C M 1996/R:7

SEDIMENTATION BASIN CHARACTERISTICS IN THE GULF OF FINLAND, BALTIC SEA

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Abstract-Sedimentation basins in Gulf of Finland were studied by sediment sampling and echosounding (12 kHz) in grids from 1.0 x 1.0 NM to 1.2 x 1.2 NM and with a line separation of 0.1 NM. Precise positioning (DGPS) provided exact location data. All data (2500 -3000 grid points/basin) were recorded during each grid run. The data were processed to isopleth and 3-D bottom topography maps with different sediment units indicated. Thicknesses of these layers were determined and areas of recent sedimentation were identified. Sediment sampling lines were based on combined information on seabed topography and sediment structure. In each point 10-20 cm long sediment cores were taken and sliced into 1 cm subsamples. The 137-Cs- activity was determined from each slice to establish the 1986 Chernobyl accident peak. This method of dating recent sediments is useful in Gulf of Finland, and it was used for relative sedimentation rate calculations. The grain size distribution was determined and the <0.063 mm fraction was chemically analysed for total concentrations and partial leaches of some 30 elements. The study shows that there is a substantial internal variation in sedimentation rate also within a single sedimentation basin. In some cases the sediments are bioturbated etc. This shows the need for better knowledge of the sediment distribution in basins used for monitoring. Representative sampling sites can not be determined without a careful study of the sediment basin. A limited number of cores is probably not sufficient for extrapolation of sedimentation over large areas.

keywords: dating, Recent sediments, sedimentary basins, sedimentation, sedimentation rate, structure, variation.

INTRODUCTION

Mass budget calculations of nutrients, contaminants like heavy metals, hydrocarbons and radio nuclides in marine environments like the Baltic Sea depend on information on sediment transport, deposition and character of sedimentary basins. This necessitates good knowledge of location of net sedimentation areas and internal sediment structure variation within these areas. Variations in within-basin sedimentation are refelected in varying stratification of pollutants, which is little studied.

Traditionally sedimentation in the Gulf of Finland has been thought of as being of basin fill type and happening in a homogenous steady state fashion in basins formed between hills of older glacial and postglacial sediments. Sediment sampling and monitoring has been carried out in roughly defined locations within these basins. Somewhat differing coordinates have been used to represent the same station depending on ship, institution and scientist. Recently introduced differential satellite navigation systems (DGPS) have improved navigation to such an extent that it has encouraged detailed studies of internal variation within sedimentary basins. In this study three basins with active sedimentation were studied during repeated cruises in the Gulf of Finland. The bathymetries of the basins were interpreted from echosounding data combined with reliable DGPS navigation. In the central area of each basin an ~ 1 x 1 NM grid area was chosen for precise study. Bathymetric maps were produced from the grid data. The variation in sediment accumulation was studied in two basins through interpretation of the echograms and through sampling along transects. Sediment cores were

