MORPHOLOGICAL AND TAXONOMICAL STUDIES OF CERTAIN DIATOM SPECIES BELONGING TO FAMILY NAVICULACEAE

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Abstract

The objective of this work is to investigate some small-celled diatom species and to reconfirm identification of three species of large-celled naviculoid diatoms. Specimens of this investigation were collected from fresh and marine water habitats in Egypt. These specimens were examined using LM and SEM. Seven species of the genus *Navicula* Bory are described in this study, six of them are belonging to the sub-genus *Navicula*, while other one (7 th) is belonging to the sub genus *Minuscula*. Full description using LM and SEM, distribution in Egypt, ecological status and comparison between small celled naviculoid diatoms are given. These species are *Navicula cryptocephela, N. gregaria, N. viridula, N. heufileri, N. lanceolata, N. pseudoreinharadti* and *N. luzonensis*. This study added a new record to the diatom flora of Egypt and confirm the identification of *Pinnularia alpina* and two species of *Mastogloia*.

Key words: Morphology, *Mastogloia, Navicula, Pinnularia,* Taxonomy.

Introduction

Little has been published till now about the micromorphology of diatoms in Egypt. Most of the available studies were restricted in few publications. (Ehrlish, 1975, Hendey and Sims. 1982, Shaaban *et al*, 1985 a,b, El- Awamri 1999 & 2000, El.Awamri & Shaaban 2000, Zalat 2001 and El- Awamri *et al*, 2003). These studies concerned with the ultra structure and taxonomy of large celled diatoms.

The small celled diatoms are extremely difficult to investigate by light microscopy alone. Some algologists neglect these small celled diatoms during their observations. It is necessary to use SEM to determine the exact form of diatom valves to confirm identification.

There is a great deal of taxonomic confusion in literature about the small naviculoid cells of diatoms. Genus *Navicula* is the largest of all diatom genera with 1860 "acceptable" and 2000 “unacceptable” species mainly bottom living forms (Mann

(ISSN: 1110-8649)

1986). Many of *Navicula* species were transferred to other genera especially after Cox (1979) who emended the description of *Navicula* type species. Cox defined the *Navicula* characters as boat shaped valves (naviculoid), lineolate striae, central external raphe endings simple, apical endings (grooves) turned to one side, internal raphe opening running in raised ribs and without visible central pores. Genus *Navicula* contains many dissimilar forms. Cleve (1894-95) divided the genus into several groups. For a long type, Cleve's system was accepted, but Hüsedt (1961) divided the genus into a number of sections with presumably regarded as belonging to a single subgenus while Patrick & Reimer (1966) subdivided *Navicula* into many sub-genera.

Therefore, the objective of this work is to investigate some small-celled diatom species and to reconfirm identification of three species of large-celled naviculoid diatoms.

Materials and Methods

Diatom samples were collected from freshwater habitats in Cairo, Giza, El-Qalubia, El-Posailly (Alexandria–Rossetta road) and El-Fayum. Three marine samples were collected as benthic epipsammic microhabitat from Lake Qarun. The collected samples were mostly epiphytic on *Phragmites* and *Ceratophyllum* or epilithic on rocks.

The collected samples were prepared for LM and SEM investigation by cleaning frustules using the method described by Jouse *et al*., (1949). For LM study, the material was mounted according to the method described by Proschkina-Laverenko *et al*., (1974). The technique used to prepare diatoms for SEM is that adopted by Hasle and Fryxell (1970).

The diatom taxa were identified according to Patrick and Reimer (1966), Gasse (1986) and Round *et al.* (1990).

The terminology of the ultrastructure of diatoms follows that suggested by Anonymous (1975), Ross et al., (1979) and Round et al., (1990).

Observations and Discussion

(I) Genus: *Navicula* Bory

Seven species of the genus *Navicula* Bory were described in this study, six of them are belonging to the sub-genus *Navicula*, while the other one (7 th) is belonging to sub genus *Minuscula*.

