Transfer of *Achnanthes hedinii* Hustedt to the genus *Crenotia* Wojtal (*Achnanthidiaceae, Bacillariophyceae*)

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The genus *Crenotia* Wojtal was described in 2013 with *Crenotia thermalis* (Rabenhorst) Wojtal as generitype (Wojtal 2013: 81). *Crenotia* differs from previously established genera within the Achnanthidiales in the unique structure of the transapical striae and the girdle bands. The striae are biseriate, and internally terminate in a shallow depression covered by a thin layer of silica. The girdle elements are without ornamentation.

Achnanthes hedinii Hustedt (1922: p. 122, pl. IX: figs 12–14, '*Hedini'*) was described by Hustedt from a sample collected from a pond by the Swedish explorer Sven Hedin during his 2nd expedition in Tibet (1899–1902) when crossing the Kekexili Basin, in the eastern part of the Kunlun Mountains (Hedin 1903) of Tibet. The sample, derived from algal mat, was also used to describe *Fragilaria asiatica* Hustedt (1922: 119, pl. IX: figs 28–30) as discussed in Rioual *et al.* (2017). The original drawings (here reproduced as Fig. 1) show heterovalvar cells of 15–25 µm long and 3–4 µm wide. The rapheless valve is characterized by a wide central area and short striae on the margin. Our first impression (Rioual *et al.* 2017) was that *Achnanthes hedinii* was a heterotypic synonym of *Crenotia thermalis* as the two taxa have a very similar size range (Table 1) but a more careful examination and new scanning electron microscope (SEM) images revealed subtle differences between the two taxa.

The only known published light microscopy (LM) images from the type slide are those given in Simonsen's Atlas of Hustedt's types (Simonsen 1987) and in the Hustedt Diatom Collection Database (2019). When reporting on this species Simonsen (1987) took the opportunity to correct its name to *Achnanthes hedinii* by removing the capital H and changing the declension of the epithet. To our knowledge *Achnanthes hedinii* has not been reported elsewhere in the diatom literature.

We analysed the type material (AS1395 and slide Ka/61), borrowed from the Hustedt Diatom Collection at the Alfred Wegener Institute in Bremerhaven (Germany), using LM (Figs 2–25) and SEM (Figs 26–42) to study the morphology and ultrastructure of *Achnanthes hedinii* Hustedt. Valve length, width and stria density were measured on digital images using ImageJ (Rasband 2013). Stria density was estimated by measuring the distance spanned by ten striae from the middle point of the valve toward the apex (not across the transapical axis), nearest to the sternum (away from valve edge) and algebraically converting to a number of striae per 10 µm. Interestingly, the stria density reported by Hustedt was 23–26 while we found 17–24 striae in 10 µm. That difference between our observations and Hustedt's description may be due to the different methods employed for the measurements but also suggests that Hustedt overestimated the stria density (as it was the case for *Fragilaria asiatica*, Rioual *et al.* 2017). The presence of biseriate striae (Figs 36, 39, 41) that internally terminate in a shallow depression covered by a thin layer of silica (Figs 40–42) and pattern less girdle bands (Figs 26–28, 37–38) indicate that *Achnanthes hedinii* belongs to the genus *Crenotia*.

We therefore propose to transfer *Achnanthes hedinii* Hustedt to the genus *Crenotia* and emend its description as follows:

***Crenotia hedinii* (Hustedt) Rioual, Ector & C.E.Wetzel, comb. nov.** (Figs 2–42)

Basionym: *Achnanthes hedinii* Hustedt ('*Hedini'*). In: Hedin, S. (Ed.).Southern Tibet, discoveries in former times compared with my own researches in 1906–1908. *Lithographic Institute of the General Staff of the Swedish Army, Stockholm*, vol. 6 (3): 122, pl. IX: figs 12–14, 1922.

Emended description: valves 7–30 µm long, 3.2–4.6 µm wide, with 17–25 striae in 10 µm at the valve centre composed of biseriate areolae at the apices only. This taxon differs from *Crenotia thermalis* by having slender valves with more acutely rounded apices, shorter striae that appear fainter under LM as they are only clearly biseriate at the apex.

