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This study presents a detailed morphological analysis using light and scanning electron microscopy of *Cymbella gravida* sp. nov. collected from the deep sediments of Laguna Potrok Aike, a maar lake in the province of Santa Cruz, Argentina. An attempt was made to describe its ecological preferences based on the diatom assemblages present in the sections where *C. gravida* was found. This newly proposed species is compared with two morphologically related taxa, *C. terrafuegiana* Krammer and *C. cistula* var. *guarrerae* Ferrario, both described from the same locality in Tierra del Fuego. Light and scanning electron microscope observations of the original material allowed the establishment of their correct taxonomy.

Keywords: *diatoms, freshwater, Cymbellaceae, Patagonia, taxonomy, subfossil*

Introduction

Southern Patagonia is an interesting region due to its richness and diversity of water bodies. Since 1997, diatoms from Laguna Potrok Aike, a maar lake located in the province of Santa Cruz, Argentina, have been studied with the aim of using them as bioproxies in paleoenvironmental reconstructions (e.g., Maidana & Corbella 1997, Haberzettl et al. 2005, Wille et al. 2007, Kastner et al. 2010). As a result of these studies, several taxa which were new to science were found in both water samples and quaternary sediments. Some of these new taxa have already been described, such as the new species *Thalassiosira patagonica* Maidana and the new genus and species *Corbellia contorta* Maidana & Round (Maidana 1999, Maidana & Round 1999). Core sediment samples retrieved during the international and interdisciplinary Potrok Aike Maar Lake Sediment Archive Drilling Project (PASADO) project were analyzed (Zolitschka et al. 2009). Numerous valves of a previously unknown diatom taxon were found in these sediment samples. Light (LM) and scanning electron microscope (SEM) observations revealed characteristic features that allowed the description of a new species of *Cymbella* C. Agardh.

In the past, the genus *Cymbella* was considered as a heterogeneous group with species characterized by cymbelloid valves, asymmetrical in the apical axis. Krammer (1982) subdivided it into three subgenera, *Cymbella*, *Encyonema* and *Cymbopleura*, based on the presence and position of the stigmata, the apical pore fields and the bending of the raphe's distal fissures. Later, Krammer (1997) redefined *Encyonema* as a genus, created the new genera *Encyonopsis*, *Cymbellopsis*, *Pseudoencyonema* and *Navicella*, and reclassified *Cymbopleura* as a genus. In 2002, Krammer amended the description of C*ymbella*, characterizing the genus by the cymbelloid shape of the valves, the raphe's terminal fissures dorsally bent and the presence of generally one apical pore field on each apex and one or more stigmata in the ventral position. Following this description, the genus probably contains more than 140 species, of which 129 were considered by Krammer (2002) in his monograph about the genus in Europe. According to the literature, 12 infrageneric taxa of *Cymbella sensu stricto* have been reported in Argentina (Krammer 2002, Vouilloud 2003). Some of those are only known from the Argentinean Patagonia, such as *C. neuquina* Frenguelli and *C. rigida* Frenguelli reported from the Neuquén region (Frenguelli 1942), and *C. terrafueguiana* Krammer (Krammer 2002) and *C. cistula* var. *guarrerae* Ferrario (Ferrario et al. 1982) from the Isla Grande de Tierra del Fuego. To date, only two taxa have been found in the province of Santa Cruz, *C. cistula* (Ehrenberg) Kirchner and *C. cymbiformis* C. Agardh, by Maidana et al. (2005) when studying diatoms from a Patagonia–Antarctica transect.

A new species, *Cymbella gravida* sp. nov. is proposed, collected from the deep sediments of Laguna Potrok Aike. Detailed morphological analyses using LM and SEM of this new taxon are presented and the resemblances and differences between the materials collected in Santa Cruz and

