

Observations on and typification of *Synedra crotonensis* f. *belgica* Grunow and *Fragilaria crotonensis* var. *prolongata* Grunow (*Fragilariaceae*, *Bacillariophyta*) and the introduction of *Fragilaria prolongata* comb. et stat. nov.

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In the 19th century, a considerable number of fragilarioid diatoms was described either in the genus *Synedra* or in the genus *Fragilaria*. One of the suggested differentiating features between the genera *Synedra* and *Fragilaria* was the absence or presence of ribbon-like colony formation with *Synedra* almost never making colonies and *Fragilaria* always producing such colonies. This distinction is quite obvious in older publications such as Van Heurck (1881) who illustrated several plates with *Synedra* (pls XXXVIII–XLIII) taxa and two plates with *Fragilaria* (pls XLIV–XLV) taxa, the latter often illustrated with valve face views and ribbon-like colonies. A large number of these taxa depicted in Van Heurck (1881) were originally described by Albert Grunow (1826–1914) in the genus *Synedra*. When the morphological details became more obvious with ultrastructure, most of these taxa have been (or should be) transferred to several other (later described) genera such as *Ulnaria*, *Ctenophora*, *Tabularia* and even *Fragilaria*. Nowadays, only a handful of taxa remain in *Synedra sensu stricto* (and these *Synedra* taxa are exclusively marine), although there is still a plethora of *Synedra* taxa that await transfer to other genera.

One of the taxa that was depicted on the Van Heurck *Synedra* plates, was *Synedra crotonensis* [var. *prolongata*] f. *belgica* Grunow (in Van Heurck 1881, pl. XL: fig. 10). Van Heurck (1885: 156, cited also in 1896: 325) named the taxon later as *Fragilaria crotonensis* (A.M. Edwards) Kitton var. *prolongata* Grunow adding a short description (“*Valve très étroite, à extrémités non capitées. Longueur environ 10 c.d.m.*” (Valve very narrow, with apices not capitate. Length about 10 c.d.m. [=100 µm]) and a locality [Jardin botanique de Bruxelles (Delogne)]. One of the slides (n° 319) in his *Types du Synopsis des Diatomées de Belgique*, a series of 550 diatom slides, contained a population of *F. crotonensis* var. *prolongata*. The material for these slides originated from a sample Charles-Henri Delogne (1834–1901) collected in the former Jardin botanique de Bruxelles. Delogne included the slide as number 63 in his series *Diatomées de Belgique*, a set of 100 slides representing diatoms of Belgium. Unfortunately, neither a collection date for the sample nor a more precise sampling habitat details, are provided (most of the samples from the Jardin botanique de Bruxelles were collected in 1877 and 1878, Van de Vijver, pers. obs.). Strangely enough, apart from the figure caption in Van Heurck (1881), the name ‘f. *belgica*’ has never been mentioned since, not even in the description of ‘var. *prolongata*’ in Van Heurck (1885). Both taxa are homotypic but nomenclaturally independently published for different ranks according to ICN Art. 11.2 (Turland & al. 2018).

Fragilaria crotonensis var. *prolongata* is rarely considered an independent taxon and is usually synonymised with *F. crotonensis* Kitton (1869: 110) (see for instance Hustedt 1931: 143 and Patrick & Reimer 1966: 121) although De Toni (1892: 683) did recognise both. Schröter & Vogler (1901) investigated the variability within *F. crotonensis* populations and separated several varieties illustrating several of them (see the drawings in Schröter & Vogler 1901: 196), one of the varieties

being *prolongata*. Unfortunately, as their material is lost, it is no longer possible to investigate the other varieties (D.M. Williams, pers. comm.).

