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Tuulikki Grönlund

The diatom flora of the Eemian deposit at Haapavesi, western Finland

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Deposits of silt and gyttja underlying a till bed at Ollala in Haapavesi, western Finland, were studied for pollen and diatoms. The results of pollen analysis from this site, considered Eemian in age, have been presented earlier (Forsström *et al.* 1987, Geol. Surv. Finland, Spec. Paper 2). The silt layer consists of marine diatom flora in which littoral species are dominant. The flora includes many diatoms mainly thriving in highly saline water and not found earlier in Finland. Diatoms that thrive in warm water and also those that prefer cold water are encountered. In the gyttja layer the diatoms pass from marine to fresh-water species, implying that the basin became isolated from the sea at that time.

Key words: diatoms, marine, fresh water, Eemian, isolation, Ollala, Haapavesi, western Finland

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INTRODUCTION

There are till-covered sediments in Finland that have been ascribed to the Eemian Interglacial mainly on account of their stratigraphic position and pollen assemblages. Some of these sites have also revealed saline-water diatoms, which are thus species of the Eemian Sea flora.

The earliest Eemian Sea diatoms were described from clods in eskers in the Karelian Isthmus, east of the present Finnish border (Fig. 1) (Brander 1937, 1943). Redeposited Eemian Sea diatoms have also been encountered in clay deposits at Somero, in southwestern Finland (Tynni 1971).

Several interglacial sediments covered by or intermixed with till have been described from Ostrobothnia. These sediments, too, contain Eemian Sea diatoms (Niemelä and Tynni 1979, Eriksson *et al.* 1980, Grönlund *et al.* 1985). Niemelä and Tynni (1979) found the highest Eemian Sea diatom abundances in till at Malax and at Nurmijärvi, where the diatom flora had undergone redeposition. Niemelä and Tynni (1979) maintain that the silt in an esker covered by till at Rova is an original Eemian deposit. Its diatom flora contains about 60 % saline or brackish-water species. The fresh-water species probably consist mainly of forms transported by streams. The formation at Norinkylä includes clay deposited in the Eemian Sea and Eemian Sea diatoms intermixed with the lacustrine gyttja (Niemelä and Tynni 1979).

A fully marine interglacial diatom flora has been presented from Evijärvi, in Ostrobothnia (Eriksson *et al.* 1980). Almost intact, the stratigraphic sequence in the Evijärvi deposit is not exactly *in situ,* and it is assumed that glacial transport has moved it to some extent. The Evijärvi deposit has been proposed as the Eemian stratotype in Finland (Donner *et al.* 1986).

Elsewhere in the Baltic Sea area, marine sediments of the Eemian Sea have been encountered on the River Mga in the Karelian Isthmus (Brander 1937). On the basis of the studies of Cheremisinova (1961), Liivrand (1984, 1987) has presented Eemian Sea diatom flora from the island of Suur-Prangli on the coast of northern Estonia, in the southern part of the Gulf of Finland, at a depth of 60—70 m below the present sea level (Fig. 1). Liivrand (1987) proposed the Eemian Sea deposit at Suur-Prangli as the stratotype for the western part of the northern Baltic.

The till-covered silt and the overlying gyttja deposit found by Forsström at Ollala, Haapavesi, in the summer of 1985 contains a fully marine diatom flora from before the last glaciation (Forsström *et. al.* 1987). The deposit has been attributed with high certainty to the Eemian Interglacial. The present stydy presents the outcome of the diatom analysis on the Ollala succession in Haapavesi and discusses the Eemian Sea diatoms in the Baltic area.

THE STRATIGRAPHY AND DIATOM ANALYSIS OF OLLALA

The Ollala lithostratigraphy (124 m a. s. l.) is composed of a silt and gyttja layer. The upper part of the gyttja is at an elevation of about 116 m a. s. l. The core taken in the summer of 1985 consists of two portions. The gyttja layer overlying the silt was sampled at two adjacent sites so that the successions partly overlap (Fig. 2). Additional samples, corresponding to the first core, were collected later.

The diatoms were identified on the basis of the following publications: Brockmann 1950, Cleve-Euler 1951—55, Foged 1980, Hendey 1964, Hustedt 1927—66, Miller 1964, 1971, Mölder and Tynni 1967—73, Niemelä and Tynni 1979, Peragallo 1897—1908, Riznyk 1973, Tynni 1975—80, 1983, 1986 and Wornardt 1967.

Fig. 1. Locations of the Eemian interglacial deposits mentioned in the text in Finland and its immediate environment: 1. Suur-Prangli, 2. Rouhiala, 3. Somero, 4. Norinkylä, 5. Malax, 6. Evijärvi, 7. Haapavesi, Ollala, 8. Rova.

The basal part of the silt was rich in diatoms, and although they decline somewhat in the upper part of the silt layer they are abundant again in the gyttja. The diatoms are well-preserved except in the topmost samples, where there are abundant fragments and corroded diatoms. Five hundred diatoms were counted from each sampling depth and 279 taxa belonging to 52 diatom genera were named. The diatoms were classified by salinity preference as polyhalobous (salinity in the habitat 35—17 parts per mille), mesohalobous, (salinity in the habitat 35—0.2 parts per mille) and oligohalobous, which are fresh-water species. The classification is that of Simonsen (1962) applied to Finnish conditions by Tynni (Tynni and Niemelä 1979) (Fig. 2) and is the same as that applied earlier to interglacial diatom populations presented from Ostrobothnia (Niemelä and Tynni 1979, Eriksson *et al.* 1980, Grönlund *et al.* 1985).

The diatom flora in the basal part of the silt layer is very uniform to a depth of 8.5 m, all the diatoms encountered there indicating saline or brackish water. The silt layer has 8—28 % polyhalobous species. The poly-mesohalobous *Melosira sulcata* is clearly the dominant species. It is a common littoral species on the coasts of Europe, but, according to Mölder (1962), seldom occurs on coast of Finland. Also abundant are *Grammatophora oceanica* and *Hyalodiscus scoticus,* which are salt-water species that thrive in brackish water, too. All three species are common in the interglacial flora of Ostrobothnia (Niemelä and Tynni 1979, Eriksson *et al.* 1980) and in the Eemian clay at Rouhiala (Brander 1937, 1943).

Dimerogramma minor, Diploneis subcinta, Navicula lyra and *Auliscus caelatus* var. *dissolutus* are other species considered typical of the Eemian Sea. Diatoms, which are alien to the postglacial Baltic Sea and occur at Rouhiala and in the interglacial flora in Ostrobothnia, include *Actinocyclys kützingii, Actinoptychus senarius, Biddulphia rhombus, Ceratoneis turgidus* and *Navicula abrupta.*

The flora at Haapavesi contains several species not encountered before in Finnish deposits interpreted as interglacial. Of them, *Amphora acuta, A. ocellata, Navicula*

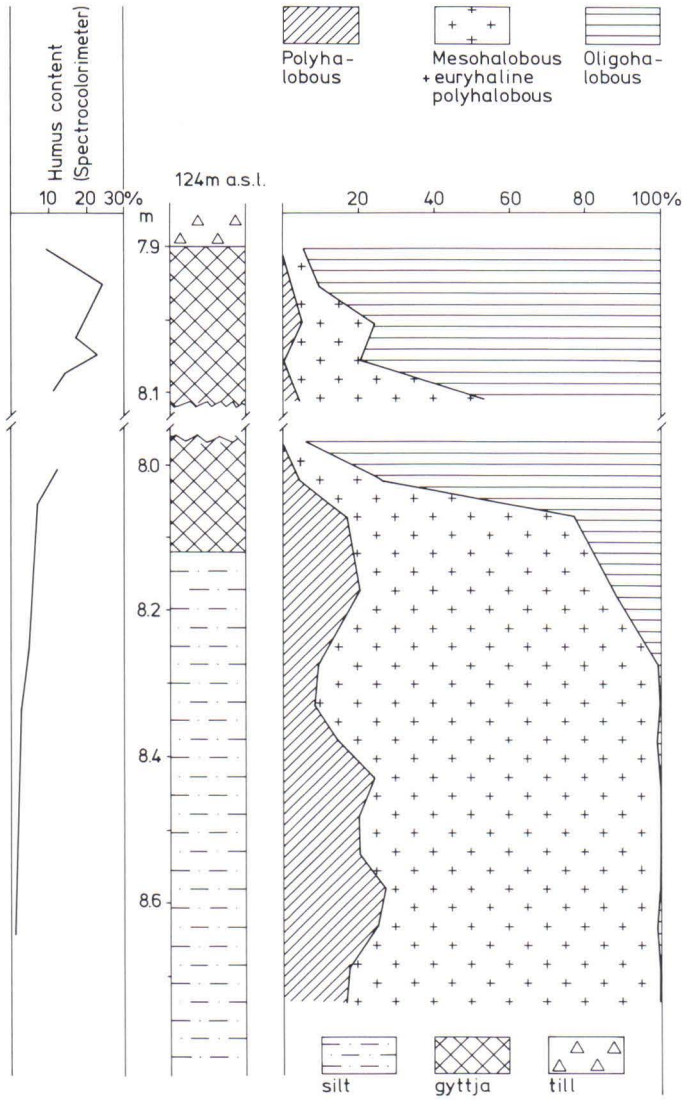

Fig. 2. Stratigraphy and diatom diagram of Ollala. Diatoms are divided into three groups according to their salinity requirements.

arenaria, N. cancellata, N. directa and *Opephora schwartzii* are polyhalobous species. The *Diploneis* species, *D. mediterranea, D. papula, D. schmidti* and *D. vacillans,* are an interesting group. All these species occur mainly in warm waters, although *D. schmidti* and *D. vacillans,* if not others, are common on the coasts of Europe up to the North Sea (Hustedt 1930). In this context, mention should also be made of the polyhalobous *Diploneis notabilis* and *D. suborbicularis,* and *Amphora crassa* var. *punctata,* which have not been encountered in Ostrobothnia but have been presented from the Rouhiala clay. The first two occur mainly in warm seas, although they also thrive on the coasts of Europe from the Mediterranean to northern Europe (Hustedt 1930).The thermophile species suggest a connection between the depositional basin and the North Sea, as does, according to Niemelä and Tynni (1979), the occurrence of *Actinocyclus kützingii* in the flora.