Distribution: *Crenotia hedinii* has only been reported from the type locality in Tibet.

The presence of *Crenotia hedinii* in Tibet has implication regarding the biogeography of the genus *Crenotia* that was considered endemic to Europe by Kociolek (2018) in his review on the biogeography of freshwater diatom genera. However, among the species currently included in *Crenotia* several appear to have a wide distribution. For example, *Crenotia thermalis*, the type species of the genus, and *Crenotia grimmei* (Krasske) Wojtal are reported in AlgaeBase (Guiry & Guiry 2019) to be distributed in North America and Asia, in addition to Europe. *Crenotia thermalis* has even been reported in Russia (Kulikovskiy *et al*. 2016), and from springs in France (Wetzel *et al.* 2019) and Tunisia (Coste *et al*. 2019). In addition, *Crenotia gibberula* (Grunow) Wojtal was found in a thermal spring in the Washington State, USA (Stockner 1968) while *Crenotia rumrichorum* (Lange-Bertalot) Wojtal was originally described from Arizona, USA, but also found in a gravel-pit lake in Slovakia (Hindáková 2009), springs of the northern Apennines, and streams in Cyprus (Lange-Bertalot *et al*. 2017). In fact, only one species, *Crenotia angustior* (Grunow) Wojtal, seems to be restricted to Europe. *Crenotia* should therefore be considered as a widely distributed genus.

