ON THE EARLY FLANDRIAN STRATIGRAPHY AND VEGETATIONAL HISTORY OF THE NORTH SATAKUNTA AREA, WESTERN FINLAND

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The stratigraphical sequence of two till beds with varved clay between them has been described from the North Satakunta area. The position of this sequence in geochronology has been compared with the retreat process of the ice in southern Finland. It has been suggested that the sequence is early Flandrian in age and it seems to show a corresponding climatic rhythm as can be seen from the pollen stratigraphy of north-western Europe (Ostfriesland, Germany) during the Pre-Boreal period. The early Flandrian vegetational history of the North Satakunta area shows the open plant communities on the emerged dry land of the archipelago character. During the regression of the Yoldia Sea and after pollen zone transition IV/V the forest expanded rapidly in the area studied.

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Introduction

In connexion with his lake studies concerning palaeolimnology and Pleistocene stratigraphy, the author has carried out observations over the past few years on the Late Weichselian and Early Flandrian glacial sequences in the North Satakunta area (see the map of Fig. 1). The terminology of the Pleistocene stages suggested by West (1968) has been used and adopted here to cover the geological time units »Late-glacial» and »Post-glacial». The aim of the present study is to describe and correlate the local stratigraphy of an area in south-western Finland with the retreat stages of the ice and to discuss the first vegetational development on the basis of the pollen stratigraphy. A tentative correlation will also be made with some other regions, *e.g.* north-western Germany in order to elucidate the problems of the facies and the megastratigraphy. The latter is a term according to Fischer (1964, p. 35) used and applied on a regional scale.

A very interesting stratigraphical sequence in the North Satakunta area consists of two till beds with varved clay or sorted sand and gravel between them. These till-covered sediments, described first by Sauramo (1924) and later by

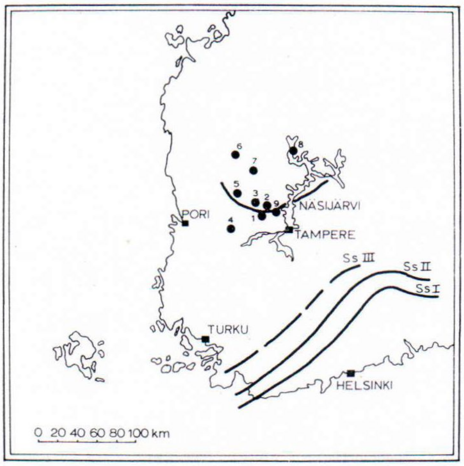

Fig. 1. The sites discussed in the text and their relation to the retreat of the ice in south-western Finland.

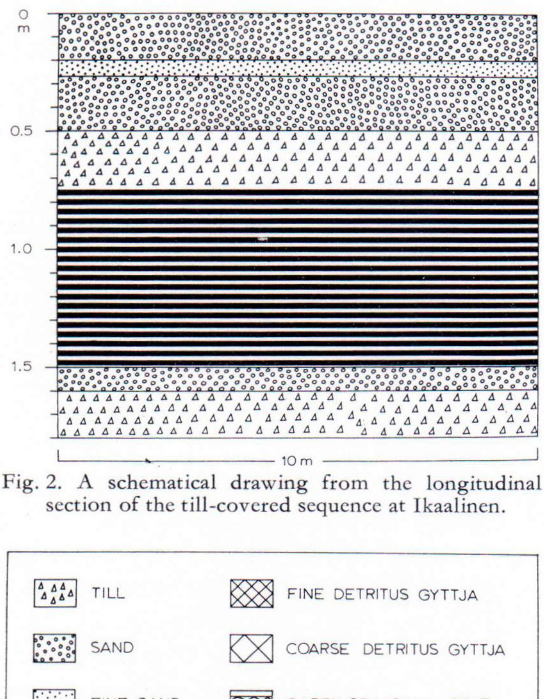

Fig. 2. A schematical drawing from the longitudinal section of the till-covered sequence at Ikaalinen.

