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DIATOM FLORA OF SAN FRANCISCO BAY AND VICINITY. II. *FOGEDIA KRAMMERI* SP. NOV.*

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Abstract. This is our second paper focusing on new diatom taxa of the San Francisco Bay area. Previously we described 11 species of *Navicula* s.str. as new for science. Here we present another new naviculoid species of the genus *Fogedia*. This new species bears the distinguishing features of the genus, including a straight internal raphe slit and short, simple external distal raphe ends. The species differs from similar *Fogedia* taxa by being smaller and having coarser stria and lower lineola density. With this new species of *Fogedia*, the number of diatoms new for science from San Francisco Bay and vicinity is 12, with more awaiting description. We discuss the relationships between the newly described and established species of *Fogedia*, and present their patterns of biogeographic distribution.

Key words: San Francisco Bay, naviculoid diatoms, diversity, biogeography, new species, *Fogedia*

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INTRODUCTION

There have been few studies on the benthic diatoms of the San Francisco Bay. Thompson and Laws (1982) discussed seasonal changes in the productivity and species composition of the microphytobenthos, with special attention to seasonal changes. Later on, Laws (1988) published the results of his study on diatom assemblages of San Francisco Bay. Laws published a complete list of species identified from surface sediments of the bay.

The material presented in this paper is part of a larger research program, the purpose of which is to develop a comprehensive diatom flora for the San Francisco Bay area. Our research was initiated with samples deposited in the Diatom Collection of the California Academy of Sciences. Later, collections were made on the oceanic coast in the vicinity of San Francisco. Finally, the Bay area (i.e. Aquatic Park) and the open ocean coast in San Francisco were sampled. LM and SEM revealed numerous undescribed taxa to which special attention was paid; these were subjected to detailed ultrastructural examination. In previous work, 11 new species of the diatom genus *Navicula* were described (Witkowski *et al.* 2009); this paper describes a new species of the genus *Fogedia* Witkowski, Lange-Bertalot, Metzeltin & Bafana.

The genus of *Fogedia* was established towards the end of the 1990s based on transfer of several taxa originally described as *Navicula* s.l. (Foged 1975; Witkowski *et al.* 1997, 2000). Most of the species belonging in *Fogedia* occur in tropical waters, with a few identified in temperate and cold waters. However, the number of species in *Fogedia*

* Dedicated to Dr. Kurt Krammer on the occasion of his 85th birthday

seems to be underestimated. Our current research shows the occurrence of potential new *Fogedia* species in the Pacific Ocean.

In *Fogedia* the most important characters allowing it to be separated from *Navicula* s.str. include the internal raphe slit being straight (it is strongly oblique in *Navicula*) and the presence of short, simple apical external raphe endings (they are strongly hooked on the same side in *Navicula* s.str.) (e.g., Cox 1979; Lange-Bertalot 2001; Witkowski *et al.* 2009). In addition, the valve face of most *Fogedia* species bears a lateral area differing from those observed either in *Fallacia* A. J. Stickle & D. G. Mann *in* F. E. Round *et al*. or in *Lyrella* Karayeva (cf. Round *et al.* 1990; Witkowski *et al*. 1997).

Material and methods

Fogedia krammeri occurred in recently collected samples from the Aquatic Park (along San Francisco's northern shore on San Francisco Bay) and at Ocean Beach, along the coast, collected by A. Witkowski and J. P. Kociolek in 2002, which are deposited in the Institute of Marine Sciences at the University of Szczecin (SZCZ).

Samples were processed by standard methods, including 10% HCl treatment in order to remove calcium carbonate, followed by rinsing with distilled water. Samples were boiled in hydrogen peroxide (37%) and again washed with distilled water. Naphrax® was used as the mounting medium. Diatoms were examined by light and electron microscopy. LM observations were made with a Leica DMLB with a Plan-apochromatic 100× (1.4 n.a.) oil immersion objective and Zeiss Axioscop with a Plan-apochromatic 100× (1.4 n.a.) oil immersion objective. For SEM, cleaned material was air-dried on filter paper. The filter paper strips were mounted on stubs and sputter-coated with gold. Observations were made with a Hitachi S-4500 microscope. Terminology related to valve ultrastructure follows Round *et al*. (1990).

