

Diatoms from the Terrebonne Diatomite On a Type Slide by Raymond Hummelink



Looking northwest at the collection site in this Pleistocene lakebottom sediment.

Introduction

This collection report illustrates a selection of microscopic fossils that Raymond Hummelink mounted onto a type slide. These fossils were found in light-colored sedimentary rocks, shown above, in central Oregon (US) west of the town of Terrebonne. They are the remains of diatoms that lived in a freshwater lake during the Pleistocene epoch. The lake existed long enough for many meters of diatom shells to accumulate on its bottom, forming diatomite. An estimate for the age of this collection suggests eighteen thousand years before the present [1].

A Few Terms Used in This Report

alveoli - elongated chambers forming part or all of a stria. The genus *Pinnularia* has striae formed by alveoli. The outer surface of an alveolus is perforated by several rows of areolae which are usually not visible in the light microscope.

diatomite - a siliceous sedimentary rock composed mainly of the fossilized skeletal remains of diatoms. Refer to <https://earthresources.vic.gov.au/geology-exploration/minerals/industrial-minerals/diatomite>.

fossil - evidence of life preserved in a geological context. From <http://npshistory.com/publications/paleontology/fossil-definition.pdf>.

girdle view - the side view of the diatom shell.

striae - the lines of pores on the valve of a diatom.

type slide - microscope slide with a set of objects arranged and mounted for study under a microscope.

valve - one of the two ends of a diatom shell.

valve view - the view of the valve face.

Diatomite (diatomaceous earth) is a very friable rock of low density and light weight with a fine-grained, chalky texture. It is composed largely of the shells of diatoms that have settled to the bottom of fresh or marine waters. Highly pure diatomite, such as the deposit at Terrebonne, is bright white in color and contains low amounts of clay, ash, and other minerals. The Terrebonne

diatomite is one of the most notable non-marine diatom deposits in the United States and perhaps the world (VanLandingham 1990).

Diatoms are microscopic unicellular algae that make shells of transparent opal which is very similar to glass (Spaulding et al. 2021). The shell consists of two valves that overlap like parts of a petri dish. The surface features of the valves are used to identify diatoms. These organisms have been placed in the taxonomic group, Bacillariophyta (Round et al. 1990).

Materials and Methods

VanLandingham (1990) separates the Terrebonne diatomite into a Pliocene section toward the east and a Pleistocene section toward the west. A sample about 5 cm on a side was collected on 16 October 2010 by Rob Kimmich (Salem, Oregon, US) from the road cut in the Pleistocene section of the diatomite (lat 44.3622, lon - 121.2879, elevation about 765 meters) on Lower Bridge Rd east of the Deschutes River crossing. He sent a portion to Raymond Hummelink (Neede, The Netherlands) who cleaned it and mounted twenty-one valves in May 2011 to make the type slide shown in Figure D. Richard Carter (Phoenix, Arizona, US) used the extensive reference materials at Arizona State University to provide most of the identifications. Rob provided the text and images.

The images were produced with a Canon T1i digital camera attached to a Nikon LaboPhot2. Image processing was done with Windows Explorer to apply tags, imageJ for measuring, and PhotoScape X for enhancing and adding scale bars.

The text and figures were prepared in Microsoft Word Office365 and exported to PDF with settings of "Create bookmarks using Headings", "PDF/A compliant", and "Optimize for image quality". The first edition was completed in February 2013. This second edition was completed on 26 May 2023.

Illustrations

Fig A Collection taken at point of hammer. Basalt layer caps the diatomite at the top of the slope.

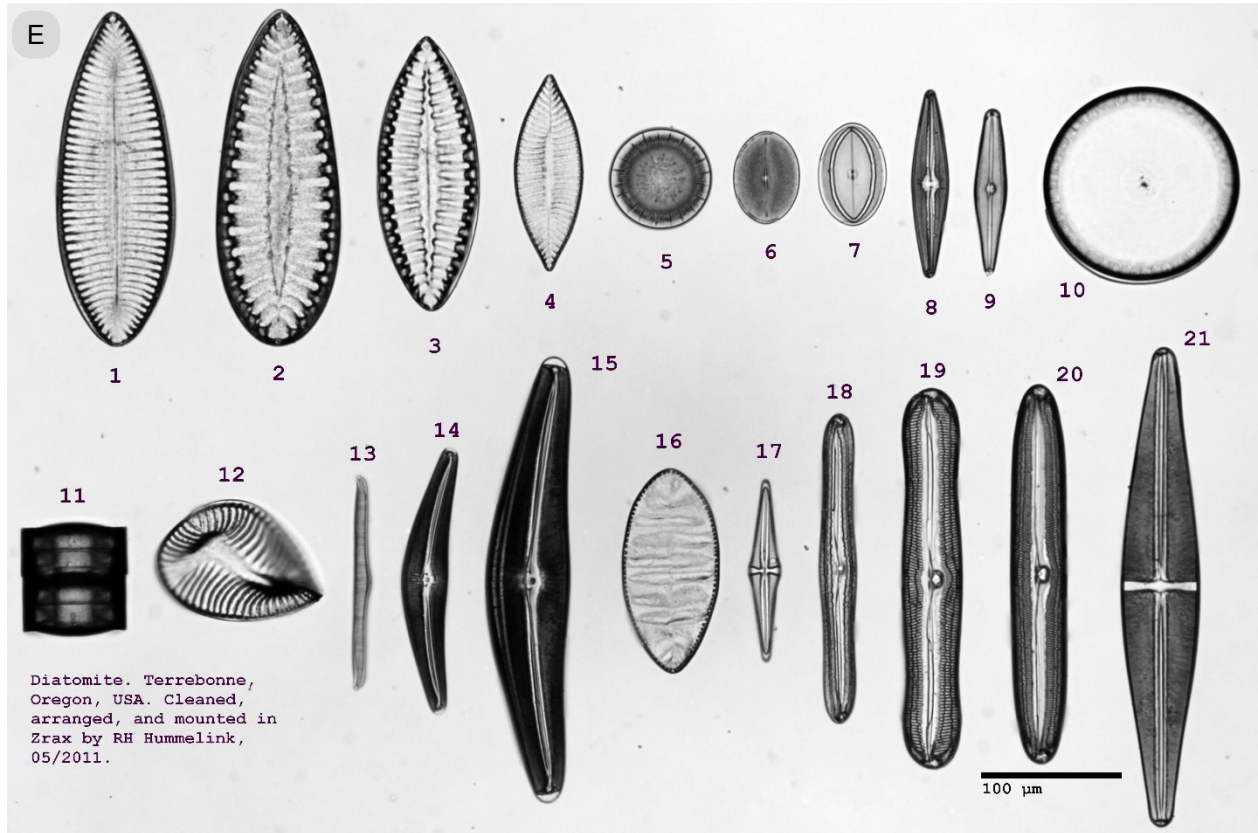
Fig B Wet mount of raw diatomite before cleaning. High purity is demonstrated by the small amount of clay and other mineral content.

