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Nitzschia imae sp. nov. (Bacillariophyta, Nitzschiaceae) from Iceland, with a redescription of *Hannaea arcus* var. *linearis*

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Abstract

Álvarez-Blanco, I. & Blanco, S. 2013. *Nitzschia imae* sp. nov. (Bacillariophyta, Nitzschiaceae) from Iceland, with a redescription of *Hannaea arcus* var. *linearis*. *Anales Jard. Bot. Madrid* 70(2): 144-151

From field-collected samples, two Icelandic diatom species were studied under light and electron microscopy, resulting in a newly described species and an emended description with a nomenclatural status change. A discussion on the morphological features of these taxa and their taxonomic affinities with related species is presented. *Nitzschia imae* is described from Blue Lagoon, south-west Iceland. The main diagnostic criteria include the presence of two differences morphotypes, one with obtusely rounded apices and the other with slightly asymmetrical valve outline and broadly rounded apices. Additionally, we propose an emended description for *Hannaea arcus* var. *linearis* since there is no concordance between morphometric features in the protologue and the type illustration.

Keywords: diatoms, new taxon, new combination, *Nitzschia*, *Hannaea*, Iceland, geothermal lake.

Resumen

Álvarez-Blanco, I. & Blanco, S. 2013. *Nitzschia imae* sp. nov. (Bacillariophyta, Nitzschiaceae) de Islandia, con una redescripción de *Hannaea arcus* var. *linearis*. *Anales Jard. Bot. Madrid* 70(2): 144-151 (en inglés).

A partir de muestras obtenidas en el campo, se han estudiado dos especies de diatomeas de Islandia mediante microscopía óptica y electrónica, siendo descrita una de ellas como nueva para la ciencia y realizándose una descripción enmendada y un cambio nomenclatural para la segunda. Se presenta una discusión de las características morfológicas de estos táxones y sus afinidades taxonómicas con especies similares. *Nitzschia imae* es descrita en la Laguna Azul, en el suroeste de Islandia. Los principales criterios de diagnóstico incluyen la presencia de dos diferentes morfotipos de la especie, uno con ápices apuntados y otro con forma valvar ligeramente asimétrica y ápices redondeados. Adicionalmente, se propone una descripción enmendada de *Hannaea arcus* var. *linearis* ya que no hay concordancia entre las características morfométricas propuestas en el protólogo y la ilustración del tipo del taxón.

Palabras clave: diatomeas, taxon nuevo, combinación nueva, *Nitzschia*, *Hannaea*, Islandia, lagos geotermales.

INTRODUCTION

The freshwater diatom flora of Iceland was initially studied first by Hansen (1872) and Ostenfeld (1904), but it was not until 1918 when the first comprehensive flora was given by E. Østrup (1918), he studied 572 samples collected from a large number of sites in the main part of the country and enumerated 468 taxa, a remarkably large number for that time. Subsequently, studies carried out by other authors provided additional contributions (e.g. Petersen, 1928a, b, 1935; van der Werff, 1941; Behre & Schwabe, 1970). Since then, few studies have been published, among them the most notable is Niels Foged's (1974) "Freshwater diatoms in Iceland", where a total of 244 samples from 170 localities were studied and 760 taxa were recorded. Nowadays, diatom taxonomy research in Iceland is scarce (Owen & al., 2008), although numerous studies on surface sediment diatom assemblages and their relationships with oceanic environmental variables to reconstruct the palaeoclimate and palaeoceanography have been carried out during the last decades (Karpuz & Schrader, 1990; Schrader & Karpuz, 1990; Koç & al., 1993; Jiang & al., 2001, 2002; Knudsen & al., 2009; Ran & al., 2011).

The present paper studies the diatom flora from two aquatic ecosystems of Iceland, the Blue Lagoon (a shallow geothermal lake), and the Laxá stream, both located in the south-west of the country. We first report a new taxon found at the Blue Lagoon belonging to genus *Nitzschia*, analyzing the valvar ultrastructure through light and scanning electron microscopy. This species is compared with some closely related species. Additionally, an emended description of *Hannaea arcus* var. *linearis* (Holmboe) R. Ross in Hartley is proposed based on the discrepancy between the original illustration and the corresponding diagnosis. Furthermore, a nomenclatural change for this taxon is proposed based on differences existing between this and the nominal variety.

MATERIAL AND METHODS

Study area

Iceland is a subpolar island situated on the Mid-Atlantic Ridge, with high volcanic activity. Freshwater habitats are common and diverse, represented by many lakes, as well as springs, streams, and temporary ponds. Iceland has a surface of 102 846 km^2, of which 12% is covered by permanent glaciers and 2% by lakes (Scher & al., 2000).

