BioOne RESEARCH EVOLVED

Fallacia emmae sp. nov., (Bacillariophyta) a New Soil-Inhabiting Diatom Species from the Sub-Antarctic Region

Author(s): Bart Van De Vijver & Eileen J. Cox
Source: Cryptogamie, Algologie, 36(3):245-254.
Published By: Association des Amis des Cryptogames
DOI: http://dx.doi.org/10.7872/crya/v36.iss3.2015.245
URL: http://www.bioone.org/doi/full/10.7872/crya/v36.iss3.2015.245

BioOne (www.bioone.org) is a nonprofit, online aggregation of core research in the biological, ecological, and environmental sciences. BioOne provides a sustainable online platform for over 170 journals and books published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Web site, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/page/terms_of_use.

Usage of BioOne content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Cryptogamie, Algologie, 2015, 36 (3): 245-254
© 2015 Adac. Tous droits réservés

Fallacia emmae sp. nov., (Bacillariophyta) a new soil-inhabiting diatom species from the sub-Antarctic Region

Bart VAN DE VIJVER[a,b*] *& Eileen J. COX*[c]

[a]*Botanic Garden Meise, Department of Bryophyta & Thallophyta, Nieuwelaan 38, B-1860 Meise, Belgium (vandevijver@br.fgov.be)*

[b]*University of Antwerp, Department of Biology, ECOBE, Universiteitsplein 1, 2610 Wilrijk, Belgium*

[c]*The Natural History Museum, Cromwell Road, London, SW7 5BD, United Kingdom*

Abstract – During a survey of the diatom flora of some caves on Île de la Possession, the main island of the Crozet archipelago, a small, unusual naviculoid taxon was observed, initially identified as *Fallacia lenzii*. The new taxon is described as *Fallacia emmae* but it shows features of two related genera: *Fallacia* and *Germainiella*. Thorough morphological research revealed details that, on the one hand, contradicted its placement in *Fallacia*, such as the relatively low number of poroids on the conopeum, the absence of external canal apertures beside the raphe slit (*Fallacia*-feature), and striae that are composed of one slit-like areola (*Germainiella*-feature). The morphology and taxonomy of the new taxon are discussed and questions are raised about the validity of genera recently split off from the genus *Navicula* on the basis of one, or occasionally two, morphological features.

Sub-Antarctica / *Fallacia* / *Germainiella* / taxonomy / new species

Résumé – Lors d'une analyse de la flore de diatomées de quelques grottes sur l'Île de la Possession, l'île principale de l'archipel Crozet, un petit taxon naviculoide inhabituel a été observé, initialement identifié comme *Fallacia lenzii*. Le nouveau taxon est décrit finalement comme *Fallacia emmae* mais il présente des caractéristiques de deux genres: *Fallacia* et *Germainiella*. La recherche morphologique approfondie a révélé des détails que, d'une part, contredisaient son placement dans *Fallacia*, tels que le nombre relativement faible de poroids sur le conopeum, l'absence d'ouvertures de canaux externes à côté de la fente du raphé (*Fallacia*) et des stries qui sont composées d'une aréole en forme de fente (*Germainiella*). La morphologie et la taxonomie du nouveau taxon sont discutées et des questions sont soulevées quant à la validité des genres récemment séparés du genre *Navicula* sur la base d'une, ou parfois deux, caractéristiques morphologiques.

Sub-Antarctique / *Fallacia* / *Germainiella* / taxonomie / nouvelle espèce

* Corresponding author: vandevijver@br.fgov.be

doi/10.7872/crya/v36.iss3.2015.245

INTRODUCTION

Diatoms (Bacillariophyceae) are one of the most abundant algal groups in the freshwater and (semi-)wet terrestrial ecosystems (Jones, 1996; Van de Vijver & Beyens, 1999) of the sub-Antarctic region. In 2002, a revision of the freshwater diatom flora of Île de la Possession, the main island of the sub-Antarctic Crozet Archipelago (southern Indian Ocean) was published (Van de Vijver *et al.*, 2002a) which resulted in the description of more than 30 new taxa. Since then, several new species have been added to the flora (Romero & Van de Vijver, 2011; Van de Vijver *et al.*, 2004, 2011, 2014; Van de Vijver, 2012). Some of these were actually corrections of identifications where taxa had been force-fitted into European species (Tyler 1996). For instance, the small *Cocconeis* species originally identified as *C. neothumensis* Kammer by Van de Vijver *et al.*, (2002a), was shown to be a new species, *C. crozetensis* Romero & Van de Vijver (Romero & Van de Vijver, 2011). A similar analysis of *Aulacoseira distans* (Ehrenb.) Simonsen populations in the entire sub-Antarctic Region, resulted in the description of *A. principissa* Van de Vijver (Van de Vijver, 2012).

