Diatoms in Mummies from Qilakitsoq

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Eight mummified Greenlanders were found in 1972. Samples of lung and columna tissue from some of them were investigated for content of diatoms in an attempt, on the basis of diatoms, to state whether they died by drowning. Samples of lung, liver, kidney, columna and femur tissue from four drowned and four non-drowned persons from the year 1981–82 were likewise analysed for diatoms, to permit a comparison between the two groups, and thus by means of diatoms to obtain a basis for the diagnosis: drowned – not drowned. The conclusion of the investigation is that no such diagnosis is possible with the method used here.

Niels Foged, deceased 1988.

Diatoms (kiesel algæ) are single-celled autotrophic plants, that is to say they can use solar energy to form organic products from inorganic matter. They most commonly occur in water (salt, brackish or fresh water), but are also found on land and in the air (troposphere) where they are transported by the wind. The valves can occur as fossils in large geological deposits that are important for many industrial processes.

Living diatoms play an important role in the synthesis of organic material in the sea and freshwater and thus provide food for many kinds of animals (crustaceans, molluscs, worms and many others). Hence they can go further along the food chain and end in the human body, coming either from meat or from the surface of vegetables. Countless diatom cells and valves will also be absorbed into the lungs, as they are found in the air we breathe. They can thus be absorbed by the epithelium of the lungs and can then be circulated via the blood to all the other organs of the body.

The valves are silicon compounds, and practically insoluble in non-alkaline fluids. They will therefore later be discoverable in the organs where they have been deposited. Since diatoms, as has been mentioned, are autotrophic, and thus dependent on light, they cannot live inside the human body.

Revensdorf (1904) used diatoms in the diagnosis of drowning, in as much as he interpreted the presence of vegetable plankton – and in particular diatoms – in the lungs as evidence of drowning. Many investigators have shared this view, and their opinions have had evidential value for forensic verdicts.

Not until 1962 were doubts raised, when Spitz (1963/1964) found diatoms in liver tissue from the body of someone who had not been drowned. Since then opinions have been strongly divided, some research workers still supporting Revensdorf's view, others denying that the presence of diatoms in human organs can have any significance for a diagnosis of drowning.

Geissler and Gerloff (1966), have pronounced on this question. They are biologists and diatomologists, and after studying the bodies of nine people who had been drowned and thirteen who had died from other causes in Berlin, they concluded that diatom analysis cannot provide an adequate diagnosis for forensic use.

As the cause of death of the Greenlanders whose mummified bodies were found in 1972, has not been clarified in most of the cases an attempt is made here to use diatom analysis to find support for Jens Rosing's theory (1979), which assumes that they all died at the same time, drowned at sea near where their bodies were found 500 years later.

For this purpose three samples presumed to be lung tissue were taken from mummies I/2, I/5 and II/8, along with samples of thoracic vertebrae from I/2, I/3, I/4, I/5, II/6, II/7 and II/8. After chemical treatment each sample provided 2–4 microscope slides with circular cover slips (16mm diameter) and in a mounting medium of Hyrax (refractive index ca. 1.65). Diatoms were sought in each slide with a 100× immersion objective and a 10× eyepiece. All valves, whole or fragments were noted. Most of the species found were photographed, and prints with a magnification of 1500× were provided (plated I, II and III).

It must be stressed here that such an analysis can only give a quite erratic and very incomplete indication both of the number and character of the diatoms that are to be found in the subjects examined. Thus it has been necessary to limit the study to few organs and few samples of each. It has only been possible to obtain samples of presumed lung tissue from three of the bodies and vertebral tissue from seven of the eight bodies found. Normally an investigation should cover tissue

Table 1

	I/2		I/3		I/4		I/5		II/6		II/7		II/8	
	taxa	valves	taxa	valves	taxa	valves	taxa	valves	taxa	valves	taxa	valves	taxa	valves
oligohalobe	47	437	8	27	10	18	68	200	27	98	18	84	19	24
unidentified (to genus only)	12		1		4		20		2		3		3	
fragments		18		4		2		52		8		10		15
meso+polyhal.	4	4	6	87	1	1	12	14			1	7	6	15
unindentified (to genus only)	1		2				1						2	
fragments								1						8
Total	51	441	14	114	11	19	80	214	27	98	19	91	25	39
unidentified (to genus only)	13		3		4		21		2		3		5	
fragments		18		4		2		53		8		10		23