Results

Fogedia krammeri Witkowski, Lange-Bertalot, Kociolek & Kulikovskiy, ***sp. nov.*** Figs 1 & 2

Valvae variabiles ad instar enim late elliptico-lanceolatae ad lineari-ellipticas apicibus ex cuneo curte et anguste subrostratis. Longitudo 20–30 µm, latitudo 9.5–12.0 µm. Raphe parum lateralis extremis centralibus terminalibusque punctiformibus. Area axialis anguste linearis. Area centralis in media parte latitudinis fasciam distinctam formans circiter rectangulata ad instar delimitata areis lateralibus et duabus striis abbreviatis utrimque. Striae transapicales subparallelae ad parum radiantes in media parte sed distinctius radiantes in partibus ad margines et sub apices, 10–12 in 10 µm. Lineolae striarum comparate bene discernendae, etiam microscopio photonico, 26–29 in 10 µm. Aspectus ultramicroscopicus externus internusque omnes structurae generaliter fissurae raphis solum usque prope poros centrales rectae apparentes ibi aliquid curvatae et in poros fortiter dilatatos guttiformes influentes. Fissurae terminales absunt quia extrema terminalia aliquid dilatata curtissime ad latus declinata. Fissurae raphis internae – ut communiter in genere – rectae omnino nec distortae ut in Navicula *s.str.* Fogedia finmarchica *et* F. acuta *cum dimensionibus similibus differunt aliquid ad instar valvarum sed proprie densitate lineolarum circiter 35–40 nec 26–29 in 10 µm.*

TYPE: U.S.A., Brackish water of San Francisco Bay, Aquatic Park macrophytes, May 2002, *leg. A. Witkowski & J. P. Kociolek* [HOLOTYPE: Praep. No. 5051 (1) in Coll. Witkowski, Institute of Marine Sciences, University of Szczecin (SZCZ); ISOTYPE: Praep. No. CAS accession number 627380, slide number 223002 in Diatom Collection, California Academy of Sciences, San Francisco].

ETYMOLOGY: The species name honors Dr. Kurt Krammer on the occasion of his 85th birthday.

LM. Valves moderately variable in outline from broad-elliptic or broadly elliptic-lanceolate to linear-elliptic, ends cuneate and at the terminus shortly-protracted subrostrate. Length 20–30 µm, breadth 9.5–12.0 µm. Raphe slightly lateral with central and terminal ends appearing punctiform by LM. Axial area narrow, linear throughout. Central area forming a shortened, almost rectangular fascia connected to the typical lateral areae (of *Fogedia*); in the marginal part on either side the transapical striae are interrupted. Striae subparallel to slightly radiate proximally, becoming more strongly radiate distally up to the ends, where they arevery slightly denser, 10–12 in 10 µm. Lineolae of the striae comparatively coarse, easily discernible by LM, 26–29 in 10 µm.

SEM. External and internal view (Fig. 1: 8–11, 2: 1–3): the general pattern of structures as in the few other known taxa of *Fogedia*. Valve surface