A small naviculoid diatom, found in a soil sample was misidentified under the name *Fallacia lenzii* (Hust.) Lange-Bert. by Van de Vijver *et al.*, (2002a). During a subsequent analysis of the sample using high-resolution scanning electron microscopy, several valves of this taxon were found. The morphology showed important similarities and differences with the genus *Fallacia* Stickle & D.G.Mann. and with a similar genus, *Germainiella* Lange-Bert. & Metzeltin, closely related to *Fallacia*, which has been erected for *Navicula enigmatica* Germain (Metzeltin *et al.*, 2005, Reichardt, 2006). A second *Germainiella* species, *G. enigmaticoides* Lange-Bert. & Metzeltin was described from Uruguay (Metzeltin *et al.*, 2005). Based on the similarities in different features of our unknown species with both genera, its taxonomic position is problematical.

In the present paper, we describe this formerly misidentified taxon as a new species: *Fallacia emmae* sp. nov. and discuss its taxonomic position and the choice for *Fallacia* as the host genus based on light and scanning electron microscopy. The ecology of *F. emmae* is addressed and its position within *Fallacia* or *Germainiella* is discussed.

MATERIAL & METHODS

The Crozet Archipelago (45°48'-46°26'S, 50°14'-52°15'E) is a group of five small volcanic islands situated in the southern Indian Ocean, just north of the Antarctic Convergence. The main island of the archipelago is Île de la Possession with a total surface area of 156 km^2. Its topography is dominated by several peaks, culminating in the Pic du Mascarin (934 m). Deep glacial valleys extend from north to east and steep cliffs border the western and southern coasts. In general the climate is oceanic and cold, with a mean air temperature of 5°C and total annual precipitation exceeding 2200 mm per year. Strong winds from the west and northwest sweep the islands. The vegetation is mainly dominated by grasses and mosses. The native vascular flora consists of only 22 species, occurring up to an altitude of 200 to 300 m. Additional information on the geography, climatology and vegetation of Île de la Possession can be found in Bougère & Bougère (1998) and Van de Vijver *et al.* (2002a).

During the austral summer of 1999, an extensive sampling campaign was undertaken on Île de la Possession, aiming to improve documentation of the diatom biodiversity in soils (Van de Vijver, 2002b). Analysis of the samples revealed the presence of a population of an unknown naviculoid diatom in a sample collected from the Pointe Basse region, in the northeastern part of Île de la Possession. This sample (BA061) was taken from a small, non-vegetated cavern in the canyon of one of the small rivers of Pointe Basse.

A small sub-sample of BA061 was prepared for LM observation 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 1h. The reaction was completed by addition of $KMnO_4$. Following digestion and centrifugation (three times 10 minutes at 3700 × g), cleaned material was diluted with distilled water to avoid excessive concentration of diatom valves on the slides. Cleaned diatom material was mounted in Naphrax®. For scanning electron microscopy (SEM), part of the cleaned suspension was pipetted onto small coverglasses glued to aluminium stubs, and sputter coated with a 20 nm thick layer of gold-palladium. Observations and photomicrography were performed at the IAC-lab (former EMMA-lab) of the Natural History Museum in London (BM, UK) using a Zeiss® Ultra plus scanning electron microscope at 3 kV. Sample, slide and stub are stored at the BR-collection, property of the Belgian federal state and given in permanent loan to the Botanic Garden Meise (Belgium).

For comparison, two samples, one (France, leg. A. Barthès) containing an unknown member of the genus *Germainiella* and one (Tibbarsbäcken, Sweden, leg. A. Jarlman) containing *Fallacia subhamulata* (Grunow) D.G.Mann, were examined.

Terminology follows Hendey (1964), Cox & Ross (1981), Mann (1981) and Round *et al.* (1990). Comparisons are mostly based on Germain (1980, 1989), Werum & Lange-Bertalot (2004) and Metzeltin *et al.* (2005).

