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Analysis of the type material of *Synedra deformis* W.Sm. and *Synedra vaucheriae* var. *deformis* Grunow (Fragilariaceae, Bacillariophyta)

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Synedra deformis W.Sm. Photo: Myriam de Haan (Meise Botanic Garden).

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ABSTRACT
Despite being one of the dominant groups in the diatom flora of our rivers and lakes, the correct taxonomic identity of several *Fragilaria* Lyngb. taxa (formerly in the genus *Synedra* Ehrenb.) is often blurred by insufficient knowledge of the different morphological types. The present paper illustrates and discusses several former *Synedra* taxa using both light and scanning electron microscope observations. Based on the morphological analysis, *Synedra deformis* W.Sm. is transferred to the genus *Fragilaria* as *Fragilaria deformis* (W.Sm.) Van de Vijver & Ector, comb. nov. A second *Synedra* species, *S. vaucheriae* var. *deformis* Grunow, is likewise investigated but proved a later synonym of *F. pectinalis* (O.F.Müll.) Lyngb. The morphological results are compared with the (type) material of several similar *Fragilaria* species such as *Fragilaria joachimii* Kahlert, *F. vaucheriae* (Kütz.) J.B.Petersen, *F. pectinalis* and *F. candidagilae* Almeida, C.Delgado, Novais & S.Blanco. Notes on the ecology of the different species are added.

KEY WORDS
Type analysis, morphology, *Fragilaria*, Europe, new combination.

RÉSUMÉ
Analyse du matériel type de Synedra deformis *W.Sm. et* Synedra vaucheriae *var.* deformis *Grunow (Fragilariaceae, Bacillariophyta).*
Bien qu'il soit l'un des groupes dominants de la flore des diatomées dans nos rivières et nos lacs, l'identité taxonomique correcte de plusieurs taxons du genre *Fragilaria* Lyngb. (auparavant décrits

dans le genre *Synedra* Ehrenb.) est souvent brouillée par une connaissance insuffisante des différents types morphologiques. Cette contribution illustre et discute plusieurs taxons du genre *Synedra* en utilisant à la fois des observations au microscope optique et électronique à balayage. Sur la base de cette analyse morphologique, *Synedra deformis* W.Sm. est transféré dans le genre *Fragilaria* sous le nom de *Fragilaria deformis* (W.Sm.) Van de Vijver & Ector, comb. nov. Une deuxième espèce de *Synedra*, *S. vaucheriae* var. *deformis* Grunow, est également étudiée mais s'est avérée être un synonyme ultérieur de *F. pectinalis* (O.F.Müll.) Lyngb. Les résultats morphologiques sont comparés avec du matériel (type) de plusieurs espèces de *Fragilaria* similaires telles que *Fragilaria joachimii* Kahlert, *F. vaucheriae* (Kütz.) J.B.Petersen, *F. pectinalis* et *F. candidagilae* Almeida, C.Delgado, Novais & S.Blanco. Des notes sur l'écologie des différentes espèces sont rapportées.

MOTS CLÉS
Analyse des types, morphologie, *Fragilaria*, Europe, combinaison nouvelle.

INTRODUCTION

A large number of *Synedra* Ehrenb. taxa (including species, varieties and forms), originally described in the 19th century by scientists such as Kützing (1844), Smith (1853, 1856) or Grunow (in Van Heurck 1882-1885), have been transferred in a recent past to a broad variety of other araphid genera such as *Fragilaria* Lyngb. (Lange-Bertalot 1980; Tuji & Williams 2013; Lange-Bertalot & Ulrich 2014). In the original protologues, regularly only a single illustration was shown, although from the original descriptions it is clear that usually more specimens must have been analysed prior to be described. This single drawing makes it in many cases difficult to interpret their correct morphology. *Fragilaria* taxa are often found to dominate the diatom communities in freshwater ecosystems (Kahlert *et al.* 2019), both in number of specimens and in species diversity. Due to taxonomic drift broadening the original 19th century descriptions and an incomplete knowledge of the original type material, a large number of taxa were lumped into taxa showing not only a broad morphological variability but also broad ecological preferences. Although this practice was originally meant to reduce the confusion and the workload of analysts working in water quality biomonitoring business (Kahlert *et al.* 2019), it also decreased the level of accuracy of the biodiversity assessment.

In recent years, there has been an increased effort to examine original type material of these former *Synedra* taxa that resulted not only in a better knowledge of well-established taxa such as *Fragilaria vaucheriae* (Kütz.) J.B.Petersen, *F. rumpens* (Kütz.) G.W.F.Carlson or *F. mesolepta* Rabenh., but also in the description or recombination of many other taxa (e.g. Tuji & Williams 2008; Delgado *et al.* 2015; Wetzel & Ector 2015). However, a large number of former *Synedra* taxa still awaiting a detailed revision, were forgotten or were put into synonymy, usually due to a complete lack or current uncertainty about the whereabouts of the necessary type material.

One of these taxa is *Synedra deformis* W.Sm., described from a sample collected in 1853 in Lewes, Sussex (United Kingdom) (Smith 1856). Contrary to other taxa Smith described, *S. deformis* was never illustrated (Smith 1853, 1856), most likely one of the reasons why the species was entirely forgotten. A few years later, Grunow in Van Heurck (1881) described *Synedra vaucheriae* var. *deformis*, later transferred by Astrid Cleve-Euler to *Fragilaria intermedia* f. *deformis* (Grunow) A.Cleve (Cleve-Euler 1932: 21). Tuji & Williams (2013) analysed the original Grunow material (sample 907, Grunow collection, W, Austria) and concluded that the taxon should be considered a synonym of *Fragilaria vaucheriae*. According to DiatomBase, *Synedra deformis* W.Sm. should be treated as a synonym of *S. vaucheriae* var. *deformis* (Kociolek *et al.* 2020).

Recently, the original material of both *Synedra deformis* and *S. vaucheriae* var. *deformis* was found in the Van Heurck diatom collection in Meise Botanic Garden (BR, Belgium). The *Synedra* populations in the original material were examined using light (LM) and scanning electron microscopy (SEM). The present contribution discusses and illustrates the morphology of both taxa. The morphological results are compared with the (type) material of several similar *Fragilaria* species: *Fragilaria joachimii* Kahlert in Kahlert *et al.* 2019, *F. vaucheriae*, *F. pectinalis* (O.F.Müll.) Lyngb. and *F. candidagilae* Almeida, C.Delgado, Novais & S.Blanco in order to establish a possible conspecificity. Based on the results, the transfer of *Synedra deformis* to the genus *Fragilaria* is proposed as *Fragilaria deformis* (W.Sm.) Van de Vijver & Ector, comb. nov., and the original William Smith material is designated as lectotype.

MATERIAL AND METHODS

The type material of the following taxa has been examined in this survey:

Family FRAGILARIACEAE Grev.
Genus *Synedra* Ehrenb.

Synedra deformis W.Sm.

A Synopsis of the British Diatomaceae: 98 (1856).

MATERIAL. — **United Kingdom**. Sussex, Lewes, P. Mill Pond; coll. date 8.III.1853 (Van Heurck diatom collection, Meise Botanic Garden, Belgium).

Synedra vaucheriae var. ***deformis*** Grunow

In Van Heurck, *Synopsis des Diatomées de Belgique. Atlas* (1881).

MATERIAL. — Sample Grunow 907 (Van Heurck diatom collection, Meise Botanic Garden, Belgium).

Family BACILLARIOPHYTA familia *incertae sedis*
Genus *Exilaria* Grev.

