Aulacoseira hibschii (Reichelt) Houk comb. nov. (Bacillariophyceae, Centrales) from the type locality in Varnsdorf (Czech Republic)

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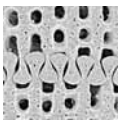

Valve morphology and ultrastructure of *Melosira hibschii* Reichelt, from raw material E 1821 "Warnsdorf, braune Schicht, leg. Reichelt" and slide A2/81 labelled "Melosira Hibschii Reich." from the Hustedt Diatom Collection, Bremerhaven, and slide B 1731 "Warnsdorf Böhmen (Elger 118)" from the Weinzierl Collection, Botanisches Staatsammlung München (Germany), were investigated using light and scanning electron microscopy to clarify the taxonomic position of this species, which is considered to belong to the genus *Aulacoseira* Thwaites. A formal transfer to this genus as *Aulacoseira hibschii* (Reichelt) Houk comb. nov. is proposed. *A. hibschii* differs from related *Aulacoseira* taxa by the characteristic location of the rimoportulae combined with the coarse areolar valve pattern and with the characteristic shape of the two types of spines. The rimoportulae are spaced in a sparse ring near the ringleist, or again sparsely near to the middle of the valve mantle, or they are situated irregularly. The species was then identified from several other Paleogene diatomites from northern Bohemia and Seifhennersdorf (Germany). The observed valve morphology and ultrastructure of *A. hibschii* are discussed and compared with those of related species. • Key words: fossil taxa, diatomite, Diatomae, Centrales, Melosira, *Aulacoseira*.

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The first mention of diatoms from a locality in northern Bohemia (Czech Republic) is in Ehrenberg (1836), when he described *Gallionella distans* from a diatomite at Kučlín near Bílina. This taxon was transferred later by Kützing (1844) into the genus *Melosira* Agardh and finally Simonsen (1979) included it into a refreshed genus *Aulacoseira* Thwaites. More scientists dealt then with these diatomites (*e.g.*, Kützing 1844, Rabenhorst 1863). At the end of the 19th Century the Tertiary diatomites of northern Bohemia had become better known especially thanks to Reichelt (1900), who identified many fossil diatom taxa in diatomite samples from this region. After that time other authors were also engaged in the fossil diatom flora from these localities (*e.g.*, J.S. Procházka 1924; M. Procházka 1954; Řeháková 1958, 1968, 1970, 1985).

Reichelt (1900) described a new fossil centric diatom species, *Melosira hibschii*, from Varnsdorf (Czech Republic) in the material he had received from Dr. O. Hermann (see Reichelt 1900, p. 30) and assigned as "Warnsdorf, braune Halden". He has also noted in the description that this species was distributed only in the Bohemian deposits. It has been cited then by several authors (*e.g.*, J.S. Procházka 1924, Řeháková 1985) from the diatomite localities of this region and Jousé & Mukhina (1978) also quoted this species, illustrated by SEM pictures, from late Pliocene sediments of the Black Sea. However, the first SEM pictures of this species from the Varnsdorf material were published by Likhoshway & Crawford (2001), showing the location of the rimoportulae, but the complete valve morphology was not compiled, because they stressed only the position of the rimoportulae. It is also necessary to point out that formal transfer of this species to the genus *Aulacoseira* Thwaites has not yet been made, despite the fact that this taxon evidently has an areolated valve mantle and structureless collar typical of the genus.

Recently, many diatomite samples were collected from Paleogene localities in the České Středohoří Mountains, northern Bohemia, to clarify the diatom assemblages. This new material was investigated in the framework of a grant project investigating Paleogene

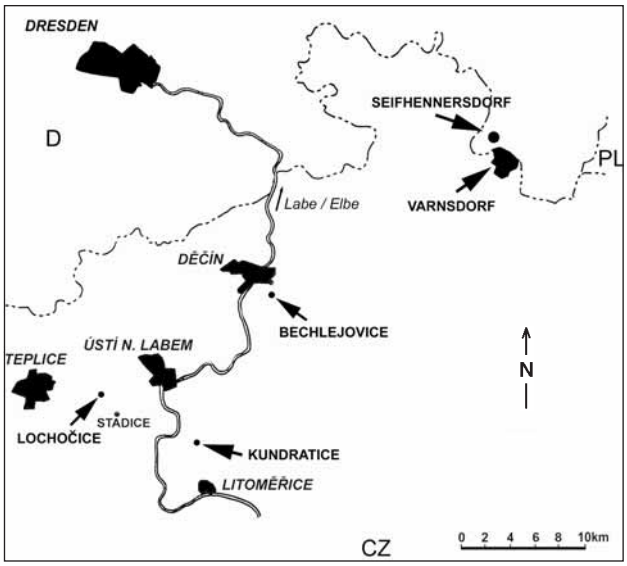


Figure 1. Map of the region with the investigated localities.

