' N and 13°11' E, in the corrie exposed towards south-east. The catchment (1.24 km^2) consists of mica-schist (muscovitic gneisses) with quartzite intrusions (Veselý 1994). The dam on the lake is of moraine origin, but it has been further piled-up and adapted. There is an artificial outlet for the control of the water level and also a small hydroelectric power station, both in operation from the dam. The power station operates as pumped storage, and part of the water from the Úhlava River had been regularly pumped back into the lake (Kopáček et al. 2003). The lake has a surface area of 19 ha, a max. vol. of water of 2.9×10^3 m^3, a max. depth of 40 m (+ about 10 m of mud), and a mean depth of 15.6 m. Annual precipitation is 1100–1500 mm, with the mean retention time in the lake of 3 years, and the maximum temperature of surface water is 18 °C (June–October; Kopáček et al. 2001a,b, Janský et al. 2005). Stratification is prominent, the lake is dimictic. There is a vertical stratification of the algae; the most prominent stratification have been observed for *Cryptomonas* (Ambrožová 1995).

The first analyses of mud and water were published by Metzger (1892), and later by Hannamann in Frič & Vávra (1897). The review of hydrochemical data is in Veselý (1994, 1996), Veselý & Majer (1992), and Vrba et al. (1996). Černé Lake was the second in the hierarchy of atmospherically acidified lakes in the Bohemian Forest, with sulphate and nitrate as the dominant anions (Procházková & Blažka 1999), with a high content of total Al and also with a high content of heavy metals, such as Be and Cd (Veselý 1987). Since the 1980s, when the acidification culminated, all hydrochemical parameters have slowly been improving. More detailed information is available in Veselý (1994, 1996), Straškrabová (1995), Vrba et al. (2000, 2003), and Nedbalová et al. (2006). The data are comparable with those of Psenner (1989), who studied some lakes from the Eastern Central Alps, where the catchments were also siliceous. According to Kamenik et al. (2001), bedrock mineralogy can explain 14.5% and vegetation 13.2% of the variation in water chemistry of lakes in the Alps. More detailed information about the hydrochemistry of Černé Lake is available in Facher & Schmidt (1996), Veselý (1987, 1996), and Vrba et al. (2000).

Zooplankton were more rich a century ago (Frič 1872, Frič & Vávra 1897, Pražáková & Fott 1994) when *Holopedium gibberum* Zaddach and another 4 species of planktonic Crustacea were collected from a total of 22 species. During the 1930s *Ceriodaphnia guadrangula* O.F. Müller was dominant. The extinction of Crustacea was likely the result of high Al content (Veselý 1994, Vrba et al. 2006). Recovery of the zooplankton, which are principal for control of planktonic algae, was recently observed (Vrba et al. 2003, Nedbalová et al. 2006).

The ichthyofauna was represented by brown trout (*Salmo trutta* L.) within the lake in 1860. In the years 1890–1893 over 40 000 young brook trout (*Salvelinus fontinalis* Mitchill) were introduced. The species lived in the lake until ca. 1975 (Veselý 1987, Vrba et al. 2003).

Nutrients in Černé Lake are limiting for algae. Total P, at 2.2–6.3 $\mu g.l^{-1}$ (after Vrba et al. 1996), must be the limiting element. Acidification is also controlling nutritional conditions for phytoplankton, in particular P availability (Vrba et al. 2006).

Sampling and determination

Phytoplankton was collected with a van Dorn sampler, the surface samples placed directly into plastic bottles, near the outlet of the lake. Samples were transported to the laboratory alive, in a cooling box. Filtration was done through a Synpor S-4 membrane filter (Synthesia, Czech Republic) in a positive pressure set, after E. Stuchlík (unpubl. data). A sample of 1–5 l was concentrated by filtration to a volume of 10 ml, then centrifuged live, and concentrated into a drop for a preparation. Preserved samples were immediately fixed at the lake with Lugol's solution and concentrated by sedimentation. The phytobenthos on stones and wood was collected with both toothbrush and knife. Algae growing on the lake bottom were collected by a Cori sampler, or by divers, who placed the samples into plastic syringes. Preparations were studied by an Amplival light microscope (Zeiss, Jena, Germany) equipped with

HI 100/1.25 or 40/0.95 objectives, then pencilled or photographed using MA8 film with a BA-1 automatic exposure unit (Zeiss, Jena, Germany). Bacillariophyceae were prepared by boiling with H_2O_2, with a spike of $K_2Cr_2O_7$, and mounted into Pleurax (of our own production), or alternatively used for transmission electron microscopy: specimens were fixed in 3% glutaraldehyde in 0,1 M phosphate buffer (pH 7.2) and postfixated by 1% osmium tetroxide. After several washes and dehydratation through alcohol series, samples were embedded in Spurr resin (Polysciences Inc.). Ultrathin sections were cut on ultramicrotome (Leica UCT), successively stained by lead citrate and uranyl acetate, and finaly examined in transmission electron microscope JEM1010 (JEOL, Japan) equipped with a CCD camera MegaWiev III (SIS Germany). For scanning electron microscopy (SEM) the specimens were fixed by 2.5% glutaraldehyde in 0.1 M potassium phosphate buffer (pH 7.2), postfixed by 1% osmium tetroxide in the same buffer, dehydrated through a graded acetone series and dried in the critical point drier Pelco CPD2. Then the samples were coated with gold and examined with scanning electron microscope JEOL 6300 (Japan).

Algae and Chytridiales were determined by using the monographs of Sparrow (1960), Huber-Pestalozzi (1961, 1962), Fott (1962), Sieminska (1964), Starmach (1966, 1968a,b), Batko (1975), Hindák (1978), Ettl (1983), and Komárek & Fott (1983). Both some unpublished results and drawings were taken from the field notebook of B. Fott (unpubl. data).

Results and discussion

The list of the algae determined in Černé Lake is in Table 1 (documented in Figs. 1–20). There are altogether 422 species, including the lake wall (a stony slope rising above the lake) and sediment core, 260 species were recent. Only 17 were planktonic, 75 species were found as subaerophytes in the lake wall. The majority of algal species of the lake occured in the benthos (90 species, Table 2). A similar proportion between the phytoplankton and benthos was found in the other lakes of the Bohemian Forest area, including the lakes of the Bavarian Forest (Weilner 1997).

The species richness (Table 3) of Algae and Cyanobacteria of mountain lakes is generally controlled by altitude. The species richness of phytoplankton in the High Tatra Mts. lakes was 2–13, and inversely related to altitudes of 1300–2200 m a.s.l. (Lukavský 1994); the total number of species was 161 (Juriš & Kováčik 1987). Sanches-Castillo (1988) evaluated the algal flora of lakes in the Sierra Nevada (Spain), at altitudes of 2500–3000 m, and found up to 149 taxa; Starmach (1973) studied algae in the largest lake, Wielki Staw, in the Polish High Tatra Mts., where species richness was 140 taxa. Nedbalová (2001) found 30 common species of phytoplankton in 7 lakes of the Bohemian Forest, Lederer & Lukavský (2001), Lukavský in Weilner (1997) evaluated the species richness of 3 lakes in the Bavarian side of the Bohemian Forest to be from 36–106. Černé Lake, with 260 species of algae and cyanobacteria, is a prominent locality.

The taxonomy affinity is not easy to compare because of different taxonomy systems, as well as the different specialisations and aims of the authors. However, rough comparisons are possible (Table 4). With respect to species richness, Černé Lake is the richest lake in the Bohemian Forest, followed by Grosser Arbersee, Kleiner Arbersee, and Rachelsee (the poorest); results for Laka Lake and Prášilské Lake have not yet been completed and published.

Benthic diatoms better reflect the changes in the environment of lakes than phytoplankton, and represent a prominent tool for the evaluation of water quality (Whitton & Rott 1996). Černé Lake was worked up by Steinich in Frič & Vávra (1897), who determined diatoms on the surface of mud from water depths of 30–35 m, and listed them along with excellent drawings (Fig. 11), so we are now better able to compare them.

Table 1. List of algae of Černé Lake 1898–2001 after **St** = Steinich in Frič & Vávra (1898), **Ha** = Hansgirg in Frič & Vávra (1898), **Fo** = B. Fott unpubl., leg.1935–1937, **Ro** = Rosa (1941), **Lu** = Lukavský (this study), leg. 1988–2000, **Re** = Řeháková in Schmidt (1992), **Am** = Ambrožová (1995), **Ne** = Nedbalová & Vrtiška (2000). C = core, after Řeháková in Schmidt (1992), C* = core after Břízová (1996), Cry = cryoseston, F = among filamentous algae in littoral, H = hypolimnion e.g. 20 m, I = on lake bottom among *Juncus* and *Isoëtes*, L = littoral of lake, M = mud on bottom in depth or core 0–10cm, N = neuston, P = plankton, Po = pool in lake slope or bank of lake, Pr = periphyton, R = wet stones or rocks at Lake Wall, S = stone submerged in lake, Sh = in *Sphagnum* on bank or wall, W = submerged wood or logs, x = precise stand not mentioned. * = see Taxonomy notes.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
CYANOBACTERIA (CYANOPHYTA, 42 taxa)								
Aphanocapsa montana Cramer				R, Po, F, L				
Aphanocapsa muscicola (Menegh.) Wille				R				
Aphanocapsa rufescens Hansg.				R				
Calothrix fusca Born & Flah.		x						
Calothrix parietina (Näg.) Thur.		x						
Calothrix solitaria Kirchn.		x						
Fischerella mirabilis (Beck-Managetta) Elenk. (= *Scytonema thermale* Kütz., *S. figuratum* Ag., *S. mirabile* (Dilw.) Born)		L		Po, S, I				
Gleocapsa aurata Stitz.				Sh				
Gleocapsa haematodes Kütz.				Sh				
Gleocapsa magna (Bréb.) Kütz.		L		R				
Gleocapsa montana Kütz.				R				
Gleocapsa rupestris Kütz.				R				
Gleocapsa sanguinea Ag. em. Nováček				R	M			
Hapalosiphon intricatus W. & G.S. West					I, L			
Hapalosiphon sp.					M			
Chroococcus giganteus W. West				R, Po				
Chroococcus minutus (Kütz.) Näg.		L		F, R				
Chroococcus montanus Hansg.		F		R				
Chroococcus pallidus Näg.				R				
Chroococcus tenax Hieron.				R				
Chroococcus turgidus (Kütz.) Näg. v. *subnudus* Hansg.				R				
Chroococcus sp.					I			

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Cyanosarcina sp.					I			
Limnothrix sp.								P
Lyngbya epiphytica Hieron.					M			
Lyngbya rigidula (Kütz.) Hansg.		x						
Merismopedia glauca (Ehr.) Näg. (=*M. glaucum* (Ehr.) v. *punctatum* Hansg.			x					
Merismopedia punctata Meyen.				P, R, Po	I			
Microcystis pulvera (Wood.) Forti in De Toni				P				
Oscillatoria insignis Skuja					M			
Oscillatoria sp.					I			
Pleurocapsa minor Hansg. (= *P. concharum* Hansg.)				S, R				
Pseudanabaena minuta Skuja					M			
Pseudanabaena sp.					P, I		P	P
Scytonema cinncinatum Thur ex Boorn. & Flah.					M, I			
Spirulina laxa Smith					M			
Stigonema hormoides (Kütz .) Born & Flah.				S, L				
Stigonema informe Kütz.		x		L				
Stigonema ocellatum Thuret		x						
Synechococcus elegans (Wolosz.) Kom.							P	
Tolypothrix lanata Wartm.		W						
EUBACTERIA								
Bacteria					P			
CHRYSOPHYCEAE (23 taxa)								
Bitrichia ollula (Fott) Bourr. (= *Diceras ollula* Fott)			P		P		P	P
Dinobryon divergens Inhof					P			
Dinobryon protuberans Lemm. (= *D. pediforme* (Lemm.) Steinecke)			P	P	P		P	P
Dinobryon sertularia Ehr.				P				
Dinobryon sp.								

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Gleochrysis turfosa (Pasch.) Bourr. (= *Geochrysis turfosa* Pasch.)					M, W			P
Chromulina echinocystis Conr.					M			
Chromulina ovalis Klebs							P	
Chromulina sp.			x					P
Chrysopyxis paludosa Fott					I			
Mallomonas acaroides Perty					M			
Mallomonas crassisquama (Asmund) Fott					M			
Mallomonas doignonii Bourr. em. Asmund & Cronberg					M			
Mallomonas cf. *pseudocoronata* Presc.					M			
Mallomonas sp.							P	P
Ochromonas fragilis Dofl.							P	
Ochromonas stellaris Dofl.					M			
Ochromonas vallesiaca Chodat			P					
Ochromonas sp.					M			P
Sphaleromantis sp.			P					
Synura echinulata Korsch.							P	P
Synura sphagnicola Korsch.					M			
STOMATOCYSTS								
Stomatocyst 35 Duff & Smol 1989 (= *Ochromonas stellaris* Dolfen, or *Mallomonas doignonii* Bourr. em. Asmund & Cromberg)					M			
Stomatocyst 73 Duff & Smol 1991					M			
DINOPHYCEAE (12 taxa)								
Amphidinium larvae Lindem.					P			
Glenodinium montanum Klebs.				R, Po				
Gymnodinium lantzschii var. *lantzschii* Uterm.			P					
Gymnodinium sp.			P					P
Gymnodinium überrimum (Altman) Kofoid & Swezy					P		P	P

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Katodinium bohemicum (Fott) Litvinenko			P		P		P	P
Katodinium planum (Fott) Loeblich III.								P
Peridinium africanum Lemm. (= *P. africanum* tab. *remotum* f. *tatrica* (Wolosz.) Lefévre, *P. tatricum* Wolosz.)			P	P				
Peridinium inconspicuum Lemm. (= *Peridinium umbonatum* Stein)					P		P	P
Peridinium palustre (Lindem.) Lefévre (= *P. chalubiński* Wolosz.)				I, M				
Peridiniuim pusillum (Pennard) Lemm. (= *Glenodinium pusillum* Penard)				Sp				
CRYPTOPHYCEAE (5 taxa)								
Cryptomonas cf. *compressa* Pasch.			P					
Cryptomonas compressa Pasch.			x					
Cryptomonas erosa Ehrenberg								P
Cryptomonas gracilis Skuja							P	
Cryptomonas ovata Ehr.							P	
BACILLARIOPHYCEAE (total 227, core 155)								
Achnantes altaica (Poretzky) Cleve-Euler						C		
Achnantes bioretii Germain					M			
Achnantes conspicua A. Mayer						C		
Achnantes helvetica (Hustedt) Lange-Bertalot						C		
Achnantes helvetica minor Flower & Jones						C		
Achnantes lanceolata (Bréb.) Grun.					M			
Achnantes lanceolata ssp. *frequentissima* Lange-Bertalot						C		
Achnantes levanderi Hust.						C		
Achnanthes marginulata Grun.					M			
Achnantes minutissima v. *minutissima* Kütz.						C		
Achnantes nodosa Cl.						C		
Achnantes oblongella Oestrup						C		

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Achnantes ploennensis Hust.					M			
Achnantes subatomoides (Hust.) Lange-Bert. & Archibald						C		
Achnantes trinodis (W. Smith) Grun.						C		
Achnantes sp.						C	P	
Amphora ovalis (Kütz.) Kütz.	M							
Anomoeoneis brachisira (Bréb.) Grun.						C		
Anomoeoneis serians (Bréb.) Cl. (= *Navicula serians* Bréb.)	M			R, Sh	M	C		
Anomoeoneis vitrea (Grun.) Ross						C		
Asterionella formosa Hass.					M			
Aulacoseira alpigena (Grun.) Kram.					M	C		
Aulacoseira distans (Ehr.) Simonsen						C		
Aulacoseira distans v. *nivalis* (W. Smith) Haworth					M	C		
Aulacoseira italica (Ehr.) Simonsen						C		
Aulacoseira leavissima (Grun.) Kram.					M	C		
Aulacoseira lacustris (Grun.) Kram.					M	C		
Aulacoseira lirata (Ehr.) Ross					M	C		
Aulacoseira nygardii Camburn						C		
Aulacoseira perglabra (Oestrup) Haworth					M	C		
Aulacoseira pfaffiana (Reinsch.) Kram.					M	C		
Aulacoseira valida (Grun.) Kram.					M	C		
Aulacoseira sp.					M	C		
Caloneis bacillum (Grun.) Cl.						C		
Cocconeis pediculum Ehr.	M							
Cyclotella ocellata Pantoczek						C		
Cyclotella radiosa (= *C. comta* (Grun.) Lemm.)						C		
Cyclotella sp.					M			
Cymbella aequalis W. Smith					M			

