Late Quaternary Development in the Northwestern Baltic Sea. – An Introduction

Abstract

This paper deals with the presumptions for a newly started project called « Late Quaternary development in the northwestern Baltic Sea ». The main focus will be placed on laminated sediments deposited during the various stages of the Baltic. The varved glacial clay will be used to establish a chronology of the ice recession after the Younger Dryas stadial. The chemical composition and the biostratigraphy of the laminated early Litorina deposits will be compared with the laminated recent sediments. An attempt to quantify the eutrophication caused by anthropogenic activities will be carried out.

INTRODUCTION

After the Weichselian deglaciation the Baltic basin passed through several stages. The basin has either been connected to the sea or acted as an isolated lake. During these stages, when favourable conditions prevailed, laminated sediments, with various genesis and distribution, were deposited (Fig. 1). During the deglaciation varved clay was formed in the Baltic Ice Lake and the Yoldia Sea. Laminated gyttja clay was deposited during the initial phase of the Litorina Sea and laminated clay gyttja during recent times. Furthermore, laminated sediments may have been formed in the Ancylus Lake and during short periods in the Litorina Sea. Very often, laminae occur in shallow lagoonal sediments deposited during the isolation phase when a bay was isolated from the Litorina Sea and also during its poststages.

There are two main purposes of the current project, « Late Quaternary development in the northwestern Baltic Sea » (Fig. 2) :

1. To establish a clay varve chronology that can be connected with the Swedish and Finnish geochronological time scales. This connection will give a better knowledge of the position of the ice front in the Baltic basin during the Younger Dryas stadial. If possible, palaeomagnetic records of the glacial clay are also to be investigated.

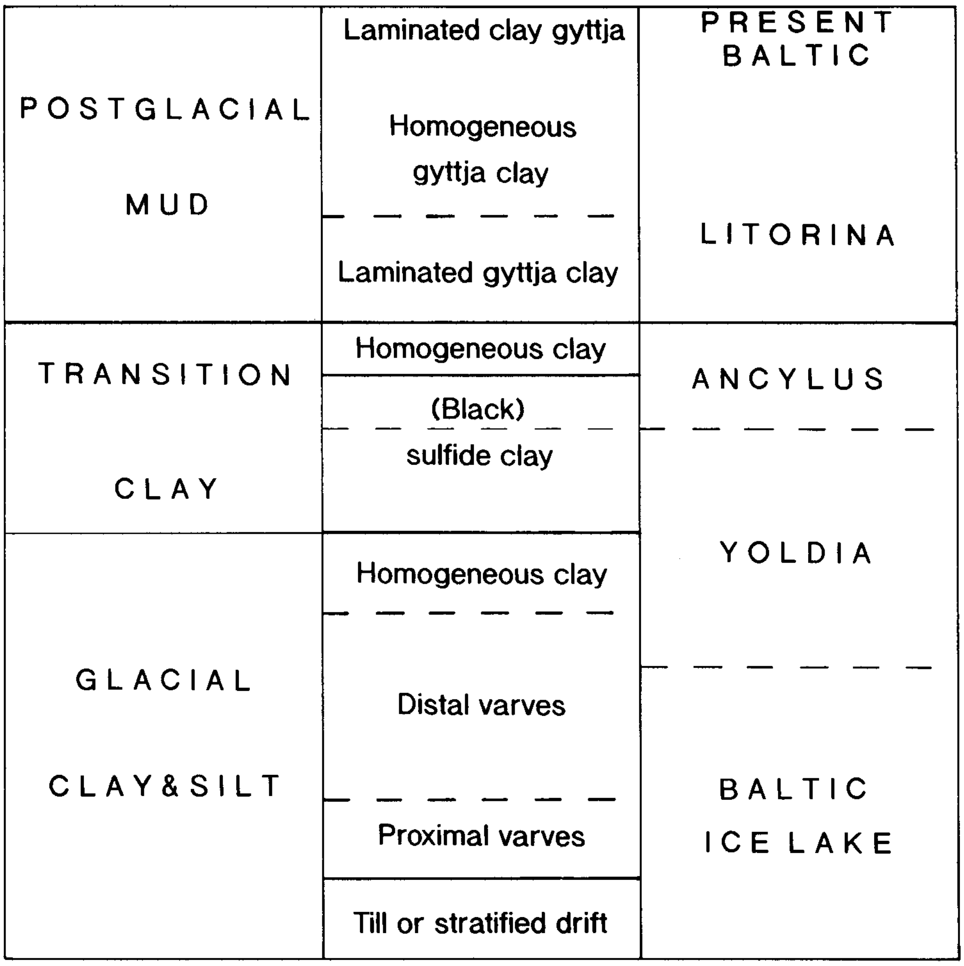

Fig. 1. General glacial and post-glacial stratigraphy of the central Baltic proper (re-drawn and simplified from Winterhalter et al., *1981, Fig. 1.33, p. 66).*