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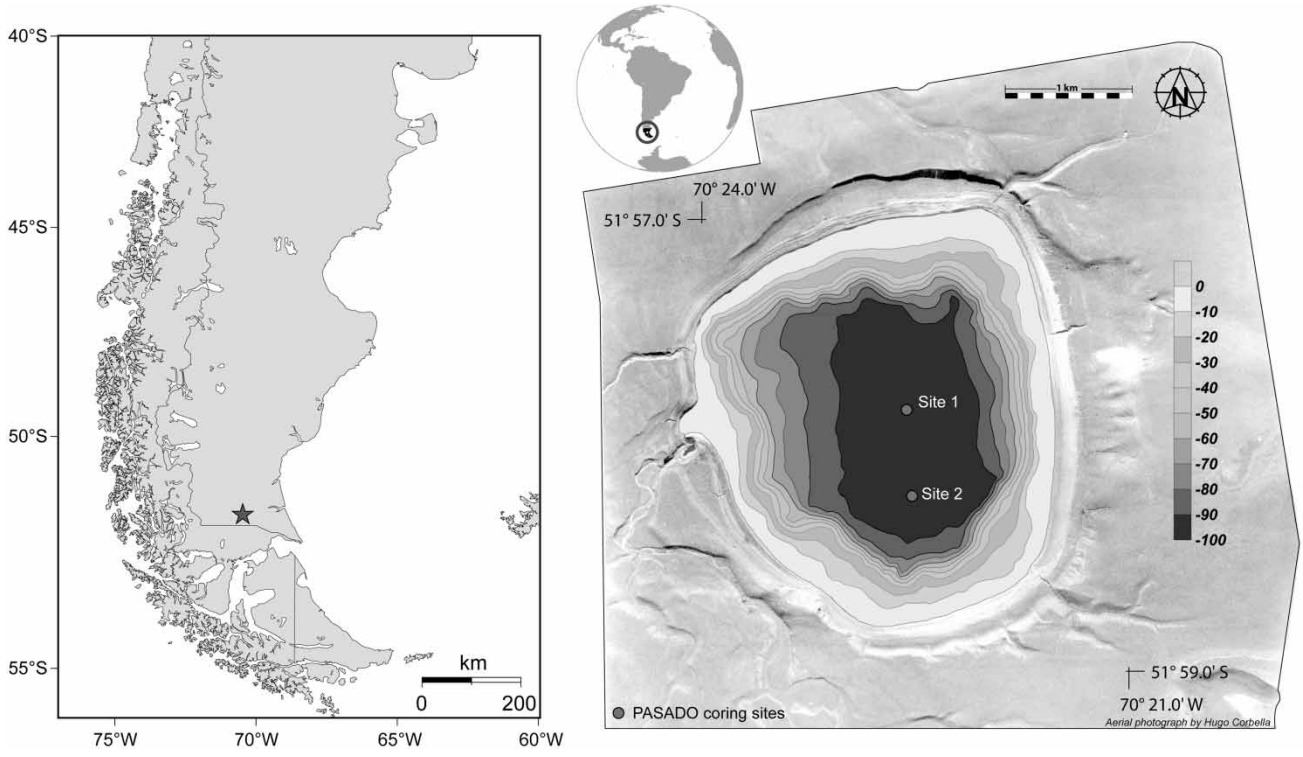


Fig 1. Map of Patagonia showing the location of Laguna Potrok Aike and a bathymetric map with the two drilling sites (bathymetric contours expressed in meters).

similar taxa such as *C. terrafuegiana* and *C. cistula* var. *guarrerae* are discussed.