Exilaria vaucheriae Kütz.

Algarum aquae dulcis germanicarum Decas III: 24 (1833).

MATERIAL. — Alg. Aquae Dulcis Germ. Dec. III. No. 24. "*Exilaria vaucheriae* Kg. an *Vaucheria clavata* im Quellen bei Leisling, Weissenfels (Germany)" (Van Heurck diatom collection, Meise Botanic Garden, Belgium).

Family FRAGILARIACEAE Grev.
Genus *Fragilaria* Lyngb.

Fragilaria candidagilae Almeida, C.Delgado, Novais & S.Blanco

In Delgado *et al.*, *Phytotaxa* 231: 3, figs 2-39 (2015).

MATERIAL. — **Portugal**. Coimbra, Mondego River Basin, Ribeira do Botão; coll. date 13.II.2012 (sample kindly provided by the original authors).

Fragilaria joachimii Kahlert

In Kahlert *et al.*, *Journal of Phycology* 55: 963, fig. 5 (2019).

MATERIAL. — Strain TCC887 isolated from Broströmmen near Norrtälje, Sweden, coll. date 24.IX.2013 (sample kindly provided by the original authors).

NOTES

For comparison, one population identified as *Fragilaria pectinalis* (O.F.Müll.) Lyngb. sampled from the Kleine Nete basin, a lowland river basin in the Antwerp Province, Belgium was added to the analysis:

Fragilaria pectinalis (O.F.Müll.) Lyngb.

Tentamen Hydrophytologiae Danicae Continens omnia Hydrophyta Cryptogama Daniae, Holsatiae, Faeroae, Islandiae, Groenlandiae hucusque cognita, Systematice Disposita, Descripta et iconibus illustrata, Adjectis Simul Speciebus Norvegicis. Hafniae: 185 (1819).

MATERIAL. — **Belgium**. Poederlee, River Aa; coll. date 7.V.1994 (sample collected by B. Van de Vijver).

SAMPLE PREPARATION

Subsamples of all selected materials were prepared for light and scanning electron microscopy observations following the method described in van der Werff (1955). Small parts of the samples were cleaned by adding 37% H_2O_2 and heating to 80°C for about 1 hour. The reaction was completed by addition of saturated $KMnO_4$. Following digestion and centrifugation (three times 10 minutes at 3700 × rpm), the resulting cleaned material was diluted with distilled water to avoid excessive concentrations of diatom valves on the slides. Cleaned diatom samples were mounted in Naphrax®. All slides were analysed using an Olympus BX53 microscope, equipped with Differential Interference Contrast (Nomarski) optics and the Olympus UC30 Imaging System. For each taxon, the number of specimens measured at random on the type slide is indicated (n = X). For scanning electron microscopy (SEM), parts of the oxidized suspensions were filtered through a 2-µm Isopore™ polycarbonate membrane filter (Merck Millipore). The stubs were sputter-coated with a platinum layer of 10 nm and studied using a JEOL-JSM-7100F field emission scanning electron microscope. Slides and stubs are stored at the BR-collection (Meise Botanic Garden, Belgium). Terminology used in the description of the structures of the siliceous cell wall is based on Anonymous (1975) and Round *et al.* (1990).

RESULTS

Class FRAGILARIOPHYCEAE Round
Order FRAGILARIALES P.C.Silva
Family FRAGILARIACEAE Grev.
Genus *Fragilaria* Lyngb.

Fragilaria deformis (W.Sm.) Van de Vijver & Ector, comb. nov., type population
(Fig. 1)

Basionym: *Synedra deformis* W.Sm., *A Synopsis of the British Diatomaceae*: 98 (1856). — Lectotype (here designated): BR-4613 (Meise Botanic Garden, Belgium). — To be excluded as synonym: *Synedra vaucheriae* var. *deformis* Grunow in Van Heurck 1881 (pl. 40, fig. 18), *Synedra vaucheriae* var. *deformis* (W.Sm.) Van Heurck (1896, p. 310, pl. 30, fig. 833) (see below for discussion).

MATERIAL EXAMINED. — **United Kingdom**. Sussex, Lewes, P. Mill Pond; coll. date 8.III.1853 (Van Heurck diatom collection, Meise Botanic Garden, Belgium). The same material and a slide are present in the Natural History Museum, London, United Kingdom (D.M.Williams, pers. comm.).

MORPHOLOGY

LM (Fig. 1A-R)

Frustules in girdle view rectangular, solitary never linked to form chains. Occasionally, two frustules linked together (Fig. 1A). Valves linear with usually parallel margins, giving the valves a rectangular outline, occasionally asymmetrical with one straight and one convex margin. Smaller valves becoming elliptic-lanceolate (Fig. 1O-R). Apices clearly protracted, rostrate to occasionally weakly capitate, placed on clearly developed shoulders.