Total number for all 7 persons: 126 oligohalobe taxa of which 34 are identified to genus only: 888 valves × 109 fragments. 22 meso- or polyhalobe taxa of which 6 are identified to genus only: 128 valves + 9 fragments.
Together 148 taxa of which 40 are identified to genus only: 1016 valves + 118 fragments.
The figures under taxa indicate the number of identified taxa (taxon means species, or variety, or forma).
Also shown are how many species it has not been possible to identity more precisely than as to genus.
The figures under valves includes all valves found, also when they only are identified as to genus.

from lungs, kidney, liver, thoracic vertebrae and femoral medulla. The diatomaceous valves in these organs will be randomly distributed. When taking samples it is impossible to see if they contain many or few valves or even none at all. The representation of different species must be assumed to vary from one place to another within the body, and we must also assume that the total number of diatomaceous remains grows with age – not regularly, but irreversibly, and varying with environmental factors.

As there are always many airborne diatom valves (Foged 1975) it must be assumed that they are constantly being inhaled. Therefore the valves can initially lodge in lung tissues and enter the bloodstream, whence they can circulate to all parts of the body and can be deposited in all organs.

The number of diatoms that can be absorbed into the body during the process of drowning will be quite small, and as a rule can hardly be distinguished with any certainty from those already present. The greatest chance will be in the lung tissue (possibly also in the alimentary tract). When a body has been immersed in water for some time after drowning it is possible that water containing diatoms could contaminate the body after the time of death, primarily the lungs.

The valve material here appeared, in the main, to be well-preserved whole cells (two conjoined valves), two or more of which sometimes formed colonies (especially small *Fragilaria*-species), besides single valves or valve fragments. Occasionally single valves or valve fragments were more or less damaged (dissolved), which is often the case with airborne valves. Fresh water forms (the oligohalobe) are much more common than the salt water varieties (mesohalobe and polyhalobe). The former are usually more or less elongated, while most of the marine types are disc-shaped.

Table 1 shows how many species and how many valves of freshwater and salt water diatoms were found in each of the seven subjects investigated. Also shown are the number of examples where it has been possible to determine the genus but not the species, and the number of valve fragments observed.

For subject I/3 the salt water species, (mesohalobe and polyhalobe), form the majority (87) of all identified valves (114). For subject II/8 the salt water species constitute a major proportion of both species identified and of the number of valves (respectively 6 out of 25 and 15 out of 39). There are the greatest number of salt water species – 12 – although with only 14 valves, in the species found in subject I/5, with a total of 80 species and 214 valves, so that the proportion of salt water specimens is no higher in this subject than in the others. The proportion of salt to fresh water species does not differ much from the proportion between the two groups found in airborne diatoms as shown, for example, in Foged (1975).

The theory that all seven subjects investigated had died at the same time and in the same coastal water cannot be supported by the current study. There is no greater similarity in the population af diatoms found in the subjects than found in other groups of deceased persons – both drowned and non-drowned – at other times and locations (see Table 2).

A review of the species found reveals that only one, the freshwater variety *Synedra ulna,* was found in six of the subjects, always with only few examples, often only

Table 2

		Not drowned								Drowned							
		L 64/1981		L 65/1981		L 75/1981		L 76/1981		L 79/1981		L 89/1981		L 102/1981		L 51/1982	
	sex – age	male – 53		male – 67		female – 57		male – 67		male – 41		female – 39		male – 25		male – 35	
	occupation	engineer		labourer		–		labourer		radiotech.		teacher		yachtsm.		diver (hobby)	
	cause of death	heart dis.		pneum.		cancer		suicide		drowned		drowned		drowned		drowned	
	locality	–		–		–		–		Ll. Belt		Odense fj.		Gr. Belt		Ll. Belt	
		tax.	valv.	tax.	valv.	tax.	valv.	tax.	valv.	tax.	valv.	tax.	valv.	tax.	valv.	tax.	valv.
Lung	Oligohalobe	20	71	41	192	5	6	4	8	5	13	57	216	–	5	11	26
	meso+polyh.	1	1	2	2	–	–	–	–	–	–	4	5	–	1	1	8
Liver	Oligohalobe	13	52	8	18	5	7	4	8	8	21	27	67	3	5	no sample	
	meso+polyh.	1	2	–	–	–	–	–	–	–	–	1	1	–	–		
Kidney	oligohalobe	23	51	21	37	4	7	7	26	2	19	33	124	3	8	13	31
	meso+polyh.	1	2	1	–	–	–	–	–	–	–	3	3	1	1	–	–
Columna	oligohalobe	12	15	8	8	5	7	2	13	33	200	37	118	1	2	5	11
	meso+polyh.	–	–	–	–	2	3	–	–	–	–	2	2	1	2	–	–
Femur	oligohalobe	no sample		no sample		4	17	8	15	2	5	27	79	15	230	1	1
	meso+polyh.					–	–	–	–	–	–	2	2	–	–	–	–
Total	oligohalobe	49	189	67	255	18	44	21	70	42	258	82	604	20	250	22	69
	meso+polyh.	3	5	3	2	2	3	–	–	–	–	10	13	2	4	2	2
Fragments		34		40		10		14		15		117		8		8	