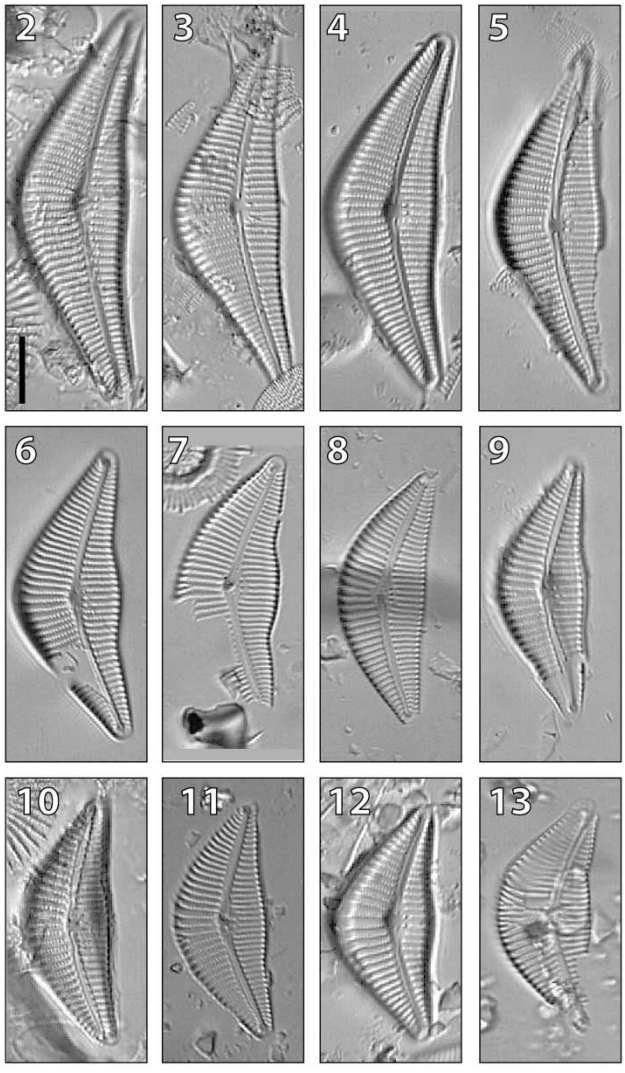
Material and methods

Samples were collected from different sediment cores retrieved from the center of the maar lake Laguna Potrok Aike (52°S, 70°W) in the province of Santa Cruz, Argentina (Fig. 1). The sediment cores were recovered during the PASADO lake drilling campaign, which took place within the framework of the International Continental Scientific Drilling Program (ICDP) from September to late November 2008 (Zolitschka et al. 2009). The sampled material was collected from core 1D, retrieved from site 1 and is explained in detail in Recasens et al. (2012), and from the composite core 5022-2CP, retrieved from site 2 and covering the last ca. 51.2 cal ka BP (Kliem et al. 2012). Sediment core treatment and subsampling for multiproxy analyses were developed especially for PASADO (Ohlendorf et al. 2011) and carried out in a laboratory at the University of Bremen, Germany. The material was treated and mounted following standard procedures (Battarbee 1986), which consists of heating 1 mg of dry sediment in 30% hydrogen peroxide. A few drops of 10% HCl were added to stop the reaction and remove the carbonates. Samples were then rinsed several times with deionized water to re-equilibrate the pH and a few drops of 20% NH_3 were added in the last rinse to facilitate the removal of clay. The suspension was mounted on permanent slides using Naphrax®. Diatom slides were studied in LM using a Leitz Diaplan microscope equipped with phase contrast optics at ×1000 magnification. Samples were also mounted directly onto aluminum stubs and covered by an ultrathin coating (ca. 15 nm) of gold for examination with a Jeol JSM 6400 (and 7001F) SEM at the Department of Geology and Paleontology, University of Geneva, Switzerland. The morphometric data presented in the species description are based on the measurement of more than 30 complete specimens.

The type material of *C. cistula* var. *guarrerae* (sample LPC 2995) collected from Lago Yehuin, Tierra del Fuego, was also examined. The slide LPC 2995(5) was examined in LM and the treated material was observed in SEM. The original material is stored in the herbarium of the División Científica Ficología, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Argentina.

Results

Cymbella gravida Recasens & Maidana sp. nov. (Figs 2–15)
Description. Valves dorsiventral, semi-rhomboid, convex dorsal margin and slightly concave ventral margin with tumid center. Apices obtusely rounded or subrostrate. Axial area narrow and central area small, rounded and asymmetrical. One to four stigmata on the ventral side. Raphe reverse-lateral. Striae broad, areolate and denser near the