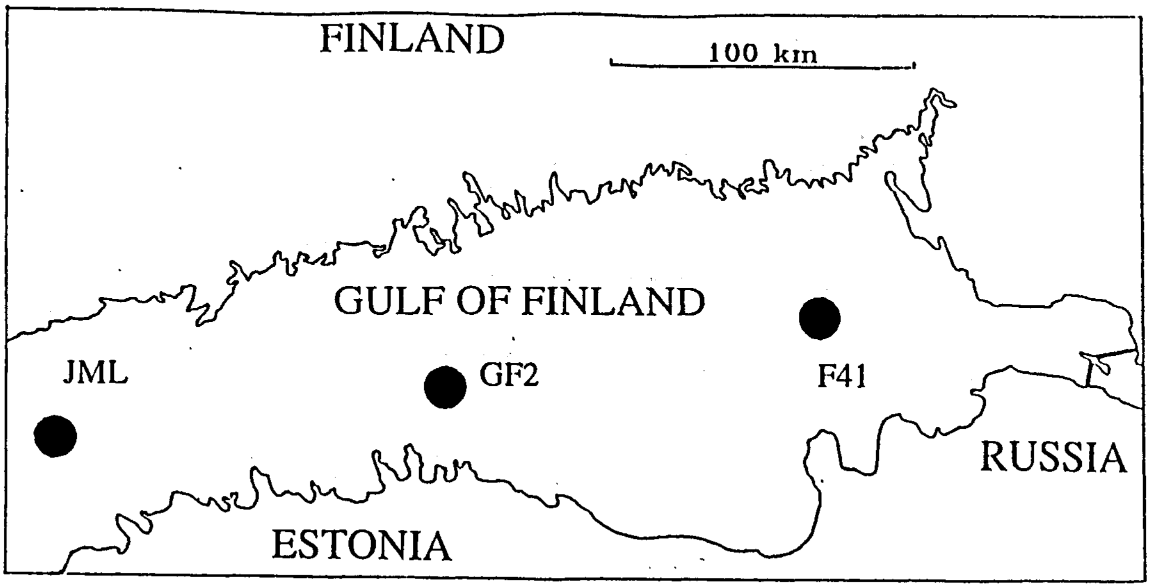

Figure 1. Study area and studied basins in the Gulf of Finland.

sliced and dated on board using gammaspectrometry, thus determining the ^{137}Cs peak of the Chernobyl nuclear power plant accident of April 1986.

STUDY AREA

Gulf of Finland is a rather shallow open bay of the Baltic Sea. The mean depth is only 38 metres. Due to differing bedrock the shores and bottom of the northern and southern coasts are significantly different. The northern coast, formed in Precambrian bedrock, constitutes an archipelago with fjords and a very rough coastline, the bottom is similar with only small isolated sedimentation basins. The southern coast is formed in Paleozoic softer sedimentary rocks, thus the coastline is smooth and even with larger sedimentation basins (Amantov et al. 1988). The bedrock is overlain by glacial and postglacial sediments of different Baltic Sea stages (Ignatius et al. 1981).

The studied basins have been monitored during earlier studies (FIMR 1995, 1996). They are located in eastern (station F41), middle (station GF2) and western Gulf of Finland (station JML), close to the centre line of the gulf (figure 1). F41 is located 7.5 NM NW of Motshjnyi island, its centre is located at 60 07.01'N 028 04.13'E (WGS84). The average water depth is 52 metres. Most of the grid area is a plateau consisting of recent sediment (figure 2a). In SW - W hummocky moraines crop out. Also in the other parts of this basin, younger sediments are underlain by glacial till . GF2 is situated in the middle of the Gulf of Finland 10 NM off Käsmu peninsula on the Estonian coast. Its centre, where the thickest recent sediments are found is located at 59 50.31'N 025 51.40'E (WGS84). The average water depth is 84 metres. The basin is a plateau of postglacial clays and silts usually covered with a sheet of recent soft sediments. It is in the northeast bordered by a outcropping bedrock and in the southwest by a hill of till. This hill is separated from the main plateau by a 15 - 20 metre deep valley. The plateau is flat with depths between 83 and 85 metres (figure 2b). JML is situated in the mouth of the gulf halfway between the cities of Hanko in Finland and Paldiski in Estonia. Its centre is located at 59 34.94'N 023 37.61'E (WGS84). The average depth is 78.5 metres. The grid area is flat with gentle slopes into valleys of 83 metres depth (figure 2c).