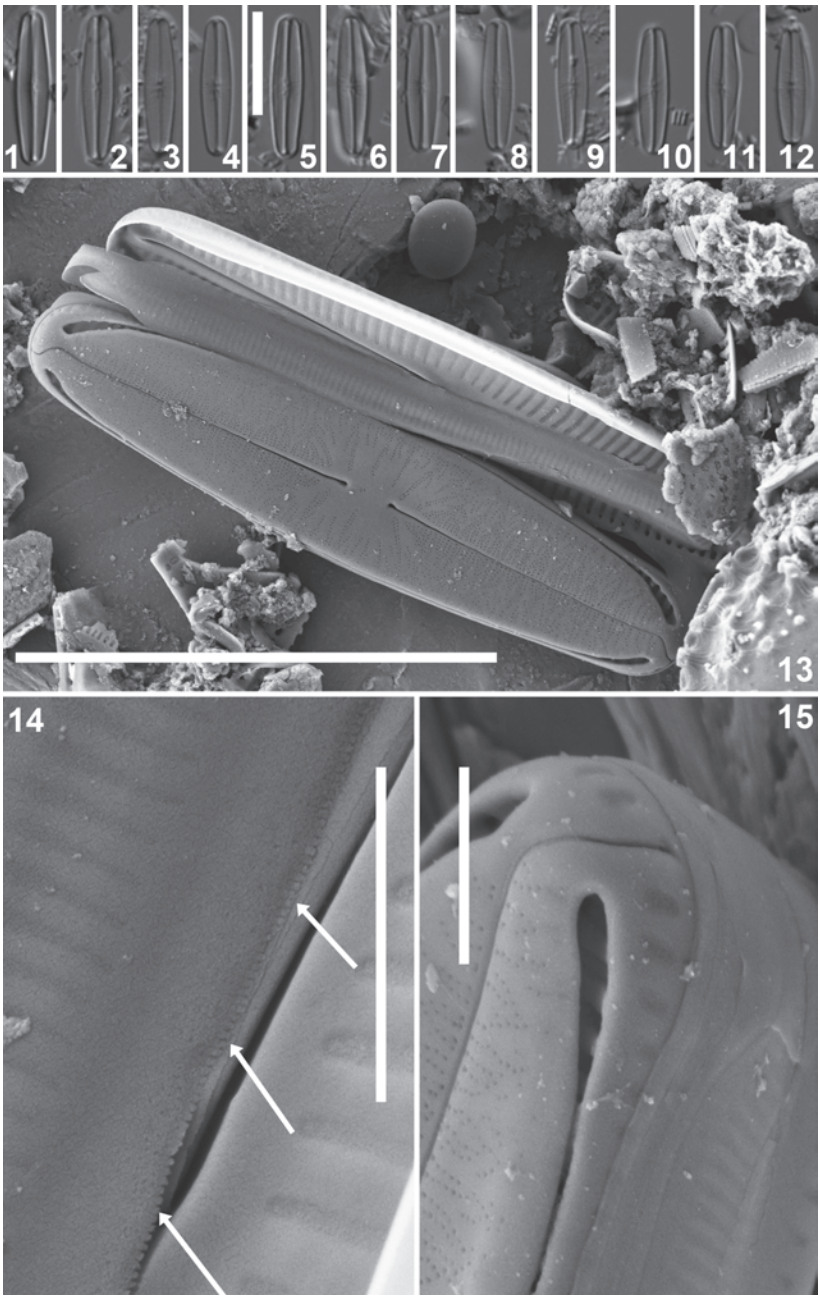
RESULTS

Fallacia emmae sp. nov. Figs 1-21

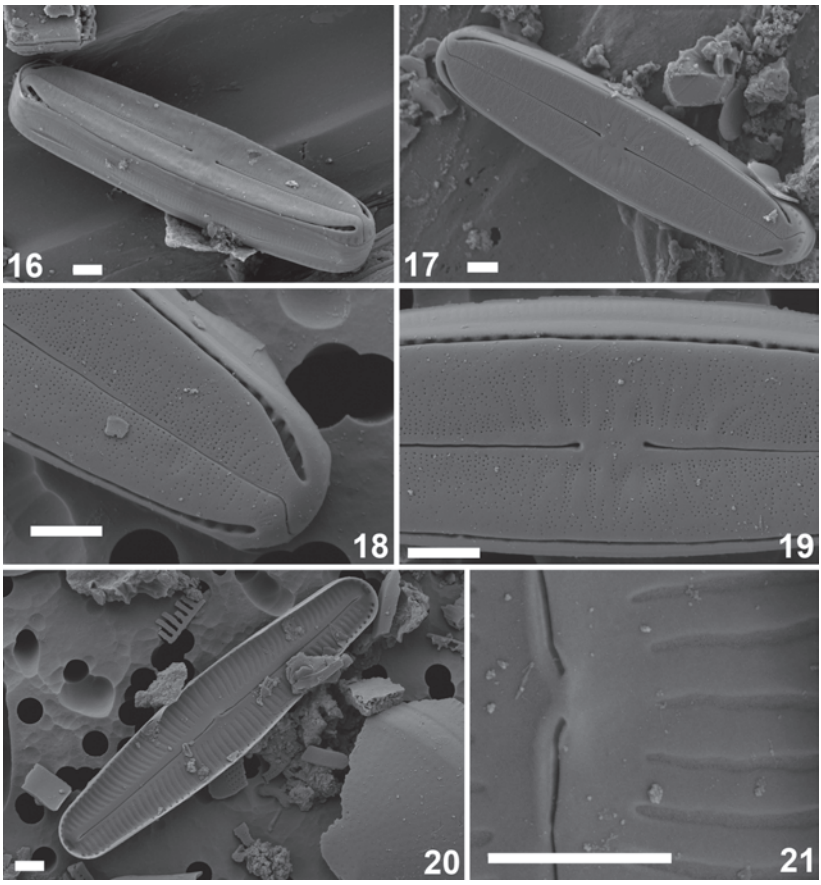
Type: Pointe Basse, Île de la Possession, Crozet Archipelago, TAAF sample BA061, leg. B. Van de Vijver, coll. date 21/11/1999 (holotype, slide no. BR-4282; isotype, slide PLP-219, University of Antwerp, Belgium).

