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## Gotland Basin Experiment (GOBEX)
## Status Report on Investigations concerning Benthic Processes, Sediment Formation and Accumulation


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## Summary

GOBEX (Gotland Basin Experiment) was initiated in 1993 as a multidisciplinary experiment to investigate the oceanographic, chemical, biological and sedimentological situation in the Eastern Gotland Basin of the Baltic. The first task force d studied aspects of hydrography in the Eastern Gotland Sea.

The second task force defined the Eastern Gotland Basin as a depositional end-member in the dynamic physical environment of the Baltic Sea and aimed to clarify pathways of materials, modifications and processes in the sediment accumulation area. These aims included the initial identification of mass fluxes of natural and anthropogenic substances, evaluation of transport processes, biological and geochemical processes, and sampling short (<200 years) and long (>1000 years) sedimentary records to hindcast historical and geological environments.

The present volume collects results obtained by participants of the second task force of GOBEX and is a complementary publication to the volume published by the hydrographic task force (HAGEN, 1996). After field work began in 1994, a considerable number of publications have appeared that are related to GOBEX. Many of these publications have appeared in or have been submitted to international journals that are reluctant to publish data tables. The first purpose of this volume thus is to document these analytical data in the form of data reports. The second purpose is to gather information that may be of value to the Baltic Sea scientific community in future studies, but is difficult to publish in international journals. This type of data includes, among others, maps, seismic records, details of dating efforts, core descriptions and core logs of physical properties. Many of the contributions of this latter category are bare-bone data reports that may contain preliminary and as yet unpublished data. We believe that their publication is in the spirit of GOBEX and we trust that any external users will contact the originators for advice on data quality and that due credit will be given to the scientists who have made them available in preliminary form.

## Contents

# 1. Gotland Basin Experiment (GOBEX): Status report on investigations concerning benthic processes, sediment formation and accumulation

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## Introduction

GOBEX (Gotland Basin Experiment) was initiated in 1993 as a multidisciplinary experiment to investigate the oceanographic, chemical, biological and sedimentological situation in the Eastern Gotland Basin of the Baltic Sea (Figure 1). Its components were formulated during a scientific conference sponsored by the European Committee on Ocean and Polar Sciences (ECOPS) on the future of Baltic Sea research (Warnemünde, 1993). During this meeting, two task forces were formed. The first task force decided to study aspects of hydrography in the Eastern Gotland (HAGEN, 1996; ZÜLICKE and HAGEN, 1997).

The second task force defined the Eastern Gotland Basin as a depositional end-member in the dynamic physical environment of the Baltic Sea and aimed to clarify pathways of materials, modifications and processes in the sediment accumulation area. These aims included the initial identification of mass fluxes of natural and anthropogenic substances, evaluation of transport processes, biological and geochemical processes, and sampling short (<200 years) and long (>1000 years) sedimentary records to hindcast historical and geological environments.

The following questions were considered to be important:

- What are flux rates of natural and anthropogenic materials into and out of the depositional system?
- What benthic and diagenetic processes are relevant in the formation of the geological record?
- What is the nature of environmental records and their relation to historical data?

The original plan was to investigate benthic and sedimentological processes in the oxic, dysoxic, and anoxic compartments of the Eastern Gotland Basin at seafloor stations in water depths of 50m, 100-150 m, and >200 m, respectively. The unexpected recharge with oxygenated water at the turn of 93/94 of the entire deep basin (the first complete replacement for 18 years) somewhat obliterated this plan, but offered a most attractive alternative: To study the sedimentary, chemical and biological fingerprints of oxic and aerobic conditions at the seafloor. The area of investigation is depicted in Figure 1.

The present volume collects result obtained by participants of the second task force of GOBEX and is a complementary publication to the volume published by the hydrographic task force (HAGEN, 1996). After field work began in 1994, a considerable number of publications have appeared that are related to GOBEX (see Appendix 1: List of GOBEX-related publications). Many of these publications have appeared in or have been submitted to international journals that are reluctant to publish data tables. The first purpose of this volume thus is to document these analytical data in the form of data reports. The second purpose is to gather information that may be of value to the Baltic Sea scientific community in future studies, but is difficult to publish in international journals. This type of data includes, among others, maps, seismic records, details of dating efforts, core descriptions and core logs of physical properties. Many of the contributions of this latter category are bare-bone data reports that may contain preliminary and as yet unpublished data. We believe that their publication is in the spirit of GOBEX and we trust that any external users will contact the originators for advice on data quality and that due credit will be given to the scientists who have made them available in preliminary form.