2. To carry out comparative studies of laminated sediments deposited during the early Litorina and recent times. The work aims at studying the geographical distribution and sediment composition. Applied analyses will include diatom stratigraphy and measurements of mineral magnetic parameters (magnetic susceptibility, SIRM and HIRM), organic carbon, biogenic silica and heavy metals. The results will be used in an attempt to quantify the anthropogenic component of the recent eutrophication in the Baltic.

The project is run by the Department of Quaternary Research, Stockholm University (SU) and financially supported by the Swedish Natural Science Research Council.

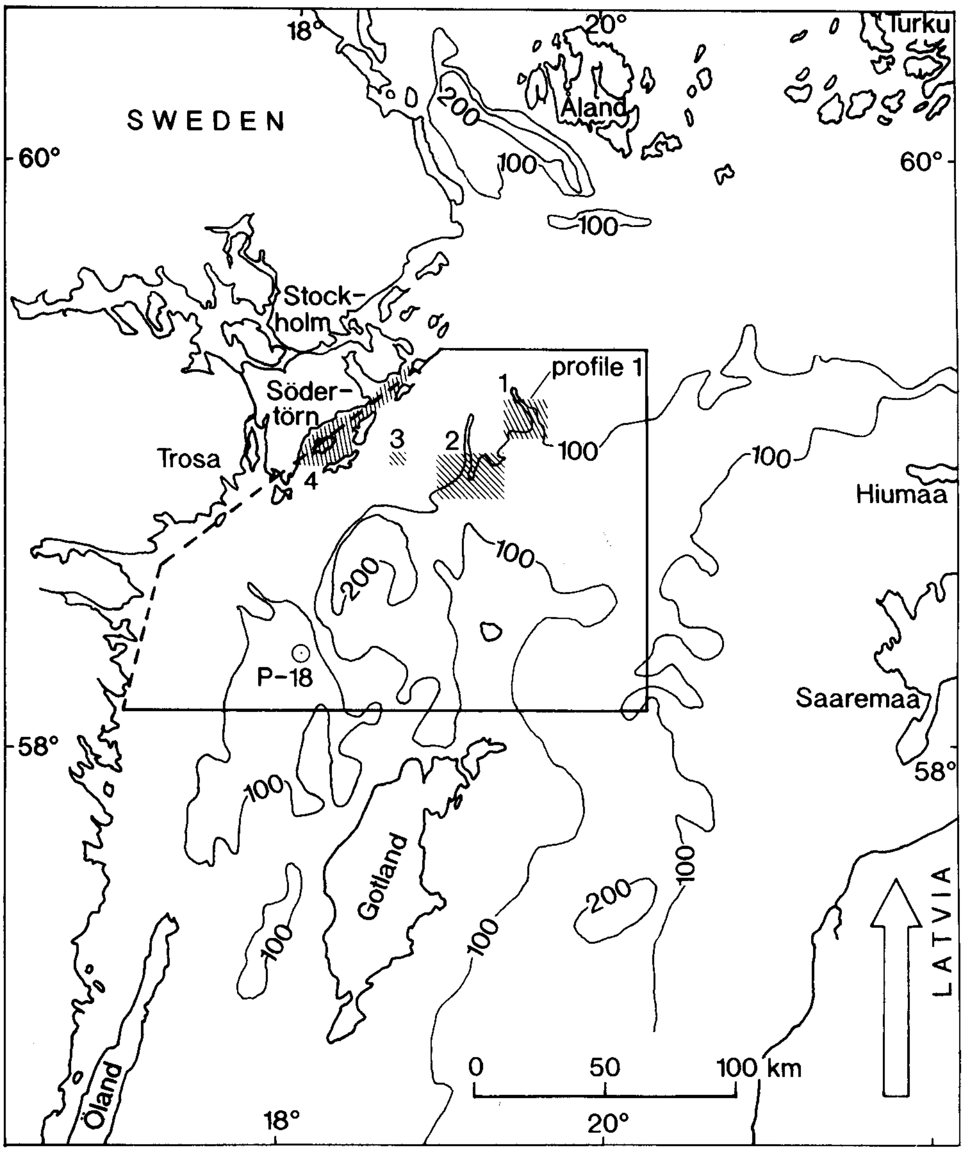

Fig. 2. Map showing the area to be investigated, location of sample P-18, sampling localities 1-4 and profile 1. Contour lines of 100 and 200 m water depth are included.

Ice recession and clay varve chronology

The recession of the last Weichselian ice sheet from Sweden and Finland/Estonia is relatively well known today. The recessional lines over the central Baltic basin are traditionally interpolated between investigated onshore sites in Sweden and Finland. There are hypotheses of both ice