The Blue Lagoon is a shallow geothermal lake located in a former lava field in Grindavík, Reykjanes Peninsula, SW Iceland. It was formed in 1976 from the effluent of the Svartsengi geothermal power plant (Pétursdóttir & Kristjánsson, 1997). The lagoon water has an average temperature of about 37 °C, a pH of 7.5 and a salt content of 2.5% (Kazandjieva & al., 2008). The salinity of the water indicates that it is composed of 65% seawater and 35% freshwater (Grether-Beck & al., 2008). The water is saturated with silica, which constantly precipitates in the lake as colloidal particles forming a layer of soft white mud (Matz & al., 2003).

Several studies have indicated that bathing in the Blue Lagoon has beneficial effects for patients with psoriasis, atopic

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dermatitis as well as healthy normal skin (Ólafsson & al., 1996, Grether-Beck & al., 2008, Kazandjieva & al., 2008). The inhabiting community is dominated by two organisms: the photoautotrophic cyanobacterium *Lyngbya erebi* var. *thermalis* G.G. Claus during summer (Matz & al., 2003), and the heterotrophic alphaproteobacterium *Silicibacter lacuscaerulensis* Pétursdóttir & Kristjánsson during autumn and winter (Suryata & al., 2010). The high rate of silica precipitation, which was estimated to be about 10 $mg.L^{-1}.h^{-1}$, could be the reason of this low diversity (Pétursdóttir & Kristjánsson, 1996).

The Laxá stream is located on the west coast of Iceland, close to the Hafnarfjall Central Volcano. The stream flows into the Borgarfjördur fjord. The water at the sampling location (64º20'25"N, 25º35'33"W) had a temperature of about 15 °C and a pH of 5.

Fig. 1. Geographic location of sample sites, Laxá stream and Blue Lagoon.

Methods

Collections were made on 29/06/2012 from scrapings of littoral, submersed rocks at both sampling stations using a toothbrush. Water temperature was measured with a hand-held field thermometer, while pH was estimated by means of litmus papers. Removed periphyton was preserved in 4% v/v formaldehyde. Organic matter was eliminated by oxidation with hydrogen peroxide 30% v/v to obtain clean frustule suspension (Blanco & al., 2008). A few drops of hydrochloric acid were added to remove carbonate inclusions. The refractive resin Naphrax®, was used to prepare permanent microscopic slides that were examined in light microscopy (LM) with phase contrast optics (Leica DMRB) under 1000×. LM photographs were taken with a Canon EOS400 camera. For scanning electron microscopy (SEM) analysis, samples were filtrated through 1 or 3 mm pore-size polycarbonate membrane filters, placed on stubs and sputtered with gold (40 nm) using a modular high vacuum coating system. These were examined using a JEOL JSM-6480 LV instrument operated at 20 kV.

RESULTS AND DISCUSSION

Nitzschia imae Álvarez-Blanco & S. Blanco, **sp. nov.**
(Figs. 2-31)

Valvae lineares-ellipticae vel lineares, nonnunquam leviter constrictae in centro quoad specimina majora, apicibus obtuse rotundatis morphotypo 1, *modice assymetricae apicibus late rotundatis morphotypo* 2, 16.5-26.0 µm *longae,* 2.8-4.1 µm *latae. Raphe excentrica, fibulae irregulatim dispositae,* 15-17 *in* 10 µm, *nodulo centrali nullo. Striae transapicales nos aspectabiles in microscopio photonico,* 40-45 *in* 10 µm, *areolis externe occlusis,* 50-60 *in* 10 µm.