Table 3. Diatom analysis of organs of 4 deaths from natural causes and 3 cases of drowning:

		lungs	liver	kidneys	columna	femur	total	polyhalobes and mesohalobes	No. of samples
L 64	taxa	22	14	23	12	–	52	3	7
	valves	72	54	53	15	–	194	5	
L 65	taxa	43	8	22	8	–	67	3	7
	valves	197	18	37	8	–	257	4	
L 75	taxa	5	5	4	4	7	20	1	5
	valves	6	7	7	17	10	47	1	
L 76	taxa	4	4	7	2	8	21	–	5
	valves	8	8	26	13	15	70	–	
L 79	taxa	5	8	2	33	2	42	–	5
	valves	13	21	19	200	5	258	–	
L 89	taxa	60	28	35	39	28	92	5	9
	valves	221	68	127	120	81	617	7	
L 102	taxa	1	3	4	2	15	22	–	5
	valves	6	5	9	4	230	254	–	

These analyses do not show significant differences between the diatom content of those who had drowned and those hwo had died from other causes.

fragments. The valves of this species can be very long (here up to 250μm). The freshwater type *Cocconeis placentula* with its variant *euglypta* occurs in five subjects; the brackish water species *Archnanthes brevipes* varian *intermedia* and the fresh water *Achnantes minutissima* and *Cocconeis placentula* in four, the salt water species *Grammatophora marina* in three, while seventeen fresh water species and the two brackish water varieties *Cocconeis scutellum* variant *parva* and *Thalassiosira* sp. were each found in two subjects. The other species occur in one subject only.

Given that all the subjects were coastal dwellers, and presumably derived most of their food from the sea, it is remarkable that more marine diatoms were not found in them, as all animal food must be assumed to contain diatom valves.

In connection with this investigation, and in order to extend my personal basis for solving the present problem, I carried out a parallel study. In this I studied the meat of mammals (pigs, cows and horses) and of fish (cod, plaice, herring, i.e. both predatory fish and plankton eaters), as well as human blood. All these samples revealed diatoms.

Finally, in 1981–82, through the good offices of Professor dr. med. Jørn Simonsen, I obtained from the Institute of Forensic Medicine at Odense University tissue samples from four victims of drowning and from four others who died from other causes. Table 2 shows the results of this study, which involved tissue samples from lungs, liver, kidneys, thoracic vertebræ and femoral medulla from each subject.

As a comparison of Tables 1 and 2 will show, there is no signigicant difference in the populations of diatoms found in the seven Greenland subjects and those found in the eight Danish subjects who lived 500 years later.

Conclusion

The diatom content of tissue samples from drowned subjects and of those from subjects who had died from other causes do not differ sufficiently to provide a reliable opinion on drowning as the cause of death. Thus, diatoms found in the tissue samples from the Greenland mummies cannot enlighten us as to the cause of their deaths.

Appendix

In order to be able to evaluate the diatom content of samples of human tissue from personal experience, in the summer of 1981 I approached Professor dr. med. Jørn Simonsen, of the University Institute of Forensic Medicine at Odense. From the Institute I obtained samples of lung, liver, and kidney tissue and vertebral and femoral medulla from eight people, four of whom had died from drowning, the remaining four from other causes.

