Geological Survey of Finland

Bulletin 320

The reflection of geological evolution in Tertiary and interglacial diatoms and silicoflagellates in Finnish Lapland

by Risto Tynni

Geologinen tutkimuslaitos
Espoo 1982

Geological Survey of Finland, Bulletin 320

THE REFLECTION OF GEOLOGICAL EVOLUTION IN TERTIARY AND INTERGLACIAL DIATOMS AND SILICOFLAGELLATES IN FINNISH LAPLAND

by

RISTO TYNNI

with 6 figures in the text and 21 plates

GEOLOGINEN TUTKIMUSLAITOS
ESPOO 1982

Tynni, R., 1982. The reflection of geological evolution in Tertiary and interglacial diatoms and silicoflagellates in Finnish Lapland. *Geological Survey of Finland, Bulletin 320,* 40 pages, 6 figures and 21 plates.

Tertiary diatoms and silicoflagellates are described from four observation sites located in central Lapland. An occurrence of clay found on the slope of Akanvaara at an elevation of 205 meters is a relict of a more extensive clay bed deposited in a marine environment during the early part of the Tertiary period. Presumably, an arm of the sea streched at the time from the Arctic Ocean via the Inari lake basin into central Lapland. The peneplane occurring in central Lapland rose during the late Tertiary, possibly in connection with block movements, some 100–200 m.

Diatom studies lend support to the view of a marine regression during the Tertiary period as well as of the prevalence of fresh-water basins during the Miocene and the Pliocene in Lapland. The diatomite situated between till beds at Naruskajärvi contains many late-Tertiary species. The stratum can thus be regarded either as primary or a redeposition dating from the Quaternary.

During the last or the previous Quaternary interglacial stage, saline- and brackish-water diatoms and silicoflagellates were deposited in the Siurunmaa region.

Key words: Diatoms, silicoflagellate, regression, interglacial, Tertiary, Quaternary, Lapland, Finland

Risto Tynni
Geological Survey of Finland
SF-02150 Espoo 15, Finland

ISBN 951-690-161-1
ISSN 0367-522X

CONTENTS

INTRODUCTION

Noteworthy results on the study of Tertiary diatoms were achieved already during the last century. It was in 1863 that Heiberg made public the diatom research done on the Moler formation of the Lower Eocene in Denmark. Considering the great activity in diatom research during the last century, not until recently has the intensive study of Tertiary diatoms been resumed. This is probably in part due to improvements in drilling equipment and, in particular, to modern deep sea coring, which has yielded abundant material for diatom and silicoflagellate research. Comparisons made between numerous marine series and with previously known deposits on land have shed light on Tertiary stratigraphy based of old on paleontological evolution. The importance of diatoms and silicoflagellates as a dating method has simultaneously increased.

The first to pay attention to the Tertiary diatom forms present in Quaternary deposits in the region of Lapland was Cleve-Euler (1915, 1951). In connection with intensified studies on Quaternary deposits in northern Finland, a number of places were located where Tertiary diatoms existed (Hirvas, Kujansuu, Tynni 1976, Grönlund 1977). The most remarkable discovery was made at an elevation of c. 205 m on the north slope of Sankavaara, in the Akanvaara area: a Tertiary clay slab approximately 80 centimeters thick. In the preliminary report an Eocene age was proposed (Hirvas & Tynni 1976). A more detailed description of this material is a central portion of the present work.

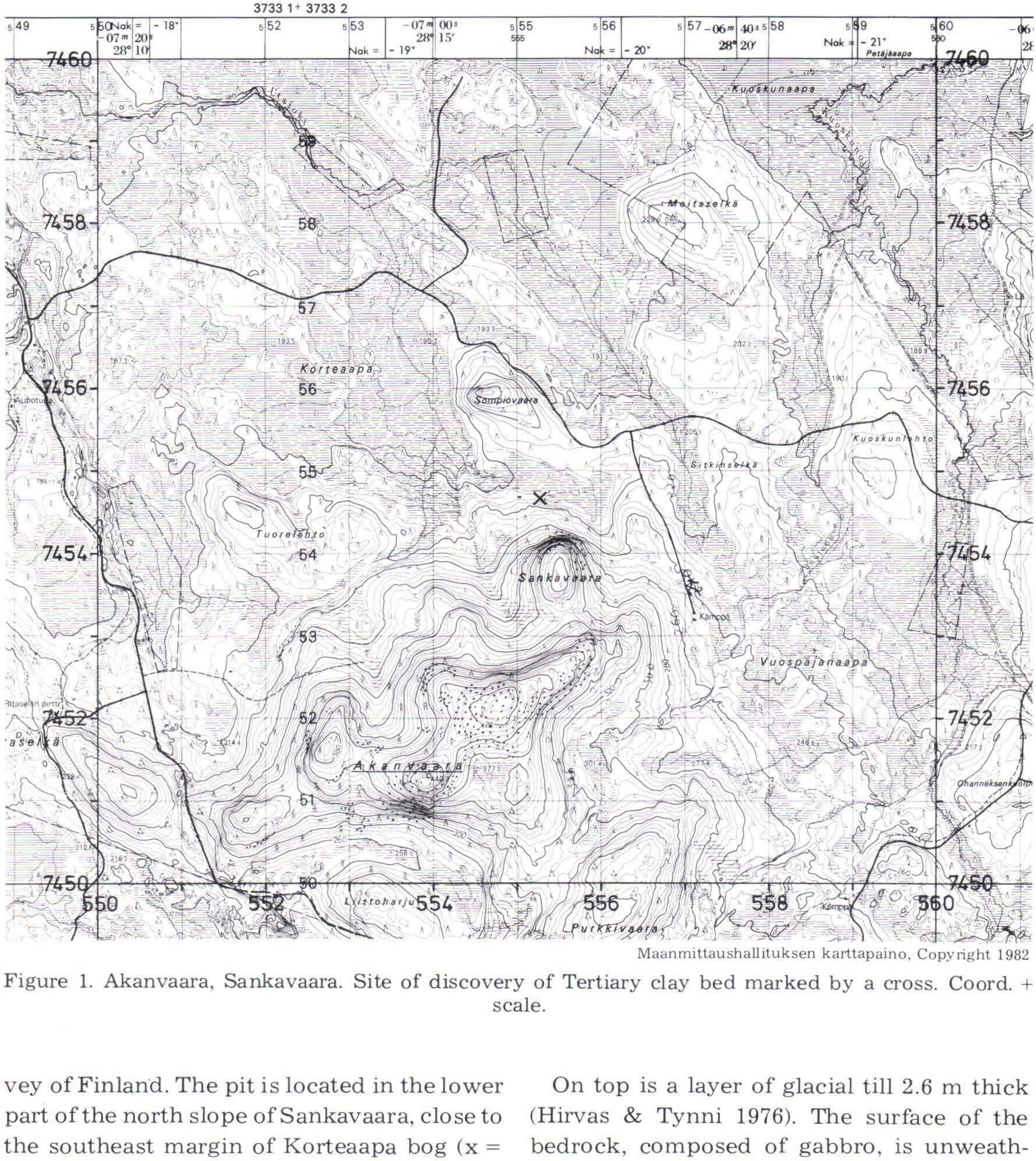
The early Tertiary dating of the Akanvaara clay is substantiated by the occurrence of certain silicoflagellate species among, for example, the diatomites of Mors and Fur in Denmark (Perch-Nielsen 1976) as well as in Paleocene-Eocene deposits drilled in the Atlantic Ocean (Bukry 1978).

It has previously been noted that also Neogene fresh-water diatom species occur in Finnish Lapland (Hirvas & Tynni 1976, Tynni 1977). A more definite concentration of fresh-water forms is found in an intercalation in glacial till at Naruskajärvi. In most of the cases cited, the Tertiary diatom component is rather meager as well as unsorted. A unique occurrence is one located on top of a fairly thick kaolin deposit in the lower part of the till bed at Siurunmaa (Hyyppä 1977). The diatom flora includes both fresh- and saline-water forms. The saline-water forms are similar to those found in marine Eem-sediments. It should be added that some Tertiary species were also observed.

OBSERVATION SITES

Akanvaara, Savukoski

The pre-Quaternary clay lens in the parish of Savukoski, eastern Finnish Lapland (Figure 1), was discovered in 1974, in a test pit dug with an excavator in connection with field work carried out by the Department of Quaternary Deposits of the Geological Sur-



Maanmittaushallituksen karttapaino, Copyright 1982

Figure 1. Akanvaara, Sankavaara. Site of discovery of Tertiary clay bed marked by a cross. Coord. + scale.

vey of Finland. The pit is located in the lower part of the north slope of Sankavaara, close to the southeast margin of Korteaapa bog (x = 7454.69, y = 555.26). The elevation is c. 205 m above sea level. The stiff symmictic clay is bluish of color when fresh and exhibits a vague banding. Postdepositional deformation is indicated by many cracks occasionally filled with sand. The clay also contains sporadic pebbles.

On top is a layer of glacial till 2.6 m thick (Hirvas & Tynni 1976). The surface of the bedrock, composed of gabbro, is unweathered. Fig. 2 presents a schematic drawing of the deposits.

According to Juho Hyyppä's clay-mineral studies, the Akanvaara clay differs clearly in composition from the Quaternary clays of Finland. It contains kaolinite and montmorillonite. These circumstances lend support to

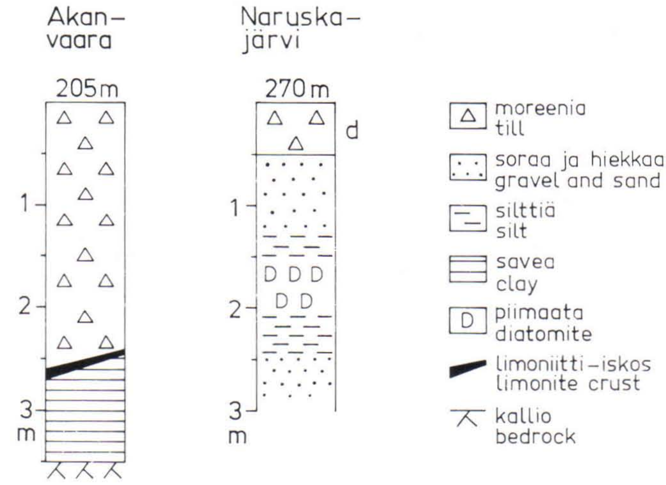


Fig. 2. Deposits of Akanvaara and Naruskajärvi represented schematically.

the view based on microfossil research that this clay is of pre-Quaternary origin rather than being a Quaternary clay deposit containing redeposited microfossils.

The clay deposit found in the pit is probably the remains of a clay bed formed in the Korteaava basin. Evidently, nearby Sankavaara, which rises to some 100 m above the surrounding, has protected the site area from total erosion. The bottom sediments of Korteaava consist of glacial till, which is situated directly on top of unweathered bedrock. This was ascertained by the drillings carried out by the Geological Survey in 1979. The weathered surface of the bedrock is rather generally visible in road cuts at the highest points in dells at Akanvaara. The foregoing circumstances indicate that the glacial erosion was strongest in low lying depressions.

The preserved clay deposit is located about one kilometer to the north-northwest from the summit of Sankavaara (345 m a. s. l.). The trend of the moraine topography created by the last glaciation is northwest-southeast. The ice sheet advanced from the northwest; hence the clay deposit on the proximal side was preserved.

The north slope of Sankavaara is steep and covered with boulders along a belt between the elevations of about 320–260 m. The 260-m elevation is a culmination point, and it is not impossible that it corresponds to a pre-Quaternary shore stage.

Naruskajärvi, Salla

In eastern Finnish Lapland, on the southeast side of Naruskajärvi, there occurs at a depth of c. 2 m, underlying a bed of glacial till, a deposit of diatomaceous earth approximately 50 cm thick.

It contens late-Tertiary microfossils (Hirvas & Tynni 1976, Hirvas *et al.* 1977, Tynni 1977). The diatomite deposit (x = 7478.30, y = 472.84) is located in a fairly flat, low-lying (270 m above sea level) area between hilly slopes (Fig. 3). On the eastern side lies the open, watery sedge-bog of Kotatsiaapa and on the western side flows Naruskajoki. Roughly four kilometers farther to the south,

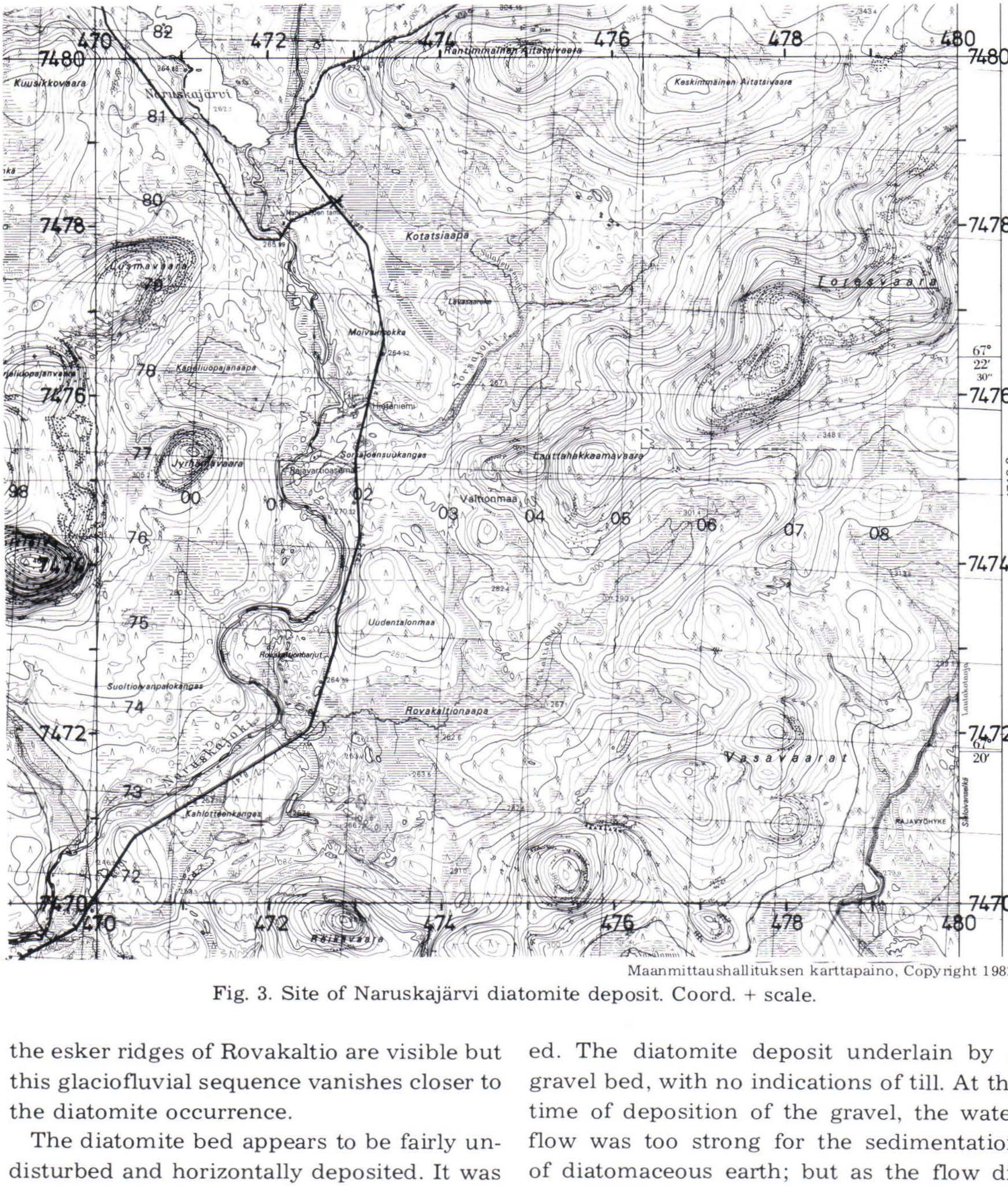


Fig. 3. Site of Naruskajärvi diatomite deposit. Coord. + scale.

the esker ridges of Rovakaltio are visible but this glaciofluvial sequence vanishes closer to the diatomite occurrence.

The diatomite bed appears to be fairly undisturbed and horizontally deposited. It was observed in the excavator pit at a depth of about 2 m and as a thinner stratum some 60 m farther south at a depth of 80 cm in the roadside ditch. The bed is obviously locally derived but whether it is the result of primary or secondary deposition cannot be ascertained. The diatomite deposit underlain by a gravel bed, with no indications of till. At the time of deposition of the gravel, the water flow was too strong for the sedimentation of diatomaceous earth; but as the flow diminished in strength, diatomite could have accumulated either by redeposition or as a primary deposit.

About 2.5 km to the south from the diatomite occurrences, on the bank of the Sorsajoki, which runs into the Naruskajoki, there occurs a deposit of silt / fine sand with an abundant content of diatoms: including *Hydrosera trifoliata* forms, found also in the diatomite. This shows the significance of postglacial river transportation in the migration of diatoms. In the case of the diatomaceous earth at Naruskajärvi, the small proportion of minerogenic material, despite the rather strong topographic relief in the area, speaks against a redeposition of the diatomite sediment, unless had occurred in a frozen state.

Värriöjoki, Salla

A postglacial silt sample taken from the Värriöjoki valley, north of the preceding observation site, contained *Hydrosera trifoliata*, which is known as a Tertiary form, as well as certain marine species known to have existed as early as the Tertiary period. The observation site is located on the south side of Mujuvaara (x = 7496.10, y = 472.90) at an elevation of about 257 m. The secondary origin of the postglacial deposit in question is apparent from its depositional attitude. The Värriöjoki silt sample was subjected to closer examination in connection with the mapping of the surficial deposits of Talkkunapää under the direction of Heikki Hirvas. We subsequently joined forces to drill the bottom sediments of a number of bog basins for the purpose of observing the secondary Tertiary component; but this work did not lead to any significant results.

Sivakkapalo, Kolari

At Sivakkapalo (x = 7487.17, y = 497.90), located at an elevation of about 200 m on the south side of Rautuvaara, there occurs a gyttja deposit between layers of glacial till. Present in the deposit are fresh-water diatoms, including Tertiary forms. In a study under preparation by Hirvas, the Quaternary stratigraphy of the Sivakkapalo sequence is discussed. I was requested to examine the diatom preparations made from his samples for the possible identification of types that are strange to the present-day flora.

The diatom forms met with are to some extent identical to the late Tertiary fresh-water species that occur farther east in Finnish Lapland. On the other hand, marine Tertiary species have not, at least as yet, been met with in western Finnish Lapland.

Siurunmaa, Sodankylä

Located in central Finnish Lapland, Siurunmaa is flat, paludified country. In 1971, seventeen auger drillings were carried out under the direction of Sakari Leskelä over a distance of eight kilometers alongside a road running east-west. All the observation points lie below the 200-m level. In the drill-core samples, the soil is mostly sand of fine or medium grades, with sporadic till occurrences. A new drilling was done in 1976 close to the deepest of the previous drill sites, and there a kaolin deposit was found at a depth of 28.0–43.5 m (Hyyppä 1977). The coordinates of the observation site are: x = 7485.15, y = 497.12.

The microfossil analyses made from the

sediment samples of Siurunmaa showed that the fine-sand-bearing sediment contains diatoms which are partly equivalent to those species found in Tertiary formations while other species are typically found in Eem sediments in the Pohjanmaa (Bothnian) region (Niemelä & Tynni 1979).

The preservation of the kaolin deposit is evidence of weak glacial erosion. The kaolin deposit has not become mixed with till, which indicates that possible glacial transport was never significant. The bottom sediments in the bedrock depression have escaped erosion. The marine diatom fossils are younger than the time of formation of the kaolin deposit. The formation of the kaolin as a weathering product took place above water level, and after that the kaolin was never redeposited in a biologically active water basin, for no organic remains are to be found in the kaolin.

TERTIARY DIATOM AND SILICOFLAGELLATE BIOSTRATIGRAPHY

A comparison between the Tertiary diatom fossils found to date in Finnish Lapland and the species occurring elsewhere in better-known Tertiary deposits reveals that the forms in Lapland consist of at least two types differing in age and ecological growth requirements. These types are to be seen most distinctly in the formations of Akanvaara and Naruskajärvi. These types are found as rare occurrences in fine-grained interglacial and late-glacial sediments of the ice-divide area.

Paleogene marine stage (Akanvaara)

The utilization of selected Tertiary diatoms for biostratigraphic zoning is still being developed (Schrader & Fenner 1976). Useful in zoning are relatively short-lived index species. On the other hand, the significance of the long-lived species is slight. For the most part, the diatoms contained in the Akanvaara clay belong to the class of long-lived forms. The dominant species, *Melosira sulcata* (var. *siberica* and var. *biseriata*), has persisted from the early Tertiary to the present day.

Present also, however, are *Trinacria pileolus*, *Hemiaulus polycystinorum*, *H. polymorphus*, and *Eunotogramma variabile*, which all had only a comparatively short existence during the early Tertiary period. The Akanvaara clay contains certain fresh-water forms the origin of which is not known for sure. The deformation of the clay suggests the possibility of a secondary origin of the fresh-water forms, although the possibility of river transport cannot be ruled out.

The quantity of silicoflagellates in the Akanvaara clay is small, though significant, for included among the fossils are certain key species on which the silicoflagellate zoning is based. Among them, *Naviculopsis minor* (Schulz) Frenguelli is a late Paleocene species, although its occurrence extends to the Oligocene period (Bukry 1976). *Corbisema inermis minor* (Gleser) Bukry is mainly Paleocene but can extend all the way to the Middle Eocene (Bukry 1978). The fact that this species is found in the Akanvaara clay is a further indication of a marine deposition in early Tertiary as deduced on the basis of the diatom flora.

Neogene fresh-water stage (Naruşkajärvi)

With respect to the species represented in it, the diatomite occurrence at Naruskajärvi does not deviate as distinctly from the flora of the present time, for the majority of the species are the same. According to Wornardt (1969), between 30 and 85 per cent of the principal Neogene marine forms exist even at present. Among fresh-water forms the proportion of species preserved is even higher. Examples of Miocene fresh-water assemblages commonly containing modern type Pennatae-group species are described by, among others, Andrews from Nebraska (Andrews 1970, 1971).

The number of species known so far only from Tertiary deposits is so large at Naruskajärvi that the relict occurrence of these forms is not likely. The most characteristic of the species is *Hydrosera trifoliata* Cleve 1881 (Tynni 1977), and it has previously been reported as occurring in, for instance, a Middle Pliocene deposit in France (Lauby 1910). Other species known in Finland as Tertiary forms are: *Melosira canadensis* Hustedt 1952, *Tetracyclus cruciformis* Andrews 1970, *Fragilaria triangulata* Moisseva 1964, *Actinella brasiliensis* Grunov.

At Naruskajärvi the state of preservation of strange forms is no worse than that of common types and therefore the diatoms cannot be divided on this basis into components of different ages. It is probable that all the species contained in the diatomite belong to the late Tertiary, more specifically the Pliocene or Miocene period. In the following are presented the species occurring at Naruskajärvi as a whole – which share features in common with the diatom forms described by Krasske (1934) from the Miocene deposits in the Hessen region, by Andrews (1970, 1971) from the early and late Miocene deposits of Nebraska, and by Rehakova (1965, 1969) from the Pliocene and Miocene deposits of Czechoslovakia.

INTERGLACIAL DIATOM FLORA

A number of biogenic deposits situated between layers of glacial till are known in Finnish Lapland. These deposits have been interpreted to be formations dating from the last Eemian interglacial. From the standpoint of diatom research, the most important diatom occurrence in addition to the one at Naruskajärvi is the Sokli occurrence (Ilvonen 1973). The species consist of fresh-water forms, of which the common ones include *Fragilaria construens* + v. *binodis*, *Stephanodiscus astraea* + v. *minutula*, *St. hantzschii* (Ilvonen, *op. cit.*). The proportion of Tertiary forms in this diatomite deposit could not be determined, the type being altogether different from the Naruskajärvi occurrence.

During the survey of surficial deposits in connection with ore prospecting in northern Finland, a number of intercalations dating from the last interglacial stage were found to occur in the till (Hirvas *et al.* 1977). These layers contained almost exclusively fresh-water diatom forms of postglacial type. Quite a few cases of minor redeposited occurrences of Tertiary diatoms were observed in till, various intercalations and in late glacial deposits (Grönlund 1977). The redeposition of Tertiary microfossils is to be expected in the Lapland area on account of weak glacial erosion. On the other hand, Tertiary forms are scarcely to be met with farther south in Finland.

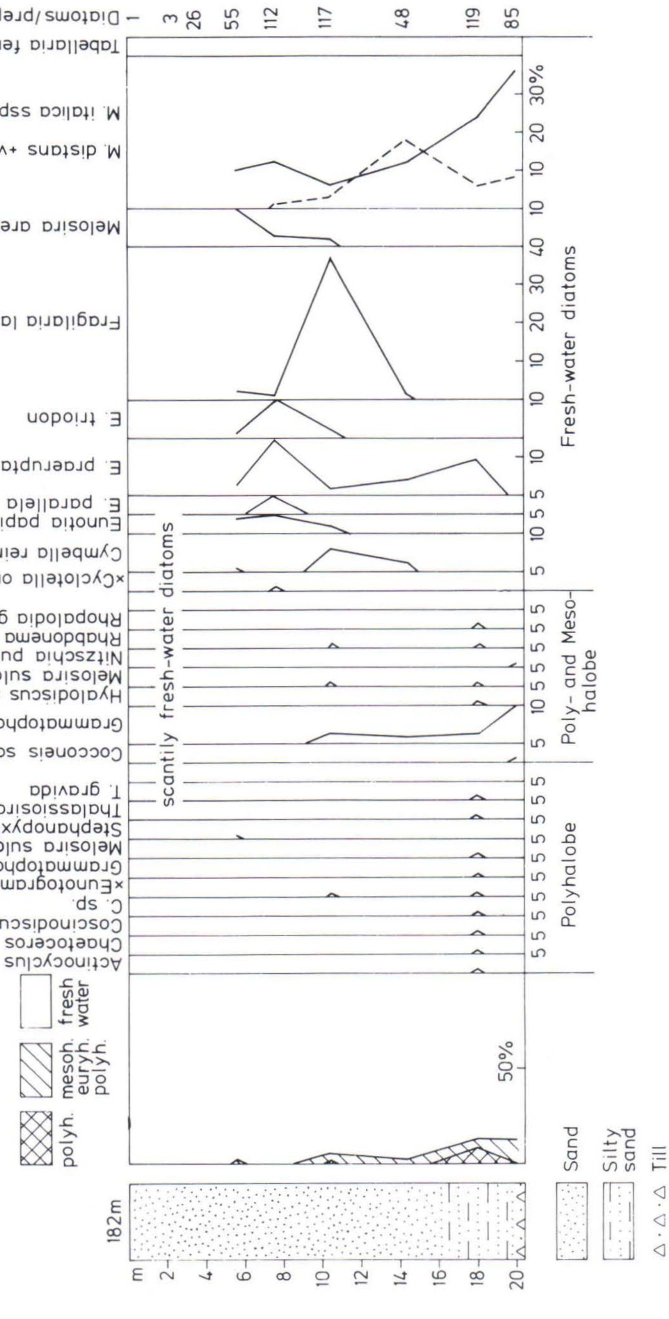


Fig. 4. Siurunmaa, drill hole No. 101, diatom diagram.