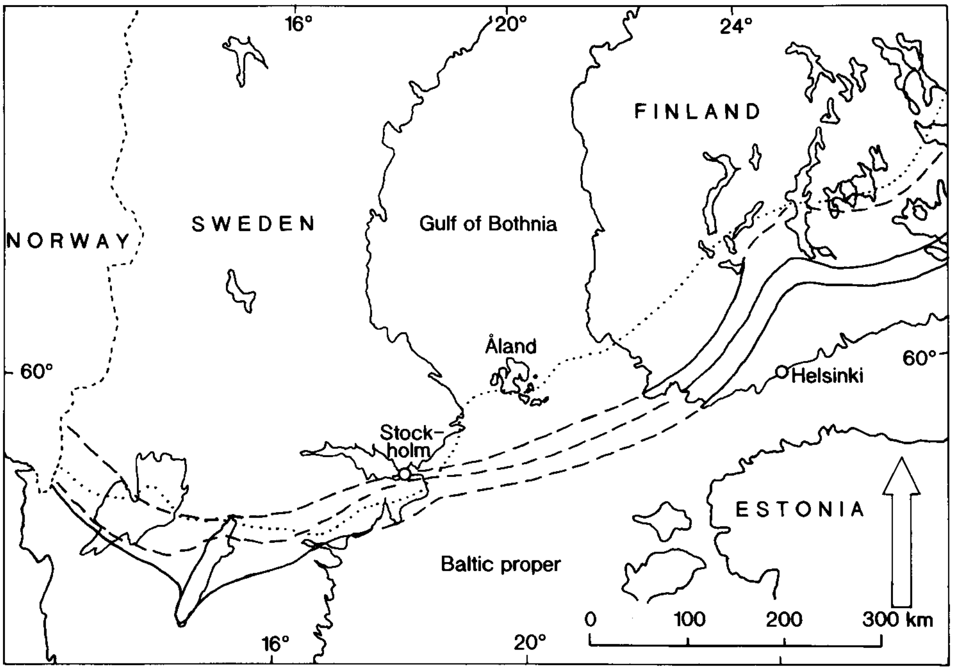

Fig. 3. Map showing possible positions of the ice margin during the Younger Dryas stadial (redrawn from Lundqvist, 1987, Fig. 1, p. 306).

lobes and a straight ice margin over the area (e.g. Mörner *et al.*, 1977, Fig. 7 ; Lundqvist, 1987, Fig. 1, p. 306). As no clay-varve investigation has been carried out in the Baltic basin these hypotheses must be considered as uncertain.

The Younger Dryas (YD) period represents a cooling of the climate, at least in the north Atlantic region. During this cool period the retreating ice margin stopped or even readvanced over the central Baltic basin and the onshore areas (Fig. 3). In sequences of glacial clay from Södertörn, south of Stockholm, a significant change of colour is registered. The change is assumed to represent variations in salinity in the Baltic Ice Lake/Yoldia Sea at the end of the YD stadial. The geographic extension of this change of colour in the glacial clay is of great importance for the knowledge of the position of the ice margin at the end of the YD stadial. During the Preboreal the rate of ice recession increased and the ice margin retreated from the central Baltic basin (Strömberg, 1990, p. 23).