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Cymbella cf. *cesatii* (Rabenh.) Grun.					M	C		
Cymbella delicatula Kütz.				R, I				
Cymbella gaeumannii Meister						C		
Cymbella hebridica (Grun.) Cl.					M	C		
Cymbella microcephala Grun.				R, I				
Cymbella minuta Hilse						C		
Cymbella parva (W. Smith) Cl. (= *C. hungarica* (Grun.) Pantoczek, *Cocconema parvum* W. Smith)	M			P, L				
Cymbella perpusilla Cleve-Euler			x					
Cymbella silesiaca Bleisch						C		
Cymbella sinuata Gregory						C		
Cymbella stomatophora Grun. (= *C. tumida* (Bréb.) Van Heurck)	M							
Cymbella sp.					M			
Denticula tenuis Kütz.						C		
Diatoma anceps (Ehr.) Kirchn.					M			
Diatoma elongatum (Lynb.) Ag. (= *D. tenuis* Ag.)				R, S, W, x				
Diatoma elongatum v. *minor* Grun.				x				
Diatoma elongatum v. *tenue* (Ag.) V. H.				x				
Diatoma hyenalis v. *quadrata* (Kütz.) Ross					M			
Diatoma hyemalis (Roth) Heiberg						C		
Diatoma mesodon (Ehr.) Kütz.					M	C		
Diatoma vulgaris v. *brevis* Grun.				S, I				
Diploneis sp.						C		
Epithemia zebra v. *saxonica* Grun. (= *E. adnata* (Kütz.) Bréb.)				P				
Eunotia arcus Ehr. (= *Himatidium arcus*)	M			R, P				
Eunotia arcus Ehr. v. *bidens* Grun.				R				
Eunotia bacetriana Ehr.						C		

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Eunotia biggiba Kütz.					M			
Eunotia bilunaris (Ehr.) Mills (= *E. lunaris* (Ehr.) Grun.)				R, S, I	M	C		
Eunotia bilunaris v. *mucophila* Lange-Bertalot & Norpel						C		
Eunotia diodon Ehr.						C		
Eunotia exigua (Bréb.) Rabenh.				R	M	C		
Eunotia exigua f. *bidens* Hust.						C		
Eunotia exigua v. *tenella* (Grun.) Hust.						C		
Eunotia faba Ehr.						C		
Eunotia fallax Cl. (= *Gunetia fallax* Cl.)						C		
Eunotia formica Ehrenb.					M			
Eunotia glacialis Meister						C		
Eunotia hemicyclus (Ehr.) Ralfs in Pritchard						C		
Eunotia incisa O. Müller					M	C		
Eunotia incisa Reg.				R, P				
Eunotia maior (W. Smith) Rabenh. v. *bidens* (Greg.) Rabenh.	M							
Eunotia meisteri Hust.						C		
Eunotia meisteri v. *bidens* Hust.						C		
Eunotia microcephala Krasske						C		
Eunotia minor (Kütz.) Grun.						C		
Eunotia monodon Ehr.					M			
Eunotia muscicola v. *tridentula* Norpel & Lange-Bertalot						C		
Eunotia naegelii Migula						C		
Eunotia paludosa Grun.						C		
Eunotia paludosa v. *trinacarina* (Krasske) Norpel						C		
Eunotia parallela Ehr.						C		
Eunotia pectinalis (Dillwyl) Rabenh. (= *Himantium pectinale* Kg.)	M			Sh, M		C		
Eunotia praerupta Ehr.					M	C		

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Eunotia rhomboidea Hust. (= *Eunotia robusta* Ralfs, *Himantium polydon* Ehr.)	M			R, I		C		
Eunotia rhynchocephala Hust.						C		
Eunotia robusta Ralfs (= *Eunotia serra* Ehr.)					M			
Eunotia cf. *septentrionalis* Oestrup						C		
Eunotia serra Ehr.					M			
Eunotia serra v. *diadem* (Ehr.) Patrick					M	C		
Eunotia serra v. *serra*						C		
Eunotia soleirolli (Kütz.) Rabenh						C		
Eunotia subarcuatoides Alles & al.					M	C		
Eunotia sudetica O. Müller						C		
Eunotia sudetica v. *bidens* Hust.					M			
Eunotia sp.					M, I	C		
Fragilaria arcus Ehr.						C		
Fragilaria capucina Desmazieres					M	C		
Fragilaria capucina v. *rumpens* (Kütz.) Lange-Bertalot						C		
Fragilaria constricta Ehr.						C		
Fragilaria exigua Grun.						C		
Fragilaria famelica (Kütz.) Lange-Bertalot						C		
Fragilaria ulna (Nitzsch.) Lange-Bertalot	M	x						
Fragilaria virescens Ralfs					M	C		
Fragilaria sp.						C	P	
Frustulia rhomboides (Ehr.) De Toni (= *Navicula rhomboides* Ehr., *N. saxonica* Rabenh., *Frustulia rhomboides* v. *saxonica* Cl.)	M			R, P, I	R, I, P	C		
Gomphonema acuminatum Ehr. v. *trigonocephalum* (Ehr.) Grun.				P, L				
Gomphonema angustatum Agardh						C		
Gomphonema augur v. *turris* (Ehr.) Lange-Bertalot						C		
Gomphonema gracile Ehr.						C		

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Gomphonema parvulum (Kütz.) Kütz.					M	C		
Hannaea arcus (Ehr.) Patrick					M			
Hantzschia amphioxys (Ehr.) Grun.	M					C		
Melosira arentii (Kolbe) Nagumo &. Kobayasi (= *Cyclotella arentii* Kolbe)					M			
Melosira distans (Ehr.) Kütz. v. *litara* (Ehr.) O. Müller (= *Galionella litara* Ehr., *G. distans* Ehr.)	M			M, S, I				
Melosira sp. (= *Galionella* sp.)	M				I		P	
Meridion circulare (Greville) Ag.						C		
Meridion circulare v. *constrictum* (Ralfs) Van Heurck (= *Meridion constrictum* Ralfs)	P	x						
Navicula accomoda Hust.						C		
Navicula atomus (Kütz.) Grunow						C		
Navicula borealis Kütz.	M			P, Sh				
Navicula borgeri Krasske						C		
Navicula brébissonii Kütz.	M							
Navicula bremensis Hust.						C		
Navicula bryophila Petersen						C		
Navicula contenta Grun.				R				
Navicula difficillima Hust.						C		
Navicula festiva Krasske						C		
Navicula gallica v. *laevissima* (Cleve) Lange-Bertalot						C		
Navicula gibba (Ehr.) Kütz.	M							
Navicula gigas F.	M							
Navicula heimansii Van Dam & Koovm.						C		
Navicula hoefleri Cholonky						C		
Navicula krasskei Hust.						C		
Navicula kriegeri Krasske						C		
Navicula maior (Kütz.) Ehr.	M							

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Navicula major Ehr.	M							
Navicula mediocris Krasske						C		
Navicula minima Grun.				R, Sh				
Navicula minuscula v. *muralis* Lange-Bertalot						C		
Navicula cf. *molesta* Krasske						C		
Navicula mutica Kütz.						C		
Navicula muticoides Hust.						C		
Navicula nivalis Ehr.						C		
Navicula radiosa Kütz.						C		
Navicula saxophila Bock						C		
Navicula seminulum Grun.						C		
Navicula schmassmannii Hust.						C		
Navicula soehrensis v. *muscicola* (Petersen) Krasske						C		
Navicula stauroptera Grun. (= *Pinnularia gibba* Ehr.)	M							
Navicula subcapitata v. *hilseana* Hust. (= *N. hilseana* Hust.)	M							
Navicula subtilissima Cl.						C		
Navicula tenuicephala Hust.						C		
Navicula viridis Kütz. (= *Pinnularia viridis* Ehr.)	x			x				
Navicula viridis Kütz. v. *clevei* Meister				x				
Navicula viridis Kütz. v. *elliptica* Meister				x				
Navicula viridis Kütz. v. *rupestris* (Hantsch.) Cl.				R, Sh, P, Pr				
Navicula vulgaris Twait (= *Frustulia vulgaris* Cl. f. *vulgaris* (Twait.) De Toni)				P				
Navicula sp.						C		
Neidium affine (Ehr.) Pfitzer (= *Navicula affinis* Ehr.)	M					C		
Neidium affine var. *amphirhynchus* (Ehr.) Cl.						C		
Neidium affine v. *longiceps* (Gregory) Cl.						C		
Neidium alpinum Hust.						C		

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Neidium bisulatum (Langeerstedt) Cl.						C		
Neidium hercynicum A. Mayer						C		
Neidium iridis (Ehr.) Cl.					M			
Neidium iridis (Ehr.) Cl. v. *amphiatum* (Ehr.) Cl.					M	C		
Neidium productum (W. Smith) Cl.						C		
Neidium sp.						C		
Nitzschia gracilis Hantsch						C		
Nitzschia microcephala Grun.				R, Sh				
Nitzschia obtusa W. Smith					M			
Nitzschia palea (Kütz) W. Smith						C		
Nitzschia perminuta (Grun.) M. Pergallo						C		
Nitzschia sigma (Kütz.) W. Smith	M							
Nitzschia sp.					M	C		
Peronia fibula (Bréb.) Ross					M	C		
Pinnularia appendiculata (Ag.) Cl.						C		
Pinnularia borealis Ehr.						C		
Pinnularia divergens W. Smith						C		
Pinnularia gibba Ehr.					M	C		
Pinnularia cf. *legumen* (Ehr.) Ehr.					M			
Pinnularia interrupta W. Smith					M	C		
Pinnularia interrupta f. *minutissima* Hust.						C		
Pinnularia lata (Bréb.) W. Smith						C		
Pinnularia maior (Kütz.) Rabenh.						C		
Pinnularia microstauron (Ehr.) Cl.					M	C		
Pinnularia nodosa Ehr.					M			
Pinnularia rupestris Hantsch.						C		
Pinnularia semicruciata (Ehr.) Cl.						C		

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Pinnularia subcapitata Gregory						C		
Pinnularia subcapitata v. *hilseana* (Janisch) O. Müller						C		
Pinnularia cf. *subsolaris* (Grunow) Cleve					M			
Pinnularia sudetica (Hilse) Peragollo					M	C		
Pinnularia viridis (Nitzsch.) Ehr.					M	C		
Pinnularia sp.					M	C		
Rhoicosphaenia curvata (Kütz.) Grun.				R				
Stauroneis anceps Ehr.					M			
Staruroneis anceps v. *gracilis* (Ehr.) Brunt.	M					C		
Stauroneis phoenicentron (Nitzsch.) Ehr.	M					C		
Stauroneis phoenicenteron Ehr. v. *gemina* Cl.				R				
Stenopterobia curvula (W. Smith) Kram.						C		
Stenopterobia delicatissima (Lewis) Bréb.					M	C		
Surirella augusta Kütz.					M			
Surirella biseriata Bréb.				M, I	M			
Surirella biseriata v. *bifrons* Kg.	M				M	C		
Surirella cf. *bohemica* Maly					M			
Surirella linearis W. Smith	M				M	C		
Surirella cf. *roba* Leclercq					M			
Surirella robusta Ehr.					M			
Surirella sp.						C		
Synedra ulna (Nitzsch.) Ehr.					M			
Tabellaria binalis (Ehr.) Grun.						C		
Tabellaria fenestrata (Lyngb.) Kütz.	M							
Tabellaria flocculosa (Rothm.) Kütz.	M			R, Sh	M	C		
Tabellaria quadriseptata Knudson						C		
Tabellaria ventricosa Kütz.						C		

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Tabellaria quadriseptata Knudson						C		
Tabellaria sp.							P	
RHODOPHYTA (5 taxa)								
Audouinella sp. (=*Chantransia* sp.)				S	S			
Batrachospermum vagum (Both.) Ag.		I						
Batrachospermum vagum v. *keratophyllum* (Bory) Sirod.		I						
Chantransia hermanni (Roth.) Desw.		S						
HETEROKONTAE (2 taxa)								
Isthmochloron trispinatum (W. & G.S. West) Skuja								P
Monollanthus stichococcoides Pasch.*		x						
CHLOROPHYCEAE (104 taxa)								
Binuclearia tectorum (Kütz.) Beger in Wichm.					W, I			
Botryococcus braunii Kütz.						C*		
Botryococcus pila Kom. & Marvan						C*		
Botryococcus neglectus (W. et G.S. West) Kom. & Marvan						C*		
Carteria multifilis (Fres.) Dill.							P	P
Carteria radiosa Korsh.								P
Carteria cf. *simplex* Pasch.			P	x				
Chlamydomonas angustissima Ettl					P			
Chlamydomonas bourrelyi Ettl							P	
Chlamydomonas costata Korsch.					M			
Chlamydomonas praecax Pasch.					P			
Chlamydomonas sp.			P	P				P
Chlorella miniata (Näg.) Oltm. (=*Pleurococcus miniatus* Näg.)				R				
Chlorococcum botryoides Rabenh. = *Protococcus botryoides* (Kütz.) Kirchen		L, F		F, x				
Chlorogonium fusiforme Matv.				N	P		P	P

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Chloromonas acidophila (Nyg.) Gerloff & Ettl							P	
Chloromonas angustissima (Ettl) Gerloff & Ettl				P	P			P
Chloromonas brevispina (Fritsch) Hoham, Roemer et Mullet (= *Cryocystis brevispina* (Fritsch) Kol, *Cryodactylon glaciale* Chodat, *Chodatella brevispina* Fritsch)					Cry			
Chloromonas cryophila Hoh. & Mullet (= *Scotiella cryophila* Chod.)					M			
Chlorosarcina superba Skuja					P, I			
Chlorosphaera angulosa (Corda) Klebs				R, Po				
Cladophora fracta (Kütz.) v. *lacustris* (Kütz.) Brand (= *C. sudetica* Kütz.)				L, B, S				
Coelastrum pascheri Luk.					M			
Coenochloris plankonvexa Hind.					S, L, W			
Dicranochaete bohemica Novák & Popovský					S			
Dicranochaete sp.				S				
Eremosphaera viridis De Bary f. *minor* G.S. Moore				R, Sh				
Hormidium flaccidum A. Br. f. typica (= *Hormiscia flaccida* (Kütz.) Lagerh.)				R				
Hormidium rivulare Kütz. (=*H. rivularis* (Kütz.) Hansg.)				R, S				
Gloeocystis botryoides (Kütz.) Näg.				R				
Gloeocystis rupestris (Lyngb.) Rabenh.				R				
Gloeocystis vesiculosa Näg.				R				
Klebsormidium sp.					I			
Koliella corcontica Hind.*					P			P
Menoidium sp.					M			
Microspora floccosa (Vauch.) Thuret (= *Conferva floccosa* Desv.)		L						
Microspora pachyderma (Wille) Lagerh.				R, L				
Microspora rufescens (Kütz.) Lagerh.				R, L, Sh				
Microspora stagnorum (Kütz.) Lagerh. (= *Conferva stagnorum* Kütz.)				S, Sh, P				
Microspora sp.				S	I			
Microthamnion strictissima Rabenh.				S	L, S			

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Monoraphidium cf. *dybowskii* (Wolosz.) Hind. & Kom.-Legn.								P
Nephrocytium agardhianum Näg. (= *N. naegeli* Grun.)				R				
Oedogonium crispum Wittr. & Nordst.		S						
Oedogonium cryptoporum Wittr.		S						
Oedogonium tenuissimum Hansg.		S						
Oedogonium sp.					I			
Ophiocytium cochleare A. Braun		F						
cf. *Pseudococcomyxa*					S			
Provasoliella sp.				H				
Pseudochlorella pyrenoidosa (Zeitl.) Lund					R			
Raphidonema nivale Lagerh.*			P				P	
Rhizoclonium hieroglyphicum (Ag.) Kütz. ampl. Stockmayer subsp. *hieroglyphicum* Kütz.				R, S, F				
Scenedesmus helveticus Chod.					P			
Scenedesmus sp.							P	
Schizochlamys gelatinosa A. Br.				R, Sh				
cf. *Stichococcus*			P					
Stigeoclonium tenue Kütz.		S		W				
Tetraspora gelatinosa (Vauch.) Desv.		Po						
Tetraëdron minimum (A. Br.) Hansg.								P
Tribonema tenerrimum Heering (= *Conferva tenerrima* Kütz.)		L						
Ulothrix tenerrima Kütz.				W	L, W			
DESMIDIALES (38 taxa)								
Arthrodesmus bifidus Bréb.				P, L				
Closterium cynthia De Not. v. *jenneri* (Ralfs) Krieger (= *C. jenneri* Ralfs)				I				
Closterium intermedium Ralfs				P, L				
Closterium navicula (Bréb.) Lütk. (= *Penium navicula*) Bréb., *P. closteroides* Bréb.)				R, Sh				
Closterium striolatum Ehr.		L						