Full description using LM and SEM, distribution in Egypt, ecological status and comparison between small celled naviculoid diatoms are given in the following:

***Navicula cryptocephela* Kütz.** (Plate I, fig. 1 and 2)
1844, Bacill. P.95, Taf, fig. XXXXXVI
Valves narrowly lanceolate with slightly sub-capitate ends. Axial area: narrow; slightly wider at the center of the valve where it emerges with the rounded, transverse central area. Central area is more or less rounded. Striae radiate throughout most of the valve, parallel or slightly convergent at the ends. One helectoglossa is present at each end.
Dimensions:
Length: 32 µm, Breadth: 6-7 µm, striae fine 16 in 10 µm.
The key character of this species is the central area irregular in length.
Distribution in Egypt: El-Fayum, Cairo, Timsah Lake, Giza, Aswan, Minya, Sinai, Nile Delta
Ecology: Widely distributed in freshwater, halophilous to indifferent. Mainly benthic diatoms, (Patrick and Reimer 1966)

***Navicula gregaria* Donk.** , 1860 p. 10, pl.I, fig.10 (Plate 1, fig.3)
Donkin Valve broadly lanceolate, with rostrate apices. The striae are more or less parallel and transverse throughout the valve but becoming convergent at the apices. Longitudinal rows of pores are easily visible. The axial rib is markedly asymmetrical at the central raphe endings.
Dimensions:
Length: 21 µm, Breadth: 5 µm, striae 14 in 10 µm.
Distribution in Egypt: El-Timsah Lake, Giza (El-Zomor, El-Mansuria canals) Luxor and benthic Qarun Lake.
Ecology: Mainly euryhaline and mesohalobous, but widely distributed in rivers (Gasse, 1986).

Navicula viridula* (Kütz.) Kütz. emend. V.H. var. *viridula (Plate I, fig. 4)
Frustulia viridula Kütz.. , linnaea 8: 551, pl. 13. fig. 12. 1833
Navicula viridula (Kütz.) Kütz., Bacill., p. 91, pl.30, fig. 47; pl. 4, figs. 10, 15 1844.
Valve linear-lanceolate; narrowing to obtuse, rostrate ends. Axial area narrow, distinct. Central area large, rounded. Axial area and central nodule appearing more heavily silicified than the rest of the valve. Striae slightly radiate throughout most of the valve, convergent toward the ends; regularly shortened and more distant from each other than the central area.
Dimensions:
Length: 38 µm, Breadth: 9-9.5 µm, straie 10 in 10 µm
Distribution in Egypt: El-Fayum, Zagazig, Giza, Nile Delta, South Egypt from Cairo to Aswan.
Ecology: Freshwater, oligohalobous (Hüstedt 1927-1966)

Navicula heufileri* Grun. var. *heufileri (Plate II, figs. 5 and 6)
Navicula heufileri: Grun. var. Zod. Bot. Ges. Wien. 10: 528 pl.3. figs. 32 a-b. 1860.
Navicula cincta var. *heufileri* (Grun.) V.H. Syn. Diat. Belgique, p. 82. 1885 V.H., pl. 7, fig. 12 1880.

Valve linear to linear- lanceolate rounded ends but sometimes these may be slightly produced. Raphe straight, filiforms, terminal fissures not seen. Axial area narrow and linear with expansion at the central nodule. Transapical striae, parallel to slightly radial and at the poles it may be slightly convergent. The striae are composed of reticulate long narrow rectangular poroids arranged in longitudinal rows parallel to the raphe, except at the centre where they curve to the central nodule.
Dimensions:
Length: 46 µm, Breadth: 7-8 µm, striae 11 in 10 µm.
Distribution in Egypt: Giza (El-Zomor canal)
Ecology: hot spring, saline lakes & swamps and as benthic aerophilous species, alkaline or slightly brackish (Patrick and Reimer 1966)

Navicula lanceolata* (Ag.) Kütz. var. *lanceolata. (Plate II, fig. 7)
Frustulia lanceolata (Ag.) Kütz. Bacill. , p. 94, k pl. 28, fig 38: pl. 30, fig. 48 1844
Valve lanceolate, narrowed toward the ends which are rounded or slightly attenuated rounded. Axial area narrow, distinct. Central area large, orbicular. Striae lineate-radiate throughout most of the valve, becoming convergent at the ends; shortened about the central area. The species is characterized by the large orbicular central area, the shape of the valve, and the angles and number of the striae
Dimensions:
Length: 27 µm, Breadth: 7-8 µm, straie 10 in 10 µm in the middle of the valve to 13 in 10 µm at the ends.
Distribution in Egypt: Zagazig
Ecology: Freshwater (oligoholobous)

***Navicula pseudoreinharadti* var *pseudoreinharadti* Patr.** (Plate II fig. 8)
Patrick and Reimer 1966, plate 49, fig.11. 1966
Navicula var *pseudoreinharadti* Patr.
Proc. Acad. Nat. Sci. Philadelphia
: 104, pl.7, fig 9. 1959
Description using LM and SEM
Naviculoid valve broadly lanceolate narrowed toward rounded ends. Distinct axial area (Raphe strenum). Central area irregular in shape due to the shorting of the striae. The median striae often shorter or longer than the striae adjacent to them. Striae radiate and sometimes curved near the center of the valve, slightly convergent at the ends;
Dimensions:
Length: 20 µm, Breadth: 5 µm, striae 18-20 in 10 µm.
The key character of this species is the central area irregular in length.
Distribution in Egypt: New to Egypt.
In the present study, *Navicula pseudoreinharadti* var *pseudoreinharadti* was recorded in El-Fayum as a benthic epipsammic.
Ecology: Slightly brackish and oligohalobous, Alkailiphilous, very rare.