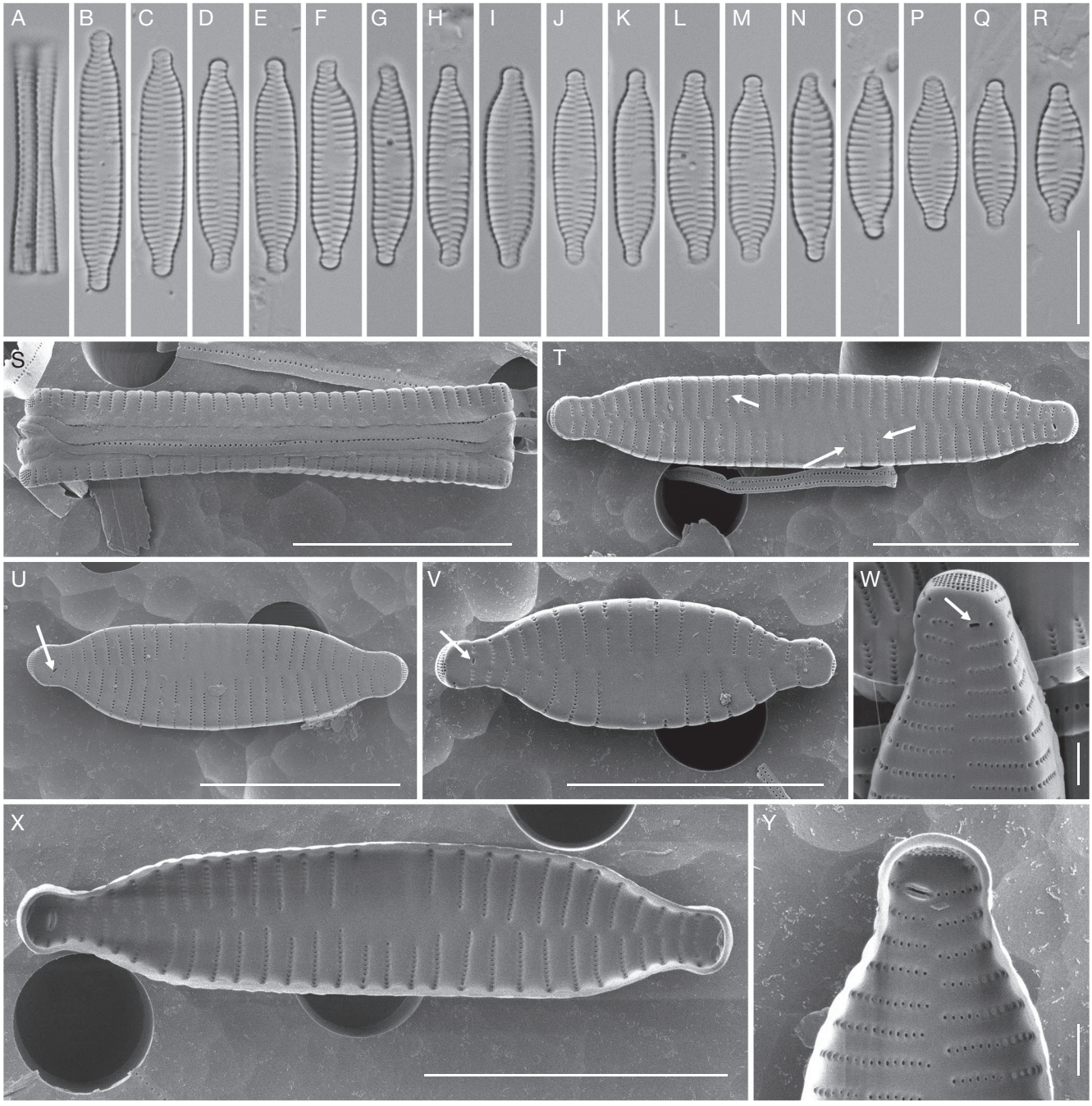

Fig. 1. — *Synedra deformis* W.Sm. Images taken from the type material (P. Mill Pond, Lewes, Sussex, United Kingdom): **A**, LM view of two frustules connected in girdle view; **B**-**R**, LM views of the population arranged in decreasing length; **S**, SEM external view of a frustule in girdle view; **T**, SEM external view of an entire valve. The **arrows** indicate interruptions in the areola series of the striae; **U**, **V**, SEM external view of two smaller valves. The **arrows** indicate the rimoportula; **W**, SEM external detail of the valve apex showing the rimoportula (**arrow**) and the apical pore field; **X**, SEM internal view of an entire valve showing the central position of the rimoportula at one apex; **Y**, SEM internal detail showing the eccentric position of the rimoportula. Scale bars: A-V, X, 10 µm; W, Y, 1 µm.

Valve dimensions (n = 25): valve length 14-29 µm, valve width 4.5-5.0 µm. Axial area narrow but distinct, linear, gradually but weakly widening towards the central area. Central area asymmetrical due to shortening or absence of striae on one side. Ghost striae often present. Striae parallel near central area becoming weakly radiate towards the apices, 14-16 in 10 µm, often irregularly spaced. Areolae not discernible in LM.

SEM (Fig. 1S-Y)

Girdle composed of several open, perforated copulae. Mantle edge covered by irregularly shaped, large mantle plaques (Fig. 1S). Mantle striae restricted to the upper part of the mantle leaving the lower part up to the edge hyaline. Striae uniseriate, composed of very small, rounded areolae (Fig. 1T-W). Virgae between the striae weakly raised, usually flat. Areola series often interrupted due to absence of one to several striae

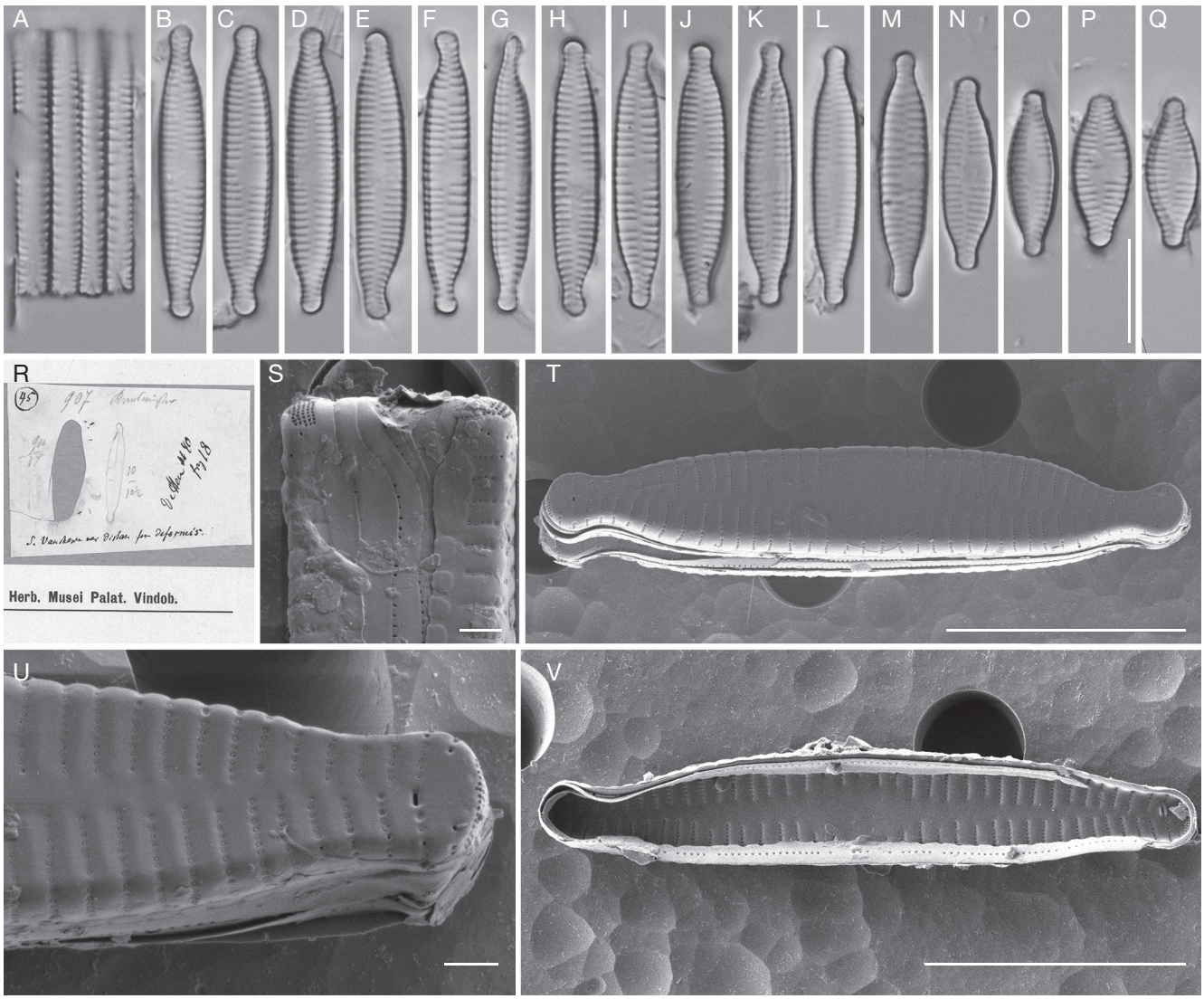

FIG. 2. — *Synedra vaucheriae* var. *deformis* Grunow. Images taken from the type material (Grunow sample 907): **A**, LM view of four frustules connected in girdle view; **B-Q**, LM views of the population arranged in decreasing length; **R**, original drawing and notes made by Grunow (Naturhistorisches Museum Wien, Austria); **S**, SEM external detail of the apex of a frustule girdle view showing the girdle bands and the apical pore fields; **T**, SEM external view of an entire valve; **U**, SEM external detail of a valve apex with the rimoportula; **V**, SEM internal view of an entire valve showing the slightly eccentric position of the rimoportula at one apex. Scale bars: A-Q, T, V, 10 µm; S, U, 1 µm.

(Fig. 1T, arrows). One rimoportula present at one apex, oblique or in line with the last stria at the apex (Fig. 1U-W, arrows). Apical pore field present at both apices, relatively large, composed of up to six rows of relatively large, rounded to squarish pores (Fig. 1W). Spines never present. Internally, rimoportula distinctly present at one apex (Fig. 1X-Y), superimposed on one of the final striae at the apex, centrally placed (Fig. 1X) or asymmetrically on one side (Fig. 1Y).