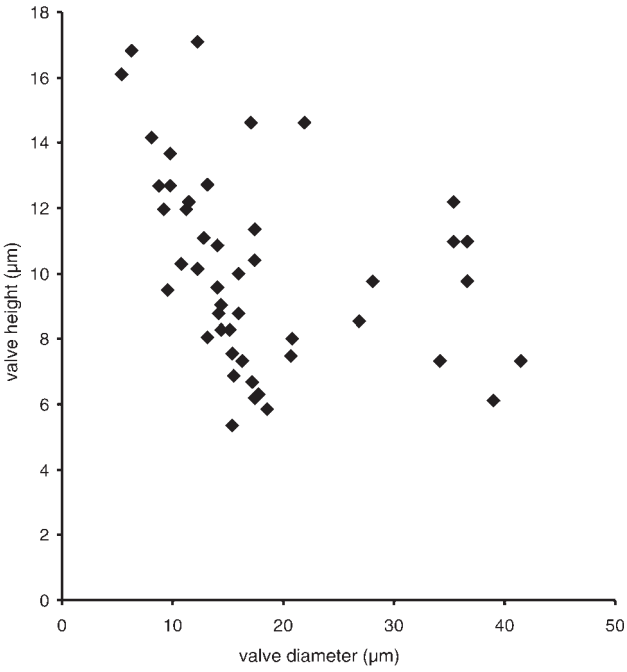


Figure 2. Relationship between valve mantle height and valve diameter of *Aulacoseira hibschii* from the northern Bohemia localities.

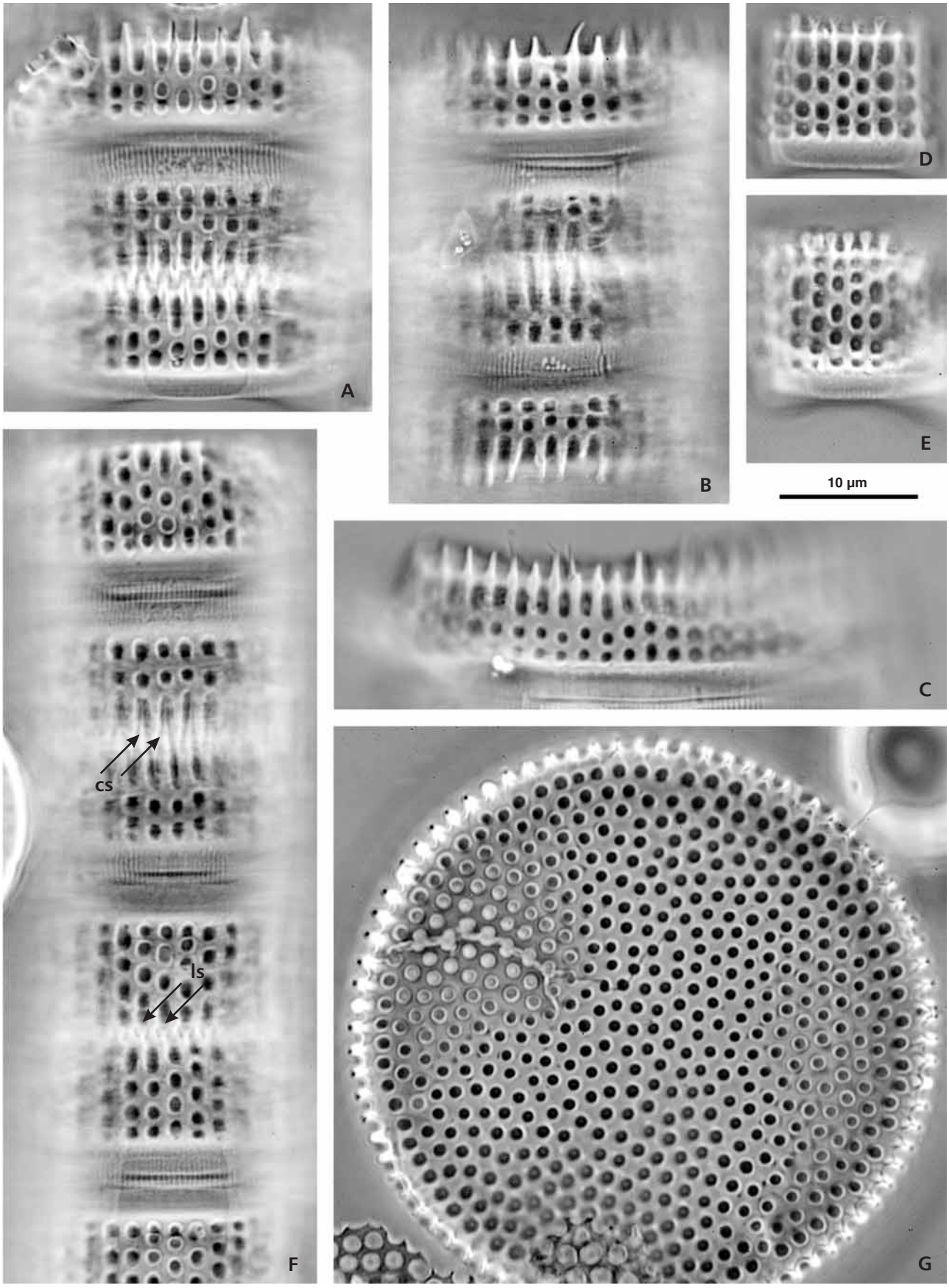
assemblages of diatoms, vascular plants, insects and fish faunas and their development in the Late Eocene–Late Oligocene volcanic environments of the České Středohoří Mountains. The research is concentrated on obtaining refined paleoecology based on improved understanding of the groups studied. The stress is laid on comparisons/confrontations of environmental characteristics derived from individual groups and explanation of anomalies. In the diatomite samples from Kundratice, Lochočice, Bechlejovice and Seifhennersdorf, an *Aulacoseira* taxon was observed in LM and SEM that strongly resembles *M. hibschii* Reichelt, but the position of its rimoportulae often differs from the specimens shown by Likhoshway & Crawford (2001). This species has also been cited by Řeháková (1985) from northern Bohemian diatomites (Lochočice, Stadice, Kundratice, Skalice at Litoměřice, Javory), and in several internal unpublished reports in Czech of the earlier Czech Geological Institute, which are hard to verify. However, Řeháková's observations were made in LM only, and so there is still a need to investigate the morphology of this species using SEM, to clarify its taxonomic position. To solve this problem, an old slide and material from the type locality in Varnsdorf (Czech Republic) of *M. hibschii*, kindly provided from the Hustedt Diatom Collection in Bremerhaven (Germany), was investigated in LM and SEM. The results of these observations are presented here and formal transfer of *Melosira hibschii* Reichelt to the genus *Aulacoseira* Thwaites is proposed.