Heinonen (1957) found the glacial till in Fennoscandia to contain pre-Quaternary and interglacial microfossils, mainly pollen grains and spores. Some typical Tertiary forms have been met with in interglacial deposits in the region of Pohjanmaa (Niemelä & Tynni 1979). On the Karelian Isthmus, the clay stratum likewise contains Tertiary mic-

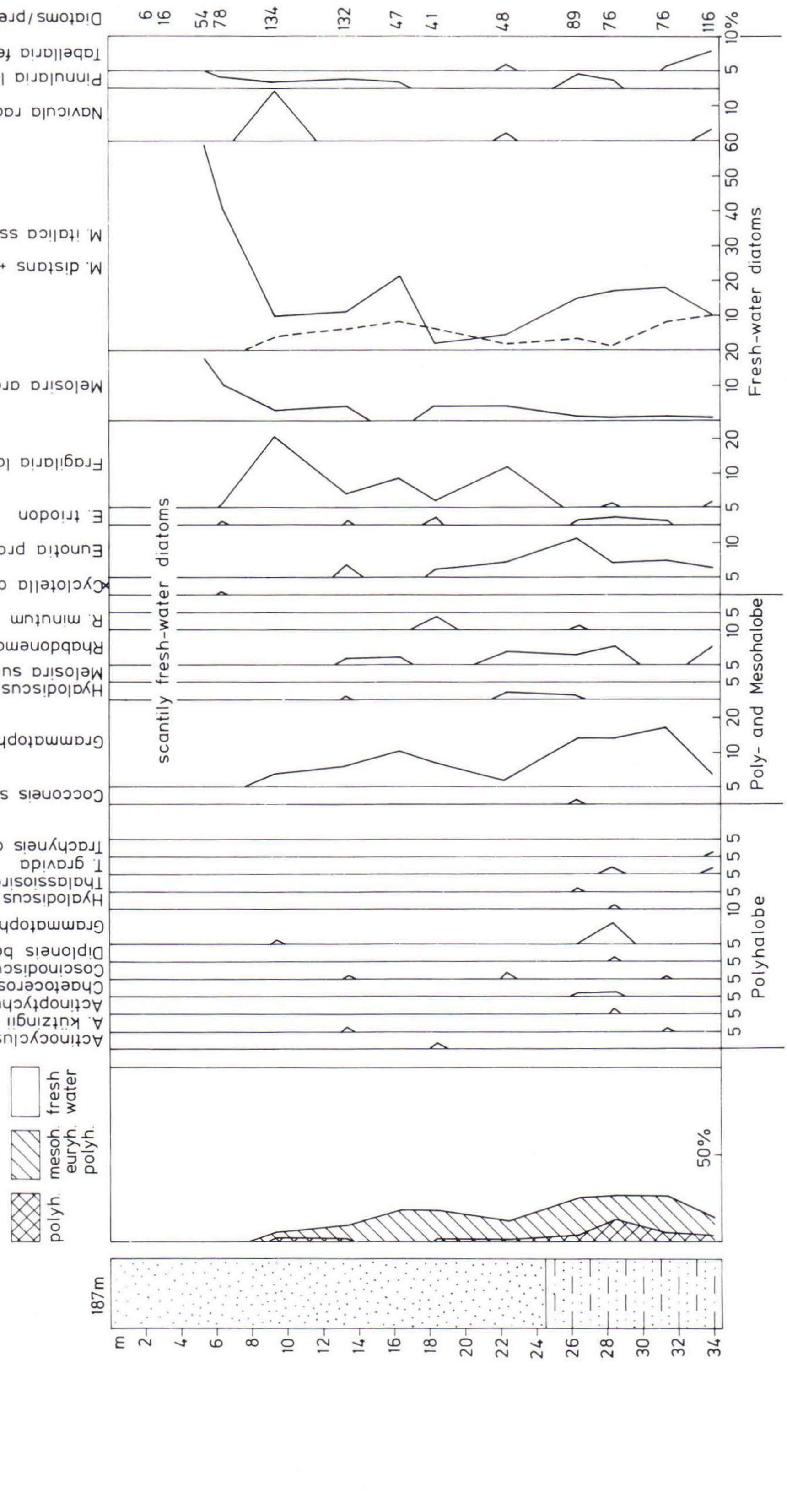


Fig. 5. Siurunmaa, drill hole No. 103, diatom diagram.

rofossils (Suomalainen & Tynni 1970). According to Eriksson (1977), the palynomorph material met with in Quaternary deposits in southern Finland dates to some extent from the early Pleistocene or late Tertiary period.

The diatom- and silicoflagellate species contained in the predominantly fine-sand deposit met with at Siurunmaa, Sodankylä, are the targets of more detailed examination in the following. In this deposit a mixed flora was observed.

Both fresh-water diatoms as well as forms characteristic of the Eem sea and saline water dating back to the Tertiary could be distinguished. The phenomenon suggests two alternative explanations: either the Eem sea extended at Sodankylä to a height of c. 200 m above present sea level, or the earlier interglacial sediment of the Quaternary period underwent redeposition. The effect of the regional glacial erosion was relatively slight (p. 10).

Characteristic of the diatom composition of the late-glacial minerogenic series of layers at Siurunmaa is the fact that in the upper part of the deposit only fresh-water small lake forms are present. Close to the surface, the diatoms are exceedingly sparse. Deeper down, above the till deposit, the sediment is silt-bearing fine sand and represents the finest-grained portion of the series of strata. Here the quantity of diatoms including also saline- and brackish-water forms is greater than elsewhere. In Figs. 4 and 5 are to be seen the most salient diatom features of the deepest drill holes, Nos. 101 and 103 (Sakari Leskelä's drillings).

In the coarser upper part of the deposit, fresh-water diatoms reflect late-glacial and present-day sedimentation environments. The genera *Cymbella*, *Eunotia*, *Fragilaria* and *Melosira* compose the maximum. Most of the species are well preserved; *Fragilaria lapponica* often occurs as colonies. No clear boundary with the lower, finer-grained deposit occurs; but there the type of flora is different, with the proportion of marine forms rising at the point marked by drill hole 103 to 26 %. With respect to species, the flora strikingly resembles the marine flora of the interglacial deposits of the Bothnian region (Niemelä & Tynni 1979). Also present are Tertiary forms, and in the following the subject will be dealt with in more detail. The hydrographic situation of the time of deposition will be considered separately later on.

Marine diatom flora and silicoflagellate observations made at Siurunmaa

The marine flora observed in the deepest part of the basin at Siurunmaa, marked by hole 103, appears in the main in the diatom diagram reproduced in Fig. 5. The groups of polyhalobes and mesohalobes + euryhaline polyhalobes selected in the grouping of diatoms is based on Simonsen's (1962) classification. More exactly classified, the polyhalobes here comprise oligoeuryhaline and meioeuryhaline polyhalobes, which require a salinity of at least 17–29 ‰. By the category of mesohalobes and eurohaline polyhalobes is here meant brackish-water forms and those salt-water forms capable of tolerating salinity variations requiring a minimum salinity of 0.2 ‰. During the postglacial period, the diatom flora of the marine stages of the Finnish coastal Baltic Sea consisted almost exclusively of mesohalobes and euryhaline polyhalobes.

The notable proportion of polyhalobes proper (> 17 ‰ salinity) indicates a more open connection with the ocean than in the case of the present inland sea type represented by the Baltic. At drill hole 103 in the Siurunmaa area, the proportion of polyhalobes at a depth of 28.3 m reaches 13 %, with *Grammatophora arcuata* most prevalent (6 %). *G. arcuata* belongs, according to Cleve-Euler (1940), to arctic key forms. This group also includes *Thalassiosira gravida* and *Trachyneis aspera*. The same species occur in, among other places, the so-called Portlandia marine deposits of the south Baltic Sea as well as in samples from Rouhiala and the Mga river (Brander 1937). According to Cleve-Euler (*op. cit.*), Portlandia and the Eem sea are of the same age and the differences appearing in the diatom flora depend on local conditions. To an even greater extent than during the last interglacial stage, cold-water forms became prevalent in the region of the preceding Leda pernula sea in Denmark (Østrup 1900, Cleve-Euler 1940).

Following are other species of polyhalobes in the sediments of Siurunmaa: *Actinocyclus ehrenbergii*, *A. kützingii*, *Actinoptychus senarius*, *Chaetoceros* sp., *Coscinodiscus symbolophorus*, *C.* sp., *Diploneis bombus*, *Hyalodiscus subtilis*, *Melosira sulcata* v. *sibirica*, *Plagiogramma staurophorum*, *Stephanopyxis turris*, *Thalassiosira eccentrica*. These species occur to this day in sufficiently saline water, but some of them are also typical contents of Tertiary deposits. A rarity present in the Siurunmaa sediment is *Eunotogramma variabilis*, characteristic of the early part of the Tertiary. It is a secondary form, one that did not grow simultaneously with the foregoing species. In association with the fresh-water forms there also occurs the Tertiary *Cyclotella omarensis*, which has also been met with in interglacial deposits in the Pohjanmaa region.

Saline- and brackish-water forms occur in the silt-bearing fine sand of Siurunmaa to an extent twice or thrice greater than salt-water forms proper. The commonest are *Grammatophora oceanica* and *Rhabdonema arcuatum*, and less common *Campylodiscus clypeus*, *Cocconeis scutellum*, *Hyalodiscus scoticus*, *Melosira sulcata* (small form), *Nitzschia punctata*, *Rhabdonema minutum*, *Rhopalodia gibberula*. The same species occur also in postglacial sediments of the Baltic Sea as well as in interglacial marine deposits in the Pohjanmaa region (Niemelä & Tynni 1979), indicating comparatively low local salinity.

Present in the silt-bearing fine sand of Siurunmaa are silicoflagellates, too, although scantily. Among the species found, *Dictyocha* sp. (*fibulá* Ehr.) and *Distephanus speculum* Ehr. occur in, for instance, interglacial marine deposits of Pohjanmaa (Niemelä & Tynni *op. cit*). On the other hand, a third species met with, *Corbisema minor* (Schulz) Perch-Nielsen (1975), is a Tertiary form. It has been described from an Eocene deposit in Denmark as well as from late Eocene deposits drilled in the South Pacific Ocean (Perch-Nielsen 1975). *Distephanus speculum* represents at Siurumaa a rather short-prickled form. A similar form is the commonest type in Pliocene and Pleistocene deposits of the South Pacific Ocean (Perch-Nielsen, *op. cit.*). The beginnings of the occurrence of *Dictyocha fibula* can also be traced back to the Tertiary period.

TERTIARY AND QUATERNARY EVENTS IN FINNISH LAPLAND

The diatom- and silicoflagellate composition of the Akanvaara clay suggest an Eocene or Oligocene age. Material of a different age has possibly also become mixed in the deposit. In any case, the deposit can be regarded as belonging to the early part of the Tertiary, the Paleogene. At that time, the sea extended deep into the region we now know as Lapland. In the area of Akanvaara, the shore of the Tertiary sea possibly reached an elevation some 260 m above present sea level.

Mikkola (1932) assumes notable displacements in Lapland during the Tertiary visible today as valleys and topographic depressions. Mikkola's view that in the southwestern part of the Laanila area in central Lapland the variations in elevation diminish from Hangasselkä in a southwesterly direction and the terrain changes into a typical peneplain is also supported by Penttilä's (1963) observations. The height of the peneplain at Vuomaselkä is 280 m above sea level. It tilts from this point toward the Gulf of Bothnia c. 1 m per km (Mikkola *op. cit.*, Penttilä *op. cit.*). The formation of a peneplain presupposes an elevation close to sea level. The region of the peneplain rose, according to Mikkola, at a relatively late date – estimated to be the late Tertiary – from 100 to 200 m higher. The basis for the estimation of a young rise is the advance of the erosion situation only to its initial stage.

Besides local movements of the earth's crust, variations in the level of the sea influenced the paleogeographic conditions. The curve drawn by Fairbridge (1964) showing the progressive retreat of the oceans from the continental platforms shows that relatively large areas were covered by water at the beginning of the Tertiary period, a decreasing trend during the middle Tertiary, a slight rising trend at the end of the Tertiary followed by a notable decrease into the situation prevailing during the Quaternary period. Corresponding to the maxima of the rising trends are strong sedimentations of limestone (climatic optima) and to the minima, glaciations.

The situation in Lapland during the Tertiary period probably is explained by the evolutionary stage of the Bothnian Bay at

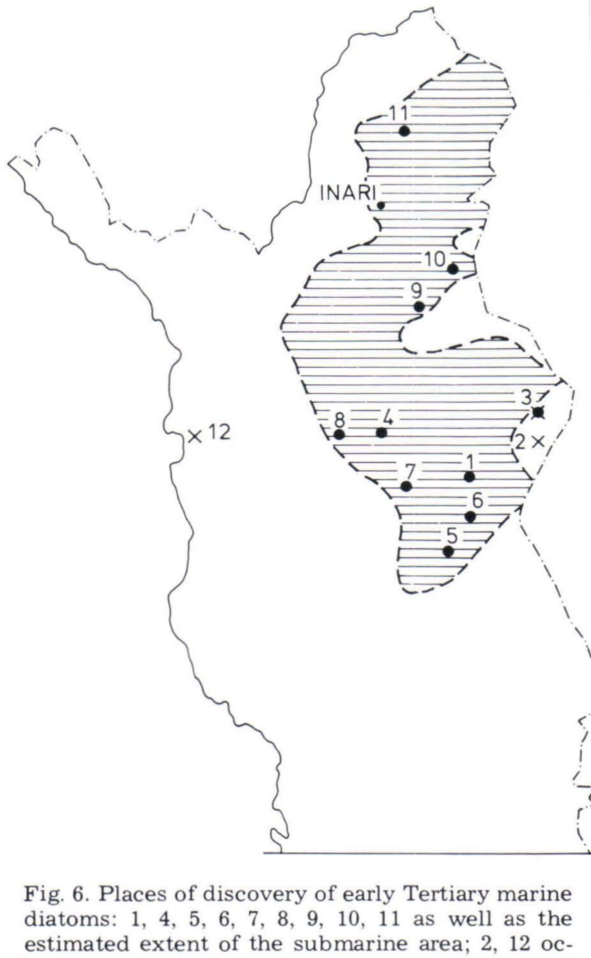


Fig. 6. Places of discovery of early Tertiary marine diatoms: 1, 4, 5, 6, 7, 8, 9, 10, 11 as well as the estimated extent of the submarine area; 2, 12 occurrences of late Tertiary fresh-water diatoms; 3, 4 late glacial sediments containing late glacial, Eem-interglacial-type and Tertiary diatoms.

that time. The basin was then considerably smaller than it is today, judging by the ancient river valleys, which extended roughly 80 m below the present sea surface. What is now the north end of the Gulf of Bothnia was at that time possibly a lake, which discharged its waters into the Bothnian Sea (cf., Winterhalter 1972, Tulkki 1977). With this in mind it is possible that central Lapland had a marine connection not via the Bothnian Bay but more directly with the Arctic Ocean.

The clay of Akanvaara in Finnish Lapland requires that during the time of sedimentation there existed stretches of dry land exposed to erosion during early Paleogene. Movements did not, however, take place during the Tertiary period in the area of the North Sea between the Mid-Norwegian Shelf and the Lofoten island group, where strata broken up by Mesozoic faults are overlain by undisturbed Tertiary deposits in the places where offshore oil exploration has been conducted (Oftedahl 1980). Postglacial faults have been observed in Lapland (Kujansuu 1964). The faults were probably caused by isostatic uplift.

Fig. 6 shows the places in Finnish Lapland (Grönlund 1977, accompanying study) where the Tertiary marine diatoms so far known have been found as well as the estimated extent of the Paleogene sea. A large part of the occurrences consist of glacially redeposited material, but in the areas of the ice divide the transport distances are short. The paleogeographic map is intended to serve only as a rough presentation. Early Tertiary marine diatom forms and flagellates have also been run across in Sweden, but precise information on the places where they occur is not available (Cleve-Euler 1941).

In late Tertiary, during the Miocene and Pliocene, the sea receded from the Lapland area and lakes formed in topographic depressions. The sediments containing freshwater diatoms that had become deposited in fresh waters were not wholly destroyed by erosion later on. The diatomite deposit underlying the glacial till at Naruskajärvi is probably a primary deposit or then it was glacially transported in a frozen state to its present location. The diatomite occurrence originally transported by the ice sheet and preserved in the Haapajärvi esker (as described by Aario, 1966) may be analogous in the mode of formation to the deposit at Naruskajärvi.

In the Siurunmaa region, the sea during the Quaternary period covered vast stretches of territory now dry land. During some intermediary stage of the glaciations, the surface of the sea was some 200 m above present sea level. The more exact dating of this stage remains for later studies to work out. On the basis of the types of occurrence of diatoms and silicoflagellates, the last or next to the last interglacial stage would seem to be possible. The former alternative appears to be the more likely one.

TAXONOMY

The clay of Akanvaara

The diatom flora met with in the clay of Akanvaara is rather scanty, besides which it is composed to a large extent of fragments. On account of the abundance of fragments and the rarity of certain forms, a substantial part of the diatoms has remained unidentified as to species. Apparently, furthermore, a considerable proportion of the diatom shells deposited as sediment was likely to have been reduced to an unrecognizable fragmentary powder or to have dissolved without leaving a trace of the original forms. For these reasons, the variety of species described is restricted probably representing only the more common and thicker-shelled forms. The possibility must nevertheless be taken into account that the number of species was limited in the first place. A situation of this kind seems to be the case in the Paleocene stratum of the Indian Ocean, where, according to Mukhina (1974), 90.5 % of all the species belong to three genera: *Hemiaulus* Ehr., *Stephanopyxis* Ehr. and *Trinacria* Heib.

In the identification of species, the bases of comparison used have been principally the descriptions in Schmidth's Atlas as well as those in many more recent publications dealing with Tertiary diatoms. Noteworthy among them are: Cleve-Euler & Hessland 1948 and Miller 1966, which describe diatoms found in Tertiary deposits in the Åhus region of southern Sweden; Benda's investigations of diatoms in the Eocene deposits of northern Germany (Benda 1965) and Denmark; Schrader and Fenner's (1976) study on the diatoms found in Cenozoic drill-core samples from the Norwegian Sea; Fenner's (1977) study on the Cenozoic diatoms of the South Atlantic and the equatorial region; Gleser, Jousé, Makarova, Proschkina-Lavrenko (Ed.), Sheshukova-Poretzkaja in a compilation (1974) dealing with Tertiary diatom species in Soviet Union.

The distribution of marine species was extensive also during the Tertiary, as revlealed by the diatom flora of distant areas. In the Tertiary deposits of California (Hanna 1927, Kanaya 1957), the region of the Arctic Ocean (Grunow 1884) and the Indian Ocean, some of the species found are the same as in the clay of Akanvaara. In the foregoing is mentioned only a small part of the diatom studies devoted to early Tertiary diatom taxonomy. For a more complete description of Tertiary diatoms the reader is referred to Fenner (1977).

GENUS CHAETOCEROS Ehrenberg (1844)
Chaetoceros sp.?
(Plate 8, Fig. 5)

GENUS COSCINODISCUS Ehrenberg (1838)
Coscinodiscus curvatulus Grunow (Schmidt Atlas, Taf. 57, Fig. 33)
(Plate 3, Fig. 3)

DESCRIPTION: Hustedt (1930, p. 406, Fig. 214)

DIMENSIONS: Diameter of valve, c. 40 μ.

OCCURRENCE: Rare in Akanvaara clay.

AGE: From the Eocene to the present (Hajos 1968).

Coscinodiscus decrescens Grunow
(Schmidt Atlas, 1878)
(Plate 10, Fig. 3)

DESCRIPTION: Hustedt (1930, p. 430, fig. 233)

DIMENSIONS: Diameter of valve, c. 25 μ.

OCCURRENCE: Rare in Akanvaara clay.

DISTRIBUTION: From the middle Eocene to the early Oligocene in the Atlantic, late Eocene in Siberia (Jousé 1974, Fenner 1977).

Coscinodiscus marginatus Ehrenberg (1841)
(Plate 3, Fig. 1, pl. 9, fig. 9)

DESCRIPTION: Resembles form described by Hustedt (1930), p. 416, Fig. 223, but is smaller. Also Fenner (1977) has described relatively small forms from Eocene and Oligocene Atlantic deposits: 33–96 μ.

DIMENSIONS: Diameter of valve, c. 27–42 μ.

OCCURRENCE: Seldom met with in Akanvaara clay.

AGE: From the Upper Cretaceous period to the present (Kanaya 1957).

Coscinodiscus oculus iridis Ehrenberg (1939)
(Plate 3, Figs. 4, 6)

SYNONYM: *C. oculus iridis* var. *borealis* (Bail.) Cleve.

DESCRIPTION: Fragments, number of areoles near the edge 2.5/10 μ, in the central portion c. 3.5/10 μ.

OCCURRENCE: A few fragments in Akanvaara clay.

DISTRIBUTION: From the Lower Eocene of Denmark (Benda 1972), the Atlantic Middle Eocene (Fenner 1977), the Upper Eocene of California (Kanaya 1957) to the present.

Coscinodiscus stellaris var. *symbolophora* (Grun.) Jörgensen (1905) (Plate 9, Fig. 2)

DESCRIPTION: Hustedt (1930, p. 396, Fig. 208)

DIMENSIONS: Fragment of central portion from fairly large individual.

OCCURRENCE: Rare in Akanvaara clay.

DISTRIBUTION: According to Benda (1965), from the Paleocene to the present.

GENUS CYCLOTELLA Kützing
Cyclotella sp.
(Plate 2, Fig. 1)

DESCRIPTION: Diameter of valve c. 40 μ. A thickening parallel to the rim on the terminal portion of the striae radiating close to the edge and transverse figures. Quite close to the edge, a dense pattern of short radial lines. The radial striae do not extend all the way to the central portion. The form resembles *C. temperi* Perag. et Heribaud species.

REMARKS: In the latest studies, the *Cyclotella* genus has not generally been observed to be present in Paleogene or Neogene diatom colonies. According to Schulz (1935), the genus *Cyclotella* occurred in early Tertiary Ananino, Archangel and Bojarkino-Simbirsk deposits in the Soviet Union; and, according to Wornardt (1971), the genus *Cyclotella* made its appearance in North America during the late Eocene. No electron SEM-micrograph of the rare *Cyclotella* could be acquired, and it has not been possible to work out the structure in detail. Thus, with regard to the structure of the marginal portions, it remains to be determined whether radial raised seams or radial internal chambers are involved. According to Round's (1970) re-determination, the last-mentioned structure belongs to the genus *Cyclotella*. The forms characterized by the former structure have been shifted over to the genus *Melosira* (Fenner 1977, p. 524).

GENUS ENDICTYA Ehrenberg 1845
Endictya aff. *japonica* Kanaya (1959)
(Plate 5, Fig. 2 a, b)

DIMENSIONS: Diameter of valve c. 27 μ, number of areoles / 10 μ, c. 3. 5.

OCCURRENCE: Only a single individual has been met with.

REMARKS: The areolate structure of the valve resembles that of *Coscinodiscus marginatus*, but the clear pattern of transverse lines in the marginal portion is sparser and corresponds to the space between the areole walls. The species also resembles the spineless forms of the species *Stephanopyxis turris*, which are, however, more convex. A closer similarity with the valve of *S. broschii* is to be observed as regards, among other things, size and the irregularity of the areolate structure. *S. broschii* possesses a conspicuously spotty membrane surface. In the Akanvaara form, the spottiness can be distinguished especially in the corners of the areoles and in the dividing walls, but in the spaces between areoles generally less clearly.

AGE: According to Wornardt (1971), the genus *Endictya* is present in the western regions of North America starting with the Cretaceous period. Kanaya (1959) has described a comparative species from a Miocene deposit. Observations from Tertiary sediments in western Europe are scanty. Hajos (1968) has described *E. hungarica* from a Miocene deposit in Hungary. *E. oceanica* has been described from a late Eocene/Oligocene deposit located in the region of the Anadyr river, in the far eastern part of the U.S.S.R. (Sheshukova-Poretzkaya 1967). The dating of the Akanvaara form remains open in this connection.

GENUS EUNOTOGRAMMA Weisse (1854)
Eunotogramma variabile Grunow in Van Heurck (1883)
(Plate 8, Fig. 8; Plate 10, Fig. 8)

DIMENSIONS: Length of frustule c. 50 μ, width of middle portion 17 μ.

AGE: Early Tertiary form, found in, for example, a Simbirsk deposit (Witt 1886), Mors' Lower Eocene deposit (Benda 1972) and a Middle Eocene deposit in the Atlantic Ocean (Fenner 1977).

GENUS GONIOTHECIUM Ehrenberg (1841)
Goniothecium odontella var. *danica* Grunow in Van Heurck (1896)
(Plate 8, Figs. 1, 2, 4)

DESCRIPTION: Van Heurck (1896, p. 428), Schulz (1935, p. 389).

DIMENSIONS: Length of valve 65 μ, width 27 μ.

OCCURRENCE: Only one observation from the valve plane.

AGE: Found previously in a Moler formation of the Lower Eocene in Denmark (Benda 1972 and cited literature), as well as from a formation of the Senonian period in Bay of Danzig (Schulz, 1935).

GENUS HEMIAULUS Ehrenberg (1844)

The genus *Hemiaulus* is generally well represented in marine Paleogene diatom flora, and it is of great significance in dating. The Akanvaara material includes an abundance of *Hemiaulus* fragments. Attempts at an accurate determination remain uncertain, and in some cases species of the *Trinacria* genus have similar appendages, with the result that determining the genus is liable to lead to confusion. Both genera are mainly Paleogene and consequently they are significant from the standpoint of dating. The following presentation of the Akanvaara forms of the *Hemiaulus* type is of a preliminary nature.

Hemiaulus nanus n. sp.
(Plate 5, Fig. 4)

DESCRIPTION: The intact half-frustule shown in side view is highest at its apical ends; in the middle is a swelling situated between the apical ends, bounded by transapical furrows extending close to the bottom level. They make a bend close to the bottom level. The surface has a scattered covering of nodules, c. 10/10 μ. The length of the apical axis is c. 18 μ, the height of the apical appendages almost on the same order, 14 and 16 μ.

REMARKS: The form strikingly resembles *H. polymorphus* var. *glacialis* Grunow (1884), but the typical var. *glacialis* form is larger and its surface structure coarser.

HOLOTYPE: Plate 5, Fig. 4, GTL slide No. D-14, Akanvaara clay bed.

AGE: Paleogene

Hemiaulus polycystinorum Ehrenberg (1854)
(Plate 5, Fig. 11)

DESCRIPTION: Grunow (1884, p. 65), Schmidt *et al.* (1874–1959), Fenner (1977).

REMARKS: In the Akanvaara form, large round areoles typical of the species are to be seen on the curved margin of the appendage. The same type of form, however, is the *Trinacria excavata* Heiberg appendage (Schmidt *et al.* 1874–, Plate 97, Fig. 9). Grönlund (1977) has described *Hemiaulus* sp. fragments found in a Quaternary deposit in the Inari region, comparing them to the variant *H. polycystinorum* var. *mesolepta* Grun.

AGE: Late Eocene/Oligocene (Gleser and Jousé 1974).

?*Hemiaulus simbirskianus* (Grunow 1884) nov. comb.
(Plate 5, Figs. 3, 12)

BASIONYM: *Hemiaulus polycystinorum* var.? simbirskiana Grunow 1884.

SYNONYM: *Hemiaulus antarcticus* Weisse 1886

DESCRIPTION: Grunow (1884, p. 65, pl. B, Figs. 44, 45), Witt (1886, pl. 6, Figs. 1, 2)

DIMENSIONS: Length of apical axis c. 40–80 μ.

REMARKS: Areoles are angular, 6/10 μ. Density of transverse lines at edge of bottom level c. 12/10 μ. Between the apical horns are numerous furrows oriented toward the bottom level. The same kind of structure is exhibited by the form *H. polymorphys* var. *charcovianus* (Jousé 1955), but the areoles are round. *H. polymorphus*, which has been depicted in Schmidt's Atlas, pl. 143, Fig. 11, resembles the Akanvaara form, too, with its angular areoles; but in the form presented by Schmidt, the outer edge of the valve has bent down toward the bottom level at the furrows. According to Grunow, *H. polycystinorum* var.? *Simbirskiana* can be more appropriately be classified as a separate species than as a variant.

AGE: Early Tertiary form. Sites of finds: Franz Josef Land (Fridtjof Nansen Land) and Simbirsk region.

Hemiaulus sp. 1
(Plate 5, Figs. 7, 10)

DESCRIPTION: Polygonal areolar structure arranged in the longitudinal direction at the apical horns. Density of areoles c. 6/10 μ. Length of horns 30–40 μ.

REMARKS: Affinity to *Hemiaulus polymorphus* species uncertain.

Hemiaulus sp. 2
(Plate 5, Fig. 9)

DESCRIPTION: Length of apical appendage 50 μ. Tiny prickles fairly densely scattered over the surface.