The diatoms at Haapavesi also contain species, such as *Campylodiscus angularis, Grammatophora arcuata, Navicula glacialis* and *Trachyneis aspera,* that favour Arctic waters. The occurrence of these species in the interglacial diatom flora of Ostrobothnia has been interpreted as implying that, at that time, the sea had an access to the White

Sea (Zans 1936, Gross 1967, Niemelä and Tynni 1979). *Cocconeis clandestina* and *Navicula finmarchica* are other diatoms that favour northern or Arctic waters (Cleve Euler 1953).

Some silicoflagellata that favour the plankton of saline waters, such as *Dictyocha fibula,* which prefers warm water, and *Distephanus speculum,* a cold-water species, were encountered in the basal part of the silt layer. The dinoflagellate *Actiniscus pentasterias* was also encountered in the basal parts of the silt layer. All these species are also common in the interglacial flora of Ostrobothnia and in the Eemian clay at Rouhiala.

In the upper part of the silt layer, fresh-water species appear in the diatom population and increase rapidly in abundance in the gyttja layer. None of the species attains dominance. Instead, all the fresh-water species increase similarly in abundance, particularly those of the genera *Achnanthes, Eunotia* and *Pinnularia.*

The fresh-water *Melosira* species encountered were *M. varians* and *M. italica var. subarctica* and *M. italica var. valida. M. italica* occurs mainly in a resting spore form. Restingspore forms were found in several stages of evolution, probably much as described by Miller (1971) from the Eemian deposit at Leveäniemi. Miller names the restingspore form chain *Melosira italica* fo. *laevis,* which name has also been applied to the more or less resting spore forms of *M. italica* in the diatom flora at Haapavesi.

In the upper part of the gyttja, saline-water species are replaced almost totally by fresh-water species. Isolation took place when the sea level was at the uppermost part of the sample core.

The list of diatoms of Ollala

Achnanthes affinis Grun.	o—h
A. brevipes Ag.	mesoh. pol.
A. brevipes v. intermedia (Kütz.) Cl.	mesoh. pol.
A. delicatula (Kütz.) Grun.	mesoh. pol.
A. exigua Grun.	o—h
A. hungarica Grun.	o—h
A. kryophila Boye	o—h
A. lanceolata (Bréb.) Grun.	o—h
A. lanceolata v. elliptica Cl.	o—h
A. lanceolata v. rostrata (Östr.) Hust.	o—h
A. laterostrata Hust.	o—h
A. levanderi Hust.	o—h
A. linearis (W.Sm.) Grun.	o—h
A. longipes Ag.	mesoh. pol.
A. nodosa A. Cl.	o—h
A. spp.	o—h
Actinocyclus ehrenbergi Ralfs.	mesoh. pol.
A. ehrenbergi v. ralfsii (W.Sm.) Hust.	mesoh. pol.
A. kützingii (A.S.) Sim.	polyh.
Actinoptychus senarius Ehr.	polyh.
Amphora acuta Greg.	polyh.
A. angusta Greg.	polyh.
A. arenaria Donk.	polyh.
A. commutata Grun.	mesoh. pol.
A. coffeaeformis (Ag.) Kütz.	polyh.
A. crassa v. punctata A.S.	polyh.
A. ocellata Donk.	polyh.
A. ovalis v. libyca (Ehr.) Cl.	o—h
A. ovalis v. pediculus Kütz.	o—h
A. proteus Greg.	polyh.
A. pusio Cl.	polyh.
A. wisei Simonsen?	polyh.
A.spp.	—
Anomoeoneis sphaerophora (Kütz.) Pfeitzer	o—h
Auliscus caelatus v. dissolutus Halden	polyh.
Bacillaria paxillifer (O.F. Müll.) Hendey	mesoh. pol.
Biddulphia rhombus (Ehr.) W.Sm.	polyh.
Caloneis bacillum (Grun.) Meresch.	o—h
C. brevis (Grev.) Cl.	polyh.
C. liber (W.Sm.) Cl.	polyh.
C. silicula (Ehr.) Cl.	o—h
C. westii (Smith) Hendey	mesoh. pol.
Campylodiscus angularis Greg.	polyh.
C. clypeus Ehr.	mesoh. pol.
C. echeneis Ehr.	mesoh. pol.
C. fastuosus Ehr.	polyh.
Cerataulus turgidus Ehr.	polyh.
Chaetoceros mitra (Bail.) Cl.	polyh.
C. muelleri Lemmermann	mesoh. pol.
C. subsecundum (Grun.) Hust.	polyh.
C. spp.	polyh.
Cocconeis clandestina A.S.	polyh.
C. peltoides Hust.	polyh.
C. placentula Ehr.	o—h
C. placentula v. euglypta (Ehr.) Cl.	o—h
C. quarnerensis Grun.	polyh.
C. scutellum Ehr.	mesoh. pol.
C. scutellum v. minutissima Grun.	mesoh. pol.
C. scutellum v. parva Grun.	mesoh. pol.
Coscinodiscus decrescens Grun.	polyh.
C. lacustris Grun.	mesoh. pol.
C. lacustris v. septentrionalis Grun.	mesoh. pol.
C. oculus iridis Ehr.	polyh.
C. spp. fragm.	polyh.
Cyclotella meneghiniana Kütz.	o—h
Cymbella naviculiformis Auersw.	o—h
C. sp.	o—h
Diatoma vulgaris v. ovalis (Fricke) Hust.	o—h
Dimerogramma fulvum (Greg.) Ralfs.	polyh.
D. minor (Greg.) Ralfs.	polyh.
Diploneis coffeiformis (A.S.) Cl.	polyh.
D. didyma (Ehr.) Cl.	mesoh. pol.
D. interrupta (Kütz.) Cl.	mesoh. pol.
D. interrupta v. heeri (Pant.) Hust.	mesoh. pol.
D. litoralis (Donk.) Cl.	polyh.
D. marginestriata Hust.	o—h
D. mediterranea (Grun.) Cl.	polyh.
D. notabilis (Grev.) Cl.	polyh.
D. ovalis (Hilse) Cl.	o—h
D. papula (A.S.) Cl.	mesoh. pol.
D. schmidti Cl.	polyh.
D. smithii (Bréb.) Cl.	mesoh. pol.
D. stroemi Hust.	mesoh. pol.
D. subcinta (A.S.) Cl.	polyh.
D. suborbicularis (Greg.) Cl.	polyh.
D. vacillans (A.S.) Cl.	polyh.
Epithemia turgida (Ehr.) Kütz.	o—h
E. zebra (Ehr.) Kütz.	o—h

E. zebra v. porcellus (Kütz.) Grun.	o—h
E. zebra v. saxonica (Kütz.) Grun.	o—h
Eunotia arcus Ehr.	o—h
E. bidentula W.Sm.	o—h
E. diodon Ehr.	o—h
E. exigua (Bréb.) Grun.	o—h
E. fallax A.Cl.	o—h
E. flexuosa Kütz.	o—h
E. formica Ehr.	o—h
E. lunaris (Ehr.) Grun.	o—h
E. meisteri Hust.	o—h
E. microcephala Krasske	o—h
E. monodon Ehr.	o—h
E. papilio (Grun.) Hust.	o—h
E. parallela Ehr.	o—h
E. pectinalis (Kütz.) Rabenh.	o—h
E. pectinalis v. minor (Kütz.) Rabenh.	o—h
E. pectinalis v. ventralis (Ehr.) Hust.	o—h
E. polydentula Brun.	o—h
E. praerupta Ehr.	o—h
E. praerupta v. bidens Grun.	o—h
E. robusta v. tetraodon (Ehr.) Ralfs.	o—h
E. tenella (Grun.) Hust.	o—h
E. veneris Hust.	o—h
E. spp.	o—h
Fragilaria bicapitata A. Mayer	o—h
Fragilaria brevistriata Grun.	o—h
F. capucina Desm.	o—h
F. capucina v. lanceolata Grun.	o—h
F. constricta Ehr.	o—h
F. construens (Ehr.) Grun.	o—h
F. construens v. venter (Ehr.) Grun.	o—h
F. crotonensis Kitton	o—h
F. intermedia Grun.	o—h
F. rumpens v. fragilarioides (Grun.) A. Cl.	o—h
F. virescens Ralfs.	o—h
F. spp.	o—h
Gomphonema acuminatum Ehr.	o—h
G. acuminatum v. coronata (Ehr.) W.Sm.	o—h
G. angustatum v. sarcophagus (Greg.) Grun.	o—h
G. augur Ehr.	o—h
G. augur v. gautieri v. Heurck	o—h
G. constrictum Ehr.	o—h
G. constrictum v. capitata (Ehr.) Cl.	o—h
G. gracile Ehr.	o—h
G. intricatum Kütz.	o—h
G. lanceolatum v. insignis (Greg.) Cl.	o—h
G. longiceps v. montana (Schum.) Cl.	o—h
G. longiceps v. montana fo. suecica Grun.	o—h
G. parvulum (Kütz.) Grun.	o—h
G. spp.	o—h
Grammatophora arcuata Ehr.	polyh.
G. marina (Lyng.) Kütz.	polyh.
G. oceanica Grun.	mesoh. pol.
G. oceanica v. macilenta (W.Sm.) Grun.	mesoh. pol.
Gyrosigma acuminatum (Kütz.) Rabh.	o—h
G. balticum (Ehr.) Rabh.	mesoh. pol.
G. distortum v. parkeri (Harrison) Cl.	o—h
Hantzschia amphioxys (Ehr.) Grun.	o—h
H. amphioxys v. vivax (Hantzsch.) Grun.	o—h
Hyalodiscus scoticus (Kütz.) Grun.	mesoh. pol.
H. subtilis Bail.	polyh.
H. spp.	polyh.
Mastogloia pumila (Grun.) Cl.	mesoh. pol.
Melosira ambigua (Grun.) O. Müll.	o—h
M. arenaria Moore	o—h
M. distans (Ehr.) Kütz.	o—h
M. granulata (Ehr.) Ralfs.	o—h
M. islandica (Dauersp.) O. Müll.	o—h
M. italica fo. laevis	o—h
M. italica v. subarctica O. Müll.	o—h
M. italica v. valida Grun.	o—h
M. moniliformis (O. Müll.) Ag.	mesoh. pol.
M. roseana Rabenh.	o—h
M. sulcata (Ehr.) Kütz.	mesoh. pol.
M. undulata v. normanni Arnott	o—h
M. varians Ag.	o—h
M. sp.	o—h