Crawford & al. (1985) investigated several populations of *F. crotonensis* from the UK. They also included an analysis of O'Meara's slide of Kitton's material for *F. crotonensis* from the Croton water supply, New York (**BM**, slide number 27963) and of slide 319 from the Van Heurck collection present at **BM** for *Fragilaria crotonensis* var. *prolongata*. They based their analysis on previous research by Canter & Jaworski (1982, 1983), who separated two forms in *F. crotonensis*: rod and flared forms based on the shape of the apices in girdle view. The rod form possessed a centrally placed rimoportula at one of the apices whereas the flared form always presented a rimoportula at the side. Crawford & al. (1985) observed further, smaller differences but also similarities between both forms (e.g., shape and structure of the ocellulimbus and the shape of the spines). Both forms seem to build very long colonies with the end valves occasionally possessing small acute spines. Crawford & al. (1985) concluded that the flared forms most likely represent *F. crotonensis* var. *prolongata* whereas the rod forms are consistent with *F. crotonensis* var. *crotonensis*. They emended the original description of the var. *prolongata*: “Frustule flared toward square tip in girdle view; thickenings in valve mantle usually visible at apex; ocellus consisting of four to five rows of small pores; rimoportula towards valve apex at corner of valve mantle and valve face.” The use of the word “ocellus” in this context is rather unusual as this is only used for pore fields in centric diatoms. Currently, ‘apical pore field’ is the more generally accepted term.

Fragilaria crotonensis var. *prolongata* is often reported in the literature but most publications give little more than the name. A few provide illustrations, but the quality of these pictures is generally insufficient for certain identification. In order to obtain a good idea of the distribution of this taxon, all records need to be verified using LM and SEM, an almost impossible task, especially since scanning electron microscopy observations of the type material of *F. crotonensis* var. *prolongata* are not available.

Recently, Lange-Bertalot & Ulrich (2014) described a new subspecies of *F. crotonensis* from the deep meso-eutrophic volcano lake “Laacher See” in Rhineland-Palatinate, Germany, which is some 3.5 km² in extent and up to 52 m deep (Block 2015): *F. crotonensis* subsp. *lacus-vulcani* Lange-Bertalot & S. Ulrich (Lange-Bertalot & Ulrich 2014: 43, pl. 20: figs 1–8; pl. 21: figs 1–11). In their discussion, the authors mentioned a possible conspecificity with *F. crotonensis* var. *prolongata* but stated that the original material for the latter was ‘hardly available’ (Lange-Bertalot & Ulrich 2014: 47).

The original material Van Heurck used to prepare his slide 319, was, however, found in the Van Heurck collection, part of the herbarium at Meise Botanic Garden (**BR**) together with three historic slides. In this contribution, we detail observations on specimens of *F. crotonensis* var. *prolongata* from slide Type n° 319, Delogne slide 63, slide VII-21-A2 (**BR** collection accession number) made by Van Heurck for his personal collection, and a new slide prepared from the material for Type n° 319 using light and scanning electron microscopy. The results of these observations indicate that both taxa (*F. crotonensis* var. *crotonensis* and *F. crotonensis* var. *prolongata*) should be separated at species rank.

Fragilaria prolongata (Grunow) Van de Vijver, C.E. Wetzel, Kusber & Ector, *comb. et stat. nov.* (Figs 1–22)

Basionym: *Fragilaria crotonensis* var. *prolongata* Grunow pl. 40: fig. 21 in Van Heurck, 1881.

Note: A description subsequently appeared in Van Heurck *Synopsis des Diatomées de Belgique*, *Texte*, p. 156, 1885. The name was validated in 1881 by analytical figures (ICN Art. 38.7).

Lectotype (designated here): BR-4628 given to slide Type n° 319 from the slide set *Types du Synopsis des Diatomées de Belgique* kept in the Van Heurck collection (**BR**).

Further specimen supporting the lectotype: BR-4629 given to the SEM stub prepared from the original material of sample Type n° 319 and depicted as Figs 16–22.

Homotypic synonym: *Synedra crotonensis* f. *belgica* Grunow in Van Heurck (1881), *Synopsis des Diatomées de Belgique, Atlas*, pl. 40: fig. 10.

Heterotypic synonym: *Fragilaria crotonensis* subsp. *lacus-vulcani* Lange-Bertalot & S. Ulrich, 2014: 43, pl. 20: figs 1–8, pl. 21: figs 1–11.