REMARKS: Structure of appendage resembles that of the species *H. subacutus* Grun.

Melosira concentrica A. Schmidt (1887)
(Plate 10, Figs. 1, 2)

DESCRIPTION: Schmidt *et al.* (1874–, pl. 176, Figs. 47–49), Fenner (1977, p. 524).

DIMENSIONS: Diameter of shell c. 40 μ.

OCCURRENCE: Extremely rare in Akanvaara clay.

AGE: Eocene (Fenner 1977).

Melosira sulcata (Ehrenb.) Kützing (1844)
and its variations

DESCRIPTION: Hustedt (1930, pp. 276–278)

DIMENSIONS: Diameter of valve c. 35–45 μ.

OCCURRENCE: Commonest diatom species in Akanvaara clay.

AGE: From the late Cretaceous to the present (Strelnikova, 1974; Hajós & Stradner, 1975).

Var. *biseriata* Grunow and var. *crenulata* Grunow
(Plate 1, Figs. 2, 3, 5, 6) (Plate 1, Figs. 4, 7)

DESCRIPTION: Hustedt

OCCURRENCE: Extremely common in Akanvaara clay.

REMARKS: In the form *M. sulcata* var. *siberica*, there are two rows of areoles in the marginal portion of the discus, as in the form var. *biseriata*, too, but var. *sibirica*, has greater areoles.

Melosira westii W. Smith (1856)
(Plate 1, Fig. 14)

SYNONYM: *Pseudopodosira westii* (W. Sm.) Sheshukova-Poretzkaya & Gleser (1964)

DESCRIPTION: Hustedt (1930, p. 268)

DIMENSIONS: Diameter of discus c. 18 μ.

OCCURRENCE: Exceedingly sparsely present in Akanvaara clay.

AGE: From the late Cretaceous period to the present (Fenner 1977).

Melosira species found in the Akanvaara clay that possible originated in Tertiary and Quaternary sediments and that probably are fresh-water forms:

Melosira akkavaarensis n. sp.
(Plate 2, Fig. 3)

DESCRIPTION: Discus level-surfaced, diameter 40 μ. On edge of ring, tiny prickles, 7/10 μ. In marginal portion, radial rows of pores over a length of c. 2/3 radius. In the central area, two rings composed of knobs, eight in each, the outer ones oval and the inner ones pear-shaped. The space in between probably granulated or pierced by pores.

REMARKS: The form has been regarded as belonging to the genus *Melosira*, for it resembles to some degree *M. roseana* Rabenh. or *M. dendoteres* (Ehr.) R. Ross and *M. dendrophila* (Ehr.) Ross & Sims forms (Ross & Sims, 1974, 1978). On the other hand, they also bear a resemblance to the structure of the genus *Trochosira*. Estimated age: Tertiary.

OCCURRENCE: Met with extremely rarely in Akanvaara clay.

HOLOTYPE: Plate 2, Fig. 3, GTL slide No. D-20, Akanvaara clay deposit.

Melosira islandica O. Müller and spore form rounded at its end – exceedingly rare in Akanvaara clay.

Melosira sp. 1
(Plate 1, Figs. 8, 9)

DESCRIPTION: Cylindrical shell with a densely areolated surface viewed longitudinally. Adjacent areoles situated in diagonal rows or grouped in scattered fashion. Larger areoles have a pore or pit in the middle. Only two valve mantles have been found. Sulcus evidently weakly developed and edge of discus lacks many prickles (Fig. 8 shows one prickle). Length of mantle 15–18 μ, width 13–10 μ. Density of areole rows c. 8/10 μ.

REMARKS: Species resembles *Melosira goetzeana* O. Müll. type. In the species *M. praeislandica*, the areoles are grouped differently, mainly lengthwise and crosswise.

Melosira sp. 2
(Plate 2, Figs. 5, 6; Pl. 10, Fig. 6)

REMARKS: Form resembles *Melosira arenaria* Moore (1843) species, which exhibits rather variable features.

GENUS ODONTOTROPIS Grunow (1884)
Odontotropis sp.
(Plate 8, Fig. 17)

REMARKS: From the apical fragment with a horn found in the Akanvaara clay deposit it can be seen that tiny pores (3/10 μ) occur at rare intervals on the surface of the valve. The keel at the edge of the horn is nicked, possibly on account of tearing.

GENUS OPEPHORA Petit (1888)
Opephora gemmata (Grun.) Hustedt (1930)
(Plate 8, Fig. 13; Pl. 9, Fig. 4)

DESCRIPTION: Hustedt (1930, pp. 136, 137)

DIMENSIONS: mainly fragments, density of transapical lines 4–5/10 μ.

OCCURRENCE: Fairly common as fragments in Akanvaara clay.

AGE: Paleocene and Eocene form (Benda 1965). Schrader & Fenner (1976): Miocene form. According to Hustedt (1930), the species is extremely rare in recent deposits. They are probably well-preserved redeposited Tertiary diatoms.

GENUS PSEUDOPODOSIRA Jousé
Pseudopodosira aff. *bella* Gleser & Posnova (1964)

DESCRIPTION: Gleser & Posnova (1964, pp. 60, 61; Pl. 1, Fig. 2), Fenner (1977, p. 526)

OCCURRENCE: Only fragments, met with extremely rarely.

AGE: Eocene (Fenner, 1977).

GENUS PTEROTHEGA (Grunow) Forti (1909)
?Pterotheca spada Brun & Tempére (1889)
(Plate 9, Fig. 8)

DESCRIPTION: Brun & Tempére (1889, PL 1, Fig. 7). Sheshukova-Poretzkaya (1967, Pl. 11, Fig. 2), Schrader & Fenner (1976, Pl. 41, Figs. 4, 5, 12, 13).

REMARKS: The Akanvaara find is poorly preserved and might correspond to the form *Pyrgupyxis (Pyxilla) carinifera* Grun., which occurs in, for instance, the Moler formation (Benda, 1972). The same form has been described by Cleve-Euler from a Tertiary deposit in southern Sweden (Cleve-Euler & Hessland, 1948).

GENUS PYRGUPYXIS Hendey (1969)
Pyrgupyxis gracilis (Temp. & Forti) Hendey (1969)
(Plate 8, Figs, 9, 10, 16)

SYNONYM: *Pyxilla gracilis* Temp. & Forti

DESCRIPTION: Forti (1909, p. 24, Pl. 2, Figs. 5–8). Fenner (1977, p. 528, Pl. 19, Figs. 1–3).

OCCURRENCE: Met with as fragments, the species is rare in the Akanvaara clay. Grönlund (1977) has described the species repdeposited from a Quaternary deposit at Riukuselkä, Inari.

AGE: The species appears to be a late Eocene (Gleser *et al.* 1974) and Middle Eocene (Fenner 1977) form. Benda has not mentioned the possible presence of the species in the Lower Eocene Moler formation (1972).

?Pyrgupyxis oligocaenica var. *tenuis* Jousé
(Plate 8, Figs. 11, 12)

DESCRIPTION: Jousé (1955 a), p. 99, Pl. 6, Figs. 4, 7)

OCCURRENCE: Met with rarely as fragments in Akanvaara clay.

AGE: From the Eocene to the Oligocene (Schrader & Fenner 1976). According to Gleser *et al.* (1974), the species would seem to be younger than *P. gracilis*.

GENUS RHAPHONEIS Ehrenberg (1844)
?Rhaphoneis sp.
(Plate 9, Fig. 11)

REMARKS: Rare fragment resembles the species *R. amphiceros*. On the other hand, the genus *Sceptroneis* might come into question. According to Schulz (1935), the first *Rhaphoneis* and *Steproneis* forms appeared in the Danish Moler and North German basalt-tuffite formations, which date back to the Lower Eocene. These species are not, however, mentioned in connection with Benda's (1972) diatom investigation of the Moler formation.

GENUS RHIZOSOLENIA Ehrenberg (1841)
Rhizosolenia hebetata var. *subacuta* Grunow (1884)
(Plate 8, Fig. 14)

DESCRIPTION: Grunow (1884, p. 96, Pl. 5, Figs. 49, 50), Fenner (1977, Pl. 20, Figs. 10, 11).

OCCURRENCE: Rarely met with in Akanvaara clay.

AGE: Early Oligocene-Pliocene, but sparsely scattered individuals also found in Middle Eocene sediments (Fenner 1977).

Rhizosolenia sp.
(Plate 9, Fig. 7)

REMARKS: Fragment of a slightly conical spine. Characteristic features are a thick cell wall and longitudinal rows of pores piercing it.

GENUS RIEDELLA Jousé & Sheshukova-Poretzkaya (1971)

From the genus *Hemiaulus* have been distinguished those forms that lack a polygonal areolar structure but that possess isolated punctae structures. The genus *Riedelia* also lacks the pseudoseptae (Schrader & Fenner 1976).

Riedella claviger (A. Schmidt) Schrader & Fenner (1976)
(Plate 8, Fig. 15)

DESCRIPTION: Schmidt *et al.* (1874–, Pl. 143, Figs. 45, 46), Schrader & Fenner (1976, Pl. 42, Figs. 6–8, 9, Pl. 42, Figs. 3, 4, 10, 11, 15).

OCCURRENCE: Fairly common as fragments in Akanvaara clay.

AGE: Found in Middle Eocene deposit in the Atlantic (Fenner 1977). According to Jousé & Sheshukova-Poretzkaya (1971), the form occurs in early Eocene and Middle Oligocene deposits.

Riedella sp.
(Plate 5, Fig. 8)

REMARKS: Characteristic of the appendage of the *Hemiaulus* type is a rather sparse occurrence of punctae. Cf., Fenner (1977, *Riedelia* sp. 1).

GENUS STEPHANOPYXIS Ehrenberg (1844)
Stephanopyxis turris (Grev. et Arn.) Ralfs in Pritchard (1861).
Var *cylindrus f. inermis* Grunow (Plate 1, Figs. 10, 11, 12; Pl. 4, Figs. 1, 2)

DESCRIPTION: Grunow (1844, p. 87), Hustedt (1930, p. 305).

Var. *intermedia* Grunow
(Plate 4, Figs. 3, 7, 9)

DESCRIPTION: Grunow (1884, p. 88), Hustedt (1930, p. 306).

Var. *artica* Grunow
(Plate 4, Figs. 5, 6)

DESCRIPTION: Grunow (1884, p. 89), Hustedt (1930, p. 306).

Var. *polaris* Grunow
(Plate 4, Figs. 8, 10)

DESCRIPTION: Grunow (1884, p. 89), Hustedt (1930, pp. 306, 307).

OCCURRENCE: *Stephanopyxis turris*, together with the aforementioned variants, is fairly commonly met with in Akanvaara clay.

AGE: *Stephanodiscus turris* is known from sediments of the Upper Cretaceous to the present day. During the Paleogene, in especial, it was a common occurrence in the USSR, Denmark, southern Sweden and the Norwegian Sea (Fenner 1977).

Stephanopyxis sp.
(Plate 4, Fig. 4, Pl. 10, Fig. 12)

DESCRIPTION: Diameter c. 25 μ. Valve has cuplike shape, areolated on the surface by irregularly shaped polygons. No clearly defined prickles.

REMARKS: The form differs from the species *Stephanopyxis turris* owing to its irregularly shaped areoles.

?*Stephanopyxis* sp.
(Plate 5, Fig. 1)

DESCRIPTION: A fragment of the marginal portion has two rows of large rounded areoles. In the row nearest the edge, the diameter of the areoles is c. 10 μ, in addition to which tiny prickles occur in conjunction with them at the edge. In the inner row, the areoles are larger, c. 13 μ in diameter.

GENUS STICTODISCUS Greville 1861

Stictodiscus sp.
(Plate 2, Fig. 2, 4)

DESCRIPTION: Diameter of valve c. 18–30 μ. The surface structure of the circular valve consists of tiny nodules, which at the marginal portion, for the length of 1/2 radius, are situated on ridges running parallel to the radius. The central area is dotted with scattered, mostly radially situated nodules. The thicker set of marginal lines along the rim consists of perpendicular prongs, the spacing of which corresponds to the interval of 1–1.5 nodule rows.

REMARKS: Systematic position is uncertain, for the structure exhibits similarities to the genus *Melosira*, specifically *M. architecturalis* Brun.

OCCURRENCE: Extremely rare in Akanvaara clay.

GENUS TRICERATIUM Ehrenberg (1839)

The genus *Triceratium* is sparsely represented in the Akanvaara clay. The diatoms are largely fragmentary or their surface structure is damaged, for which reason one must generally be content with an approximate determination of the species.

Triceratium cellulosum Greville
(Plate 10, Fig. 5)

DESCRIPTION: Schmidt *et al.* (1884–, Pl, 95, Figs. 28–32)

DIMENSIONS: Length of side c. 30 μ; density of areole papillae c. 6/10 μ.

OCCURRENCE: Uncommon in Akanvaara clay.

AGE: The coarser form *T. cellulosum* var. *simbirskiana* Witt is met with commonly in early Tertiary deposits in the Simbirsk government of the Archangel-Kurojedowo region (Witt 1886).

REMARKS: Owing to the limited material, the genus connection is uncertain.

OCCURRENCE: Rare in Akanvaara clay.

Triceratium kinkeri A. Schmidt
(Plate 10, Fig. 9)

SYNONYM: *Trinacria simulacrum* Grove & Sturt (1887)

DESCRIPTION: Schmidt *et al.* (1874–, Pl. 112, Fig. 21)

REMARKS: Only a fragment of the angle, where a typical marginal structure appears, has been found in the Akanvaara clay. As well-developed processes are lacking, the species has not been classified as belonging to the genus *Trinacria* in the present work.

AGE: Most of the observations are from Eocene sediments (Fenner 1977).

Triceratium cf. *kinkerianum* Witt
(Plate 6, Figs. 1, 2)

DESCRIPTION: Witt (1886, p. 169, Pl. 8, Fig. 10), Schmidt *et al.* (1874–, pl. 95, Figs. 15, 17, 18).

DIMENSIONS: Length of side 35–40 μ. The midportions of the sides and the end angles are joined by seams, which form a hexagon.

REMARKS: The areolar structure appears in the Akanvaara form to be coarser than in the case of the kinkerianum species.

AGE: The comparative species belongs to the typical diatoms of, for example, the Moler formation in Denmark.

?*Triceratium* cf. *lateps* Fenner
(Plate 7, Fig. 2)

DESCRIPTION: Schrader & Fenner (1976, p. 1003, pl. 26, Fig. 12).

REMARKS: In the fragment inspected, the areole size is large and the areoles are irregular in shape and grouping. The form and structure do not altogether correspond to Fenner's description. A comparative species has been found in a Middle Oligocene formation in the Norwegian Sea.

Triceratium aff. *macroporum* Hajós
(Plate 7, Fig. 5)

DESCRIPTION: Hajós (1968, p. 132, pl. 35, Figs. 1–10)

DIMENSIONS: Length of side c. 40 μ.

REMARKS: The form resembles the species *Triceratium condecorum* characterized by large areoles (Fenner 1977, pl. 28, Fig. 7). The Akanvaara species, however, bears a closer resemblance to the species *T. macroporum* Hajos.

AGE: The species has previously been described from a Miocene deposit in Hungary (Hajós, *op. cit.*), but the probability is that the type of form existed as early as the Eocene (cf., Fenner, *op. cit.*).

Triceratium aff *mirabile* Jousé
(Plate 6, Fig. 3)

DESCRIPTION: Jousé 1949?

DIMENSIONS: Length of side c. 25 μ.

REMARKS: The species resembles *Tr. crenulata* Cr. & St. but is probably smaller of size and also relatively smaller around the middle.

AGE: A characteristic Lower Eocene diatom of the Uljanov (Simbirsk) area of the Middle Volga region (Gleser 1970, Gleser *et al.* 1974)

Triceratium ventriculosum A. Schmidt
(Plate 6, Fig. 5 a, b)

DESCRIPTION: Schmidt *et al.* (1874–, Pl. 111, Figs. 3–7), Gleser *et al.* (1974, Pl. 18, Fig. 12).

REMARKS: The form has features typical of the genus *Trinacria*, and some researchers have classified it as belonging to this genus. The corner processes are so short that the species has not been included in the genus *Trinacria* in the present connection.

DIMENSIONS: Length of side 35 μ.

OCCURRENCE: Extremely rare in Akanvaara clay.

AGE: In the Volga (Central Povolzh) and western Siberian regions, a characteristic Lower Eocene species (Gleser 1970, Gleser *et al.* 1974).

Triceratium aff. *weissii* Grunow
(Plate 6, Figs. 11, 12)

DESCRIPTION: Schmidt *et al.* (1884–, Pl. 95, Figs. 2–12).

DIMENSIONS: Length of side 25–30 μ.

OCCURRENCE: Exceedingly rare in Akanvaara clay.

AGE: A typical early Paleocene form found e.g. in the Volga region (Gleser 1970). According to Benda (1965), the species existed from the Upper Cretaceous period to the Upper Eocene.

Triceratium sp. 1
(Plate 7, Figs. 3, 4)

DESCRIPTION: Owing to the destruction of the surface structure, only the outer edge and part of the areolar structure are to be observed. The sides are convex, c. 38 μ. The surface structure is reticular, the areole count c. 3/10 μ.

REMARKS: The contour and structure of the valve bring to mind the form *Biddulphia reticulata* Roper fo. *trigona* Grun. Cf., Cleve-Euler (1951, p. 119, Fig. 256 c). The form under consideration is larger, however, than the Akanvaara one.

GENUS TRINACRIA Heiberg (1863)

The genus differs from *Hemiaulus* only on account of its three-sided shell (Grunow 1884). The genus also includes foursided forms.

Trinacria aff. *excavata* Heiberg (1863)
(Plate 7, Fig. 1)

DESCRIPTION: Hustedt (1930, pp. 887, 888)

REMARKS: Fragment found as a rarity in Akanvaara clay, characterized by the form of a narrowed apex of a triangle and large areoles in the marginal portion.

AGE: Occurrence extended at least from the Paleocene to the Oligocene (Benda 1965).

Trinacria pileolus (Ehr.) Grunow (1884)
(Plate 5, Figs, 5, 6; Plate 6, Figs. 6, 8–10)

DESCRIPTION: Grunow (1884, p. 68, Pl. B, Figs. 59, 60), Hustedt (1930, pp. 885–887).

OCCURRENCE: Numerous fragments in Akanvaara clay.

AGE: Mostly found in Eocene deposits, but observations from as early as the late Cretaceous period extending to the early Pliocene (Schrader 1976; McCollum 1975). The younger observations in question are from the southeastern Pacific Ocean and the South Seas.

Trinacria sp. 1
(Plate 6, Fig. 4)

DESCRIPTION: Valve square, with convex sides, c. 20 μ in length. At corners, short conical appendages. On surface of valvar plane, areoles, c. 7/10 μ, grouped almost radially.

REMARKS: Worn condition of valve limits exact description. However, it closely resembles the form *Trinacria excavata* fo. *tetragona* A. Schmidt. The Akanvaara form is small and at the same time the size of the areole is comparatively large, for which reason it has not been connected to the *excavata* species here.

?*Trinacria* sp. 2.
(Plate 10, Fig. 4)

DESCRIPTION: Shell triangular, ends elongated and blunt. Length of side c. 17 μ. Small, round areoles, c. 7/10 μ, on surface.

OCCURRENCE: Exceedingly rare in Akanvaara clay.

GENUS XANTHIOPYXIS Ehrenberg (1844)
?*Xanthiopyxis* aff. *microspinosa* Andrews (1976)
(Plate 10, Fig. 10)

DESCRIPTION: Andrews (1976, p. 18, Pl. 6, Figs. 1–3)

DIMENSIONS: Length of frustule c. 48 μ width 30 μ.

REMARKS: Structure of valvar plane is composed of scattered papillae. No sharp prickles have been observed. Affinity of form to the genus *Xanthiopyxis* remains uncertain. A comparative species has been described from the Middle Miocene stratum of the Choptank formation in Maryland. The form bears an equally close resemblance to *Biddulphia* sp. (Taf. XII: 52, Taf. XV: 64) described by Cleve-Euler (Cleve-Euler & Hessland 1948).

?*Xanthiopyxis* sp.
(Plate 10, Fig. 11)

REMARKS: Valve of *X. microspinosa* type, but narrower and smaller. Length 35–40 μ, width c. 16 μ. Apical ends are sharp but at the same time curve outward from the middle level. The form resembles the genus *Goniothecium*, but it differs with respect to the surface structure in that the genus *Goniothecium* has a regular grouping of the papillae.

OCCURRENCE: Rare in Akanvaara clay.

Silicoflagellates and +ebridians in the Akanvaara clay

In the identification of silicoflagellates, the more extensive studies published by Gleser (1966/70) and Loeblich *et al.* (1968) + have been consulted in the first place for the present work in conjunction with more recent descriptions of the silicoflagellates present in early Tertiary formations. Noteworthy among them in particular are Bukry & Forster (1974), Bukry (1976, 1978), Martini (1974) and Perch-Nielsen (1976). The occurrence of silicoflagellates in Akanvaara clay is limited; hence the findings dating back to the time of deposition in question are not representative. Nevertheless the species identified are important from the standpoint of dating, and the occurrences lend support to the dates arrived at, which otherwise would depend solely on the evidence provided by diatoms.

Corbisema hastata (Lemmermann) Frenguelli (1940)
(Plate 11, Fig. 8)

SYNONYM: *Dictyocha triacantha* var. *hastata* Lemm.

DIMENSIONS: Length of longest side c. 50 μ. The lattice in the middle is relatively broad.

AGE: Principal occurrence in Europe in early Eocene deposits (Moler formation in Denmark, Greifswalder Oie in East Germany, the Volga region). Observations further reported from Paleocene deposits in the USSR (Gleser 1966/70) and from Tertiary deposits in southern Sweden (Miller 1966). Bukry & Foster (1974) have differentiated the *Corbisema hastata* zone as corresponding to the Paleocene in the deep marine region.

Corbisema inermis f. minor (Gleser) Bukry (1976)
(Plate 11, Fig. 4)

SYNONYM: *Ebria tripartita* Ehr. sensu Jousé (1955 b), Tynni 1976, *Dictyocha triacantha* var. *inermis* f. minor Gleser (1966, p. 231).

DIMENSIONS: Length of side c. 23 μ.

AGE: Met with in early Paleocene and early Eocene deposits on the European side of the USSR in the Uljanov (Simbirsk) region. Farther east, in Eocene and Oligocene deposits. Bukry (1968) has come across the form in late Paleocene and Middle Eocene deposits in the Atlantic Ocean.

Dictyocha elata var. *media* f. *reducta* Gleser (1964)
(Plate 11, Fig. 10)

DIMENSIONS: Diameter c. 16 μ.

AGE: The form has been described previously from Eocene and Oligocene deposits on the Asian side of Soviet territory (cf., Gleser 1966/70).

Dictyocha frengellii Deflandre var. *carentis* Gleser (1964)
(Plate 11, Figs. 9)

DIMENSIONS: Diameter of frustule without processes c. 25 μ.

REMARKS: Form resembles *Dictyocha fibula* Ehr., but it differs from it owing to its coarser and broader spines.

AGE: In Soviet Union, the variant has been met with in Eocene and early Oligocene deposits. In the Volga region, the Middle Eocene deposit probably affords the closest point of comparison. The main form is present in Lower Eocene deposits in Denmark (Martini 1974).

Distephanus crux (Ehr.) Häckel (1887)
(Plate 11, Figs. 1 a, b, 3)

SYNONYM: *Dictyocha crux* Ehrenberg

DIMENSIONS: Length 35–45 μ, width 22–37 μ.

AGE: The species has a long period of occurrence and this has no great significance from the standpoint of dating. Jousé (1955 b) has described the type of form from the upper part of the Paleogene in the USSR. On the other hand, the form still lives in the Black Sea and the Sea of Okhotsk (Gleser 1966/70). Brander (1943) has met with the species in interglacial clay at Rouhiala (Karelia). In the Atlantic region, *Distephanus crux crux* is common in the *Naviculopsis biapiculata* zone (Bukry 1974, 1978), which corresponds to the late Oligocene or early Miocene. The species (*D. crux* s. ampl.) occurs as a rarity in an Eocene deposit at Site 385.

Naviculopsis minor (Schulz) Frenguelli (1940)
(Plate 11, Figs. 2, 7 a, b)

SYNONYM: *Dictyocha navicula* Ehr. var. *minor* Schulz, *Naviculopsis biapiculata* var. *minor* Gleser.

DIMENSIONS: Total length 58–80 μ, width c. 12–14 μ. The tubular part of the ring at the base is relatively broad, c. 7–8 μ.

REMARKS: *Naviculopsis constricta* resembles this form, but in its typical state it can clearly be perceived to be contracted in the middle, and its surface is not principally smooth but covered with tiny nodules (cf., Perch-Nielsen 1976).

AGE: A form dating from the early Eocene, which is met with in, among other places, the Fur and Mors areas in Denmark (Perch-Nielsen, *op. cit.*) as well as in Cuxhaven, northern Germany (Martini 1974).

The Akanvaara clay bed contains, in addition, silicoflagellate fragments of other species, which have not been identified (Plate 11).

Ebrides are exceedingly rare in the clay, and only the following forms have been observed: The ebride found in the Akanvaara clay resembles with respect to its structure the Tertiary genus *Ammodochin* Hovasse (1932) so closely as to warrant its being classified as belonging to this genus.

Ammodochium lapponicum n. sp.
(Plate 11, Fig. 6)

DESCRIPTION: The silica sceleton is squarishly oval in shape with larger and smaller openings. The apertures are symmetrically situated in relation to the long axis. Two larger and two smaller apertures are to be seen located crosswise on half the shell. The outer margin of the sceleton is roughly serrated. On one end, the granulated structural area is relatively large. Length c. 30 μ, width 24 μ.

REMARKS: The Akanvaara form resembles the species *Ammodochium danicum* Defl., but it is larger and somewhat deviant in structure. It also resembles the Lower Tertiary form found by Miller (1971) in the Quaternary deposit of Tofthög (Fig. 8: 10).

HOLOTYPE: Plate 11, Fig. 6, GTL slide No. D-14, Akanvaara clay deposit.

AGE: Paleogene?

Ebria gracile n. sp.
(Plate 11, Fig. 12)

DESCRIPTION: The sceleton is formed by three radially adjacent windows of equal size, structurally similar to *Ebria tripartita* (Schum.) Lemmermann. The form differs from the *tripartita* species owing to the lack of outer windows. The siliceous spicules are exceedingly thin and smooth also along their outer edge, with the exception of the tiny outermost point of the outer edge, where there is a rough surface. On the surface can be distinguished extremely slender areoles of varying size. Diameter of sceleton 15 μ.

HOLOTYPE: Plate 11, Fig. 12, GTL slide No. D-14, Akanvaara clay deposit.

Falsebria sp.
(Plate 11, Fig. 17)

REMARKS: No accurate description can be given of the fragmentary and rare occurrence. Typical of the form are three main spines projecting from the middle, which are also likely to branch out.

Diatomite of Naruskajärvi

The species met with in the diatomite deposit at Naruskajärvi are presented briefly in the following in their entirety. Those species that do not belong to the present flora of the Lapland region are marked with a + sign, and a more detailed description of them is given after this list.

Achnanthes biasolettiana (Kütz.) Grun.
A. calcar Cl
A. exigua Grun.
A. flexella (Kütz.) Grun.
A. holsti Cl.
A. lanceolata (Bréb.) Grun.

A. lanceolata v. elliptica Cl.
A. lapponica Hust.
A. linearis (W.S.) Grun.
A. obligua (Greg.) Hust.
A. peragalli Brun & Herib.
A. sp.
\+ *Actinella brasiliensis Grun.*
Amphora ovalis Kütz.
Anomoeoneis follis (E.) Cl.
A. serians (Bréb.) Cl.
A. serians v. brachysira (Bréb.) Cl.