Synedra vaucheriae var. ***deformis*** Grunow, type population (Fig. 2)

Fragilaria intermedia f. *deformis* (Grunow) A.Cleve. — Basionym: *Synedra vaucheriae* var. *deformis* Grunow in Van Heurck, *Synopsis des Diatomées de Belgique. Atlas*, pl. XL, fig. 18 (1881) (original drawing and note in Fig. 2R). — Lectotype (designated in Tuji & Williams 2013): *Grunow sample 907* (W).

MORPHOLOGY

LM (Fig. 2A-Q)

Frustules in girdle view rectangular, solitary or linked to short chains of maximum eight cells (Fig. 2A). Valve outline linear in longer valves with convex to occasionally parallel margins, often irregularly shaped, gradually narrowing towards the apices. Shoulders never clearly developed. Smaller valves becoming more elliptic (Fig. 2O-Q). Apices clearly protracted, capitate to rostrate in smaller specimens, often deformed. Valve dimensions (n = 20): valve length 16-28 µm, valve width 4.0-4.5 µm. Axial area narrow but distinct, linear to weakly lanceolate, gradually

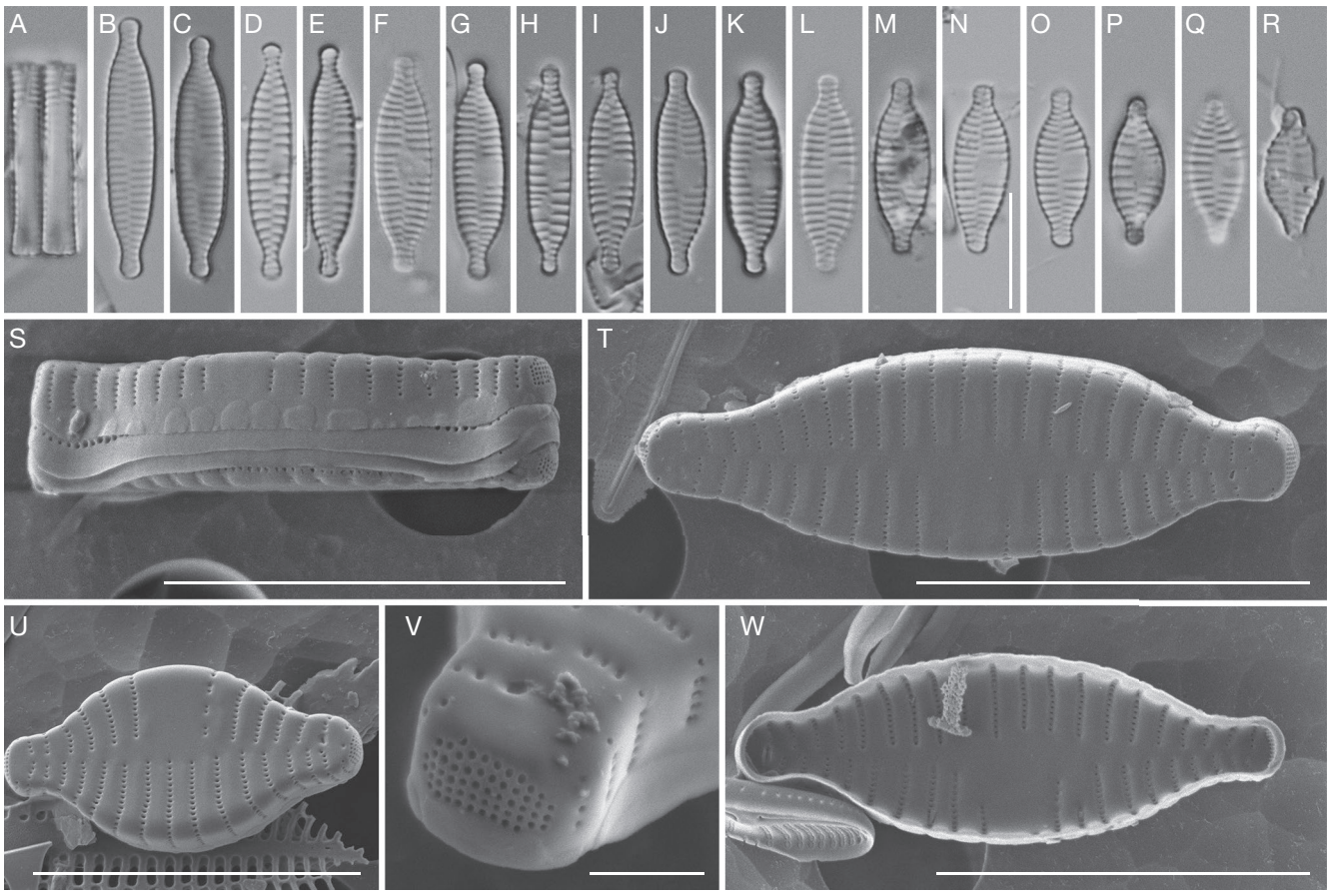

Fig. 3. — *Fragilaria candidagilae* Almeida, C.Delgado, Novais & S.Blanco. Images taken from the type material (Ribeira do Botão, Mondego River Basin, Coimbra Portugal): **A**, LM view of two frustules connected in girdle view; **B**-**R**, LM views of the population arranged in decreasing length; **S**, SEM external view of a frustule in girdle view showing the girdle bands, the apical pore fields and the mantle plaques; **T**, SEM external view of an entire valve; **U**, SEM external view of an entire small valve; **V**, SEM external detail of a valve apex with the rimoportula and the apical pore field; **W**, SEM internal view of an entire valve showing the slightly eccentric position of the rimoportula at one apex. Scale bars: A-U, W, 10 µm; V, 1 µm.

but weakly widening towards the central area. Central area small to often asymmetrical due to irregular shortening of striae on one side. Ghost striae never present. Striae parallel throughout, becoming weakly radiate near the apices, 13-15 in 10 µm, occasionally irregularly spaced. Areolae not discernible in LM.

SEM (Fig. 2S-V)
Girdle composed of several open, perforated copulae (Fig. 2S). Mantle edge covered by irregularly shaped, large mantle plaques (Fig. 2S). Mantle composed of broad hyaline edge. Mantle striae restricted to the upper part of the mantle (Fig. 2S). Striae uniseriate, composed of very small, rounded areolae (Fig. 2T, U), covered by individual external hymenes (Fig. 2U). Virgae between the striae weakly raised (Fig. 2U). One rimoportula present at one apex, in line with the last stria at the apex (Fig. 2T-U). Apical pore field present at both apices, relatively large, composed of up to six rows of relatively large, rounded to squarish pores (Fig. 2S). Spines never present. Internally, rimoportula distinctly present at one apex (Fig. 2V), superimposed on one of the final striae at the apex, weakly oblique.

Fragilaria candidagilae Almeida, C.Delgado, Novais & S.Blanco, type population
(Fig. 3)

Basionym: *Fragilaria candidagilae* Almeida, C.Delgado, Novais & S.Blanco in Delgado *et al.*, *Phytotaxa* 231: 3, figs 2-39 (2015).