Navicula luzonensis* Hüst var. *luzonensis (Plate III, fig. 9)

Navicula luzonensis Hüst. , Internat, Rev, Ges, hydrobiol. , 42: 59 fig 106 1942

Valve elliptic. Axial area narrow, linear. Raphe straight. filiform. Median ends somewhat distant. Central area lacking, Coarse striae slightly radiate at the center of the valve and parallel near the poles.

Dimensions:

Length: 9-10 µm, Breadth: 4-4.5 µm, striae 20 in 10 µm.

Distribution in Egypt: New to Egypt

Ecology: It seems to prefer water of high water content (Patrick & Reimer 1966).

Table 1: Comparison of different taxa of *Navicula* studied in this work

Name of Taxa	Shape	Axial area	Central area	Stria orientation (middle of valve)	Stria orientation (valve end)	Length by µm	Breadth by µm	Striae in 10 µm
Navicula cryptocephela Kütz.	narrowly lanceolate	narrow	Rounded	radiate	convergent	32	6-7	16
Navicula gregaria Donk.	broadly lanceolate	narrow	irregular	nearly parallel	convergent	21	5	14
Navicula viridula (Kütz.) Kütz. emend. V.H. var. *viridula*	linear lanceolate	narrow	large rounded	slightly radiate	convergent	38	9-9.5	10
Navicula heufileri: Grun. var. *heufileri*	linear lanceolate	narrow	narrow	parallel	slightly convergent	46	7-8	11
Navicula lanceolata (Ag.) Kütz. var. *lanceolata*	lanceolate	narrow	large orbicular	radiate	convergent	27	7-8	13
Navicula pseudoreinharadti Patr.	broadly lanceolate	distinct	Irregular	radiate	slightly convergent	20	5	18-20
Navicula luzonensis Hüst var. *luzonensis*	elliptic lanceolate	narrow	not prsesent	coarse & slightly radiate	parallel	9-10	4-4.5	20

It is obvious from the comparison between the seven species investigated here (Table 1), that *Navicula luzonesis* which belonged to the sub-genus *Minuscula* (Cl.) Patr. is quite different from the rest of *Navicula* species which are belonging to the sub-genus *Navicula*. Most of characters of *N. luzonesis* are dissimilar to the sub-genus *Navicula*. Members of the sub-genus *Minuscula* have very small valves and axial area usually indistinct, central area very small. The striae are fine and indistinctly punctuate (Patrick and Reimer, 1966).

The sub-genus *Navicula* Bory may include more than 125 species according to Lange-Bertalot 1993. The lineolate valves first attributed to the well known taxa such as *Navicula radiosa*, *Navicula rhynchocephala* and especially *Navicula cryptocephela*

often proved to be quite as delineated in major floras. The incorporation of details seen only by SEM essential to achieve critical segregation. The comparisons between the six investigated taxa belonging to the sub-genus *Navicula*, reveald that most of them are more or less similar in more than one character and differs in others and there is a great difficult to differentiate between the lineolate species without using SEM.

(II) *Pinnularia alpina* W.Sm.var *alpina* (Plate III, figs. 10 to12)

Pinnularia alpina (W.Sm. Syn.British Diat.,vol..I, p.55), pl.18, fig.168.1853
Navicula alpina (W.Sm.) Ralfs. in Pritch., Hist Infusoria, 4th ed., p.906 1861.
Description using LM and SEM
Naviculoid valve elliptical-lanceolate with broadly rounded ends. Axial area usually less than one-third the breadth of the valve. Raphe turned slightly to one side. Axial and central areas forming a lanceolate space which is somewhat rounded, particularly on one side in the region of the central area. Transapical striae very robust, striae radiate parallel or slightly convergent at the poles. Striae 2.5-3.5 in 10 µm, length 90-100 µm, breadth 35-40 µm.
This species is distinguished by the peculiar shape of the terminal fissure and the shape of the valve.