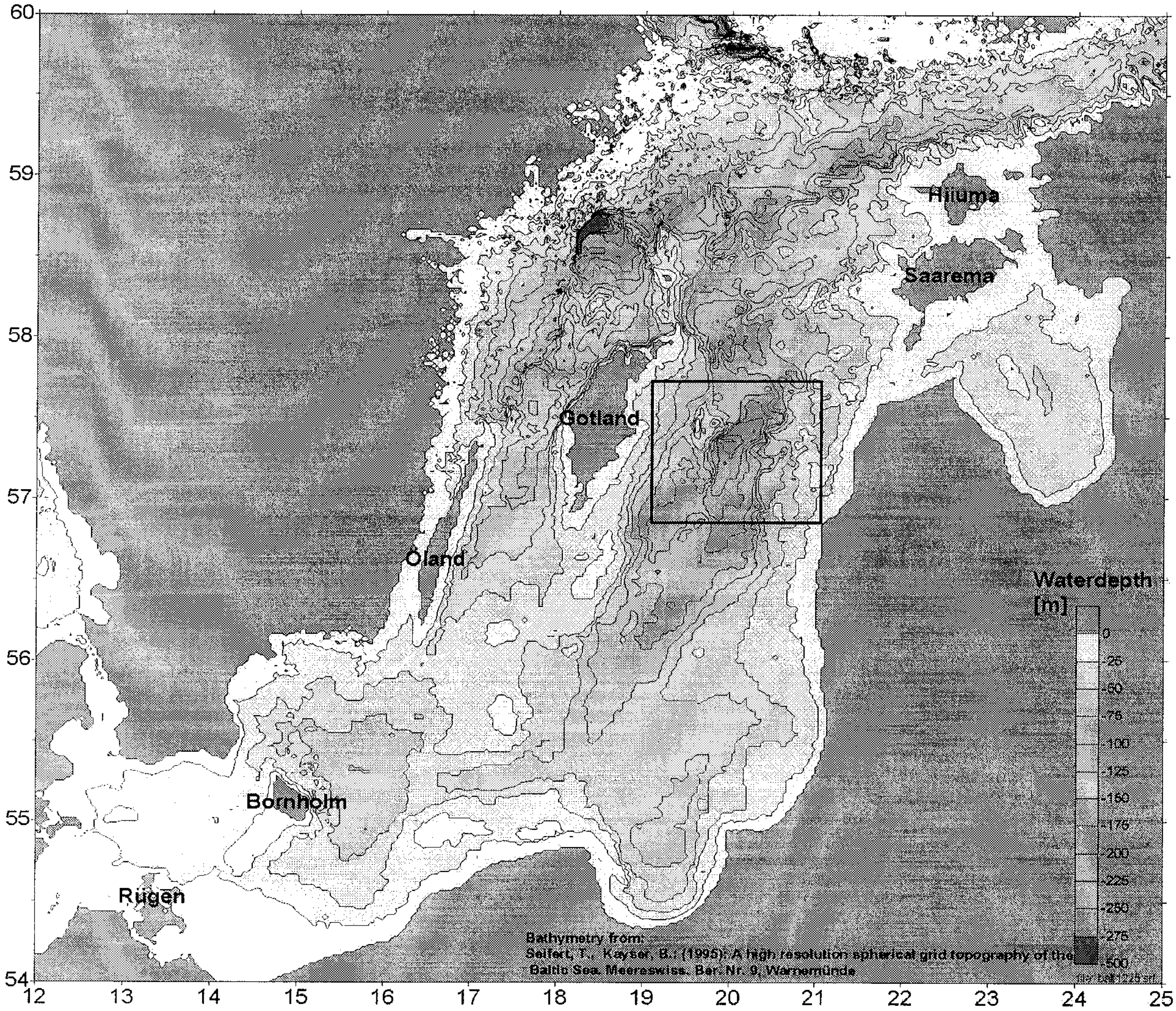


Figure 1: The GOBEX working area in the Eastern Gotland Basin

## Field campaigns

In the course of field activities under GOBEX task force 2, three expeditions were mounted by the Institut für Ostseeforschung in the period from 1994 to 1996.