Registration: <http://phycobank.org/102645>

Description: Frustules in girdle view rectangular, often connected two per two (Figs 2, 3). Frustules occasionally linked by linking spines forming short chains with only the central parts connected (Figs 4, 18). Valves fusiform with an elongated, inflated, unconstricted central part, gradually narrowing towards the acutely rounded, non-protracted apices. In girdle view, apices almost not flared, rectangular. Large, irregularly shaped mantle plaques present on the mantle edge (Figs 18, 19). Valve dimensions (n=25): valve length 90–115 µm, valve width 2.5–3.0 µm at the centre, 1.0–1.3 µm (apices). Axial area very narrow in narrowest parts of the valves, gradually widening towards the central area. Central area large, rectangular, reaching both margins. Ghost striae often visible (Figs 10, 16, 17). Striae parallel throughout, never becoming radiate, regularly spaced, 16–17 in 10 µm, clearly alternating. Stria length distinctly increasing from apices to central area. Striae uniseriate, composed of relatively small, rounded areolae (Figs 16, 20). Virgae between the striae clearly raised, often with a thin ridge (Fig. 16). Mantle striae continuing from the valve face till halfway to the abvalvar mantle edge (Fig. 19). Spines present on all valves. Two types of spines observed on interlocking valves: broad, spatulate spines present only in the central part of the valves (Fig. 18) whereas towards the apices, valves never linking showing small, conical spines (Fig. 19). Separation valves (majority of the observed valves) with