Distribution in Egypt: Mariut, epilithic in lake Qarun, rarely recorded in Bahr Youssif
Ecology: It prefers water of lower mineral content, (Patrick and Reimer 1966) but here it is recorded also in haline and mesohalobous water

***Mastogloia elliptica* Ag.** (Plate IV, figs. 13 to 16)

Mastogloia elliptica (Ag.) Cleve, Nav. Diat. 2p. 152 (1895). Synonyms. *Frustulia elliptica* Ag. Syst. alg. p.312 (1824). *Cymbella elliptica* Ag. Con.sp. crit'. diat. P.8 (1830). *Mastogloia elliptica* f. *major australies* Cleve, I.c., p.152 (1895).
Description using LM and SEM
Dumbbell shaped protrecta cells naviculoid, valves isopolar elliptical to elliptical-lanceolate with broadly drawn out ends, valve face flat Raphe branches strongly wavy (filiform) axial area very narrow, central area circular, fairly large. Cell wall with strongly, radial transapical ribs. In the external valve striae uniseriate and poroid, radial. Raphe -sternum central, narrow, extendeted into the flaps externally which overlap the raphe such that the external raphe fissures are sinuous central endings of the raphe straight end. Internal valve differs from normal valve in its basic structure. The valve bears pseudosepta. The vavocopula bears a complex system of internal bulbulous chambers (partecta) and the tubes, which open to the outside. There are two heteroglossa on each raphe ends. The partecta is heavily silicified and double shaped (plate V, fig.16) and reached to the one-third of the valve. The internal valve has a heavily silicified ending, striae obviously radiate.
Dimensions: length 45-50µm, breadth 12-14µm, striae 18-20 in 10 µm.
Distribution in Egypt: El- Bardawil lagoon and Qarun Lake
Ecology:
subaerial on the saline habitats (Hustedt,1927-66).

***Mastogloia braunii* Grun.** (Plate V figs. 17-18)

Mastogloia braunii Grun. , Verch. Zool. Bot. ces. Wien. 13:156. pl.4 fig.2. 1863. valves elliptical with bareky drown out ends,. Raphe undulate, straight only on the apices and near the central pore (helectoglossa). Axial area narrow central area contiguous with the longitudinal clear areas on each side forming an lyrate shaped (H-shaped) configuration with large four cournred.

Transapical striae punctuate, radial, linear septum marginal composed of numerous rectangular loculi which are larger in the middle of the valve and become smaller towards the poles.

Dimensions:

40-75µm long, 16-25µm width, striae 15-20 in 10 µm, puncta 16-20 in 10 µm, loculi 4.5-6 in 10 µm in the middle, becoming 8-8.5 10 µm toward the end. Length.

Distribution in Egypt El-Fayum, Qarun Lake and El-Bardwail lagoon.

Ecology: Brackish and mesohalobous (Patrick and Reimer, 1966).

There is a verification of identification in *Pinnularia alpine, Mastogloia elliptica and Mastogloia braunii.* In this studies reconfirmation occurred and it is noted that the main characteristic feature of *Pinnularia alpina* is the peculiar shape of the terminal fissure and the shape of valve.

In *Mastogloia braunii* the presence of striae interrupted by a lyre shaped, non-porous thickened area of silica which is often slightly depression below the general level of the valve face is the main feature of this species. In *Mastogloia elliptica,* the shapes of the outer valve and protrecta are the key characters of this species.

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دراسات مورفولوجية و تصنيفية على بعض أنواع الدياتومات المنتمية إلى العائلة Naviculaceae

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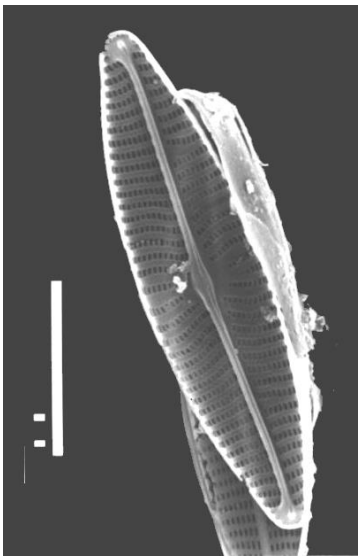
يهدف هذا البحث إلى الدراسة الدقيقة لبعض أنواع الدياتومات صغيرة الحجم و المنتمية إلى العائلة Naviculaceae بالإضافة إلى التاكيد على تعريف ثلاثة أنواع من الدياتومات كبيرة الحجم التى تنتمى إلى نفس العائلة.