Clay varve chronological investigations have proved to be a useful tool for studies of the ice recession in offshore areas (Andrén, 1990, p. 51). Therefore, in the area under investigation, it is possible to apply clay varve

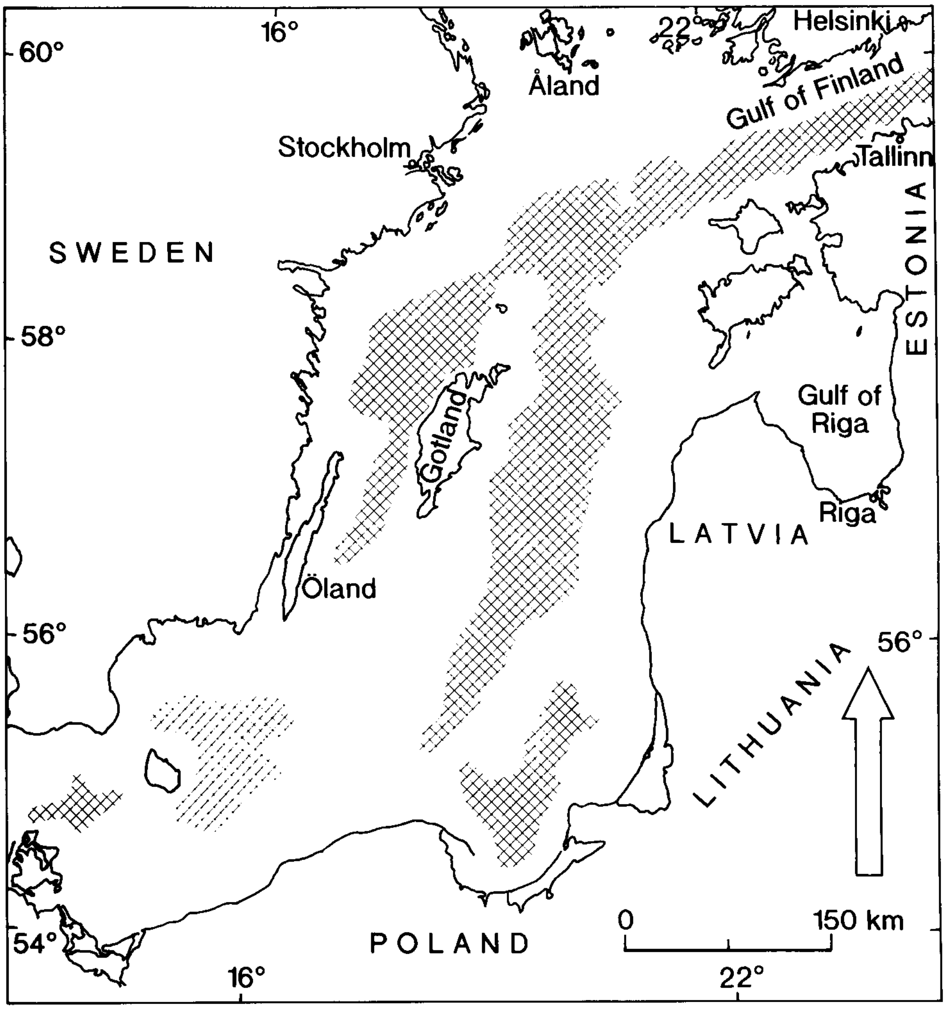

Fig. 4. Map showing the probable extent of laminated surficial sediments in the Baltic proper (redrawn and simplified from Jonsson et al., *1990, Fig. 3, p. 154).*

studies to the lower part of the sedimentary strata from the sea bottom and correlate them with sites in coastal areas onshore (cf. Brunnberg in *Risberg* et al., *1991*, Fig. 2, p. 34).

At present, intense work is being carried out in both Sweden and Finland on the revision of the geochronological time scales. In 1990 an international project dealing with the problems during the YD period was initiated within the IGCP-project 253 « Termination of the Pleistocene » with Prof. Jan Lundqvist, SU, as project leader (Lundqvist and Saarnisto eds, 1990). The project presented here is a supplement to this work.