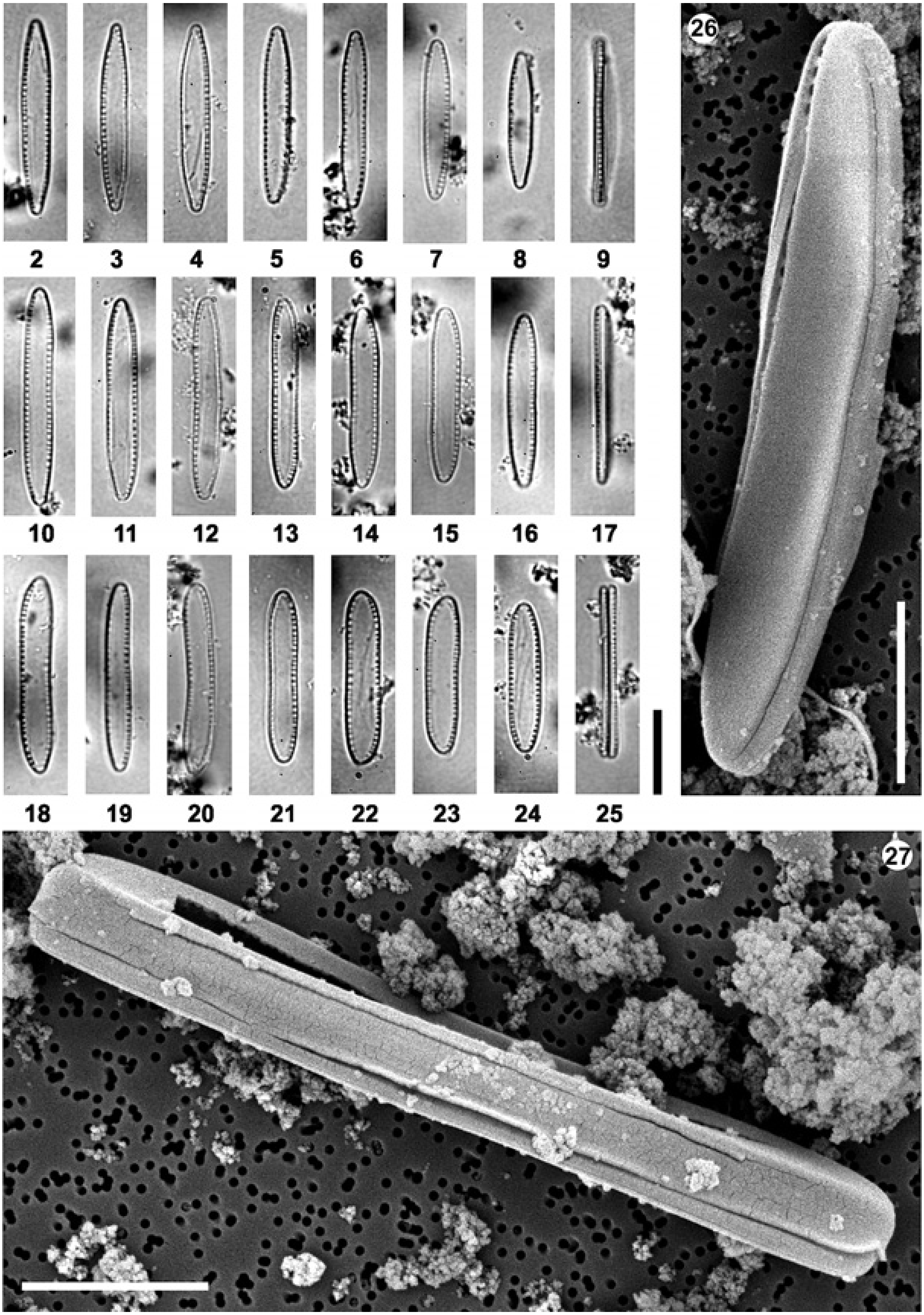
Valves linear-elliptic to linear, sometimes slightly constricted in the central region in larger individuals, with obtusely rounded apices in morphotype 1 (Mt1) (Figs. 2-8) and slightly asymmetrical with broadly rounded apices in morphotype 2 (Mt2) (Figs. 18-24), 16.5-26.0 µm long, 2.8-4.1 µm broad. Raphe eccentric, fibulae irregularly spaced, 15-17 in 10 µm, central nodule absent (Figs. 28, 30). Transapical striae in LM not resolvable, 40-45 in 10 µm, with externally occluded areolae (Figs. 26-31), 50-60 in 10 µm.

Holotypus: Iceland, Blue Lagoon, 63º52'50"N, 22º26'50" W, 40 m a.s.l., 29.VI.2012, coll. *E. Bécares*. LEB! Microscopic slide and stub no. 025, Figs. 2-31.

Etymology: The specific epithet refers to the acronym of Instituto de Medio Ambiente (IMA), León, Spain, where the study took place.