تم الفحص باستخدام المجهر الضوئى و الإلكترونى الماسح لعدد عشرة أنواع من الدياتومات سبع منها تنتمي إلى جنس *Navicula* (*Navicula cryptocephela* ، *N. gregaria* ، *Navicula viridula* ، *N. heufileri*، *N. lanceolata* ، *N. pseudoreinharadti* ، *N. luzonensis*).

و لقد تم عمل وصف دقيق و مقارنة بين الأنواع المختلفة كذلك تم حصر و ذكر الظروف البيئية وانتشار كل نوع منها فى مصر مع تصحيح تعريف نوعين من الأنواع كبيرة الحجم *Mastogloia*, *Pinnularia* ، كذلك أظهرت الدراسة تسجيلا لنوع جديد على الفلورا المصرية.



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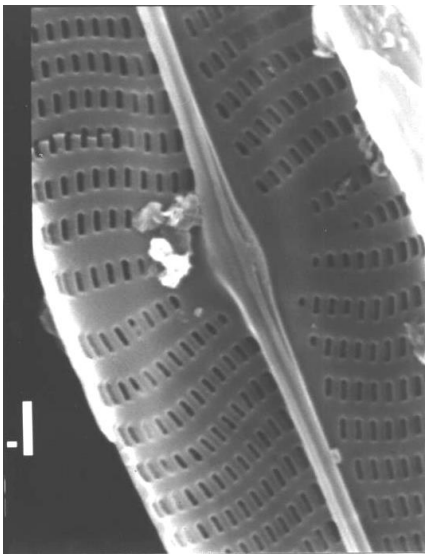

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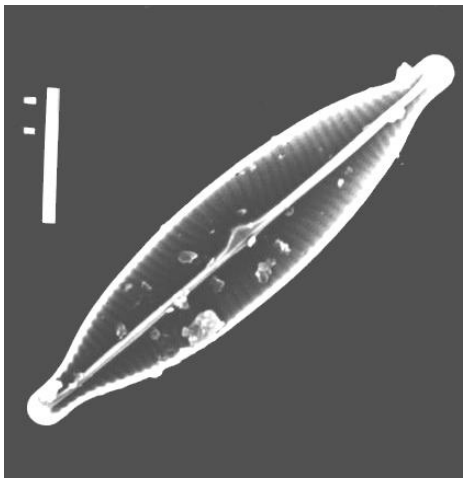

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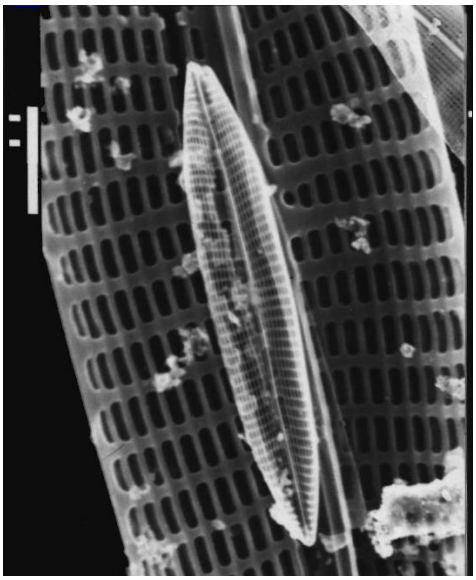
Plate I: Fig. 1: *Navicula cryptocephela* Kütz. Notice, narrow lanceolate valve, 2 helectoglossa at the raphe ending, narrow axial area, girdle band, radiate striae SEM, bar = 10 μm, fig. 2: *N. cryptocephela* Kütz. (magnified, part) Note central nodule, radiate striae, rectangular poroids and part of girdle band, SEM, bar = 10 μm, fig. 3: *N. gregaria* Donk. Notice external valve with rostrate apeices, parallel striae, longitudinal poroids, raphe and raphe endings. SEM, bar = 1 μm, fig. 4: *N. viridula* (Kütz.) Kütz. emend. V.H. var. *viridula*, notice linear lanceolate valve straight raphe, narrow axial area, arrangement of striae, heavily silicified central nodule. SEM, bar = 10 μm.