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Closterium striolatum Ehr. v. parvulum Näg.				L, Sh				
Cosmarium margaritiferum Menegh. f. *regularior* West (= *C. confusum* Cooke v. *regularis* Nordst.)				R, Sh				
Cosmarium obliquum Nordst.				R				
Cosmarium palangula Bréb. (= *Dysphinctium palangula* Bréb.)		L						
Cosmarium parvulum Näg.		L						
Cosmarium phaseolus Bréb. v. *elevatum* Nordst.				R				
Cosmarium quadratum Ralphs f. *willei* W. West & G.S. West (= *Dysphinctium quadratum* (Ralfs) Hansg. v. *willei* Schmidle)				R, F				
Cosmarium trachypleurum Lund				R, Sp				
Cosmarium undulatum Corda v. *minutum* Wittr.				R, Sp				
Cosmarium subtumidum Norst.				R, F				
Cylindrocystis brébissonii Menegh.				R, Sh				
Cylindrocystis brébissonii Menegh. v. *jenneri* (Ralfs) Hansg. (= *Penium jenneri* Ralfs, *P .brébissoni* (Menegh.) Ralfs v. *jenneri* (Ralfs.) Kirchn., *Cylindrocystis jenneri* (Ralfs) W. West & G.S. West.)				R, Po				
Cylindrocystis crassa De Bary				R, Sh				
Euastrum ansatum (Ehr.) Ralfs		L						
Euastrum binale (Turp.) Ehr.				x				
Euastrum binale v. *gutwinski* Schmidle				R				
Euastrum didelta (Turp.) Ralfs		L						
Mesotaenium chlamydosporum De Bary				R				
Mesotaenium de greyi Turn.				R, Sh				
Mesotaenium de greyi v. *breve* W. West				R				
Mesotaenium de greyi v. *tenuis* W. West & G.S. West.				R, Sh				
Mesotaenium macrococcus (Kütz.) Roy & Bisset v. *micrococcum* Kütz.				R				
Micrasterias rotata (Grév.) Ralfs		L						
Netrium digitus (Ehrenb.) Itzigs. & Rothe (= *Penium digitus* Bréb., *P. interruptum* Bréb.)				Sh, R				

Table 1. Continued.

	St	Ha	Fo	Ro	Lu	Re	Am	Ne
Penium cylindrus (Ehr.) Bréb.					L, W			
Staurastrum dilatatum Ehr.				R				
Staurastrum hirsutum (Ehr.) Bréb.		x						
Staurastrum muticum Bréb. v. *hirsutum* (Ehr.) Bréb.		L						
Staurastrum pileolatum Bréb. v. *cristatum* Lütkem				R				
Staurastrum puctuatum Bréb. v. *pygmaeum* (Bréb.) W. West & G.S. West (= *S. pygmaeum* Bréb.)				R, F				
Tetmemorus brébissonii (Menegh.) Ralfs				R, F				
Tetmemorus laevis (Kütz.) Ralfs				R				
Tetmemorus laevis (Kütz.) Ralfs v. *minutus* (De Bary) (= *T. minutus* De Bary)		L		R				
ZYGNEMACEAE (6 taxa)								
Mougeotia parvula Hass.		L						
Mougeotia viridis (Kütz.) Wittr.		x						
Mougeotia sp. steril. diam. 5–6 µm cf. *M. parvula, M. viridis*				R, L				
Mougeotia sp. steril. diam. 7 µm				L, W	L, W			
Mougeotia sp. steril. diam. 12 µm				L, W	L, W			
Zygnema stellinum (Vauch.) Ag. v. *tenue* (Kütz.) Kirchen.				R				
FUNGI (3 taxa)								
cf. *Actinospora megalospora*					P			
Chionaster nivalis (Bohl.) Wille (= *C. bicornis* Kol)					M			
Torulopsidosira ellipsoidea Tschermak-Woess					I			
CHYTRIDIALES (3 taxa)								
Micromycopsis zygnemicola Cejp				R				
Rhizophydium polinis-pini (Braun) Zopf					N			
Rhizophydium sp.					S			

Table 2. Species richness of algae of Černé Lake in different stands, after **St** = Steinich in Frič & Vávra (1897), **Ha** = Hansgirg in Frič & Vávra (1897), **Fo** = B. Fott unpubl., leg. 1935–1937, **Ro** = Rosa (1941), **Lu** = Lukavský 1988–1992, unpubl., **Re** = Řeháková in Schmidt et al. (1992). *Total species richness is 422, calculated from Table 1.

Stand (code in Table 1)	**St**	**Ha**	**Fo**	**Ro**	**Lu**	**Re**	**Am**	**Ne**
Stand not mentioned (x)	1	10	2	6	0	–	0	0
Plankton (P)	1	0	9	16	17	–	23	24
Mud on bottom (M)	30	0	0	0	90	–	–	–
Stone in lake (S)	–	5	0	12	6	–	–	–
Rocks at lake wall (R)	–	0	0	75	2	–	–	–
Littoral (L)	–	16	0	12	7	–	–	–
Wood in water (W)	–	0	0	5	7	–	–	–
In *Sphagnum* (Sh)	–	2	0	11	0	–	–	–
On *Isoëtes lacustris* (I)	–	1	0	2	18	–	–	–
Pool on bank (Po)	–	0	0	1	0	–	–	–
Periphyton (Pr)	–	0	0	1	0	–	–	–
Neuston (N)	–	0	0	1	1	–	–	–
Filamentous algae in littoral (F)	–	2	0	5	0	–	–	–
Hypolimnion (H)	–	0	0	1	0	–	–	–
Core (C)	–	–	–	–	–	158	–	–
Total (422*)	32	36	11	148	260	158	23	24

Table 3. Taxonomy affinity of Algae, Cyanobacteria and Chytridiomycetes in different mountain lakes (in %) and total species richness (in absolute numbers). **Luk**. – Černé Lake, core is not included, Lukavský (this paper), **Sanch**. – lakes of Sierra Nevada (Granada, Spain), Sanchez-Castillo (1988), **Starm** – lake Wielki Staw, the High Tatra Mts., Starmach (1973), **Juriš** – lakes in the High Tatra Mts., Juriš & Kováčik (1987), **Weiln**. – lakes in the Bavarian Forest, Weilner (1997), **GA** = Grosser Arbersee, **KA** = Kleiner Arbersee, **RA** = Rachelsee. After Lederer & Lukavský (2001).

Taxonomy affinity	**Sanch. S. Nevada**	**Starm. W. Staw**	**Juriš H. Tatra**	**Luk. Černé L.**	**Weiln. GA**	**Weiln. KA**	**Weiln. RA**
Cyanobacteria	21	30	5.6	18.5	16	20	14
Chromophyta				50.4	40	40	55
Chrysophyceae total	5		20.5	9.9	16	14	17
Chrysomonadales				8.6			
Dinophyceae	2		5.6	6.8	5.6	7	5.5
Bacillariophyceae	51	65	22.4	24.1	12.2	15.3	30
Heterokontae			0.6	0.9			
Cryptophyta			2.5	2.1	2	1	
Chlorophyta	28	4.3	27.9	44.3	23.6	21	19.4
Desmidiales			12.4	16.4	12.3	7	5.5
Zygnemaceae	34			2.6			
Euglenophyta	8		2.5	0	3	3.5	3
Rhodophyta		0.7		2.1	1	1	
Chytridiales, Fungi				1.2	2	6	3
Total spec. richness	**149**	**140**	**161**	**260**	**106**	**85**	**36**

Table 4. Taxonomy affinity of algae of Černé Lake, without Bacillariophyceae in the sediment core (157 taxa). Total species richness is 422, calculated from Table 1.

Cyanobacteria (Cyanophyta)		42
Chromophyta, total		117
	Chrysophyceae	23
	Chrysomonadales	20
	Dinophyceae	16
	Cryptophyceae	5
Chlorophyta, total		56
	Bacillariophyceae	2
	Heterokontae	103
	Desmidiales	38
	Zygnemaceae	6
Rhodophyceae		5
Chytridiales		3

In comparison with Steinich (in Frič & Vávra 1897), there have been 80 new taxa of Bacillariophyceae recorded for the lake (with the exception of a core, where 113 taxa were found by Řeháková in Schmidt et al. 1993). Unfortunately, it is hardly possible to avoid the influence of recent better sampling techniques, as well as the progress in taxonomy and determination literature, on the incremental increase of species diversity. On the other hand, 13 species of Bacillariophyceae disappeared from a total of 225 taxa of Bacillariophyceae, determined in the lake, including the core (this group is the most frequent at 24%, Table 3).

The littoral algae were not documented, but only listed without drawings by Hansgirg in Frič & Vávra (1897). That is why this group is less reliable for such comparisons, because concepts of species are changing over time, as well as due to the different weights given to characteristics, etc. Species missing from the list are: *Oedogonium cryptophorum*, *O. crispum*, and *O. tenuissimum*. The genus *Oedogonium* was substituted by genera *Binuclearia*, *Microspora*, *Microthamnion*, *Ulothix*, and mainly by *Mougeotia*, which is recognized as an indicator of acidification.

Isoëtes lacustris has no epiphytes on the surfaces of leaves, but they are covered by dense clusters of filaments associated with the plants (Fig. 10). Dominants during autumn (15 Oct 2004 and 2 Nov 2005) were *Scytonema cinncinatum*, *Mougeotia* sp. steril, *Oedogonium* sp., *Microspora amoena*, and *Melosira* sp. in different proportions, with additions of *Binuclearia tectorum* and *Klebsormidium ribonematoideum*. On the filaments, a few epiphytes were firmly attached, such as: *Chrysopyxis paludosa*, *Kephyrion inconstans* (syn. *Stenocalyx inconstans*), from Chrysophytes; together with the pennate diatom *Eunotia,* cyanobacterial genera *Cyanosarcina*, *Pseudanabaena*, *Phormidium*, and *Merismopedia*, and an epiphytic fungus *Torulopsidosira pallida*. The filaments are shadowing the plants, consuming nutrients and CO_2.

Snow algae: The elevation of the Bohemian Forest from 1000 m a.s.l. enables the persistence of snow fields until late spring and thus the development of cryoseston in some years. The first record of snow algae was in 1991–1992 (Lukavský 1993). A few green spots on snow fields on the lake wall, near the lake, were found in mid of May 1991. In the snow fields there were: *Chloromonas brevispina* (syn. *Cryocystis brevispina*, Fig. 10: 1–2), *Cryodactylon glaciale*, and spores of Deuteromycetes. Some species of cryoseston have also been recorded in the hypolimnion of the lake (fungus *Chionaster* and alga *Scotiella*-like cysts of

Chloromonas nivalis). The planktonic alga *Raphidonema nivale* also should be recognised as a cryoseston species, since it was described from coloured snow on Mt. Pichincha, Equador.

Long-term changes

Written records about life in Černé Lake date back to 1897, and core analyses enables us to evaluate the biological history of the lake from postglacial times. The genus *Botryococcus* was the dominant green alga found in cores at depths of 0.75–1 m, indicating a high eutrophication, that resulted from high rates of erosion caused by the retreat of the forest in this layer was as also suggested by high content of Mg (Břízová 1996, Veselý 1998). According to Jankovská & Komárek (1998), the 3 species of *Botryococcus (B. pila*, *B. neglectus*, and *B. braunii*) were the exclusive dominants during the whole Holocene period, especially in the Middle and Late Holocene, where *B. pila* indicate dystrophic conditions and *B. neglectus* mesotrophic ones. It is interesting that *Botryococcus* disappeared just recently; while *B. braunii* alone was once observed in the phytoplankton of the neighbouring Čertovo Lake (Lukavský, unpubl. data). A similar dominant role of *Botryococcus* was recorded in Slepé Pleso Lake in the High Tatra Mts., Slovakia (Lukavský 1994), however, this lake is only a small pool on the surface of a large peat bog.

Long-term trends in the hydrochemistry of acidified lakes have been discussed in several papers (Veselý 1996, Vrba et al. 2000). The concentrations of the principal ions (such as NO_3, SO_4) were increasing until 1985, and then, generally, have been slowly decreasing (Vrba et al. 2006). The dramatic decrease of SO_2 in the atmosphere (by ca. 70%) was followed by a 50% decrease of SO_4 in wet deposition, and a 26–30% decrease in the water of Černé Lake (Veselý 1996, Kopáček et al 2002, Kopáček & Vrba 2006). The NO_3 content in the water is also correlated with the decrease of both NH_4 and NO_3 in deposition.

Phosphorus, which is the limiting nutrient in Černé Lake, has not been periodically evaluated. Its concentration is connected with the total Al, which is capable of immobilizing P; so that acidification controls, via Al, the productivity of algae (also when the P load was stable for ca. 40 years; Vrba et al. 2000, 2006).

The quantity of algae in Černé Lake was evaluated for the first time by B. Fott (unpublished) who found, using centrifuation or an Utermöhl chamber, about 260 cells.ml^{-1} in the surface water (August 1936). In August 1992 following species were found (Ambrožová 1995): *Peridinium* (Fott = 68, Ambrožová = 165), *Monallanthus stichococcoides* (60/0), *Chromulina* and Chrysomonads (35/706), *Carteria*, *Chlamydomonas*, and green cells (30/0), *Merismopedia* (30/0), *Dinobryon protuberans* (16/14), *Bitrichia* (*Diceras) ollula* (10/706), *Cryptomonas* (3/0). *Peridinium* and Chrysophyta increased in quantity, while green flagellates and Heterokontae substantially decreased. The total cell number was 1828 cells.ml^{-1} in 1992, which is in contradiction to the trend indicated by Secchi depth (Fig. 21).

The Secchi depth of the lake has been changing considerably over time (Fig. 21). A substantial increase of Secchi depth in the period 1960–1990 can be explained by the precipitation of humic compounds, caused by Al (Kopáček et al. 2001b, Vrba et al. 2006). Even the origin of the name, Černé Lake, was inspired by the dystrophic, blackish water (Vrba et al. 2000). It may be, that this was the second acidification period in the lake's history, since the dystrophic Holocene period is indicated by the dominance of *Botryococcus pila* in the core (Jankovská & Komárek 1998).

The acidification of Černé Lake is still prominent, but an obvious recovery is indicated, e.g., by the comeback of *Ceriodaphia quadrangula* (Vrba et al. 2003). Acid substrates in the catchmend, numerous peat bogs within it, and norway spruce as the dominant tree in the surrounding forest have all accelerated acidification. Air pollution emissions were, however,

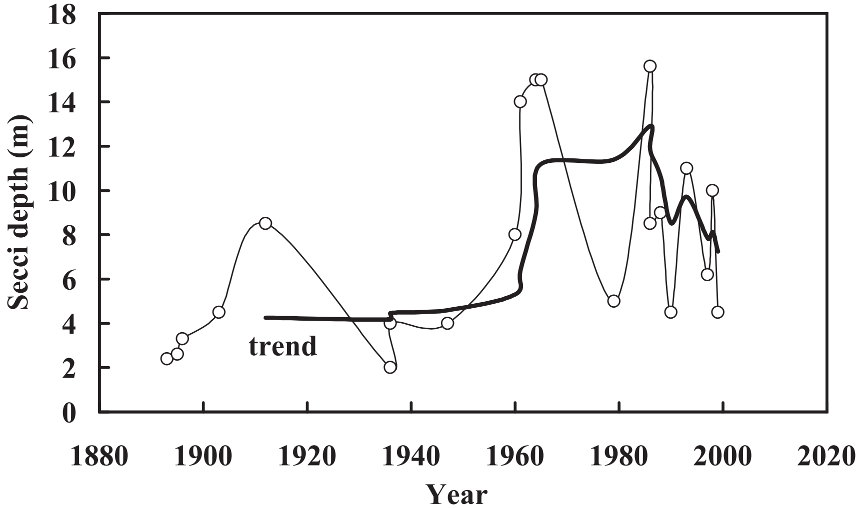

Fig. 21. Secci depth plotted from all available data from Černé Lake (Vrba et al. 2000). ○–○ individual data, ▬ trend, sliding average with step of 5 years.

the principal cause of the acidification. According to Veselý & Majer (1992), the Bohemian Forest was exposed to 11–18 kg.ha^{-1}.yr^{-1} of wet N deposition, which is about 35 kg.ha^{-1}.yr^{-1} of the total in the 1980s. Total S deposition was about 30 kg.ha^{-1}.yr^{-1} in 1990. Since that time, both the N and S deposition have been slowly decreasing (Veselý 2000), in concordance with general trends in Europe. According to Veselý (1994), changes in pH were for 1936: 6.3–7, 1947: 6.2, 1960: 6, 1976: 6, 1979: 4.3–4.8, 1989: 4.6. Long-term trends in acidification of the lakes were presented by Vrba et al. (2000), e.g. the black colour of the Černé Lake water in the past had then turned to blue and finally to green at the present. Acidification in the Bohemian Forest is specific; it is also influenced by the deposition of nitrogen compounds, such as NH_4. The concentration of NO_3 was about 10 µM.l^{-1} in 1935, up to 35 in 1960, and about 100 µM.l^{-1} in 1990. The most important genus indicating acidification, *Eunotia*, represents 16.4% of the total species richness of Bacillariophyceae within the lake. Present species indicating acidity are *Eunotia exigua*, *E. rhombidea*, *Pinnularia subcapitata*, and *Tabellaria flocculosa*.