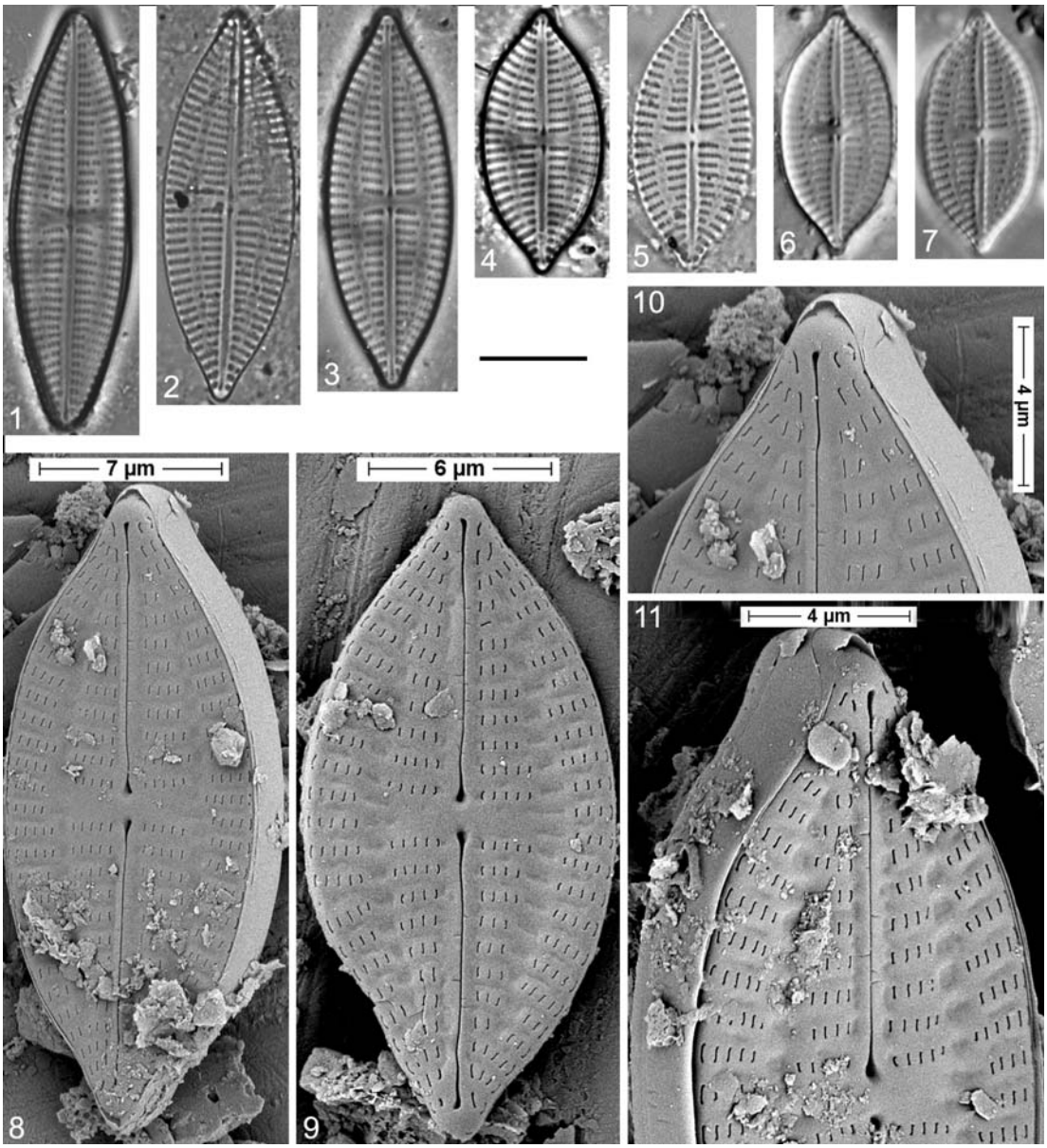

Fig. 1. *Fogedia krammeri* Witkowski, Lange-Bertalot, Kociolek & Kulikovskiy, *sp. nov.* 1–7 – valve view of specimens from type habitat (6 & 7a represent holotype specimen); 8 & 9 – external valve view of whole specimens; note the slightly undulating raphe, expanded external central raphe endings and short, slightly bent terminal raphe endings; 10 & 11 – closeup of valve; note depression of lateral area. 1–7 – LM: 1–5 – brightfield optics, 6 & 7 – DIC optics; 8–11 – SEM. Scale bar for 1–7 = 10 µm.

flat, slightly depressed in the form of lateral areae. External central raphe endings largely expanded and very shortly declined. External apical raphe endings very unlike the terminal fissures of *Navicula* s.str., short and slightly bent on one side. Raphe slit internally quite straight from the central nodule to the helictoglossa; it is not twisted, which is the condition observed in *Navicula* s.str.

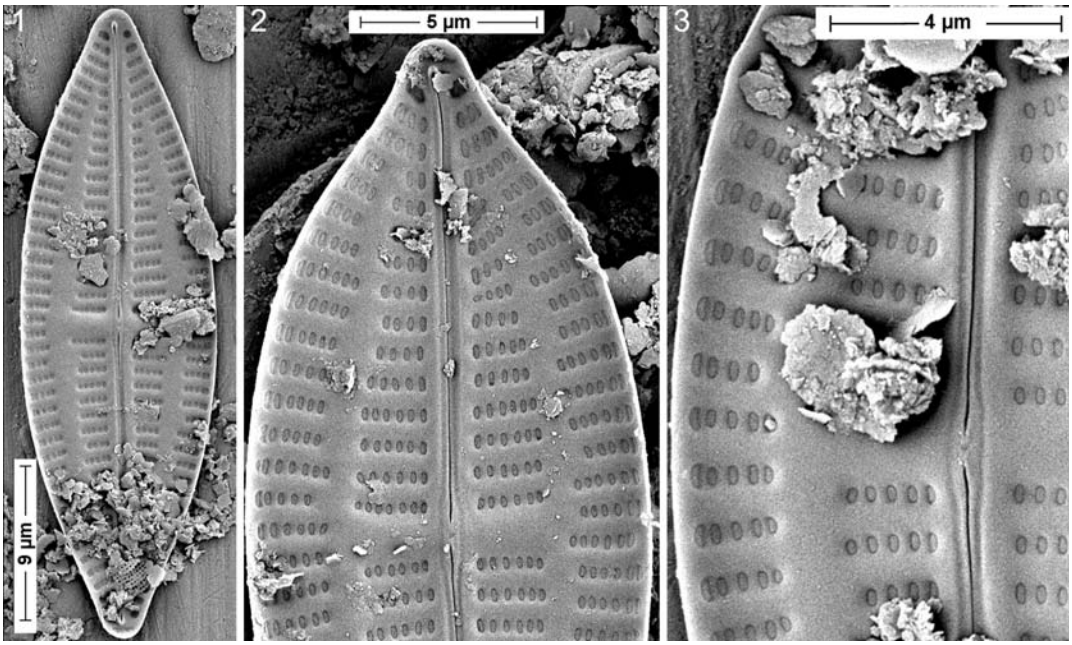

Fig. 2. *Fogedia krammeri* Witkowski, Lange-Bertalot, Kociolek & Kulikovskiy, *sp. nov*. 1 & 2 – internal valve view, note internal raphe slit running straight; 3 – closeup of internal view of central part of valve; note structureless internal view of lateral area, simple internal central raphe endings and domed areolae occlusions. All SEM.