Morphology
LM (Fig. 3A-R)
Frustules in girdle view rectangular, solitary or two cells linked together (Fig. 48). Valves elliptic-lanceolate with convex or parallel margins in larger specimens, strictly convex margins in smaller valves. Valves occasionally irregularly shaped. Shoulders distinctly developed with clearly protracted, capitate to rostrate (in smaller specimens) apices. Valve dimensions (n = 25): valve length 11-23 µm, valve width 4-5 µm. Axial area very narrow linear, almost not widening towards the central area. Central area small, clearly asymmetrical due to absence or shortening of striae on one side, forming an asymmetrical fascia. Striae parallel throughout, becoming weakly radiate near the apices, 12-14 in 10 µm, often irregularly spaced. Areolae not discernible in LM.

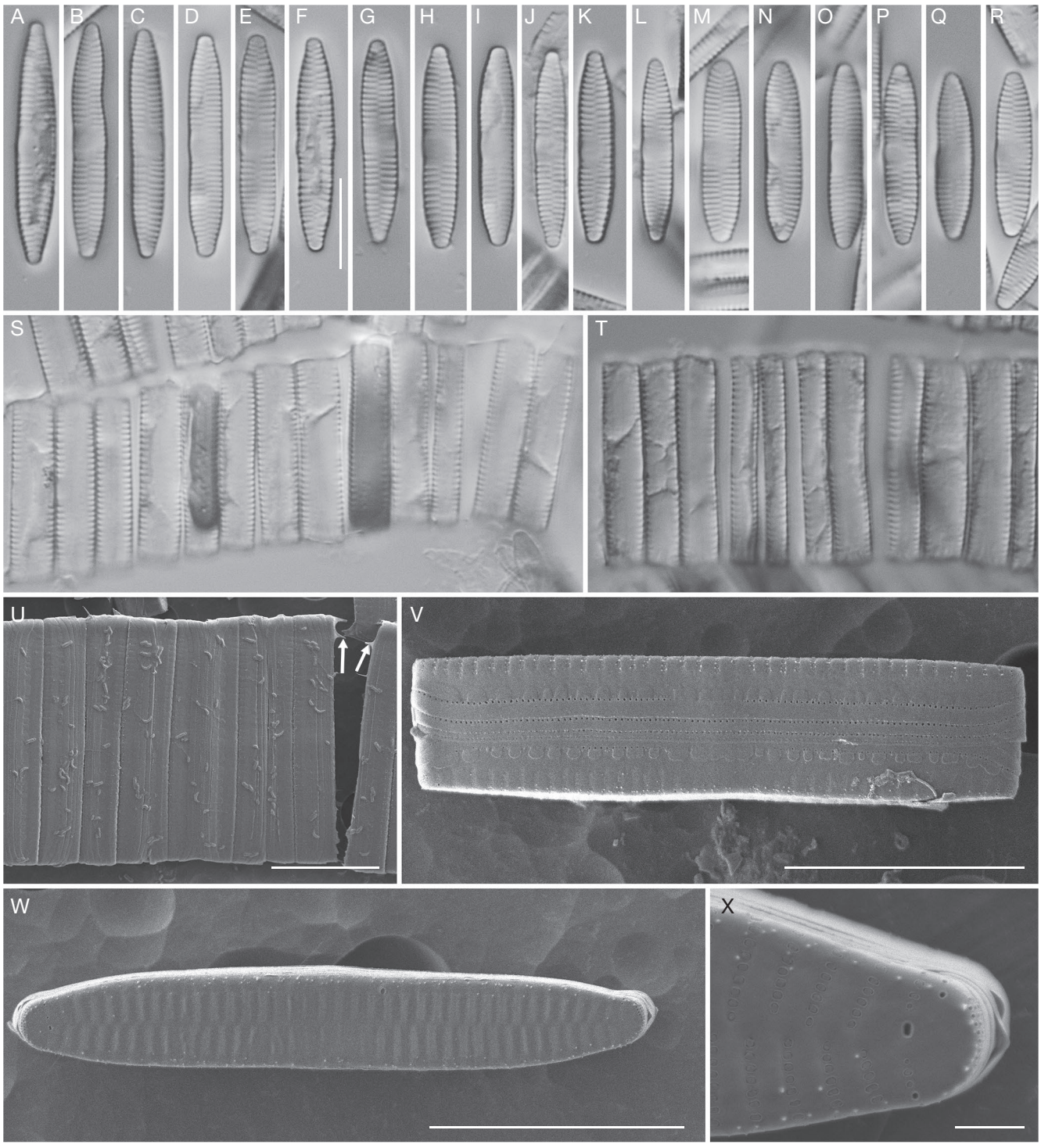

FIG. 4. — *Fragilaria joachimii* Kahlert. Images taken from the type material (Strain TCC887 isolated from Broströmmen near Norrtälje, Sweden): **A**-**R**, LM views of the population arranged in decreasing length; **S**, **T**, LM views of several frustules connected to form long chains in girdle view; **U**, SEM external view of several frustules in girdle view connected via mucus (indicated by the **arrows**); **V**, SEM external view of a frustule in girdle view showing the girdle bands and the mantle plaques. Note the small spines and granules near the valve face/mantle junction; **W**, SEM external view of an entire valve with scattered small spines on the margin; **X**, SEM external detail of a valve apex with the rimoportula and the apical pore field. Scale bars: A-W, 10 µm; X, 1 µm.

SEM (Fig. 3S-W)

Girdle composed of several open, perforated copulae (Fig. 3S). Large, irregularly shaped mantle plaques present on the mantle edge (Fig. 3S). Mantle striae continuing from the valve face till halfway the mantle edge (Fig. 3S). Striae uniseriate, composed of very small, rounded areolae (Fig. 3T-U). Virgae between the striae very weakly raised to flat (Fig. 3V). One rimoportula present at one apex, in line with the before last stria at the apex (Fig. 3T-V). Apical pore field present at both apices, relatively large, composed of up to five rows of relatively large, rounded

TABLE 1. — Comparison of the valve dimensions of the species discussed in this paper.

	Length (µm)	Width (µm)	Striae (in 10 µm)
Synedra deformis W.Sm.	14-29	4.5-5.0	14-16
Synedra vaucheriae var. *deformis* Grunow	16-28	4.0-4.5	13-15
Fragilaria candidagilae Almeida, C.Delgado, Novais & S.Blanco	11-23	4.0-5.0	12-14
Fragilaria joachimii Kahlert	14-28	3.5-4.5	14-16
Fragilaria pectinalis (O.F.Müll.) Lyngb.	20-35	3.5-5.0	14-15
Fragilaria vaucheriae (Kütz.) J.B.Petersen	14-50	4.0-5.0	11-14

to squarish pores (Fig. 3V). Spines never present. Internally, rimoportula distinctly present at one apex, superimposed on one of the final striae at the apex, weakly oblique (Fig. 3W).

Fragilaria joachimii Kahlert, type population (Fig. 4)

Basionym: *Fragilaria joachimii* Kahlert in Kahlert *et al.*, *Journal of Phycology* 55: 963, fig. 5 (2019).

MORPHOLOGY

LM (Fig. 4A-T)

Frustules in girdle view rectangular, in culture linked forming long chains of up to several tens of cells (Fig. 4S-T). Valves linear with parallel margins and broadly rounded, protracted, rostrate, never capitate apices. Shoulders poorly developed, gradually tapering into the apices. Centrally, valves often slightly inflated. Valve dimensions (n = 40): valve length 14-28 µm, valve width 3.5-4.5 µm (length 5-31 µm, width 3.3-4.6 µm in the protologue, Kahlert *et al.* 2019). Axial area very narrow linear, not widening towards the central area. Central area large, forming a broad, often asymmetrical, inflated fascia, due to several shortened striae on one side. Striae parallel throughout, becoming weakly radiate near the apices, 14-16 in 10 µm, often irregularly spaced. Areolae not discernible in LM.