Table 1: Scientific party of expedition 94.44.13.2 (R/V ALEXANDER VON HUMBOLDT): Klaipeda-Rostock, 22.08. - 02.09. 1994 (EMEIS, 1994)

| Name | Task | Institute |
|---|---|---|
| Benesch, D. | water and sediment sampling, oxygen | IOW, Marine Geology |
| Dr. Christiansen, C. | acoustic survey | Univ. Aarhus |
| Dr. Emeis, K.-C. | chief scientist | IOW, Marine Geology |
| Dr. Endler, R. | acoustic survey | IOW, Marine Geology |
| Jähmlich, S. | bottom water sampling, microbiology | GEOMAR Kiel |
| Dr. Kuleshov, A. | Nephelometer | P.P. Shirshov Inst. Kaliningrad |
| Matthiesen, H. | sediment sampling, geochemistry | Univ. Aarhus |
| Dr. Neumann, T. | pore water sampling, geochemistry | IOW, Marine Geology |
| Dr. Sivkov, V. | Nephelometer | P.P. Shirshov Inst. Kaliningrad |
| Springer, B. | bottom water sampling, macrobenthos | GEOMAR Kiel |
| Dr. Struck, U. | geological sampling, sedimentology, | IOW, Biology |
| Dr. Zhurov, Y. | Nephelometer | P.P. Shirshov Inst. Kaliningrad |

During this first expedition, the accumulations of mud in the Eastern Gotland Basin were mapped by acoustic methods and sediment cores were taken for preliminary analyses. In addition, a basic hydrographic program was performed to determine the water-column properties at the time.

The second expedition was dedicated to biological oceanography, but short and long sediment cores were also taken in the Gotland Basin.

Table 2: Scientific party of expedition POS-204 (R/V POSEIDON): Rostock-Rostock, 18.-26.02.1995 (VOß, 1995)

| Name | Task | Institution |
|---|---|---|
| Buuck, B. | Biology | IOW |
| Ebert. M. | Biology | IOW |
| Gronau, N. | Chemistry | IOW |
| Dr. Kähler, P. | Nitrogen cycle | IOW |
| Lehnert, G. | Technician | IOW |
| Ruickholt, H. | CTD | IOW |
| Siegmund, H. | Technician | IOW |
| Dr. Struck, U. | Coring | IOW |
| Thomas, H. | Carbonate system | IOW |
| Dr. Voß, M. | Chief scientist | IOW |
| Dr. Saarinen, T. | Paleomagnetism | Geol. Survey of Finland |

Based on the two preceding expeditions, the third expedition with R/V Poseidon extended the areal coverage of seismic investigations and concentrated on the recovery of gravity cores and multicores from areas of high sediment accumulation rates and from locations, were older sedimentary units were found to be within the penetration range of gravity cores. Pore waters were sampled from some of these cores and paleomagnetic samples were taken.

Table 3: Scientific party of expedition R/V POSEIDON 215B (4.3.-13.3.96) (EMEIS, 1996)

| Name | Task | Institution |
|---|---|---|
| Dr. Blanz, T. | sedimentology | IOW |
| Dr. Böttcher, M. | geochemistry | Univ. Oldenburg |
| Dr. Emeis, K.-C. | chief scientist | IOW |
| Dr. Endler, R. | geophysics | IOW |
| Frahm, A. | coring | IOW |
| Klutentreter, H. | sedimentology | IOW |
| Nickel, G. | geophysics | IOW |
| Schoster, F. | geochemistry | Univ. Oldenburg |
| Dr. Struck, U. | sedimentology | IOW |
| Reich, M. | sedimentology | IOW |
| Dr. Roberts, A. | paleomagnetism | Univ. Davis, U.S.A. |
| Dr. Winsemann, J. | sedimentology | Univ. Hannover |

## Overview of publications and contents of this volume

The collaborative efforts in subsequent shorebased studies resulted in a considerable number of publications (see Appendix 1: list of GOBEX-publications as of September, 1998). In this volume, several contributions render the data that formed the basis of these publications; in addition, new data and data on the long cores are given. ENDLER et al. (1996) and ENDLER et al. (1997) presented their work on the acoustic properties of the Eastern Gotland Basin based on intensive surveys using CHIRP sonar technology. A by-product of their field work is a map that is based on echosoundings along the ships´ tracks; combined with previous compilations (FLODÉN, 1995) of water depth determination, this new map is the most comprehensive map available to date and is used as the master map to which most of the contributions in this volume refer (ENDLER and FLODÉN, this volume).