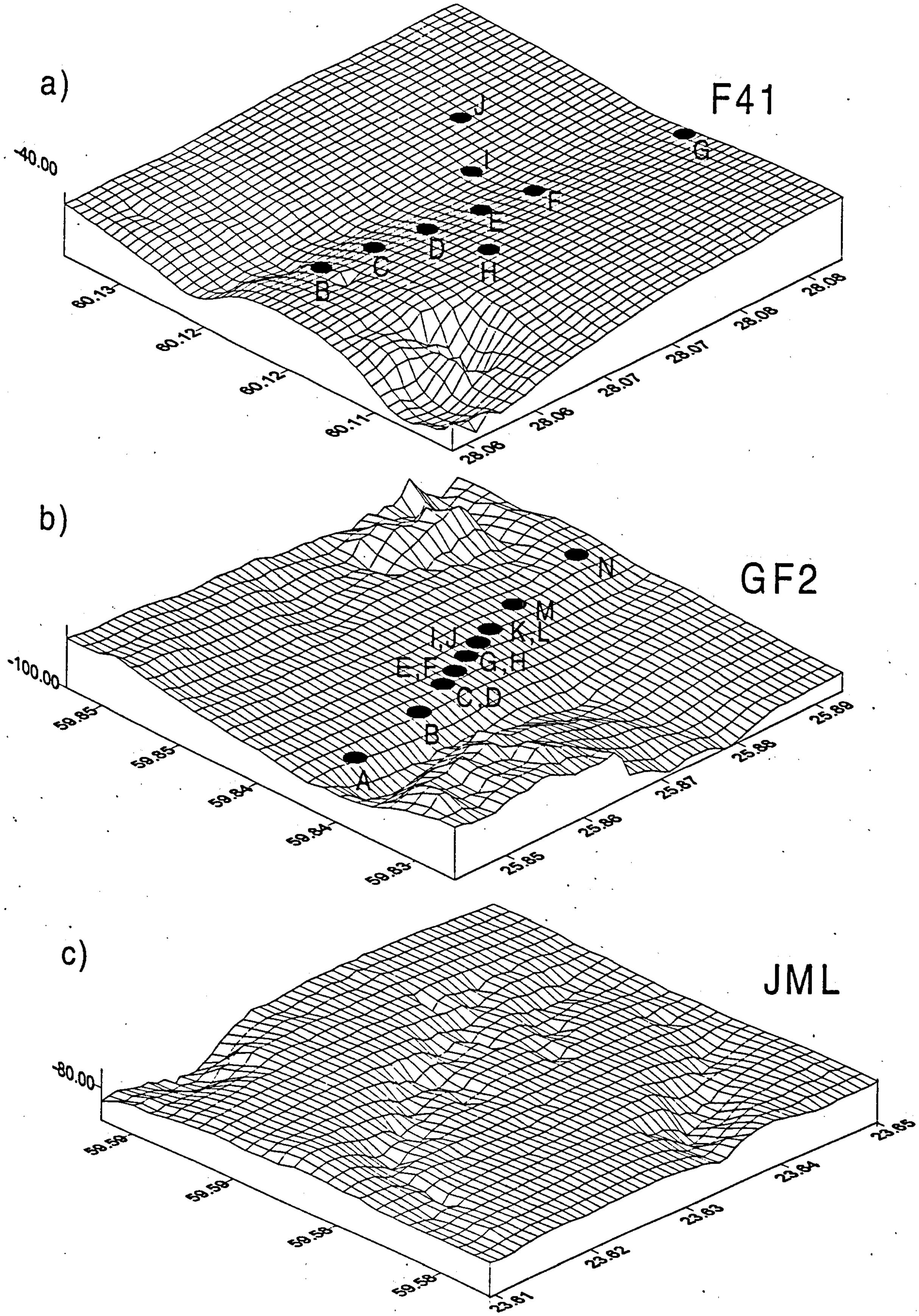

Figure 2. Bathymetry of basins F41 (2a), GF2 (2b) and JML (2c).Locations of transects is shown in basins F41 and GF2. View from SW.

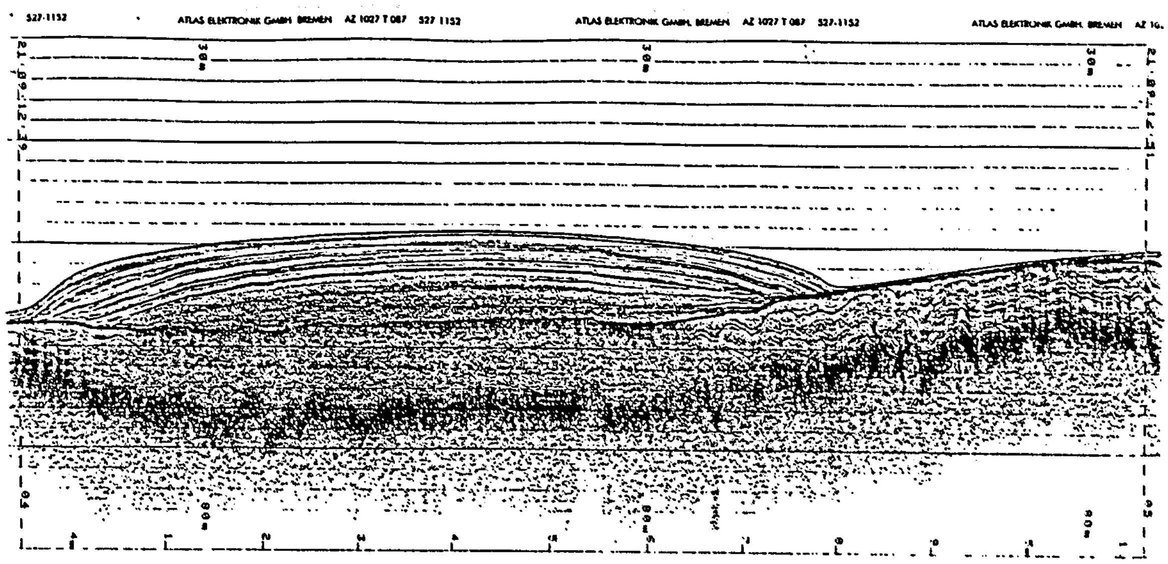

Figure 3.Vertical section through western margin of basin F41 in S - N (left to right) direction, 1 NM. Till at the bottom of section (thick black zone) is overlain by younger and recent fine sediments. Compare with figure 2a.