SEM (Fig. 4U-X)

Girdle composed of several open, perforated copulae (Fig. 4U-V). Frustules not linked using linking spines but by mucus (Fig. 4U, arrows). Large, irregularly shaped mantle plaques present on the mantle edge (Fig. 4V). Mantle striae continuing from the valve face till halfway or ⅓ of the mantle edge (Fig. 4V). Striae uniseriate, composed of small, rimmed, rounded areolae (Fig. 4W-X), individually covered by external hymenes (Fig. 4X). Virgae between the striae weakly raised (Fig. 4W). One rimoportula present at one apex, in line with the last stria at the apex (Fig. 4X). Apical pore field present at both apices (Fig. 4X). Small spines and granules scattered throughout the entire valve face and mantle (Fig. 4W-X).

Fragilaria pectinalis (O.F.Müll.) Lyngb. (Fig. 5)

Tentamen Hydrophytologiae Danicae Continens omnia Hydrophyta Cryptogama Daniae, Holsatiae, Faeroae, Islandiae, Groenlandiae hucusque cognita, Systematice Disposita, Descripta et iconibus illustrata, Adjectis Simul Speciebus Norvegicis. Hafniae: 185 (1819). — Basionym: *Conferva pectinalis* O.F.Müll., *Nova Acta Academiae Scientiarum Imperialis Petropolitanae* 3: 91, figs 4-7 (1788).

MATERIAL USED. — Population from the River Aa, Belgium.

MORPHOLOGY

LM (Fig. 5A-AJ)

Frustules in girdle view rectangular, solitary or two cells linked together (Fig. 5T-U). Valves linear throughout the entire cell cycle with parallel margins and protracted, rostrate, rarely capitate, apices. Shoulders poorly developed, gradually tapering into the apices. Valves often irregularly shaped, building sometimes large populations (Fig. 5V-AI). Valve dimensions (n = 60): valve length 20-35 µm, valve width 3.5-5.0 µm. Axial area narrow linear, gradually widening towards the central area. Central area large, forming an asymmetrical, occasionally inflated, fascia, with several shortened striae on one side lacking ghost striae. Several valves observed with depressed central area (Fig. 5W, AA, AE). Striae parallel throughout, becoming weakly radiate near the apices, 14-15 (occasionally up to 18) in 10 µm, often irregularly spaced. Areolae not discernible in LM.

SEM (Fig. 5AK-AO)

Large, irregularly shaped mantle plaques present on the mantle edge (Fig. 5AK). Mantle striae continuing from the valve face till ⅓ of the mantle edge (Fig. 5AK). Striae uniseriate, composed of small, rounded areolae (Fig. 5AL-AM), individually covered by external hymenes (Fig. 5AL). Virgae between the striae weakly raised (Fig. 5AN). One rimoportula present at one apex, obliquely positioned at the before last stria at the apex (Fig. 5AM). Apical pore field present at both apices composed of several rows of small pores (Fig. 5AM-AN). Small spines or granules scattered throughout the entire valve face and mantle (Fig. 5AN). Internally, rimoportula obliquely positioned at one of the apices (Fig. 5AO).

ECOLOGY OF *FRAGILARIA DEFORMIS* AND *SYNEDRA VAUCHERIAE* VAR. *DEFORMIS*

The original samples used to study the morphology of these two taxa were not accompanied by ecological notes in what environmental conditions these samples were collected. Based on the accompanying diatom flora, it is however possible to get an indication of the possible ecological conditions in what these two species could be found.

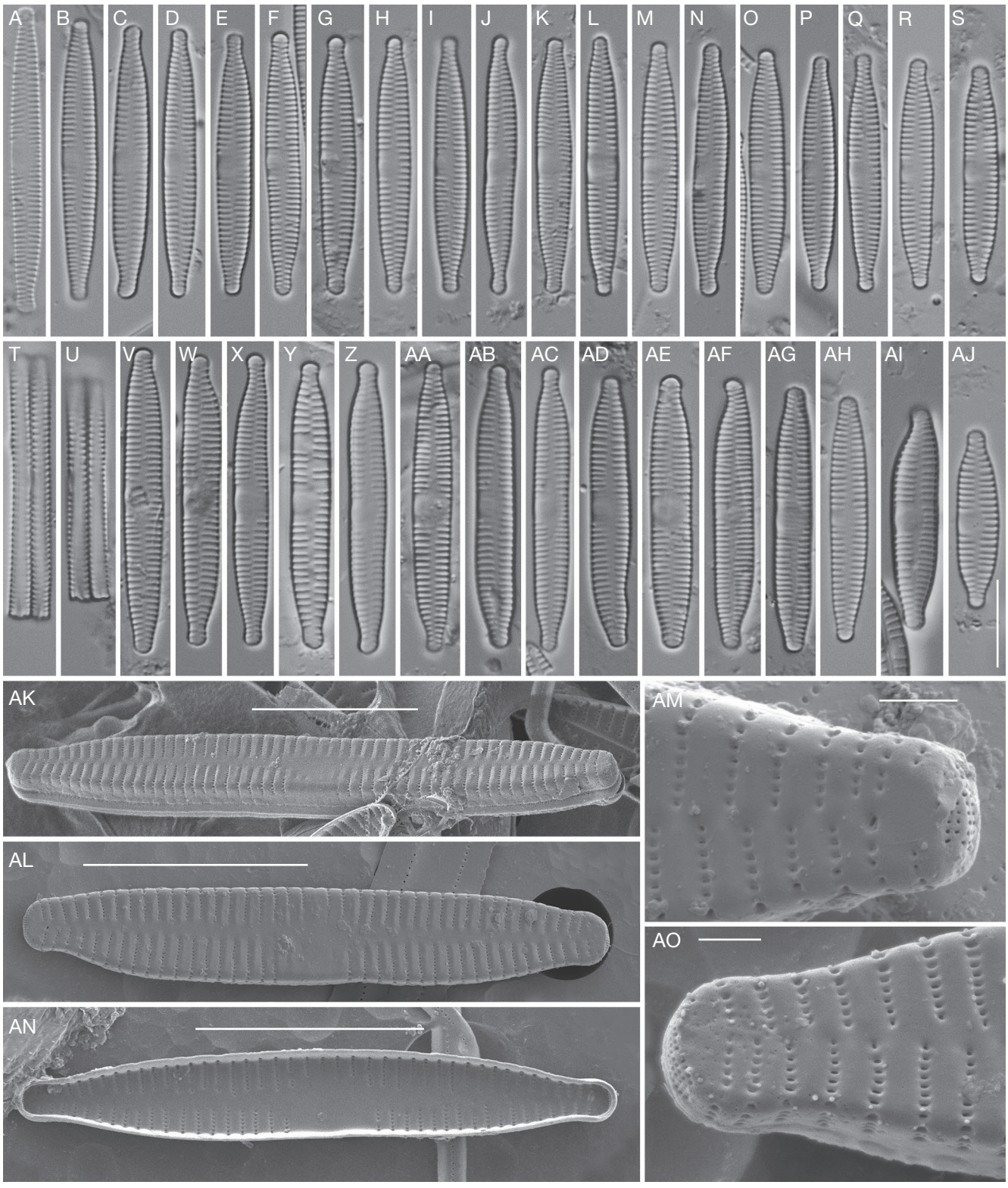

Fig. 5. — *Fragilaria pectinalis* (O.F.Müll.) Lyngb. Images taken from the River Aa, province of Antwerp, Belgium: **A**-**S**, LM views of more or less normally formed valves of the population arranged in decreasing length; **T**, **U**, LM views of two frustules connected in girdle view; **V**-**AJ**, LM views of several deformed valves of the population arranged in decreasing length; **AK**, SEM external view of a frustule in oblique view showing the girdle bands and the mantle plaques; **AL**, SEM external view of an entire valve; **AM**, SEM external detail of a valve apex with the rimoportula; **AN**, SEM external detail of a valve apex lacking the rimoportula. Note the spines and small granules at the valve margin; **AO**, SEM internal view of an entire valve showing the slightly eccentric position of the rimoportula at one apex. Scale bars: A-AL, AN, 10 µm; AM, AO, 1 µm.