Caloneis bacillum (Grun.) Meresch.
C. silicula (E.) Cl.
Campylodiscus hibernicus E.
Cocconeis diminuta Pantoc.
Cyclotella kützingiana Twaites
C. kützingiana v. radiosa Fricke
Cymatopleura elliptica v. nobilis (Hantz.) Hust.
Cymbella aequalis W. S.
C. cistula (Hempr.) Grun.
C. cuspidata Kütz.
C. cymbiformis Ag.
C. cymbiformis v. nonpunctata Fontell
C. gracilis (Rabenh.) Cl.
C. hustedtii Krasske
C. incerta (Grun.) Cl.
C. sinuata Greg.
C. tumida (Bréb.) V. H.
C. turgida Greg.
C. sp. 1
C. sp. 2

Diploneis elliptica (Kütz.) Cl.
D. elliptica v. ladogensis Cl.
D. finnica (E.) Cl.
D. ovalis (Hilse) Cl.
D. parma Cl.

Epithemia sorex Kütz.
E. zebra v. porcellus (Kütz.) Grun.
Eunotia arcus E.
E. bigibba v. pumila Grun.
E. diodon E.
E. faba (E) Grun.
E. formica E.
E. gracilis (E.) Rabenh.
E. lapponica Grun.
E. lunaris (E.) Grun.
E. monodon E.
E. pectinalis Rabenh.
E. pectinalis v. minor (Kütz.) Rabenh.
E. pectinalis v. ventralis (E.) Hust.
\+ *E. polyglyphis Grun. f. tetraglyphis*
E. praerupta E.
E. praerupta v. bidens (W. S.) Grun.
E. robusta v. diatema (E.) Ralfs
E. robusta v. tetraodon (E.) Ralfs
E. robusta v. tetraodon f.
E. sudetica O. Müller
E. tenella (Grun.) Hust.
E. valida Hust.
E. veneris (Kütz.) O. Müller

Fragilaria brevistriata Grun.
F. constricta E.
F. constricta f. stricta (A. Cl.) Hust.
F. construens v. binodis (E.) Grun.
F. construens v. subsalina Hust.
F. construens v. venter (E.) Grun.
\+ *F. convexa n. sp.*
\+ *F. giganthea Lauby*
F. lapponica Grun.
F. pinnata v. lancettula (Schum.) Hust.
\+ *F. triangulata Moiss.*
F. virescens Ralfs
F. virescens v. elliptica Hust.
Frustulia rhomboides v. amphipleuroides Grun.
F. rhomboides v. saxonica Rabenh.

Gomphonema acuminatum E.
G. acuminatum f. brébissonii (Kütz.) Cl.
\+ *G. brasiliense Grun.*
G. constrictum v. capitata (E.) Cl.
G. intricatum v. vibrio (E.) Cl.
G. longiceps v. montana (Schum.) Cl.
G. olivaceoides Hust.
G. subtile E.
Gyrosigma attenuatum (Kütz.) Rabenh.
G. sciotense (Sullivan & Wormley) Cl.

Hantzschia amphioxys (E.) Grun.
\+ *Hydrosera trifoliata Cl.*

Melosira ambigua (Grun.) Müller
M. arenaria Moore + f. teres (Brun) n. comb.
\+ *M. canadensis Hust.*
M. distans (E.) Kütz.
M. distans v. lirata (E.) Bethge
M. granulata (E.) Ralfs
M. islandica Müller
M. islandica ssp. helvetica Müller
M. italica (E.) Kütz.
M. italica ssp. subarctica Müller
M. undulata (E.) Kütz.
Meridion circulare (Grev.) Ag.

Navicula aboensis (Cl.) Hust.
N. amphibola Cl.
N. anglica Ralfs
N. bacillum E.

N. cryptocephala Kütz.
N. dicephala (E.) W. S.
N. hasta Pantoc.
N. jentzschii Grun.
N. placenta E.
N. pseudoscutiformis Hust.
N. pupula v. rectangularis (Greg.) Grun.
N. pusio Cl.
N. radiosa Kütz.
N. rostochiensis Heiden.
N. rotaeana (Rabenh.) Grun.
N. scutiformis Grun.
N. viridula Kütz.
N. vulpina Kütz.
Neidium decoratum Brun
N. dubium (E.) Cl.
N. hitchcockii (E.) Cl.
N. iridis (E.) Cl.
Nitzschia acidoclinata Lange-Bertalot
N. amphibia Grun.
N. angustata (W. S.) Grun.
N. denticula Grun.

Opephora martyi Hérib.
\+ *O. sp.*

Pinnularia acrosphaeria Bréb. + var. undulata Cl.
P. aestuarii Cl.
P. brandelii Cl.
P. brevicostata Cl.
P. cardinalis (E.) W. S.
P. dactylus E.
P. divergens W. S.
P. divergens. v. elliptica Grun.
P. divergens v. parallella (Brun) Patrick
P. divergentissima (Grun.) Cl.
P. esox E.
P. gibba v. linearis Hust.
P. gracillima Greg.
P. hemiptera (Kütz.) Cl.
P. mesolepta (E.) W. S.
P. nodosa E.
P. polyonca (Bréb.) Cl.
P. semicruciata (A. S.) A. Cl.
P. stomatophora Mayer
P. undulata Greg.
P. viridis (Nitzsch) E.

Rhopalodia gibberula (E.) O. Müller
R. parallela v. ingens Fricke

Stauroneis acuta W. S.
S. anceps. E.
S. phoenicenteron (Nitzsch) E.
S. prominula (Grun.) Hust.
S. smithii v. incisa Pant.
Stephanodiscus astraea v. minutula (Kütz.) Grun.
S. dubius (Fricke) Hust.
S. hantzschii Grun.
Surirella linearis W. S.
S. robusta + v. splendida f. punctata
S. turgida W. S.
Synedra parasitica (W. S.) Hust.
S. ulna (Nitzsch) Grun.

Tabelleria fenestrata (Lyngb.) Kütz.
T. flocculosa (Roth) Kütz.
\+ *Tetracyclus cruciformis Andrews*
\+ *T. ellipticus (E.) Grun.*
\+ *T. ellipticus v. clypeus (E.) Hust.*
\+ *T. ellipticus v. lancea (E.) Hust.*
T. emarginatus (E.) W.S.
T. lacustris Ralfs
\+ *T. lacustris v. capitata Hust.*
\+ *T. lacustris v. capitata fo. heterocapitata n. f.*
T. lacustris v. strumosa (E.) Hust.

The commonest of the species are *Melosira distans* + var. *lirata*, *M. italica* ssp. *subarctica*, *Tetracyclus lacustris*, *T. emarginatus*, *Melosira ambigua*, *M. granulata*, *M. islandica* + ssp. *helvetica*, *Diploneis parma*, *Fragilaria virescens*, *Gomphonema constricum* v. *capitata*, *Tabellaria flocculosa*. The proportion of species not represented among flora of the present time is generally less than one per cent. Exceptions are *Tetracyclus ellipticus* and *Fragilaria triangulata*, the share of which is approximately 2–1 %. In percentage, the proportion of forms alien to present times amounts to about nine per cent of the total.

The species present in the diatomite of Naruskajärvi are comparable to the species contained in Neogene fresh-water deposits or relict occurrences. Examples of studies of fresh-water diatoms found in Neogene deposits are, inter alia: Lauby's (1910) study on Tertiary diatoms of the Central Massif in France; Cleve-Euler's (1915, 1951, 1955) studies on redeposited diatoms in northern Finland; Krasske's (1934) study on Neogene diatoms of the Wamara region in central Japan; Okuno's (1952) study on the species present in diatomite deposits in Japan; Rehakova's (1965, 1969) studies on the Tertiary diatoms of southern Bohemia; Lohman's (1938) studies on Pliocene diatoms of the Kettleman Hills region of California; Van Landingham's (1964) investigations in the Yakima area of southern Washington; Andrews's (1970, 1971) studies on the Miocene diatoms of Nebraska; Abbott's (1971) research on Miocene diatoms in Oregon; and the studies of Poretzky (1953 a, b), Cheremisinova (1956, 1968), Sheshukova-Poretzkaja & Moisseva (1964) and Moisseva (1971) carried out in the Soviet Union. Late Tertiary species may still occur in places as relicts in very limited areas, and descriptions of such recent forms elucidate well diatom evolution in general. Cf., among others, Hustedt (1965), Patrick & Reimer (1966), Foged (1973).

During the late Tertiary, the fresh-water diatom flora began to resemble that existing at present. According to Rehakova (1971), the proportion of species that became extinct in the Pliocene was nearly double the corresponding figure for the Miocene (when it was c. 25 %). Two or three species prevail, but species belonging to the Pennales group increased in, particularly, the latter half of the Pliocene. In the following will be described the forms alien to the present time that support the conception of the formation of late-Tertiary diatomite in the Naruskajärvi area.

The diatomaceous earth was probably deposited during the Pliocene.

Actinella brasiliensis Grunow
(Plate 14, Fig. 19)

SYNONYM: *Actinella guyanensis* Grun. in Cleve (1881),? *A. pliocenica* Herib. & Per.

DESCRIPTION: Schmidt *et al.* (1874–, Pl. 292, Figs. 10–19/Hustedt 1913), Hustedt (1965, Figs. 12–15), Zabelina et al. (1951, p. 157).

DIMENSIONS: Length 70–110 μ, density of lines c. 13/10 μ.

OCCURRENCE: Numerous observations in Naruskajärvi diatomite, share approximately 0.2 per cent.

DISTRIBUTION: Recent observations reported from Brazil (V. Heurck 1896), the Demerara river in Guayana (Hustedt 1913) and the prefecture of Osaka in Japan (Okuno 1952). Fossil observations reported from Pliocene deposits in Soviet coastal areas (Moisseva 1971), Pliocene deposits in the Tunkiski and Baikal areas and a Miocene deposit in Siberia (Cheremisinova 1968, Gleser *et al.* 1977). Layby (1910) has desctribed *Actinella pliocenica* from Miocene deposits in France.

Fragilaria convexa n. sp.
(Plate 14, Figs. 1–5)

DESCRIPTION: The shell tapers on the valvar plane evenly from the midportion to the ends. The ends are broad, differing in this respect from the species. *F. virescens*. The transapical lines are densely spaced and the pseudoraphe is exceptionally narrow, as in the species *F. triangulata* Moiss., which is of the same type with respect to surface structure. Length averages 25–35 μ, density of lines c. 18/10 μ.

REMARKS: Naruskajärvi form is likely to be closely related to the species *F. triangulata*, for they occur in the same samples. It also bears a resemblance to the species *Fr. pliocen* (Brun. 1893), which however has a sparser pattern of lines: 10/10 μ.

OCCURRENCE: Numerous observations, but percentually uncommon in Naruskajärvi diatomite.

HOLOTYPE: Plate 14, Fig. 2, GTL slide No. D-50, Naruskajärvi diatomite.

Fragilaria giganthea Lauby
(Plate 14, Figs. 7, 8)

DESCRIPTION: Lauby (1910, p. 214, Pl. 9, Fig. 17) Andrews (1970 A 11)

DIMENSIONS: Length of Naruskajärvi form, 50–60 μ, is shorter than the 70 μ mentioned by Lauby. Line density is 15/10 μ.

OCCURRENCE: Rare species in Naruskajärvi diatomite.

DISTRIBUTION: *According to Andrews (op. cit.)*, the species occurs in the late Miocene stratum in the Kilgore area of Nebraska as well as in the Plaisancian deposit located in the Route du Mont-Dore à Besse area in France (Lauby 1910, Wood *et al.* 1941). Plaisancian belongs, according to Lauby (1910), to the early Pliocene, but according to Wood *et al.* (1941) and Andrews (1978) to the Middle Pliocene.

Fragilaria triangulata Moisseva
(Plate 14, Figs. 9, 10, 12)

DESCRIPTION: Sheshukova-Poretzkaja, Moisseva, 1964, p. 100, Figs. 1–5, Moisseva, 1971, p. 52, Pl. 6, Figs. 1–6, Pl. 18, Figs. 1–5.

DIMENSIONS: Length of the side of the triangular valve varies, c. 20–30 μ. Forms elongated at the ends, which Moisseva (1971) has described from the Soviet Union, have not been noted in the Naruskajärvi material. Density of the transapical lines c. 18/10 μ.

OCCURRENCE: Numerous observations, but proportionally c. 1 per cent of the diatom species present at Naruskajärvi.

DISTRIBUTION: Species is a characteristic form in the early Pliocene stratum in the SE Soviet Union (Gleser *et al.* 1974).

Gomphonema brasiliense Grun.
(Plate 15, Fig. 10)

DESCRIPTION: O. Müller 1903, Pl. 1, Fig. 9; Foged 1973, Pl. 18, Figs. 17, 18.

DIMENSIONS: Length c. 28 μ, line density 12/10 μ.

OCCURRENCE: Exceedingly rare in Naruskajärvi diatomite.

DISTRIBUTION: Rare species, of which, however, observations of recent occurrence have been reported from different areas: Brazil, Bengal (Cleve 1894), Japan (Okuno 1952), Africa (O. Müller 1903, Foged 1966) and southwestern Greenland (Foged 1973). Information about Tertiary occurrences appears to be scanty. *Comphonema praelanceolata* Cheremisinova 1968 closely resembles *G. brasiliense* and may be a synonym.

Hydrosera trifoliata Cleve
(Plate 12, Fig. 12)

DESCRIPTION: Cleve 1881, p. 23, Pl. 6, Fig. 71.

BASIONYM:. *Triceratium (Hydrosera; Terpsinoe?)* trifoliatum Cl.

SYNONYMS: *Terpsinoe inflata* Brun (1891), Schmidt *et al.* 1874–, Pl. 204, Fig. 9; *Terpsinoe trifolium* Cl. in Peragallo 1897–1908, Lauby 1910; *Terpsinoe trifoliata* (A. Cleve 1915), *Triceratium trifoliatum* Cl. (Cleve-Euler 1951), *Hydrosera trifoliata* Cl. (Tynni 1977). Non *Triceratium trifolium* A. S.

DIMENSIONS: Diameter of valve c. 40–65 μ.

REMARKS: Species has a tendency to produce anomalous forms. In the Naruskajärvi diatomite, there also occur bipolar and relatively round forms (Tynni 1977, Pl. 1).

OCCURRENCE: Rare in Naruskajärvi diatomite and many other interglacial and postglacial deposits in northern Finland.

DISTRIBUTION: In Middle Pliocene sediments in the Lamber and Ceussac areas of La Roche, France (Lauby 1910). In New Zealand, rarely present in fresh and brackish water (Cleve 1881), possibly in a secondary position. Fossil occurrence at Sendai, Japan (Brun 1891, De Toni 1891). Fossil occurrence reported from Paltamo, Finland (Cleve-Euler 1915, 1951).

Melosira arenaria Moore *f. teres* (Brun) n. comb.
(Plate 12, Fig. 7)

SYNONYM: *Melosira teres* Brun

DESCRIPTION: Schmidt *et al.* (1874–, Pl. 179, Figs. 13, 14), Foged (1973, p. 951, Pl. 6, Figs. 3, 5, 7).

OCCURRENCE: Rare in Naruskajärvi diatomite.

REMARKS: According to Evans (1964), *M. teres* differs from the species *M. arenaria* owing to projecting points visible in side view, the shape of the radial striae of the discus and the characteristic »scabrous sculpturing.» *M. arenaria* and *M. teres* resemble each other, and possibly the *M. arenaria* observations reported from Finland include *M. teres* occurrences. The *Melosira scabrosa* Östr. rather commonly reported from Miocene and Pliocene deposits in the USSR is conceivably a synonym for the *M. teres* form (Evans *op. cit.*).

Melosira canadensis Hustedt
(Plate 12, Figs. 1, 2, 3)

DESCRIPTION: Hustedt 1952, p. 372, Figs. 21–30.

DIMENSIONS: Height of cylinder c. 10–18 μ, diameter c. 8 μ.

REMARKS: The *Melosira praeislandica* (O. Müll.) Jousé 1952 reported to have been observed in several places in the USSR is probably a synonym for the species described by Hustedt – or the other way around.

OCCURRENCE: Rare species in Naruskajärvi diatomite. Form has also been found in the Norinkylä interglacial deposit (Niemelä & Tynni 1979).

DISTRIBUTION: Besides the fossil occurrences reported from Canada (Hustedt 1952), the species has been found in the Miocene stratum in the Yakima region (Van Landingham 1964) and in Oregon (Abbott 1971). *Melosira praeislandica* has been reported to occur in the Baikal region of the USSR, the SE Soviet Union and the Kamchatka region – bein mainly present in Miocene and Pliocene deposits (Gleser *et al.* 1974).

Melosira undulata (E.) Kütz.
(Plate 12, Fig. 11)

DESCRIPTION: Hustedt, 1930, pp. 243–246.

DIMENSIONS: Diameter of valve 40–50 μ, on the average. Radial lines on discus surface varies from radial to fairly spiral.

REMARKS: Species known from many Pliocene and Miocene deposits, but it still grows in Finland, for which reason its occurrence is of little significance. Also var. *normanni* Arnott occurs in the Naruskajärvi diatomite deposit.

Opephora sp.
(Plate 14, Fig. 11)

REMARKS: The species resembles the form *Opephora parva* Krasske, which Cleve-Euler (1951) connects with the form *Fragilaria pinnata* v. *subsolitaris* (Grun.) Mayer.

Tetracyclus cruciformis Andrews 1970
(Plate 13, Figs. 7, 8)

SYNONYM: *Tetracyclus floriformis* Cheremisinova 1968.

DESCRIPTION: Andrews 1970, p. A 11, Pl. 1, Figs. 14–17. Cheremisinova 1968, p. 73, Pl. 6, Fig. 4, not precisely determined.

DIMENSIONS: Length of valve c. 40–45 μ, with c. 40 μ.

OCCURRENCE: Exceedingly rare in Naruskajärvi diatomite.

DISTRIBUTION: Found in Miocene deposit in Baikal region (Tsheremisinova 1968). Forms described by Andrews (1970) are from a late Miocene deposit in the Kilgore region of Nebraska.

Tetracyclus ellipticus (Ehr.) Grunow
(Plate 13, Figs. 1–3)

DESCRIPTION: Schmidt *et al.* (1874–, Pl. 280, Figs. 9–15; Pl. 281, Figs. 16, 24/Hustedt 1912), Moisseva (1971, p. 36, Pl. 3, Figs. 3–9, Pl. 16, Figs. 10–12).

DIMENSIONS: Length c. 20 μ.

REMARKS: Form resembles *Diatoma hiemale* v. *mesodon* (E) Grun., but the surface structure is coarser, and *Tetracyclus ellipticus* possesses intercalary bands and septa.

OCCURRENCE: Several occurrences in Naruskajärvi diatomite, but the percentage falls under 1.

DISTRIBUTION: According to Van Landingham (1964), the species is met with in a fossil state in numerous connections in North America. It corresponds to the Oligocene-present day situation. To date the species has not been reported from Finland. In the USSR, it is also commonly present in Miocene and Pliocene deposits (Gleser *et al.* 1977).

Var. *clypeus* (Ehr.) Hust.
(Plate 13, Fig. 4)

DESCRIPTION: Schmidt *et al.* (1874–, Pl. 281, Fig. 23)

DIMENSIONS: Length of nearly circular shells c. 15 μ.

OCCURRENCE: Exceedingly rare in Naruskajärvi diatomite.

DISTRIBUTION: Neogene occurrences in Colombia and Oregon (Moisseva 1971).

Var. *lancea* (Ehr.) Hustedt
(Plate 13, Fig. 5)

DESCRIPTION: Schmidt *et al.* (1874–, Pl. 281, Fig. 10), Moisseva (1971, p. 37, Pl. 4, Figs. 1–3; Pl. 17, Fig. 5).

DIMENSIONS: Length c. 30 μ.

OCCURRENCE: Rarely met with in Naruskajärvi diatomite.

DISTRIBUTION: Observations reported from Pliocene and Miocene deposits in USSR (Gleser *et al.* 1977).

Tetracyclus lacustris v. capitata Hustedt
(Plate 13, Figs. 10, 11)

DESCRIPTION: Schmidt *et al.* (1874–, Pl. 269, Fig. 6/Hustedt 1911).

DIMENSIONS: Length c. 30 μ, breadth 18 μ.

OCCURRENCE: The proportion of forms symmetrical at the ends contained in Naruskajärvi diatomite is considerably smaller than that of the following, heteropolar form.

Tetracyclus lacustris v. *capitata* f. *heterocapitata* n. f.
(Plate 13, Fig. 15)

DESCRIPTION: Midportion of valve is comparatively broad, the ends are distended, and the widths of the contracted places and ends differ remarkably. Length c. 30–50 μ, width c. 20–30 μ.

OCCURRENCE: Form commonly present in Naruskajärvi diatomite.

REMARKS: Heteropolar *T. emarginatus* is also fairly common in the present material. *T. lacustris* and *T. emarginatus* are often anomalous in structure in that the right and left valves of the shell differ in size, the thick transapical ridges run irregularly and the septa pattern of the lamellae in between varies.

HOLOTYPE: Plate 13, Fig. 15, GTL slide No. D-89, Naruskajärvi diatomite deposit.

Table 12, Fig. 13 shows an unidentified diatom with an asymmetric structure. It measures 48 μ in length and c. 30 μ in breadth. One side of the elliptical shell is crossed by a smooth field, in which the raphe is probably situated. Only a single individual has been met with in the diatomaceous earth at Naruskajärvi.

Silt deposit of Värriöjoki

In the silt bed deposited during the late glacial period there occur redeposited Tertiary diatoms and marine diatoms younger than the Tertiary but older than the late glacial period. The origin of the commonest species, *Melosira distans* + var. cannot be determined with certainty, for their worn condition could also indicate redeposition. Many of the frustules are fragmented to the extent of precluding identification. In the following are listed the forms alien to the present-day flora. Their combined occurrence in the preparation amounts to approximately 1–5 %, but separately they account for appreciably less than 1 %. The species marked with the + sign are described separately.

Actinoptychus senarius Ehr.

Bacillaria bacillifer (O. M.) Hendey

Campylodiscus echeneis Ehr.
+ *Cyclotella ovata n. sp.*
+ *C. aff. superba Schm.*
+ *Cymbella heteropleura Ehr. f. maior n. f.*

Eunotia sibirica Cl.
Eunotogramma variabile Grun.

+ *Fenestrella sp.*
Fragilaria triangulata Moiss.

Grammatophora oceanica (Ehr.) Grun.

Hemiaulus sp.
Hydrocera trifoliata Cl.

Melosira arenaria f. teres (Brun)
+ *M. sculpta (Ehr.) Grun.*
M. sulcata (Ehr.) Kütz.
+ *M. sp.*

Navicula sect. lyratae Cl.

Opephora gemmata (Grun.) Hust.

Rhabdonema arcuatum (Ag.) Kütz.

+ *Stephanopyxis broschii Grun.*
+ *S. sp.*
S. turris (Grev. et Arnott) Ralfs

Thalassiosira baltica (Grun.) Ostenf.

Cyclotella ovata n. sp.
(Plate 16, Fig. 9, Pl. 18, Figs. 1–21)

DESCRIPTION: The discus surface of the valve is to a noticeable extent eccentrically bent. The form of the outer edge varies from round to elliptical. From the outer edge toward the center, there are short, ribbonlike swellings. More inward, pointlike areoles are at first grouped radially, but in the central area they are generally directed toward two separate points about 1/3 from the apical ends. The diameter of the larger rounded forms is c. 28 μ, the length of the smaller ones c. 18 μ, and the breadth 12 μ.

REMARKS: The form resembles very closely the species *Coscinodiscus lacustris*, with which is connected also the elliptical smaller type: *C. lacustris* v. *septentrionalis* f. *deformis* A. Cl. 1942, but spicules have not been noted on the marginal portion of the forms found in Lapland. The form also resembles the species *Cyclotella omarensis* (Kütz.) Losseva & Makarova 1977, as well as the genus *Fenestrella* Grev. 1863, which has two eyelets that also affect the trend of the rows of areoles.

OCCURRENCE: Uncommon in Värriöjoki silt and Siurunmaa fine sand. The form has also been found in an interglacial deposit in the Finnish Bothnian region (Pohjanmaa) (Rova) (Niemelä & Tynni 1979, Pl. VI 46).

HOLOTYPE: Plate 16, Fig. 9, GTL slide No. D-149, silt deposit of Värriöjoki.

Cyclotella aff. superba Schmidt
(Plate 16, Fig. 10)

DESCRIPTION: Schmidt *et al.* (1874–, Pl. 222, Figs. 35, 36)

DIMENSIONS: Diameter of discus c. 23 μ.

REMARKS: The Värriöjoki form has 9 nodules in the central area, where as in Schmidt's description there are 7 nodules or pits. A more important distinguishing feature is the outer and inner pattern of radial lines appearing in the marginal portion on two different levels.

DISTRIBUTION: *C. superba* has been described in a fossil state from the Seville region.

Cymbella heteropleura Ehr. *f. major*
(Plate 16, Fig. 14)

DESCRIPTION: Differs from the species mainly owing to its larger size. Length 195 μ, breadth 45 μ. With regard to size, the form corresponds to *C. heteropleura* v. *subrostrata Cl.*, but in the Värriöjoki form the ends have not become elongated.

REMARKS: The species is known as a rare freshwater form of arctic and other northern regions, including Finnish Lapland. It has also been found in the interglacial deposit of Ruosseljänaapa in the Sodankylä district.

? *Fenestrella sp.*
(Plate 16, Fig. 12)

DESCRIPTION: Discus nearly round and bent saddle-fashion. Surface areolated into regular radial rows intersecting at a 60° angle, except in the area of two indistinct eyelets, which are situated on the diameter about 1/3 from the margin. In the marginal portion are c. 5-μ long bands 9/10 μ. Diameter is c. 38 μ.

OCCURRENCE: Exceedingly rare in the silt of the Värriöjoki area.

REMARKS: Closely resembles the species *Fenestrella gloriosa* described by Brun (1893), which has been met with at Oamary in a fossil state. *F. gloriosa*, however, is considerably larger (130–160 μ) than the Värriöjoki form. On the other hand, the species resembles one of the types of *Cyclotella ovata* described in the foregoing.

Melosira sculpta (Ehr.) V. Heurck
(Plate 16, Fig. 3)

DESCRIPTION: Cleve-Euler (1951, p. 33, Fig. 31 a, b)

DIMENSIONS: Diameter c. 25 μ.

REMARKS: Only one occurrence reported, and the identification is not incontrovertible. The dense areolar structure is eccentrically arranged in the marginal portion, and the structure resembles *Thalassiosira eccentrica* with its small areoles.

Melosira sp. *(M. goetzeana* O. Müll. – typ*)*
(Plate 16, Fig. 1)

DESCRIPTION: Schwabe & Simonsen 1961, p. 265. Cylindrical mantle, length c. 12 μ, width 8 μ. Surface densely covered with nodules, 10/10 μ. Nodules are grouped in a direction of the long axis and intersecting the long axis at a 60° angle. The cell halves are probably lacking long spines.

OCCURRENCE: Rarely met with in Värriöjoki silt.

REMARKS: Owing to its poor preservation, more many-sided observations are lacking. Occurrence resembles terminal cell of *M. granulata*, but the structure is denser.

Stephanopyxis broschii Grunow
(Plate 16, Fig. 4)

DESCRIPTION: Grunow (1884, p. 90, Figs. 26–30)

DIMENSIONS: Diameter c. 20 μ, number of areoles 3–4/10 μ.

OCCURRENCE: Extremely rarely present in Värriöjoki silt.

DISTRIBUTION: Grunow has described the species as contained in fossil material collected from Franz Josef Land.

Stephanopyxis sp.
(Plate 16, Fig. 7)

DESCRIPTION: Valve is convex and covered with pointed nodules, situated at even intervals of c. 4/10 μ. Diameter of valve c. 20 μ. Spicules situated on corners of areoles, as in the case of the species *S. ferox* (Grev.) Ralfs, which is, however, noticeably larger.

OCCURRENCE: Very rare in Värriöjoki silt deposit.

Gyttja deposit of Sivakkapalo

Dealt with in the following review are only those diatoms of the gyttja deposit of Sivakkapalo that are not presented in the present-day flora of Finnish Lapland or are exceedingly rare.