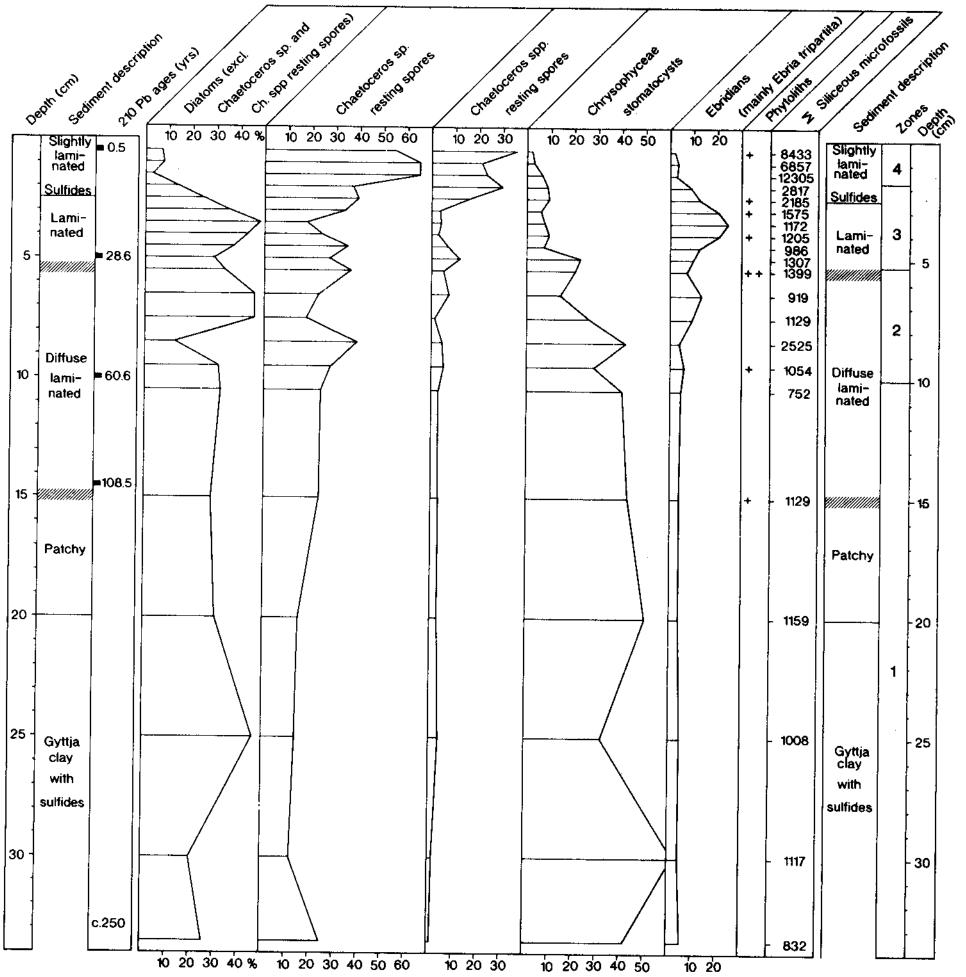

Fig. 5. Total siliceous microfossil stratigraphy of sediment core P-18 (from Risberg, 1990, Fig. 2, p. 168). « Chaetoceros *sp. resting spores» is the most frequently occurring taxon. All other taxa have been grouped within «* Chaetoceros *spp. resting spores». For location see Fig. 1.*

Laminated sediments deposited during the early Litorina

From several works carried out on sedimentary sequences from the Baltic Sea, laminated sediments have been identified at the Ancylus Lake/Litorina Sea boundary. The boundary is distinct and easily identifiable within the sediments. The clayey sediments of the older stages pass into gyttja-clays and/ or clay-gyttjas, often laminated, indicating eutrophic and anoxic conditions (Eronen, 1988, p. 17). Laminations have been observed in sediment cores from the Bothnian Bay (Andrén pers. comm.), Gulf of Finland (Åker *et al.*, 1988, Fig. 5, p. 106) and from the Baltic proper (Paabo, 1985 ; Abelmann, 1985). The geographical extension, however, is not known. Upwards, the sediments gradually change into more or less homogeneous deposits.