Meridion circulare (Grev.) Ag.	o—h
M. circulare v. constricta (Ralfs.) v. Heurck	o—h
Navicula abrupta (Greg.) Donk.	polyh.
N. anglica Ralfs.	o—h
N. arenaria Donk.	polyh.
N. cancellata Donk.	mesoh. pol.
N. crucicula (W.Sm.) Donk.	mesoh. pol.
N. cruciculoides Brock.	mesoh. pol.
N. cryptocephala Kütz.	o—h
N. dicephala (Ehr.) W.Sm.	o—h
N. digitoradiata (Greg.) A.S.	mesoh. pol.
N. directa W.Sm.	polyh.
N. elegans W.Sm.	mesoh. pol.
N. finmarchica Cl. & Grun.	polyh.
N. forcipata Grev.	mesoh. pol.
N. glacialis (Cl.) Grun.	polyh.
N. granulata Bail.	polyh.
N. gregaria Donkin.	mesoh. pol.
N. hennedyi W.Sm.	polyh.
N. hungarica Grun.	o—h
N. hungarica v. capitata (Ehr.) Cl.	o—h
N. lapidosa Krasske	o—h
N. latissima Greg.	polyh.
N. lyra Ehr.	polyh.
N. lyra v. elliptica A.S.	polyh.
N. lyroides Hendey	polyh.
N. marina Ralfs.	polyh.
N. palpebralis Bréb.	polyh.
N. peregrina (Ehr.) Kütz.	mesoh. pol.
N. plicata Donk.	o—h
N. pupula Kütz.	o—h
N. pupula fo. capitata Hust.	o—h
N. pupula v. rectangularis (Greg.) Grun.	o—h
N. pygmaea Kütz.	mesoh. pol.
N. radiosa Kütz.	o—h
N. radiosa v. tenella (Bréb.) Grun.	o—h
N. ramosissima (Ag.) Cl.	polyh.
N. rhynchocephala Kütz.	o—h
N. rostellata Kütz.	mesoh. pol.
N. salinarum Grun.	mesoh. pol.
N. spp.	o—h
Neidium affine (Ehr.) Cl.	o—h
N. affine v. longiceps (Greg.) Cl.	o—h
N. bisulcatum (Lagerst.) Cl.	o—h
N. iridis fo. vernalis Reichelt	o—h
Nitzschia acuminata (W.Sm.) Grun.	polyh.
N. amphibia Grun.	o—h
N. apiculata (Greg.) Grun.	o—h
N. constricta (Greg.) Grun.	polyh.
N. filiformis (W.Sm.) Hust.	mesoh. pol.
N. hungarica Grun.	mesoh. pol.
N. punctata (W.Sm.) Grun.	mesoh. pol.
N. scalaris (Ehr.) W.Sm.	mesoh. pol.
N. sigma (Kütz.) W.Sm.	mesoh. pol.
N. tryblionella Hantzsch	o—h
N. tryblionella v. victoriae Grun.	o—h
N. tryblionellae	?
Opephora marina (Greg.) Petit	polyh.
O. schulzi (Brockm.)	mesoh. pol.
O. schwartzii Petit	polyh.
Pinnularia acrosphaeria Bréb.	o—h
P. appendiculata (Ag.) Cl.	o—h
P. borealis Ehr.	o—h
P. braunii (Grun.) Cl.	o—h
P. brevicostata Cl.	o—h
P. cardinalis (Ehr.) W.Sm.	o—h
P. cruciformis (Donk.) Cleve	polyh.
P. distinquenda (Cl.) Cleve-Euler	o—h
P. divergens W.Sm.	o—h
P. gentilis (Donk.) Cl.	o—h
P. gibba Ehr.	o—h
P. gibba fo. lineata Hust.	o—h
P. gibba v. mesogongyla (Ehr.) Hust.	o—h
P. gibba fo. subundulata (Mayer) Hust.	o—h
P. hemiptera (Kütz.) Cl.	o—h
P. krockii (Grun.) Hust.	o—h
P. lata (Bréb.) W.Sm.	o—h
P. mesolepta (Ehr.) W.Sm.	o—h

P. microstauron (Ehr.) Cl.	o—h
P. microstauron v. brebissonii (Kütz.) Hust.	o—h
P. nobilis Ehr.	o—h
P. nodosa Ehr.	o—h
P. polyonca (Breb.) O. Müll.	o—h
P. quadratarea A.S.	polyh.
P. ruttneri Hust.	o—h
P. stomatophora Mayer	o—h
P. streptoraphe Cl.	o—h
P. trevelyana (Donk.) Rabh.	polyh.
P. viridis (Nitzsch.) Ehr.	o—h
P. viridis v. sudetica (Hilse) Hust.	o—h
P. spp.	o—h
Plagiogramma staurophorum (Greg.) Heiberg	polyh.
Pleurosigma elongatum W.Sm.	mesoh. pol.
Podosira sp.	polyh.
Rhabdonema arcuatum (Lyng.) Kütz.	mesoh. pol.
R. minutum Kütz.	mesoh. pol.
Rhoicosphenia curvata (Kütz.) Grun.	mesoh. pol.
Rhopalodia gibba (Ehr.) O. Müll.	o—h
R. gibba v. ventricosa (Ehr.) Grun.	o—h
R. gibberula (Ehr.) O. Müll.	mesoh. pol.
R. operculata (Ag.) Håkansson	mesoh. pol.
Scoliopleura peisonis Grun.	mesoh. pol.
S. tumida (Bréb.) Rabenh.	mesoh. pol.
Stauroneis anceps Ehr.	o—h
S. anceps fo. gracilis Rabh.	o—h
S. anceps v. hyalina Brun. & Peragallo	o—h
S. gregorii Ralfs.	mesoh. pol.
S. kriegeri (Krieg.) Patrick	o—h
S. phoenicenteron Ehr.	o—h
S. smithi Grun.	o—h
Stephanodiscus astraea (Ehr.) Grun.	o—h
Stephanopyxis turris (Grev.) Ralfs.	polyh.
S. sp. fragm.	polyh.
Surirella striatula Turpin	mesoh. pol.
Synedra crystallina (Ag.) Kütz.	polyh.
S. gaillonii (Bory) Ehr.	polyh.
S. nana Meist.	o—h
S. pulchella (Ralfs.) Kütz.	mesoh. pol.
S. tabulata (Ag.) Kütz.	mesoh. pol.
S. ulna (Nitzsch.) Ehr.	o—h
Tabellaria fenestrata (Lyng.) Kütz.	o—h
T. flocculosa (Roth.) Kütz.	o—h
Thalassionema nitzschioides Grun.	polyh.
Thalassiosira decipiens (Grun.) Joergensen	polyh.
T. eccentrica (Ehr.) Cl.	polyh.
Trachyneis aspera (Ehr.) Cl.	polyh.
Tropidoneis vitrea (W.Sm.) Cl.	polyh.
T. sp.	polyh.

Observations on some diatom species, most of them (marked with*) not found earlier in Finland or in Rouhiala, East Karelia (USSR).

Amphora acuta Greg.* (Pl. IV, Fig. 6)
(Peragallo 1897—1908, p. 222, Pl. XLIX Fig. 26)
(Cleve-Euler 1953, p. 101, Fig. 696 a)
Ecology: polyhalobous, meioeuryhaline
Distribution: Frequent on the west coast of England and Scotland (Hendey 1964). Found in the basal part of the silt layer at Ollala.
Amphora arenaria Donk.* (Pl. IV, Fig 18)
(Cleve-Euler 1953, p. 103, Fig. 702)
(Hendey 1964, p. 268, Pl. XXXVIII, Figs. 13 and 14)
Ecology: polyhalobous
Distribution: Common on all North Sea shores. Encountered in the silt layer at Ollala.
Amphora crassa var. punctata A.S. (Pl. IV, Figs. 1—3)
(Peragallo 1897—1908, p. 208, Pl. XLVI, Fig. 8)
(Cleve-Euler 1953, p. 95, Fig. 676 a—c)
Ecology: polyhalobous, meioeuryhaline
Distribution: Marine-arctic, also common in warm-water marine conditions (Cleve-Euler 1953). Met with in the basal part of the Ollala silt layer. Found at Rouhiala, too (Brander 1937).
Amphora ocellata Donk.* (Pl. IV, Figs. 21—23)
(Clever-Euler 1953, p. 103, Fig. 702)
(Hendey 1964, p. 268, Pl. XXXVIII, Figs. 13 and 14)
Ecology: polyhalobous, meioeuryhaline
Distribution: Common on the coasts of most North Atlantic countries (Hendey 1964). Found in the basal part of the Ollala silt layer.
Amphora wisei (Salah) Simonsen* (Pl. IV, Figs. 13 and 14)
(Simonsen 1962, p. 94, Fig. 2)
Ecology: polyhalobous, meioeuryhaline
Dimension: In the Ollala material: length of valve 19—22 μm, breadth 4—6 μm.
Distribution: Encountered in the Ollala silt layer.