Other anthropogenic impacts

Černé Lake, as well as the neighbouring Čertovo Lake, were intact until the 16th century. Afterwards, the virgin forest was cleared, and the wood used for charcoal in the local iron industry; later as a source of potash for the glass industry, as well as for timber (Veselý et al. 1993, Veselý 1998). The lake corrie was used for pasture, and a small hotel was built on the shore of Černé Lake around 1880. In 1911, the area was proclaimed as a nature reserve. In the 1950s, the whole catchment was closed as a frontier area and the hotel removed, with access by people curtailed. When the "iron curtain" fell in 1989, intensive tourist activities began, however, under some limitations (no free access of cars or free access into the corrie, etc.). In contrast, there are the intensively exploited Bavarian lakes (Grosser Arbersee and Kleiner Arbersee) with hotels, boat rentals, tourist pathways around the entire lake, etc. Only the Rachelsee is strictly protected. The species richness is highest in Grosser Arbersee and lowest in Rachelsee (Table 3). Černé Lake is in a middle position. Studies on other lakes in the Bohemian Forest have not been published yet, but species richness can be estimated as follows: Čertovo Lake – 50, Prášilské Lake – 40, Plešné Lake – 50, and Laka Lake – 50 (Lukavský, unpubl. data).

Taxonomy remarks

Černé Lake is a *locus classicus* for algal taxonomy. Fott (1937, 1938) described three species new to the science from here (*Bitrichia ollula*, *Katodinium bohemicum*, and *K. planum*); Rosa (1941) found 11 new species for Bohemia and Lukavský (2006) found *C. pascheri*, sp.n. and Stomatocyst 35 and Stomatocyst 73 sp.n. for Bohemia, as well in the lake.

Stomatocysts are a prospective tool for long-term monitoring, together with Bacillariophyceae and scales of chrysomonads, because they are very resistant to decay and could be determined from the sediment cores. Facher & Schmidt (1996) determined 126 morphotypes of stomatocysts in surface sediments of 50 lakes of Central Europe, with a strong correlation to pH ($r^2 = 0.78$). Černé Lake was sampled, but its cores have not been evaluated, yet.

Stomatocyst 35 Duff & Smol 1989 (Fig. 2: 14, Fig. 7: 2,3, Fig. 8: 1,2) is, according to the unpublished opinion of H. Kling, the cyst of *Mallomonas doignonii* (Duff et al. 1995). The cyst was also found on the surface of mud in the littoral and in the hypolimnion of Grosser Arbersee and Kleiner Arbersee in the Bavarian Forest. Until now, it has been mentioned as well from Canada: Northwest Territories, Lake Ontario, and British Columbia; USA: Connecticut, New York, and Oregon; and Europe: Denmark. It was found in acidic or neutral cold waters. This alga is new for the Czech Republic, as a recent organism, but it was found by Facher & Smith (1996) in Plešné Lake, in a core from the depth of 14.5–15 cm; it has no clear ecological preference according to the latter authors.

Stomatocyst 73 Duff & Smol 1991 (Fig. 7: 1). The biological affinity of this organism is unknown (Duff & Small 1995). It was described from Upper Wallface Pond, Adirondack Park, NY, U.S.A. from a core in a depth of 10–10.5 cm, and also from the Yukon Territory, Canada. It is produced by an organism tolerant to pH <5, and possibly to elevated concentrations of Al. This alga is new for Černé Lake, but it was found in the sediment of Plešné Lake in the depth of 19.5–20 cm by Facher & Schmidt (1996).

Raphidonema nivale Lagerh. This extremely pleiomorphic alga was described from cryoseston in Ecuador. Hoham (1973) tested it in laboratory cultures, and found that its morphological spectrum in some parts resembles a few species from other genera (e.g. *Koliella*, *Stichococcus*, and *Chodatella*). The alga may be more widely distributed, "morphologically camouflaged" as other genera (see the following paragraph).

"*Stichococcus* ?": There is also an interesting small alga, in an original drawing of B. Fott, from 1935 (and also 1936), labelled as "*Stichococcus* ?", with the note "green" (Fig. 1: 11). Retrospectively, it is impossible to identify it precisely. In the drawing from 1935, there are visible prominent oil drops, a parietal chloroplast, cells are rounded, and there is a vacuole in every tip of a cell. This alga was common in deep layers of the lake, almost 8000 cells.ml^{-1} in 20 m, also hundreds of cells.ml^{-1} in 37 m. The drawing from 1936 is a little different, cells were sometimes joined in chains, one chloroplast, but also a few tips of a cell sharpened after staining by gentian violet revealed the massive mucilage envelope. Other possible generic affiliations would be *Monallanthus brevicylindricus* Pasch., *Monallanthus stichococcoides* Pasch., or *Koliella sempervirens* Hindák. Because of the note "green", I also believe that *Raphidonema nivale* Hoham is the most probable determination of the B. Fott's "*Stichococcus ?*". Short cells of *Koliella corcontica* Andreoli (Fig. 3: 22, 23) also resemble this alga.

Koliella antarctica Andreoli et al. 1998 was isolated from samples of the sea near the Italian Station at Terra Nova Bay, Ross Sea, Antarctica. Cultivation in different salinities, however, demonstrated that the alga could be a freshwater or snow variety, and that it was subsequently transported to the sea. Its morphology, single to a few cell filaments, is very similar to the drawings of B. Fott.

Coelastrum pascheri Lukavský 2006. The alga was found several times in lakes of the Bohemian Forest: Černé Lake (leg. June 1989), as well as Grosser Arbersee and Kleiner Arbersee (both leg. July 1995), in *Sphagnum* sp. in the small puddle "Upolínová louka" in the Slavkovský Les Mts. (leg. May 1996). It is very similar to *Coelastrum morus* W. & G.S. West, sensu Skuja (1930), but differ in its ecology, cell size, and some other morphological features. One time, a coenobium with a more prolonged processes was observed, resembling *Coelastrum morus* f. *acutiverrucosum* Bourr. & Manguin 1946.

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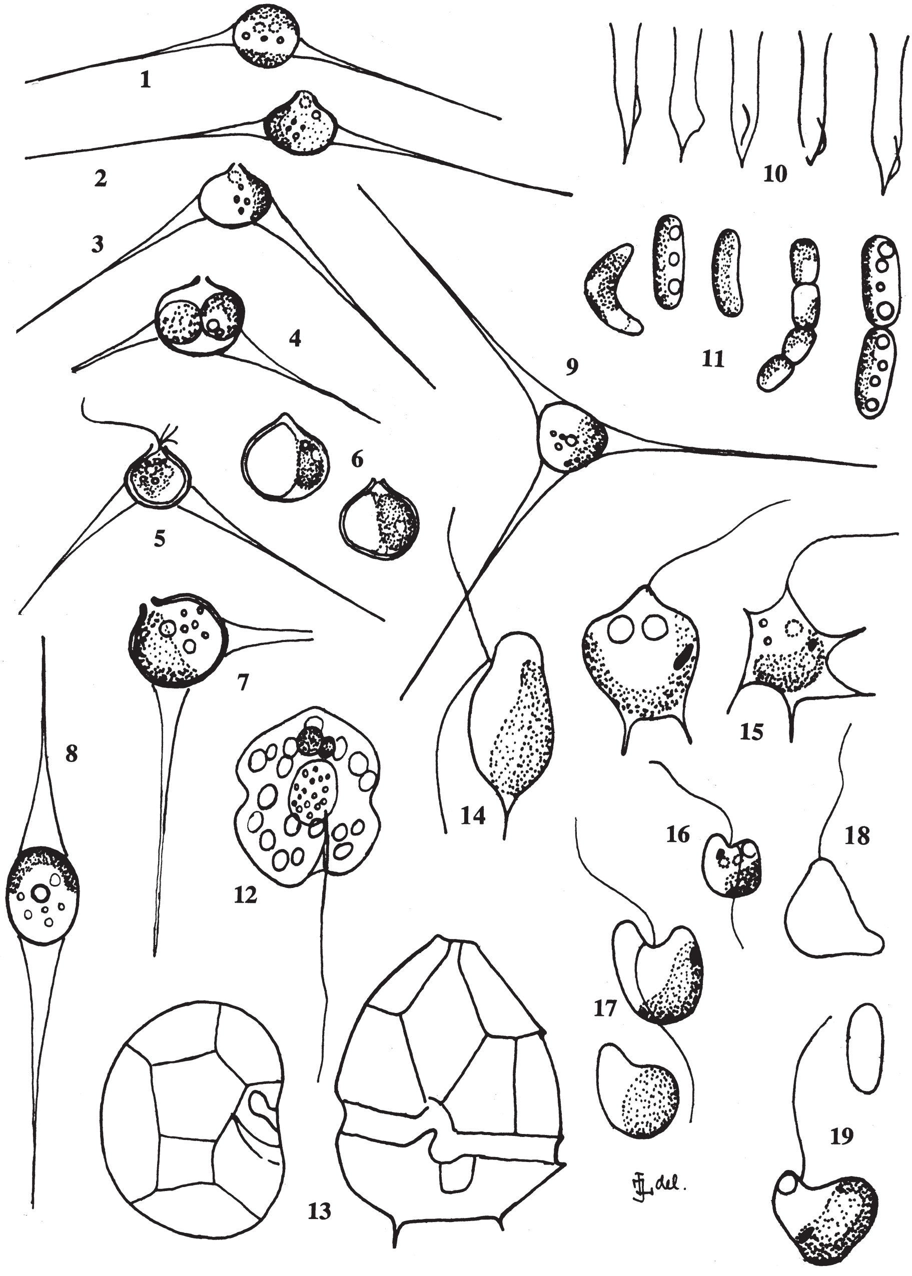


Fig. 1. Algae of Černé Lake in period 1935–1936, after unpublished field book and iconotheca of B. Fott, drawing J. Lukavský: **1–9** *Bitrichia ollula*, **1–3, 7, 8** variability in the shell and position of setas, **4** daughter protoplasts after division, **5** rhizoids emerging from the cell, **6** cysts from depth of 30–37 m, **9** a rare cell with 3 setas, **10** *Dinobryon* cf. *pediforme*, **11** cf. *Stichococcus* sp., **12** colorless *Gymnodinium lantzschii* var. *lantzschii,* **13** *Peridinium inconspicuum*, **14–15** *Ochromonas vallesiaca*, **16–19** *Sphaleromantis* sp.

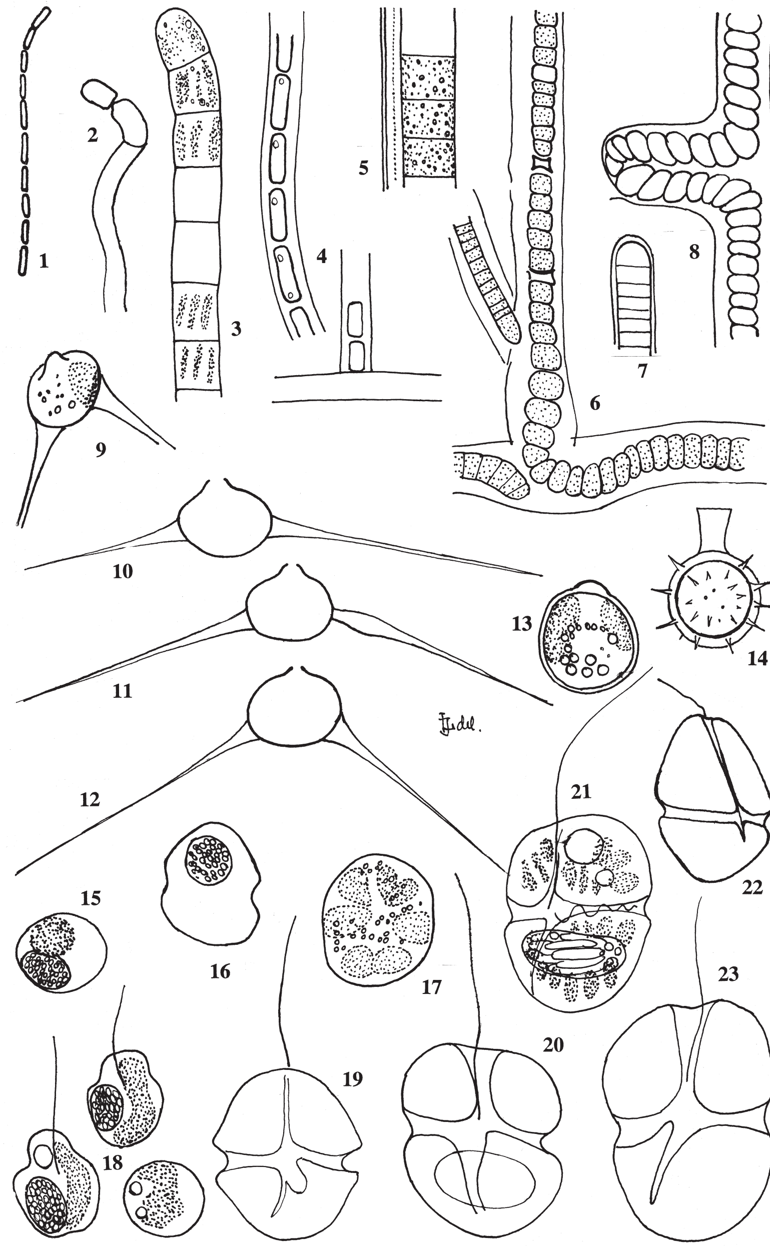


Fig. 2. Algae of Černé Lake in the period 1988–2004: **1** *Pseudanabaena minuta*, **2** *Spirulina laxa*, **3** *Oscillatoria insignis*, **4** *Hapalosiphon intricatus*, **5–8** *Scytonema cincinatum*, **9–12** *Bitrichia ollula*, variablity in the angle of position of spines, **13** cyst of *Dinobryon pediforme*, **14** stomatocyst no 35, cf. cyst of *Ochromonas stellaris* (cf. also *Chromulina echinocystus*), see also Fig. 7: 2, 3, **15–17** *Katodinium (Gymnodinium) bohemicum*, **18** *Amphidinium larvae*, **19–23** *Gymnodinium uberrimum*. Orig. author.