Materials and methods

Samples of Paleogene diatomites from the following localities (see Fig. 1) in northern Bohemia were used for LM and SEM investigations:

1. Varnsdorf, Hustedt Collection slide A2/81 "Melosira Hibschii Reich.", AWI Bremerhaven, Germany.
2. Varnsdorf, Hustedt Collection raw material E 1821 "Warnsdorf, braune Schicht, leg. Reichelt", AWI Bremerhaven, Germany.
3. Varnsdorf, Weinzierl Collection slide B 1731 "Warnsdorf Böhmen (Elger 118)", Botanical Garden Munich, Germany.
4. Bechlejovice, raw material, Charles University Praha.
5. Kundratice MMg and Kundratice Nrgs124, raw material, Charles University Praha.
6. Lochočice-Stadice M 33 52 Bc, raw material, Czech Geological Survey.
7. Seifhennersdorf Sf 7781 (Germany, Zittauer Gebirge).

Figure 3. *Aulacoseira* hibschii (Reichelt) Houk, LM. • A, B, D–G – Varnsdorf, Hustedt Collection slide A2/81 "Melosira Hibschii Reich.". • C – Varnsdorf, Weinzierl Collection slide B 1731 "Warnsdorf Böhmen (Elger 118)". • A–F – valve mantle views. • A, B, F – valves with conical spines. • D, E – valves with spatulate linking spines. • F – short chain of frustules with conical (cs) and spatulate linking (ls) spines. • G – valve view.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The diatomite localities Bechlejovice, Kundratice and Lochočice-Stadice belong to the Ústí Formation volcano-sedimentary complex (*sensu* Cajz 2000) and represent the Early Oligocene interval between *ca* 34.0 to 30.0 Ma (see Bellon *et al.* 1998; Konzalová 2003; Kvaček & Walther 2003, 2004). The diatomite deposit of Seifhennersdorf is on the periphery of a basaltoid lava flow, which discontinuously covered an area between the towns Neugersdorf – Eibau – Oberderwitz – Grossschöna – Varnsdorf – Seifhennersdorf. The age of the basaltoid lava flow overlying the diatomite is 30.44 ± 1.52 Ma (Bellon *et al.* 1998) and so it also represents the Early Oligocene period. The map of these sites is shown in Fig. 1.

The terminology used follows that suggested by Anonymous (1975) and Ross *et al.* (1979).

A Zeiss-Jena JENALUMAR light microscope equipped with an HI 100x/1.35 planapochromate objective was used for LM observations with pictures taken and processed as described in Houk (2003, p. 8). The raw material from localities No. 4–7 was cleaned in the laboratory of the Czech Geological Survey, Praha, by cooking in a mixture of hydrogen peroxide and hydrochloric acid, decanted and washed. The cleaned material was dried on glass cover slips, mounted in Pleurax for LM observations or mounted on aluminium stubs and coated with gold in a Polaron coating unit E 5000 for SEM investigations. A Hitachi S-3000 N scanning electron microscope and Jeol JSM-7401F were used for observations.

From the SEM-pictures, interareolar and interstriae distances and the number of rimoportulae were investigated; valve diameter, mantle height, ringleist depth (including wall) and mantle wall thickness were measured in the light microscope.

The terms distal and proximal are used in the sense of Edgar *et al.* (2004), which means that the collum is the proximal part of the valve mantle, while the valve face is the distal part of the valve.