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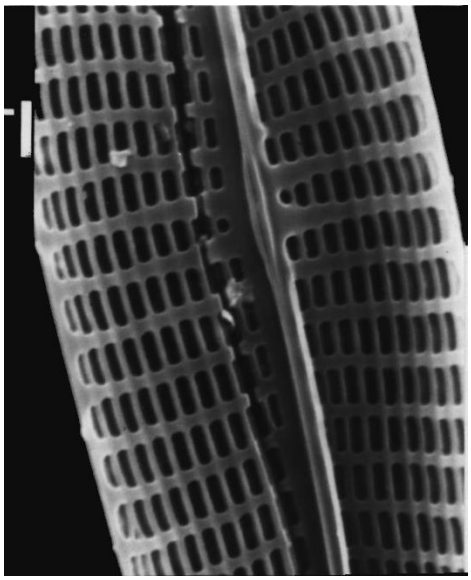

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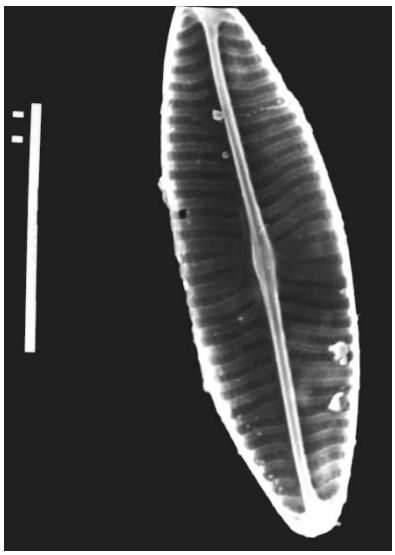

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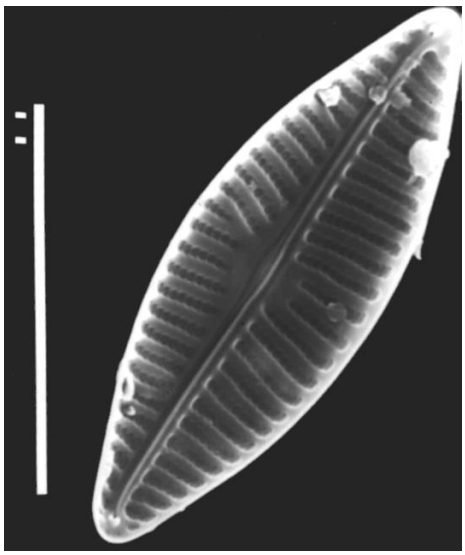

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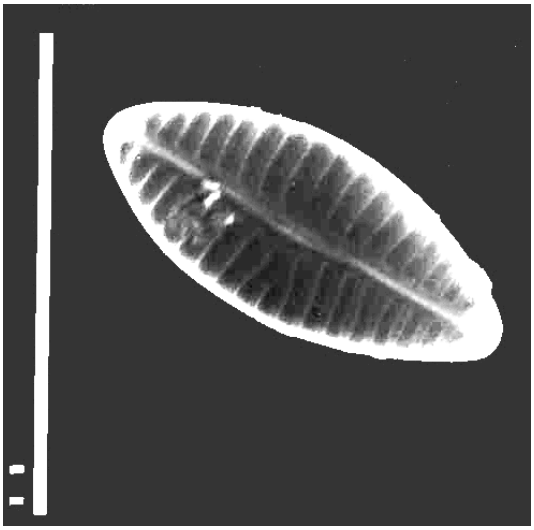
Plate II: Fig. 5: *Navicula heufileri* Grun. var. *heufileri* Notice, linear lanceolate valve parallel striae, longitudinal rows of pores, rectangular poroids. SEM, bar = 10 µm, fig. 6: *N. heufileri* Grun. var. *heufileri* (magnified part) notice, asymmetrical axial rib, central nodule, rows of striae, reticulate rectangular poroids. SEM, bar = 1 µm, fig. 7: *N. lanceolata* (Ag.) Kütz. var. *lanceolata.* Notice lanceolate valve, narrow axial area, central area, shortened striae about central area. SEM, bar = 10 µm, fig. 8: *N. pseudoreinharadti* var *pseudoreinharadti* Patr. Notice broadly lanceolate valve, irregular central area, short central striae, radiate striae, helictoglossa. SEM, bar = 10 µm.