Etymology: The species is named after the EMMA (Electron Microscopy and Mineral Analysis) laboratory, the former name of the Imaging and Analysis Centre (IAC) at the Natural History Museum (BM) in London (UK), to thank the staff for their help and advice during several sessions on the Zeiss Ultra Microscope.

LM (Figs 1-12): Valves narrowly lanceolate with weakly convex, almost parallel margins and broadly rounded, barely protracted apices. Valve dimensions (n = 25): length 11.5-16.0 µm, width 3.0-3.6 µm. Axial area narrow, forming an apparently raised raphe sternum above the valvar plane. Central area not expanded, axial area narrower between the proximal raphe endings. Raphe filiform, straight. Proximal raphe endings straight, clearly enlarged, positioned close together. Distal raphe endings difficult to resolve in LM. Transapical striae barely discernible in LM, parallel to weakly radiate throughout, 32-36 µm. Central striae more widely spaced, hence slightly easier to discern.



Figs 1-15. *Fallacia emmae*, images of specimens from the type population (BR-4282, Île de la Possession, Crozet archipelago) to show morphological range. **1-12.** LM valve face views. **13.** SEM external view of a broken frustule showing girdle bands and a valve interior. **14.** SEM external detail of a girdle band showing the series of covered, rectangular slits and fringed edges (arrows). **15.** SEM external detail of a valve apex showing the different girdle bands. Scale bar = 10 µm for Figs 1-13 and 1 µm for Figs 14 & 15.



Figs 16-21. *Fallacia emmae*, images of specimens from the type population (BR-4282, Île de la Possession, Crozet archipelago). **16.** SEM external view of an entire valve in oblique view showing the mantle/valve face junction and the mantle structure; **17.** SEM external view of an entire valve; **18.** SEM external detail of an apex with the conopeum and the distal raphe endings; **19.** SEM external detail of the central area; **20.** SEM internal view of an entire valve. Note the striae composed of a single areola covered by an internal hymen; Fig. **21.** SEM internal detail of the central area. Scale bar = 1 µm for Figs 16-21.

SEM (Figs 13-21): Girdle apparently composed of several open bands showing a continuous series of elongated, covered slits and fringed edges (Figs 13-15). Valve face entirely covered by a wide conopeum reaching the valve face/mantle junction (Figs 13, 16). Conopeum with irregular rows of small, rounded pores, 140-160 in 10 µm (Figs 17-19). Narrow groove visible between mantle and conopeum, enlarged towards the apices (Figs 16-19). Transapical striae not discernible due to the presence of the conopeum. Striae visible near the apices, apparently consisting of one elongated areola, bordered by raised virgae (Fig. 18). Striae on the mantle composed of one large areola, larger around the valve apices (Figs 15-16). External raphe branches straight (Fig. 17). Proximal raphe endings straight to weakly deflected, enlarged (Fig. 19). Distal fissures bent, continuing onto the valve mantle (Fig. 18). Internal proximal raphe endings short, clearly deflected towards the

primary side (Figs 20-21). Distal raphe endings straight, terminating in slightly raised helictoglossae (Fig. 20). Striae consisting of transapically elongated shallow grooves, entirely occluded by hymenate coverings (Fig. 21). Striae briefly interrupted near the valve face/mantle junction, continuing on the mantle (Fig. 20).