small, acute spines regularly positioned on the striae (Fig. 16). One rimoportula present at one apex, located on the valve face/mantle junction (Fig. 20). Apical pore field of the ocellulimbus-type, composed of up to six rows of very small, pinpoint pores (Figs 19, 20). Irregularly placed small spines and granules present on the apical pore fields (Figs 19, 20). Internally, rimoportula distinctly present at one apex, situated against the mantle (Fig. 21). Striae located in shallow grooves, bordered by raised virgae (Fig. 17). Copulae open with one row of perforations (Fig. 22).

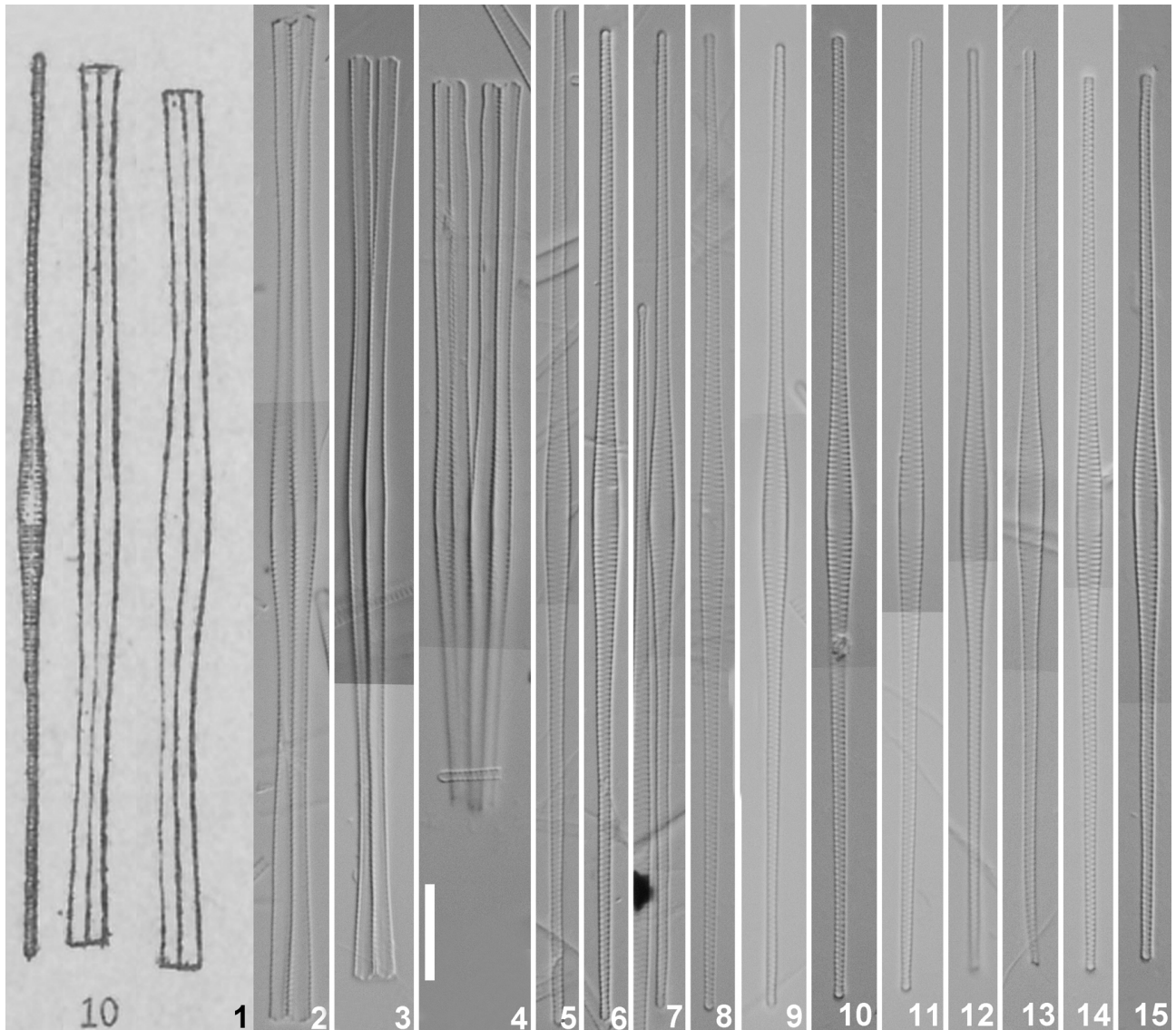
There are several important differences between *F. prolongata* and *F. crotonensis*. The position of the rimoportula is quite distinct with all *F. crotonensis* valves observed so far having its rimoportulae positioned on the valve face, replacing one of the last striae whereas in *F. prolongata*, the rimoportula is located on the valve face/mantle junction. *Fragilaria crotonensis* builds very long ribbon-like colonies linking the central parts using spatulate interlocking spines. Occasionally, separation valves with acute spines are present. In *F. prolongata*, the converse was observed. Most valves in the population had small spines whereas valves with linking spines were in a minority (clearly visible in SEM analysis). The central part of the valves in *F. crotonensis* is almost always constricted whereas this was never the case in *F. prolongata*. Based on these differences, the species status for *F. prolongata* can be justified.