The William Smith sample for *Synedra deformis* is entirely dominated by the latter species. Up to 80% of all observed diatoms in the sample belong to this species. Less frequent taxa in the slide include *Fragilaria vaucheriae*, *Amphora pediculus* (Kütz.) Grunow, *Navicula cryptotenella* Lange-Bert., *N. veneta* Kütz., *N. lanceolata* Ehrenb. and *Nitzschia dissipata* (Kütz.) Rabenh. All these species are known to prefer circumneutral to alkaline, eutrophic, α-mesosaprobic conditions (Lange-Bertalot *et al.* 2017). Sample Grunow 907 was dominated in almost equal numbers by three taxa: *Synedra vaucheriae* var. *deformis*, *Odontidium mesodon* (Kütz.) Kütz. and *Meridion circulare* (Grev.) C.Agardh. The latter two taxa are often found in oligo- to mesotrophic, circumneutral to weakly acid conditions (Lange-Bertalot *et al.* 2017).

DISCUSSION

Based on the morphological analysis of the two historic samples of *Synedra deformis* and *S. vaucheriae* var. *deformis*, several conclusions can be made regarding the taxonomic identity of both taxa. Table 1 compares the valve dimensions of all taxa discussed in this paper.

Firstly, the morphology of both taxa is sufficiently different to contradict the conspecificity that was suggested in DiatomBase (Kociolek *et al.* 2020). The overall valve outline differs markedly. *Synedra deformis* has clearly parallel margins with well-developed shoulders, a feature not present in *S. vaucheriae* var. *deformis*. This gives the former species a more sturdy outlook compared to the more slender outline of *S. vaucheriae* var. *deformis*. The valve width of both taxa differs with *S. deformis* being slightly larger (4.5-5.0 µm) than the other taxon (4.0-4.5 µm), although the difference is not very large. Both taxa have an overlapping stria density, with *S. deformis* having a slightly higher stria density (up to 16 vs 15 in 10 µm in *S. vaucheriae* var. *deformis*). The central area in both taxa also differs with *S. vaucheriae* var. *deformis* having a more irregular central area lacking ghost striae and *S. deformis* showing a larger central area often with ghost striae. Finally, based on the accompanying diatom flora, there also seems to be a difference in ecological preferences. *Synedra deformis* seems to prefer eutrophic conditions versus the mesotrophic conditions in *S. vaucheriae* var. *deformis*. It should be noted however that this observation is based on only one sample per species and further research will be necessary to detect the correct ecological preferences for each taxon. Nevertheless, there are sufficient arguments to conclude that both taxa should be kept separately.

There has been a lot of confusion in the past regarding these two taxa. Grunow (in Van Heurck 1881) illustrated one valve as *Synedra vaucheriae* var. *deformis* Grunow. This population was illustrated based on sample 907. On the original drawing (see our Fig. 2R), Grunow actually identified the valves first as *Synedra vaucheriae* var. *distans* f. *deformis*, indicating that he believed the population to be a deformed valve of the var. *distans*. So he apparently never made any reference to the species W. Smith described, which may indicate that he had no knowledge of *S. deformis* W.Sm. In 1896, Van Heurck illustrated the same valve (pl. 30, fig. 833) but named the species *Synedra vaucheriae* var. *deformis* (W.Sm.) Van Heurck, apparently correcting the name Grunow had given it in 1881 and connecting that name to the taxon Smith described in 1856. This should be considered as an error, especially since Van Heurck used the drawing that was already published in 1881 under a different name. Although Van Heurck made this connection, we believe that the names *Synedra vaucheriae* var. *deformis* Grunow and *Synedra vaucheriae* var. *deformis* (W.Sm.) Van Heurck should be excluded from being synonyms to *Synedra deformis* W.Sm.

Synedra deformis possesses a rather unique valve outline that is hardly observed in any *Fragilaria* species worldwide. Based on its morphological features, it is clear that the taxon does not belong to the genus *Synedra* and should be transferred to the genus *Fragilaria*, as defined by its typus generis *F. pectinalis* (Tuji & Williams 2006). Typical features include uniseriate striae with externally occluded areolae, one rimoportula per valve, located on one of the apices, the presence of mantle plaques and open girdle bands. Therefore, the new combination *Fragilaria deformis* Van de Vijver & Ector, comb. nov., was proposed.

Remarks

Most likely, *Fragilaria deformis* populations have been erroneously identified as *F. capucina* var. *capitellata* (Grunow) Lange-Bert. (see for instance Krammer & Lange-Bertalot 2000, pl. 109, figs 25, 26) or *F. recapitellata* Lange-Bert. & Metzeltin (see Lange-Bertalot *et al.* 2017, pl. 9, figs 45, 46). Tuji & Williams (2008) and Delgado *et al.* (2015) studied the type material of *S. capitellata* Grunow (basionym of *F. recapitellata*) and concluded that most *F. recapitellata* populations in Europe represented a different taxon. For these populations, a new taxon, *Fragilaria candidagilae* was described. Analysis of the type material of *F. candidagilae*, however, showed similarities but also some small differences between *F. deformis* and *F. candidagilae*. Both taxa share the same more sturdy valve outline with the parallel margins in the longer specimens and more convex margins in smaller valves. Both taxa have developed shoulders leading towards the apices. Valve length and width are overlapping with *F. candidagilae* being a little bit shorter (11-23 µm) than *F. deformis* (14-29 µm). The striation pattern shows the same irregular distancing in both taxa. The most important difference is the shape of the valve apices. *Fragilaria candidagilae* has typically clearly capitate apices that are more protracted than in *F. deformis* where the apices are shorter and more rostrate than capitate. The shape difference is almost non-existing in smaller specimens (compare for instance Figure 1R and Figure 3O) reducing the value of this feature. Another difference between these two species is the stria density. *Fragilaria deformis* has a higher stria density (14-16 in 10 µm) than *F. candidagilae* (12-14 in 10 µm) lacking any overlap between both taxa. It is therefore unclear whether *F. deformis* and *F. candidagilae* are conspecific or not. Morphological analysis of more populations that unambiguously could be identified as *F. candidagilae* will be necessary to confirm or reject a possible conspecificity.