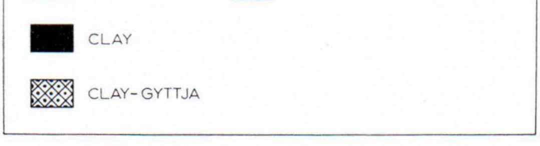

Fig. 3. Symbols used in diagrams.

Virkkala (*e.g.* 1959, 1963), were formed during the local oscillations of the ice margin during its retreat (see also Donner 1965, p. 213). The above-mentioned sequence is also related to the origin and age of the most important Pleistocene formation of Hämeenkangas, which forms part of the ice-marginal feature called the »Näsijärvi marginal formation» by Virkkala (1963, pp. 57—66). Because the stratigraphical position of the North Satakunta oscillation compared with the geological time units has not yet been determined more precisely, an attempt is made in the present study to date this oscillation on the basis of the varve chronology described by Sauramo (1924) from the area now under discussion.

On the stratigraphy of the sites

Fig. 1 shows the sites in North Satakunta and their relation to the retreat of the ice. In the following a short description of the stratigraphy of the sites is given. The numbers refer to the site numbers on the map of Fig. 1.

1. Hämeenkyrö. Sauramo (1924, p. 21) reports the following stratigraphy in the village of Hämeenkyrö: lowermost about 6 m varved clay, about 75 cm till, about 75 cm blue clay deposited on till.

2. Viljakkala, Haveri. Virkkala (1959, 1963) has found two till beds at Haveri in the parish of Viljakkala. Between each of the till beds there is about 50 cm varved clay in which at least a hundred varves could be counted. According to microfossil analysis the clay contains *Betula*-dominated pollen flora and 30—40 per cent salt-water diatoms such as *Rhabdonema arcuatum*, *Grammatophora oceanica* and *Coscinodiscus* spp. (Virkkala 1963, p. 64).

3. Ikaalinen. The author has found a similar sequence in the center of the parish Ikaalinen. Fig. 2 shows a schematical drawing of this section where the stratigraphy is as follows: (the symbols used in the diagrams are presented in Fig. 3)

0—20	cm	sand
20—27	cm	fine sand
27—50	cm	sand
50—75	cm	till
75—150	cm	varved clay
150—160	cm	sand
160—		till, here only 20 cm is observed

The clay contains 82 varves, but in many other sites at Ikaalinen the author has counted 90—110 varves. No microfossils have been found in the varved clay.

4. Kiikoinen. In the proximity of the church of Kiikoinen Virkkala (1959, 1963, p. 64) has reported a small ice-marginal ridge with lumps of varved clay embedded in the poorly sorted drift. The clay contains salt-water diatoms and *Betula*-dominated pollen flora.

5. Jämijärvi, 6. Karvia and 7. Parkano. A till-covered sand and gravel sequence is common in many sites according to Virkkala (1959, p. 52).

8. Virrat. Similar observations have been made by Virkkala (1959, p. 52) in the parish of Virrat, where 1.5 m varved sediment was found in the glaciofluvial stratigraphy.

9. Hämeenkyrö, Komi. This site lies just in the front of Rasinkangas (see Virkkala 1963, Fig. 29). Grain-size analyses of this till-covered material show that it is well-sorted consisting of 64 % silt, 28 % clay and 8 % sand and fine sand.

The age and correlation of the North Satakunta sequence

Fig. 4 shows the ice recession in south-western Finland after Salpausselkä II. The ice recession lines for every 100 years have been drawn and used on the basis of the data of Sauramo (1923, 1924). The varve chronology which he established for southern Finland can also be correlated with the retreat of the ice margin in the North Satakunta area (*cf.* Sauramo 1924). As is well-known, Sauramo's ±0 year has been correlated with the last drainage of the Baltic Ice Lake at Billingen in Sweden. According to earlier dating (Fromm 1963; see also Alhonen 1966) this drainage took place in 8305 B.C., but according to the latest revised dating of the Swedish varve chronology by Erik Nilsson (in Donner 1969a) the drainage of the Baltic Ice Lake occurred in the year 8213 B.C. (Donner 1969a, p. 147, 1969b, p. 7). This was just after the formation of Salpausselkä II and the dating of the position of the ice margin is thus about 8200 B.C.