Observations (LM- and SEM combined)

***Aulacoseira hibschii* (Reichelt) Houk comb. nov.**
Figures 3–6

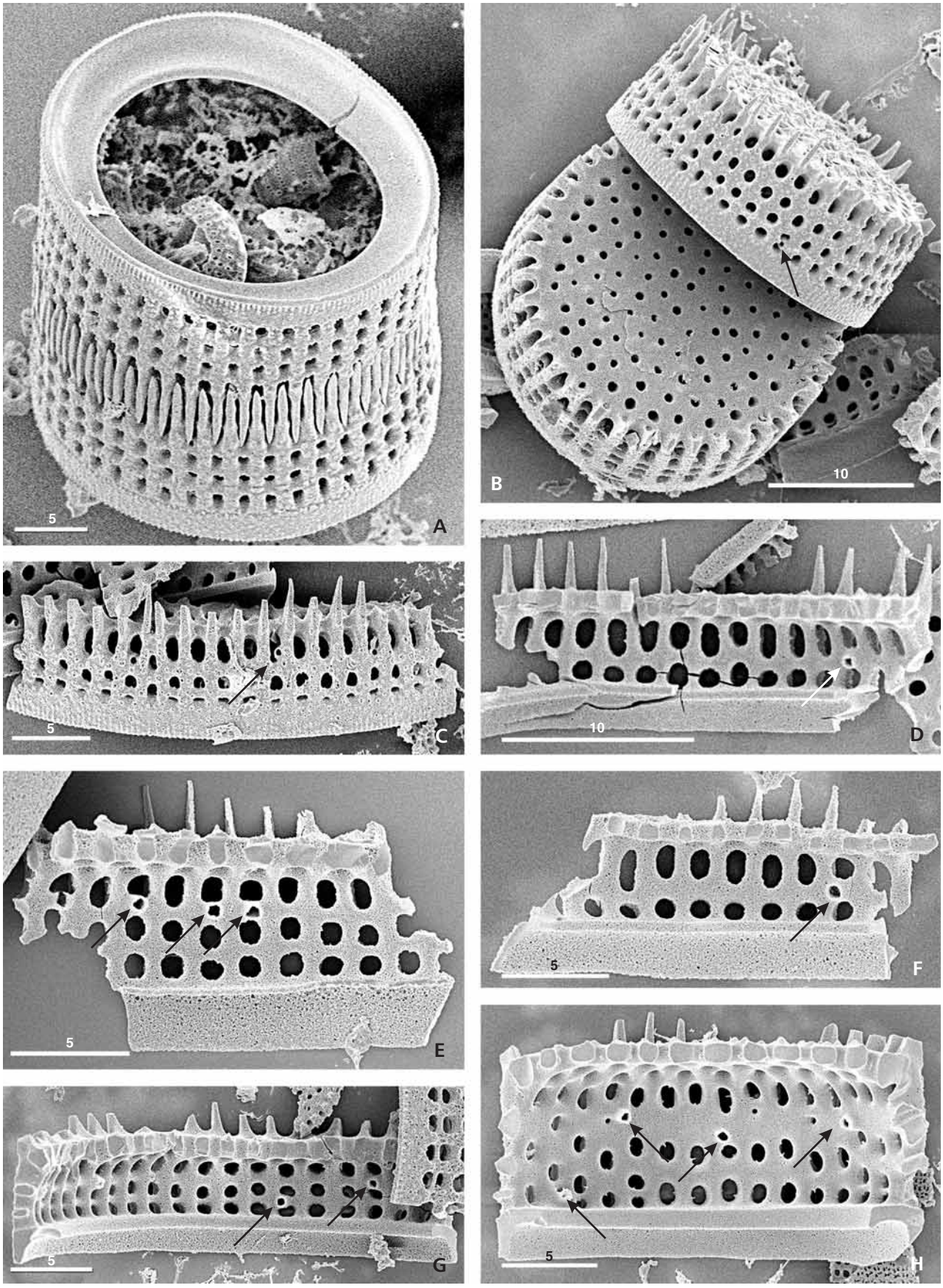
Basionym. – *Melosira Hibschii* Reichelt (1900), *Berichten der Naturforschenden Gesellschaft zu Leipzig*, 1899–1900, 27–35.

Type locality. – Varnsdorf, northern Bohemia (Czech Republic).

Description. – Vegetative cells are cylindrical, connected with tapered spines to form short chains. Frustules are rectangular in girdle view, circular in valve view, valves 4.9–56.0 μm in diameter, mantle height 5.6–17.1 μm, mid-mantle wall thickness *ca* 0.5–1.8 μm. The relationship between the valve mantle height and the valve diameter is plotted on the graph in Fig. 2. The valve mantle has straight pervalvar rows of relatively coarse, circular to nearly quadrate areolae, *ca* 0.35–0.85 μm in diameter, 2–5(6) areolae in a row. Areolae in the first transverse row, below the valve face/mantle junction, are sometimes elongated (Figs 3D, 4C–F). When there are 2–3 areolae only in one pervalvar row, transverse rows are also created (Figs 4C–G). The areolae are occluded by complex vela, near surface supported at several points around areola (Fig. 6J), internally with individual rosettes of the vela (Fig. 6H). Interstriae distance 1.2–1.8 μm and interareolar distance 0.7–1.6 μm. Two types of spines can be observed, the relatively long tapered spines and clavate linking ones. The interstriae taper beneath the valve face into mostly *ca* 2–4 μm long, tapered buttressed spines (Figs 4A, 6A, B, K) or into claviform shaped spines (Fig. 5A, B), creating thus a regular ring at the valve face/valve mantle junction. Rarely, an extra pervalvar row of areolae can run from a broadened base of one of spines (ir – in Fig. 6B, C). The proximal part of the valve mantle is a collum, which is structureless or milled with short pervalvar wrinkles at the valve rim (Fig. 3A, B, F). The robust ringleist projects into the cell, extending one-eighth (valves with large diameter, *e.g.*, Fig. 4G) to one-half (valves with small diameter, *e.g.*, Fig. 6K) of the radius of the valve. Some valve mantles show a "Müller Step" (*sensu* Müller 1884 and Crawford & Likhoshway 1999) (MS – in Fig. 6G). Rimoportulae are numerous, 4–14, internally with a short internal stalk (Fig. 6H), their small external openings associated with areolae (Figs 4B, C, 5A, 6C). Rimoportulae are spaced in a sparse ring near the ringleist (Fig. 5C), or in a sparse ring near to the middle of the valve mantle (Figs 4E, 6C), or they are distributed irregularly (Fig. 5B). The valve faces are flat, with areolae irregularly spaced or lying in more or less diagonal rows (Fig. 3G), sometimes papillae or rugosities are present on the valve face (Fig. 6I, J). The girdle band is composed of several copulae (Fig. 5D). Initial cells were not observed.