DIFFERENTIAL DIAGNOSIS. The only species that has a similar valve outline is *F. acuta* Witkowski, Lange-Bertalot & Metzeltin, known from salt marshes and found also in Netarts Bay, Oregon, U.S.A. (Riznyk 1973). *Fogedia krammeri* is distinguished easily from *F. acuta* by its smaller cell dimensions, coarser striae and lower lineola density. Valves of *Fogedia finmarchica* differ from those of *F. krammeri* by their lanceolate outlines and having 35–40 lineolae per 10 µm, which are very difficult to resolve by LM.

DISTRIBUTION. *Fogedia krammeri* is known only from San Francisco Bay. Specimens figured and identified as *Navicula finmarchica* (Cleve & Grunow) Cleve (= *Fogedia finmarchica* Witkowski, Metzeltin & Lange-Bertalot *in* Witkowski) by Riznyk (1973) from Yaquina Bay in Oregon, appear more similar to *Fogedia krammeri*.

DISCUSSION

Our light and electron microscopy-based research on samples from the San Francisco Bay area revealed the presence of a new species of *Fogedia*. In this paper we also provided data on the ultrastructure of *Fogedia* as a genus. Based on our observations, the gross morphology of *Fogedia* is consistent, exhibiting little variation within the genus (e.g., Witkowski *et al*. 1997, 2000), unlike in *Navicula* s.str. (Lange-Bertalot 2001; Witkowski *et al.* 2009).

In its generic characters, *Fogedia krammeri* conforms with the generitype *F. finmarchica*. *Fogedia* species are characterized by linear-lanceolate, rarely elliptic valve shape. With the exception of *F. heterovalvata* (Simonsen) Witkowski, Lange-Bertalot & Metzeltin (Witkowski *et al.* 2000), *Fogedia* species possess a lateral area. At the ultrastructural level, on the exterior of *Fogedia* are simple distal raphe ends slightly bent to the same side, while internally there is a straight and simple slit-like raphe (Witkowski *et al.* 2000). It is interesting to note that taxa inhabiting temperate waters have robust, heavily silicified valves, whereas those from tropical waters are fragile (Witkowski *et al.* 1997).

Some variation in the distribution of *Fogedia* species was observed. In general we have few species, including *Fogedia giffeniana* (Foged) Witkowski, Lange-Bertalot & Metzeltin, that are confined to warm waters. They occur in the western Indian Ocean (Oman, Yemen, Kenya) and in the Mediterranean Sea (Witkowski *et al.* 2000; A. Witkowski, unpubl.). Taxa similar to *Fogedia finmarchica* have a very broad geographic distribution, though apparently absent from the Southern Ocean. *Fogedia finmarchica* and related taxa represent the epipelon and inhabit marine littorals including tidal flats of the North Atlantic and neighboring seas (Salah 1953, 1955; Hendey 1964; Witkowski *et al.* 2000). They also were reported from the United States Pacific coast, Oregon (Riznyk 1973). Here we report *Fogedia krammeri*, which is known so far from the San Francisco Bay area, a region influenced by the cold-water California Current.

With respect to valve morphology, *Fogedia* may be a rather close relative of *Hippodonta* Lange-Bertalot, Witkowski & Metzeltin. This is suggested by the very similar, slit-like, apically elongate striae in most of *Hippodonta* and in all *Fogedia* species (Lange-Bertalot *et al.* 1996; Witkowski *et al.* 1997; Lange-Bertalot 2001). *Fogedia* and *Hippodonta* also share the same type of plastid, that is, two girdle-apprised lobes, the same as in *Navicula* s.str. (Cox 1979; Lange-Bertalot 2001; J. Park *et al.,* unpubl.). The two genera also have significant differences. The valve face of *Hippodonta* species, for example, is always arched, whereas in *Fogedia* taxa it is flat. Finally, *Hippodonta* bears apical striae, which are missing in *Fogedia* (e.g., Lange-Bertalot *et al*. 1996; Witkowski *et al*. 1997; Witkowski *et al.* 2000; Lange-Bertalot 2001). Further work is required to elucidate the phylogenetic relationships of this branch of the diatom tree of life.

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