Fig C Lab of Raymond Hummelink in Neede, The Netherlands, where he made the type slide.

Fig D Type slide.

Fig E This is the arrangement of the valves inside the small inner circle on the type slide. Index numbers, scale bar, and text were later added to the image.

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The following figures illustrate the diatom fossils on the type slide. Scale bars = 10 μm . Figure numbers correspond to index numbers in Figure E. More image detail can be seen by expanding the view.

The nomenclature for the surirelloid diatoms in Figures 2 to 4 has been revised based on molecular and morphological data (Ruck et al. 2016).

Fig 1 *Surirella elegans* Ehrenberg. L = 238, W = 77 μm .

One of the main traits that Jahn et al. (2017) uses to distinguish *Iconella* in LM is an apically running wavy line, named a looping line (Schleifenbildung), where the canals of the wings (alar canals) meet the valve face. *Iconella* has looping lines while *Surirella* does not. This specimen does not appear to have looping lines so it is identified here as *Surirella*.

Krammer and Lange-Bertalot (2000) puts this in the Robustae while saying that the alar projections (wings) are not as clear as other species in the group. Sims (ed.) (1996) includes a cross section diagram that suggests slight alar projections, but the drawings do not appear to have the looping lines such as those in *Surirella robusta* (pl 278 fig 2).

Refer to Carter 2011a for identification as *Surirella*; Sims (ed.) (1996) pl 270 figs 2-4; Krammer and Lange-Bertalot (2000) pg 187, lead 16b.

Fig 2 *Iconella robusta* (previously *Surirella robusta* Ehrenberg). L = 239, W = 87 μm , porcae = 6.6 in 100 μm . Looping lines visible. Refer to Carter 2011a; Sims (1996) pl 278 figs 2-4.

Fig 3 *Iconella* sp. (previously *Surirella* sp.) Specimen L = 195, W = 72, Porcae = 10 in 100 μm . Looping lines visible.

Carter 2011a: "With one illustration of *S. oregonica*, and no description, I can't say that this specimen represents that species. The one illustration shows a diatom with a much lower aspect ratio than the 2.7 which this specimen exhibits. The combination of isopolar outline and morphometrics seems to match nothing in Krammer and Lange-Bertalot. Not being very knowledgeable about this genus, I am stumped again. All I can suggest is that it probably does not occur in Europe, and that we need to look at American species."

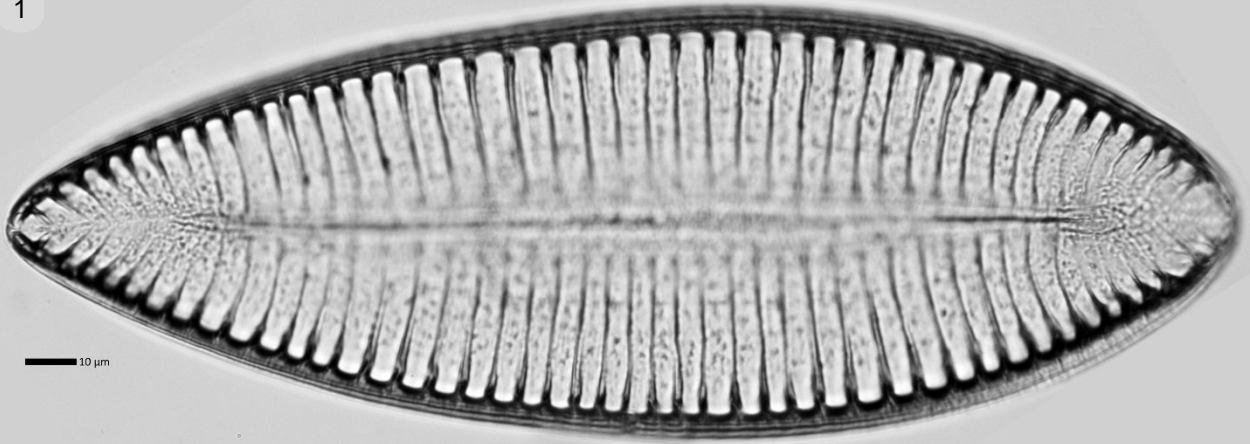
Fig 4 *Iconella biseriata* (previously *Surirella biseriata* Brébisson). L = 139, W = 49, Porcae = 16 in 100 μm . Looping lines visible.

Carter 2011a: "Lacks the spine bases of *S. bifrons* and at 2.8 the aspect ratio is too high. On the comparison slide by Klaus Kemp, the nine specimens of *S. bifrons* had a range of 1.7-2.2 while the six specimens of *S. biseriata* had a range of 2.5-3.3."