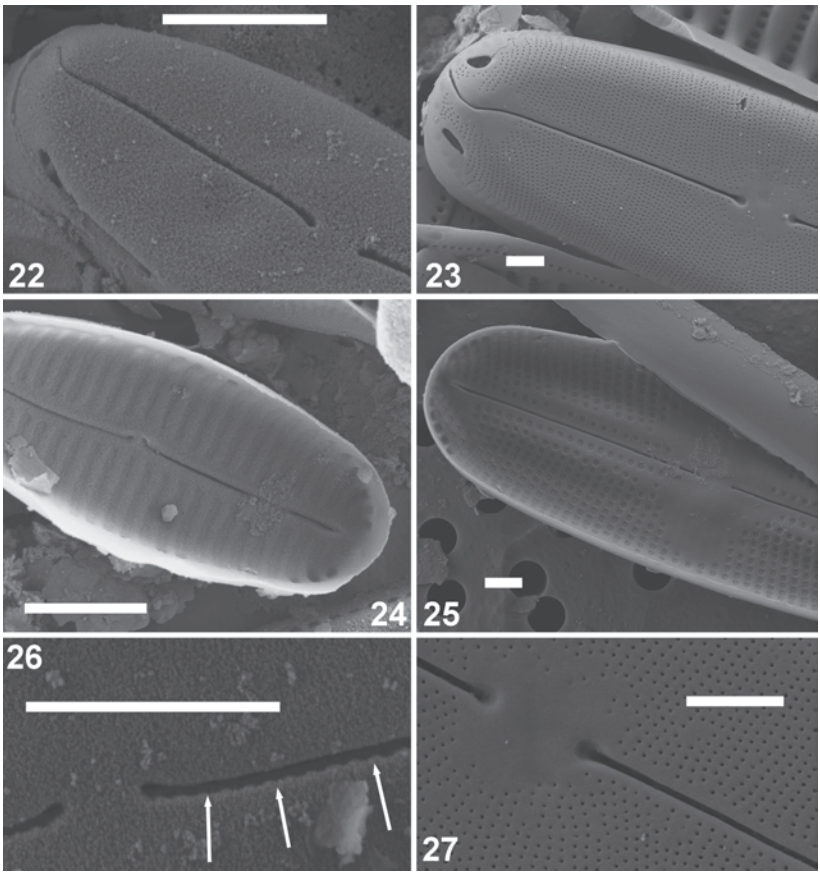
Habitat and associated diatom taxa — So far this species has only been found in one very dry soil sample. The sample was taken from a small cavern lacking any vegetation with a ground layer of coarse-grained gravel. No chemical measurements were performed since too little soil was available. The sample was dominated by several *Chamaepinnularia* and *Humidophila* species, a.o. *H. subantarctica* (Le Cohu & Van de Vijver) Lowe *et al.*, *Denticula sundaysensis* R.E.M.Archibald, *Planothidium aueri* (Krasske) Lange-Bert., *Achnanthes naviformis* Van de Vijver & Beyens, *Diatomella balfouriana* Grev. and an as yet unidentified centric diatom.

DISCUSSION

The new species shows features of two genera: *Fallacia*, described in 1990 by D.G. Mann (Round *et al.*, 1990) and *Germainiella*, recently described from Uruguay (Metzeltin *et al.*, 2005). Both genera are quite similar to each other but can be separated based on several (smaller) differences. A conopeum is present in both but the density of the small pores on the conopeum differs based on the generic descriptions. *Germainiella* has a conopeum with 350-400 pores in 10 µm (Fig. 22) that covers entirely the valve face and even reaches till the mantle, whereas *Fallacia* has a conopeum with only 80-140 pores in 10 µm (Fig. 23), that is often smaller and restricted to the valve face. A second difference is in the raphe structure. *Germainiella* has a series of external canal apertures beside the raphe (Fig. 26, see arrows), which are absent in *Fallacia* (Fig. 27). Finally, the stria structure also differs markedly. In *Fallacia*, the striae are composed of a series of small areolae, each covered internally by a hymen (Germain, 1989: figs 23-29) (Fig. 25). *Germainiella* on the other hand has one elongated areola per stria, covered internally by one long hymen (Germain, 1989: fig. 30 as *Navicula enigmatica* Germain) (Fig. 24).

Two groups of species can be identified within *Fallacia* that show considerable morphological differences between each other. The genus was originally described based on *Navicula pygmaea* Kütz. and one of the key features was the presence of a lyre-shaped canal (Round *et al.,* 1990). Most *Fallacia* species, such as *F. forcipata* (Grev.) Stickle & Mann, *F. scaldensis* Sabbe & Muylaert and *F. tenera* (Hust.) D.G.Mann share this feature. However, a small number of *Fallacia* species (confined to freshwater habitats), lack this feature. *Fallacia subhamulata*, *F. langebertalotii* (E.Reichardt) Reichardt, *F. lenzii* and *F. ecuadoriana* Lange-Bert. & Rumrich are typical examples of the latter group that lack the lyre-shaped canal. A third group of former *Fallacia* species was recently split off and described as a separate genus, *Pseudofallacia* Liu *et al.* (Liu *et al.*, 2012).