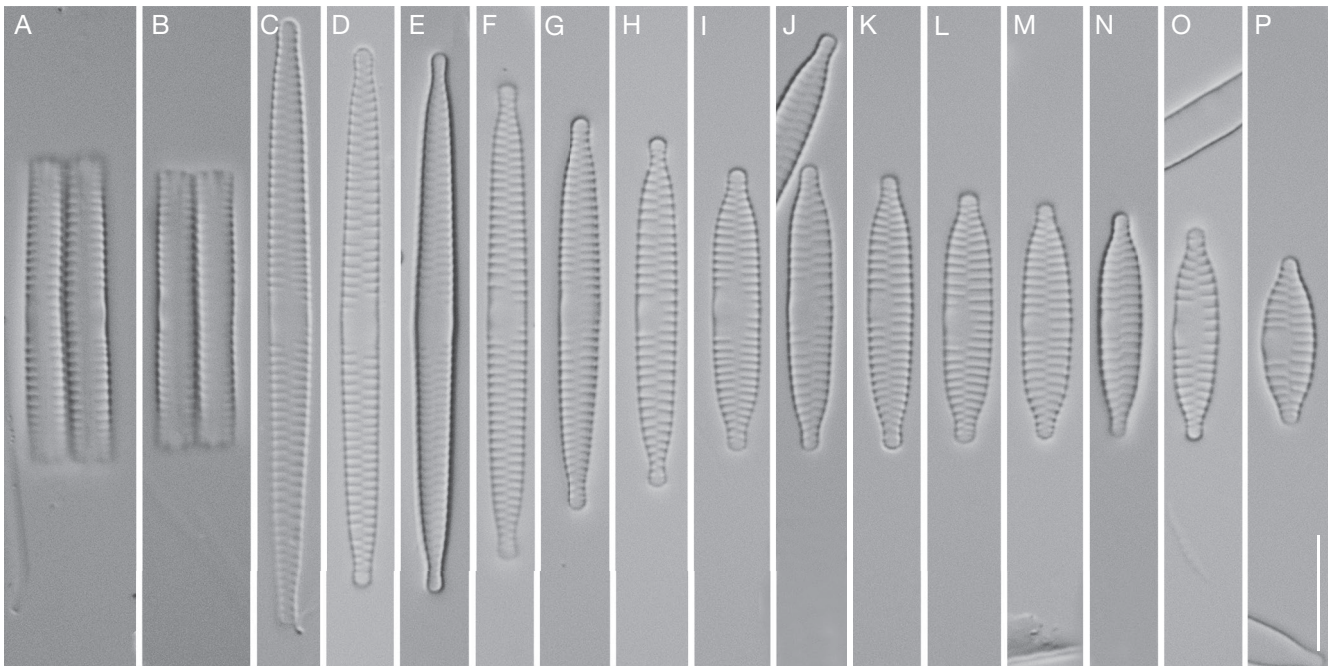

FIG. 6. — *Fragilaria vaucheriae* (Kütz.) J.B.Petersen. Images taken from the type population (Quellen bei Leisling, Weissenfels, Germany): **A**, **B**, LM views of two frustules connected in girdle view; **C**-**P**, LM views of the population arranged in decreasing length. Scale bar: 10 µm.

Another taxon that shows some resemblance to *F. deformis* is the recently described *F. joachimii* from Sweden (Kahlert *et al.* 2019). Both taxa have parallel margins. However, several morphological differences separate both taxa. The apices in *F. joachimii* are typically shortly rostrate and bluntly rounded lacking typical shoulders whereas *F. deformis* has more protracted, rostrate to rostrate-capitate apices with clearly developed shoulders. *Fragilaria joachimii* has a weakly inflated central area, a feature never observed in *F. deformis*. The colony formation in *F. joachimii* is most likely only an effect of culturing this diatom species. Diatom taxa in laboratory cultures can produce colonies by linking the frustules via mucus (Pinseel 2019) even when typical linking spines, such as observed in for instance *F. capucina* Desm. (Heudre *et al.* 2019), are absent. It is unclear whether *F. joachimii* also forms colonies in natural conditions as the species was solely isolated and cultured and the natural sample was no longer available. Therefore, this apparent difference should not be taken into account. There are however sufficient differences between *F. deformis* and *F. joachimii* to exclude conspecificity. Therefore, *F. deformis* should be kept as an independent species. During a survey of the diatom flora in Swedish rivers, several populations, formerly identified as *F. capucina* var. *capitellata*, were investigated and confirmed as being *F. deformis* (Van de Vijver, unpubl. res.). Similarly, the species was also identified in samples collected from rivers in Belgium and the Netherlands (Mertens, unpubl. res.). These observations show clearly that the species is most likely more distributed in Europe than originally thought.

Finally, according to Tuji & Williams (2013), *S. vaucheriae* var. *deformis* should be treated only as a synonym of *Fragilaria vaucheriae* as it agreed with the current (i.e., in Tuji & Williams 2013) concept of *F. vaucheriae*. Wetzel & Ector (2015) and Delgado *et al.* (2016) re-analysed the type material of *Exilaria vaucheriae* Kütz., the basionym of *Fragilaria vaucheriae*. A slide made of this type material was examined again for the current paper (Fig. 6) in order to compare the morphological variability of *F. vaucheriae* with *Synedra vaucheriae* var. *deformis*. It is clear that both taxa are not conspecific based on differences in valve outline, valve dimensions and stria density. *Fragilaria vaucheriae* has a more slender valve outline, with gradually tapering margins towards the protracted rostrate apices, contrary to *S. vaucheriae* var. *deformis* that has more sturdy valves with protracted, rostrate to capitate apices. *Fragilaria vaucheriae* can reach a valve length of up to 50 µm whereas the longest valves in *S. vaucheriae* var. *deformis* never exceed 30 µm. Given a similar valve width (4-5.0 µm), *F. vaucheriae* has therefore a more slender outlook. The stria density in *F. vaucheriae* is 11-14 in 10 µm whereas it is 13-15 in 10 µm for the variety *deformis*. Therefore considering *S. vaucheriae* var. *deformis* as a synonym of *F. vaucheriae* should not be accepted. A possible link with *F. joachimii* should also be excluded as the latter always has an inflated central area, only weakly protracted, rostrate apices. However, the morphology of *Fragilaria pectinalis* resembles quite well the observations made on *Synedra vaucheriae* var. *deformis* in the current paper. The original material of *Conferva pectinalis* O.F.Müll. is no longer available (Tuji & Williams 2006). Tuji & Williams (2006) analysed in detail all possible material that could be used as type material for this species. They finally based their morphological analysis on material from Dillwyn (1803 in 1802-1809) that Lyngbye had used and that was designated in 2006 as epitype (Tuji & Williams 2006, p. 198). In Tuji & Williams (2008)

this material was illustrated again, showing more valves based on LM and SEM observations. The morphology of these valves, including the presence of small spines, shows a large similarity with the Belgian population illustrated in the current paper, justifying our identification of the latter population as *F. pectinalis*. When comparing *Synedra vaucheriae* var. *deformis* with the Belgian *F. pectinalis* population, it is clear that both populations are identical. A high degree of deformed valves was observed in the Belgian population. These, most likely teratological forms, often occur in large *Fragilaria* populations and may be due to metal or pesticide pollution of the water (Duong *et al.* 2008; Morin *et al.* 2008; Falasco *et al.* 2009). Valve outline, valve dimensions, shape and outline of the central area and the stria density are overlapping. Therefore, we consider *S. vaucheriae* var. *deformis* being a later synonym of *F. pectinalis*.

CONCLUSION

The results of this paper show that despite our growing knowledge of the diatom flora in European rivers and lakes, there is still a high amount of poorly studied taxa. In several cases, these unrevised taxa represent not more than synonyms of previously described, well known taxa, as is the case for instance for *S. vaucheriae* var. *deformis*. Occasionally independent taxa, often with a larger distribution area than originally accepted, are found. The morphological analysis and transfer of *Synedra deformis* to the genus *Fragilaria* is a good example of such a result. It is clear that more taxa, usually only known from line drawings or a simple, non-illustrated description, will be discovered during the ongoing survey of the *Synedra*/*Fragilaria* flora of Europe that is currently being undertaken.

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