Results of the analysis of tissue samples received from

the five organs from the seven subjects so far studied can be summarized as follows:
No. 64/1981 (53-year-old man): 194 whole valves (+34 fragments); in all 52 taxa.
No. 65/1981 (67-year-old man): 257 whole valves (+ a large number of *Fragilaria* valves in girdle view and 140 fragments), in all 67 taxa.
No. 75/1981 (57-year-old woman): 47 whole valves (+ 10 fragments); in all 20 taxa.
No. 76/1981 (67-year-old man): 70 whole valves (+ 14 fragments); in all 21 taxa.

These four subjects all died from other causes than drowning (viz. sudden heart disease, lung infection, suddenly after an operation for cancer, and suicide by hanging).

No. 79/1981 (41-year-old man): 258 valves (+ many *Fragilaria* valves in girdle view); in all 42 taxa.
No. 89/1981 (39-year-old woman): 617 valves (+ 117 fragments); in all 92 taxa.
No 102/1981 (25-year-old man): 230 valves (+ 6 fragments and some few *Fragilaria* valves in girdle view); in all 22 taxa.

These three subjects drowned respectively in the Little Belt, South of Funen, in Odense Fjord, and in the Great Belt. No. 102/1981 drowned on 22nd August, and the body was recovered on 11th September.

The number of valves found varies greatly from one subject to another, and the same is the case in the different organs from the same body, as can be seen in Table 3.

In all seven subjects, apart from a very few polyhalobe and mesohalobe taxa, only oligohalobe species were found. In subject 102/1981, which drifted in the salt water of Great Belt for two and a half weeks, only fresh water diatoms were found (and only 6 valves in the lungs, compared with 230 in the femoral medulla).

A curiosity was the discovery in subject 89/1981 of two valves of *Eunotia sibirica* Cleve in lung samples. This species has not previously been identified in Denmark.

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Note on Plates I–III

The examples illustrated are all taken from the tissue samples used in this study, and show that diatoms can be absorbed into human body whatever their size and shape. Nearly all species have been observed before in recent material from West Greenland. An exception in *Gomphonitzschia ungeri* from Subjects II/6 (four valves) and II/8 (one valve). Outside Africa it is only found, and then only very rarely, in Finnish Lapland. Also *Mastogloia splendida* is new for Greenland, although widespread in all coastal regions, if commonest in warmer seas. It is evident from these two examples that knowledge of the distribution of diatoms is still very imperfect, in that again and again it transpires that species described as rare or perhaps endemic (tied to a particular place, or associated with a limited geographical area), are often found a long way from their point of discovery. Any sample from a given locality will only encompass a few square centimetres, and presumably can only hold a chance selection of the diatom flora there. More and more fresh water diatoms turn out to be cosmopolitans.
The scale shown at the bottom of the plates indicated 10 μm, and is valid for all the figures on the plate apart from the few that show some larges species; these are supplied with a separate scale, also to 10 μm.
1 μm = 1 micron = 1/1000 mm.

Plate I

1. *Actinoptychus adriaticus* Grun. Diam. 62 µm. I/2 (lung).
2. *Cyclotella striata* (Kütz.) Grun. Diam. 15 µm. I/2 (lung).
3. *Cyclotella meneghiniana* Kütz. Diam. 15 µm I/2 (lung).
4. *Cyclotella comta* (Ehr.) Kütz. Diam. 20 µ. II/6 (columna).
5. *Achnanthes minutissima* Kütz. var. *cryptocephala* Grun. 18 × 2 µm. I/2 (lung).
6. *Melosira italica* (Ehr.) Kütz. subspec. *subarctica* Müller. 11 × 7µm. II/6 (columna).
7. *Tabellaria flocculosa* (Roth) Kütz. Breadth 17 µm. I/2 (columna).
8. *Fragilaria capucina* Desmaz. 20 × 4 µm. I/5 (lung).
9. *Fragilaria construens* (Ehr.) Grun. 15 × 7 µm. II/6 (columna).
10. *Fragilaria brevistriata* Grun. 17× 4.8 µm. I/2 (columna).
11. *Tabellaria fenestrata* (Lyngb.) Kütz. 30 × 6 µm. II/7 (columna).
12. *Melosira granulata* (Ehr.) Ralfs. 12 × 8 µm. II/6 (columna).
13. *Eunotia tenella* (Grun). Hust. 16 × 3 µm. I/2 (lung).
14. *Meridion circulare* Agardh. 47 × 7-2 µm. I/2 (columna).
15. *Meridon circulare* Agardh. Length 47 µm. II/7 (columna).
16. *Eunotia rhomboidea* Hust. 19 × 17-8 µm. I/2 (columna).
17. *Eunotia rhomboidea* Hust. 22 × 4 µm. I/2 (columna).
18. *Synedra ulna* (Nitzsch) Ehr. 92 × 9 µm. I/5 (columna).
19. *Eunotia lunaris* (Ehr.) Grun. 46 × 5 µm. II/7 (columna).
20. *Eunotia faba* (Ehr.) Grun. 11 × 4 µm. I/5 (lung).
21. *Achnanthes lanceolata* Bréb. var. *elliptica* Cleve. 10 × 5 µm. II/6 (columna).
22. *Grammatophora marina* (Lyngb.) Kütz. 15 × 10 µ. I/3 (columna).
23. *Eunotia praerupta* Ehr. 25 × 9 µm. I/5 (lung).
24. *Eunotia diodon* Ehr. 25 × 4-4.5 µm. I/2 (lung).
25. *Diatoma elongatum* Agardh. 42 × 3 µm. II/8 (columna).