Achanthes elliptica v. pungens A. Cl.-E.
(Plate 21, Fig. 1)

DESCRIPTION: The elliptical valve is elongated at the ends, which appear slightly rostrated. The pattern of lines of the raphe half is sharply radial, the line density being c. 18/10 μ. The lines form slightly S-shaped curves. The area of the raphe axis is narrow but widens slightly close to the central area. The central area has expanded transversally, to broaden out sidewise. In the axis area on the pseudoraphe side, there is a rather broad pseudoraphe, the bounding lines of which are c. 10/10 μ. On one side of the central point is a horseshoe-shaped area. Length c. 40–45 μ.

REMARKS: Structurally, the form resembles *A. peragalli* Brun but deviates from that by its larger size and the shape of its tips.

OCCURRENCE: Rarely met with in Sivakkapalo gyttja, but a few observations have been made.

Coscinodiscus sp.
(Plate 20, Figs. 4 a, b)

DESCRIPTION: Tiny form, diameter of discus averages 9 μ. Surface eccentrically bent, and covered with radially arranged tiny nodules. Situated near the ring at sparse intervals are 6–10 larger nodules.

REMARKS: Form resembles closely *C. miocenicus* Schrader 1973 described by Schrader & Fenner (1976) (Plate 15, Figs. 3, 6). Nodules on the marginal portion have not been mentioned in connection with the species *C. miocaenicus* described by Krasske (1932). Points of resemblance with the species *Melosira albicans* Sheshukova-Poretzkaja (1964) have also been noted. Fresh- or brackish water form.

OCCURRENCE: Rarely met with in Sivakkapalo gyttja, occurring at a depth, for instance, of 84 dm.

AGE: Probably Neogene species.

Cyclotella kützingiana var. *planetophora* Fr. f. *verticillata* Cl.-E.
(Plate 20, Figs. 5, 6)

DESCRIPTION: Cleve-Euler 1951, P. 51, Fig. 65 v.

REMARKS: Characteristic of the form are pores situated at the margin of the central field. Cleve-Euler (1932) ran across the form in a Lake Tåkern deposit.

Cyclotella ovata n. sp.
(Plate 18, Figs. 1–21)

DESCRIPTION: See p. 32, description of Värriöjoki form. At Sivakkapalo, drill hole M 1, at depth of 8.0–8.8 m variation in size is greater, c. 30–6 μ.

OCCURRENCE: Fairly common in Sivakkapalo deposit.

Eunotia polyglyphis f. tetraclyphis Grunow
(Plate 14, Fig. 17)

SYNONYM: *Eunotia tetraglyphis* Ehrenberg

DESCRIPTION: Four-knobbed *E. polyglyphis* appears to be the only representative of the species in Naruskajärvi diatomite or Sivakkapalo gyttja; hence limiting of the form is warranted. Length of valve c. 30 μ, density of lines c. 13/10 μ.

REMARKS: Hustedt associates it with the principle form, but Rehakova (1969) has described a four-knobbed specimen slightly deviating form the foregoing that was found in a Lower Miocene deposit in the northern part of Bohemia. No four-knobbed *polyglyphis* form has previously been reported from Finland.

Eunotia sp.
(Plate 20, Fig. 12)

DESCRIPTION: Tiny thicksilicious form. Thickness of valve c. 1.5 μ length 18–20 μ. Visible in the inner portion is a line pattern of the *E. pectinalis v. minor* type, but smaller. Length c. 17 μ, crosswise lines c. 25/10 μ. Inner pattern is apt to be lacking or replaced by a lengthwise line.

REMARKS: Possibly, the form in question corresponds to the polymorphy of a thinner species under unfavorable conditions.

OCCURRENCE: Exceedingly rare, about ten observations made in the gyttja deposit of Sivakkapalo.

Fragilaria lapponica Grun. var. *maior* n. var.
(Plate 20, Figs. 19, 20)

DESCRIPTION: Length of valve 35–65 μ, breadth c. 7 μ; density of short bands along edge 6–7/10 μ. Otherwise, identical to principal form.

REMARKS: According to Hustedt, length of *F. lapponica* is 12–40 μ; and, according to Cleve-Euler, generally 15–25 μ, or distinctly smaller than in the gyttja deposit at Sivakkapalo. It resembles the species *Fr. spinosa* Skv.

OCCURRENCE: A few observations recorded; on the other hand, the principal form is common.

HOLOTYPE: Plate 20, Fig. 20, GTL slide HH/80, Sivakkapalo gyttja deposit, 8.4 m depth.

Fragilaria leptostauron (Ehr.) Hust. var. *binodis* n. var.
(Plate 20, Fig. 9)

REMARKS: The form in question is comparatively broad (f. *latissima*) averaging 25 μ in length and 9 μ in breadth. The same type form is commonly encountered also in the interglacial diatomite deposit of Sokli (Ilvonen 1973). In Finland, it is more generally found in postglacial deposits and as a recent occurrence whith a more elongated shape, *F. construens* v. *binodis* (Ehr. Grun.)

Hydrosera trifoliata Cleve
(Plate 20, Figs. 14–16)

REMARKS: The species is common in places in the gyttja deposit of Sivakkapalo, but its share of the total generally falls under 1 %. In shape and structure, the species varies and anomalous forms are common. The form described represents a relatively large, well-developed type, exhibiting a regular point structure of the triangle corners and spicules situated at sparse intervals.

Melosira arenaria Moore f. *teres* (Brun) n. comb. occurs in the gyttja of Sivakkapalo together with the principal form. In each, the radial banding is sharply bounded only on the marginal portion, but the areolar structure of the mantles exhibits a regular surface structure with tiny nodules situated at sparse intervals.

Melosira islandica O. Müll., restring spores
(Plate 20, Fig. 3)

DESCRIPTION: Aario (1966, Figs. 6; 1–8).

OCCURRENCE: Exceedingly commonly present in the gyttja deposit of Sivakkapalo. However, growth forms proper were not met with.

REMARKS / COMPARISONS: The form registers its maximum in the Pohjanmaa region in redeposited diatomite overlain by glacial till at Haapajärvi (Aario 1966). The situation did not correspond to a water temperature warmer than that prevailing at present, and the formation of the deposit is believed to have required either an interstadial or interglacial cool stage (Aario, *op. cit.*). Also in the diatomite deposit at Sokli as well as the interglacial or interstadial deposits in Pohjanmaa, the form occurs less commonly (Niemelä & Tynni 1979). It is further known from Pliocene deposits in the Kama region (Gleser *et al.* 1974).

Navicula reinhardtii Grun.
(Plate 21, Fig. 10)

REMARKS: The species is represented in the Sivakkapalo deposit by a blunt-ended form relatively narrow in the middle.

Pinnularia legumen Ehr. fo. *inflata* n. fo.
(Plate 21, Figs. 5, 7)

DESCRIPTION: Length c. 100 μ, line density c. 8/10 μ. Trend of lines in middle section fairly radial, convergent at ends. It differs from the principal form essentially by the distention of the midportion.

OCCURRENCE: A few observations made in Sivakkapalo sediment.

HOLOTYPE: Plate 21, Fig. 5, GTL slide HH/80, Sivakkapalo gyttja deposit.

Pinnularia sp. 1
(Plate 21, Fig. 6)

DESCRIPTION: Shorter form possibly related to the foregoing. Length c. 70 μ. Raphe diagonal, axial area broad and extending in the midsection as far as one of the edges.

OCCURRENCE: A few observations made in Sivakkapalo sediment at a depth of 8.8 m.

Pinnularia sp. 2
(Plate 21, Fig. 11)

DESCRIPTION: Fairly broad and convex in the middle, narrowing to rostrate ends. The transapical set of lines is throughout radial, the line density being 12–13/10 μ. The axial zone in the middle is exceedingly broad and narrows toward the ends parallel to the terminal pattern. The central pores of the raphe have bent to one side, but the outermost raphe-ends are not clearly visible. Length c. 50 μ, breadth 11 μ.

REMARKS: The form has features of the genus *Caloneis*; but the lengthwise lines of the marginal area characteristic of the genus could not be perceived.

Tetracyclus lapponicus n. sp.
(Plate 19, Figs. 7, 10–15)

DESCRIPTION: On the valve could be distinguished eight swellings, of which two were at the ends, two on the sides in the middle and four between the midmargin and the ends. The basic form is roundish oval, c. 27 μ in length and c. 23 μ in breadth. On the surface can be perceived five long crosswise bands and in between at the edge short bands. Delicate transapical pattern of dots, but in the mid-area occur coarser dots at sparser intervals. The form resembles the species *T. japonicus* (Petit) Hustedt (Schmidt Atl. 282, Figs. 1, 2), but the species *japonicus* has about 12 bulges along the edge and it is almost round in shape.

REMARKS: The species *Tetracyclus* is well represented in the gyttja deposit of Sivakkapalo. *T. ellipticus* var. *lancea* f. *subrostrata* Hust. – *T. lapponicus* with their intermediate forms constitute a transitional series (Pl. 19), from which it becomes evident that *T. ellipticus* and *lapponicus* are closely related forms.

AGE: The species probably belongs to the diatom flora of the Neogene. It closely resembles the form *T. japonicus* described from the Neogene stratum of White Russia (Khursevich & Loginova 1980).

HOLOTYPE: Plate 19, Fig. 12, GTL slide HH/80, gyttja deposit of Sivakkapalo; depth 8.0 m.

ACKNOWLEDGMENTS

The material providing the basis for the present study was collected by the Geological Survey of Finland in connection with the mapping of Quaternary deposits and ore prospecting operations in the years 1972–76. The study complements the preliminary report issued five years earlier by Hirvas and Tynni (1976). Another area of interest was the microfossil research done on the sediments of Siurunmaa. Sakari Leskelä, Ph. M., participated in the Siurunmaa project, but his share in the work was cut short by a fatal accident. It is fitting here to honor the memory of a reliable coworker.

For discussions illuminating the subject of my research, I wish to thank Professor Kauko Korpela, research director on the staff of the Geological Survey, and my colleagues Drs. Heikki Ignatius and Boris Winterhalter.

I also wish to acknowledge the valuable support given me at different stages of my work by Research Assistant Kalevi Hokkanen.

My Finnish manuscript was translated into English by Paul Sjöblom, M. A.

REFERENCES

Aario, R., 1966. Kieselgur in fluvioglazialen Ablagerungen in Haapajärvi in Ostbottnien. C. R. Soc. géol. Finlande 38, 3–30.

Abbott, W. H., 1971. Micropaleontology and Paleoecology of Miocene Non-Marine Diatoms from the Harper District, Malheur County, Oregon. Nova Hedwigia, 23 (4), 847–906.

Andrews, G. W., 1970. Late Miocene nonmarine diatoms from the Kilgore area, Cherry County, Nebraska. U. S. Geol. Surv. Prof. Pap. 683-A, 24 p., 3 plates.

–, 1971. Early Miocene nonmarine diatoms from the Pine Ridge area, Sioux County, Nebraska. U. S. Geol. Surv. Prof. Pap. 683-E, 17 p., 2 plates.

Benda, L., 1965. Diatomeen aus dem Eozän Norddeutschlands. Paläont. Z. 39 (3/4), 165–187.

–, 1972. The Diatoms of the Moler Formation of Denmark (Lower Eocene). A Preliminary Report. Nova Hedwigia Beih. 39, 251–266.

Brander, G., 1937. Ein Interglazialfund bei Rouhiala in Südfinnland. Bull. Comm. Géol. Finlande 118, 76 p.

–, 1943. Neue Beiträge zur Kenntnis der interglazialen Bildungen in Finnland. Bull. Comm. Géol. Finlande 128, 85–137.

Brun, J., 1891. Diatómees Marines, Fossiles ou Pélagíques. Mémoires de la Société de Physique et d'Histoire Naturelle de Geneve, 31, (1), p. 1–47, pl. 11–22.

Bukry, D., 1974. Stratigraphic Value of Silicoflagellates in Nontropical Regions. Geol. Soc. America Bull. 85, 1905–1906.

–, 1976. Cenozoic Silicoflagellate and Coccolith Stratigraphy, South Atlantic Ocean, Deep Sea Drilling Project Leg 36. Natl. Sci. Found. Initial Rep. of the Deep Sea Drilling Proj. 35, 885–917.

–, 1978. Cenozoic Silicoflagellate and Coccolith Stratigraphy, Northwestern. Atlantic Ocean, Deep Sea Drilling Project Leg 43. Natl. Sci. Found. Initial Rep. of the Deep Sea Drilling Proj. 44, 775–805.

Bukry, D. & Foster, J. H., 1974. Silicoflagellate zonation of Upper Cretaceous to Lower Miocene Deep-Sea sediment. J. Res. U. S. Geol. Surv., 2 (3), 303–310.

Cheremisinova, Ye. A., 1956 a. Melosira miocaenica sp. nova e Miocaeno Sibiriae Occidentalis. Bot. mater. Otd. sporov. rast. BIN AN SSSR, 11, 60–71.

–, 1956 b. Diatomeae novae ex Oligicaeno Ucrainae. Bot. mater. Otd. sporov. rast. BIN AN SSSR, 11, 62–64.

–, 1968. Novye dannye o diatomeyakh Neogenovykh Otlozheniy Pribaykal'ya *in* Iskopayemye Diatomovye Vodorosli SSSR, Moscow, Akad. Nauk. SSSR, p. 71–74, pls. 3–6.

Cleve, P. T., 1881. On some new and little known Diatoms. Kongl. Sven. Vetensk.-Akad. Handl., 18 (5), 1–28.

Cleve-Euler, A., 1915. New Contributions to the Diatomaceous Flora of Finland. Arkiv för Botanik, 14 (9), 1–81.

–, 1940. Das letztinterglaziale Baltikum und die Diatoméenanalyse. Bot. Zentralbl. 60, Beih. Abt. B, 287–334.

–, 1942. Coscinodisci et Thalassiosirae Fennosueciae. Eine kritische Übersicht. Bot. Not., 231–278.

–, 1951. Die Diatomeen von Schweden und Finnland. I. Kungl. sven. Vetensk.-Akad. Handi., 4. Ser., 2, 162 p.

–, 1955. Die Diatomeen von Schweden und Finnland. IV. Kungl. sven. Vetensk.-Akad. Handl., 4. Ser., 5, 232 p.

Cleve-Euler, A. & Hessland, I., 1948. Vorläufige Mitteilung über eine neuentdecte Tertiärablagerung in Süd-Schweden. Bull. Geol. Inst. Upps., 32, 155–182.

De Toni, J. B., 1891–94. Sylloge bacillariearum omnium hucusque cognitarum. Pata VII. 1556 p.

Eriksson, B., 1977. Nykyflooralle vieraita palynomorfeja Suomen myöhäiskvartäärikerrostumista. Summary: Palynomorphe foreign to precent flora in some Late Quaternary deposits of Finland. Geol. Surv. Finland, Rep. Invest. 17, 3–18.

Evans, G. H., 1964. Two fossil diatoms from the Lake Deposits of the English Lake District. New Phytol. 63, 413–417.

Fairbridge, R. W., 1964. Thoughts about an expanding globe. Repr. fr. Advancing Frontiers in

Geology and Geophysics, Osmania Univ. Press. 59–88.

Fenner, J., 1977. 1. Cenozoic Diatom Biostratigraphy of the Equatorial and Southern Atlantic Ocean. Natl. Sci. Found. Initial Rep. of the Deep Sea Drilling Proj., 39, 491–624.

Foged, N., 1973. Diatoms found in a bottom sediment sample from a small deep lake on the Northern Slope, Alaska. Nova Hedwigia Beih. 21, 923–1035.

Frenguelli, J., 1940. Consideraciones sorbe los silicoflagelados fósiles. Rev. Museo La Plata, ser. 2, (2), Paleont. 7, 37–112.

Gleser, S. I., 1964. Novye kremnevye zhgutikovye vodrosli Paleogena SSSR, Silicoflagellatae fossiles novae URSS. Akad. Nauk SSSR, Nov. sist. nizshikh rast., otdel. ottisk, 46–58.

–, 1966. Kremnevye zhgutikovye vodrosli (Silikoflagellaty). Silicoflagellatophyceae: Flora Sporovykh Rasteniy SSSR, Flora Plantarum Cryptogammarum URSS, 7, Akad. Nauk SSSR, Bot. Inst. V. L. Komarova, Moscow, Leningrad, 1–330.

–, 1970. Cryptogamic plants of the U.S.S.R. 7. Silicoflagellatophyceae. (Transl. from Russian) Israel Progr. Sci. Transl. Jerusalem, 363 p.

Gleser, S. I. *et al.* **1974.** The diatoms of the USSR. Fossil and Recent, 1, Leningrad, 109–146.

Gleser, S. I. & Posnova, A. N., 1964. Diatomeae novea marinae ex Eoceno Kazachstaniae occidentalis. Nov. sist. nizshikh rast. Akad. Nauk SSSR, o delnyi ottisk, 59–66.

Grönlund, T., 1977. Tertiäärisiä piileväesiintymiä Lapista. Abstract: The occurrence of Tertiary diatoms in Lapland. Geol. Surv. Finland, Rep. Invest. 17, 19–30.

Grunow, A., 1884. Die Diatomeen von Frans Josefs-Land. Denkschr. d.k. Akad. d. Wiss. math. naturw. Classe 48. Bd. 2., 53–112, 5 pls.

Hajós, M., 1968. Mátraalja Miocén Üledékeinek Diatomái/Die Diatomeen der miozänen Ablagerungen des Mátravorlandes. Geologica Hungarica, Palaeontol., Fasc. 37, 402 p.

Hajós, M. & Stradner, H., 1975. Late Cretaceous Archaeomonadaceae, Diatomaceae, and Silicoflagellatae from the South Pacific Ocean, Deep Sea Drilling Project, Leg 29, Site 275. Natl. Sci. Found. Initial Reports of the Deep Sea Drilling Project, 29, 913–1009, Washington.

Hanna, G. D., 1927. The lowest known Tertiary diatoms in California. J. Paleontol., 1, 103–126.

Heiberg, P. A. C., 1863. Conspectus criticus Diatomacearum Danicarum. Wilh. Priors, København, 135 p.

Heinonen, L., 1957. Studies on the microfossils in the tills of the north European glaciation. Ann. Acad. Sci. Fennicae A III, 52, 92 p.

Hendey, I. N., 1969. *Pyrgupyxis*, a new genus of diatoms from a south Atlantic Eocene core. Occ. Pap. Calif. Acad. Sci., 72, 1–5, San Francisco.

Hirvas, H., Kujansuu, R. & Tynni, R., 1976. Till stratigraphy in northern Finland. I. G. C. P. 73/1–24, Quaternary glaciations in the Northern Hemisphere, session Bellingham USA/1975. Rep. 3, 256–273.

Hirvas, H. & Tynni, R., 1976. Tertiääristä savea Savukoskella sekä havaintoja tertiäärisistä mikrofossiileista. Summary: Tertiary clay deposit at Savukoski, Finnish Lapland, and observations of tertiary microfossils, preliminary report. Geologi 28, 33–40.

Hovasse, R., 1932. Note préliminaire sur les Ebriacées, Bull. Soc. Zool. France, 57, 118–130.

Hustedt, F., 1930. Die Kieselalgen Deutschlands, Österreichs und der Schweiz mit Berücsichtigung der übrigen Länder Europas sowie der angrenzenden Meeresgebiete. *In* Kryptogamenflora von Deutschland, Österreichs und der Schweiz. by Rabenhorst, L. 7, (1), 920 p.

–, 1952. Neue und wenig bekannte Diatomeen, IV. Bot. Not. H. 4, 366–410.

–, 1965. Neue und wenig bekannte Diatomeen. IX. Süsswasserdiatomeen aus Brasilien, insbesondere des Amazonasgebietes. Int. Revue ges. Hydrobiol. 50 (3), 391–410.

Hyyppä, J., 1977. Kaoliinia Sodankylän Siurunmaassa. Geologi 29, 52–56.

Ilvonen, E., 1973. Eem-kerrostuma Savukosken Soklilla. Summary: An Eem- Interglacial deposit at Sokli in Savukoski, Finnish Lapland. Geologi 25, 81–83.

Jousé, A. P., 1952. K istorii diatomovoy flory ozera Hanka. V kn. Trudy Inst. geogr. SSSR, 51, (6) 226–252.

–, 1955 a. Silicoflagellatae aetatis paleogenae. Akad. Nauk SSSR. Bot. Inst. Bot. Mater., Otdel Sporovykh Rastenii, 10, p. 77–81.

–, 1955 b. Species novae diatomacearum aetatis paleogenae. Akad. Nauk SSSR. Bot. Inst. Bot. Mater., Otdel Sporovykh Rastenii, 10, 81–103.

–, 1974. Diatoms in the Oligocene-Miocene biostratigraphic zones of the tropical areas of the Pacific Ocean. *In* Micropaleontology of Oceans and Seas. ed. by A. P. Jousé, Akad. Nauk USSR, Moscow, 34–48.

Jousé, A. P. & Sheshukova-Poretzkaya, V. S., 1971.

Genus novum *Riedella* Jousé et Sheshukova-Poretzkaya (Bacillariophyta). Novit. Syst. Plant. non Vasc., 8, p. 19–25.

Kanaya, T., 1957. Eocene diatom assemblages from the Kellogg and »Sidney» shales, Mt. Diablo area, California. Sci. Rep. Tohoku Univ., Sendai, Japan, 2nd ser. (Geol.) 28, 124 p.

–, 1959. Miocene diatom assemblages from the Onnagawa Formation and their distribution in the correlative formations in Northeast Japan. Sci. Rep. Tohoku Univ., Sendai, Japan, 2nd ser. (Geol.) 30, 130 p.

Khursevich, G. K., Loginova, L. P., 1980. The fossil diatom flora of Byelorussia: (In Russian). Acad. Sci. Byelorussian SSR Inst. Geochem. Geophys., Minsk »Nauka i tekhnika», 1–122.

Krasske, G., 1932. Die Diatomeenflora der hessischen Kieselgurlager. Sitzungsberichte d. Heidelberger Akad. Wiss. Mat. Nat. Klasse Jahrg. 1932, 3–27.

Kujansuu, R., 1964. Nuorista siirroksista Lapissa. Summary: Recent faults in Finnish Lapland. Geologi 16, 30–36.

Lauby, A., 1910. Recherches Paléophytologiques dans le Massif Central. Bull. Serv. Carte Géol. France 125, (20) p. 1–398, 14 pl.

Loeblich, A. R. III, Loeblich, L. A., Tappan, H. & Loeblich, A. R. Jr. 1968. Annotated index of fossil and recent silicoflagellates and ebridians with descriptions and illustrations of validly proposed taxa. Mem. Geol. Soc. America 106, 319 p.

Lohman, K. E., 1938. Pliocene diatoms from the Kettleman Hills, California. U. S. Geol. Surv. Prof. Pap. 189-C, 79–102.

Losseva, E. I. & Makarova, I. V., 1977. De specie Cyclotellae Kütz. nova notula. Akad. Nauk SSSR, Nov. Sist. Nizshikh Rast., 14, 29–31, 2 pl.

Martini, E. 1974. Silicoflagellate zones in the Eocene and early Oligocene. Senckenbergiana leth. 54, 527–532.

Mc Collum, D. W., 1975. Diatom stratigraphy of the Southern Ocean. Natl. Sci. Found. Initial rep. of the Deep Sea Drilling Proj. 28, 515–538.

Mikkola, E., 1932. On the physiography and late-glacial deposits in northern Lapland. Bull. Comm. géol. Finlande 96, 88 p.

Miller, U., 1966. Tertiary diatoms and silicoflagellates in the Kristianstad plain. *In* Geological data from the Kristianstad plain, Southern Sweden. Sveriges Geol. Unders. C 605, plates I–IX.

–, 1971. Microfossils in the Quaternary layers at Tofthög, southern Scania. Geol. Fören. i Stockh. Förh. 93, 507–524.

Moisseva, A. I., 1971. Atlas neogenovykh diatomovykh vodorosley Primorskogo kraya. Tr. VSEGEI, nov. ser., 171. L. »Nedra», 152 p.

Mukhina, V. V., 1974. Paleotsenovye diatomovye ily v vostochnoj chasti Indiyskogo Okeana. Okeanol., S.S.S.R. 14, 852–858.

Niemelä, J. & Tynni, R., 1979. Interglacial and interstadial sediments in the Pohjanmaa region, Finland. Geol. Surv. Finland, Bull. 302, 48 p., 4 app., 10 pl.

Nilsson, K., 1966. Geological data from the Kristianstad plain, Southern Sweden. Sveriges Geol. Unders., C 605. plates I–IX

Oftedahl, Chr., 1980. Geology of Norway. Norges Geol. Unders. 356, Bull. 54, 3–114.

Okuno, H., 1952. Atlas of fossil diatoms from Japanese diatomite deposits. Bot. Inst. Kyoto Univ. of Ind. Arts and Textile Fibers, Kamikyoku, Kawakita Print, Kyoto. 49 p., 29 pls.

Östrup, E., 1900. Leda pernula Leret ved Selbjerggaard i Vester Hanherred. 4. Floraen. Medd. Dansk geol. Forh. 6, 10–17.

Patrick, R. & Reimer, C. W., 1966. The Diatoms of the United States, 1. Acad. Natl. Sci. Philadelphia. 688 p.

Penttilä, S., 1963. The deglaciation of the Laanila area, Finnish Lapland. Bull. Comm. géol. Finlande 203, 71 p.

Peragallo, H. & M., 1897–1908. Diátomees Marines de France et des Districts Marimes Voisins. Micrographe-Éditeur, à Gres-sur-Loing (S. et M.) Texte 491 + 48, Atlas 137 pls.

Perch-Nielsen, K., 1975. Late Cretaceous to Pleistocene Archaeomonads, Ebridians endoskeletal Dinoflagellates, and other siliceous Microfossils from the Subantarctic Southwest Pacific, DSDP, Leg 29. Natl. Sci. Found., Initial Rep. Deep Sea Drilling Proj., 29, 873–907.

–, 1975 a. Late Cretaceous to Pleistocene Silicoflagellates from the southern Southwest Pacific, DSDP, Leg 29. Natl. Sci. Found. Initial Rep. Deep Sea Drilling Proj., 29, 677–721.

–, 1976 a. New silicoflagellates and a silicoflagellate zonation in north European Palaeocene and Eocene diatomites. Bull. Geol. Soc. Denmark, 25, 27–40.

–, 1976 b. Eocene to Pliocene Archaeomonads. Ebridians, and endoskeletal Dinoflagellates from the Norwegian Sea, Leg. 38. Natl. Sci. Found., Initial Rep. Deep Sea Drilling Proj., 38, 147–175.

Poretsky, V. S., 1953 a. Iskopaemye diatomovye vodorosli Kisatibi Akhaltsikhskogo rayona Gruzinskoy SSR. Diatom. sborn., Ist. Leningr. Univ. Biol.-Pochven. Fak., 13–54.

–, **1953 b.** Iskopaemye diatomovye vodorosli Nurnusa i Arzni Erevanskogo rayona Armyanskoy SSR. Ist. Leningr. Univ. Biol.-Pochven. Fak., 55–106.

Proschkina-Lavrenko, A. I. (Ed.), 1974. The Diatoms of the USSR. Fossil and Recent. 1, Leningrad, 190 p.

Rehakova, Z., 1965. Fossile Diatomeen der südböhmischen Beckenablagerungen. Rozpravy Ústredniho ústavu geologického 32, Praha. 96 p.

–, **1971.** Changements qualitatifs des associations de Diatomées dans les sédiments tertiaires et quaternaires de Tchécoslovaquie. Union Intern. pous l'étude du Quaternaire, 8. Congrès INQUA, Paris, Paléont. végetale, 275–286.

Ross, R. and Sims, A., 1974. Observations on Family and Generic Limits in the Centrales. Nova Hedwigia, Beih. 45, 97–128.

–, **1978.** Notes on some diatoms from the Isle of Mull, and other Scottish localities. Bacillaria 1, 151–168.

Round, F. E., 1970. The delineation of the genera *Cyclotella* and *Stephanodiscus* by light microscopy transmission and reflecting electron microscopy. Nova Hedwigia, Beih. 31, 591–589.

Schmidt, A. (1874–1959), Atlas der Diatomaceen-Kunde, 1874–1959. Leipzig, pl. 1–460.