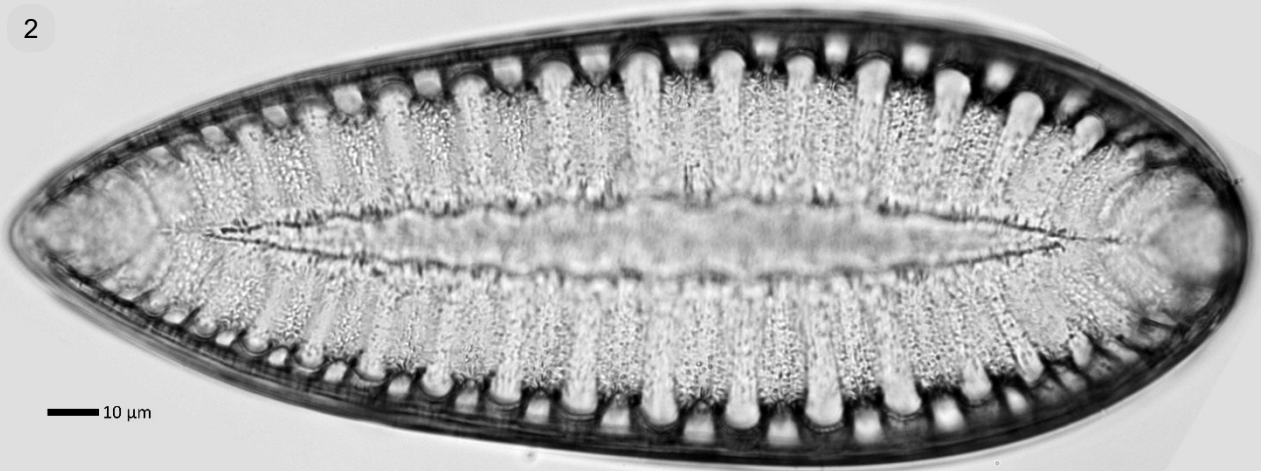
S. biseriata in Sims (1996) pl 267 fig 1 (middle image) matches well.

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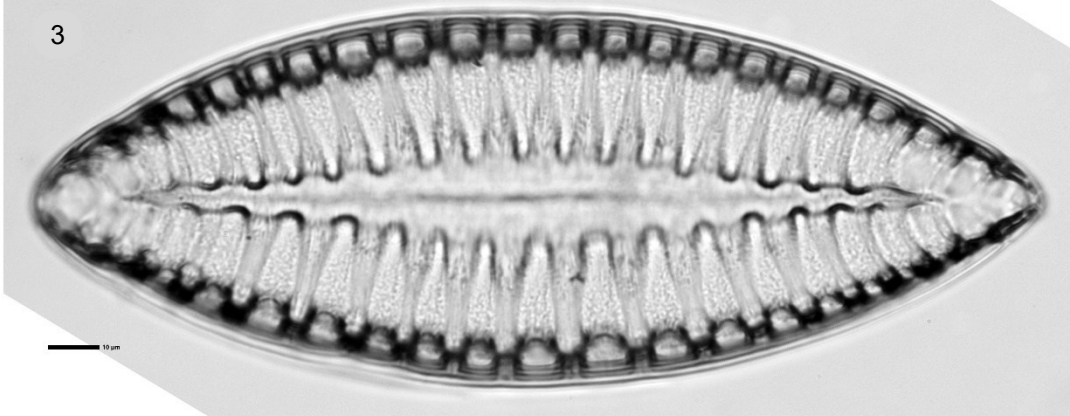
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Fig 5 *Stephanodiscus niagarae*. Internal view; (top) up focus on outline, spines, and perimeter striae; (bottom) down focus on central striae. Refer to Yu (2011).

Fig 6 *Cocconeis grovei*. Rapheless valve, internal view; (left) up focus on outline, (right) down focus on valve center.

VanLandingham says in text-figure 3 that *C. grovei* is extinct. Evidence from Bahls suggests that *C. grovei* is still extant. Bahls (2020) agrees that this is *C. grovei* by the wide band of marginal striae which is very unlike *C. placentula*. Bahls has many extant examples from the Pacific Northwest of valves very like this specimen and concludes that *C. grovei* is still extant. This report follows Bahls and assumes that *C. grovei* still lives in waters of the Pacific Northwest.

Refer to VanLandingham (1990) text-figure 3 and pl 1 fig 13-14; Kimmich and Bahls (2020); Bahls (2020 Apr 07 email).

Fig 7 *Cocconeis grovei*, external view of a raphe valve. Refer to VanLandingham (1990) text-figure 3 and pl 1 fig 13-14; Kimmich and Bahls (2020); Bahls (2020 Apr 07 email).

Fig 8 *Navicula walkeri*. Defined as *Navicula* by the lineolate areolae and as *N. walkeri* by the shadow line and hooked proximal raphe ends. This diatom is still living and is endemic to northwest North America. Refer to Bahls (2011a).