Campylodiscus angularis Greg. (Pl. IX, Fig. 9)
(Peragallo 1897—1908, p. 237, Pl. LI, Fig. 6)
(Cleve-Euler 1952, p. 127, Fig. 1574)
Ecology: polyhalobous
Distribution: Marine-arctic (Cleve-Euler 1952). Common in northern seas (Hendey 1964). Met with in the basal part of the Ollala silt layer. Found also at Rouhiala, Norinkylä and Hietakangas (Niemelä and Tynni 1979).
Campylodiscus fastuosus Ehr. (Pl. IX, Figs. 4 and 5)
(Syn. C. thuretii Bréb.)
(Hendey 1964, p. 290, Pl. XL, Fig. 13)
Ecology: polyhalobous, meioeuryhaline
Distribution: A common marine species, frequent on sandy beaches on all North Sea coasts (Hendey 1964). Encountered in the basal part of the Ollala silt layer. Found also at Evijärvi, Hietakangas, Norinkylä and Rouhiala.
Cocconeis clandestina A.S. (Pl. III, Figs. 16—18)
(Hustedt 1962, p. 331, Fig. 784)
(Cleve-Euler 1953, p. 4, Fig. 488)
Ecology: polyhalobous, mesoeuryhaline
Distribution: Littoral on coasts of northern Europe (Hendey 1964). Nordic-arctic form (Cleve-Euler 1953). Found also at Norinkylä. Met with in the basal part of the Ollala silt layer.
Cocconeis peltoides Hust.* (Pl. III, Fig. 13)
(Hustedt 1939, p. 606, Figs. 23—27)
(Brockmann 1950, p. 13, Pl. 6, Figs. 5 and 6)
(Hendey 1964, p. 181)
Ecology: polyhalobous, mesoeuryhaline
Distribution: Found mainly on European coasts (Simonsen 1962). A widely distributed littoral species commonly found attached to sand grains (Hendey 1964). Encountered in the Ollala silt layer.
Diploneis mediterranea (Grun.) Cleve* (Pl. V, Figs. 10 and 11)
(Hustedt 1962, p. 596, Fig. 1014)
Ecology: polyhalobous
Distribution: A common marine species, particularly in warm seas in Europe (Hustedt 1962). Found in the Ollala silt layer.
Diploneis notabilis (Grev.) Cleve* (Pl. V, Figs. 12 and 13)
(Cleve-Euler 1953, p. 74, Fig. 638)
(Hustedt 1962, p. 682, Fig. 1074)
(Hendey 1964, p. 224, Pl. XXXII, Fig. 11)
Ecology: polyhalobous
Distribution: Common on all coasts, even those with brackish water (Hustedt 1962). North Sea coasts, probably a warm-water form (Hendey 1964). Found in the upper part of the Ollala silt layer.
Diploneis papula (A.S.) Cleve* (Pl. V, Figs. 14 and 20)
(Cleve-Euler 1953, p. 67, Fig. 616 A)
(Hustedt 1962, p. 679, Fig. 1071)
Ecology: polyhalobous, mesoeuryhaline
Distribution: Common on the coasts of warm seas (Hustedt 1962). Found in the Ollala silt layer.
Diploneis schmidti Cleve* (Pl. V, Figs. 22 and 23)
(Hustedt 1962, p. 701, Fig. 1083)
Ecology: polyhalobous
Distribution: Common on European coasts (Hustedt 1962). Encountered in the basal part of the Ollala silt layer.
Diploneis subcinta (A.S.) Cleve (Pl. V, Figs. 7 and 8)
(Cleve-Euler 1953, p. 70, Fig. 630)
(Hustedt 1962, p. 680, Fig. 1072)
Ecology: polyhalobous, meioeuryhaline

Distribution: European coasts (Hustedt 1962). Found in the Ollala silt layer and also at Norinkylä, Nummijärvi and Hietakangas.
Diploneis suborbicularis (Greg.) Cleve (Pl. V, Figs. 21 and 24)
(Cleve-Euler 1953, p. 69, Fig. 626)
(Hustedt 1962, p. 612, Fig. 1026)
Ecology: polyhalobous, meioeuryhaline
Distribution: A warm-sea species frequent on European coasts from the Mediterranean to northern Europe (Hustedt 1962). Found in the Ollala silt layer.
Diploneis vacillans (A.S.) Cleve (Pl. V, Figs. 16—19)
(Cleve-Euler 1953, p. 81, Fig. 651)
(Hustedt 1962, p. 662, Fig. 1060)
Ecology: polyhalobous
Distribution: All coasts from the Mediterranean to the North Sea (Hustedt 1962). Found in the Ollala silt layer.
Navicula abrupta (Greg.) Donk. (Pl. VI, Fig. 3)
(Cleve-Euler 1953, p. 106, Fig. 711)
(Hustedt 1964, p. 516, Fig. 1558)
Ecology: polyhalobous, meioeuryhaline
Distribution: Marine, cosmopolitan. Encountered in the Ollala silt layer, at Rouhiala, the River Mga and Norinkylä.
Navicula arenaria Donk.* (Pl. VII, Figs. 2—4)
(Cleve-Euler 1953, p. 132, Fig. 763)
(Hendey 1964, p. 196, Pl. XXX, Fig. 15)
Ecology: polyhalobous
Distribution: A marine littoral species. Frequent on all North Sea shores and in the Baltic (Hendey 1964). Found in the Ollala silt layer.
Navicula cancellata Donk. (Pl. VII, Fig. 15)
(Cleve-Euler 1953, p. 132, Fig. 758)
(Hendey 1964, p. 203, Pl. XXX, Figs. 18—20)
Ecology: polyhalobous, mesoeuryhaline
Distribution: Common on the west coast of the British Isles, particularly on sandy beaches (Hendey 1964). Encountered in the Ollala silt layer.
Navicula directa (W.Sm.) Ralfs. (Pl. VII, Figs. 18 and 19)
(Cleve-Euler 1953, p. 129, Fig. 751)
(Peragallo 1897—1908, p. 90, Pl. XII, Fig. 6)
Ecology: polyhalobous, meio- to mesoeuryhaline
Distribution: Frequent on coasts of northern Europe. Often in North Sea plankton (Hendey 1964). Found in the basal part of the Ollala silt layer.
Navicula finmarchica (Cleve and Grun) Cleve* (Pl. VII, Figs. 5 and 6)
(Cleve-Euler 1953, p. 128, Fig. 746)
(Hendey 1964, p. 198, Pl. XXX, Fig. 5)
Ecology: polyhalobous, meioeuryhaline
Distribution: Marine-arctic (Clever-Euler 1953). Marine, littoral, North Sea coasts (Hendey 1964). Found in the Ollala silt layer.
Navicula ramosissima (Ag.) Cleve (Pl. VII, Fig. 10)
(Cleve-Euler 1953, p. 129, Fig. 7528)
(Hendey 1964, p. 194, Pl. XXX, Fig. 9)
Ecology: polyhalobous, mesoeuryhaline
Distribution: Common and widespread on almost any hard substratum on all coasts of northern Europe (Hendey 1964). Occurs in the Ollala silt layer.
Pinnularia cruciformis (Donk.) Cleve (Pl. VIII, Fig. 8)
(Brockmann 1950, p. 19, Pl. 5, Figs. 9 and 14)
(Hendey 1964, p. 232, Pl. XXXIV, Fig. 12)
Ecology: polyhalobous, meioeuryhaline
Distribution: Littoral around the North Sea (Hendey 1964). Found in the Ollala silt layer.

Pinnularia trevelyana (Donk.) Rabenhorst (Pl. VII, Figs. 6 and 7)
(Cleve-Euler 1955, p. 8, Fig. 978)
(Brockmann 1950, p. 19, Figs. 22 and 23)
Ecology: polyhalobous, meioeuryhaline
Distribution: Marine-littoral (Cleve-Euler 1955). Littoral on all shores around the North Sea (Hendey 1964). Found at Rouhiala and in the Ollala silt layer.

CONCLUSIONS

Diatoms of the Eemian Sea have been encountered at several localities within Finland and nearby areas, although often as redeposited. A fully marine diatom flora has been found from three sites: on the island of Suur-Prangli in the southern Gulf of Finland, at Evijärvi and Ollala, Haapavesi in Ostrobothnia. At Rova and Norinkylä the diatoms probably represent a less saline facies of the Eemian Sea.

The Eemian Sea was transgressive. The Eemian transgression has been recognised in Estonia (Liivrand 1984, 1987) but not in Finland. The initial stage of the Eemian Sea is visible only in the succession at Suur-Prangli, in which cool fresh-water diatoms intermixed with saline-water diatoms precede the marine stage proper. The marine species mentioned are *Actinocyclus ehrenbergii, Grammatophora* sp. and *Hyalodiscus scoticus* (Liivrand 1987). According to Liivrand (1987), the sea water started to invade the glacial lake at this stage.

The marine stage proper is characterized by an abundant diatom flora. Littoral diatoms, such as *Grammotophora oceanica, Hyalodiscus scoticus* and *Melosira sulcata,* dominate and true plankton species are almost totally absent. At the elevation of Ollala and Evijärvi the flora probably represents a littoral facies, although in the Suur-Prangli deposit the plankton species are in a minority. According to Liivrand (1987), in the Eemian Sea east of Suur-Prangli, the water was deeper and plankton diatoms thrived.

The Eemian Sea flora contained not only abundant Holocene species and warm-sea species alien to the present time but also diatoms of cold arctic waters. It is assumed that the Eemian Sea was connected to the Atlantic ocean and the White Sea.

Evidence for the isolation from the Eemian Sea is seen only in the Ollala (124 m a.s.l.) deposit. The Evijärvi deposit is at a lower level. Its present elevation is 67 m and that of the upper part of the silt about 59 m. According to the pollen stratigraphy, the Evijärvi deposit represents a later Eemian stage without clear evidence of isolation (Eriksson *et al.* 1980). The Suur-Prangli deposit is at such a low elevation that it was presumably in continuous connection with the Eemian Sea.