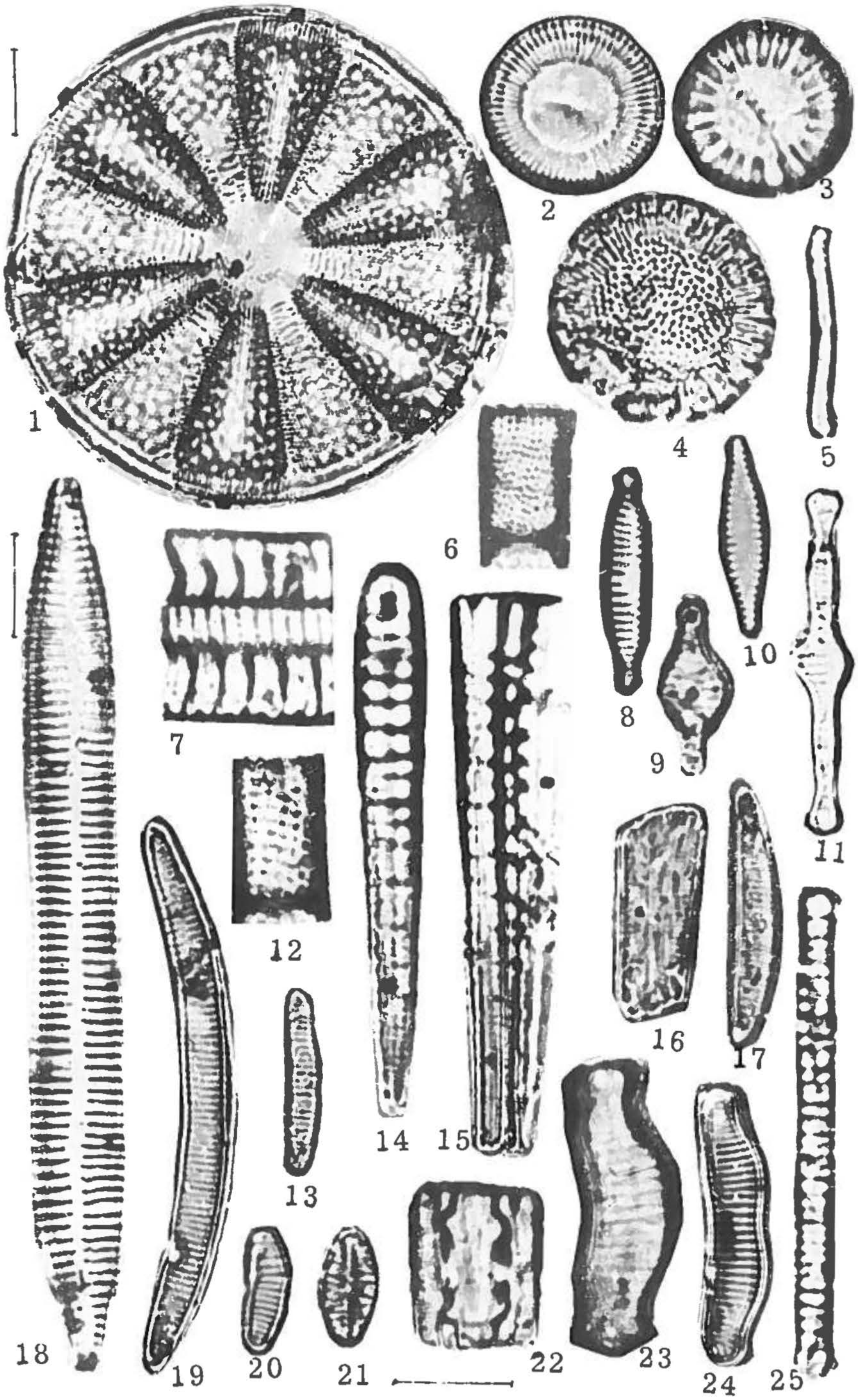
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Plate II