MATERIALS AND METHODS

The soft sediments in active sedimentary basins of the Gulf of Finland are mostly (>90%) clay, silty clay, clayey silt or silt. In some places sand is a minor component. The borders of the basins are usually coarser grained. Organic matter is always present in the fine surface sediments, 5 to 11.5 % in the topmost 10 cm of basins GF2 and JML, expressed as colorimetrically determined humus content.

For this study the research vessel 'Aranda' of the Finnish Institute of Marine Research was used during repeated cruises. The ship is equipped with a dynamic positioning system and navigation is based on differential GPS (DGPS). Data from DGPS combined with depth data was used to make a bathymetric, bottom topography map. The structure of each basin was observed using a ATLAS DESO 12 kHz echosounder, which is capable of good penetration through soft sediments. In each basin an ~ 1 x 1 NM grid area was chosen for precise study. The area was studied in 1 NM long grid lines with 0.1 NM spacing and the echograms of the grid lines were interpreted simultaneously. A 1.0 - 1.6 NM transect across the study area with 7 - 9 sediment sampling sites was determined according to map and acoustic profile data. At station JML, the ship was kept exactly at the midpoint while a varying ships heading of 0, 90, 180, 270 degrees was taken. A subsample was taken after each new heading (total 4 samples). The samples were thus taken within approximately 50 x 50 metres area. The sediment surface was sampled using a GEMINI double tube gravity corer (second generation Niemistö-corer) with a inner diameter of 80 mm. The sediment profiles were sliced into 1 cm thick slices and dated on board using gammaspectrometry, thus determining the ^{137}Cs peak of the Chernobyl accident of 1986 (Kyzyurov et al., 1994). Relative sedimentation rates were calculated based on this data. Later, these sediment slices were analysed chemically for major and minor elements and heavy metals (ICP/AES,ICP/MS) at the Chemical laboratory of the Geological Survey of Finland. Grain size distribution of the sediment cores were determined with a Sedigraph analyser at the Geological Survey of Finland.