Schrader, H.–J., 1976. Cenozoic planktonic diatom biostratigraphy of the Southern Pacific Ocean. Natl. Sci. Found. Initial Rep. Deep Sea Drilling Proj. 36, 605–671.

Schrader, H.-J. & Fenner, J., 1976. Norwegian Sea Cenozoic diatom biostratigraphy and taxonomy. Part. 1. Norwegian Sea Cenozoic diatom biostratigraphy. Natl. Sci. Foun. Initial Rep. Deep Sea Drilling Proj. 38, 921–1099.

Schulz, P., 1935. Diatomeen aus senonen Schwammgesteinen der Danziger Bucht. Zugleich ein Beitrag zur Entwicklungsgeschichte der Diatomeen. Bot. Arch., Zeit. für die Geamte Bot., 37, 383–413.

Sheshukova-Poretskaja, V. S., 1967. Neogenovye morskie diatomovye vodorosli Sakhalina i Kamchatki. Izd. Leningr. Univ. 432 p.

Sheshukova-Poretskaja, V. S. & Gleser, S. I., 1964. Diatomeae marinae novae e Paleogeno Ucraineae. Acad. Nauk. U.S.S.R. Nov. sist. nizschich rast. otdel bentii o Hisk, isdatelbstwo Nauka, 78–92.

Sheshukova-Poretskaja, V. S. & Moisseva, A. I., 1964. Novie i intersnie presnovodnie diatomovie vodorosli iz neogena Zapadnoi sbiri idalnego vosloka (Diatomeae Aquae dulcis novae et curiosae e neogeno sibirae occidentalis et orientis extremi). Nov. syst. nizschikh rast., Akad. Nauk. U.S.S.R., Botan. inst. im. V. L. Komarova, 92–103.

Simonsen, R., 1962. Untersuchungen zur Systematik und Ökologie der Bodendiatomeen der westlichen Ostsee. Int. Rev. gesamt. Hydrobiol. System. Beih. 1, 144 p.

Skvortzov, B. V., 1937. Neogene Diatoms from Wamura, Nagano Prefecture, Central Nippon. Mem. Coll. Sci. Kyoto Imper. Univ., Ser. B, 12 (2), 137–156.

Strelnikova, N. I., 1974. Diatomei pozdnogo mela. »Nauka», Moscow, 204 p.

Suomalainen, T. & Tynni, R., 1970. Der präquartäre Mikrofossilienbestand der Tonvorkommens von Kaljala auf der Karelischen Landenge. Bull. Comm. Géol. Finlande 245, 81 p.

Tulkki, P., 1977. The bottom of the Bothnian Bay Geomorphology and sediments. Merentutkimusl. julk. 241, 5–89.

Tynni, R., 1977. *Hydrosera trifoliata* und ihre Mutationsformen. Comm. Biol. 90, 1–12 p.

Van Heurck, H., 1896. A Treatise on the Diatomaceae. Translated by W. E. Baxter, William Wesley & Son, London, 558 p., 35 pls.

Van Landingham, S. L., 1964. Miocene Non-marine Diatoms from the Yakima Basalt in South Central Washington. Nova Hedwigia, Beih. 16, 74 p., 56 pls.

Winterhalter, B., 1972. On the geology of the Bothnian Sea, an epeiric sea that has undergone Pleistocene glaciation. Geol. Surv. Finland, Bull. 258, 66 p.

Witt, O. N., 1886. Ueber den Polierschiefer von Archangelsk-Kurojedowo im Gouv. Simbirsk. Verhandl. d. Russisch-Kaiserlichen Mineral. Gesells. St. Petersburg. 2. Ser., Bd. 22, 137–177, 7 pls.

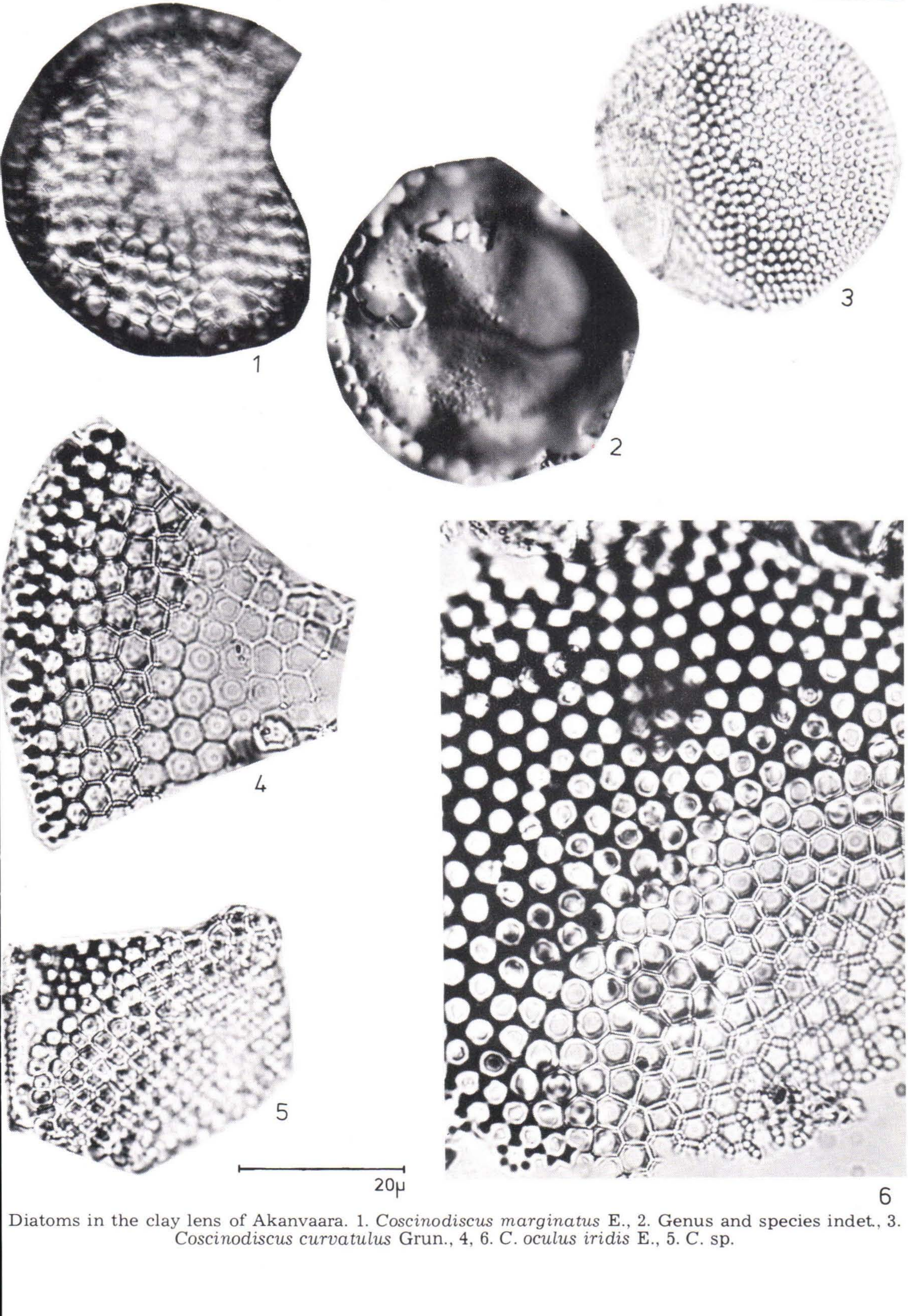
Wood, H. E., Chairm., Chaney, R. W., Clark, J., Colbert, E. H., Jepsen, G. L., Reeside, Jr. J. B., Stock, C., (Committee), 1941. Nomenclature and Correlation of the North American Continental Tertiary. Bull. Geol. Soc. America, 52, 1–48.

Wornardt, Jr. W. W., 1969. Diatoms, past, present, future. Proceed. of the first intern. conf. planktonic microfossils, Geneve 1967, 2, 690–714.

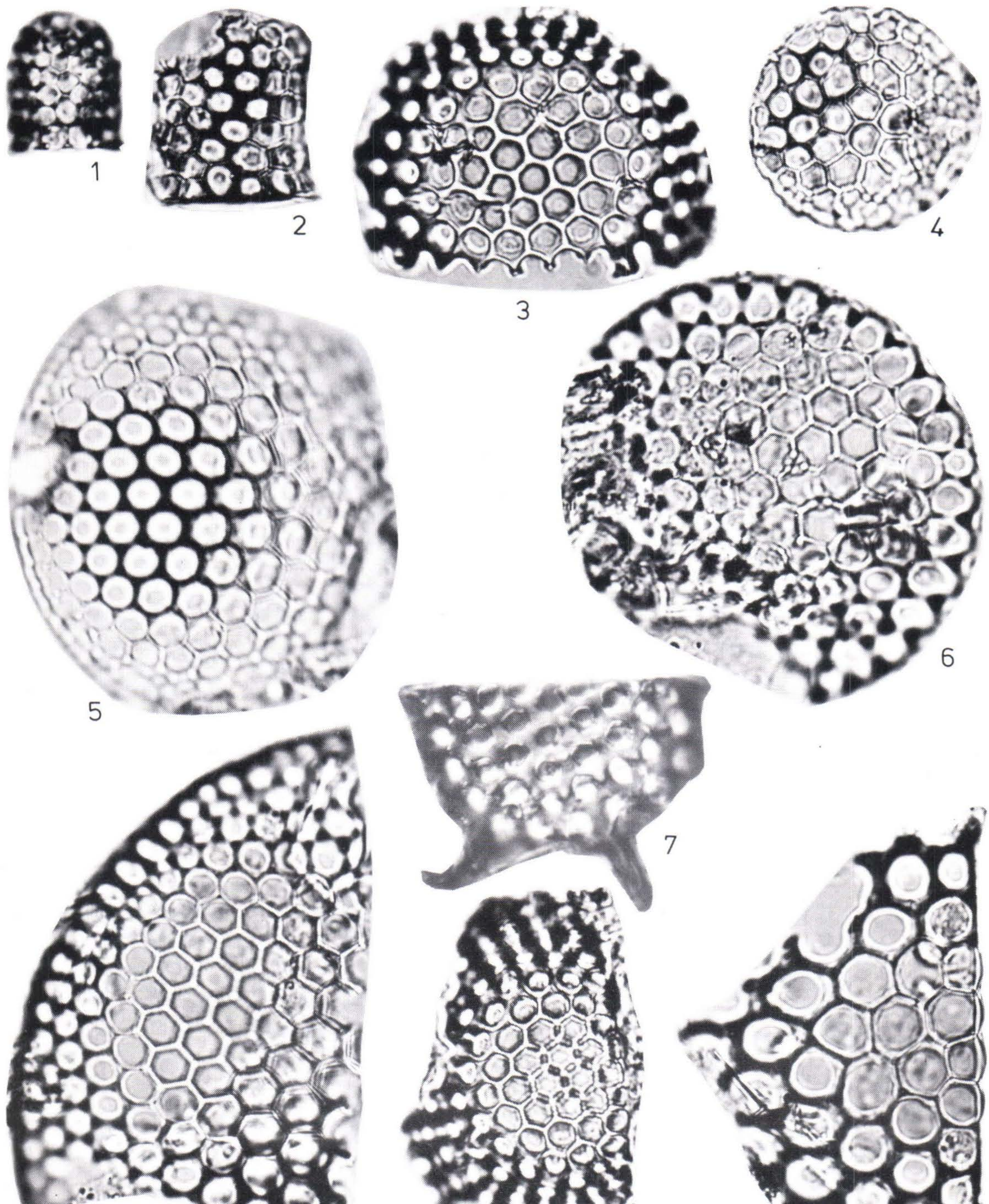
–, **1971.** Eocene, Miocene and Pliocene marine diatoms and silicoflagellates studied with the scanning electron microscope. Proceed. of the II planktonic conf., Roma 1970, Ed. A. Farinacci, 1277–1300.

Diatoms in the clay lens of Akanvaara. 1. *Melosira sulcata* var. *sibirica* Grun., 2, 3, 5, 6. *M. sulcata* var. *biseriata* Grun, 4, 7. *M. sulcata* var *crenulata* Grun., 8, 9. *Melosira* sp. 1, 10. a, b., 11 a, b., 12. *Stephanopyxis turris* var. *cylindricus* f. *inermis* Grun., 13. *Melosira sulcata*, 14. *Melosira westii* W. S.

Diatoms in the clay lens of Akanvaara. 1 a, b. *Cyclotella* sp., 2, 4. *Stictodiscus* sp., 3 a, b. *Melosira akkavaarensis* n. sp., 5, 6. *Melosira* sp., 2, 7. Genus and species indet.

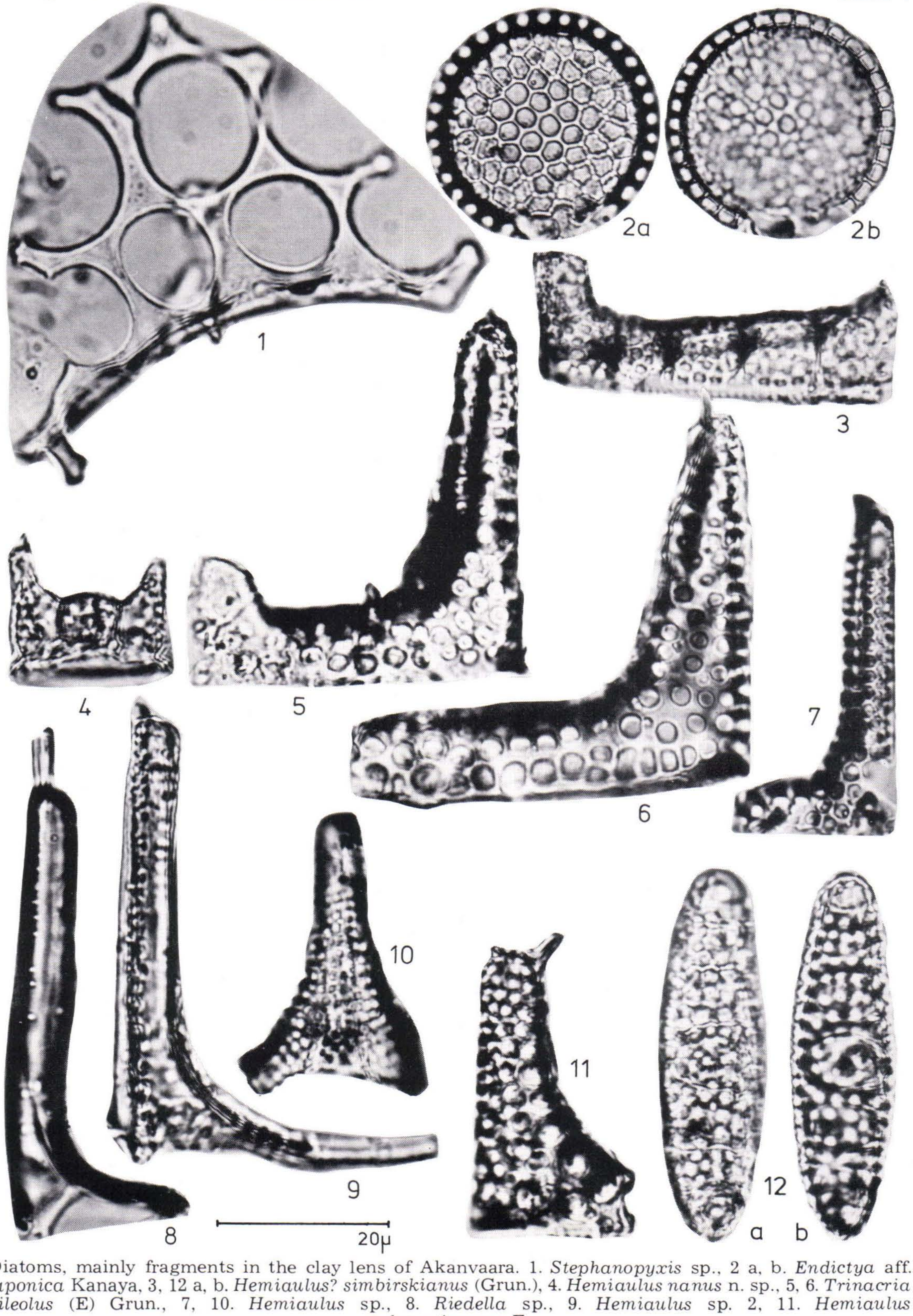


Diatoms in the clay lens of Akanvaara. 1. *Coscinodiscus marginatus* E., 2. Genus and species indet., 3. *Coscinodiscus curvatulus* Grun., 4, 6. *C. oculus iridis* E., 5. *C.* sp.

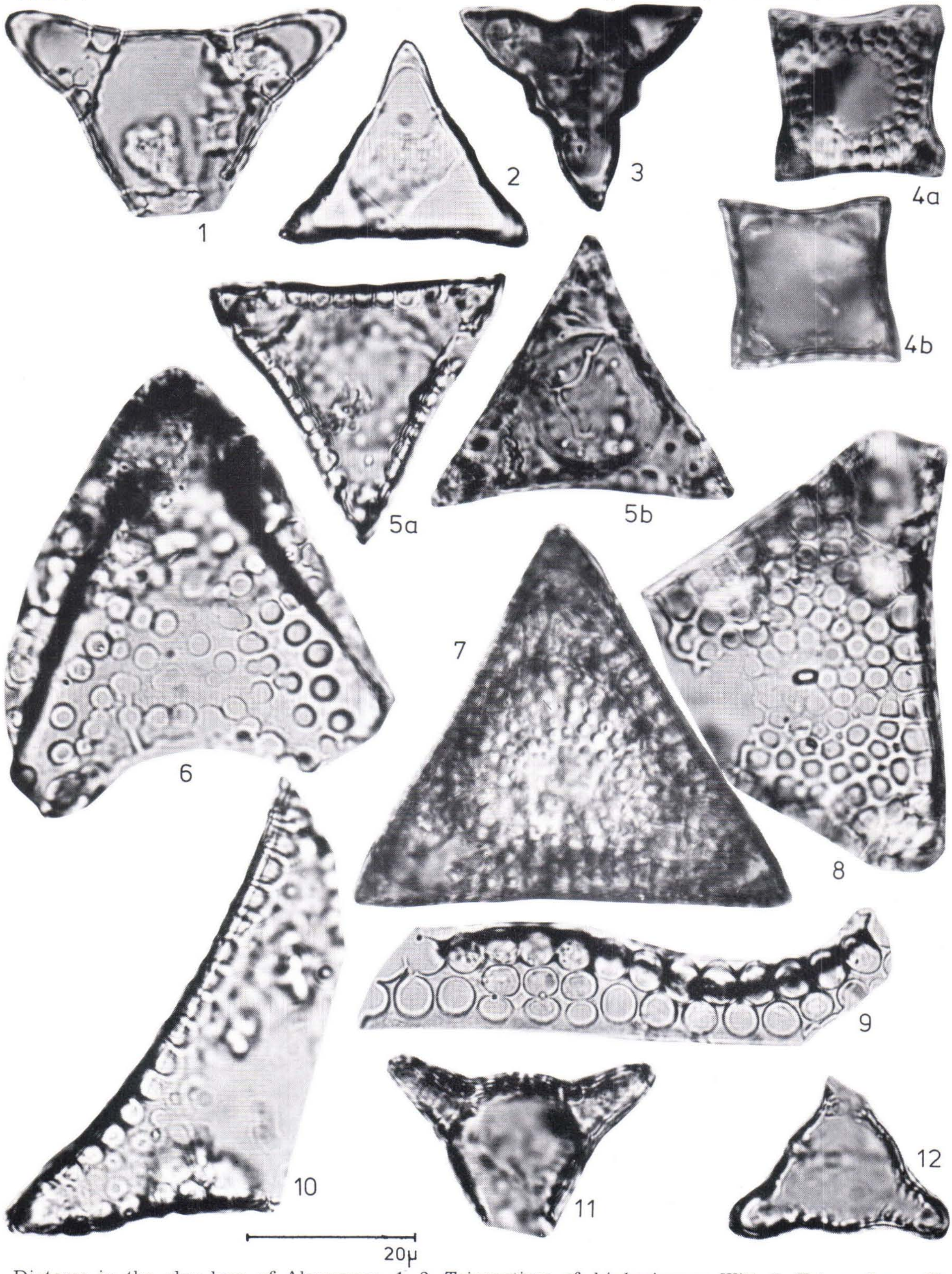


Diatoms in the clay lens of Akanvaara. 1, 2. *Stephanopyxis turris* var. *cylindrus* f. *inermis* Grun., 3, 7, 9. *S. turris* var. *intermedia* Grun., 4. *Stephanopyxis* sp., 5, 6. *S. turris* var *arctica* Grun., 8, 10. *S. turris* var. *polaris* Grun.

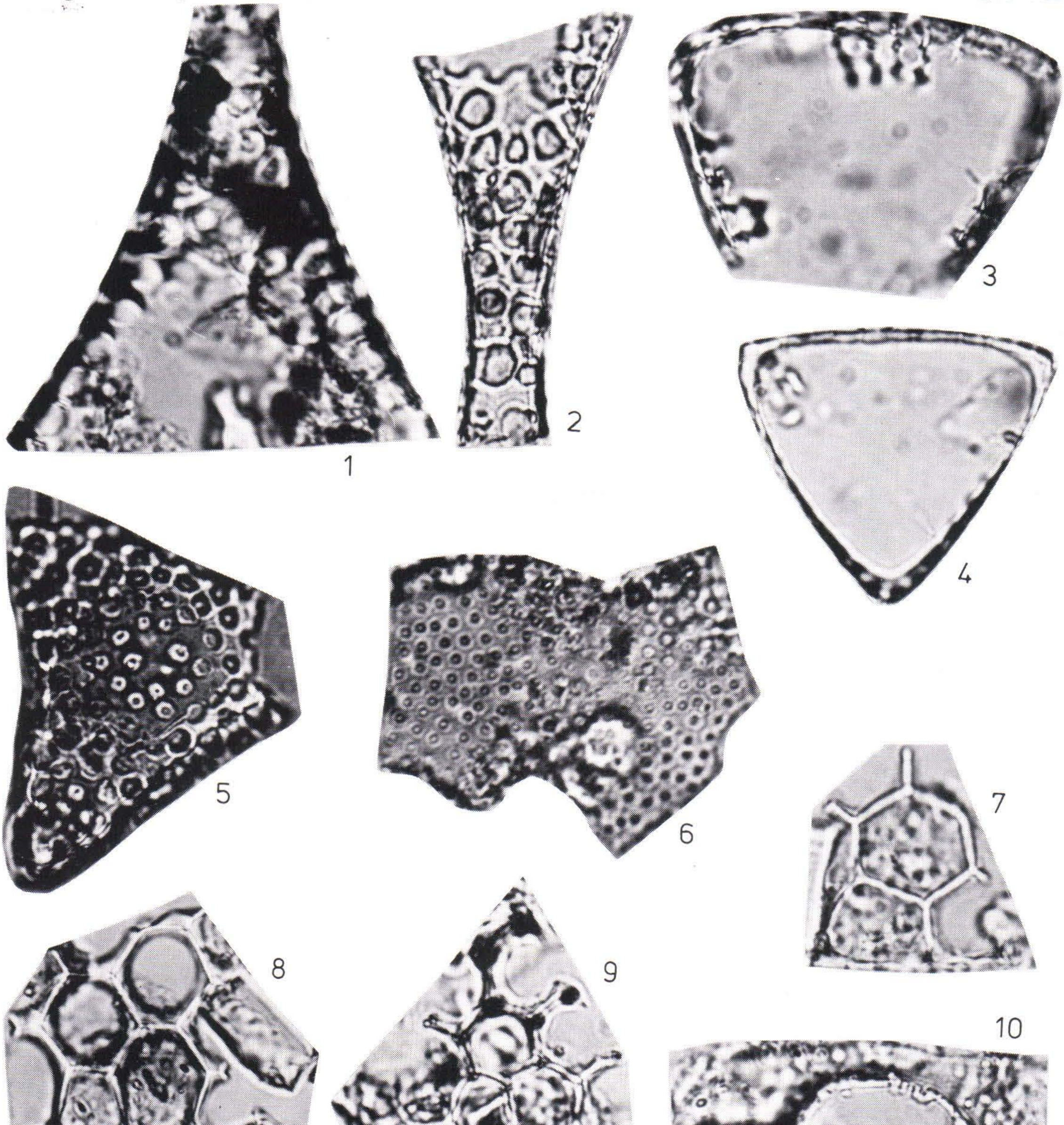
Plate V



Diatoms, mainly fragments in the clay lens of Akanvaara. 1. *Stephanopyxis* sp., 2 a, b. *Endictya* aff. *japonica* Kanaya, 3, 12 a, b. *Hemiaulus? simbirskianus* (Grun.), 4. *Hemiaulus nanus* n. sp., 5, 6. *Trinacria pileolus* (E) Grun., 7, 10. *Hemiaulus* sp., 8. *Riedella* sp., 9. *Hemiaulus* sp. 2, 11. *Hemiaulus polycystinorum* E.

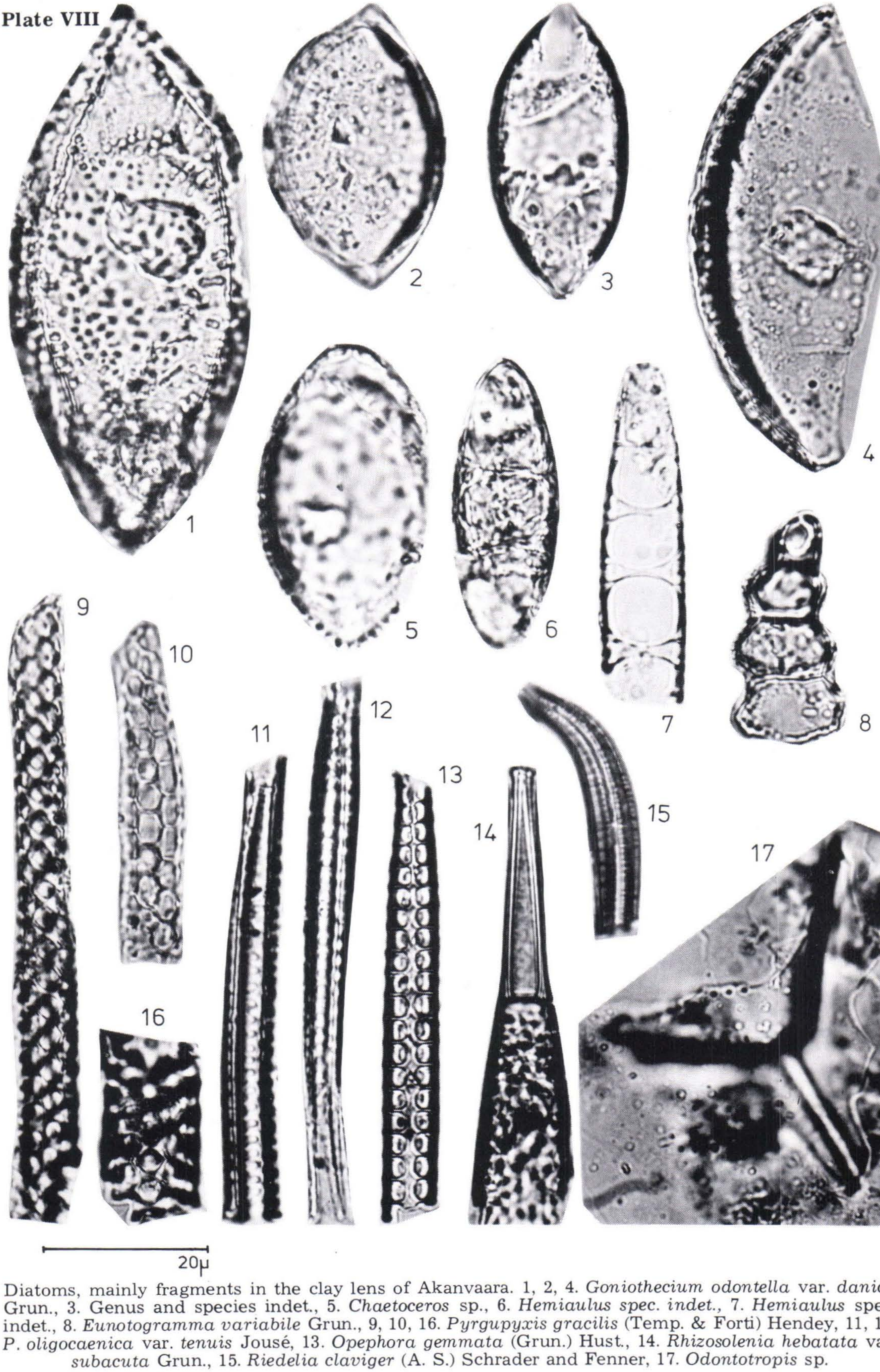


Diatoms in the clay lens of Akanvaara. 1, 2. *Triceratium* cf. *kinkerianum* Witt, 3. *Triceratium* aff. *mirabile* Jousé, 4 a, b. *Trinacria* sp. 1, 5 a, b. *Triceratium ventriculosum* A. S., 6, 8, 9, 10. *Trinacria pileolus* (E) Grun., 7.? *Trinacria pileolus* var. *media* Grun., 11, 12. *Triceratium* aff. *weissii* Grun.