1. *Achnanthes brevipes* Agardh. 58 × 16-17 µm. II/8 (columna).
2. *Achnanthes brevipes* Agardh. 58 × 15-16 µm. II/8 (columna).
3. *Mastogloia splendida* (Greg.) Cleve. 46 × 36 µm. I/5 (lung).
4. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve. 28 × 9 µm. I/3 (columna).
5. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve. 28 × 9 µm. I/3 (columna).
6. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve. 29 × 7 µm. I/3 (columna).
7. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve. 28 × 10 µm. II/8 (columna).
8. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve. 28 × 10 µm. II/8 (columna).
9. *Achnanthes lanceolata* (Bréb.) Grun. 23 × 9 µm. I/4 (columna).
10. *Cocconeis placentula* Ehr. var. *euglypta* (Ehr.) Cleve. 22 × 13 µm. I/5 (lung).
11. *Cocconeis pediculus* Ehr. 18 × 13 µm. I/3 (columna).
12. *Cocconeis placentula* Ehr. 25 × 18 µm. I/5 (lung).
13. *Cocconeis scutellum* Ehr.. 26 × 16 µm. I/5 (lung).
14. *Navicula contenta* Grun. fo. *biceps* Arnott. 13 × 3-4 µm. I/5 (lung).
15. *Mastogloia pumila* (Grun.) Cleve. (?). 23 × 10 µm. II/8 (columna).
16. *Meridion circulare* Agardh. 16 × 8-2 µm, II/7 (columna).
17. *Frustulia vulgaris* Thwaites. 46 × 11 µm. I/5 (lung).