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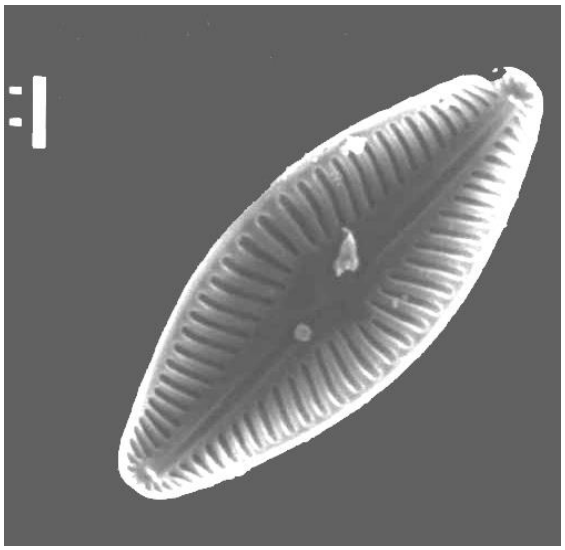

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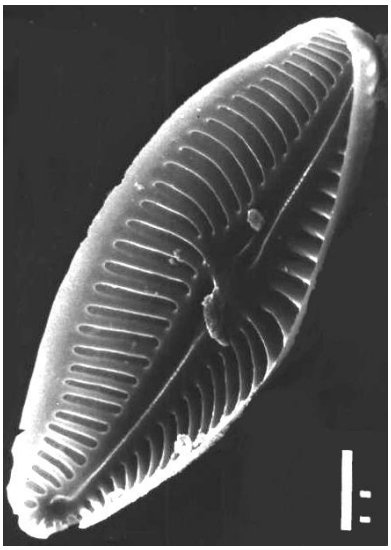

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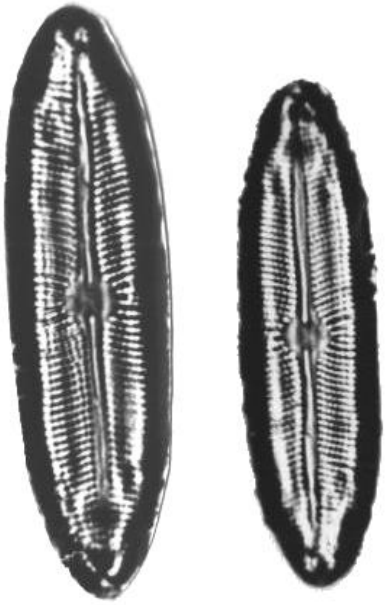
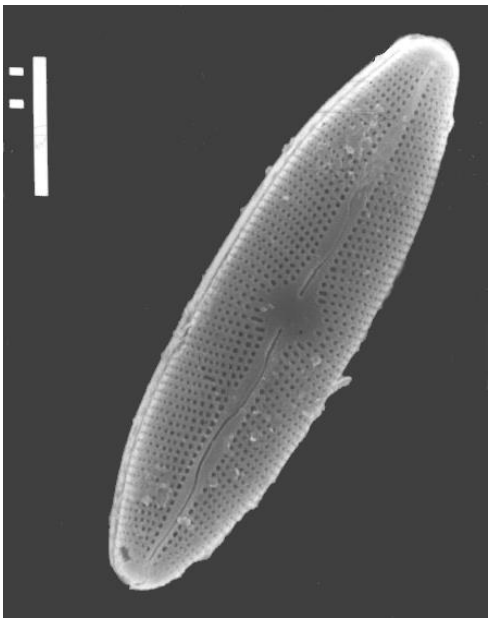
Plate III: Fig. 9: *Navicula luzonensis* Hüst var. *luzonensis* Notice, elliptic valve, narrow axial area, straight raph lacking central area, coarse slightly radiate striae, fig. 10: *Pinnularia alpina* W.Sm.var *alpina* Notice, valve shape, robust striae, axial area, central area, raph valve. LM, x1000, figs. (11 & 12): *P. alpina* W.Sm.var *alpina* Notice, axial and central area, robust, radial striae, mantle edge, boat valve shape. SEM, bar = 10 µm.



13 – a

13 – b



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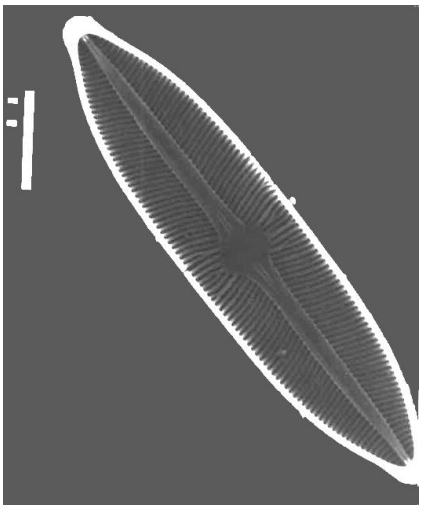