Remarks. – *Aulacoseira hibschii* constitutes about 70% of the diatom population in the material from Varnsdorf, with another, smaller *Aulacoseira*, morphologically similar to *A. distans* (Ehrenberg) Simonsen, adding almost 30%, and a few *Melosira undulata* (Ehrenberg) Kützing completing

Figure 4. *A. hibschii* (Reichelt) Houk, SEM; scale bars in μm. Varnsdorf, Hustedt Collection raw material E 1821 "Warnsdorf, braune Schicht, leg. Reichelt". Valves with conical spines. • A – tilted sibling valves. • B – tilted valves; outer opening of rimoportula arrowed. • C – valve exterior view; outer opening of rimoportula arrowed. • D–H – valve interior views; internal openings of rimoportulae arrowed.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the assemblage. *A. hibschii* is also frequent in the raw material from the near locality in Seifhennersdorf Sf 7781. In the diatomite material from Kundratice in the České středohoří Mountains more than 99% of the diatom population constitutes *A. hibschii*. Except for this taxon, *Ellerbeckia* sp. (Centrales, Paraliaceae) can also be rarely observed. *A. hibschii* was also observed in other diatomites from the České středohoří Mountains. First of all it create more than 99% of the diatom population in the diatomite from the locality Lochočice-Stadice (Fig. 6F, I). Another locality where this species was observed is the diatomite from Bechlejovice (Fig. 6K), but it is very rare there and was not reliably identified and photographed in LM due to the presence of several similar *Aulacoseira* taxa in the sample. However, to find *A. hibschii* and exactly identify it in the SEM was relatively easy.

Discussion

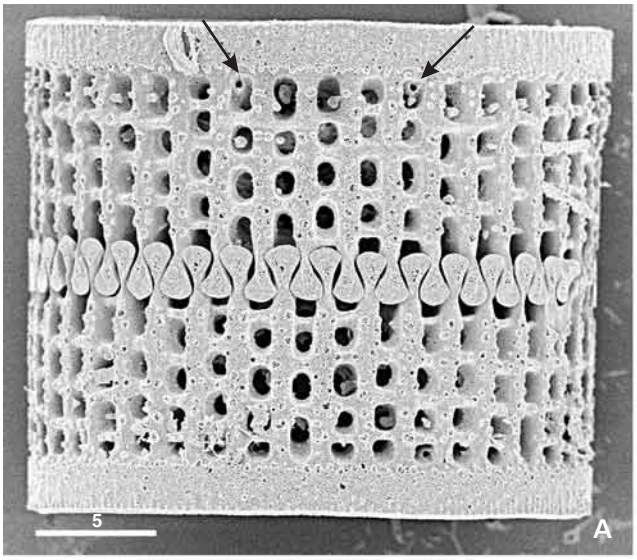
Reichelt (1900) described his *Melosira hibschii* as cells with frustules mostly shorter than wider, with rounded valves with large dots arranged irregularly, but lying in shorter and longer rows, and with the "girdles" (die Gürtelbänder in orig.) with three to five transversal rows of large, rectangular punctae. He also mentioned that in the middle of the "girdle-band side" (die Gürtelbandseite in orig.), there is a smooth ring around the cell, and so Reichelt thus described the structure that he called a collum, present in representatives of the genus *Aulacoseira* Thwaites. He also noted that he had observed this species only in the diatomites of northern Bohemia. Using this description it is easy to identify this species in the raw material from Varnsdorf, deposited in the Hustedt Collection and assigned as "Warnsdorf, braune Schicht, leg. Reichelt", and in the slides from the Hustedt and Weinzierl collections (Figs 3, 4), which seem to be made from this Reichelt's Varnsdorf material as they contain the same diatom assemblage.