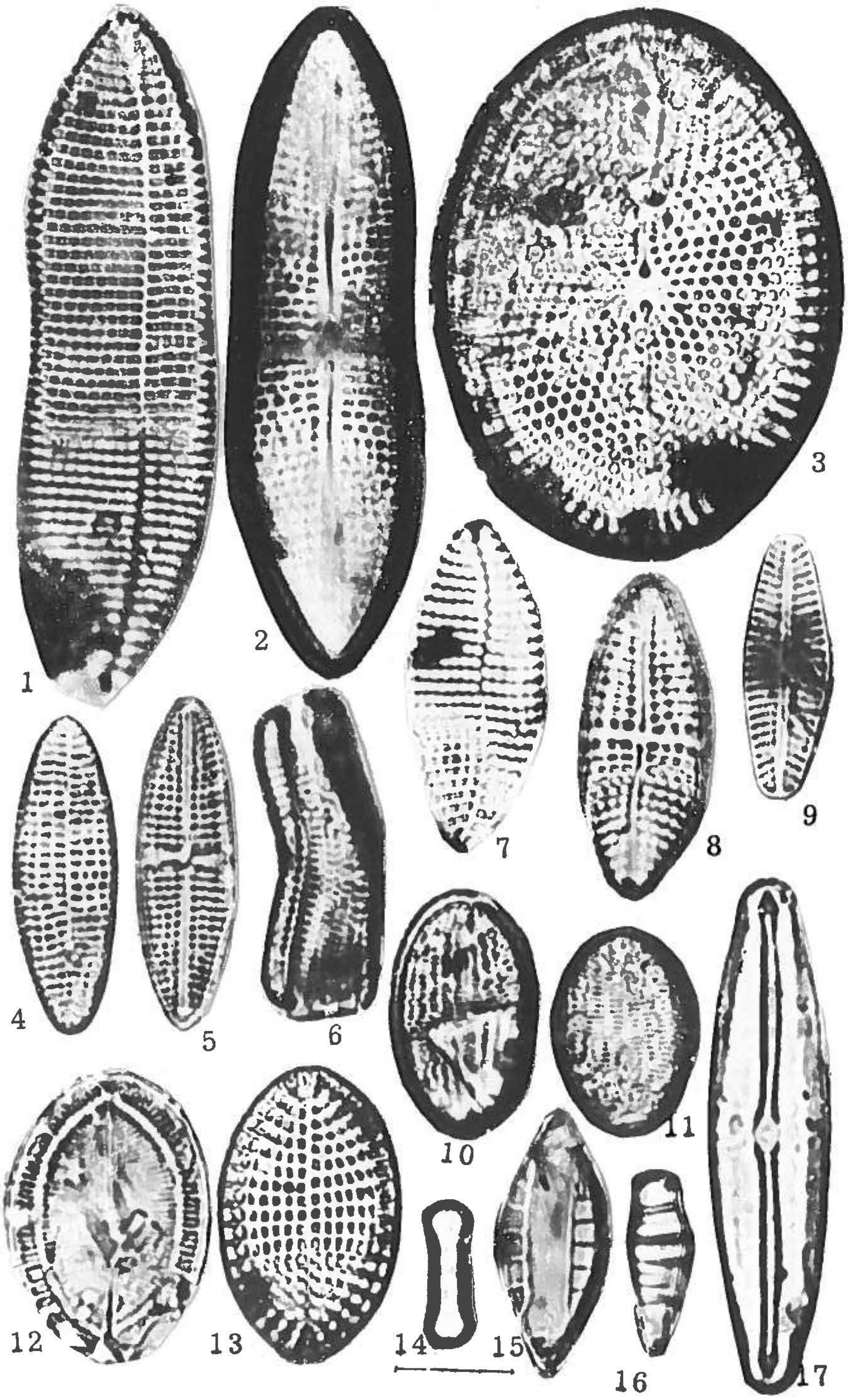
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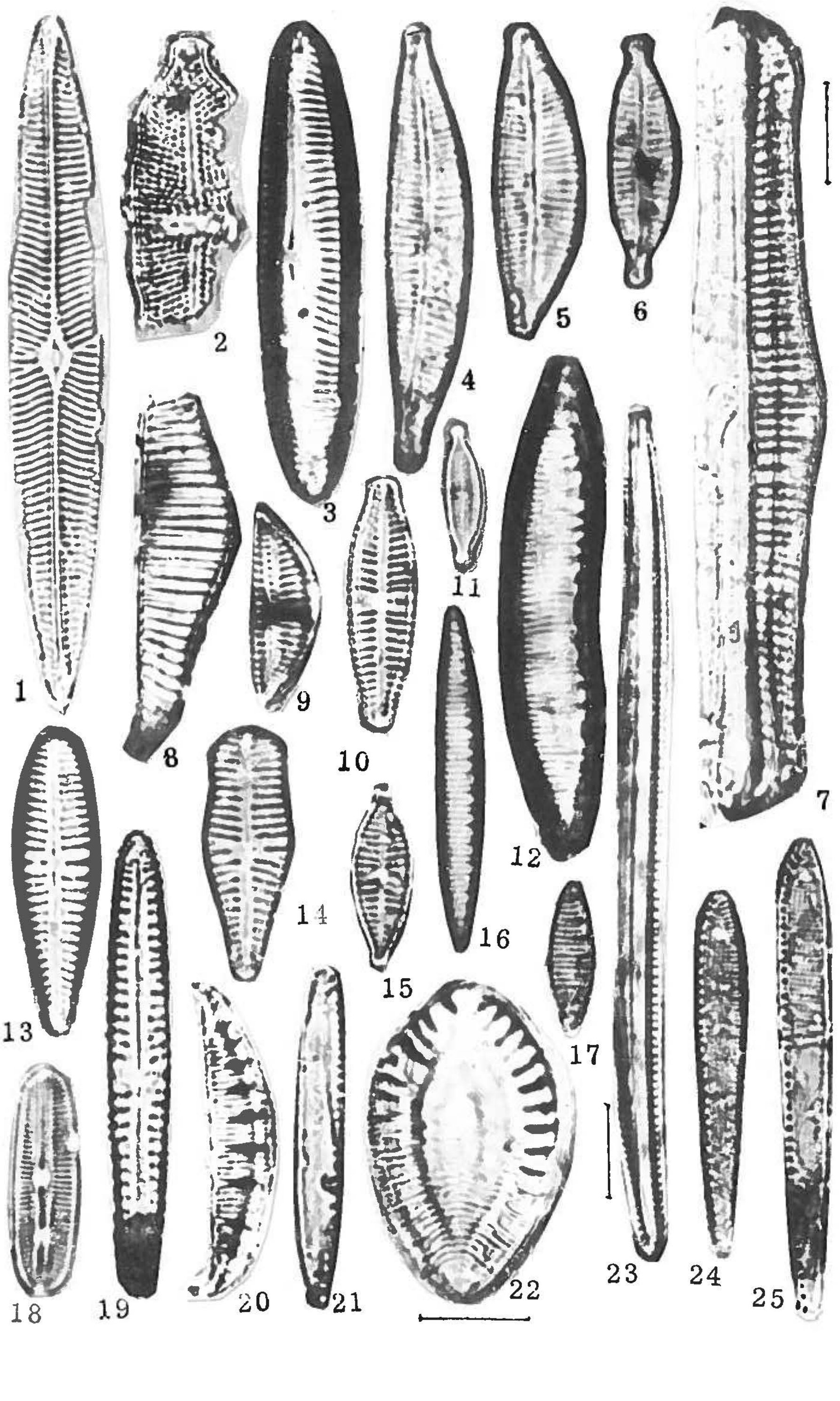
Plate