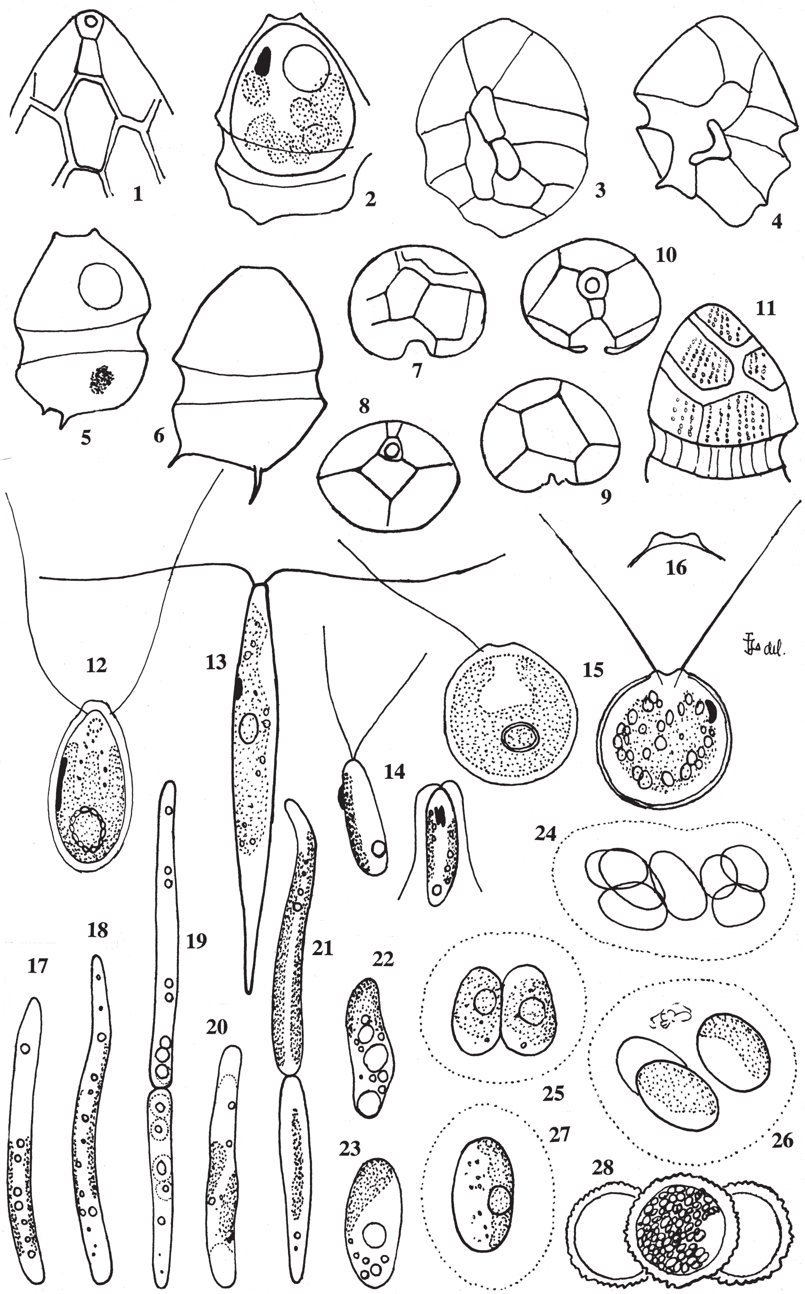


Fig. 3. Algae of Černé Lake in the period 1988–2004: **1–11** *Peridinium incospicuum* (*P. umbonatum*), **12** *Chlamydomonas costata*, **13** *Chlorogonium fusiforme*, **14** *Chlamydomonas angustissima*, **15–16** *Chlamydomonas praecox*, **17–21** *Koliella corcontica*, **22–23** *Monoraphidium dybowski*, **24–27** *Coenochloris planconvexa*, **28** *Coelastrum pascheri*. Orig. author.

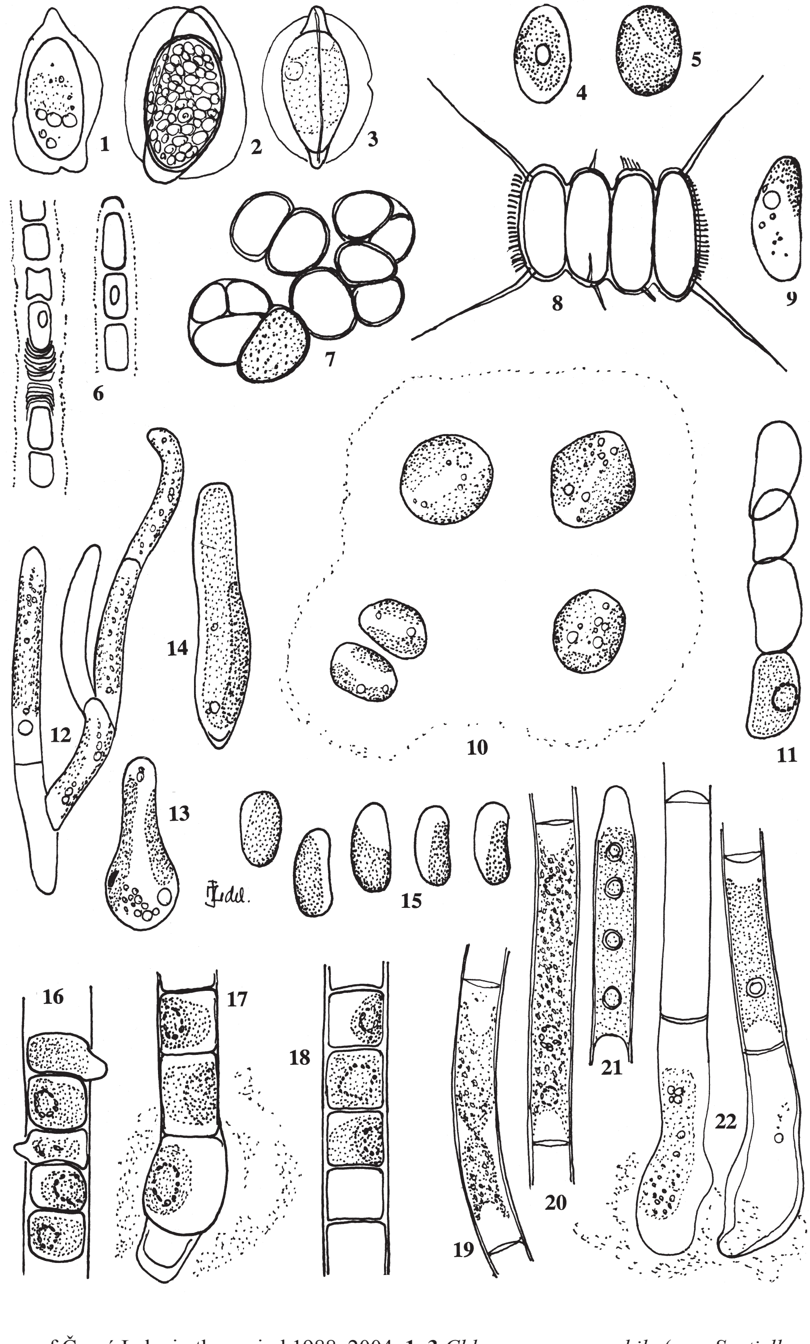


Fig. 4. Algae of Černé Lake in the period 1988–2004: **1–3** *Chloromonas cryophila* (syn. *Scotiella cryophila*), **4–5** cf. *Coenochloris helvetica*, **6** *Binuclearia tectorum*, **7** *Chlorosarcina superba*, **8** *Scenedesmus helveticus*, **10** *Gloeochrysis turfosa*, **11** *Audouinella* sp. (*Chantransia* sp.), **12–14** *Microthamnion strictissimum*, **9, 15** cf. *Pseudococcomyxa*, **16–18** *Ulothrix tenerrima*, **19–22** *Mougeotia* sp. steril. Orig. author.

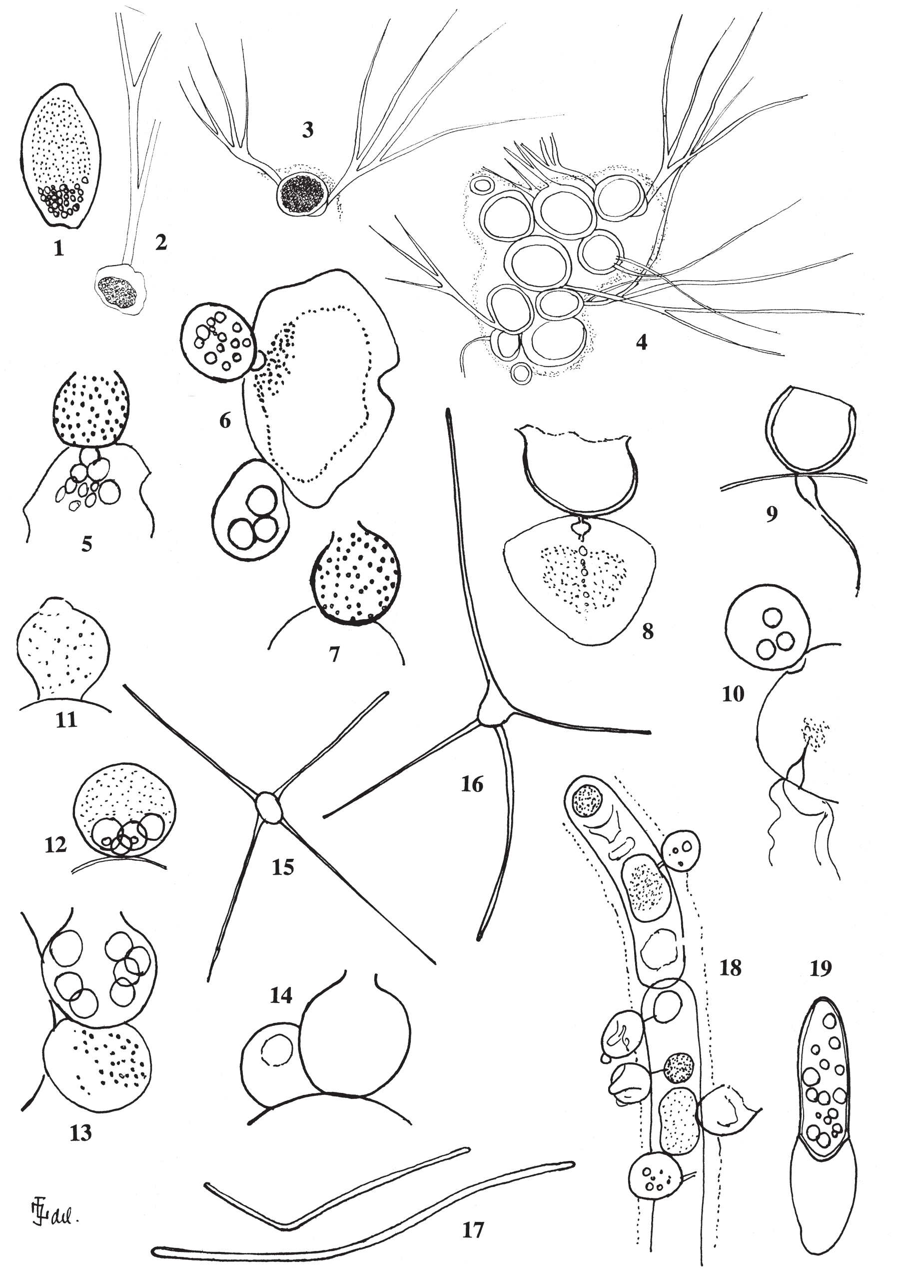


Fig. 5. Algae and Chytridiales of Černé Lake in the period 1988–2004: **1** an unknown organism, **2–4** *Dicranochaete bohemica*, **5–7** *Phlyctidium* sp. on *Peridinium*, **8–10** Sporangium of Chytridiomycetes on *Gymnodinium* sp., **11–14** cf. *Rhizophydium polinis-pini* on pollen grains of *Pinus silvestris*, **15–16** cf. *Actinospora megalospora* (spores of Deuteromycetes), **17** Eubacteria, **18** cf. *Rhizophydium* sp. on *Binuclearia tectorum,* **19** *Chionaster nivalis*. Orig. author.

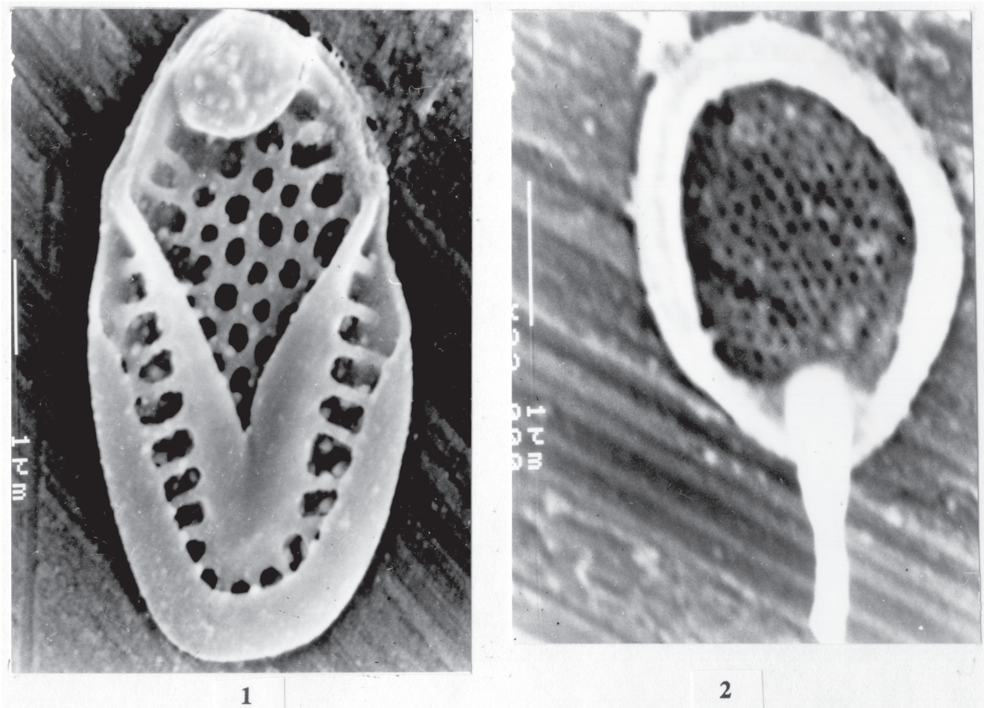


Fig. 6. Scales of Chrysomonads, surface of mud in depth of water ca. 10 m. **1** *Mallomonas crassisquama*, **2** *Synura sphagnicola*. Orig. author.

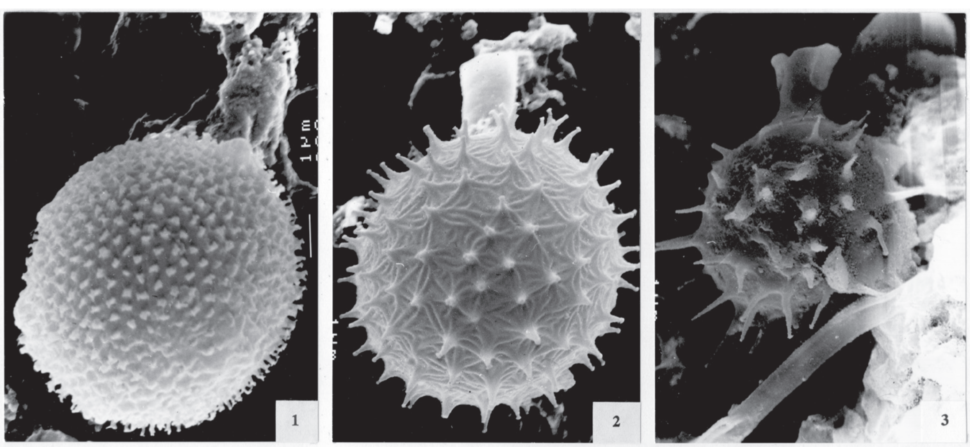


Fig. 7. Stomatocysts, cysts of Chrysomonads, surface of mud in depth of water 10 m: **1** Stomatocyst no. 73, mother organism unknown, **2–3** *Ochromonas stellaris*. Orig. author.