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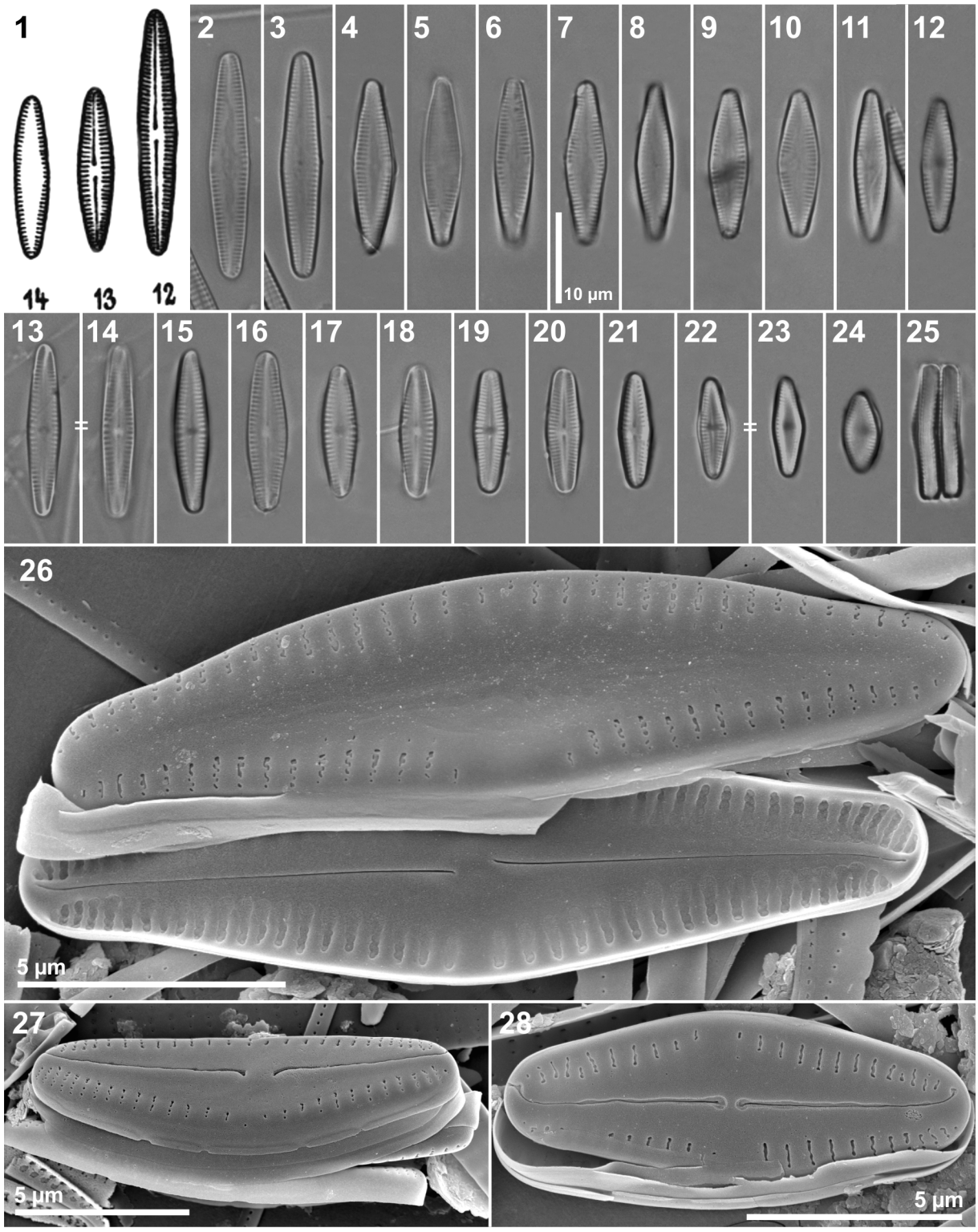
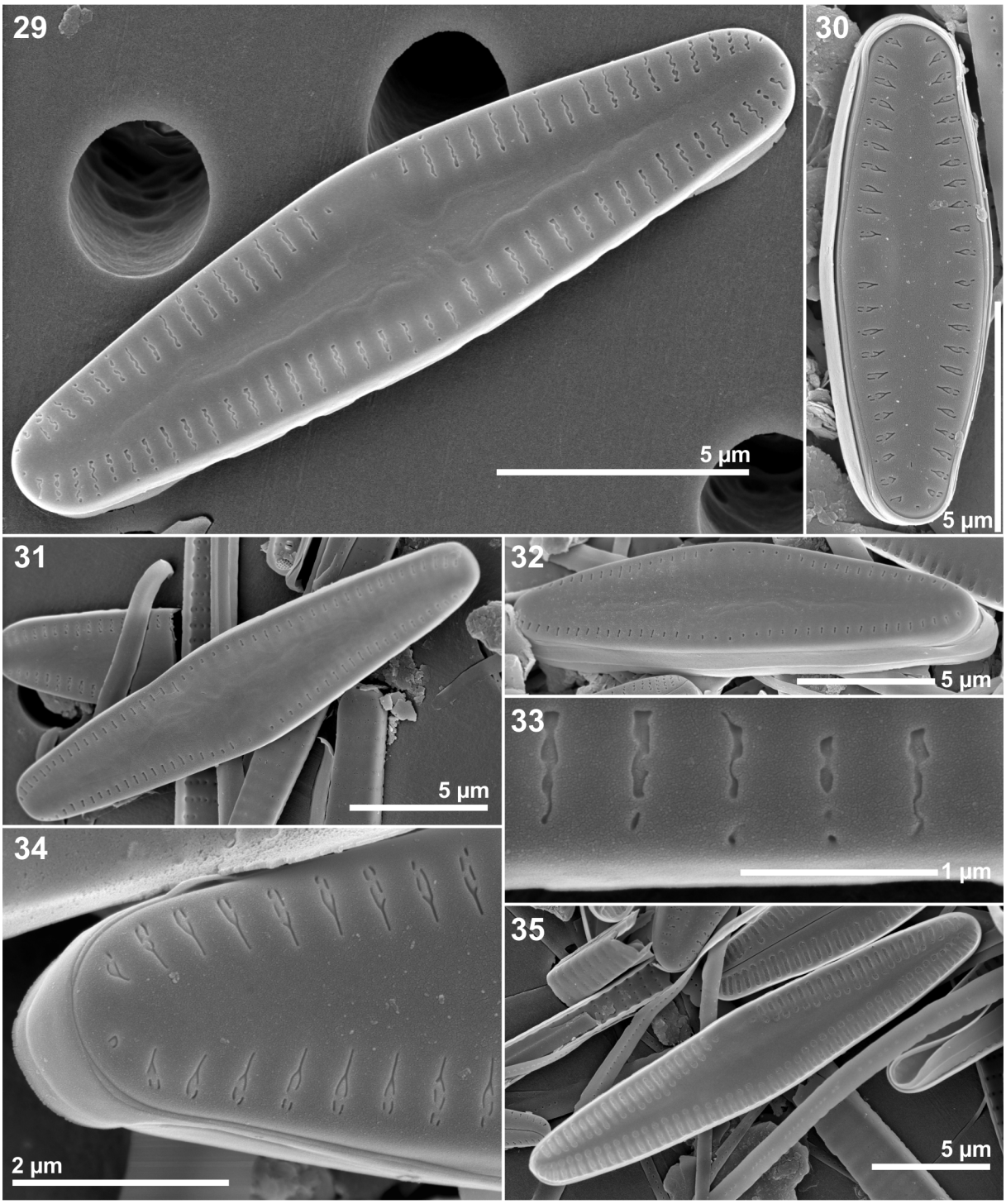
Table 1. Comparison between the morphometric data of *Crenotia hedinii* gathered from the literature and from our analyses and *Crenotia thermalis* (n = number of images analysed).