Comparison with the illustrations and description of *F. crotonensis* subsp. *lacus-vulcani* in Lange-Bertalot & Ulrich (2014, pl. 20: figs 1–8) showed no morphological differences between both taxa. The rimoportulae are positioned identically at the valve margin, the valve dimensions entirely overlap, most valves possess small, acute spines with linking valves rarely present. The only difference between both taxa might be the more subcapitate to occasionally capitate shape of the apices in the subsp. *lacus-vulcani* whereas in *F. prolongata*, valves are very rarely weakly subcapitate. Lange-Bertalot & Ulrich (2014) already expressed the view that both taxa might be conspecific, and our present observations confirm this. Therefore, *F. crotonensis* subsp. *lacus-*

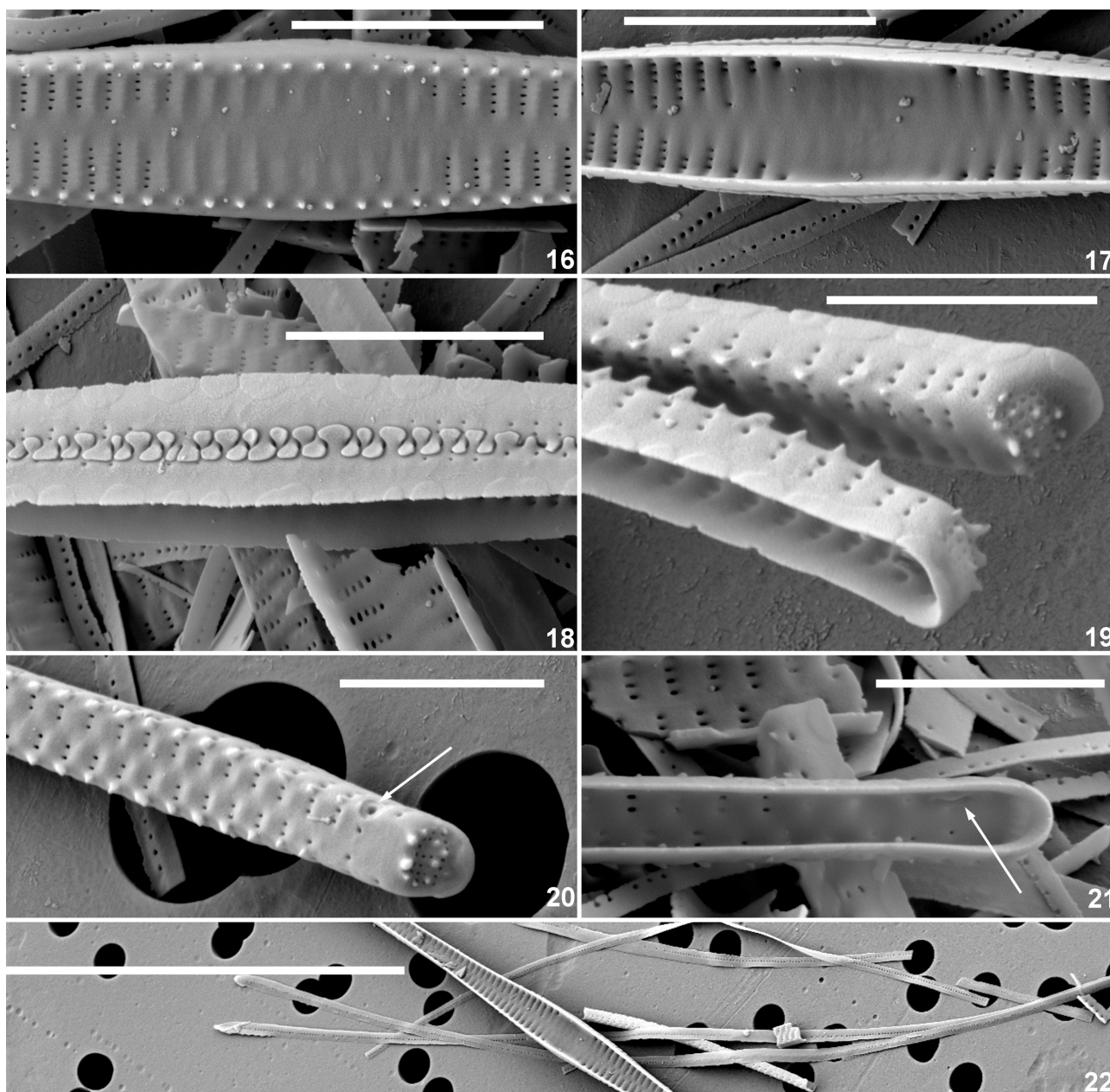


vulcani should be considered a later heterotypic of *F. prolongata*. A peculiar detail is that in the same sample from which the subsp. *lacus-vulcani* has been described, Lange-Bertalot & Ulrich also described *F. tenuissima* Lange-Bertalot & S. Ulrich (Lange-Bertalot & Ulrich 2014: 15, pl. 6: figs 6–13), a species that also seems to be relatively abundant in the type material of *F. prolongata* (Van de Vijver, pers. obs.).