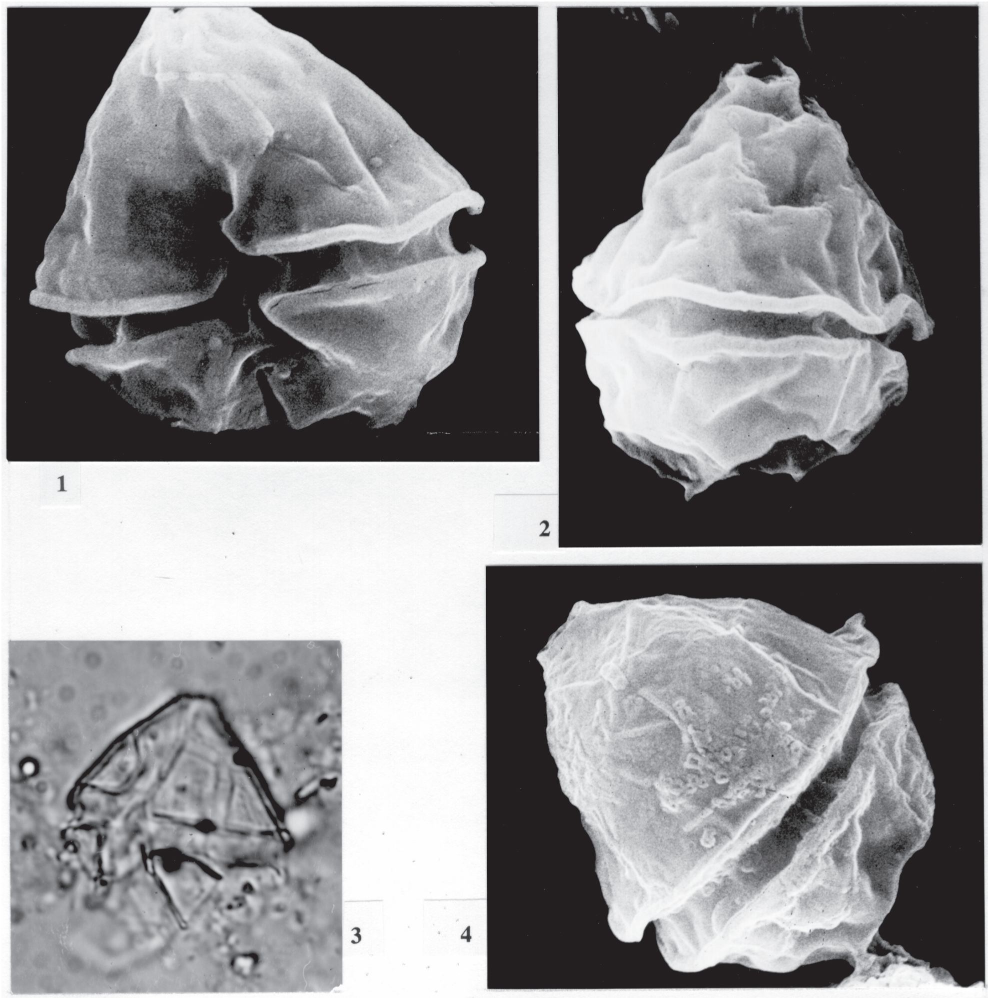


Fig. 8. *Peridinium incospicuum* (*P. umbonatum*), **1, 2, 4** transmission electron microscope, **3** light microscope. Orig. author.

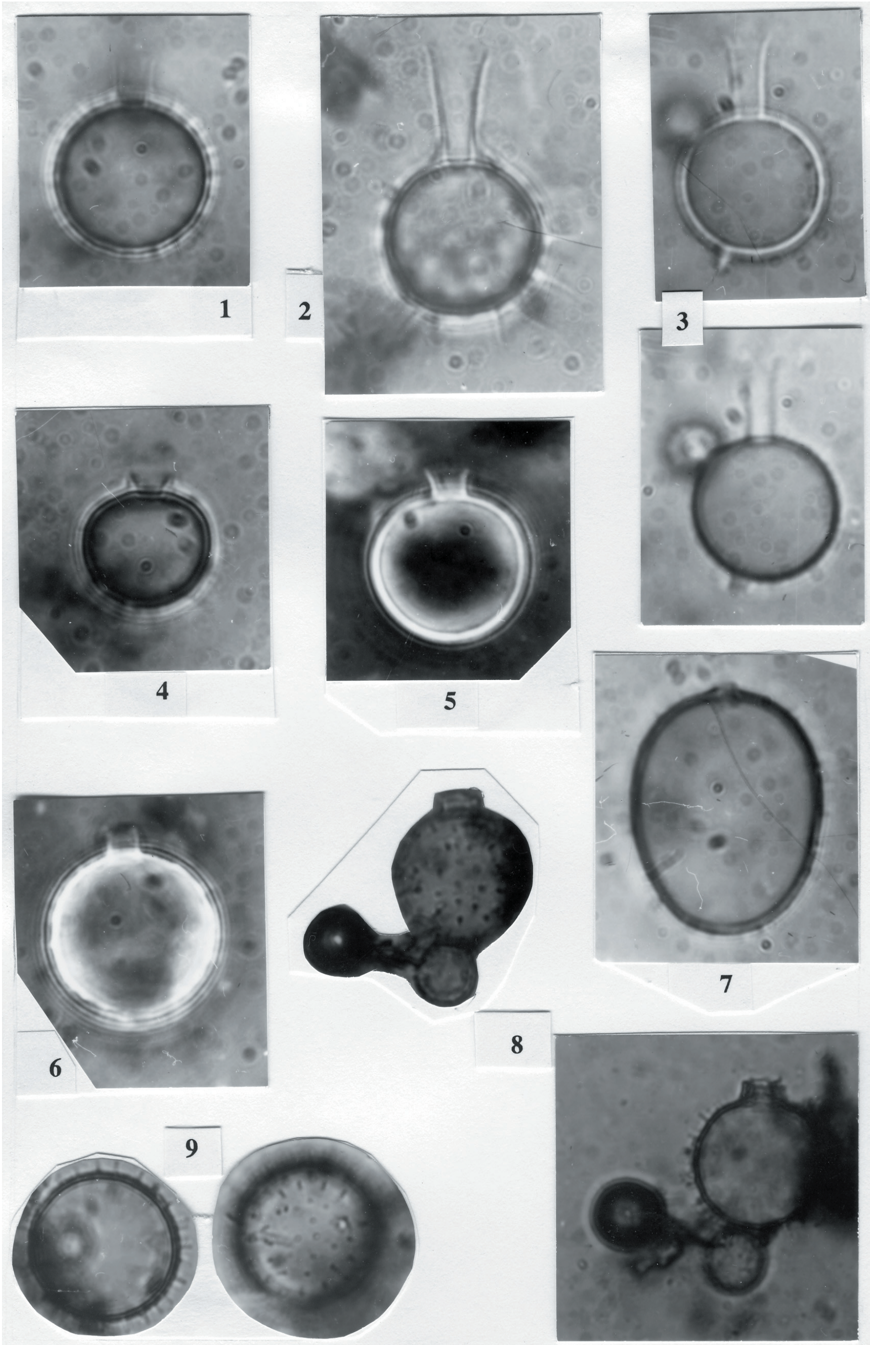


Fig. 9. Cysts of Chrysomonadales, surface of mud in depth of water ca. 10 m: **1–6** *Ochromonas stellaris*, **7** **S**tomatocyst no. 1**,** mother organism is *Mallomonas* cf. *pseudocoronata*, **8, 9** cyst of *Mallomonas acaroides*. Orig. author.

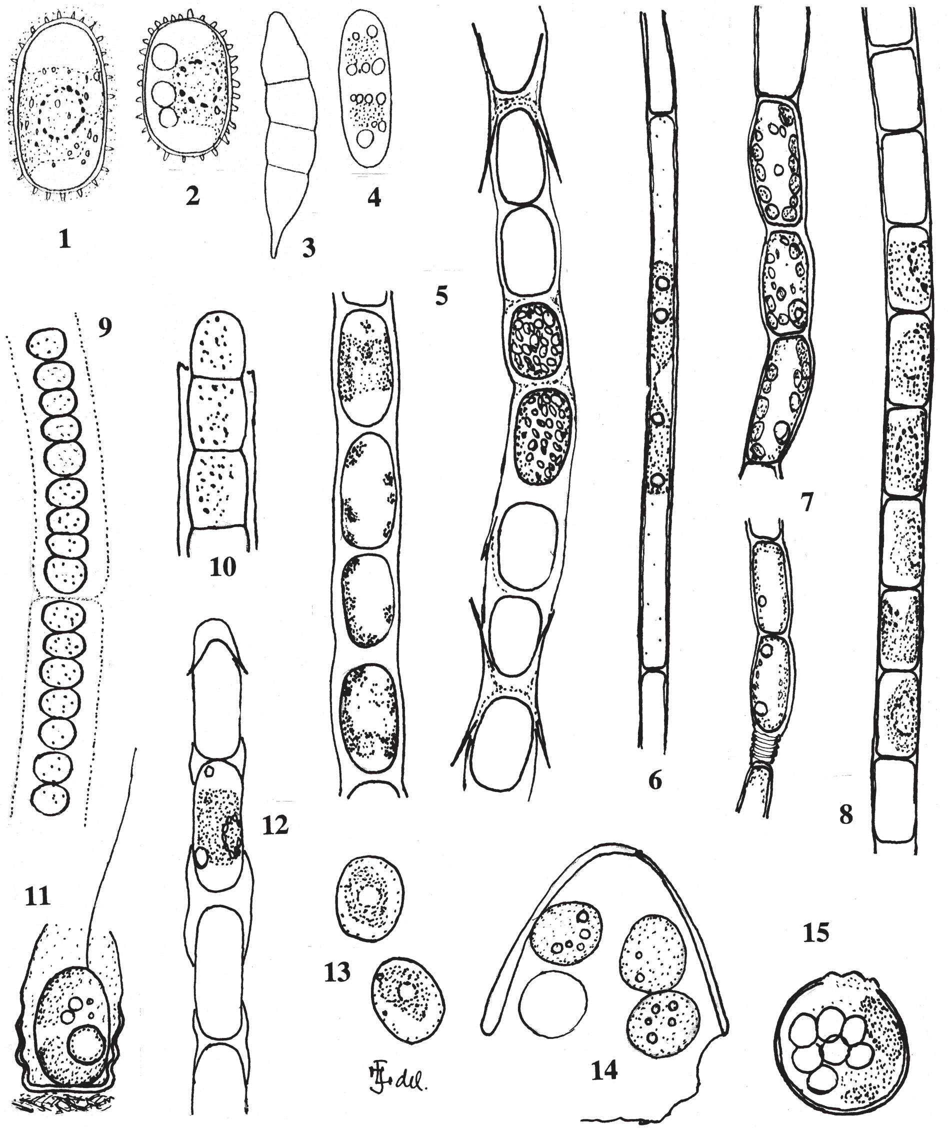
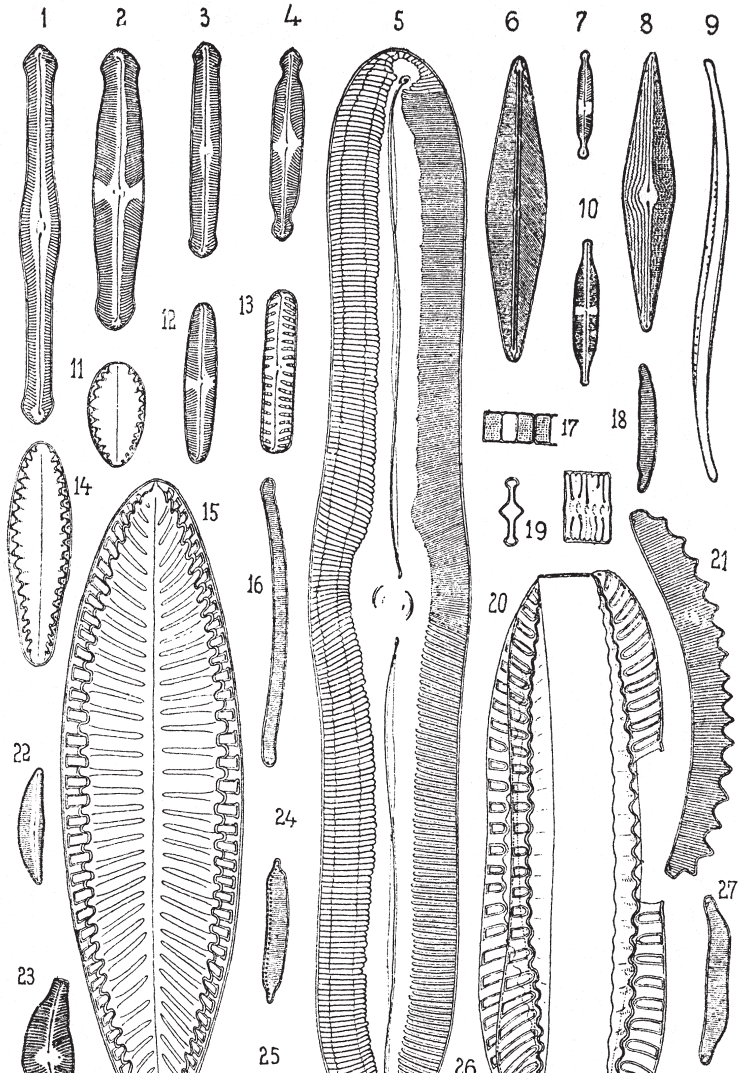


Fig. 10. Cryoseston of a snow field by Černé Lake (1–4), and clusters of algae on *Isoëtes lacustris* (5–15): **1, 2** *Chloromonas* (*Cryocystis*) *brevispina*, **3** cf. *Dactylella submersa* or *Actinospora crassa* (spore of a Deuteromycet), **4** *Cryodactylon glaciale*., **5** *Microspora amo*ena, **6** *Mougeotia* sp. steril., **7** *Oedogonium* sp., **8** *Klebsormidium* sp., **9** *Torulopsidosira ellipsoidea*, **10** *Phormidium* sp. **11** *Kephyrion inconstans*, **12** *Binuclearia tectorum*, **13** cf. Stichogloeales, **14** *Synechocystis aquatilis*, **15** cyst of a Chrysophyte. Orig. author.



Obr. 12. **Rozsivky Černého Jezera.**

1. a **3.** Navicula tabellaria Kg. **2.** Navicula stauroptera Grn. **4.** Navicula gibba Kg. **5.** Navicula gigas E. **6.** Navicula rhomboides E. **7.** Navicula Hilseana Jan. **8.** Navicula serians Kg. **9.** Nitzschia sigma Sm. **10.** Stauroneis anceps var. gracilis. **11. 14.** Surirella linearis Sm. **12.** Navicula Brébissonii Kg. **13.** Navicula borealis Kg. **14.** v. **11. 15. 20.** Surirella biseriata var. bifrons Kg. **16.** Himantidium arcus. **17.** Gaillonella distans E. **18.** Himantidium pectinale Kg. **19.** Tabellaria floculosa Ag. **20.** v. **15. 21.** Eunotia robusta Pritsh. **22.** Cocconema parvum Sm. **23.** Cymbella stomatophora Gr. **24.** Hantzschia amphioxys Grun. **25.** Gaillonella lirata Kg. **26. 28.** Gaillonella sp. **27.** Himatidium majus var. bidens. Sm. **28.** v. **26.**

Fig. 11. Diatoms of Černé Lake. After Steinich in Frič & Vávra (1898).

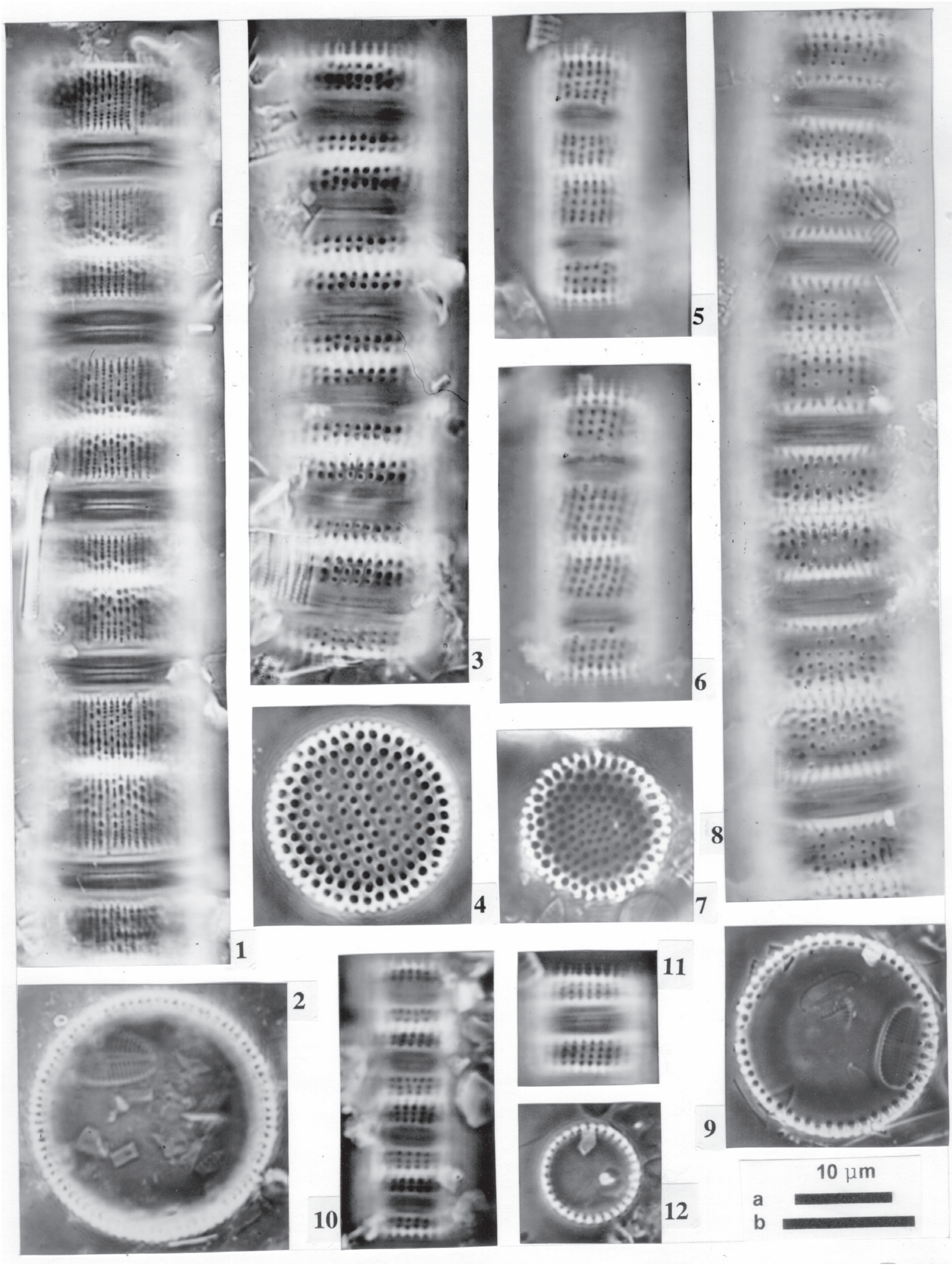


Fig. 12. Centric diatoms of Černé Lake: **1, 2** *Aulacoseira lacustris* (syn. *Galionella*), **3, 4** *Aulacoseira pfaffiana*, **5–7** *Aulacoseira distans* var. *nivalis*, **8, 9** *Aulacoseira lirata*, **10–12** *A.* sp. Orig. V. Houk and author.