Differential diagnosis: Nitzschia imae is morphologically close to *N. latens* Hustedt, both taxa have a similar valve outline, slightly asymmetrical, with obtusely to broadly rounded apices and irregularly spaced fibulae (Table 1). Nevertheless, *N. imae* is distinguished from *N. latens* on the basis of valve length and breadth: according to Hustedt (1949), *N. latens* is 24-30 µm long and 4.0-4.5 µm wide, but Kociolek & Herbst (1992) extend its size range to 8-42 µm long and 4.0-5.5 µm wide, and show individuals with more irregularly spaced fibulae. Additionally, *N. imae* (Mt1) resembles *N. pusilla* Grunow and *N. perspicua* Cholnoky, with respect to the shape of valve apices and morphometric parameters (Table 1); however, both taxa have evenly spaced fibulae and lanceolate or elliptic valve outlines unlike the linear valve shape showed by *N. imae*. *Nitzschia imae* (Mt2) can be also compared morphologically with *N. communis* Rabenh.; nevertheless, *N. communis* has a larger size (6-40 µm long and 4-6 µm wide, according to Krammer & Lange-Bertalot, 1988) and a lower density of equidistant fibulae (8-14 in 10 µm according to Hofmann & al., 2011) (Table 1).

Comments: The diatom assemblage in the Blue Lagoon was composed almost exclusively by *Nitzschia imae*. The water at the sampling location had a temperature of about 19 °C and a pH of 5.5. No further records of diatom assemblages were found in the literature for this lake. According Pétursdóttir & Kristjánsson (1996) the low biological diversity in this system could be explained by the high rate of silica precipitation. The silica particles can also have reflective effects similar to the salt crystals in brines, thus increasing the exposure of microorganisms to UV and visible light and hence reducing species diversity (Atlas & Bartha, 1993). Furthermore, the salinity of 2.5%, the unusual source and the chemical composition of the dilute geothermal sea water are extreme characteristics that could explain the floristic particularities found in this unique environment (Pétursdóttir & al., 2009).



Figs. 2-27. *Nitzschia imae* sp. nov. Type material. **2-25,** light micrographs showing the valve variability within the species; **2-8, 10-16, 18-24,** valve views; **9, 17, 25,** girdle views; **26, 27,** scanning electron micrographs; **26,** external oblique view of an entire frustule; **27,** external girdle view of an entire frustule. Scale bar = 10 µm (Figs. 2-25), 5 µm (Figs. 26, 27).

Table 1. Morphometric data and morphological characteristics of *N. imae* compared with other related *Nitzschia* species.

	N. imae	***N. latens***	***N. pusilla***	***N. communis***	***P. perspicua***
Length (μm)	16.5-26.00	24-30[a] 8-42[d]	15-30[b] 8-33[c,g]	6-40(60)[e] 19.5-28.0[f] 6-40[g]	17-25(36)[c,e]
Width (μm)	2.8-4.1	4.0-4.5[a] 4.0-5.5[d]	3-5[b] 2.5-5[c,g]	4.0-5.8[e] 4.0-4.8[f] 4-6[g]	3-4[c,e]
Length/width ratio	5.9-6.3	6.0-6.7[a] 2.0-7.6[d]	5-6[b] 3.2-6.6[c,g]	1.5-6.9[e] 4.9-5.8[f] 1.5-6.7[g]	5.7-6.2[c,e]
Striae in 10 μm	40-45		50[b] 40-55[c,g]	28-38[e,g]	50[c]
Fibulae in 10 μm	15-17	16(10-20)[a] 10-21[d]	17-20[b] 14-20(24)[c,g]	(8)10-14[e] 11-13[f] 8-14[g]	15-17(20)[c] 15-17[e]
Fibulae arrangement	Irregularly spaced	Irregularly spaced[a,d]	Regular distribution[c]	Equidistantly spaced[e,g]	Equidistant[c] Evenly spaced[e]
Valves	Linear-elliptic to linear	Broadly linear[a] Parallel sides (larger valves) elliptical (smaller valves)[d]	Lanceolate[b] Linear-lanceolate to linear,rarely elliptic[c]	Elliptical, linear-elliptic to linear[e,g]	Narrow elliptic[c,e]
Apices	Obtusely rounded (Mt1), broadly rounded (Mt2)	Rounded blunt wedge-shaped[a] Protracted[d]	Rounded[b] Obtuse to broadly rounded[c]	Broadly rounded, rarely weakly produced and very obtusely rounded[e,g]	Bluntly rounded[c] Obtusely rounded[e]

a, Hustedt (1949); b, Germain (1981); c, Krammer & Lange-Bertalot (1988); d, Kociolek & Herbst (1992); e, Witkowski & al. (2000); f, Ector & Hlúbikovà (2010); g, Hofmann & al. (2011).