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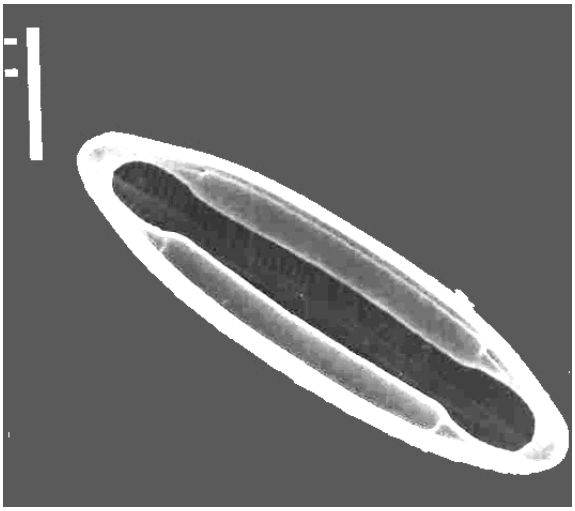

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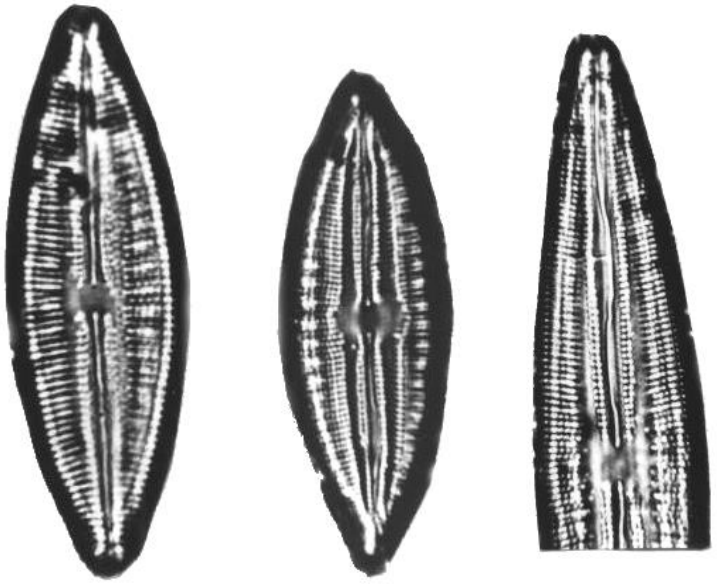
Plate IV: Fig. 13: *Mastogloia elliptica* Ag. Notice, elliptical lanceolate valve, filiform raphe, narrow axial area, circular central area. LM, x1000, fig. 14: *M. elliptica* Ag. Notice, external valve, filiform raphe, radiate striae poroids, narrow axial area. SEM, bar = 10 μm, fig. 15: *M. elliptica* Ag. Internal valve. Notice, axial area, radiate striae, valve ends, central area. SEM, bar = 10 μm, fig. 16: Girdle band (Valvocopula) Notice, Dumbbell shaped protrecta (girdle band), the internal valve. . SEM, bar = 10 μm.



17 – a **17 – b** **17 – c**

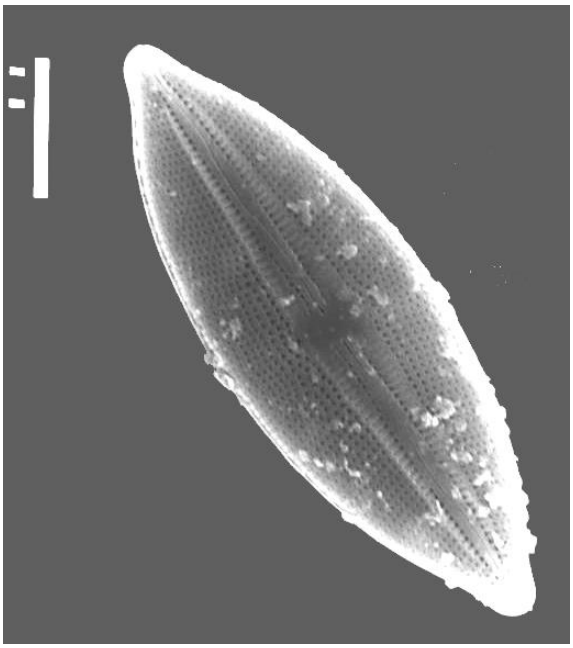


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Plate V: Fig. 17 (a, b &c): *Mastogloia braunii* Grun. Notice, elliptical valves, figs. 17-a & b, elliptical lanceolate axial and central area, fig. 17-c, filiform raphe, lyrate shaped, protrecta at the side of the valve, radiate striae. Lm, x1000. fig. 18: *M. braunii* Grun. External valve. Notice, filiform raphe, hyaline axial and central area (lyrate shaped) radiate striae.