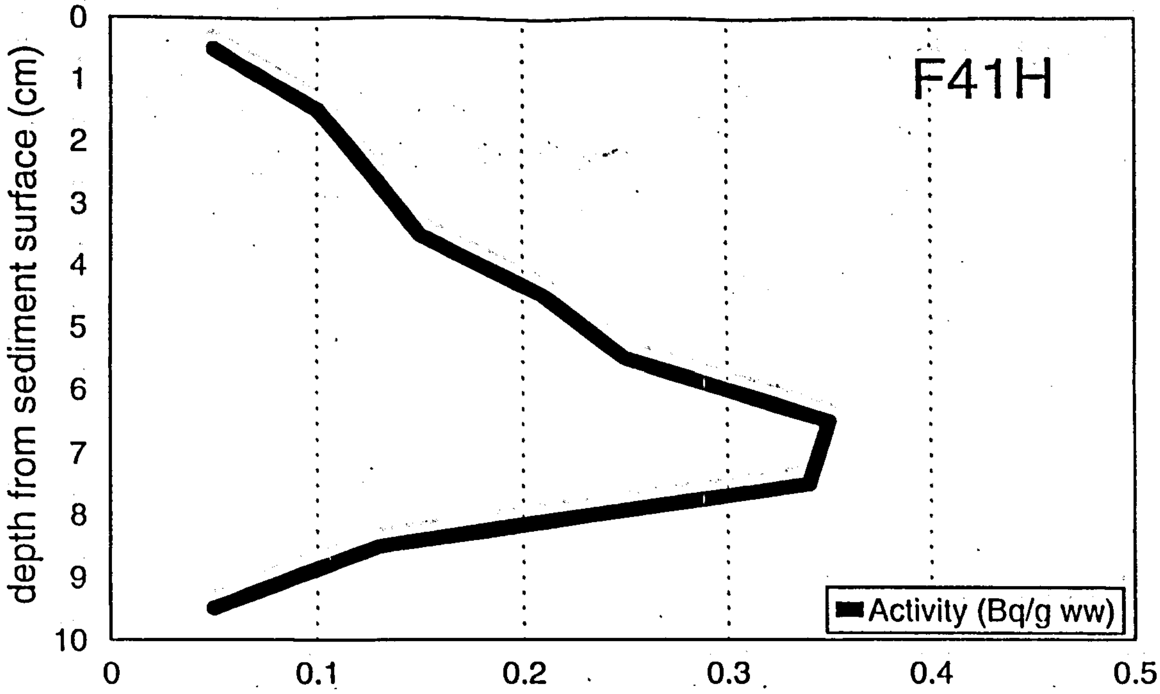

Figure 4. ^{137}Cs-activity profile from sediment core at site F41H.

RESULTS

The acoustic profiles from the studied areas show significant differences in sedimentation history especially in the older postglacial sediments (figure 3). In all studied basins Precambrian bedrock is covered with glacial and postglacial deposits. In most places a thin sheet (10-30 cm) of recent soft sediment covers the older sediments of the sedimentary plateaus. In NE and SW corners of station GF2 and on the SW-W side of station F41 the hills of bedrock and till are areas of non-deposition or erosion. The valley in SW at GF2 is an area of erosion due to local increase in bottom near currents deflected by the nearby hilly topography. The thickness of the layer of recent and subrecent sediments in the central area is some 1 - 3 metres with a maximum of some 5 metres. This indicates differences in sedimentation rates in such areas. The JML-site represents an area of rather uniform recent sedimentation.

Gammaspectrometry of the 1 cm thick slices of the sediment cores provided data on profiles of ^{137}Cs distribution in the sediment core. These profiles are well interpretable (figure 4) and can be used for relative sedimentation rate calculations as the ^{137}Cs content in the trajectory of the airborne particles from the accident at the nuclear power plant of Chernobyl is quite high (Kyzyurov et al. 1994). These profiles can be used for calculations of relative sedimentation rates. In basin GF2 the rate varies between 2.5 mm and 7.5 mm per year (figure 5a). The slowest rates are measured in the borders of the plateau and the highest rates from the middle of the basin. In basin GF2 the thickest bed of recent sediments is situated in the area where the thickest layers of postglacial silts/clays are found. The horizontal distribution of these beds differs from station to station. At GF2 the pattern is irregular but at F41 and JML quite regular. At station F41 the rate of recent sedimentation is between 6.5 mm and 9.5 mm per year (figure 5b). The highest sedimentation rates are not found in the middle of the basin, but instead at the western, eastern and southern borders of the basin. There is a hill of hummocky moraine with steep sides on the W - SW side of this station and 3 NM to the NW of this station, runs the main shipping route to St. Petersburg. Both these factors might affect sedimentation at basin F41. At JML no long sampling transect has yet been made but instead the four mid area substations were sampled. Recent sedimentation was in these points measured to be between 3.5 mm and 5.5 mm per year.

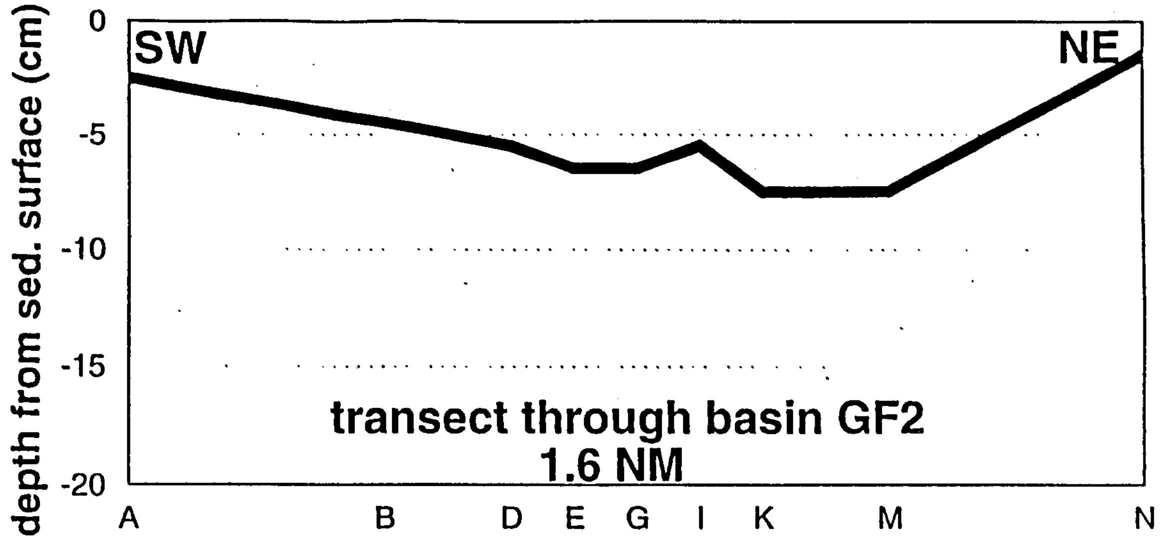

Figure 5a. Depth of the Chernobyl ^{137}Cs peak in recent sediment of station GF2