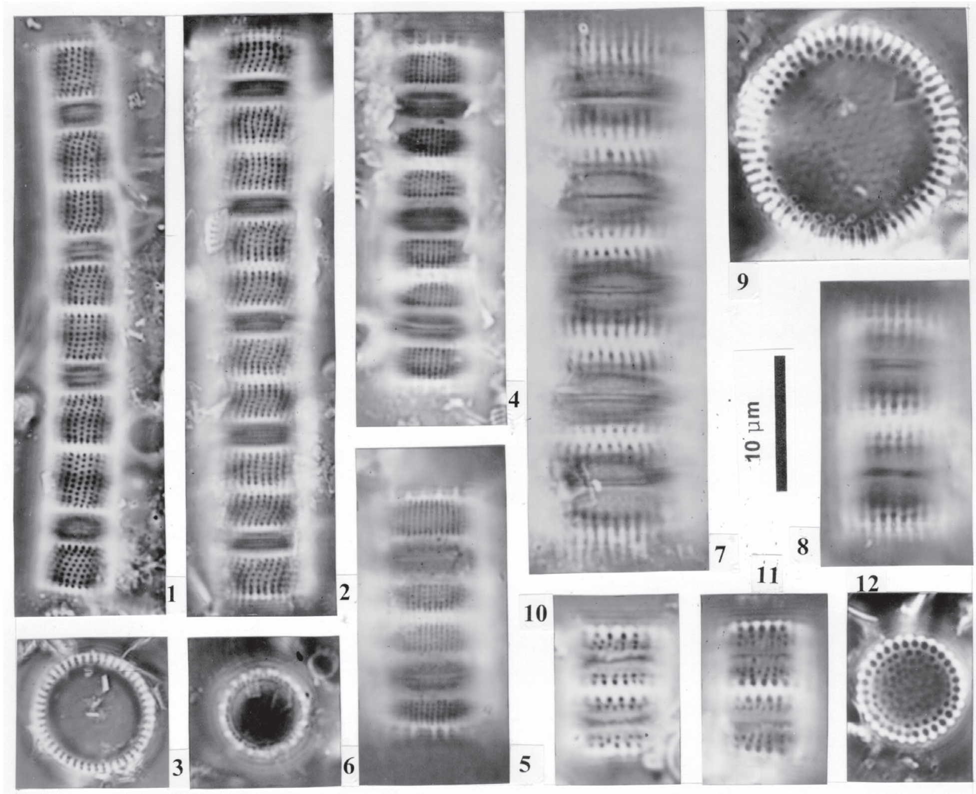


Fig. 13. Centric diatoms of Černé Lake: **1–3** *Aulacoseira alpingena*, **4–6** *Aulacoseira laevissima*, **7–9** *Aulacoseira perglabra,* **10–12** *Aulacoseira* sp. Orig. V. Houk and author.

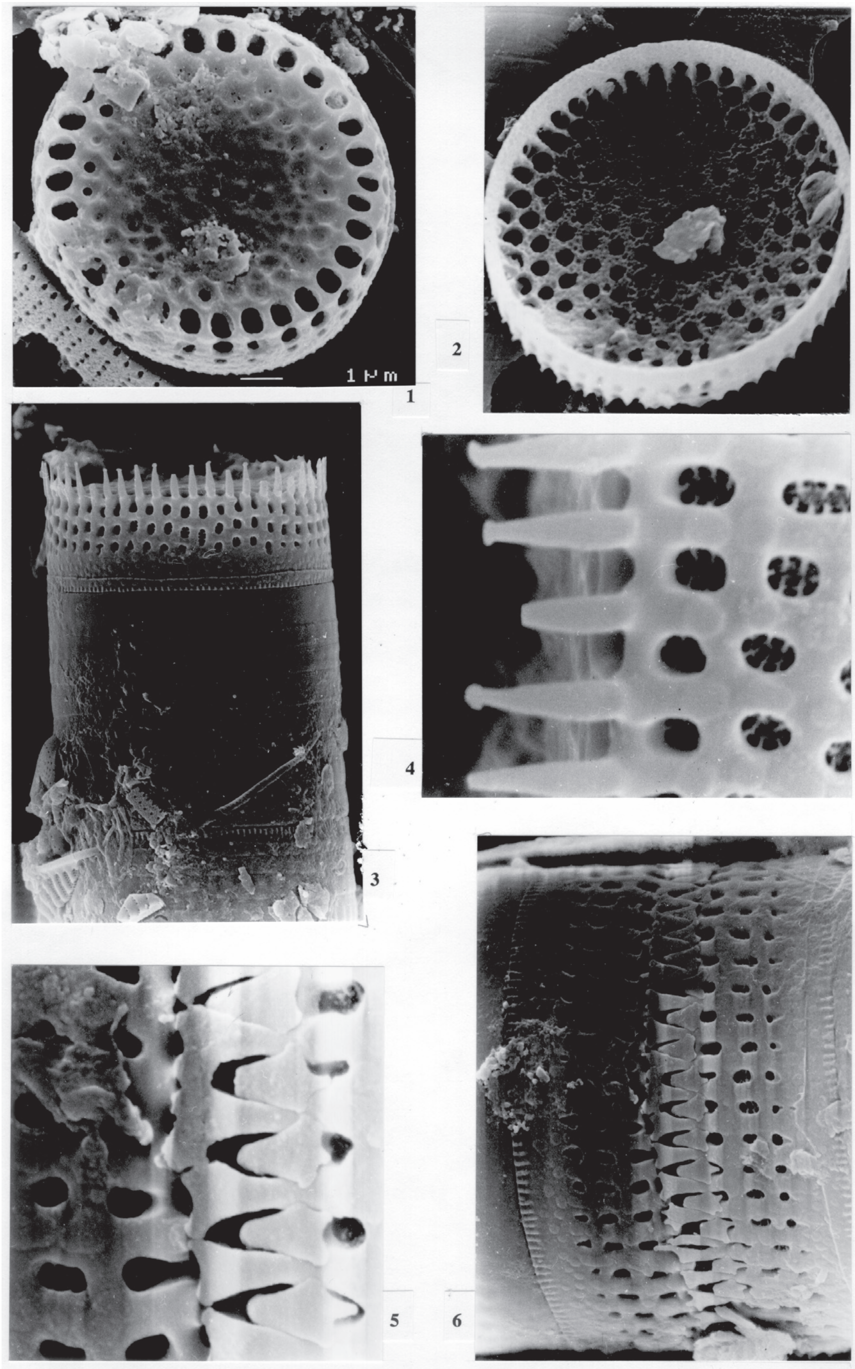


Fig. 14. Centric diatoms of Černé Lake in SEM: **1–6** *Aulacoseira distans* var. *nivalis* (syn. *Galionella*). Orig. author.

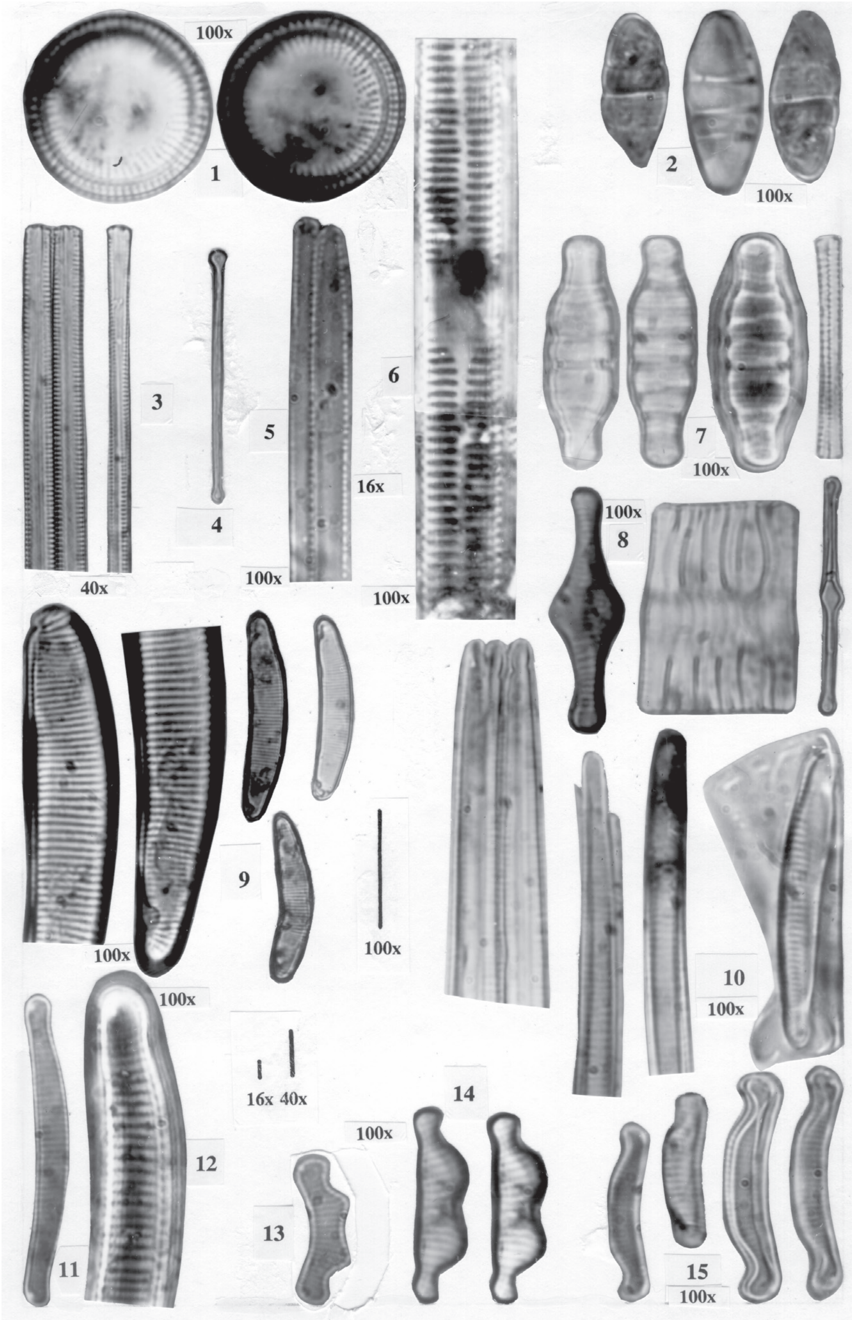


Fig. 15. Diatoms of Černé Lake. **1** *Cyclotella* sp., **2** *Diatoma hyemalis* var. *quadrata* (*D. hiemalis* var. *mesodon*, *D. mesodon*), **3, 6** *Synedra ulna*, **4** *Asterionella formosa***,** **5** cf. *Nitzschia linearis*, **7** *Diatoma anceps*, **8** *Tabellaria flocculosa*, **9** *Eunotia* cf. *monodon*, **10** *Eunotia subarcuatoides*, **11** *Eunotia* sp., **12** *Eunotia monodon,* **13** *Eunotia* cf. *praerupta*, **14** *Eunotia* cf. *diodon.* **15** *Eunotia* cf. *exigua.* Orig. author.

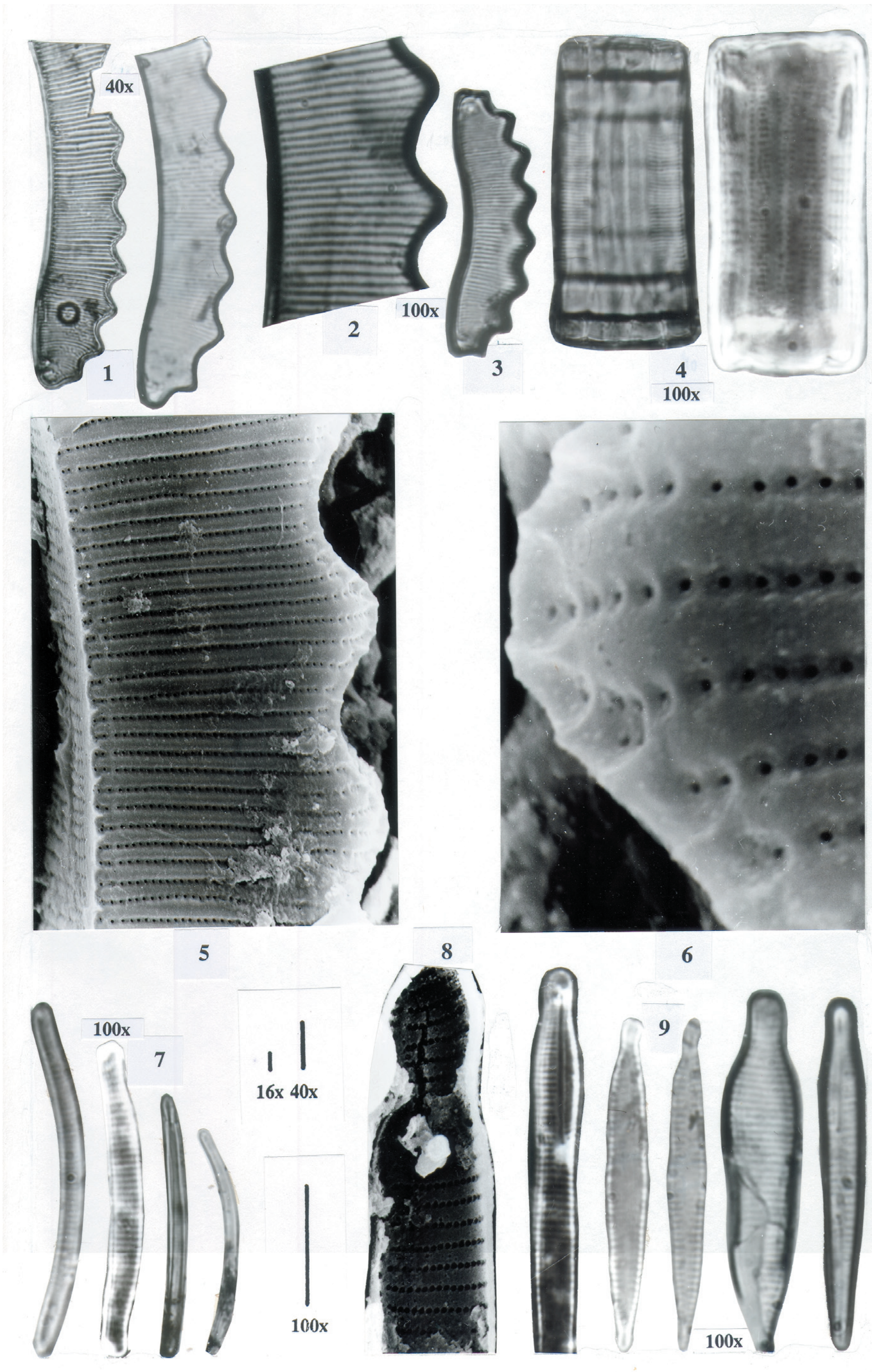


Fig. 16. Diatoms of Černé Lake. **1–3** *Eunotia serra*, **4–6** *Eunotia serra* var. *diadema*, **7** *Eunotia bilunaris* (*E. curvata*), **8, 9** cf. *Peronia fibula*. Orig. author.