### Water column

During most of the expeditions, a series of CTD casts were made to sample the water column. SIVKOV et al. (this volume) discuss aspects of nepheloid layers during the August 1994 expedition that were detected by the turbidity sensor and the CTD. JÄHMLICH et al. (this volume) investigated the bottom boundary layer in particular and present data on the microbiological and isotopic properties of particulate material in this transitional layer between the water column and the sediment.

### Surface sediments and short cores

A most important component of post-cruise work was detailed radiometric dating of multicores (Table 4), which permitted us to reconstruct temporally well-resolved records of variations in depositional conditions and in anthropogenic input over the last 200 years (KUNZENDORF and CHRISTIANSEN, 1995; KUNZENDORF and CHRISTIANSEN, 1996; KUNZENDORF et al., 1997; KUNZENDORF et al., 1998; CHRISTIANSEN et al., submitted). In the contribution by CHRISTIANSEN

Table 4: Core locations and status analyses of GOBEX multicores.

| IOW # | Cruise | Latitude | Longitude | WD | Dated | Isotopes | Chemistry | Other |
|---|---|---|---|---|---|---|---|---|
| 20000-7 | A.v.Humboldt | 57 ° 15.17 'N | 20 ° 33.64 'E | 112 | X | X | X | Pore waters |
| 20001-5 | Aug 94 | 57 ° 18.33 'N | 20 ° 03.00 'E | 243 | X | X | X | |
| 20003-6 | | 57 ° 17.53 'N | 20 ° 17.69 'E | 196 | | | | |
| 20004-1 | | 57 ° 18.28 'N | 20 ° 13.66 'E | 236 | X | | X | Pore waters |
| 20005-1 | | 57 ° 17.49 'N | 20 ° 19.57 'E | 188 | | | | |
| 20007-1/-2 | | 57 ° 23.14 'N | 20 ° 15.60 'E | 225 | X | X | X | |
| 20008-3/-4 | | 57 ° 27.60 'N | 21 ° 09.60 'E | 68 | X | | X | Pore waters |
| 20009-2 | | 57 ° 29.04 'N | 21 ° 15.52 'E | 60 | | | | |
| 20030-1 | | 57 ° 12.48 'N | 20 ° 36.52 'E | 106 | X | | | |
| 20053-1 | POSEIDON Feb 95 | 57 ° 23.14 'N | 20 ° 15.51 'E | 241 | | | | |
| 201301-4 | POSEIDON | 57 ° 20.10 'N | 19 ° 57.500 'E | 237 | X | | | |
| 201302-6 | Feb 96 | 57 ° 15.28 'N | 20 ° 11.830 'E | 249 | X | | | |
| 201303-1 | | 57 ° 11.09 'N | 19 ° 55.680 'E | 237 | X | | | |
| 201308-2 | | 54 ° 49.87 'N | 19 ° 18.940 'E | 117 | X | | X | Gdansk Basin |

and KUNZENDORF (this volume), the authors document the results on all cores that have been analysed. Their results permitted analyses of eutrophication history based on stable isotopes of nitrogen and carbon (STRUCK and VOSS, 1996; STRUCK et al., 1997; STRUCK et al., in press; STRUCK et al., submitted), as well as of trace metal inputs and accumulation rates (EMEIS et al., 1996; EMEIS et al., 1998; NEUMANN et al., this volume). Comparing the geochemical records with historical data on the frequency of salt-water intrusions led to the realisation that layers with manganese carbonate correlate with events of re-oxygenation (NEUMANN et al., 1997). Matthiesen and co-workers (MATTHIESEN, 1996; MATTHIESEN et al., 1996; MATTHIESEN, 1998; MATTHIESEN et al., in press; MATTHIESEN, this volume) analysed pore waters with a view towards clarifying the reflux of phosphorus from the sediments to the bottom waters. Their results suggest a significant contribution of recycled phosphorus to the entire phosphorus budget of the Baltic Sea, which may explain why phosphate reduction measures have not significantly reduced the level of eutrophication (MATTHIESEN et al., in press).