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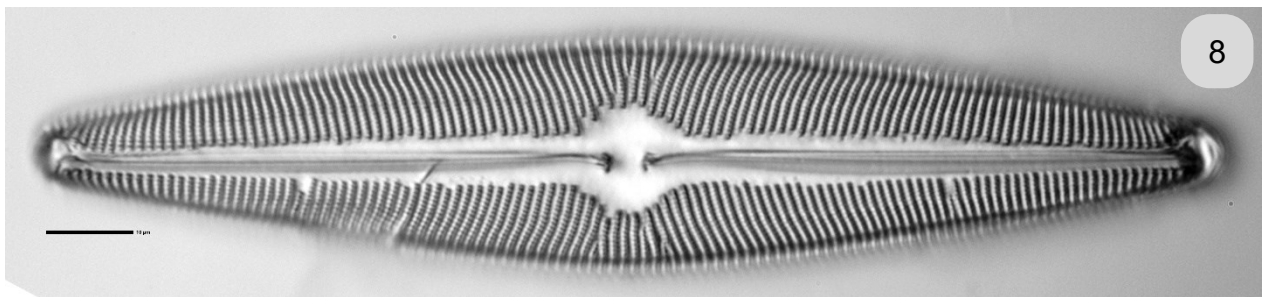
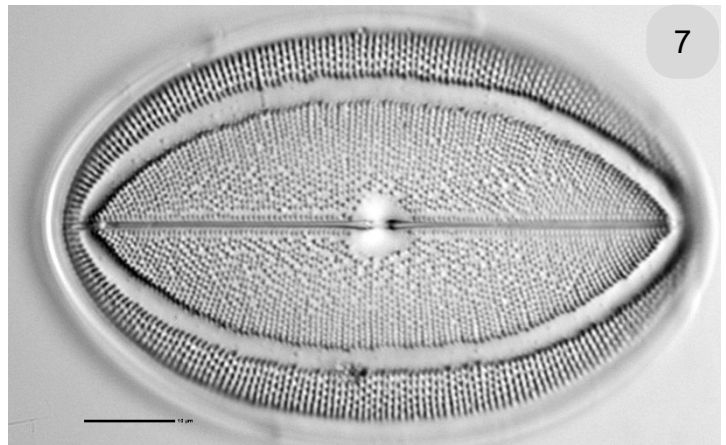
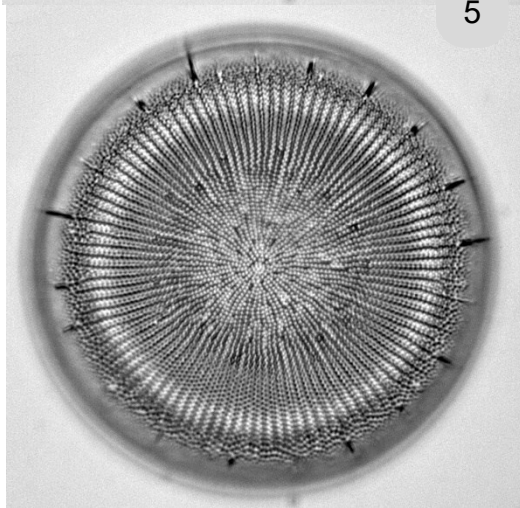
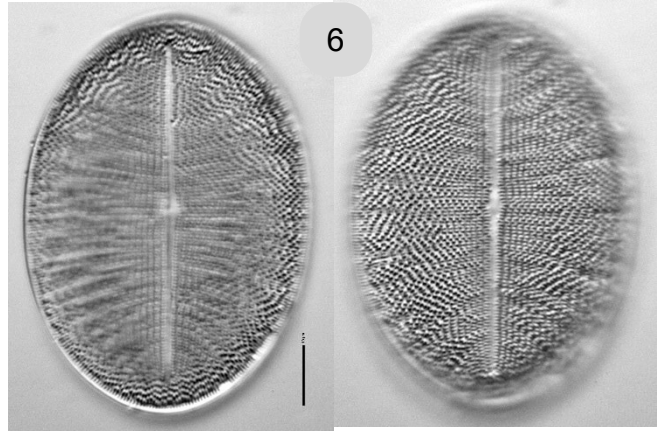
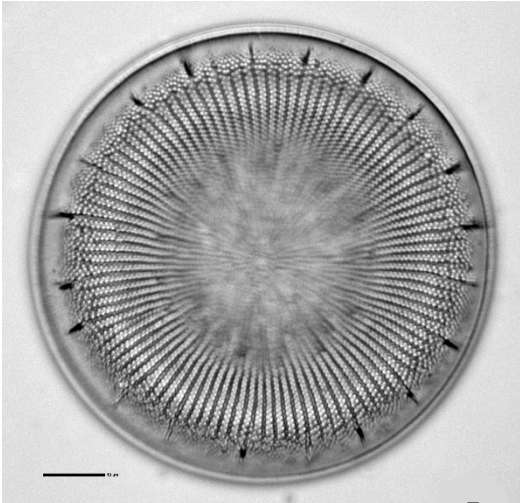


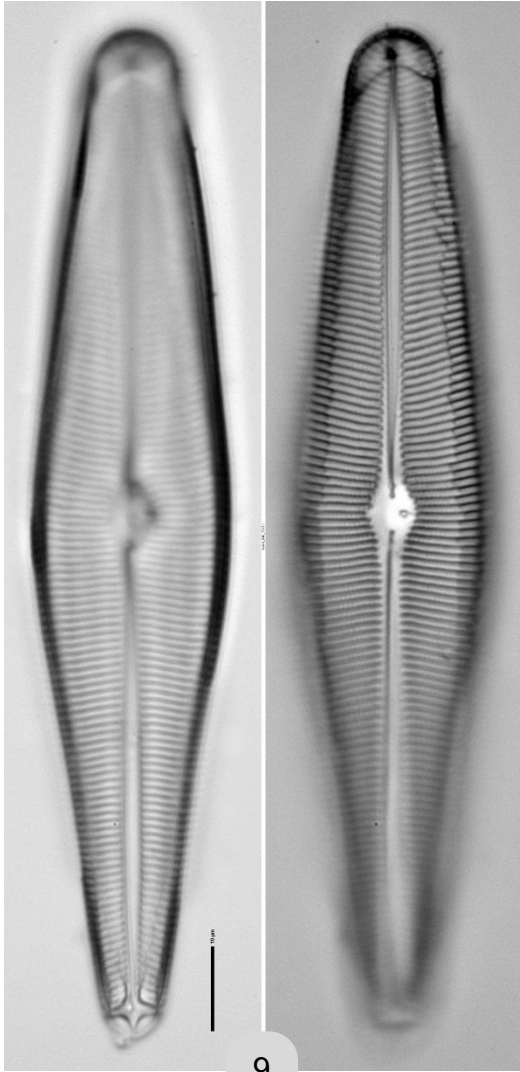
Fig 9 *Gomphoneis* sp. (left) focus on footpole with pore field, (right) focus on center and headpole with pseudoseptum.