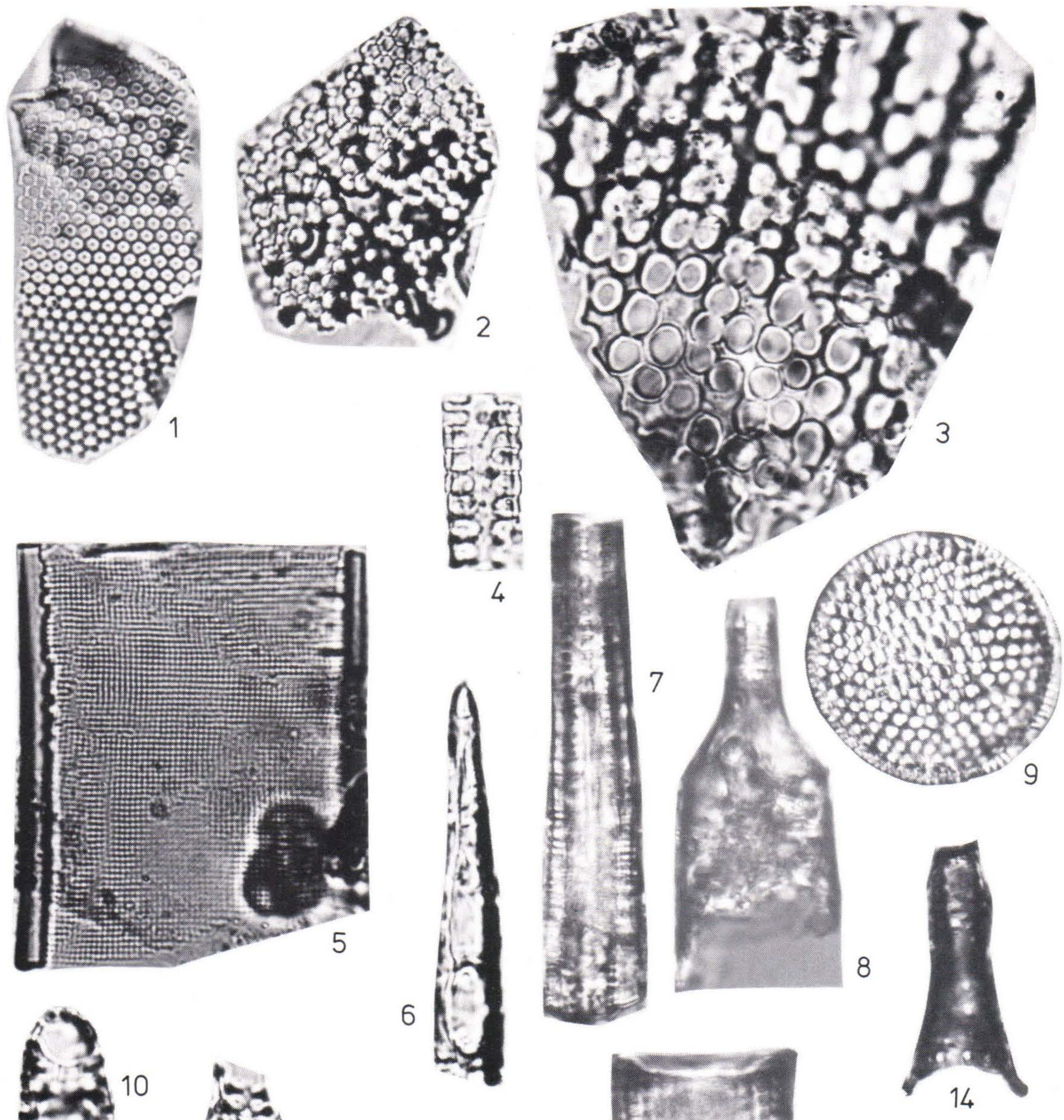


Diatoms fragments in the clay lens of Akanvaara. 1. *Trinacria* aff. *excavata* Heib., 2. *Triceratium* cf. *lateps* Fenner, 3, 4. *Triceratium* sp. 1, 5. *Triceratium* aff. *macroporum* Hajós, 6–11. Genus and species indet.

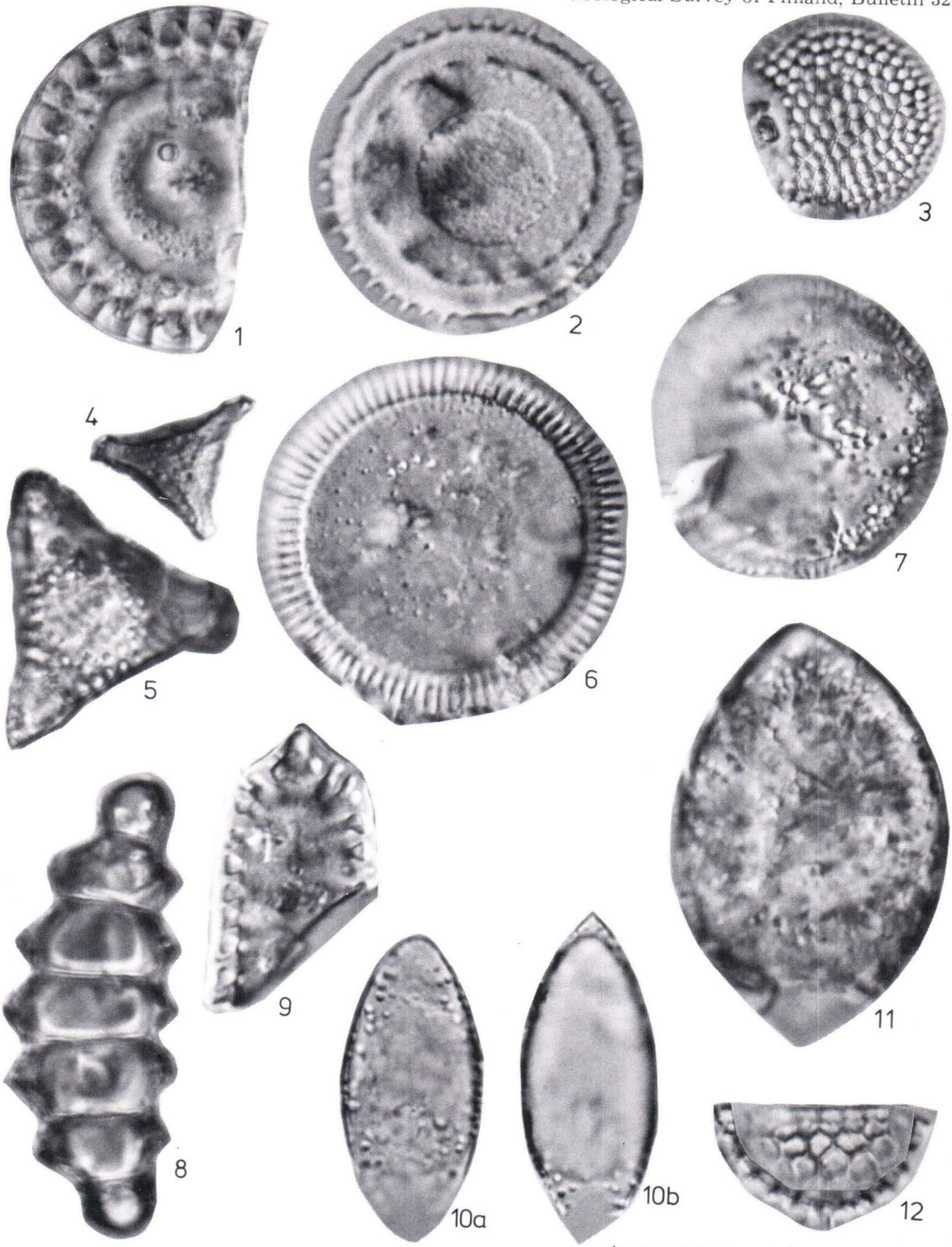
Plate VIII



Diatoms, mainly fragments in the clay lens of Akanvaara. 1, 2, 4. *Goniothecium odontella* var. *danica* Grun., 3. Genus and species indet., 5. *Chaetoceros* sp., 6. *Hemiaulus spec. indet.*, 7. *Hemiaulus* spec. indet., 8. *Eunotogramma variabile* Grun., 9, 10, 16. *Pyrgupyxis gracilis* (Temp. & Forti) Hendey, 11, 12. *P. oligocaenica* var. *tenuis* Jousé, 13. *Opephora gemmata* (Grun.) Hust., 14. *Rhizosolenia hebatata* var. *subacuta* Grun., 15. *Riedelia claviger* (A. S.) Schrader and Fenner, 17. *Odontotropis* sp.

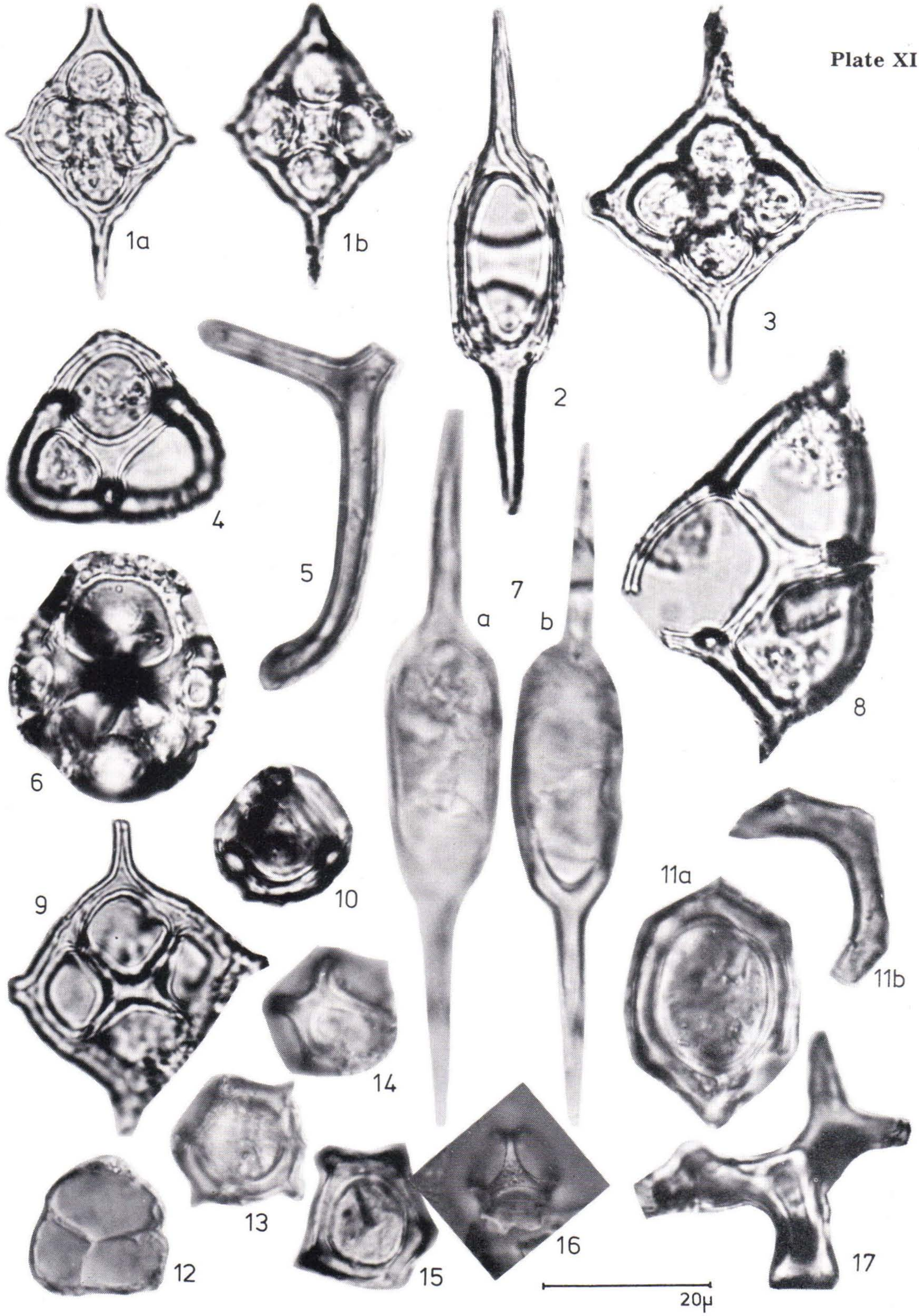


Diatoms fragments in the clay lens of Akanvaara. 1, 3. Genus and species indet., 2. *Coscinodiscus stellaris* var. *symbolophora* (Grun.) Jörg., 4. *Opephora gemmata* (Grun.) Hust., 5.? *Coscinodiscus symbolophorus* (cf. Sheshukova-Porezkaya 1967, pl. 22, fig. 3), 6. *Grammatophora* sp., 7.? *Rhizosolenia* sp., 8.? *Pterotheca spada* Brun and Temp., 9. *Coscinodiscus marginatus* E, 10. *Hemiaulus* sp., 11.? *Rhaphoneis* sp., 12. *Melosira* sp., 13. *M. granulata* (E) Ralfs, 14. Genus and species indet.

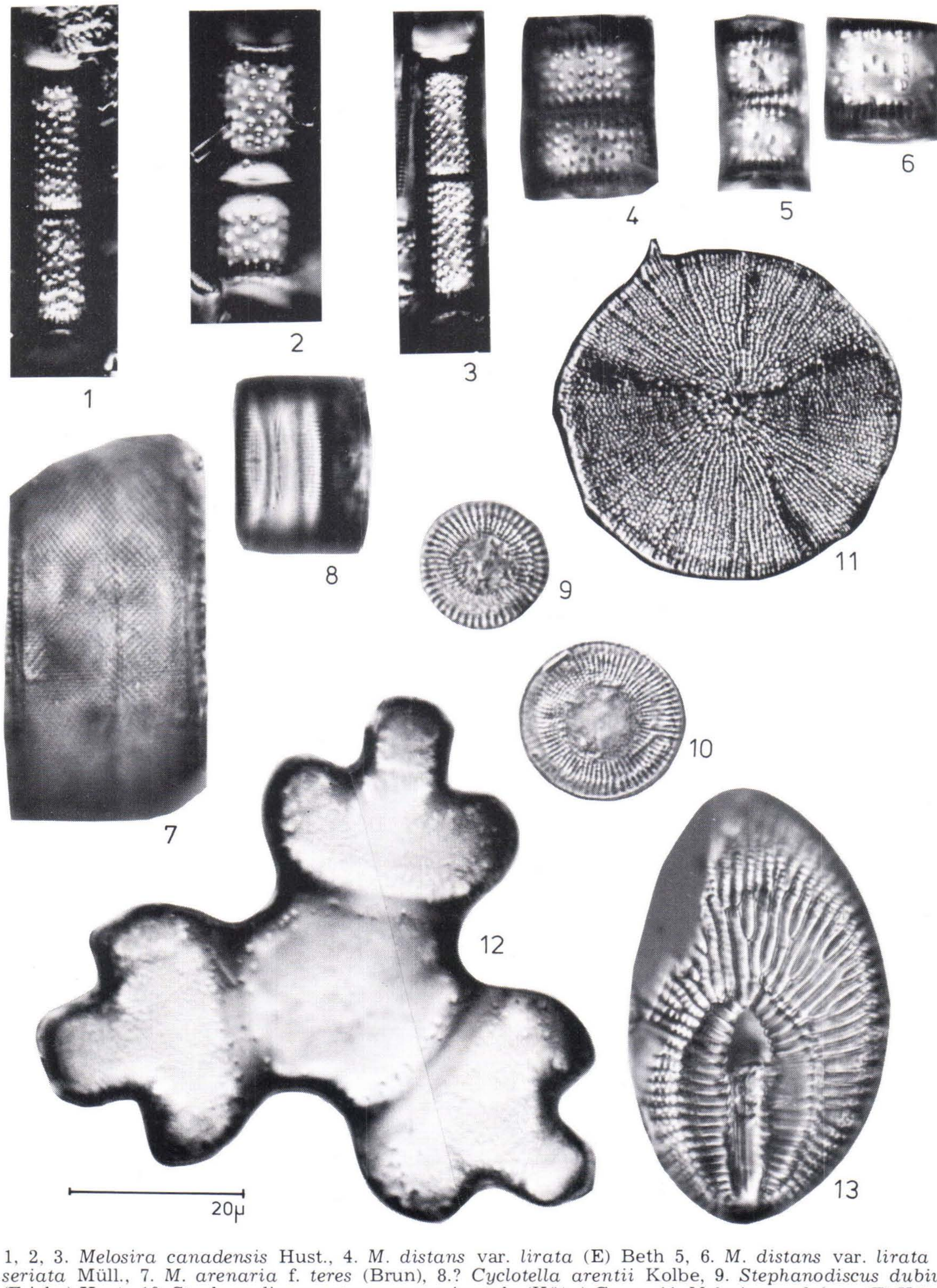


Diatoms in the clay lens of Akanvaara. 1, 2. *Melosira concentrica* A. S., 3. *Coscinodiscus decrescens* Grun., 4. *Trinacria* sp. 2, 5. *Triceratium cellulosum* Grev., 6. *Melosira* sp., 7. Genus and species indet., 8. *Eunotogramma variabile* Grun., 9. *Triceratium kinkeri* A. S., 10 a, b. *Xanthiopyxis* aff. *microspinosa* Andrews, 11. *Xanthiopyxis* sp., 12. *Stephanopyxis* sp.

Plate XI

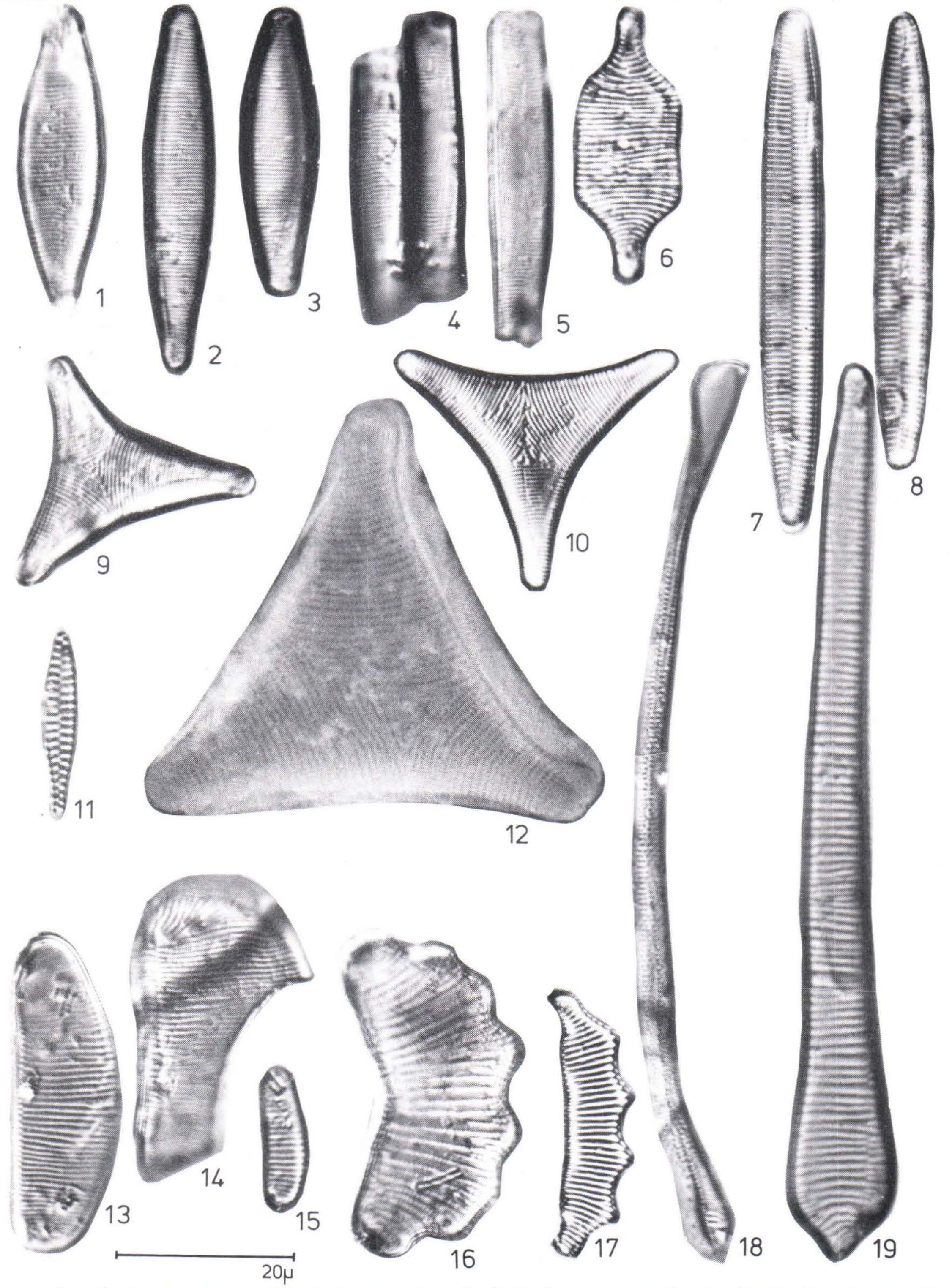


Silicoflagellates and ebridians in the clay lens of Akanvaara. 1 a, b, 3. *Distephanus crux* (E) Häckel, 2, 7 a, b. *Naviculopsis minor* (Schulz) Freng., 4. *Corbisema inermis* f. *minor* (Jouse) Bukry, 5. Genus and species indet., 6. *Ammodochium lapponicum* n. sp., 8. *Corbisema hastata* (Lemm.) Freng., 9. *Dictyocha frenguellii* var. *carentis* Gles., 10. *Dictyocha elata* var. *media* f. *reducta* Gles., 11 a, b. Genus and species indet., 12. *Ebria gracile* n. sp., 13, 14, 15. *Dictyocha frenguellii* var. *carentis* f. *incerta* Gles., 16. Genus and species indet. 17. *Falsebria* sp.



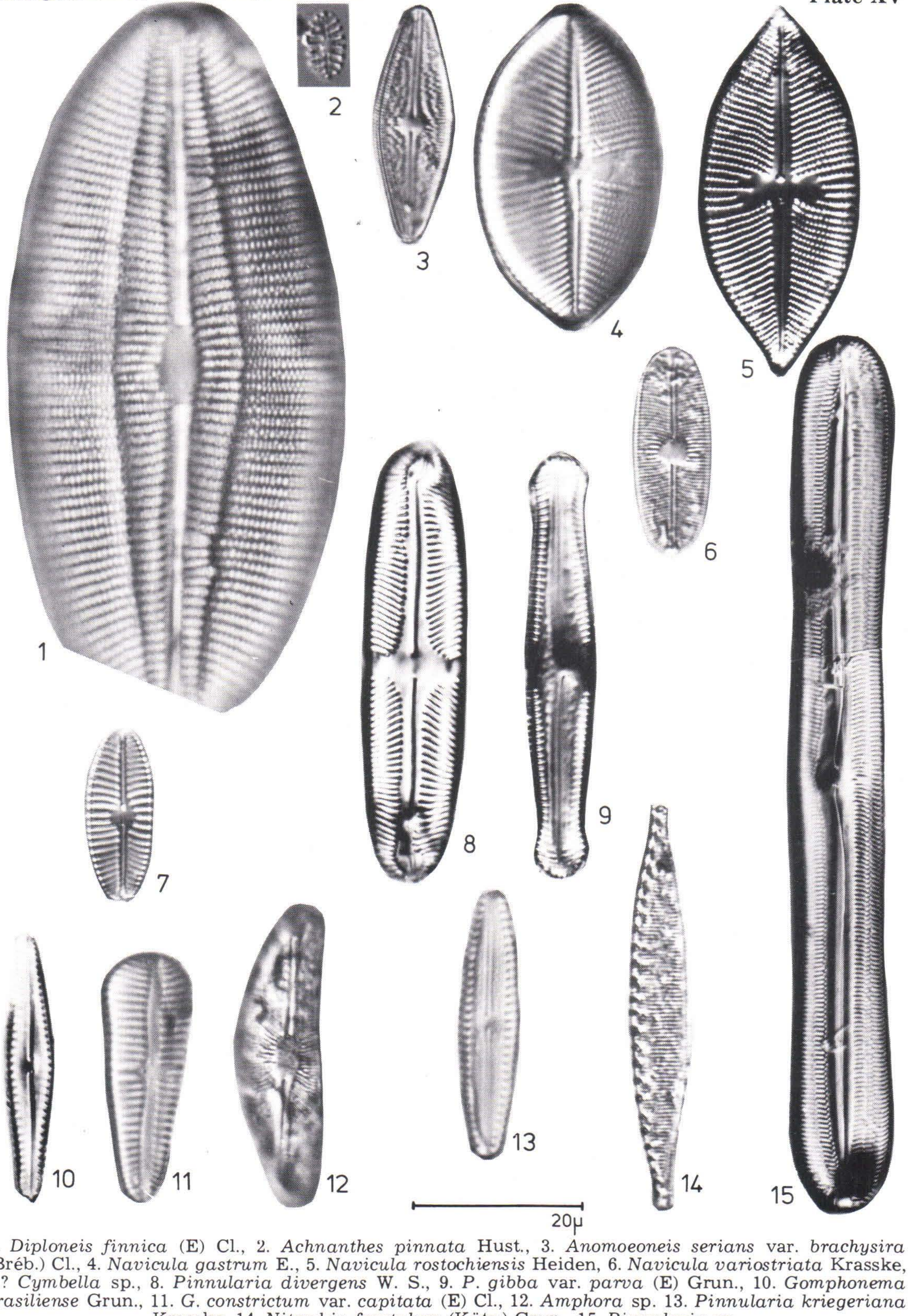
1, 2, 3. *Melosira canadensis* Hust., 4. *M. distans* var. *lirata* (E) Beth 5, 6. *M. distans* var. *lirata* f. *seriata* Müll., 7. *M. arenaria* f. *teres* (Brun), 8.? *Cyclotella arentii* Kolbe, 9. *Stephanodiscus dubius* (Fricke) Hust., 10. *Stephanodiscus astraea* var. *minutula* (Kütz.) Grun., 11. *Melosira undulata* (E) Kütz., 12. *Hydrosera trifoliata* Cl., 13. Genus and species indet.

1, 2, 3. *Tetracyclus ellipticus* (E) Grun., 4. *T. ellipticus* var. *clypeus* (E) Hust., 5, *T. ellipticus* var. *lancea* (E) Hust., 6. *T. lacustris* var. *lanceolatus* Moiss., 7, 8. *T. cruciformis* Andrews, 9. *T. emarginatus* (E) W. S., 10, 11. *T. lacustris* var *capitata* Hust., 12. *T. lacustris* var. *elongatus* Hust., 13. *T. emarginatus* (E) W. S., 14. *T. ellipticus* var. *inflata* Hust., 15. *T. lacustris* var. *capitata* f. *heterocapitata* n. fo., 16. *T. lacustris* var. *capitata*, 17. *T. emarginatus*.