Comparing the morphology of the new species with *Fallacia*, *Germainiella* and *Pseudofallacia*, it is unclear where it should be placed. It is clear that the new species does not belong to *Pseudofallacia*. A conopeum is present in the latter but very reduced covering only a small part of the striae. As a consequence, the typical structure of the new species with the narrow groove between mantle and valve face



Figs 22-27. SEM comparison between *Germainiella* sp. (Figs 22, 24, 26) and *Fallacia subhamulata* (Figs 23, 25, 27). **22-23.** SEM external detail of the conopeum; Figs 24-25. SEM internal detail of the striae; **26-27.** SEM external detail of the central area. Note the presence of a series of external canal apertures beside the raphe in *Germainiella* (Fig. 26, see arrows). Scale bar represents 1 µm.

is not present in *Pseudofallacia*, but instead two elongate pores are present near the distal raphe endings (Liu *et al.*, 2012, Fig. 14). There is however a similarity in stria structure since *Pseudofallacia* also possesses one elongated areola per stria, similar to our new species but contrary to all known *Fallacia* species. These areolae are however split into two parts with one part situated in a depression, visible both internally and externally (Liu *et al.*, 2012, Figs 15 & 17). This is never the case in the new species.

The new taxon from Île de la Possession bears some similarities to the second group of *Fallacia* species, based on the shape and size of the pores on the conopeum, raphe structure and a conopeum that completely covers the valve face, leaving only a narrow groove at the valve face/mantle transition. Canal apertures beside the raphe also seem to be lacking, as in *Fallacia* rather than *Germainiella*. On the other hand, the new taxon has a similar stria structure to *Germainiella,* with one, transapically elongated areola covered by a large internal hymen. This stria type is not uncommon and has been found in a.o. the genera

Labellicula Van de Vijver & Lange-Bert., *Microfissurata* Lange-Bert. *et al.* and *Olifantiella* Riaux-Gobin & Compère, and in the complex of species around *Navicula schmassmanii* Hust. (Van de Vijver *et al.*, 2005, Riaux-Gobin & Compère, 2009, Werum & lange-Bertalot, 2004). In *Luticola* D.G.Mann although there are several round to slit-like external areola openings per stria, they are occluded internally be a single continuous hymen (Round *et al.,* 1990).

The extreme rarity of the new species, its small dimensions and the nature of the sample (dry soil sample with a high density of inorganic debris) made it almost impossible to analyze the shape and structure of the chloroplast. On the other hand, the structure and shape of the chloroplast in *Germainiella* is also unknown since neither Germain (1980) nor Metzeltin *et al.* (2005) recorded the chloroplasts. Due to the lack of molecular data, it is also at present unclear whether or not *Germainiella* and *Fallacia* are (phylogenetically) related to each other.

The intermediate features of *F. emmae*, resembling both *Fallacia* and *Germainiella,* raise questions about the validity of some of the small genera split off from the former catch-all genus *Navicula*, such as *Lecohuia* Lange-Bert. in Rumrich *et al.*, *Veigaludwigia* Lange-Bertalot & Rumrich, *Germainiella*, *Lacunicula* Lange-Bertalot *et al.*, *Prestauroneis* Bruder & Medlin, *Crucicostulifera* Taylor & Lange-Bert. and *Labellicula*, all described over the last 15 years (Rumrich *et al.*, 2000; Lange-Bertalot *et al.*, 2003; Van de Vijver *et al.*, 2005; Metzeltin *et al.*, 2005; Metzeltin & Lange-Bertalot, 2007; Bruder & Medlin, 2008; Taylor & Lange-Bertalot, 2010). Although some of these genera were described based on detailed morphological research, and seem to warrant separation, others were only distinguished by having or lacking one, occasionally two discrete morphological features that were absent or present in other, larger genera. As a consequence, their validity has been strongly questioned. For instance, *Lacunicula* was recently rejected as an independent genus by Morales & Le (2005), stating that the presence of the deep grooves next to the raphe alone is insufficient to separate the species from *Craticula* Grunow as all other features linked *L. sardiniensis* Lange-Bert. *et al.* to *Craticula*.

The discussion about generic validity is related to the question of the value of each morphological feature. In describing new genera, authors are not always consistent about the value of individual characters. On the one hand, Lange-Bertalot (1989) rejected the separation of several small-celled fragilarioid genera described by Williams & Round (1987) on the basis of single criteria (*i.e*. areola type), but on the other hand (e.g., Taylor & Lange-Bertalot, 2010), used later only a limited number of features on which to separate *Lacunicula* and *Crucicostulifera*. Similarly, Morales & Le (2005) rejected *Lacunicula* because it was only based on one feature, but the genus *Sarcophagodes* E.Morales was described to accommodate *S. delicatula* E.Morales based only on stria structure (Morales 2002). In his opinion paper on generic definitions, Round (1996) listed several types of features that can be used to discriminate genera, although he did not provide answers on the value of these features. Later, Cox (2009) discussed changes in taxonomic concepts stating that when "the interpretation of a genus is too tightly limited to the characters seen in the generitype, closely related species may be unnecessarily separated into new genera", also providing suggestions for the better description of new taxa. Intermediate taxa, like *F. emmae,* combining features of two, closely related, genera may help in establishing clearer generic boundaries and may support the need for genus emendation, rather than the uncontrolled proliferation of new, often monotypic genera. In many cases, molecular analysis can provide additional information as to whether the separation of two genera is justified or not. Bruder & Medlin (2008) separated *Navicula integra* (W.Smith) Ralfs from *Navicula,* as *Prestauroneis integra*

(W.Smith) Bruder & Medlin based on its close proximity in the molecular tree to *Stauroneis* Ehrenb. and *Craticula*. Molecular analysis is clearly a valuable aid to the assessment of phylogenetic relationships but, as with morphological studies, relies on the inclusion of an appropriate range of comparative taxa in the analysis.