Hannaea linearis (Holmboe) Álvarez-Blanco & S. Blanco, **comb.** et **stat. nov.** et **emend.** (Figs. 32-42)

≡*Ceratoneis arcus* f. *linearis* Holmboe in Arch. Math. Naturvidensk. 22: 31. 1899, *basyonimus*

≡*Ceratoneis arcus* var. *linearis* (Holmboe) F.Meister in Beitr. Kryptogamenfl. Schweiz. 4(1): 91. 1912

≡*Hannaea arcus* var. *linearis* (Holmboe) Foged in Biblioth. Phycol. 53: 61. 1981, comb. inval.

≡*Hannaea arcus* var. *linearis* (Holmboe) R. Ross in Hartley, B. (ed.), J. Mar. Biol. Assoc. U.K. 66: 608, 1986

Typus: Pl. 37, fig. 7 (left) in Van Heurck, H., Atlas Syn. Diatom. Belg., 1880-1881

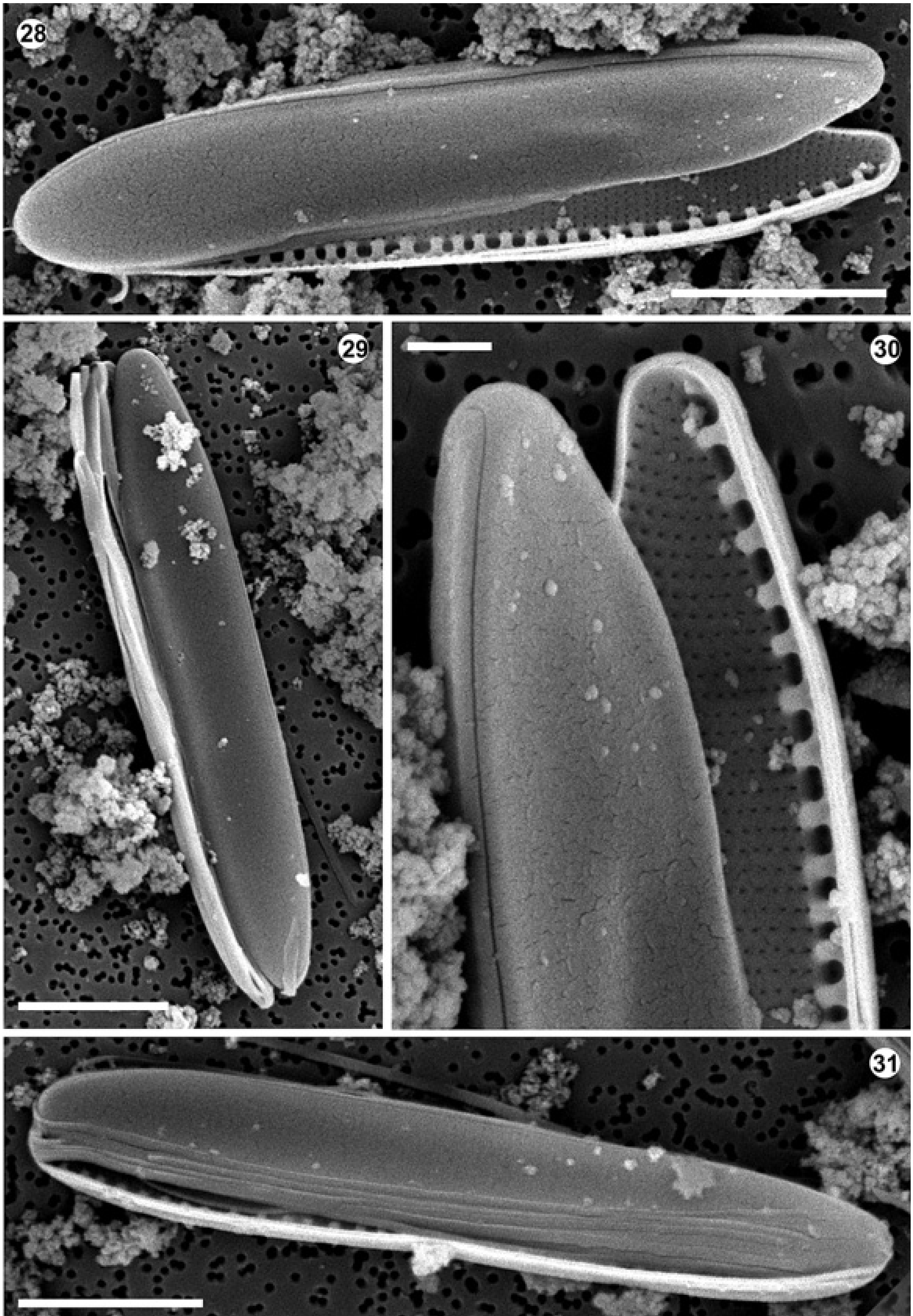
Comments: This species was originally described as *Ceratoneis arcus* f. *linearis* by Holmboe (1899) from several locations in Norway, referring to one of Van Heurck's (1880-1881) drawings of *Ceratoneis arcus* (Ehrenberg) Kützing [≡*Hannaea arcus*] as the type of the taxon. However, the morphometric values provided in Holmboe's diagnosis do not fit with this illustration since its length (96 μm) falls out of the length of "ca. 80 μm" specified in the original description. This fact and the subsequent finding of other populations outside the type locality (e.g. Foged, 1981; Bixby, 2001) account for a broader concept for this taxon, thus leading us to propose the following emended diagnosis:

Valves arcuate with capitated ends and a central unilateral inflation on the ventral margin, 81.9-137.3 μm long, 5.3-5.4 μm wide (at inflation) (Figs. 32-36). Raphe absent, axial area narrow. Striae parallel and uniseriate, 15-16 in 10 μm (Figs. 37-42). Spines arranged around the valve margin, irregularly spaced (Figs. 38, 42). Valve apices with a single rimoportula per valve (Figs. 39-42).

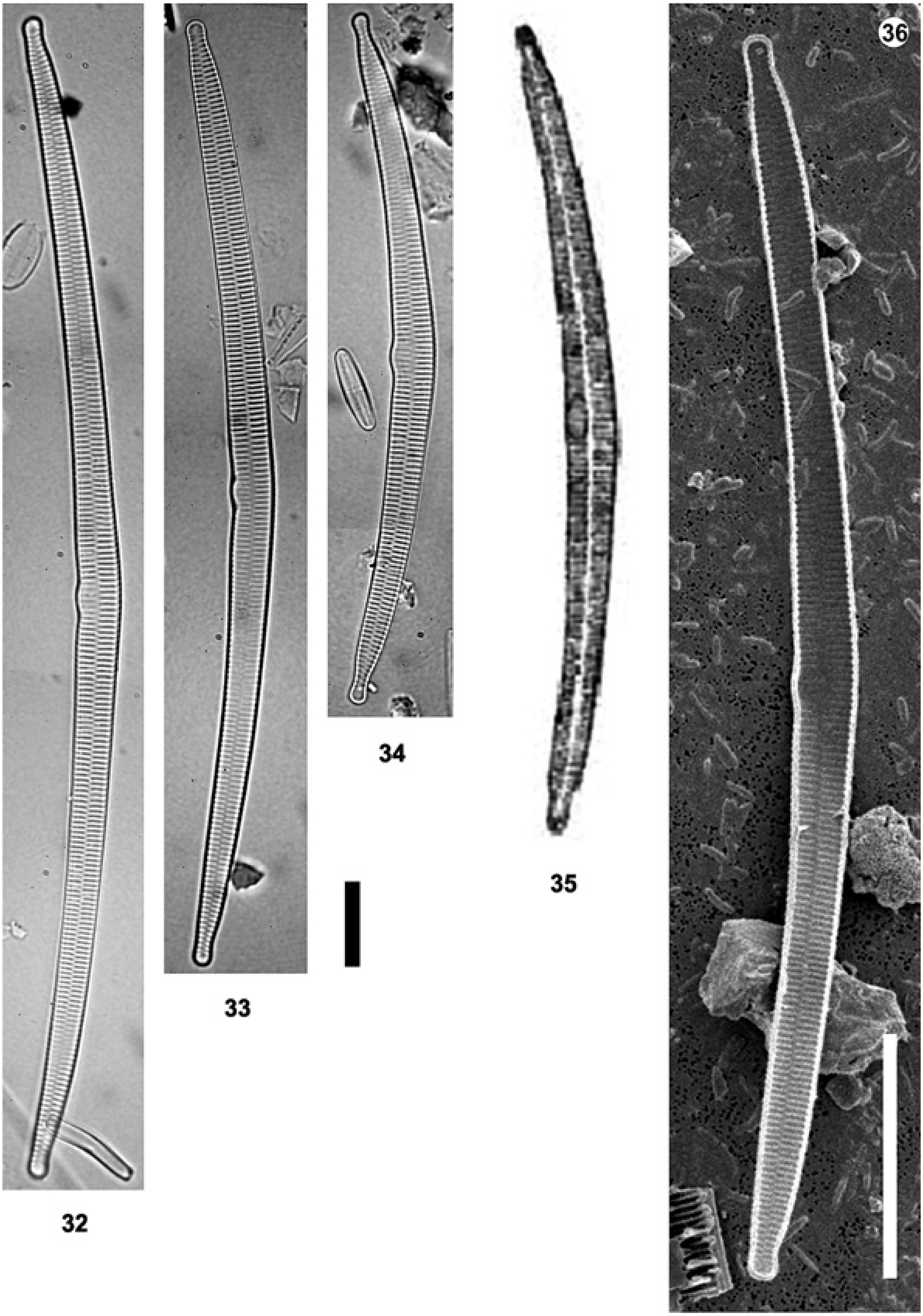
Differential diagnosis: H. linearis is morphologically close to *H. arcus* var. *arcus*; both taxa have similar valve outlines, uniseriate striae, spines along the valve margins and a single apical rimoportula. Nevertheless, *H. linearis* may be distinguished from *H. arcus* var. *arcus* by its morphometric data, the major difference being in valve length: *H. linearis* ranges from 81.9 to 137.3 μm, whereas that of *H. arcus* var. *arcus* ranges from 31.3 to 47 μm (Ehrenberg, 1838). Bixby & Jahn (2005) found valves up to 67 μm long in Ehrenberg's original material, and accept a length range from 35.4 to 80.3 μm in modern collections. There is no overlap in valve width either (5.3-5.4 μm in *H. linearis* vs. 6-7 μm in *H. arcus* var. *arcus*, according to the original description). Size values found in the literature for *H. linearis* (see Bixby, 2001, for a review), with individuals down to 40.4 μm in length, might denote mixed populations with *H. arcus* var. *arcus*. This last taxon can be also discriminated by a more pronounced ventral inflation (Hustedt, 1962). Despite being similar from a ultrastructural perspective and often co-occurring in oligotrophic habitats, Bixby (2001) has argued against the synonymization of these two taxa, based on clear differences in the valve outline, ecological preferences and growth habits, suggesting that *H. arcus* var. *linearis* might be raised to species status. Following this view, we also consider the morphological and morphometric disagreement between both varieties enough to propose a new combination within genus *Hannaea* as a distinct species.