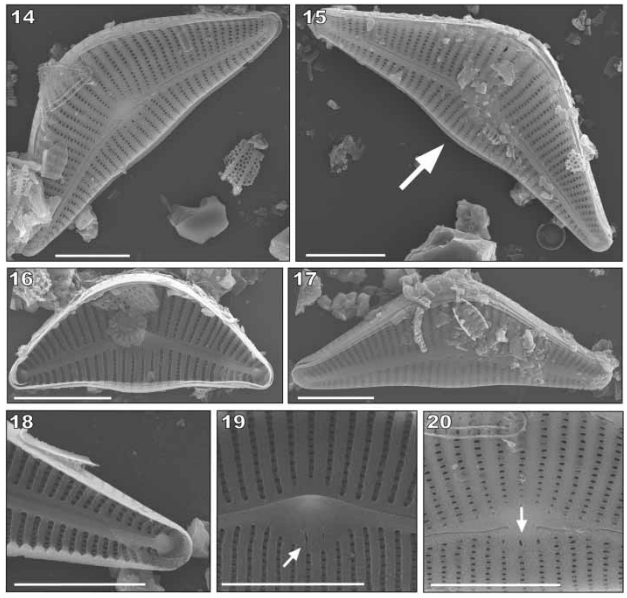


Figs 2–13. *Cymbella gravida* sp. nov. from Laguna Potrok Aike, LM, showing variability in size range and valve outline. Fig. 4. Holotype specimen. Scale bar = 10 μm.

ends. Length: 25.2–56.8 (40.6 ± 7.5) μm; width: 11.7–16.7 (14.2 ± 1.3) μm; length:width ratio: 1.6–3.8 (2.9 ± 0.4); proximal dorsal striae: 8–12 (9.8 ± 1.0) in 10 μm; distal dorsal striae: 10–14 (12.3 ± 1.2) in 10 μm; proximal ventral striae: 9–13 (10.6 ± 1.1) in 10 μm; distal ventral striae: 10–16 (12.9 ± 1.6) in 10 μm; areolae: 18–26 (22.4 ± 2.4) in 10 μm.

Holotype. Circled specimen on slide MHNG GEPI 2012-3, Museum of Natural History of Geneva, Switzerland. From type material sample 5022-2CP-796 (composite core 5022-2CP, 16 m depth below lake floor, ca. 14.9 cal ka BP). Fig. 4 represents the holotype.

Isotypes. Slides 5022-2CP-212, 5022-2CP-497, 5022-2CP-749, 5022-2CP-781 and 5022-2CP-4686, Department of Geology and Paleontology, University of Geneva, Switzerland. Raw material from the whole sedimentary sequence is



Figs 14–20. *Cymbella gravida* sp. nov. from Laguna Potrok Aike, SEM external (Figs 14–15, 17, 20) and internal (Figs 16, 18–19). **Figs 14–17.** Whole valve showing tumid ventral side (arrow). **Fig. 18.** Valve apex showing the apical pore field. **Fig. 19.** Valve center showing the stigmata (arrow). **Fig. 20.** Valve center showing the proximal raphe ends, striae and stigmata (arrow). Scale bars = 10 μm.

stored at 4°C in the GEOPOLAR core repository in Bremen, Germany.

Type locality. Laguna Potrok Aike (51°57.789′S, 70°22.754′W), Province of Santa Cruz, southern Patagonia, Argentina. Collected by the PASADO Science Team during the drilling campaign from September to November 2008. Fossil material from cores 5022-1D and 5022-2CP.

LM observations. The cymbelloid valves have a semi-rhomboid, strongly dorsiventral outline, with a very convex dorsal margin and a slightly concave ventral margin (Figs 2–13). The ventral margin always presents a more or less developed tumid center. The valve apices appear obtusely rounded to subrostrate in most specimens. The axial area is narrow and the central area is small, rounded but asymmetrical, absent or reduced to one or two shorter striae on the dorsal side and larger on the ventral side, with one to four stigmata. The raphe is reverse-lateral (type 6, as in Krammer & Lange-Bertalot 1986, pl. 124, fig. 12) with distal fissures bent dorsally and directed towards the ventral side of the valve. The striae are broad, areolate and slightly denser near the apices.

SEM observations. The apices of *C. gravida* have large pore fields situated on the valve margin and mantle (Figs 15–16, 18). Externally, the raphe fissures are dorsally deflected at the valve apices (Figs 14–15, 17) and internally the distal raphe fissures terminate in a prominent helictoglossa (Figs 16, 18). The stigmata appear rounded

Table 1. Comparison of biometric data and some morphological features between *Cymbella gravida* and *C. terrafueguiana*, included are the features of *C. terrafueguiana* and *C. cistula* var. *guarrerae* and the type material from Lago Yehuin (sample LPC 2995).