Acknowledgements. The authors wish to thank Drs. Pieter Ledeganck and Prof. Dr. E. Vidal for their help during the sampling campaign. Sampling on Crozet has been made possible thanks to the logistic and financial support of the French Polar Institute-Paul-Emile Victor in the framework of the terrestrial program 136 (Ir. Marc Lebouvier & Dr. Yves Frenot). Part of this research was funded within the FWO project G.0533.07. Dr. Alex Ball and the staff of the EMMA laboratory at the Natural History Museum are thanked for their help with the scanning electron microscopy. This study was supported by the BELSPO project CCAMBIO and an EU Synthesys grant to BVDV to visit the National History Museum in London, UK. Mrs. Amélie Barthès is thanked for the sample of *Germainiella* and Mrs. A. Jarlman is thanked for the sample of *Fallacia subhamulata*.

REFERENCES

BESSEY C.E., 1907 — A synopsis of plant phyla. *Nebraska university studies* 7: 275-373.

BOUGÈRE E. & BOUGÈRE J., 1998 — Régime hydrologique d'un bassin versant subantarctique: la Rivière du Camp (Archipel Crozet – Terres australes et antarctiques françaises). *Géomorphologie: relief, processus, environnement* 4: 79-88.

BRUDER K. & MEDLIN L.K., 2008 — Morphological and molecular investigations of naviculoid diatoms. II. Selected genera and families. *Diatom research* 23: 283-329.

COX E.J. & ROSS R., 1981 — The striae of pennate diatoms. *In:* Ross R. (ed.) *Proceedings of the sixth symposium on recent and fossil diatoms*. Koenigstein, Otto Koeltz Science Publishers, pp. 267-278.

COX E.J., 2009 — What's in a name? – Diatom classification should reflect systematic relationships. *Acta botanica Croatica* 68: 443-454.

GERMAIN H., 1980 — Trois diatomées nouvelles dans le bassin d'une serre à Angers. *Cryptogamie, Algologie* 1: 19-27.

GERMAIN H., 1989 — Dissemblance entre les côtés externes et internes de la valve observe en microscopie électronique à balayage chez quelques diatomées pennées. *Cryptogamie, Algologie* 10: 173-179.

HENDEY N.I., 1964 — *An introductory account of the smaller algae of British coastal waters. Part V: Bacillariophyceae (Diatoms)*. London, Her Britannic Majesty's Stationery Office, 317 p.

JONES V.J., 1996 — The diversity, distribution and ecology of diatoms from Antarctic inland waters. *Biodiversity and conservation* 5: 1433-1449.

LANGE-BERTALOT H., 1989 — Können *Staurosirella*, *Punctastriata* und weitere Taxa sensu Williams & Round als Gattungen der Fragilariaceae kritischer Prüfung standhalten? *Nova Hedwigia* 49: 79-106.

LANGE-BERTALOT H., CAVACINI P., TAGLIAVENTI N. & ALFINITO S., 2003 — Diatoms of Sardinia. *Iconographia diatomologica* 12: 1-438.

LIU Y., KOCIOLEK J.P., FAN Y. & WANG Q., 2012 — *Pseudofallacia* gen. nov., a new freshwater diatom (Bacillariophyceae) genus based on *Navicula occulta* Krasske. *Phycologia* 51: 620-626.

MANN D.G., 1981 — Sieves and flaps: siliceous minutiae in the pores of raphid diatoms. *In:* Ross R. (ed.), *Proceedings of the sixth symposium on recent and fossil diatoms*. Koengistein, Otto Koeltz Science Publishers, pp. 279-300.

MEDLIN L.K. & KACZMARSKA I., 2004 — Evolution of the diatoms: V. Morphological and cytological support for the major clades and a taxonomic revision. *Phycologia* 43: 245-270.

METZELTIN D., LANGE-BERTALOT H. & GARCÍA-RODRÍGUEZ F., 2005 — Diatoms of Uruguay. Compared with other taxa from South America and elsewhere. *Iconographia diatomologica* 15: 1-736.

METZELTIN D. & LANGE-BERTALOT H., 2007 — Tropical diatoms of South America II. Special remarks on biogeographic disjunction. *Iconographia diatomologica* 18: 1-867.