H. linearis can also be compared with *H. superiorensis* Bixby & Edlund in Bixby & al. Both taxa have central unilateral inflation, uniseriate striae and a single polar rimoportula. However, *H. superiorensis* has arcuate valves with a secondary reflexion towards dorsal margin and a lower density of striae (10.3-15.1 in 10 μm, Bixby & al., 2005).

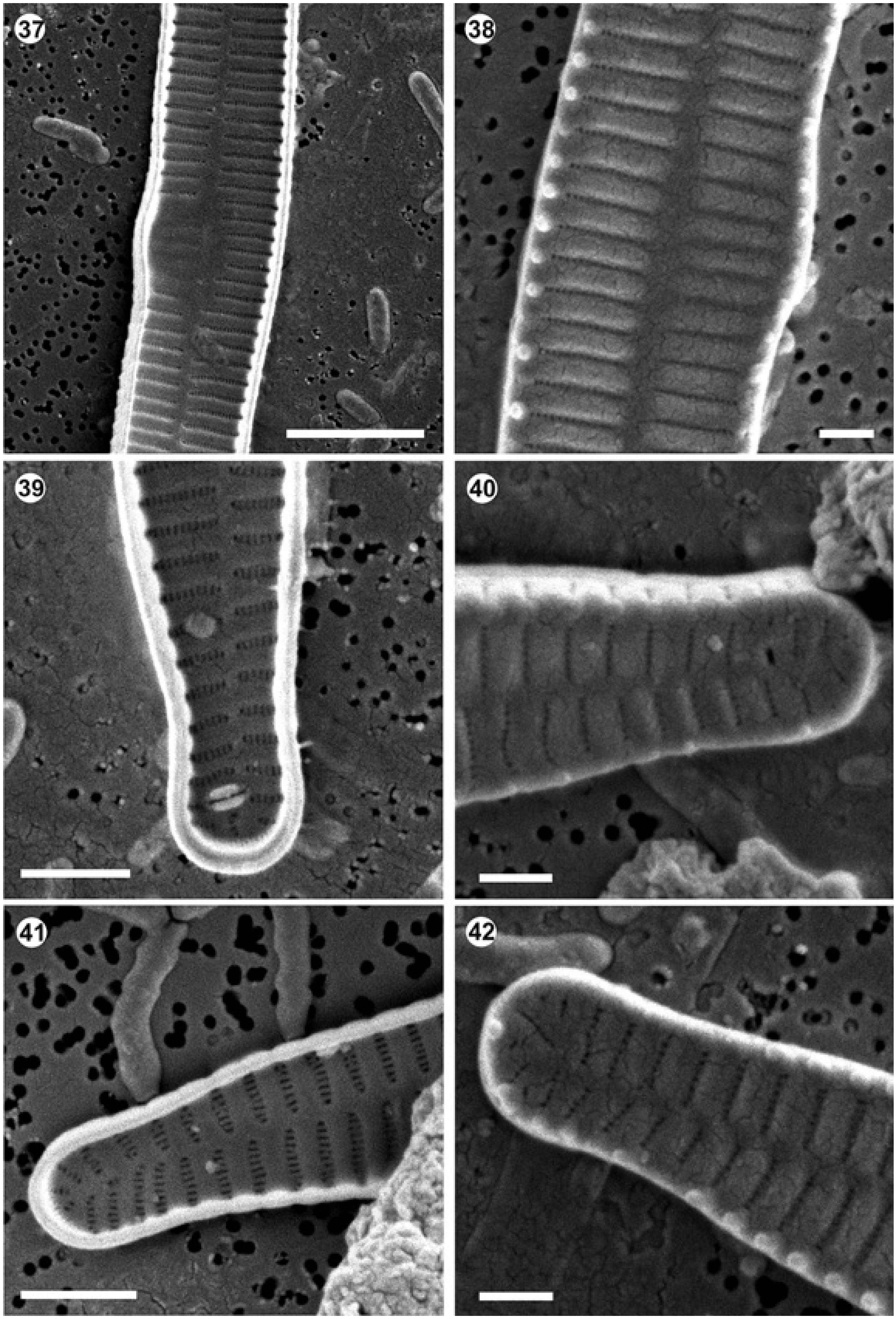
Ecological remarks: the diatom flora was very diverse in the Laxá stream, dominated by *Achnanthidium minutissimum* (Kütz.) Czarn. *Hannaea linearis* appeared as a subdominant species within the assemblage, together with *Encyonema silesiacum* D.G. Mann in Round & al. and *Meridion circulare* (Grev.) C.Agardh. The finding of this population only 1 km off the Borgarfjördur fjord coast (22 m a.s.l.) contrasts with usual reports of this taxon at high altitudes (e.g. Potapova, 1996). *Hannaea linearis* occurs in many high-latitude countries of the northern hemisphere, but with a restricted habitat. Foged (1974) had found it widespread in Icelandic freshwaters, preferentially in rivers and streams. In our study, water temperature and pH value at the sampling site (15 ºC and 5 units, respectively) do not fit either with the ranges found in the literature for *Hannea* taxa, usually restricted to 0-15 ºC and 6-8 pH units, respectively. Moreover, this species is often regarded as



Figs. 28-31. Scanning electron micrographs of *Nitzschia imae* sp. nov. Type material. **28,** external and internal valve views of an open frustule showing the raphe canal with the irregular fibulae arrangement and the eccentric keel; **29,** external oblique valve view; **30,** detail of