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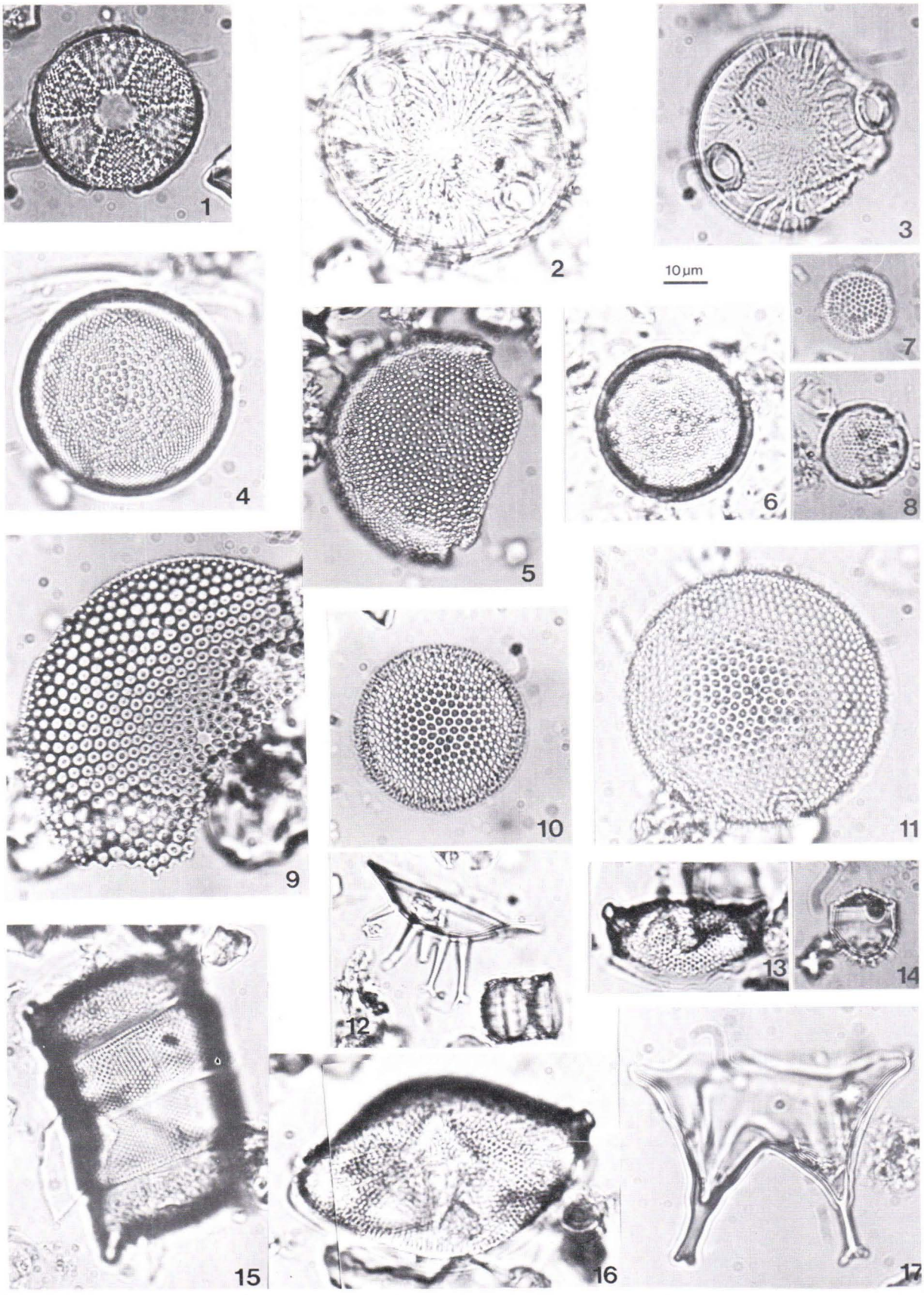

Plate I. 1. *Actinotyphus senarius,* 2. *Auliscus caelatus v. dissolutus,* 3. *Auliscus caelatus v. dissolutus,* 4. *Actinocyclus ehrenbergi,* 5. *Actinocyclus ehrenbergi,* 6. *Actinocyclus kützingi,* 7. *Thalassiosira oestrupii,* 8. *Thalassiosira decipiens,* 9. *Coscinodiscus oculus iridis,* 10. *Thalassiosira eccentrica,* 11. *Thalassiosira eccentrica,* 12. *Chaetoceros subsecundus, Melosira sulcata,* 13. *Biddulphia rhombus* fragm., 14. *Chaetoceros* sp. 15. *Biddulphia rhombus,* 16. *Biddulphia rhombus* fragm., 17. *Chaetoceros mitra.*

Plate II

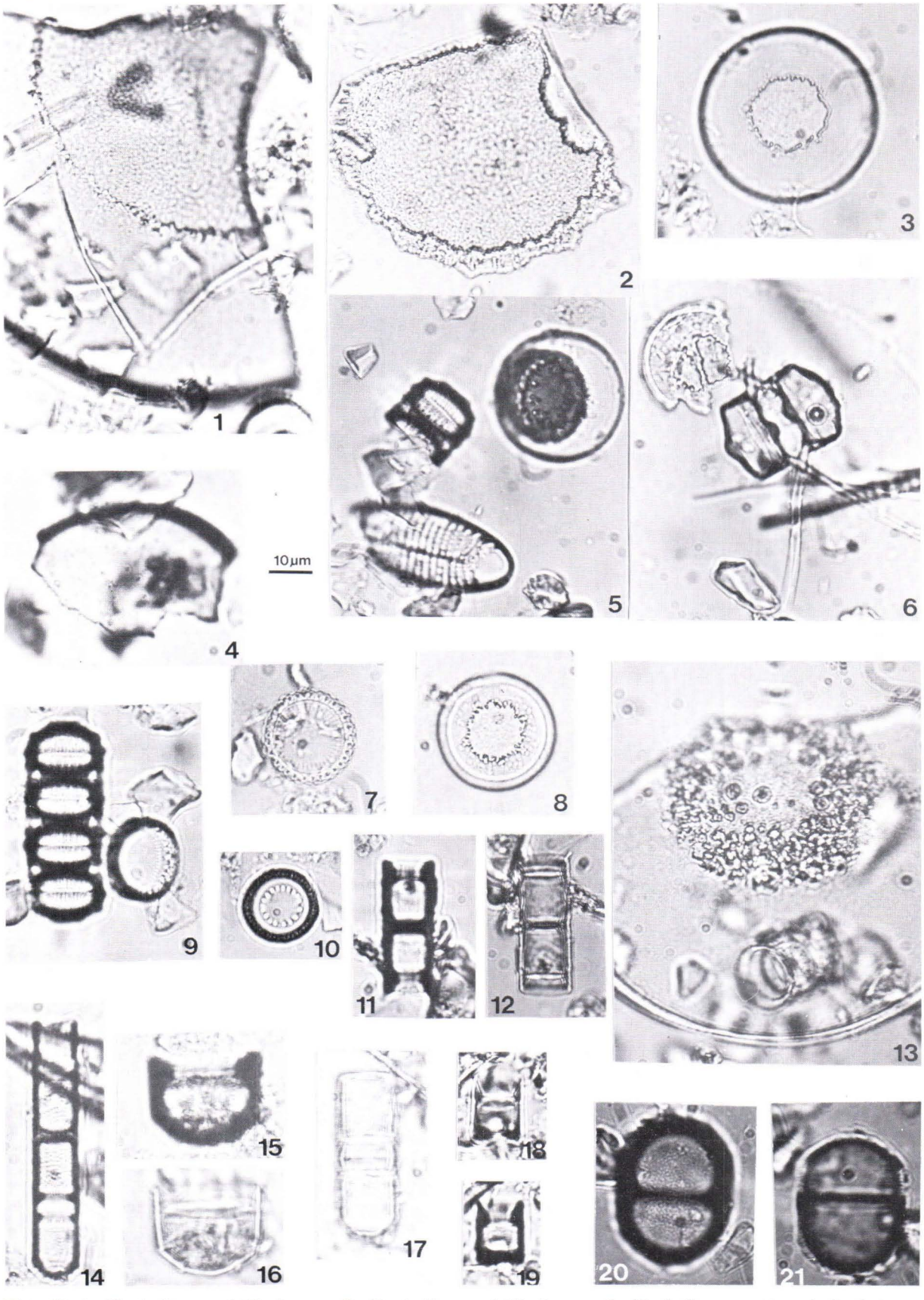

Plate II. 1. *Hyalodiscus subtilis* fragm., 2. *Hyalodiscus subtilis* fragm., 3. *Hyalodiscus scoticus* 4. *Podosira* sp. fragm., 5. *Rhabdonema arcuatum, Melosira sulcata, Hyalodiscus scoticus,* 6. *Hyalodiscus scoticus, Chaetoceros* sp., 7. *Melosira sulcata,* 8. *Hyalodiscus scoticus,* 9. *Melosira sulcata,* 10. *Melosira sulcata,* 11. *Melosira italica* fo. *laevis,* 12. *Melosira italica* fo. *laevis,* 13. *Hyalodiscus* sp. fragm., 14. *Melosira italica* fo. *laevis,* 15. *Melosira italica* fo. *laevis,* 16. *Melosira italica* fo. *laevis,* 17. *Melosira italica* fo. *laevis,* 18. *Melosira italica* fo. *laevis,* 19. *Melosira italica* fo. *laevis,* 20. *Melosira moniliformis,* 21. *Melosira moniliformis.*