Variable	*C. gravida* (this study)	*C. terrafueguiana*		
		C. terrafueguiana Krammer (2002)	*C. cistula* var. *guarrerae* Ferrario et al. (1982)	Type material from Lago Yehuin Slide LPC 2995(5)[a]
Dorsal side	Semi-rhomboid	Semi-rhomboid	Semi-rhomboid	Semi-rhomboid
Ventral side	Concave with tumid center	Straight or very slightly convex	Straight	Straight or very slightly convex
Apex	Rounded to subrostrate	Acutely rounded	Acutely rounded	Acutely rounded
Length (μm)	25.2–56.8	64–74	80–95	56.7–89.0
Width (μm)	11.7–16.7	18–22	21–25	15.9–23.4
Maximum length:width ratio	3.8	3.6	n.d.	4.5
Dorsal central area	Absent or reduced to one or two shorter stria	Absent	Absent	Absent or reduced to one or two shorter stria
Striae in 10 μm at center	8–12 on dorsal side 9–13 on ventral side	8–9	8–9	8–10
Striae in 10 μm at apex	10–14 on dorsal side 10–16 on ventral side	11	n.d.	9–11
Areolae in 10 μm	18–26	19–21	18–25	20–25
Number of stigmata	1–4	2–4	2	1–4

Notes: n.d.: no data. ; A: according to the literature, sample LPC 2995 is the type material for both *C. terrafueguiana* and *C. cistula* var. *guarrerae*.

in external views of the valve and slit-like in internal views (Figs 14, 16, 19–20). The striae are areolate and the areolae do not seem to be covered internally (Figs 14–20).

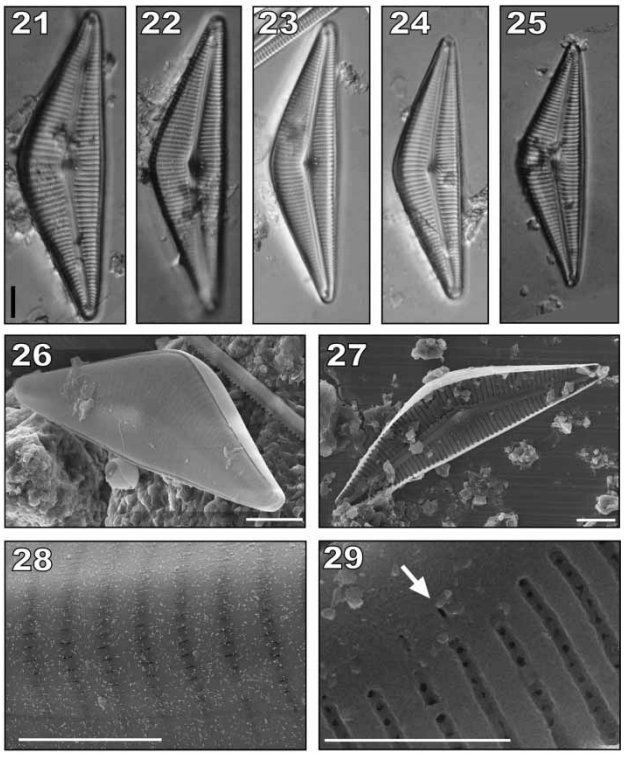
Ecology and associated diatom species

Cymbella gravida was found in sediment samples of Laguna Potrok Aike, a closed maar lake with a maximum diameter of 3.5 km and water depth of 100 m in the center of the basin (Fig. 1). Today, strong winds in the area prevent stratification of the water body, which leads to polymictic conditions and impedes the development of an ice cover in winter. The limnology of the lake is characterized by an average water column pH of 8–9, water temperatures of 9–13°C in summer and 3–7°C in winter, salinity ca. 2.2–2.5 g L^{-1} and electrical conductivity of ca. 3000 μS cm^{-1} (Zolitschka et al. 2006). *Cymbella gravida* was found throughout the whole sedimentary sequence, covering the last ca. 51.2 cal ka BP. It was most abundant in samples dominated by the planktonic *Discostella stelligera* (Cleve & Grunow) Houk & Klee and *Cyclostephanos patagonicus* Guerrero & Echenique. Among other species present were *Karayevia clevei* (Grunow) Round & Bukhtiyarova, *Cocconeis placentula* Ehrenberg, *Amphora pediculus* (Kützing) Grunow, *Cymbella cistula* (Hemprich & Ehrenberg) Kirchner *sensu lato* and *Diploneis chilensis* (Hustedt) Lange-Bertalot, along with small fragilarioid taxa, such as *Staurosirella pinnata* (Ehrenberg) D.M. Williams & Round, *Staurosira venter* (Ehrenberg) Hamilton and *Staurosira alpestris* (Krasske) Van de Vijver. *Cyclostephanos patagonicus* was reported from fresh and oligotrophic waters (Guerrero & Echenique 2002), whereas *D. stelligera*, although cosmopolitan, tends to prefer more nutrient-rich waters. Because of the abundance of these planktonic species in most samples containing *C. gravida*, it appears that this latter taxon prefers freshwater conditions. Nevertheless, some specimens of C. *gravida* were recorded in sediment samples from the same core where the dominating diatom flora indicates that the waters were more saline (Recasens et al. 2012), therefore it can be argued that this species could probably tolerate higher salinities.