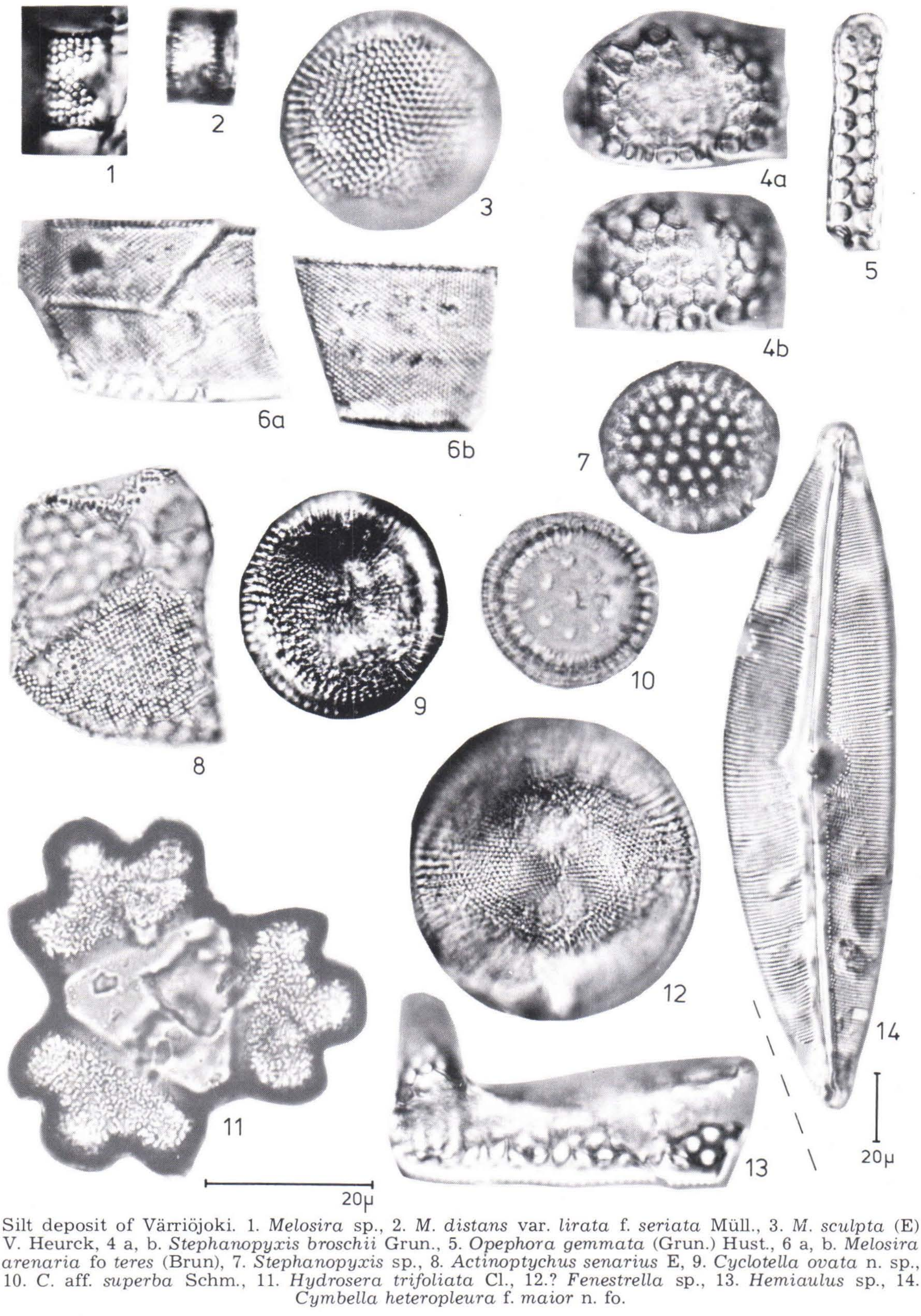


1–5. *Fragilaria convexa* n. sp., 6. *F. constricta* E, 7, 8. *F.* giganthea Lauby, 9. 10. *Fragilaria triangulata* Moiss., 11. *Opephora sp.*, 12. *F. triangulata*, SEM-picture, 13. *Eunotia faba* f. *lata* n. fo., 14.? *Eunotia* sp. *(E. giganthea)*, 15. *E. faba* var *densestriata* Ostr. 16. *E. robusta* var. *diadema* (E) Ralfs, 17. *E. polyglyphis* f. *tetraglyphis* Grun., 18.? *Actinella* sp., 19. *Actinella brasiliensis* Grun.

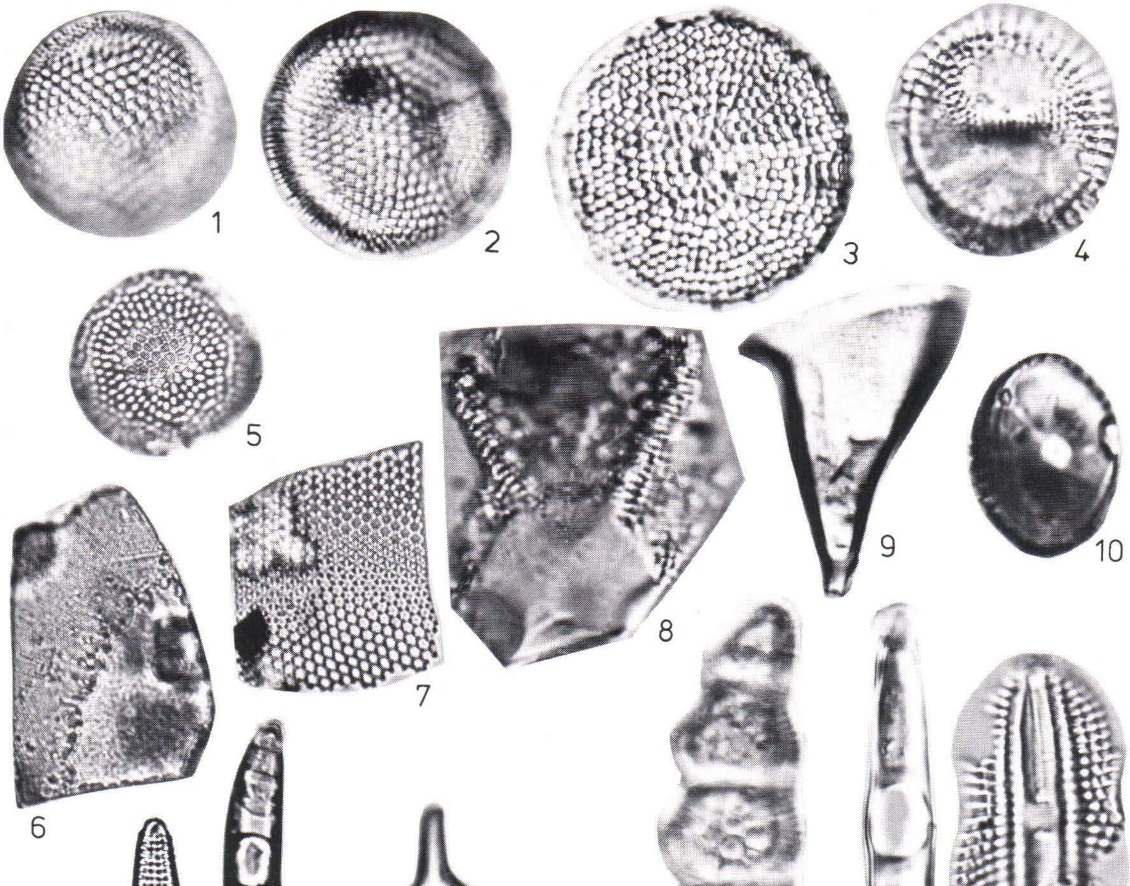
Plate XV



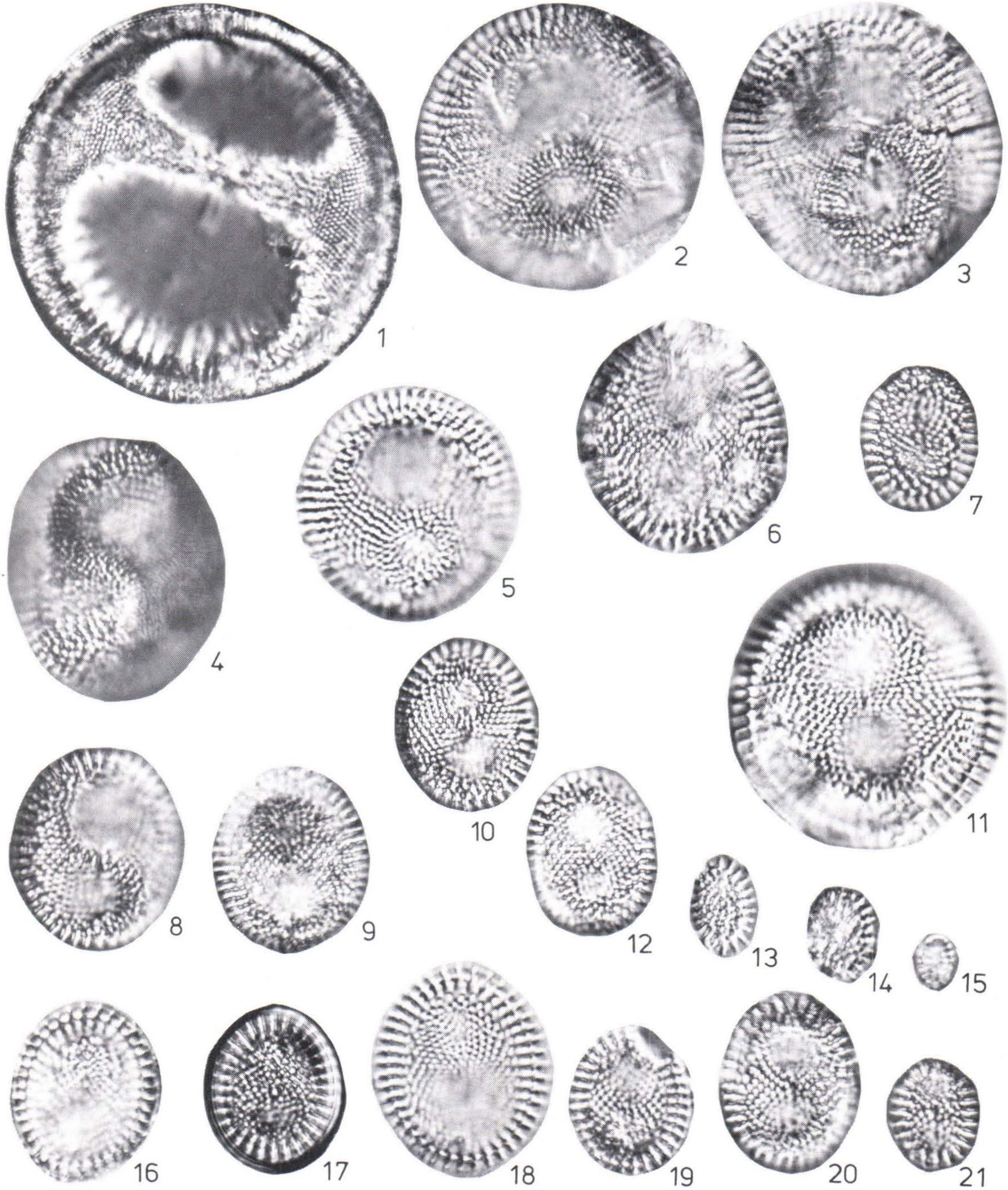
1. *Diploneis finnica* (E) Cl., 2. *Achnanthes pinnata* Hust., 3. *Anomoeoneis serians* var. *brachysira* (Bréb.) Cl., 4. *Navicula gastrum* E., 5. *Navicula rostochiensis* Heiden, 6. *Navicula variostriata* Krasske, 7.? *Cymbella* sp., 8. *Pinnularia divergens* W. S., 9. *P. gibba* var. *parva* (E) Grun., 10. *Gomphonema brasiliense* Grun., 11. *G. constrictum* var. *capitata* (E) Cl., 12. *Amphora* sp. 13. *Pinnularia kriegeriana* Krasske, 14. *Nitzschia frustulum* (Kütz.) Grun., 15. *Pinnularia* sp.



Silt deposit of Värriöjoki. 1. *Melosira* sp., 2. *M. distans* var. *lirata* f. *seriata* Müll., 3. *M. sculpta* (E) V. Heurck, 4 a, b. *Stephanopyxis broschii* Grun., 5. *Opephora gemmata* (Grun.) Hust., 6 a, b. *Melosira arenaria* fo *teres* (Brun), 7. *Stephanopyxis* sp., 8. *Actinoptychus senarius* E, 9. *Cyclotella ovata* n. sp., 10. *C.* aff. *superba* Schm., 11. *Hydrosera trifoliata* Cl., 12.? *Fenestrella* sp., 13. *Hemiaulus* sp., 14. *Cymbella heteropleura* f. *maior* n. fo.

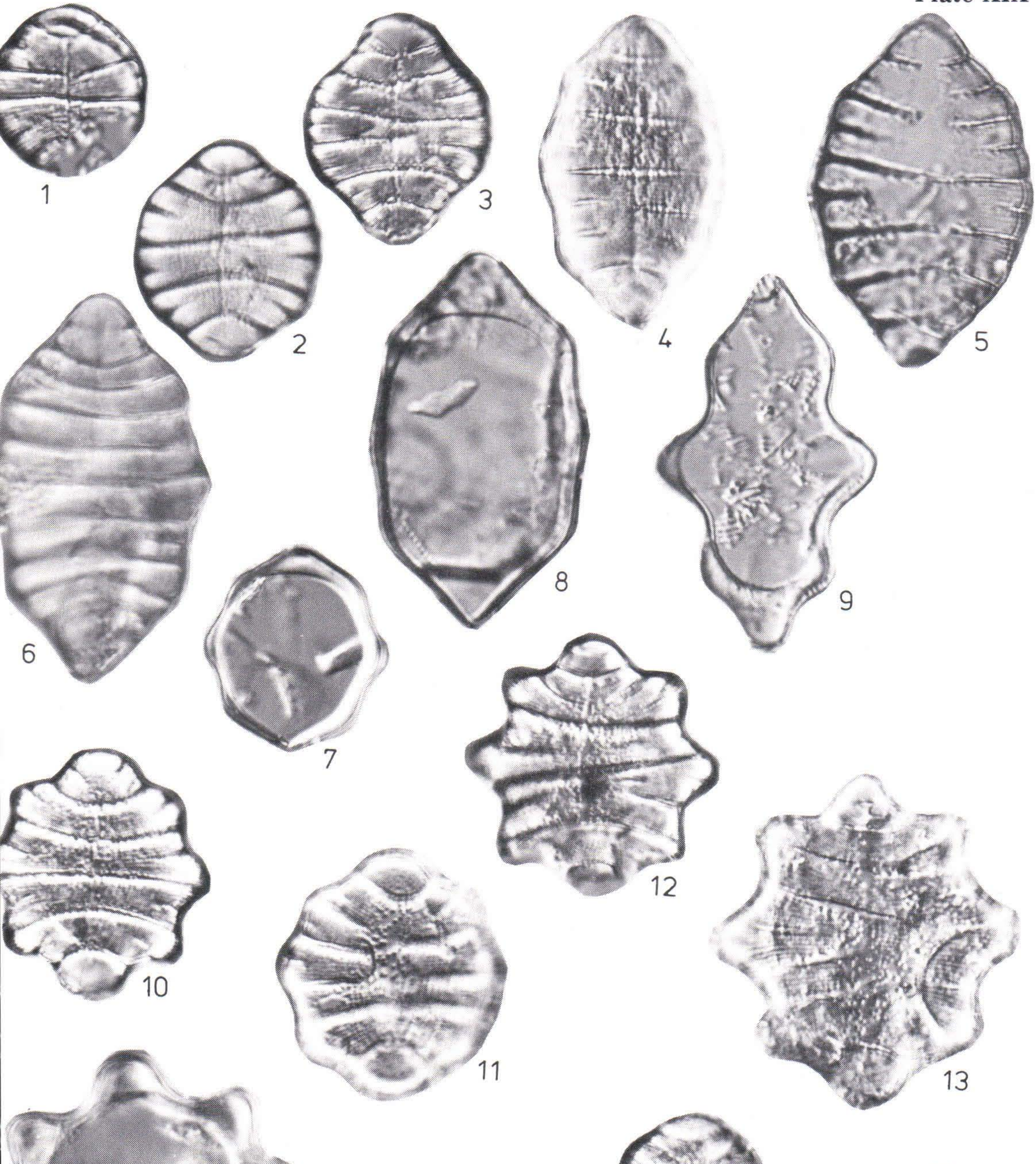


Fine-sand-bearing sediment of Siurunmaa. 1, 2. *Thalassiosira eccentrica* (E) Cl., 3. *Actinocyclus kützingii* (A. S.) Sim., (without margin), 4. *Cyclotella* aff. *ovata*, 5. *Thalassiosira gravida* Cl. rest. sp., 6. *Hyalodiscus subtilis* Bail., 7. *Coscinodiscus* sp., 8. *Actinoptychus senarius* E, 9. *Chaetoceros* sp., 10.? *Chasea ornata* Hajós and Stradner, 11. *Rhabdonema minutum* Kütz., 12. *Plagiogramma staurophorum* (Greg.) Heib., 13. *Grammatophora arcuata* E, 14. *Eunotogramma variabile* Grun., 15. *Grammatophora oceanica* (E) Grun., 16. *Diploneis bombus* E, 17. *Corbisema minor* (Schulz) Perch-Nielsen, 18. *Dictyocha fibula* E, 19. *Diploneis chersonensis* (Grun.) Cl., 20. *Distephanus speculum* E.



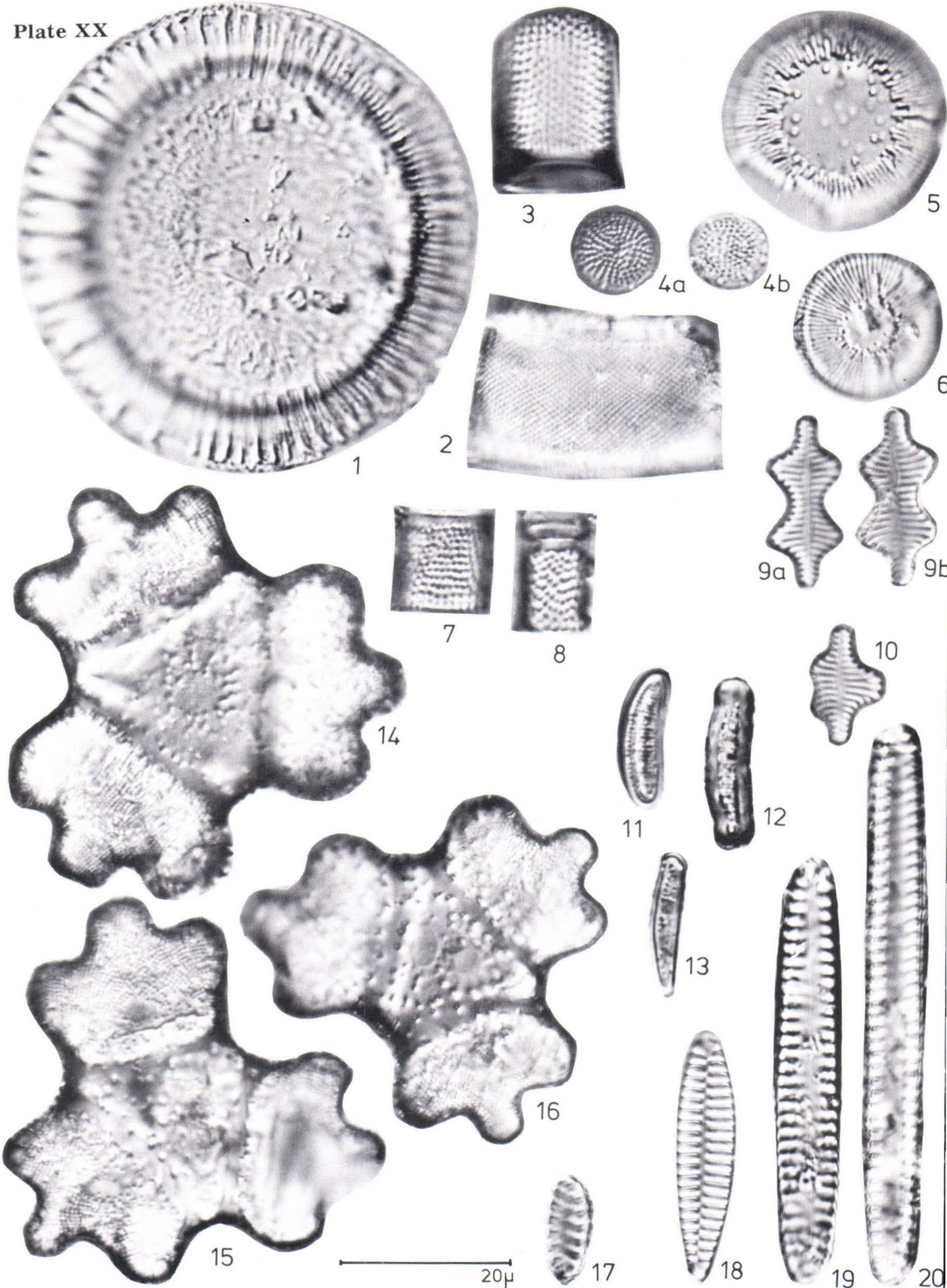
Gyttja deposit of Sivakkapalo. 2–21. *Cyclotella ovata* n. sp., range of large spherical to small oval forms. 1. possible auxospore formation.

Plate XIX



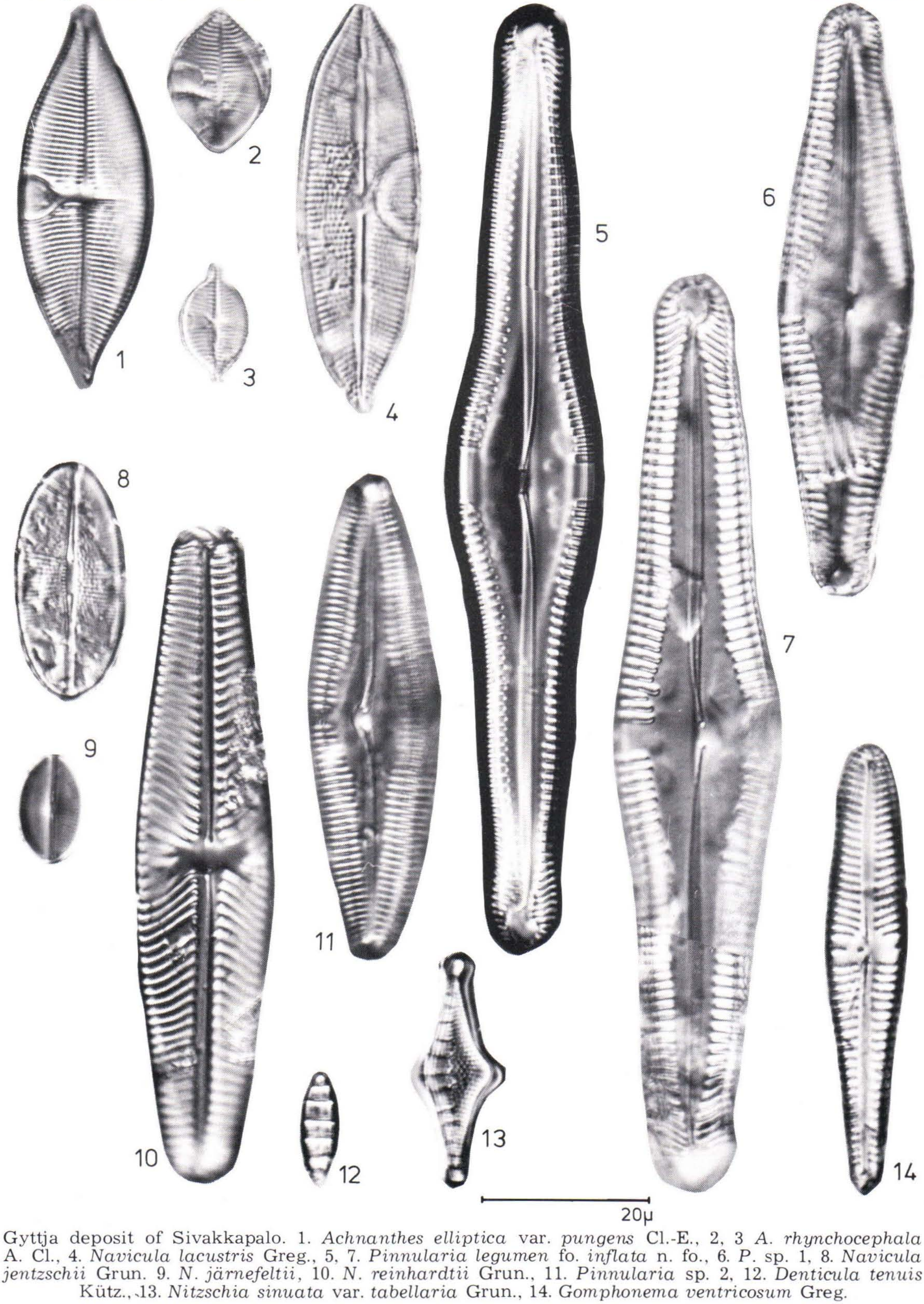
Gyttja deposit of Sivakkapalo. 1. *Tetracyclus ellipticus* var. *clypeus* (E) Hust., 2, 3. *T. ellipticus* var *inflata* Hust., 4–6. *T. ellipticus* var. *lancea* f. *subrostrata* Hust., 8. *T.* sp., 9. *T. lacustris* f. *rostrata* n. fo., 7, 10–15. *T. lapponicus* n. sp. 16. *T.* sp., 17. *T. lacustris* Ralfs.

Plate XX



Gyttja deposit of Sivakkapalo. 1, 2. *Melosira arenaria* var. *teres* (Brun), 3. *M. islandica* subsp. *helvetica* Müll., restr. spore, 4 a, b. *Coscinodiscus* sp., 5, 6. *Cyclotella kützingiana* var. *planetophora* f. *verticillata* Cl.-E., 7, 8. Melosira ambigua (Grun.) Müll. fo., 9 a, b. *Fragilaria leptostauron* var. *binodis* n. comb., 10. variation form of *F. leptostauron* and *F. leptostauron* var. *binodis*, 11. *Eunotia tenella*, 12. *E.* sp., 13.? *Actinella* sp., 14–16. *Hydrosera trifoliata* Cl., 17. *Fragilaria lapponica* Grun., 18. *Opephora martyi* Hérib., 19, 20. *F. lapponica* var. *maior* n. var.

Plate XXI



Gyttja deposit of Sivakkapalo. 1. *Achnanthes elliptica* var. *pungens* Cl.-E., 2, 3 *A. rhynchocephala* A. Cl., 4. *Navicula lacustris* Greg., 5, 7. *Pinnularia legumen* fo. *inflata* n. fo., 6. *P.* sp. 1, 8. *Navicula jentzschii* Grun. 9. *N. järnefeltii*, 10. *N. reinhardtii* Grun., 11. *Pinnularia* sp. 2, 12. *Denticula tenuis* Kütz., 13. *Nitzschia sinuata* var. *tabellaria* Grun., 14. *Gomphonema ventricosum* Greg.

Tätä julkaisua myy	Denna publikation säljes av	This publication can be obtained from
VALTION PAINATUSKESKUS MARKKINOINTIOSASTO	STATENS TRYCKERICENTRAL MARKNADSFÖRINGSAVDELNINGEN	GOVERNMENT PRINTING CENTRE MARKETING DEPARTMENT
Postimyynti PL 516 00101 HELSINKI 10 Puh. 90-539 011	**Postförsäljning** PB 516 00101 HELSINGFORS 10 Tel. 90-539 011	**Bookshop** Annankatu 44 00100 HELSINKI 10 Phone 90-17341
Kirjakauppa Annankatu 44 00100 HELSINKI 10 Puh. 90-17341	**Bokhandel** Annegatan 44 00100 HELSINGFORS 10 Tel. 90-17341	**Orders from abroad:** **AKATEEMINEN KIRJAKAUPPA** Keskuskatu 1 SF-00100 Helsinki 10

ISBN 951-690-161-1
ISSN 0367-522X