Refer to Spaulding and Edlund (2009); Carter (2011d): "Unable to resolve to species. I don't think it's the common *G. herculeana*, as the valve outline looks rather different. In that species the outline resembles that of *Gomphonema truncatum*, with a much broader head pole. *G. mammilla* occurs at Klamath Falls (as well as modern sites in Oregon), but in that species the head pole is acute. Western North America is characterized by extensive speciation in this genus, and I unfortunately have no further literature/illustrations. Your specimen does not seem to match any of the illustrations on the ANSP website."

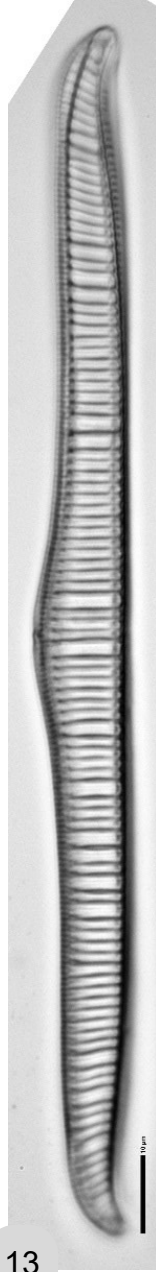
Fig 12 *Campylodiscus hibernicus*. This is a focus stack of several images. Carter (2011b): "I can't make your *Campylodiscus* series look like a *Surirella*. It is certainly a malformed specimen, with no saddle-shape to speak of, but it still has the other characters of *C. hibernicus*." Refer also to Sims (1996), plate 48 fig 6.

Fig 13 *Rhopalodia gibba*. L = 151 μm , W = 12 μm . Refer to Kociolek (2011a).

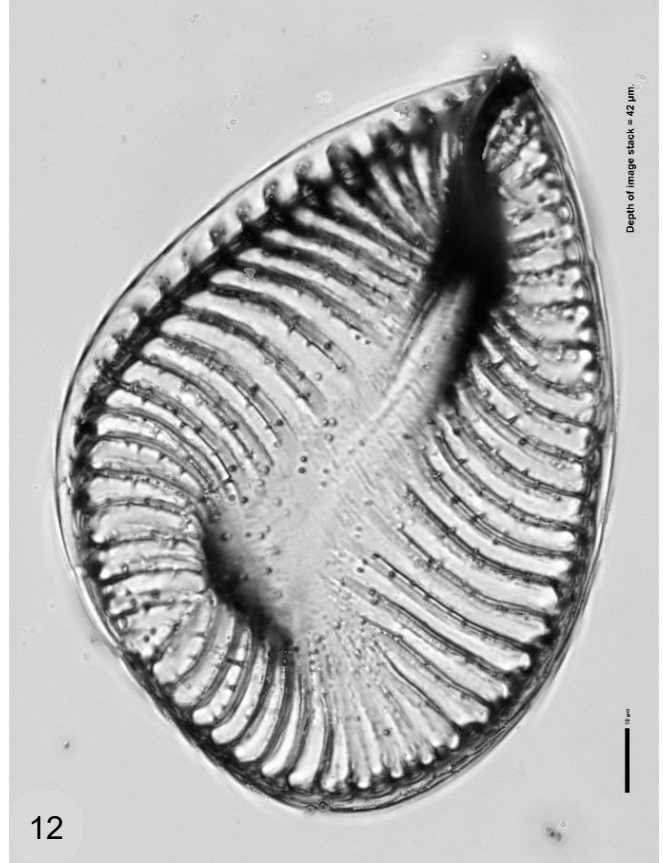
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Figures 10 and 11 show species of *Ellerbeckia*, distinguished by the stepped cameo valves and the crosshatch pattern of the striae on the copulae. *Ellerbeckia baileyi* (Crawford & Sims 2007) and *Ellerbeckia arenaria* (Bahls 2012) both seem to be possible names. The two species share many characters, only separated by the differing radial markings on the faces of the linking valves (Crawford & Sims 2007).

Since the only valve view on the type slide appears to be a separation valve (Fig 10), the important view of the faces of linking valves were not available so no species epithet was assigned.

Fig 10 *Ellerbeckia* sp. Valve view of possibly a separation valve.

Fig 11 *Ellerbeckia* sp. Girdle view of two frustules. (left) Down focus on outline. (right) Up focus on the mantle. **(a)** arrowhead at step on cameo valve in both images, **(b)** arrowhead at ridges of the intaglio valve that would interlock with the next sibling valve in the chain, **(c)** arrowhead on crenulate junction between valvocopula and valve, **(d)** copulae showing the crosshatching pattern of areolae.