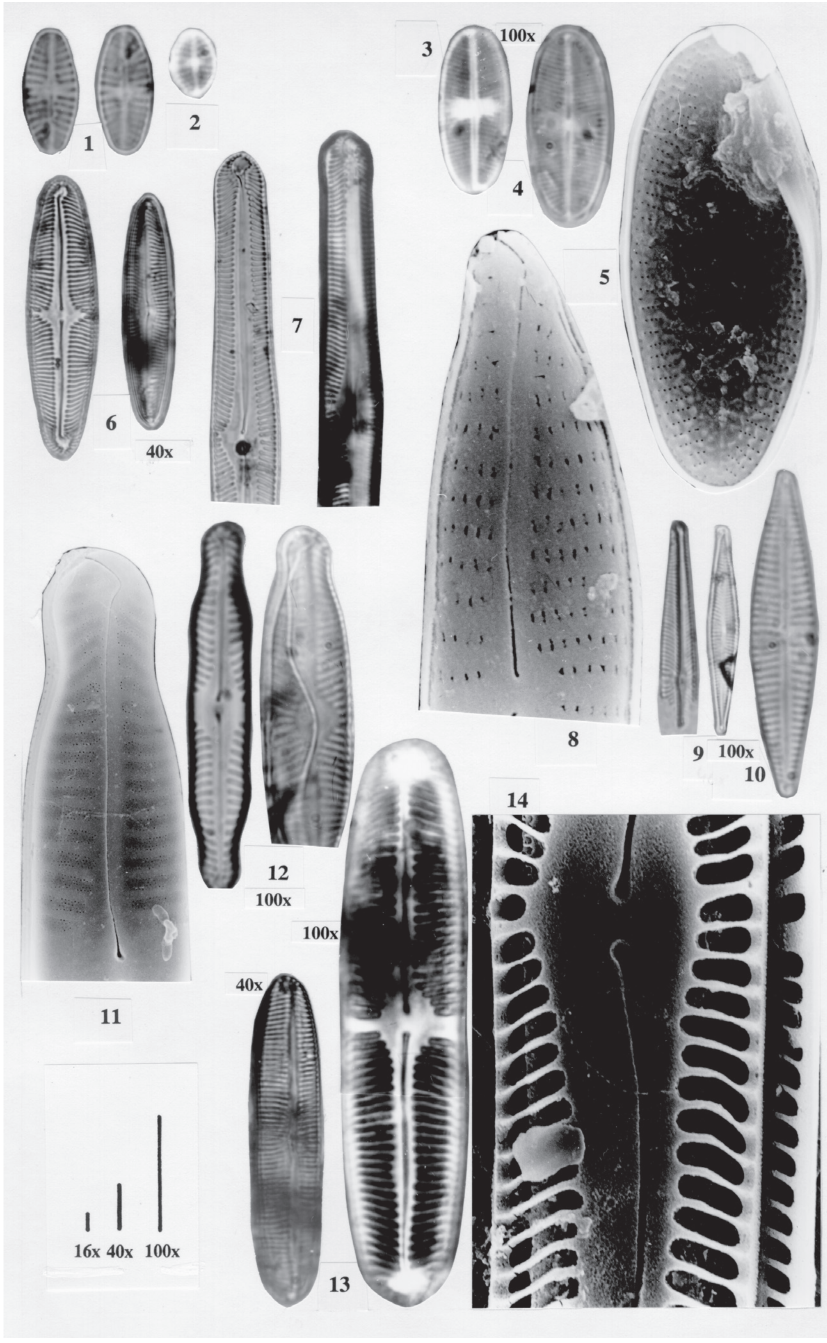


Fig. 17. Diatoms of Černé Lake. **1–2** *Achnanthes lanceolata*, **3–5** *Achnanthes bioretii*, **6** *Pinnularia* cf. subsolaris, **7** *Pinnularia gibba*, **8** *Cymbella* cf. *cesati*, **9**, **10** *Cymbella aequalis*, **11–12** *Pinnularia nodosa*, **13–14** *Pinnularia viridis*. Orig. author.

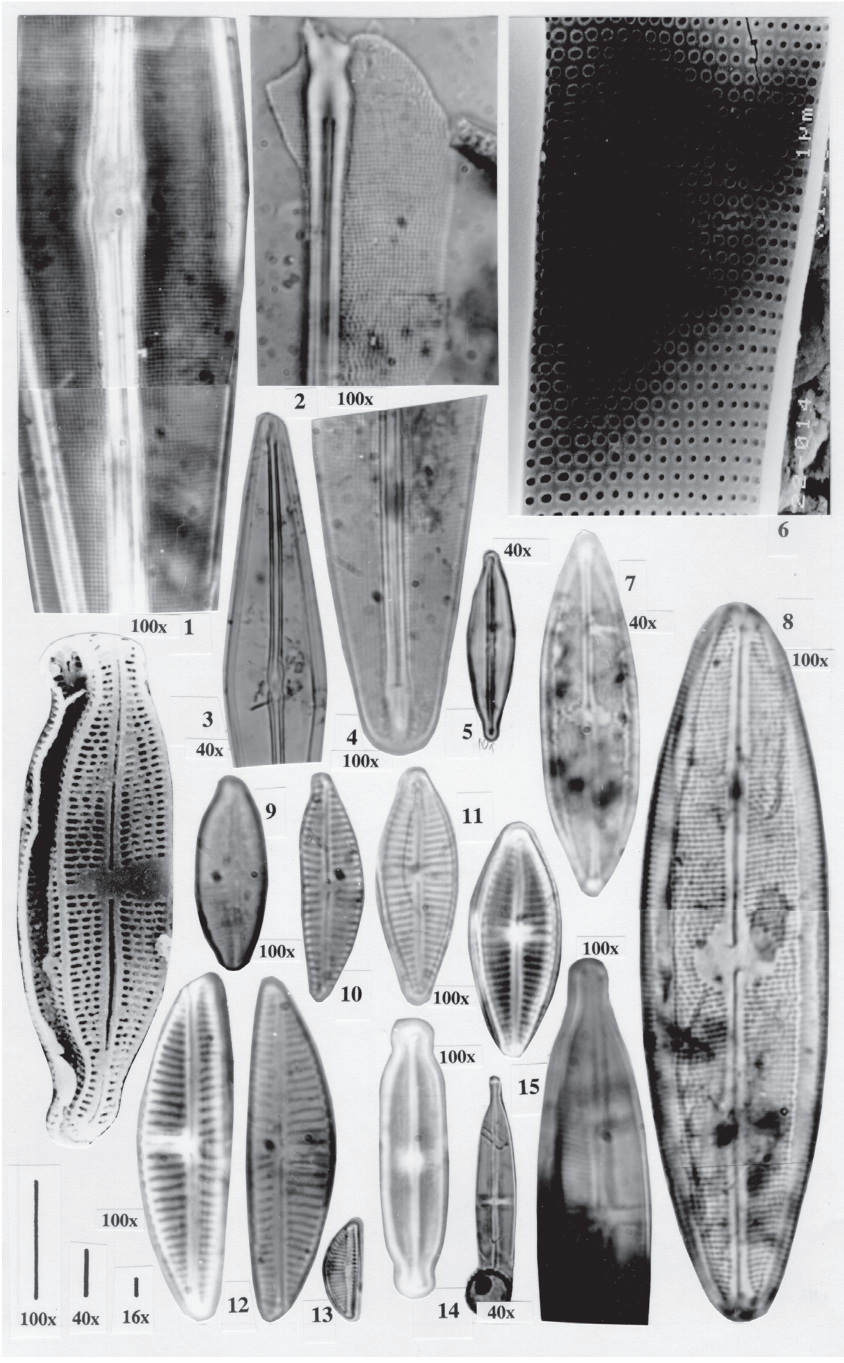


Fig. 18. Diatoms of Černé Lake. **1–6** *Frustulia rhomboides*, **7–8** *Neidium iridis*, **9** *Achnanthes ploenensis*, **10** cf. *Cymbella hebridica*, **11** cf. *Gomphonema parvulum,* **12–13** *Cymbella hebridica*, **14–15** *Stauroneis aceps*. Orig. author.

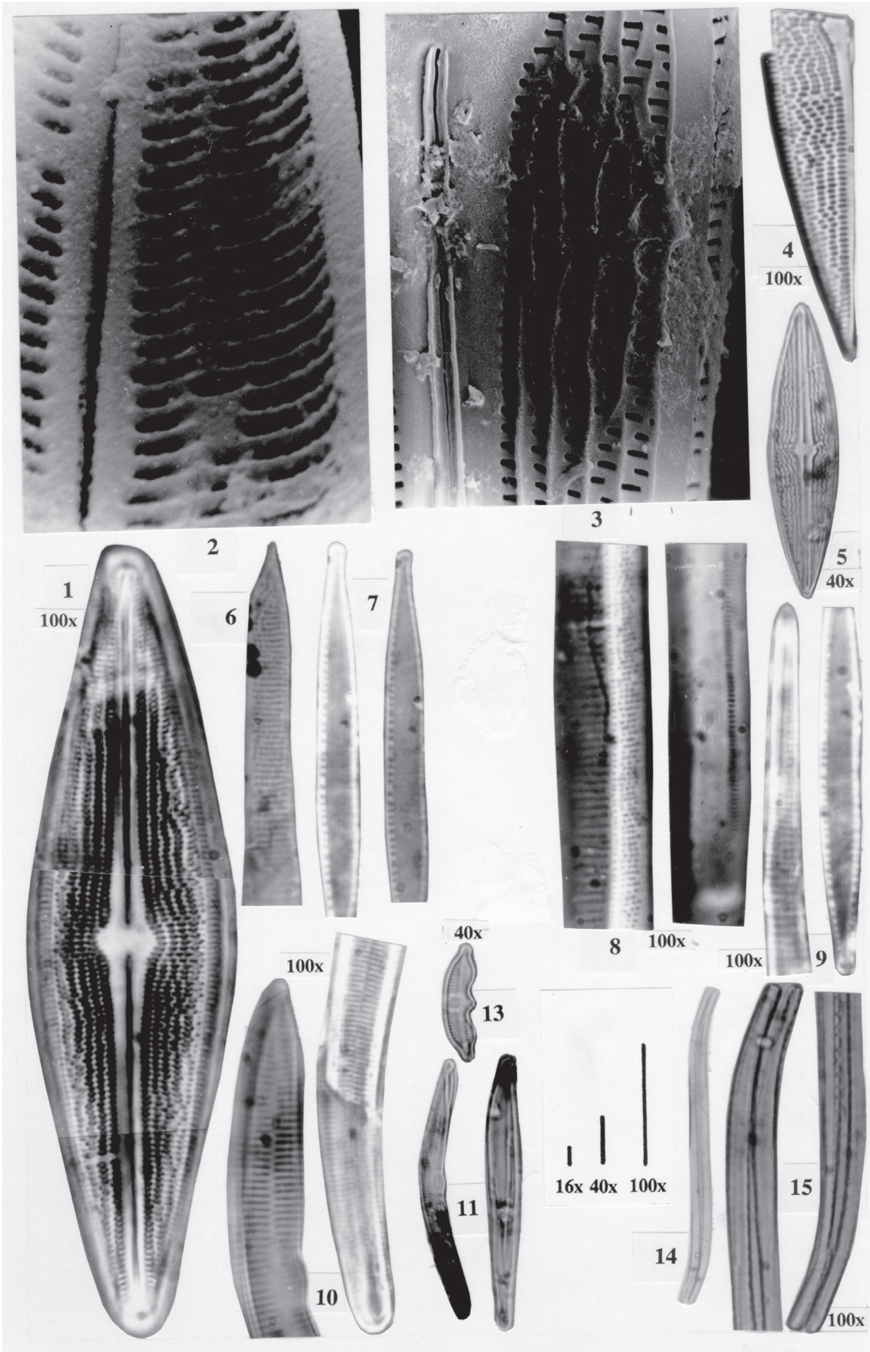


Fig. 19. Diatoms of Černé Lake. **1–5** *Anomoneis serians*, **6–9** *Nitzschia* sp., **10–13** *Hannaea arcus,* **14–15** *Nitzschia obtusa*, Orig. author.

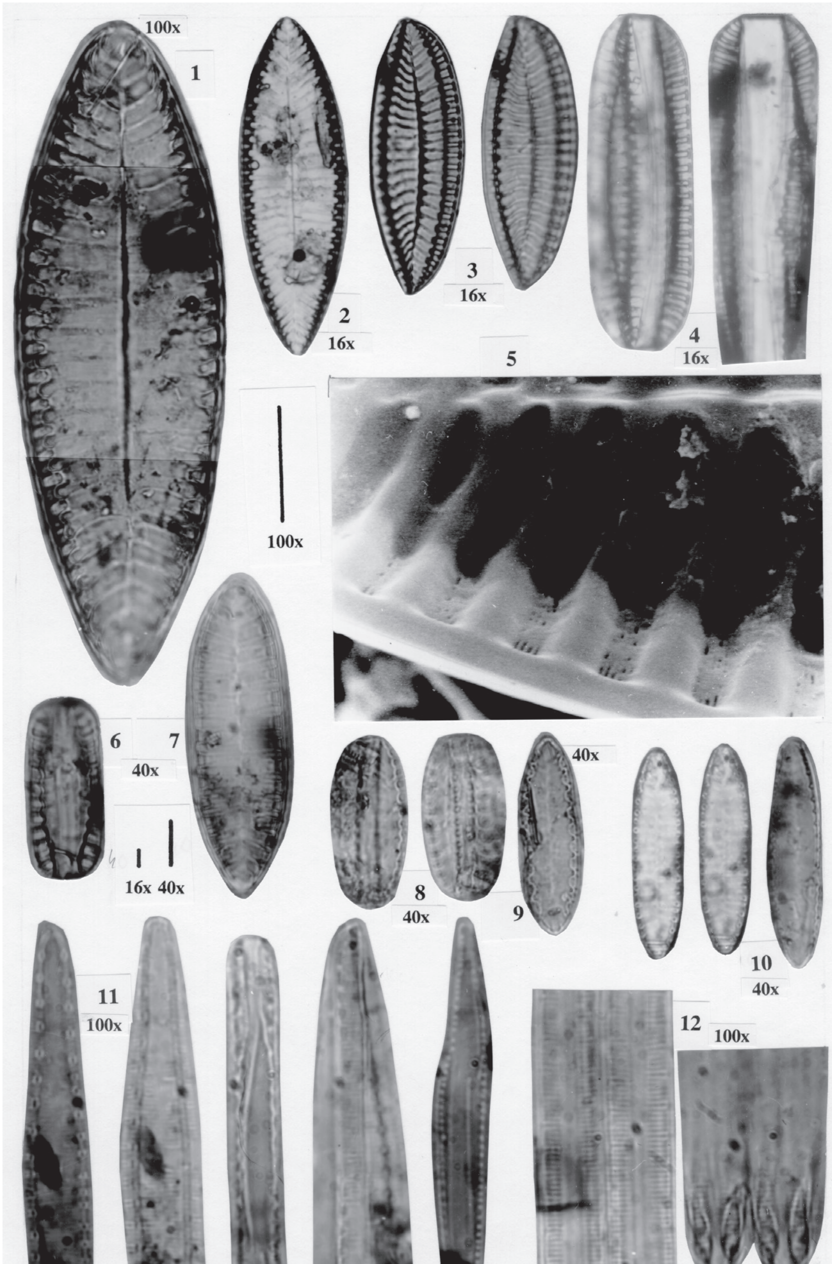


Fig. 20. Diatoms of Černé Lake. **1–5** *Surirella biseriata*, **6, 7** *Surirella linearis,* **8, 9** cf. *Surirella roba* or *S. bohemica*, **10** *Surirella augustata*, **11–12** *Steropterolobia delicatissima*. Orig. author.

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