The positions of the rimoportulae in the valves from the Varnsdorf material can vary strongly (Figs 4H, 5B), whereas their position in the valves in material from other localities is rather reduced to a sparse ring near to the middle of the valve mantle (Fig. 6D, L). The relationship between the valve mantle height and the valve diameter (Fig. 2) is similar to that found by Haworth & Sabater (1993) in their taxon *Aulacoseira ceretana*, where the larger the valve diameter, the shorter is the valve mantle height. These authors also made a table of character descriptions of large, coarsely areolate fossil *Aulacoseira* species based on original descriptions, where *A. ceretana* Haworth & Sabater, *M. youngi* Skvortzow, *M. youngi* var. *tenuissima* Skvortzow, *A. canadensis* (Hustedt) Simonsen, *M. hibschii* Reichelt, *A. praeislandica* (Jousé) Simonsen, *A. praegranulata* (Jousé) Simonsen, *A. praegranulata* var. *angustissima* (Jousé) Simonsen and *M. praedistans* Jousé were compared. Even though Haworth & Sabater (1993) mentioned that all of these taxa should have been considered as *Aulacoseira* species, *Melosira youngii* Skvortzow with its varieties and *M. praedistans* Jousé were not formally transferred to this genus. Of all of these taxa, only *Aulacoseira ceretana* and *A. canadensis* from the type material were investigated in SEM. The type material of *Melosira youngi* Skvortzow is lost (Haworth & Sabater 1993) as is that of *Aulacoseira praeislandica* (Jousé) Simonsen, *A. praegranulata* (Jousé) Simonsen and *Melosira praedistans* Jousé (Dr. N. Strelnikova, pers. com.), which means that it is impossible to directly compare their ultrastructures and so find out the taxonomic position of *Melosira youngi*, *M. praedistans*, *Aulacoseira praeislandica* and *A. praegranulata*. Even when Kaczmarska (1985) reduced *A. canadensis* (Hustedt) Simonsen to a form of *M. youngi* Skvortzow (as *M. youngi* forma *canadensis*), Haworth & Sabater (1993) preferred to retain the separation at species level just for the reason that the type material of *Melosira youngi* is absent.

The SEM investigations of *Aulacoseira ceretana* and *A. canadensis* showed Haworth & Sabater (1993) that their rimoportulae are located on the ringleist (pseudoseptum in orig.) and so they differ in this character from *A. hibschii* presented in this paper, where the rimoportulae have never been found on the ringleist. Similarly *A. hibschii* differs in this character from *A. paucistriata* Bradbury, *A. solida* (Eulenstein *in* Van Heurck) Krammer and *A. krammeri* Edgar, R.K., Kociolek & Edgar, S.M., which also have their rimoportular canals inside the ringleist (Bradbury 1991, Edgar *et al.* 2004). *A. distans* (Ehrenberg) Simonsen also has a sparse ring of the rimoportulae located in near the ringleist (Crawford & Likhoshway 1999), but it differs from the larger, coarsely areolated *A. hibschii* in other characters.

As mentioned above, Jousé & Mukhina (1978, p. 934, pl. 12, figs 2, 3, 6, 7) labelled four valve exterior SEM pictures as "*Melosira hibschii* Reich." from the late Pliocene sediments of the Black Sea. However, after comparison of the cell morphology of these valves/cells with those from