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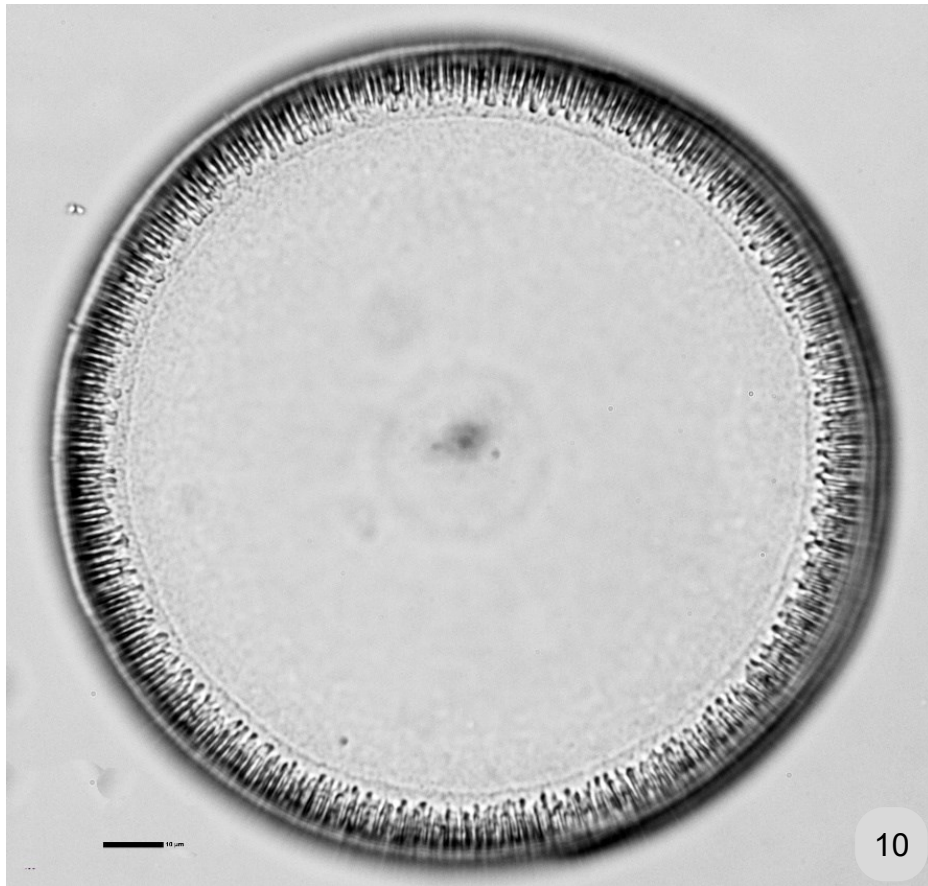
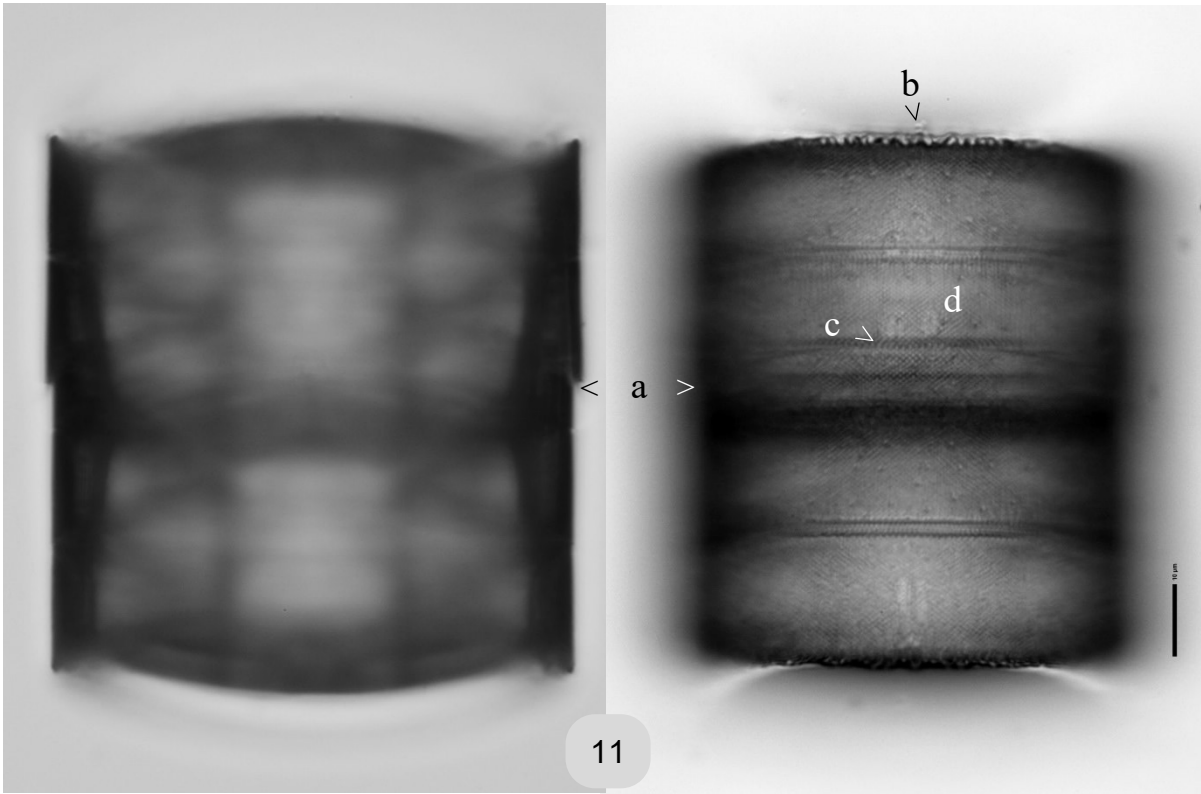


Fig 14 *Cymbella mexicana* (left) whole valve. (right) top and bottom focus on terminal fissures, middle focus on central area. L = 191 μm , W = 32 μm , Striae = 6 in 10 μm . This specimen seems to have different stria features from images on Diatoms of North America. Refer to Johnson (2011).

Fig 15 *Cymbella janischii* (left) whole valve. (right) top and bottom focus on terminal fissure, middle focus on central area. Refer to Kociolek (2011b).

Fig 16 *Cymatopleura cochlea*. Opposite quadrants of the valve twist putting the outline out of focus at those points. The nomenclature was chosen after discussion on groups.io diatom-forum between Dick Carter (message 1244) and Klaus Kemp (message 1237). Valve has symmetrical torsion of both ends of the valve. Refer to Schmidt (1874-1959).

Fig 17 *Stauroneis acuta*. Internal view, (left) up focus on valve outline, (right) down focus on central area of the valve face. Refer to Bahls (2011b).