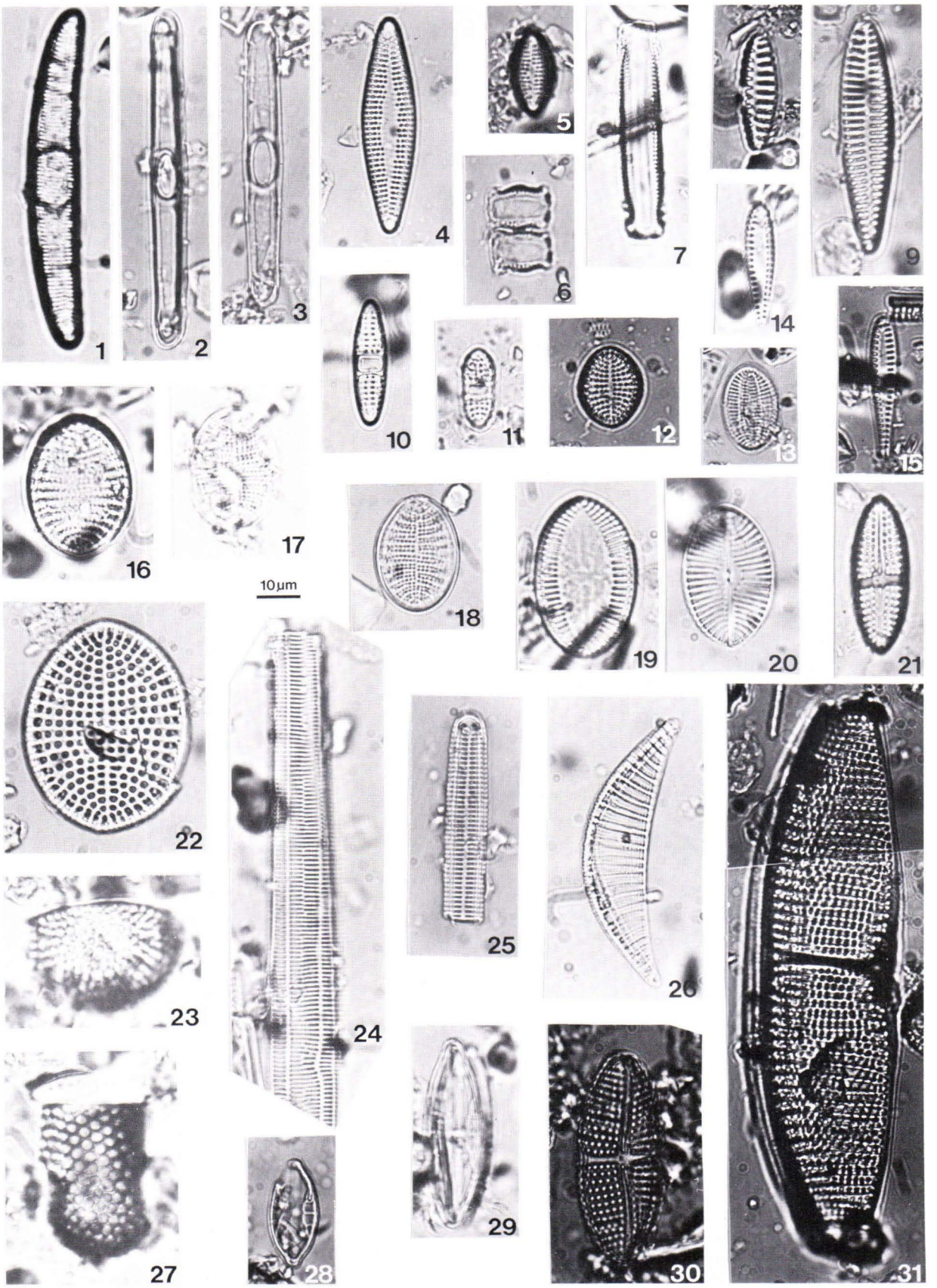

Plate III. 1. *Grammatophora arcuata*, 2. *Grammatophora oceanica*, 3. *Grammatophora oceanica*, 4. *Dimerogramma minor*, 5. *Dimerogramma minor*, 6. *Dimerogramma minor*, 7. *Dimerogramma fulvum*, 8. *Opephora schwartzii*, 9. *Opephora schwartzii*, 10. *Plagiogramma staurophorum*, 11. *Plagiogramma staurophorum*, 12. *Cocconeis scutellum* v. *parva*, 13. *Cocconeis peltoides*, 14. *Opephora marina*, 15. *Opephora marina*, 16. *Cocconeis clandestina*, 17. *Cocconeis clandestina*, 18. *Cocconeis clandestina*, 19. *Cocconeis quarnerensis*, 20. *Cocconeis quarnerensis*, 21. *Achnanthes brevipes* v. *intermedia*, 22. *Cocconeis scutellum*, 23. *Stephanopyxis turris*, 24. *Synedra crystallina* fragm. 25. *Synedra crystallina* fragm. 26. *Rhopalodia gibberula*, 27. *Stephanopyxis turris*, 28. *Mastogloia pumila*, 29. *Mastogloia pumila*, 30. *Achnanthes brevipes* v. *intermedia*, 31. *Achnanthes brevipes*.

Plate IV

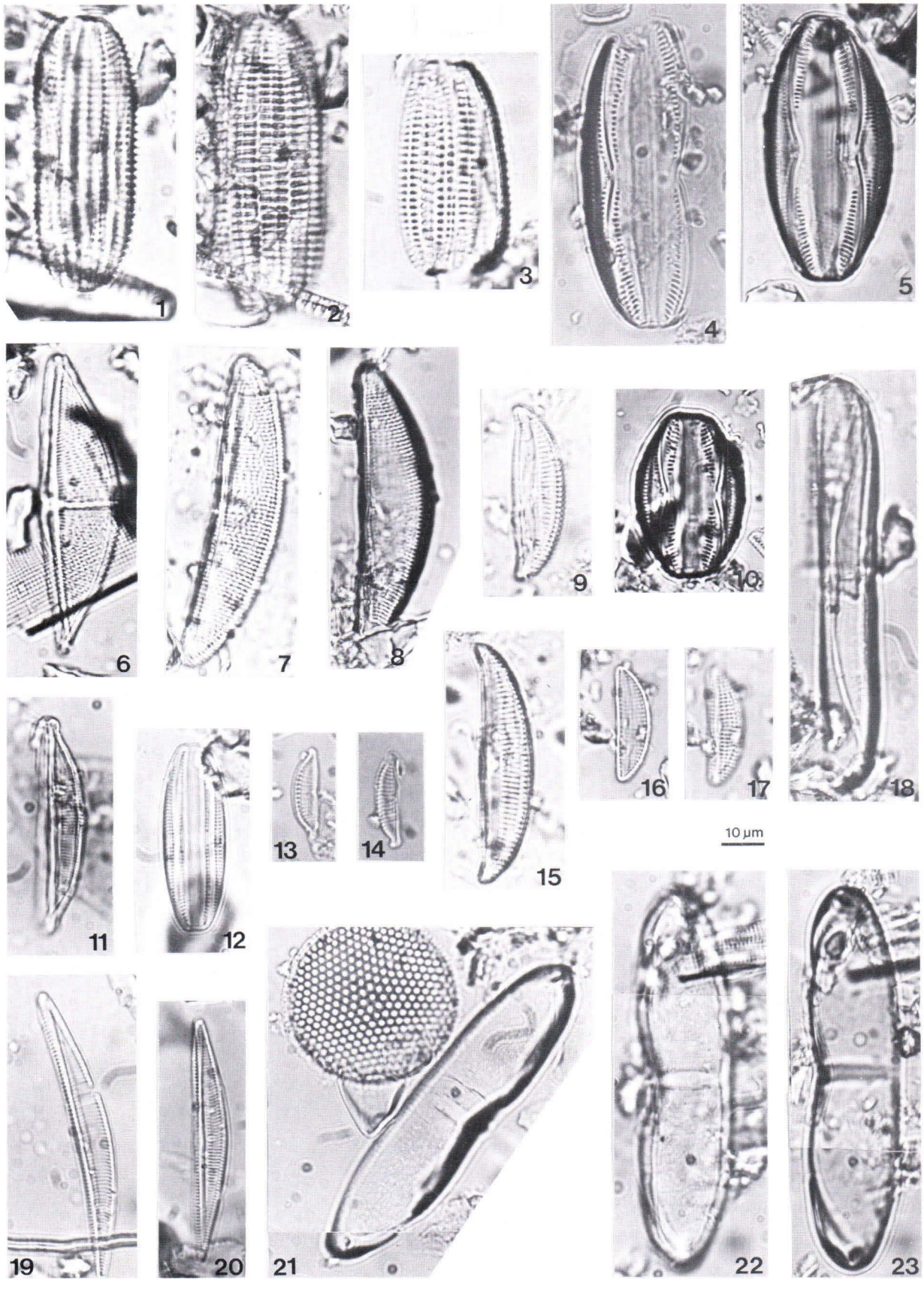

Plate IV. 1. *Amphora crassa* v. *punctata,* 2. *Amphora crassa* v. *punctata,* 3. *Amphora crassa* v. *punctata,* 4. *Amphora proteus,* 5. *Amphora proteus,* 6. *Amphora acuta,* 7. *Amphora* sp., 8. *Amphora* sp., 9. *Amphora commutata,* 10. *Amphora proteus,* 11. *Amphora coffeaeformis,* 12. *Amphora* sp., 13. *Amphora wisei?,* 14. *Amphora wisei?,* 15. *Amphora commutata,* 16. *Amphora* sp., 17. *Amphora* sp., 18. *Amphora arenaria,* 19. *Amphora angusta,* 20. *Amphora angusta,* 21. *Amphora ocellata, Thalassiosira eccentrica,* 22. *Amphora ocellata,* 23. *Amphora ocellata.*