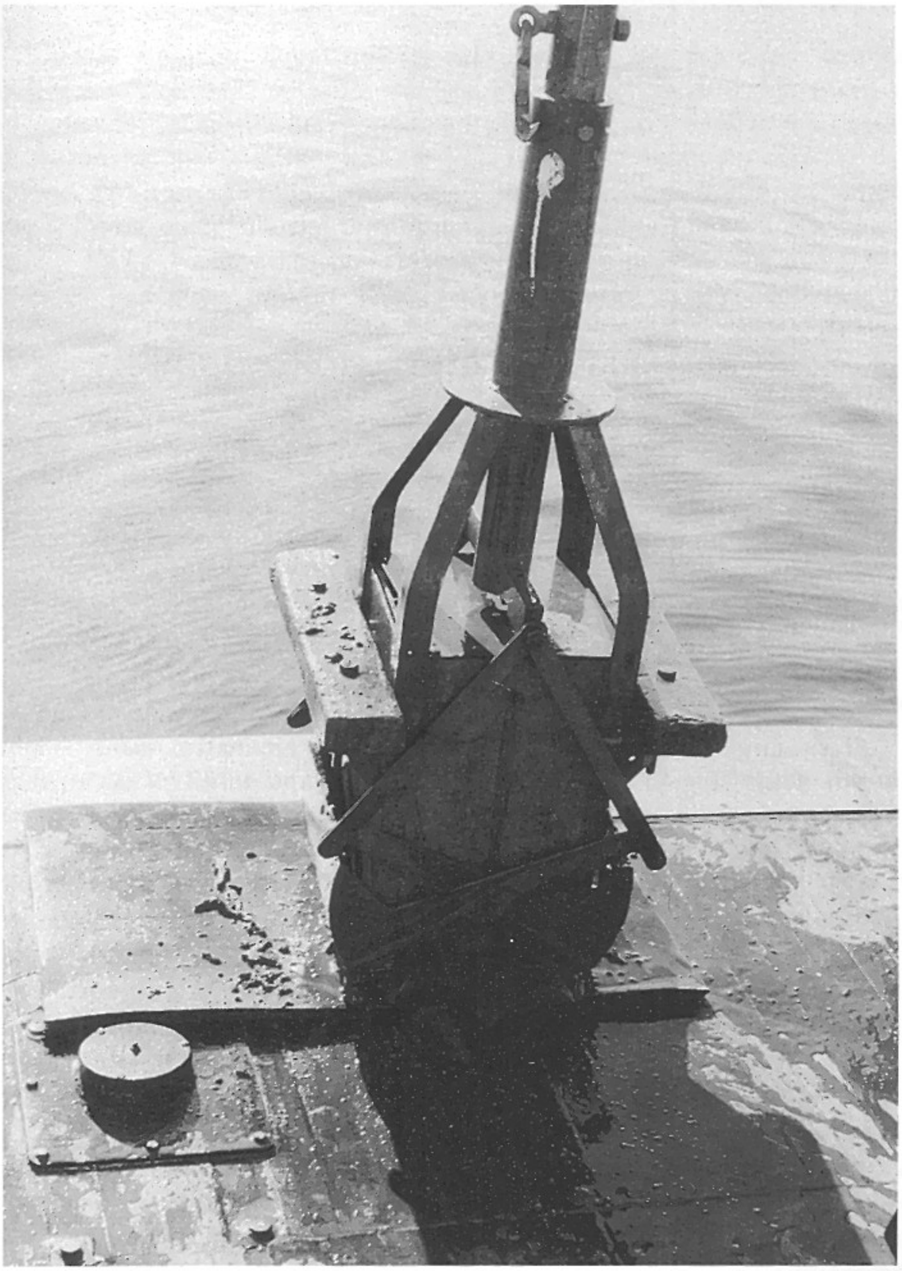

Fig. 6. Photo of the box sampler used for sampling unconsolidated top sediments. The size of the box is c. 40 × 40 × 50 cm.