A seen in Fig. 4, the till-covered sequence in the area studied can be correlated with the position of the ice margin of 7600 B.C. Assuming that the picture of the ice retreat in southern Finland is correct the short-lived cold oscillation in the North Satakunta area is early Flandrian (early Post-glacial) in age rather than older as was suggested by Virkkala (see 1959, p. 53, 1962, p. 54 and 1963, p. 74). On the basis of the subfossil diatom flora the oldest Baltic sediments in the area studied were deposited in the Yoldia Sea. As an example of the diatom stratigraphy the basal part of core 14 from the bottom sediments of Lake Kyrösjärvi (see Alho-

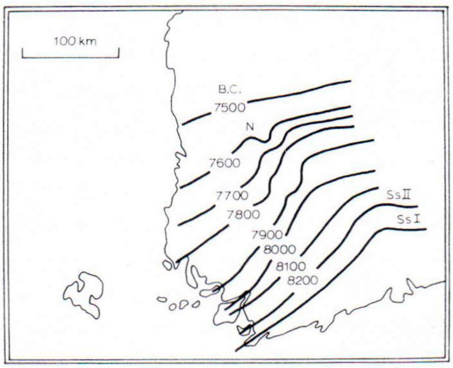

Fig. 4. A schematical representation of the ice recession in south-western Finland. The ice recession lines for every 100 years have been drawn on the basis of the data from Sauramo (1923, 1924). N = »Näsijärvi marginal formation».

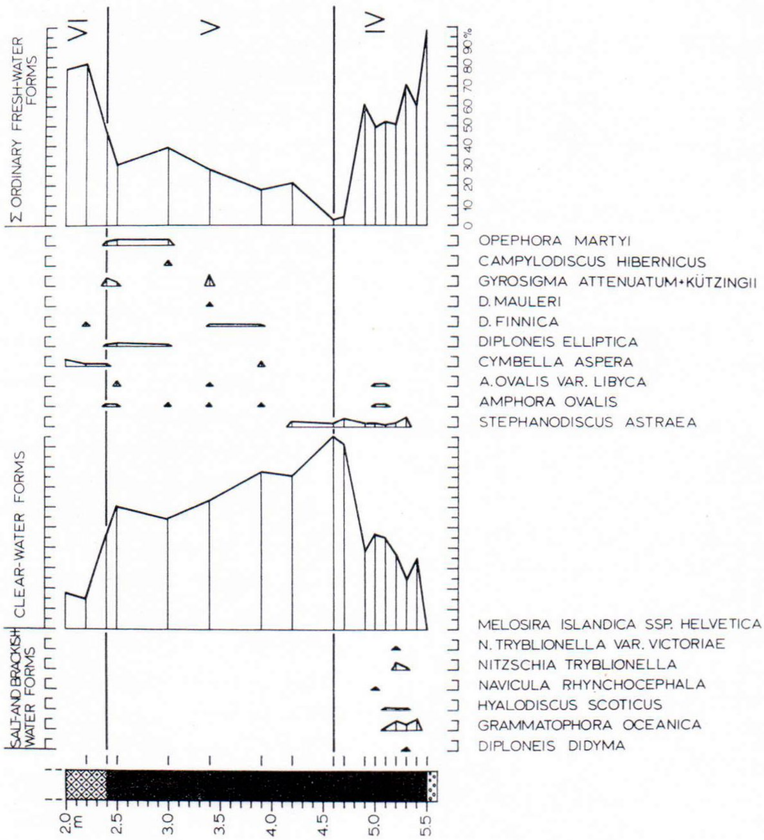

Fig. 5. An example of the early Flandrian diatom stratigraphy of the North Satakunta area: the basal part of core 14 from the bottom deposits of Lake Kyrösjärvi (Alhonen 1967, Fig. 10).

nen 1967, Fig. 10) is presented in Fig. 5. Assuming that the influx of salt water in southern Finland took place in 7921 B.C. (see Donner 1969a, p. 147), then the first marine stage, the Yoldia Sea, occurred in North Satakunta about 200—300 years later when compared with varve chronology (see Fig. 4). It is clear that the sea followed the retreat of the ice. According to Tauber (1969), the mean ice recession rate in south-western Finland inceased after 7700 B.C. being *e.g.* between the years 7600—7500 B.C. 27 km/100 years.