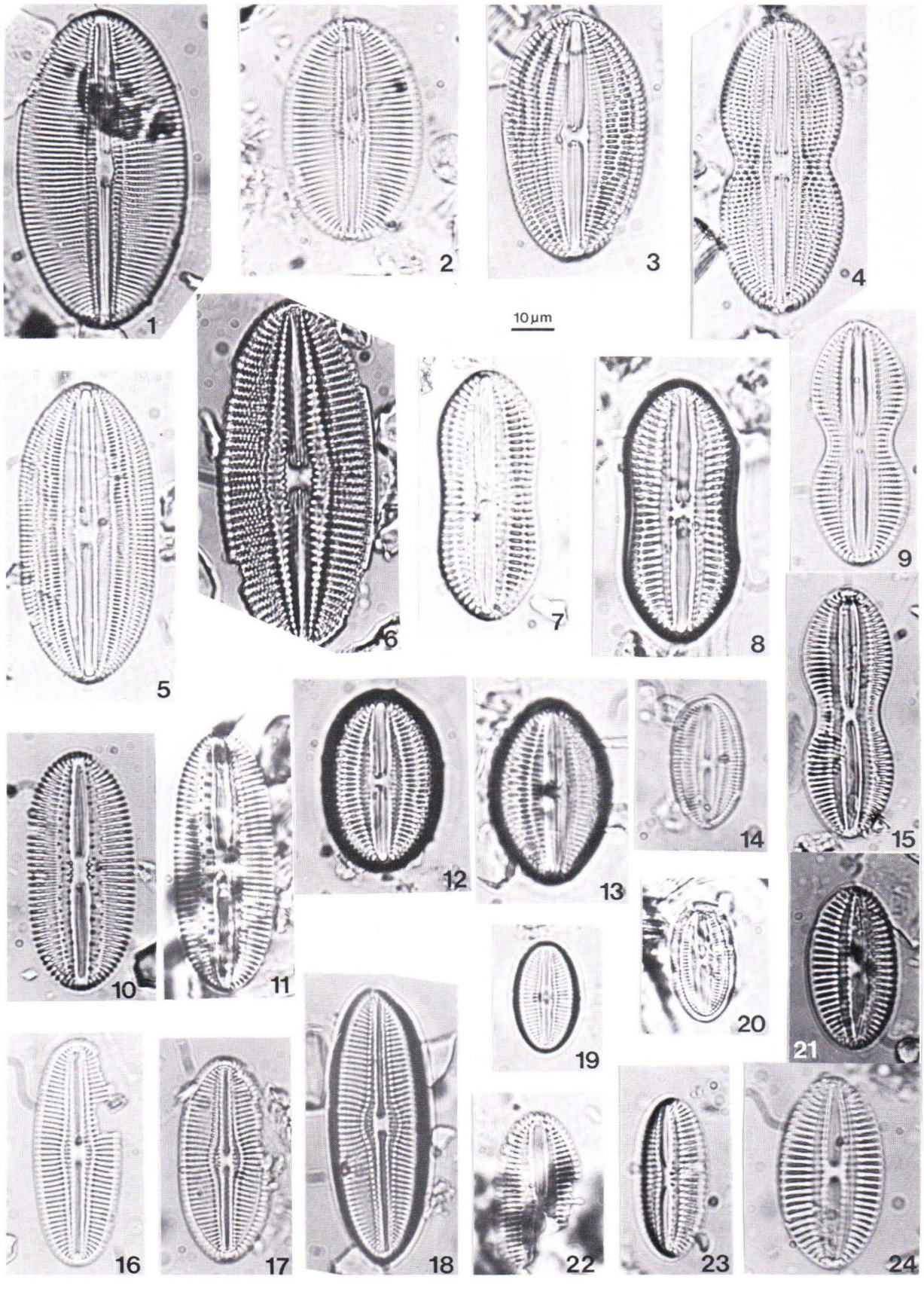

Plate V. 1. *Diploneis litoralis,* 2. *Diploneis litoralis,* 3. *Diploneis notabilis,* 4. *Diploneis didyma,* 5. *Diploneis notabilis,* 6. *Diploneis smithi,* 7. *Diploneis subcinta,* 8. *Diploneis subcinta,* 9. *Diploneis stroemii,* 10. *Diploneis mediterranea,* 11. *Diploneis mediterranea,* 12. *Diploneis notabilis,* 13. *Diploneis notabilis,* 14. *Diploneis papula,* 15. *Diploneis stroemii,* 16. *Diploneis vacillans,* 17. *Diploneis vacillans,* 18. *Diploneis vacillans,* 19. *Diploneis vacillans,* 20. *Diploneis papula,* 21. *Diploneis suborbicularis,* 22. *Diploneis schmidti,* 23. *Diploneis schmidti,* 24. *Diploneis suborbicularis.*

Plate VI

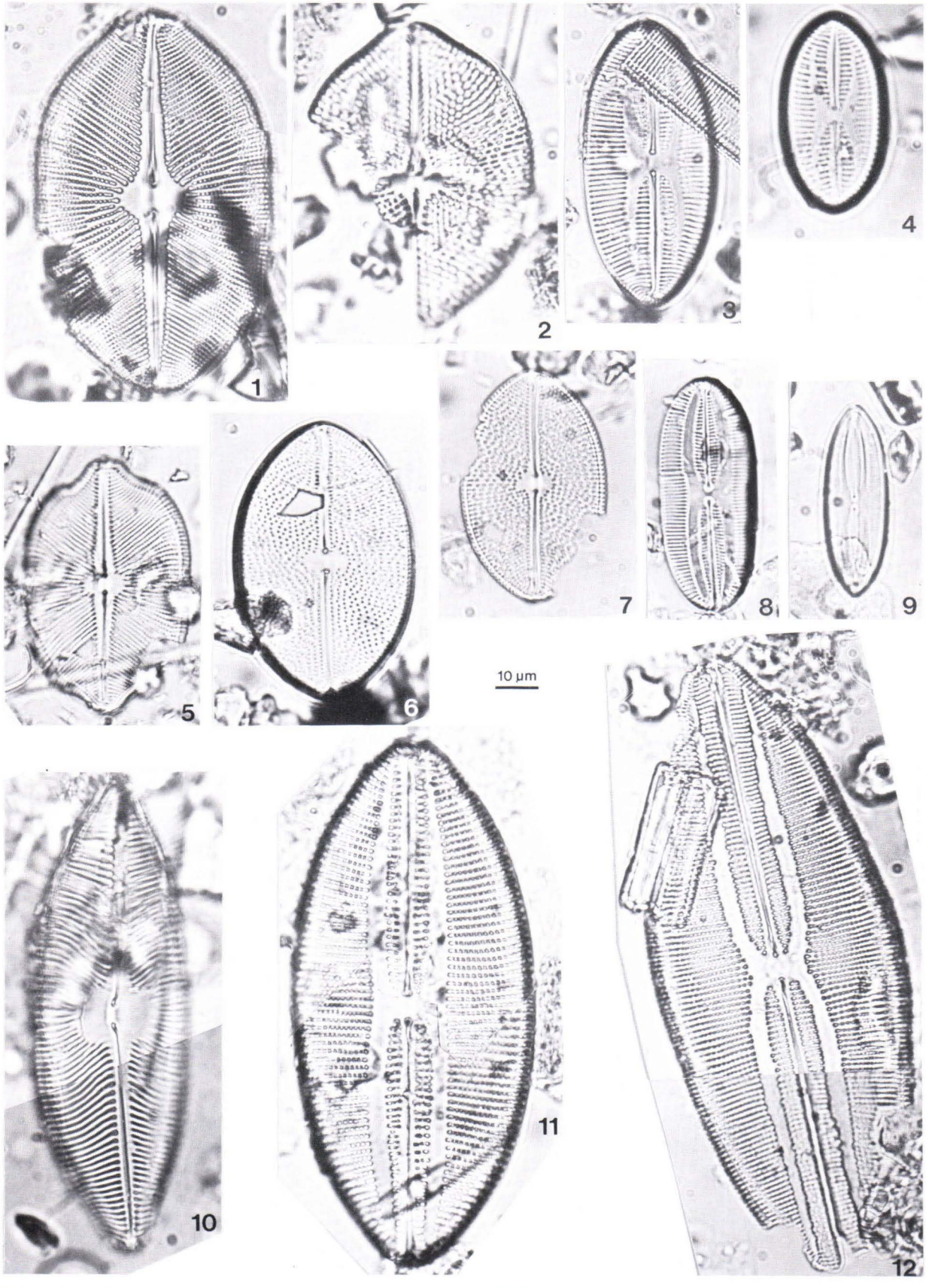

Plate VI. 1. *Navicula latissima,* 2. *Navicula granulata* fragm., 3. *Navicula abrupta,* 4. *Navicula abrupta,* 5. *Navicula latissima,* 6. *Navicula glacialis,* 7. *Navicula glacialis,* 8. *Navicula forcipata,* 9. *Navicula pygmaea,* 10. *Navicula elegans,* 11. *Navicula lyroides,* 12. *Navicula lyra.*

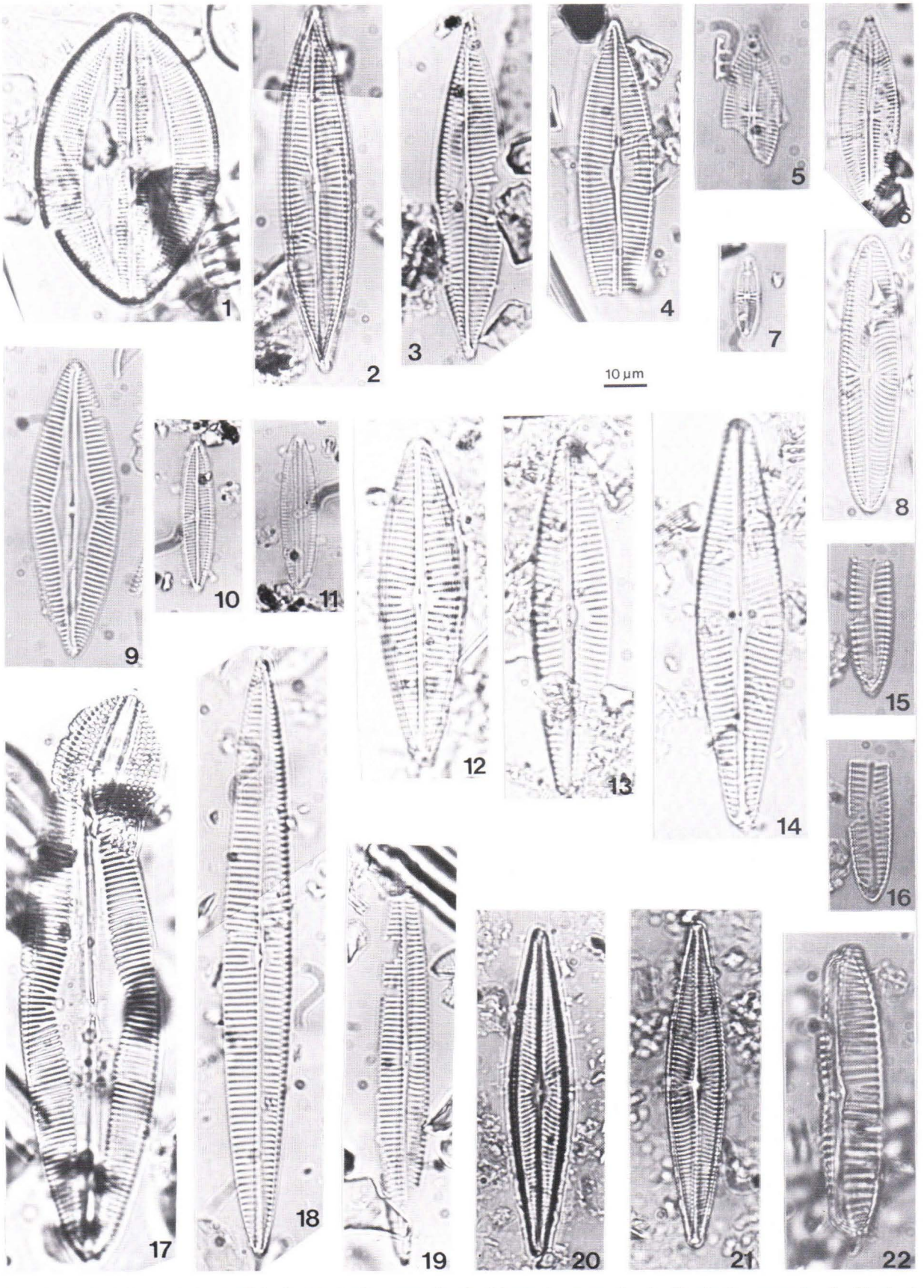

Plate VII. 1. *Navicula hennedyi,* 2. *Navicula arenaria,* 3. *Navicula arenaria,* 4. *Navicula arenaria,* 5. *Navicula finmarchica,* 6. *Navicula finmarchica,* 7. *Navicula* sp?, 8. *Navicula digitoradiata,* 9. *Navicula palpebralis,* 10. *Navicula ramosissima,* 11. *Navicula* sp., 12. *Navicula peregrina,* 13. *Navicula peregrina,* 14. *Navicula peregrina,* 15. *Navicula cancellata,* 16. *Navicula cancellata,* 17. *Navicula palpebralis,* 18. *Navicula directa,* 19. *Navicula directa,* 20. *Navicula radiosa,* 21. *Navicula radiosa,* 22. *Navicula cancellata.*