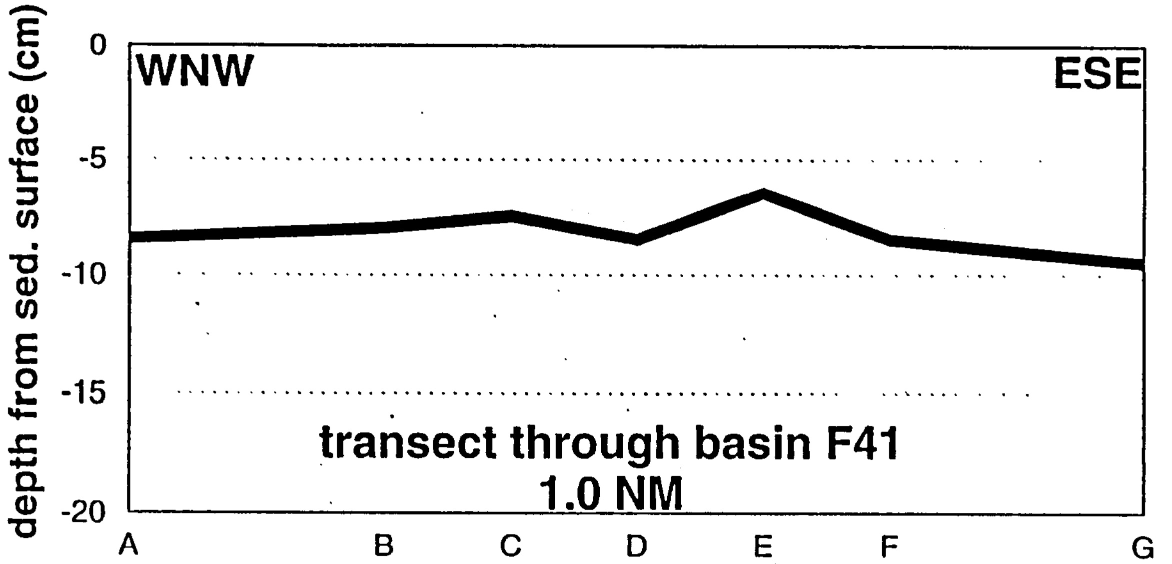

Figure 5b. Depth of the Chernobyl ^{137}Cs peak in recent sediment of station F41

Grain size distribution analyses of the profiles at station GF2 show that clay size is the most common fraction. The average clay content in the profiles is 68 %, and it varies normally between 65 and 73%. The rest is usually silt. Normally only 1- 4 % of the material is sand. In the easternmost site the clay content decreases to 50 %, and 8 % sand is present. The chemical data of total zirconium correlates well with the measured sand contents. Data on metal contents of partial leaches of the sediments were used as comparison with ^{137}Cs datings.

CONCLUSIONS

Along the transects significant differences in relative sedimentation rates were measured. This shows the heterogeneity of the basins and that cores taken within some tens of metres spacing, or more, should not be compared without prior having the results of ^{137}Cs datings. This study shows the importance of exact knowledge of the studied sedimentary basins as well as of the importance of exact navigation and positioning. Reliable dating of modern sediments in the Gulf of Finland is possible by using gammaspectrometric determination of ^{137}Cs.

The run of a grid of the size described here takes three to five hours depending on the weather, with a average speed of three to five knots. The run of the transect plus sampling of seven to nine sites takes two additional hours. We consider this method to be relatively rapid for getting valuable and crucial information about the sedimentation conditions within basins. We suggest the use of this method in studies in the Gulf of Finland and in the southern Bothnian Sea, where ^{137}Cs dating is reliable. In general we emphasize that the use of different tracers should provide comparable data on sedimentation variations also in other marine environments.

In this study we have experienced that a limited number of cores is probably not sufficient for extrapolation of sedimentation over large areas.

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