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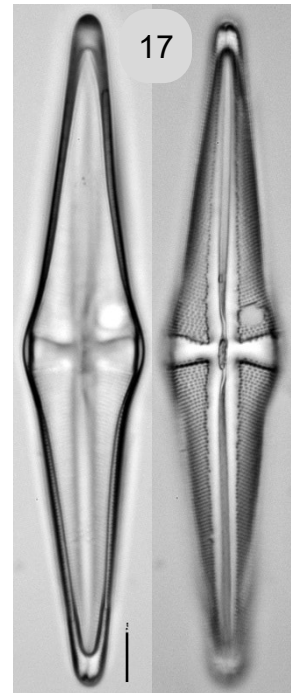
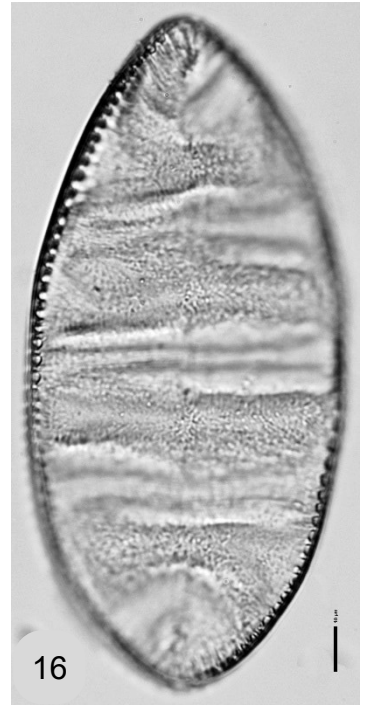
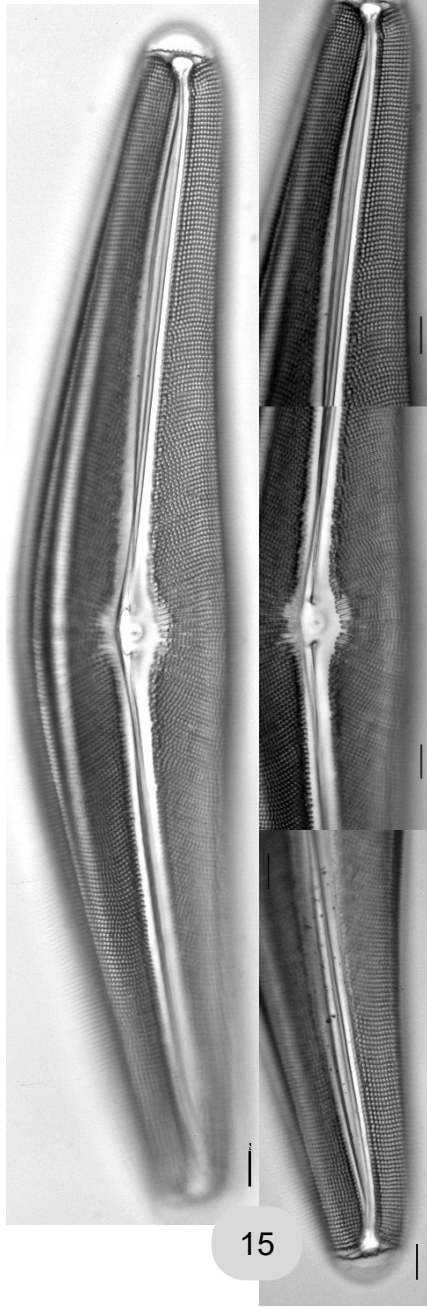
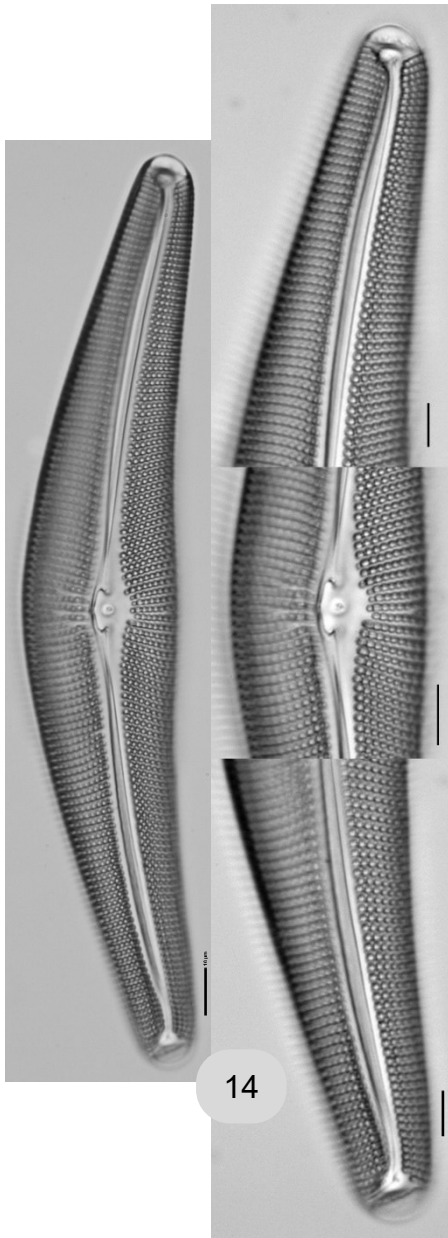
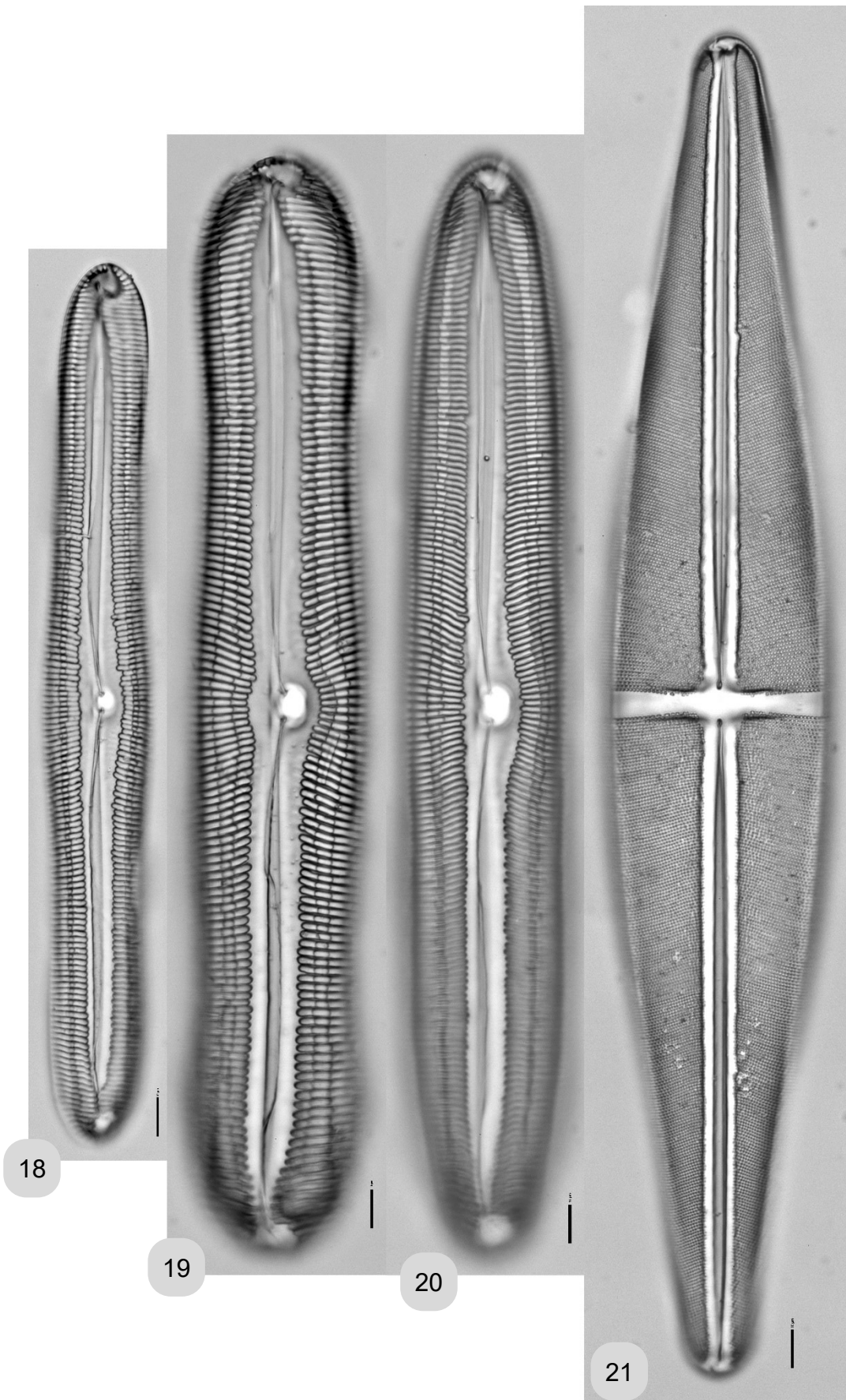