Taxon (as reported in references)	Reference	n	Valve length (µm)	Valve width (µm)	Striae in 10 µm
Achnanthes hedinii	Hustedt (1922)	n/a	15–25	3–4	23–26
Achnanthes hedinii	Simonsen (1987)	8	7.6–29.8[1]	3.2–4.4[1]	21–25[1]
Achnanthes hedinii	Hustedt Diatom Collection Database (2019)	6	19.2–21.8[2]	3.5–4.1[2]	19–22[2]
Crenotia hedinii	this study (LM)	46	13.7–22.8	3.5–4.6	19–23
	this study (SEM)	17	14.8–29.3	3.8–4.6	17–24
Achnanthes thermalis [*Crenotia thermalis*]	Krammer & Lange-Bertalot (2004)	n/a	7–34	3.3–5.5	20–26
		13	11.1–31.6[3]	3.5–5.4[3]	18–24[3]

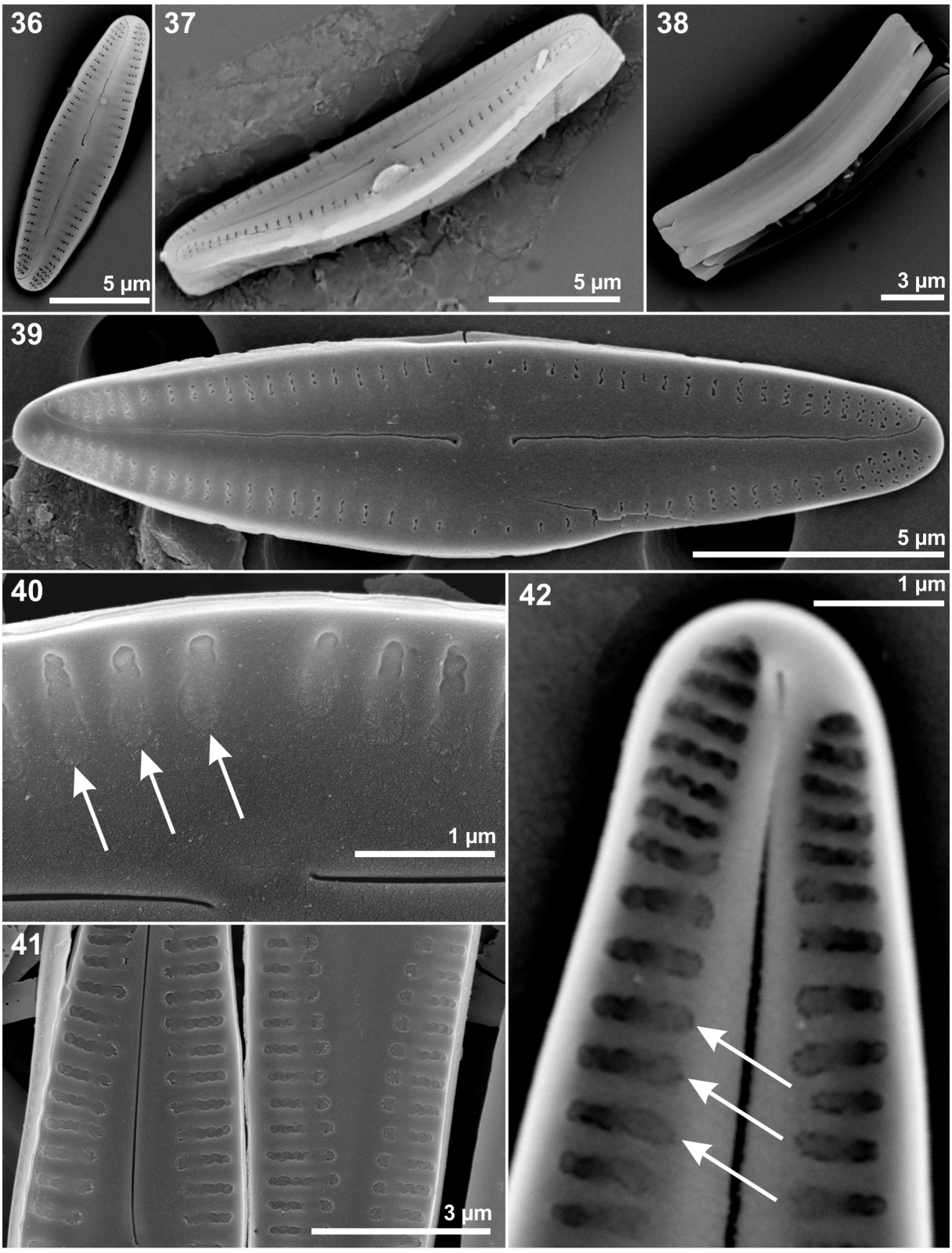
[1]Measured from the 8 images published by Simonsen (1987)
[2]Measured from the 6 images available from the Hustedt Diatom Collection Database (2019)
[3]Measured from the 13 images published by Krammer & Lange-Bertalot (2004) from lectotype material "Mineralwässer zu Cannstatt" Rabenhorst



Figs 1–28. *Crenotia hedinii* (Hustedt) Rioual, Ector & C.E.Wetzel, *comb. nov*. Fig. 1: Reproduction of *Achnanthes hedinii* Hustedt (1922, Pl. IX, figs 12–14, '*Hedini*'). Figs 2–25: LM images from original raw material AS1395 (Hustedt Diatom Collection). Figs 26–28: SEM images. Fig. 26: Overview of open frustule and girdle bands. Detail of apex showing biseriate striae of rapheless valve. Figs 27–28: External view of small concave raphe valves. Type locality: Tibet, between camps XXVII and XXVIII, "Chaîne van de Putte", 17.8.1900.



Figs 29–35: *Crenotia hedinii* (Hustedt) Rioual, Ector & C.E.Wetzel, *comb. nov*. SEM images from type material AS1395. Rapheless valves. Figs 29–34: External view of convex rapheless valves showing variable patterns of areolae and asymmetrical central area. In larger valves the striae appear very short (Figs 31 and 32). Figs 33–34: Distinct patterns of areolae. Fig. 35: Internal view of a rapheless showing shallow depressions terminate the striae.



Figs 36–42: *Crenotia hedinii* (Hustedt) Rioual, Ector & C.E.Wetzel, *comb. nov*. SEM images from type material AS1395. Raphe valves. Fig. 36: External view of raphe valve, detail of apex showing biseriate striae. Figs 37–38: Whole frustules in girdle view, copulae are without any ornamentation. Fig. 39: External view of concave raphe valves showing terminal fissures sharply curved to the same side. Figs 40–42: Internal areolae openings occluded with fine radiant hymenate structures (white arrows) which are partially merged with adjacent hymens on both rapheless (Fig. 41) and raphe valves (shallow depressions near the axial area). Fig. 42: Internal view of raphe valves with details of proximal raphe endings and of a small helictoglossa at distal end.