Figure 5. A–F – *A. hibschii* (Reichelt) Houk, SEM; scale bars in μm. Varnsdorf, Hustedt Collection raw material E 1821 "Warnsdorf, braune Schicht, leg. Reichelt". • A–C –valves with spatulate linking spines. A – valve exterior view; small outer openings of rimoportulae associated with areola arrowed. B, C – valve interior views; internal openings of rimoportulae arrowed. • D – valve with the remains of the girdle band; single copulae arrowed, vc = valvocopula. • E, F – valve face exterior views.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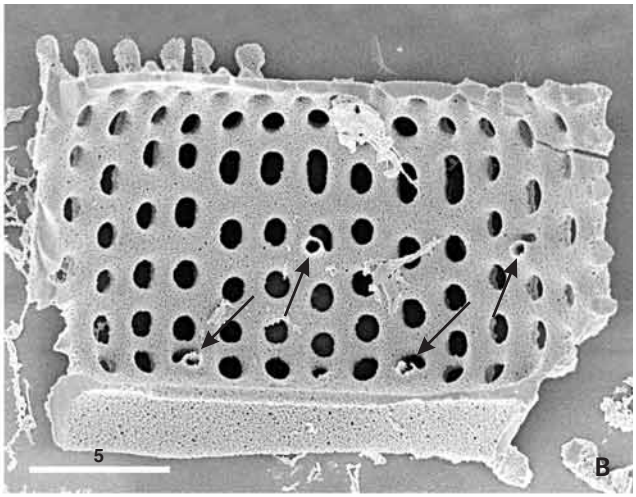
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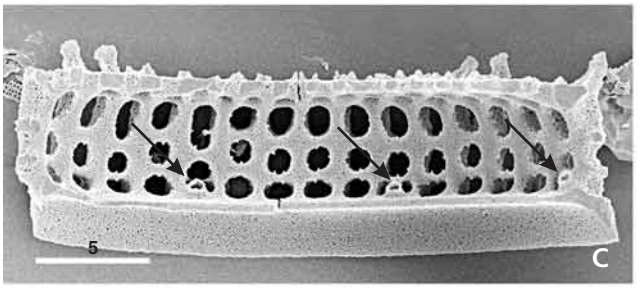
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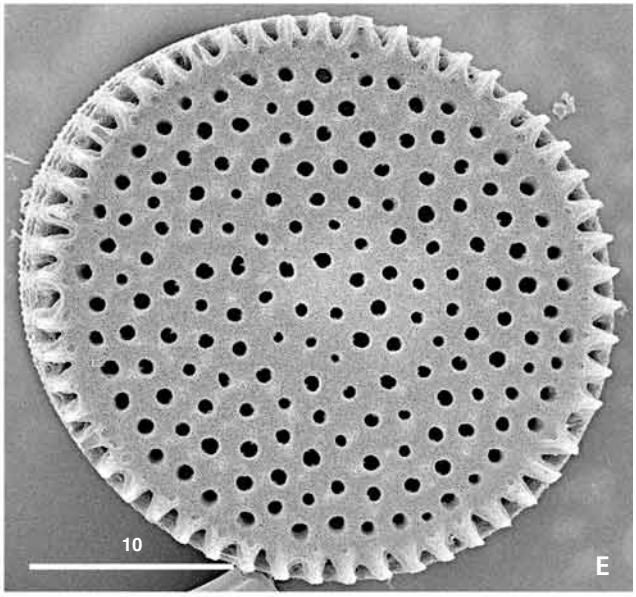
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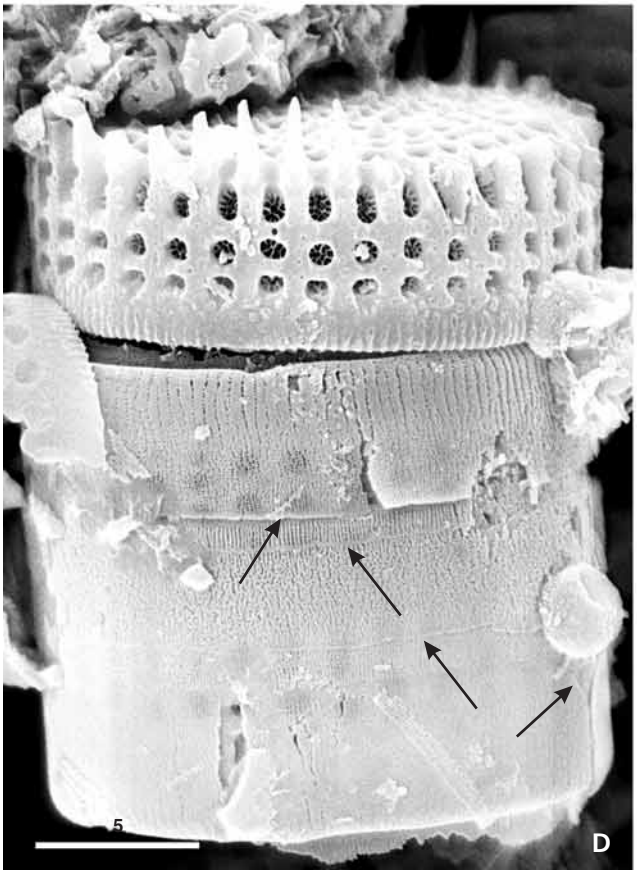
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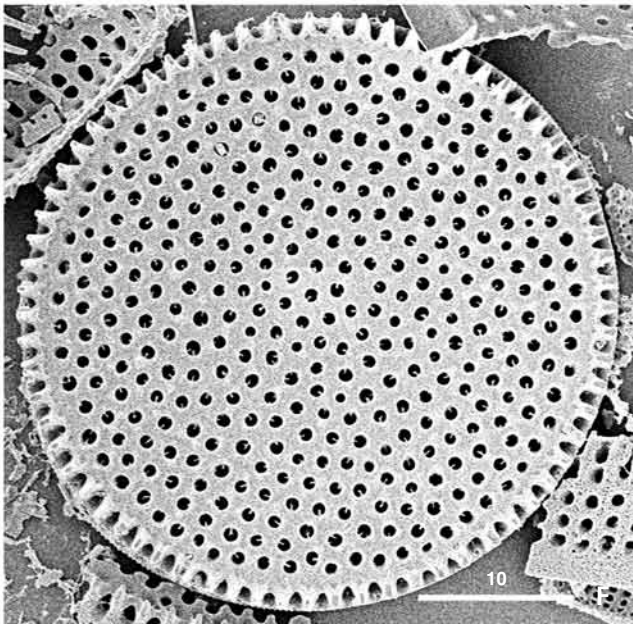
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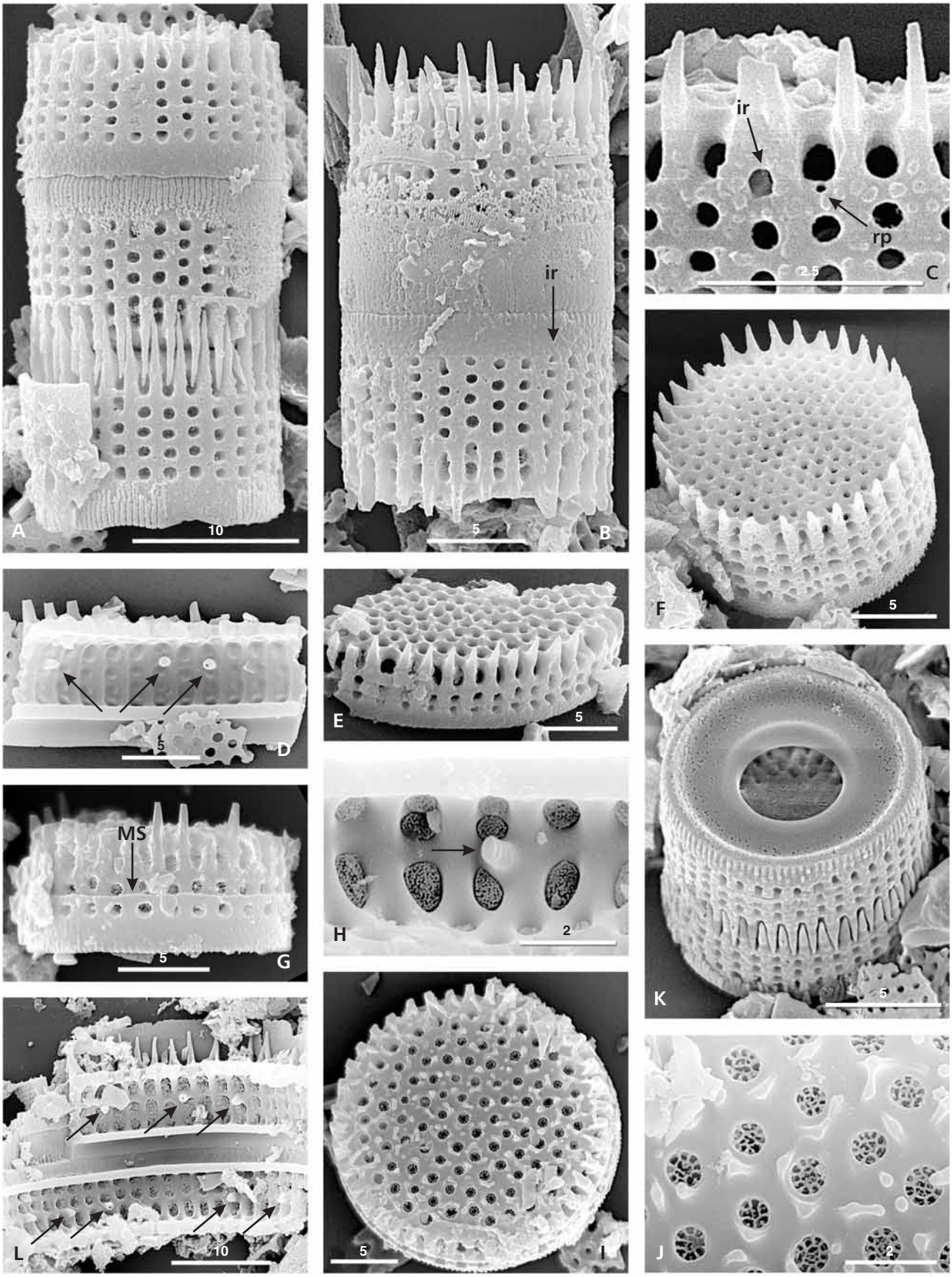
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the Varnsdorf material, the "disk" pictures in Figs 2, 3 do not represent *A. hibschii*, and also the identity of the cells represented in Figs 6, 7 with initial valves that were not observed in the material from the type locality, is rather doubtful.