Fig 18 *Pinnularia neomajor* var. *inflata* Krammer. L = 222, W = 27, Alveolae = 7.6 in 10 μ m. Carter (2011c): "A good fit with Krammer's description and photos, and Krammer says it is the commonest variety."

Fig 19 *Pinnularia nobilis* var. *regularis* Krammer. L = 271, W = 44, Alveolae = 4.8 in 10 μ m. Carter (2011c): "The central area is more distinct than in the nominate variety, and the swelling of the ends and (especially) the center is not so great."

Fig 20 *Pinnularia mesogongyla* Ehrenberg. L = 249, W = 40, Alveolae = 5.9 in 10 μ m. Carter (2011c): "Not entirely happy with this ID, but it seems to fit better than anything else in Krammer. It's slightly too wide, and the sides show a bit less taper toward the ends."

Fig 21 *Stauroneis rex*. L = 340, W = 57, Striae = 11.5 in 10 μ m. Refer to Bahls (2011c).



Conclusion

VanLandingham (1990, pg 193) considered *Cocconeis grovei* (Figs 12 and 13) to be extinct but Kimmich and Bahls (2020) have shown that it is probably extant. Other species on the type slide have the same morphology as diatoms alive today in freshwater lakes and ponds in Oregon, suggesting that many species have persisted in this area for a long time.

The whole process of collecting and collaborating with Raymond and Richard on this type slide of fossil diatoms provided many hours of interesting work.

Acknowledgements

Mady Kimmich joined me on the trip to the Terrebonne Diatomite and took the photograph in Figure A. She also commented on an early draft.

Notes

[1] The estimate of eighteen thousand years before present for the age of this collection was derived as follows. These sediments accumulated during the Pleistocene epoch which extended from 2 million years ago to 10,000 years ago (Miller 2014, VanLandingham 1990). The lake at Terrebonne formed about 1.2 million years ago when a lava flow dammed part of a drainage in this part of Oregon (Smith et al. 1987 pg 1083). Possibly this was lava that flowed down the Crooked River and backed up into the Deschutes River forming an intracanyon basalt (Miller 2014 pg 239).

The lava at the top of the beds, shown in the title picture and Fig A, formed before Mt Mazama exploded 7,700 years ago. (Miller 2014 pg 246, pre-Mazama basaltic flow). Since the diatomite formed during the Pleistocene the lava would have had to bury the sediments about 10,000 years ago.

This age estimate uses two assumptions: **(1)** The top of the diatomite bed was covered by lava about 10,000 years ago. **(2)** Sediment accumulated at a half millimeter per year. This rate is based on the rate found in one paper about ocean bottom accumulation of diatoms in the north Pacific Ocean which was much less than one half millimeter per year.

The collection was about 4 meters below the top of the beds. This means that the sample was taken at about 8,000 years below the top of the diatomite deposit (4000 mm at 0.5 mm per year). Adding 10,000 years for the age of the top of the diatomite (when it was covered by lava) yields a minimum age of the collection of 18,000 years before the present.

This age may be thousands of years earlier or later. According to one geologist, in contrast to remote oceanic basins, terrestrial deposits are notoriously difficult to date accurately. Terrestrial basins are potentially subject to numerous local influences. For example, deposition may cease altogether for some unrecognized period of time, a local erosional event may remove part of the deposit, or some of the deposit may have slumped on top of an adjacent section.

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Comments and questions welcome.

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