1. *Navicula radiosa* Kütz. 64 × 9 µm. I/2 (lung).
2. *Navicula charlatii* Perag. (34) × (13) µm. I/5 (lung).
3. *Pinnularia microstauron* (Ehr.) Cleve var. *brebissonii* (Kütz.) Hust. 45 × 11 µm. II/7 (columna).
4. *Cymbella naviculiformis* Auerswald. (?). 40 × 8 µm. I/2 (lung).
5. *Cymbella tumidula* Grun. 29 × 9 µm. I/2 (lung).
6. *Cymbella similis* Krasske. 23 × 7 µm. I/2 (lung).
7. *Rhopalodia gibba* (Ehr.) O. Müller. 86 × 15 µm. I/4 (columna).
8. *Rhopalodia gibba* (Ehr.) O. Müller var. *ventricosa* (Ehr.) Grun. (46) × 15 µm. II/8 (lung).
9. *Cymbella ventricosa* Kütz. 18 × 5 µm. I/5 (lung).
10. *Gomphonema angustatum* (Kütz.) Rabh. var. *producta* Grun. 23 × 6.5 µm. II/7 (columna).
11. *Cymbella microcephala* Grun. 13 × 4 µm. I/2 (lung).
12. *Hantzschia amphioxys* (Ehr.) Grun. 47 × 9 µ. II/6 (columna).
13. *Gomphonema lanceolatum* Ehr. 28 × 8 µm. II/6 (columna).
14. *Gomphonema constrictum* Ehr. 23 × 9 µm. II/8 (lung).
15. *Gomphonema parvulum* Kütz. 15 × 6 µm. II/6 (columna).
16. *Nitzschia amphibia* Grun. 32 × 4 µm. I/5 (lung).
17. *Nitzschia denticula* Grun. 14 × 5 µm. II/8 (lung).
18. *Diploneis ovalis* (Hilse) Cleve var. *oblongella* (Naeg.) Cleve. 21 × 6 µm. I/5 (lung).
19. *Gomphonema intricatum* Kütz. 44 × 5 µm. I/2 (columna).
20. *Rhopalodia gibberula* (Ehr.) O. Müller var. *protracta* Grun. 28 × 6 µm. I/5 (columna).
21. *Nitzschia communis* Rabh. (?). 32 × 4.5 µm. II/8 (columna).
22. *Surirella ovalis* Bréb. 31 × 19 µm. I/2 (columna).
23. *Nitzschia vermicularis* (Kütz.) Grun. 97 × 7 µm. I/5 (lung).
24. *Gomphonitzschia ungeri* Grun. 35 × 5-2 µm. II/6 (columna).
25. *Gomphonitzschia ungeri* Grun. 33 × 5-2.5 µm. II/8 (columna).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