Conclusions

It is clear from the SEM investigations of the Varnsdorf material and materials from other localities in northern Bohemia that *Aulacoseira hibschii* is a species with a high morphological variability. Nevertheless, the species is clearly distinguishable from other similar taxa in the characteristic location of rimoportulae in combination with the coarse areolar valve pattern and with the characteristic shape of the spines. The valve morphology and ultrastructure of *Aulacoseira hibschii* (Reichelt) Houk comb. nov. presented here will help to dispel confusion in taxonomy and clarify nomenclature of this and related fossil *Aulacoseira* taxa.

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Figure 6. *A. hibschii* (Reichelt) Houk, SEM; scale bars in µm. • A–D – Kundratice MMg raw material. • E–J – Lochočice Stadice M 33 52 Bc raw material. • K – Bechlejovice raw material. • L – Seifhennersdorf Sf 7781 raw material. • A, B – valves exterior views. See long conical spines. • B, C – ir = interstitial row of areolae runnig into buttressed base of spine (arrowed). • C – detail of the valve mantle exterior; rp = small opening of rimoportula associated with areola. • D – valve interior view; see rimoportulae situated in a sparse ring in the middle of the valve mantle (arrowed). • E, F – tilted valves exterior. • G – valve exterior view; MS = "Müller Step". • H – short inner stalk of rimoportula with the slit perpendicular to stalk axis (arrowed). • I – valve face exterior. • J – detail of the valve face exterior with areolae occluded by complex vela. • K – tilted sibling valves; note the deep ringleist. • L – valve interior view; see rimoportulae situated in a sparse ring in the middle of the valve mantle (arrowed).

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