an open frustule showing the striae and fibulae arrangement in the internal valve view and the raphe slit on the eccentric, slightly elevated keel in an external valve view; **31,** external oblique valve view. Scale bar = 5 µm (Figs. 28, 29, 31), 1 µm (Fig. 30).



Figs 32-36. Light and scanning electron micrographs of *Hannaea linearis* and original drawing of *Ceratoneis arcus* f. *linearis* from Van Heurck (1880-1881). **32-34,** light micrographs of *Hannaea linearis* showing the valve variability within the species; **35,** *Ceratoneis arcus* f. *linearis,* line drawing from Van Heurck (1880-1881) plate XXXVII fig. 7; **36,** scanning electron micrographs of *Hannaea linearis,* internal valve view. Scale bar = 20 µm (Fig. 36), 10 µm (Figs. 32-35).



Figs 37-42. Scanning electron micrographs of *Hannaea linearis*. **37,** central part of valve in internal view showing the hyaline unilateral area; **38,** external view of central area showing spines visible along the valve margin; **39,** internal view of valve apex with rimoportula showing uniseriate striae; **40,** external view of valve apex with rimoportula; **41,** detail of apex without rimoportula in internal view; **42,** external view of valve apex without rimoportula showing spines along the valve margin. Scale bar = 5 µm (Fig. 37), 2 µm (Figs. 39, 41), 1 µm (Figs. 38, 40, 42).

indicator of low nutrient concentrations, although Bixby (2001) states its association with high ionic content waters. These discrepancies would indicate that the autoecology of *H. linearis* is still not well resolved and needs of further research.

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