Plate VIII

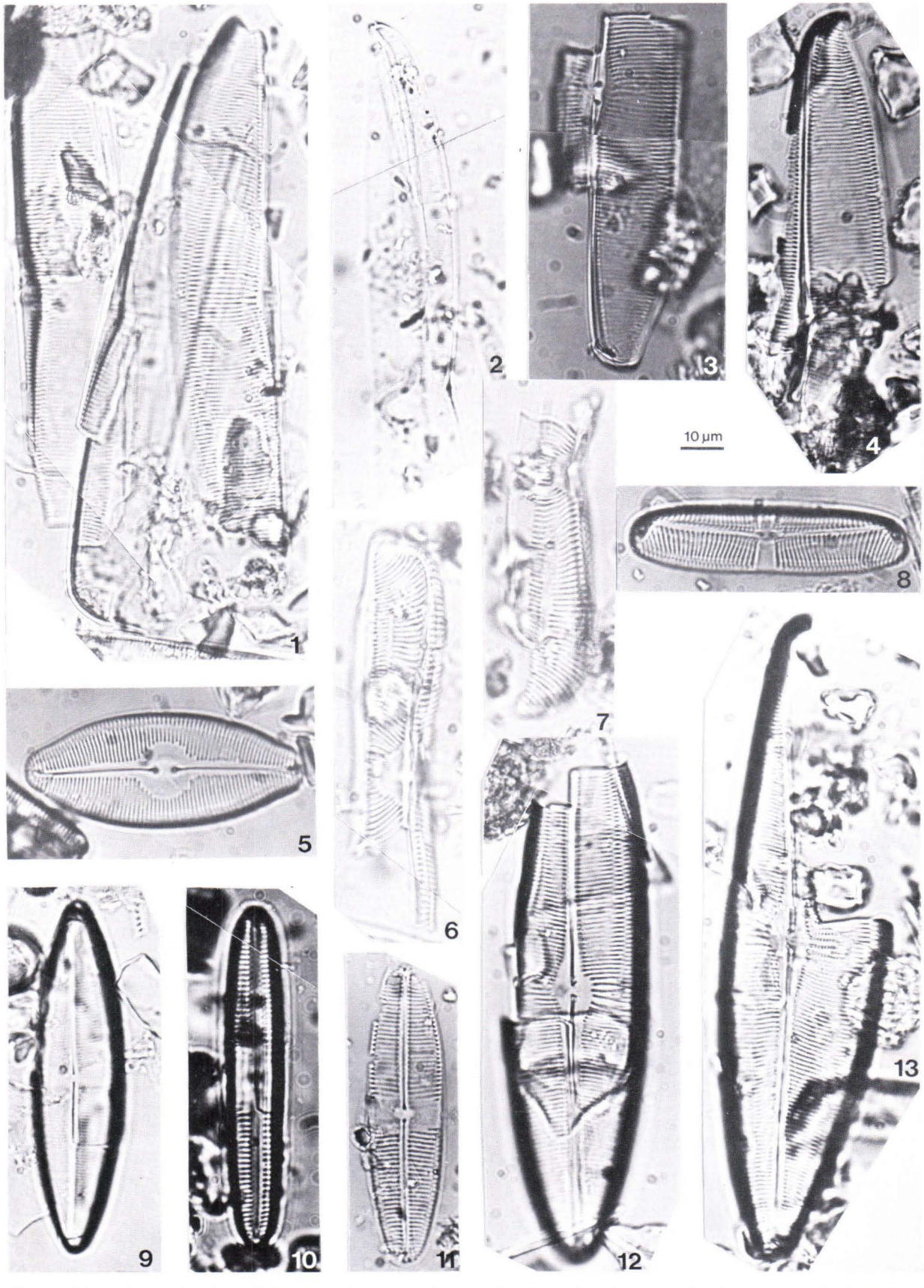

Plate VIII. 1. *Navicula plicata?*, 2. *Tropidoneis* sp. fragm., 3. *Navicula plicata?*, 4. *Navicula plicata?*, 5. *Caloneis brevis*, 6. *Pinnularia trevelyana* fragm., 7. *Pinnularia trevelyana* fragm. 8. *Pinnularia cruciformis*, 9. *Stauroneis gregorii*, 10. *Pinnularia quadratarea*, 11. *Pinnularia quadratarea*, 12. *Scoliopleura tumida*, 13. *Scoliopleura tumida*.

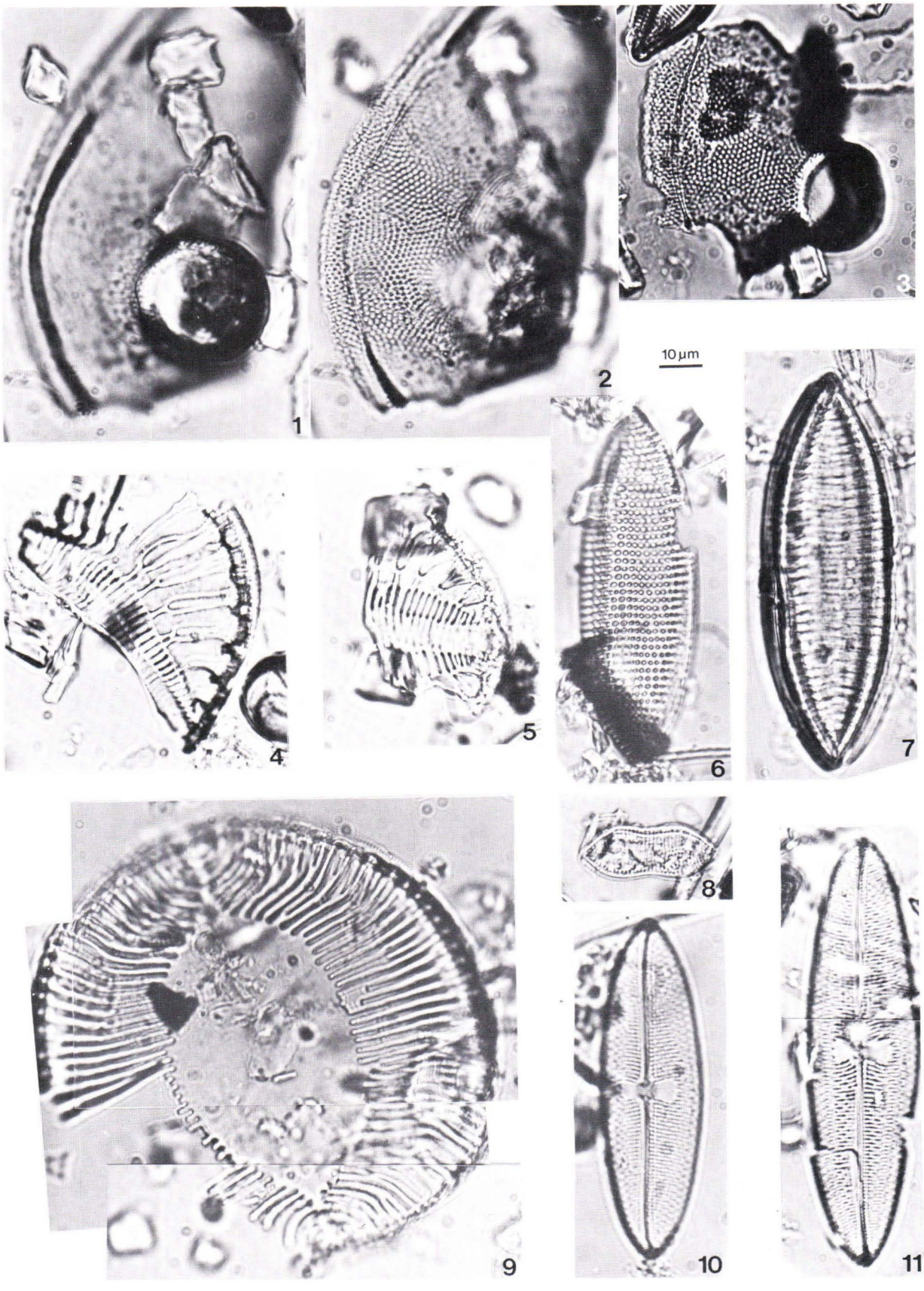

Plate IX. 1. *Cerataulus turgidus* fragm., 2. *Cerataulus turgidus* fragm., 3. *Cerataulus turgidus* fragm., 4. *Campylodiscus fastuosus* fragm., 5. *Campylodiscus fastuosus* fragm., 6. *Nitzschia punctata,* 7. *Nitzschia tryblionella,* 8. *Nitzschia constricta,* 9. *Campylodiscus angularis,* 10. *Trachyneis aspera,* 11. *Trachyneis aspera.*

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