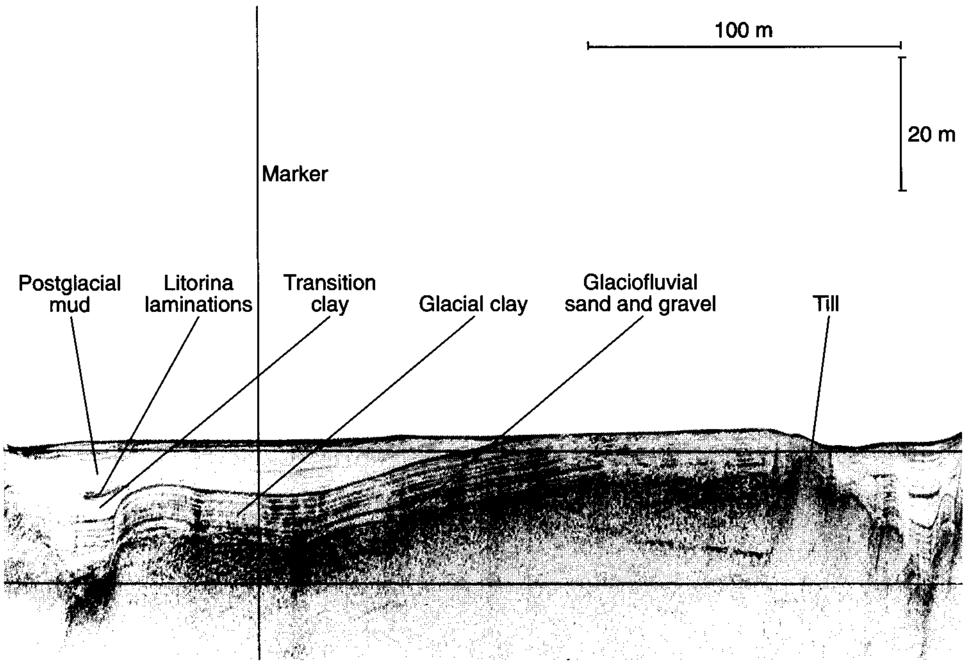

Fig. 7. Sub-bottom penetrating echo-sounding diagram of profile 1 (for location see Fig. 1). Fequency used: 5 kHz. The vertical marker line indicates the position of a box sample.

Laminated recent sediments

Today large areas of the Baltic proper show laminated and/or sulphide rich sediments (Fig. 4). This is supposed to be the result of an increased input of nutrients, especially nitrogen (N) and phosphorus (P), together with a reduced input of oxygen-rich water from the Atlantic (Jonsson *et al.*, 1990; Miller and Risberg, 1990; Risberg, 1990; Rosenberg *et al.*, 1990). The inputs of N and P have increased by a factor of 4 and 8, respectively, since the beginning of the 20th century. Most of the increase is likely to have taken place after 1950 (Rosenberg *et al.*, 1990).

It is concluded that nitrogen availability limits primary production in the Baltic proper. In the Bothnian Bay, phosphorus is the limiting nutrient (Rosenberg *et al.*, 1990). The Baltic Sea is naturally rich in silica. Concentrations in the surface water, however, have decreased during recent years (Wulff and Rahm, 1988). This indicates that silica in the future might become a limiting factor if the input of nutrients continues to increase. A siliceous microfossil analysis has been carried out from P-18 (Fig. 5). An increase of Chaetoceros spp. resting spores was noted towards the sediment/water interface. This might indicate a change in environmental conditions. It may also result in confining silica to the sediments.

The salinity in the central Baltic proper of today varies between 7-13 per mille and there is a halocline at 60-80 metres depth.

Sampling techniques and fieldwork

During sampling great efforts will be put on achieving complete sedimentary sequences covering the late Pleistocene (Late Weichselian) and Holocene (including the unconsolidated top sediments). This will be carried out by means of profiling with a low frequency mud penetrating echo sounder and test samplings. The consolidated sediments will be sampled using a piston corer and the unconsolidated top sediments by a box sampler (Fig. 6). Probably, several cores taken at various depths, will have to be combined and connected. If so, lithostratigraphical changes and magnetic susceptibility curves will be used for correlation purposes.

During the field season 1991, two well-defined sedimentary basins were test sampled (Fig. 2) and a total of 7 cores (each 6 m) and 8 box samples were retrieved. One of these sedimentary basins, c. 115 m deep, represents anoxic bottom conditions and displayed laminated top sediments. The water depth of the other basin is c. 85 m. Each box sample was sub-sampled directly on deck with 40 cm long plastic tubes. During sub-sampling great care was taken not to compact or destroy the unconsolidated laminated top sediments. The sampling stations were chosen from thorough profiling with a subbottom penetrating echo sounder (Fig. 7).

Dating

In order to achieve a chronology for the various significant stages of the Baltic, analysis of radioactive isotopes will be used for dating purposes. In the lower part of the sedimentary sequence, i.e. the varved glacial clay and transition clay, any shell fragments found can be dated by radiocarbon. The same method will be applied on the laminated early Litorina sequence. The results can be compared with visual countings of the laminae. The laminated top sediments will be dated by ^{137}Cs.

Acknowledgements

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