As seen in Fig. 5 the diatom stratigraphy is correlated with the pollen zones. Here the facies of the Yoldia Sea (pollen zone IV) in its initial stage is mainly characterized by marine or brackish species *e.g. Grammatophora oceanica* (Ehr.) Grunow, *Hyalodiscus scoticus* (Kützing) Grun., *Nitzschia tryblionella* Hantzsch and var. *victoriae* Grun. together with *Melosira islandica ssp. helvetica* Müller. This is a planktonic species of clear-water (arenaria) character, but can even occur in slightly brackish water (see *e.g.* Mölder and Tynni 1967, p. 207). The proportion of ordinary fresh-water forms is high. Further it should be mentioned that although *Grammatophora oceanica* is an epiphytic form (see *e.g.* Miller 1964, p. 47) it often occurs in plankton (Mölder and Tynni 1969, p. 240).

The clear-water plankton increases rapidly showing its maximum (95 %) in the zone boundary IV/V. *Melosira islandica ssp. helvetica* dominates in pollen zone V indicating the Ancylus Lake stage of the Baltic Sea in this profile. The regressive development of the Ancylus Lake is reflected by the occurrence of non-planktonic species in the upper part of the clay (see Fig. 5). The diatoms show further that the isolation of Lake Kyrösjärvi occurred at the boundary between clay and clay-gyttja where the dominating influence of the clear-water forms diminishes and the total curve of the ordinary fresh-water forms sharply rises. This event corresponds to pollen zone transition V/VI (see also Alhonen 1967, p. 26).

The till-covered sequence in the area studied has been compared tentatively with the pollen stratigraphy and climate development in north-western Europe (Ostfriesland, Germany: Behre 1966, 1967), where a short-lived improvement of the climate at the beginning of the Pre-Boreal period (pollen zone IV) was found. Behre (1966, 1967) has given this short climatic oscillation together with the advance of *Pinus* the preliminary name of »Friesland Oscillation» (8300—8100 B.C.). He *(op. cit.)* was able to distinguish three phases of the Pre-Boreal period in north-western Germany (see also the facies map of Lüttig 1967, Fig. 23, p. 257). The following slight deterioration of the climate is equivalent to the alpine »Piottino Oscillation» of Zoller (1960) on the basis of C^{14}-datings. This oscillation (8100—7700 B.C.) was followed by the final improvement of the climate (7700—6800 B.C., Behre 1966, p. 76).

The oscillation sequence in the North Satakunta area seems to show a corresponding climatic rhythm, and it can be seen in the lithostratigraphy. In the following the North Satakunta oscillation is interpreted so that the varved clay roughly corresponds to the Friesland Oscillation and the upper till bed (see Fig. 2) is more or less equivalent to the Piottino Oscillation. The minor differences in age between the datings in North Satakunta and in north-western Germany are probably only methodological and do not disturb the general picture. It should be mentioned in this connexion that a similar lithostratigraphical sequence (minerogenic/organic/minerogenic) has been reported by Repo and Tynni (1969) from the eastern parts of the Salpausselkä area. They give two C^{14}-datings for silty gyttja (8250 ± 300 years B.C., Fig. 15) and for *Bryales*-peat in fine sand (8150 ± 400 years B.C., Fig. 22). These organic deposits probably represent the improvement of the climate and would correspond to the varved clays in North Satakunta. According to Repo and Tynni (1969) the decrease in organic content in that sequence is probably due to the deterioration of the climate during the transition from the Younger Dryas to the Pre-Boreal period. On the other hand, it would be equivalent to the upper till bed in the North Satakunta area.