MORALES E.A., 2002 — Studies in selected fragilarioid diatoms of potential indicator value from Florida (USA) with notes on the genus *Opephora* Petit (Bacillariophyceae). *Limnologica* 32: 102-113.

MORALES E.A. & LE M., 2005 — The taxonomy of the diatom *Lacunicula sardiniensis* Lange-Bertalot, Cavacini, Tagliaventi et Alfinito and its relationship with the genus *Craticula* Grunow (Bacillariophyceae). *Proceedings of the Academy of natural sciences of Philadelphia* 154: 155-161.

REICHARDT E., 2006 — Bemerkenswerte Diatomeenfunde aus Bayern V – Neue une seltene Arten aus der Schwarzachklamm. *Berichte der Bayerischen botanischen Gesellschaft* 76: 41-51.

RIAUX-GOBIN C. & COMPÈRE P., 2009 — *Olifantiella mascarenica* gen. & sp. nov., a new genus of pennate diatom from Reunion Island, exhibiting a remarkable internal process. *Phycological research* 57: 178-185.

ROMERO O.E. & VAN DE VIJVER B., 2011— *Cocconeis crozettensis*, a new monoraphid diatom from subantarctic freshwater and moss habitats. *Diatom research* 26: 89-98.

ROUND F.E., CRAWFORD R.M. & MANN D.G., 1990 — *The Diatoms, Biology and Morphology of the Genera*. Cambridge, Cambridge University Press, 747 p.

ROUND F.E., 1996 — What characters define diatom genera, species and infraspecific taxa? *Diatom research* 11: 203-218.

RUMRICH U., LANGE-BERTALOT H. & RUMRICH M., 2000 — Diatomeen der Anden. Von Venezuela bis Patagonien/Feuerland. *Iconographia diatomologica* 9: 1-649.

TAYLOR J. & LANGE-BERTALOT H., 2010 — *Crucicostulifera*, a new diatom genus described from the Magaliesburg mts, South Africa. *Polish journal of botany* 55: 43-48.

TYLER P.A., 1996 — Endemism in freshwater algae, with special reference to the Australian region. *Hydrobiologia* 336: 127-135.

VAN DE VIJVER B. & BEYENS L., 1999 — Biogeography and ecology of freshwater diatoms in sub-Antarctica: a review. *Journal of biogeography* 26: 993-1000.

VAN DE VIJVER B., FRENOT Y. & BEYENS L., 2002a — Freshwater diatoms from Île de la Possession (Crozet Archipelago, Subantarctica). *Bibliotheca diatomologica* 46: 1-412.

VAN DE VIJVER B., LEDEGANCK P. & BEYENS L., 2002b — Soil diatom communities from Île de la Possession (Crozet, Subantarctica). *Polar biology* 25: 721-729.

VAN DE VIJVER B., GREMMEN N.J.M., BEYENS L. & LE COHU R., 2004 — *Pinnularia sofia* Van de Vijver & Le Cohu spec. nov., a new spine-bearing, chain-forming *Pinnularia* species from the sub-Antarctic region. *Diatom research* 19: 103-114.

VAN DE VIJVER B., FRENOT Y., BEYENS L. & LANGE-BERTALOT H., 2005 — *Labellicula*, a new diatom genus (Bacillariophyta) from Île de la Possession (Crozet Archipelago, Subantarctica). *Cryptogamie, Algologie* 26: 125-133.

VAN DE VIJVER B., ZIDAROVA R., STERKEN M., VERLEYEN E., DE HAAN M., VYVERMAN W., HINTZ F. & SABBE K., 2011 — Revision of the genus *Navicula* s.s. (Bacillariophyceae) in inland waters of the Sub-Antarctic and Antarctic with the description of 5 new species. *Phycologia* 50: 281-297.

VAN DE VIJVER B., 2012 — *Aulacoseira principissa* sp. nov., a new centric diatom species from the sub-Antarctic region. *Phytotaxa* 52: 33-42.

VAN DE VIJVER B., DE HAAN M. & LANGE-BERTALOT H., 2014 — Revision of the genus *Eunotia* (Bacillariophyta) in the Antarctic Region. *Plant ecology & evolution* 147: 256-284.

VAN DER WERFF A., 1955 — A new method for cleaning and concentrating diatoms and other organisms. *Verhandlungen der Internationalen Vereinigung für theoretische und angewandte Limnologie* 12: 276-277.

WERUM M. & LANGE-BERTALOT H., 2004 — Diatoms in springs from Central Europe and elsewhere under the influence of hydrogeology and antropogenic impacts. *Iconographica diatomologica* 13: 1-417.

WILLIAMS D.M. & ROUND F.E., 1987 — Revision of the genus *Fragilaria*. *Diatom research* 2: 267-288.