Discussion and conclusions

Cymbella gravida was assigned to the *C. cymbiformis* complex *sensu* Krammer (2002) due to its cymbiform valve outline, dimensions, type of raphe, number of stigmata and essentially for its almost indistinct to absent central area on the dorsal side. This last characteristic, together with the relatively high number of areolae in 10 μm, is what distinguishes it from the *C. cistula* complex.

The most closely related taxa, with characteristic triangular valve outlines, are *C. terrafuegiana* and *C. cistula* var. *guarrerae*. Similarities and differences between these two taxa and *C. gravida*, according to their protologues and the results of our observations on the original material from Lago Yehuin, are summarized in Table 1. *Cymbella cistula* var. *guarrerae* and *C. terrafuegiana* were



Figs 21–29. Type material (sample LPC 2995) of *Cymbella terrafuegiana* from Lago Yehuin, Tierra del Fuego, Argentina, LM (Figs 21–25), SEM external (Figs 26, 28) and internal (Figs 27, 29) views. Figs 21–25. Valves showing variability in size range. Figs 26–27. Whole valves. Fig. 28. Part of the valve showing striae formed by slit-like areolae. Fig. 29. Valve center showing areolae and stigmata (arrow). Scale bars = 10 μm (Figs 21–27); 5 μm (Figs 28–29).

both described and so far encountered only in Tierra del Fuego, Argentina, which is located close to our study area in southern Patagonia. *Cymbella cistula* var. *guarrerae* was described for Lago Yehuin (Ferrario et al. 1982) and reported only twice from Tierra del Fuego (Mariazzi et al. 1987, Martinez Macchiavello & Salas Aramburu 1991). According to Krammer(2002), *C. terrafuegiana* was found in a river close to Lago Yehuin, and so far this species has only been cited from its type locality. Even though the description of the type localities is slightly different between these two taxa, they were both described from the same sample 2995 from Lago Yehuin. Nevertheless, Krammer (2002) did not mention the first one and their features have never been compared. After revising the original material using LM and SEM, only one taxon was observed; hence it is concluded that the differences between the two descriptions (see Table 1) are subtle enough to be interpreted as intrapopulation variations. Therefore, it is proposed that *C. terrafueguiana* and *C. cistula* var. *guarrerae* should be considered as the same species. The observed specimens in this type material (Figs 21–29) present a dorsal central area reduced to one or two slightly shorter striae. Consequently, the taxon described by Ferrario et al. (1982) cannot be attributed to the *C. cistula* group. Based on the remaining valve characteristics, this taxon should be considered as part of the *C. cymbiformis* group. As a result of this, it is proposed that *C. terrafueguiana* is the valid species name and *C. cistula* var. *guarrerae* should be considered as a synonym. Based on the descriptions of both taxa and our observations of the original material, *C. terrafuagiana* has the following valve morphometrics: 56.7–95.0 μm in length and 15.9–25.0 μm in width, with 8–11 striae in 10 μm and 18–25 areolae in 10 μm.

In comparison with *C. terrafuagiana*, *C. gravida* is considerably smaller, has a stronger triangular shape, a more angular dorsal side and a distinctive tumid ventral side. The valve apices are obtusely rounded to subrostrate in *C. gravida*, whereas they are acutely rounded in *C. terrafueguiana*. Further high-resolution studies of the PASADO sediment cores being carried out will help to better define the paleolimnology of this lake and help constrain the ecology of the different diatom assemblages, including *C. gravida* preferences.

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