Pollen stratigraphy and vegetational history

The pollen stratigraphy and the vegetational history of the North Satakunta area are well seen in the diagram of Fig. 6. The sediment core was taken from the southern end of Lake Teijärvi from its shore bog. Teijärvi is a morphometrically longish small lake in the parish of Ikaalinen. Its altitude is about 96 m and it flows into Lake Kyrösjärvi. The core stratigraphy is as follows:

0— 45 cm	*Sphagnum*-peat
45— 60 cm	*Carex-Sphagnum*-peat
60—120 cm	coarse detritus gyttja, brown in colour
120—225 cm	brown fine detritus gyttja
225—240 cm	pale grey, compact clay-gyttja
240—345 cm	blueish clay, which is deposited on sand

The pollen stratigraphy of Lake Teijärvi has been divided into zones according to the scheme of Donner (1963, pp. 4—7) for southern Fin-

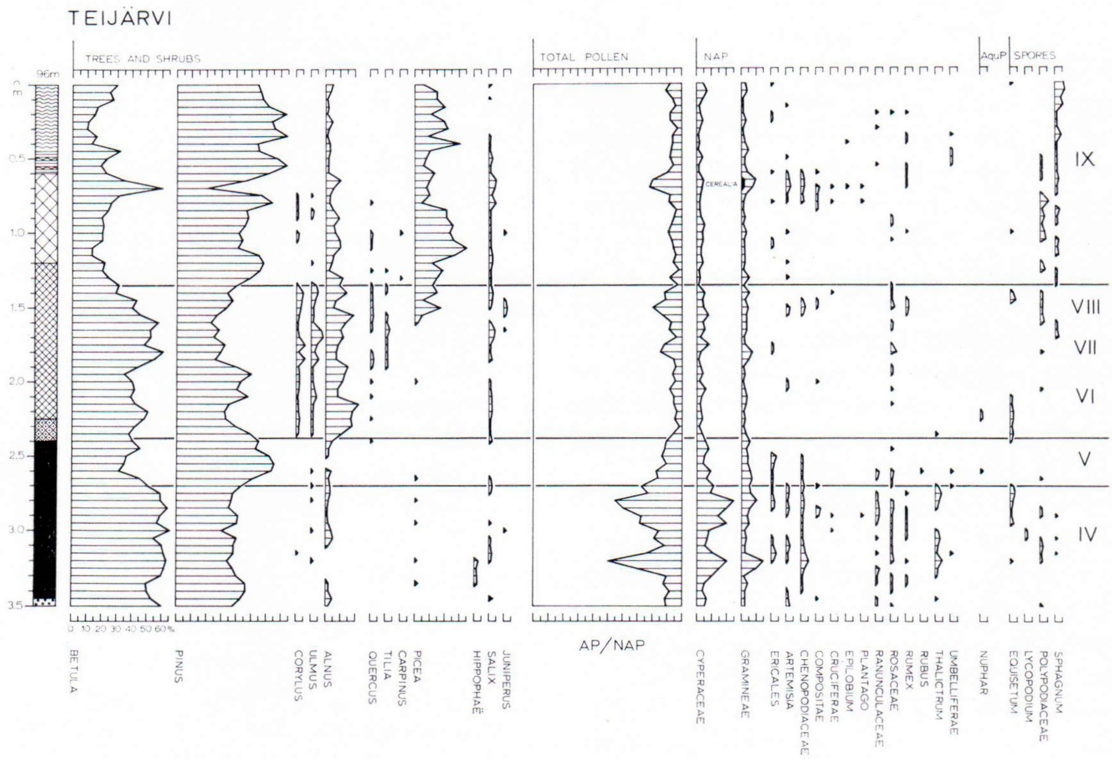

Fig. 6. Pollen stratigraphy of Lake Teijärvi

land. Zones IV and V which appear in clay are well defined and easily distinguishable. Zone boundary V/VI coincides with the stratigraphical transition between the clay and clay-gyttja as in the sediment history of Lake Kyrösjärvi (Alhonen 1967, Fig. 7). Zones VI, VII and VIII cannot be separated, because there are no marked vegetational changes between them (see Donner 1963, p. 8 and Fig. 2). In some cases the rational limit of *Tilia* (T°) and the *Ulmus* decline (U⁻) have been used as local zone boundaries, the former as zone boundary VI/VII and the latter as VII/VIII (*e.g.* Alhonen 1967). Zone boundary VIII/IX has been defined mainly on the basis of the curves of thermophilous trees (*Corylus*, *Ulmus*, *Quercus* and *Tilia*) and it occurs at a depth of 135 cm in the fine detritus gyttja.