- Block, U. (2015). *Übersicht über die Phosphatthematik am Laacher See „PhoLaaSee“*. LUWG Rheinland-Pfalz & FH Bingen. 42 pp. Available online.
- Canter, H.M. & Jaworski, G.H.M. (1982). Some observations on the alga *Fragilaria crotonensis* Kitton and its parasitism by two chytridiaceous fungi. *Annals of Botany* 49: 429–446.
- Canter, H.M. & Jaworski, G.H.M. (1983). A further study on parasitism of the diatom *Fragilaria crotonensis* Kitton by chytridiaceous fungi in culture. *Annals of Botany* 52: 549–563.
- Crawford, R.M., Canter, H.M. & Jaworski, G.H.M. (1985). A study of two morphological variants of the diatom *Fragilaria crotonensis* Kitton using electron microscopy. *Annals of Botany* 55: 473–485.
- De Toni, G.B. (1892). *Sylloge algarum omnium hucusque cognitarum. Vol. II. Sylloge Bacillariarum. Sectio II. Pseudoraphideae*. pp. [i–v], 491–817. Padova [Padua]: Sumptibus auctoris.
- Hustedt, F. (1931). Die Kieselalgen Deutschlands, Österreichs und der Schweiz unter Berücksichtigung der übrigen Länder Europas sowie der angrenzenden Meeresgebiete. Bd. VII: Teil 2: Lieferung 1. In: *Rabenhorst's Kryptogamen Flora von Deutschland, Österreich und der Schweiz*. (Anon. Eds), pp. [1]–176. Leipzig: Akademische Verlagsgesellschaft m.b.h.
- Kitton, F. (1869). Notes on New York diatoms with description of a new species *Fragilaria crotonensis*. *Hardwicke's Science-Gossip* 5: 109–110, 3 figs.
- Lange-Bertalot, H. & Ulrich, S. (2014). Contributions to the taxonomy of needle-shaped *Fragilaria* and *Ulnaria* species. *Lauterbornia* 78: 1–73, 30 pl., 2 tables.
- Patrick, R.[M.] & Reimer, C.W. (1966). The diatoms of the United States exclusive of Alaska and Hawaii. Volume 1: Fragilariaceae, Eunotiaceae, Achnanthaceae, Naviculaceae. *Monographs of the Academy of Natural Sciences of Philadelphia* 13: 1–688.
- Schröter, C. & Vogler, P. (1901). Variationsstatistische Untersuchung über *Fragilaria crotonensis* (Edw.) Kitton im Plankton des Zürichsees in den Jahren 1896–1901. *Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich* 46: 185–206, 5 figs.
- Turland, N.J., Wiersema, J.H., Barrie, F.R., Greuter, W., Hawksworth, D.L., Herendeen, P.S., Knapp, S., Kusber, W.-H., Li, D.-Z., Marhold, K., May, T.W., McNeill, J., Monro, A.M., Prado, J., Price, M.J. & Smith, G.F., editors (2018). *International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code)* adopted by the Nineteenth International Botanical Congress Shenzhen, China, July 2017. *Regnum Vegetabile*, Vol. 159. pp. [i]–xxxviii, 1–253. Glashütten: Koeltz Botanical Books.
- Van Heurck, H. (1881). *Synopsis des Diatomées de Belgique*. pls XXXI–LXXVII [31–77]. Anvers: Ducaju et Cie.
- Van Heurck, H. (1885). *Synopsis des Diatomées de Belgique. Texte*. pp. 1–235. Anvers: Martin Brouwers & Co.
- Van Heurck, H. (1896). *A treatise on the Diatomaceae*. Translated by W.E. Baxter. pp. 1–558, pls 1–35. London: William Wesley & Son.



Figs 1–15. *Fragilaria prolongata* (Grunow) Van de Vijver, C.E.Wetzel, Kusber & Ector, *comb. et stat. nov.* **Fig. 1.** Original drawing from Van Heurck (1881, pl. 40, fig. 10). **Figs 2–15.** Diminishing size series of *Fragilaria prolongata* (Grunow) Van de Vijver, C.E.Wetzel, Kusber & Ector, *comb. et stat. nov.* Figs 2–4. Frustules in girdle view. Scale bar = 1 μm .



Figs 16–21. *Fragilaria prolongata* (Grunow) Van de Vijver, C.E. Wetzel, Kusber & Ector, *comb. et stat. nov.* SEM micrographs of the lectotype material (Jardin botanique de Bruxelles, sample Type n° 319). **Fig. 16.** External view of the central hyaline area showing the ghost striae and the slightly raised virgae. **Fig. 17.** Internal view of the large hyaline central area. Note the clearly raised virgae. **Fig. 18.** External view of the central part of two valves linked by spatulate interlocking spines. **Fig. 19.** External detail of the apex showing the apical pore fields, the small apical spines and the two clearly separated valve apices. **Fig. 20.** External detail of the valve apex showing the rimoportula (arrow). **Fig. 21.** Internal detail of the valve apex with the rimoportula (arrow). **Fig. 22.** View of open copula. Scale bars = 5 μm except for figs 19–22 where scale bar = 3 μm .