The North Satakunta area was an archipelago immediately after the retreat of the ice and no real »tundra» phase can be shown in the initial development of the vegetation in this area. There were islands rising above the water level of the Yoldia Sea and when more dry land had emerged as a result of the shore-line displacement the areas of open vegetation were covered by forest. The higher NAP, which occur in the clay part of Lake Teijärvi and in many other pollen diagrams of this area (see *e.g.* Mölder, Valovirta and Virkkala 1957, Salmi 1962 and Alhonen 1964, 1967) reflect the initial stage with open plant communities. As can be seen in the pollen diagram (Fig. 6) these consist mainly of Cyperaceae and Gramineae, but Ericales, *Artemisia*, Chenopodiaceae, Compositae, Cruciferae, Ranunculaceae, Rosaceae, *Rumex* and *Thalictrum* belong to this open vegetation. *Hippophaë*, *Salix* and *Juniperus* also indicate the woodless conditions. It is interesting to note that the pollen flora discussed here is identical with that found by Donner (1966) in the Varrassuo profile on Salpausselkä I, where the initial vegetation and spread of forest was similarly dependent on the emergence of dry land (Donner 1966, p. 14). A more or less similar NAP character has been described from several sites in eastern and north-eastern Finland (*e.g.* Hyvärinen 1966, pp. 14—15, Tolonen 1967, Fig. 121 and Vasari 1962) where the first vegetational phase with different open plant communities occurred in the larger supra-aquatic areas immediately after deglaciation. As has been suggested by Donner (1958, Fig. 1 B), the forest followed close after the retreating ice in the early Post-glacial period, but in some areas there was probably a narrow »tundra» (open vegetation) belt near the ice margin (Donner 1958, p. 84). These conditions also prevailed in the North Satakunta archipelago. During the regression of the Yoldia Sea and after pollen zone transition IV/V the forest expanded rapidly. This is clearly indicated in Fig. 7, where the percentages of *Artemisia* spp. have diminished in pollen zone V. It is probable that at least a part of the *Betula*-pollen of zone IV reflects the more or less clear presence of *Betula*-forests in the neighbouring areas, while the rest may be derived from the long-distance transport. The forest spread reflected in the ratio of AP/NAP in the pollen diagram of Fig. 6 after zone transition IV/V indicates the expansion of *Pinus*-forests in the area studied. Further it should be mentioned that *Alnus* often has high percentages in pollen zone IV, but especially in zone V (*cf.* Alhonen 1967, Fig. 6). It is probable that *Alnus* grew in the North Satakunta archipelago as it does on the shores of the recent archipelago. In the Helsinki area *Alnus* was common already during the early Boreal before its general spread (Sauramo 1954, p. 218, Donner 1954). These *Alnus*-pollen represented *A. glutinosa* according to measurements and determination by Donner (1954, pp. 52—55).

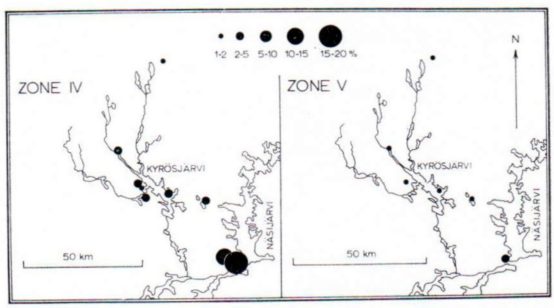

Fig. 7. The map showing the occurrence of *Artemisia* spp. in the area studied during pollen zones IV and V. The diminishing percentages show the rapid forestration in zone V. Data from Mölder, Valovirta and Virkkala (1957, Figs. 8 and 9), Salmi (1962, Fig. 2), Alhonen (1963 a, Fig. 2, 1963 b, Fig. 5, 1964, Fig. 1, 1967, Figs. 4 and 6) and Teijärvi in this study.

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