### Acoustic investigations, physical properties and sedimentology of long sediment cores

Based on the acoustic reflector geometry, which is presented by ENDLER et al. (this volume), the expeditions occupied coring locations at which kasten cores and gravity cores were taken (Table 5). EMEIS (this volume), ENDLER (this volume), MEYER (this volume) and STRUCK and REHDER (this volume) document core descriptions, physical properties based on multi-sensor track analyses of split cores and on discrete samples, radiographies, and color scans of split core surfaces. The images and data tables are appended on the accompanying CD-ROM.

Table 5: Core locations and status of analyses of GOBEX gravity cores and kasten cores.

| IOW # | Expedition | Latitude | Longitude | WD | Type | Penetration | Recovered | Description | X-ray | MSCL | Scans | PP | Carbon |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20001-6 | A.v.Humboldt | 57 ° 18.33 N | 20 ° 03.00 ´E | 243 | SL | 6.4 | 5.8 | X | X | | | | |
| 20002-1 | Aug 94 | 57 ° 18.04 N | 20 ° 14.02 ´E | 236 | SL | 6.5 | 5.6 | X | | X | X | | |
| 20007-3 | | 57 ° 23.14 N | 20 ° 15.60 ´E | 225 | SL-F | 6.5 | 2.4 | X | | | | | |
| 20007-4 | | 57 ° 23.19 N | 20 ° 15.50 ´E | 225 | SL | 6.5 | 5.8 | | | X | X | | |
| 20008-10 | | 57 ° 27.60 N | 21 ° 09.62 ´E | 68 | SL-F | 6.5 | 3.8 | X | | | | | |
| 20030-2 | | 57 ° 12.52 N | 20 ° 36.91 ´E | 106 | SL-F | 6.5 | 5.7 | X | | | | | |
| 20030-3 | | 57 ° 12.41 N | 20 ° 36.56 ´E | 106 | SL | 6.5 | 5.8 | | | X | X | | |
| 20031-1 | | 57 ° 17.40 N | 20 ° 20.06 ´E | 190 | | 6.5 | 5.7 | X | | | | | |
| 20048-1 | POSEIDON | 57 ° 23.14 N | 20 ° 15.51 ´E | 241 | KL | 11.0 | 10.4 | X | X | | | | |
| 20048-4 | Feb 95 | 57 ° 23.14 N | 20 ° 15.51 ´E | 241 | SL | 12.0 | 10.4 | X | | X | X | X | X |
| 20049-1 | | 57 ° 17.41 N | 20 ° 20.01 ´E | 197 | SL | 10.0 | 8.5 | | | | | | |
| 20050-1 | | 57 ° 18.76 N | 20 ° 08.53 ´E | 252 | SL | 12.0 | 10.0 | X | | X | X | | |
| 20051-1 | | 57 ° 20.27 N | 19 ° 56.69 ´E | 239 | SL | 11.5 | 10.0 | X | | X | | | |
| 20052-1 | | 57 ° 21.47 N | 19 ° 46.63 ´E | 197 | SL | 11.0 | 10.0 | | | | | | |
| 201301-5 | POSEIDON | 57 ° 20.10 N | 19 ° 57.50 ´E | 237 | KL | 12.0 | 10.70 | | X | | | | |
| 201302-5 | Feb 96 | 57 ° 15.14 N | 20 ° 11.99 ´E | 249 | KL | 12.0 | 7.00 | | X | | | | |
| 201304-1 | | 57 ° 11.14 N | 19 ° 55.69 ´E | 241 | SL | 12.0 | 10.1 | | | X | X | | |
| 201305-3 | | 57 ° 15.08 N | 20 ° 11.84 ´E | 248 | SL | 12.0 | 9.0 | X | | X | X | | |
| 201306-1 | | 57 ° 22.66 N | 20 ° 17.85 ´E | 235 | SL | 12.0 | 9.0 | X | | X | X | | |
| 201307-1 | | 57 ° 00.00 N | 19 ° 26.99 ´E | 182 | SL | 12.0 | 10.0 | | | X | | | |
| 201308-1 | | 54 ° 49.87 N | 19 ° 18.94 ´E | 117 | SL | 12.0 | 10.7 | | | X | | X | |

Since 1995, particular attention was paid to core location IOW#20048 in the NE corner of the Eastern Gotland Basin, where muds of the Littorina stage were found to be thickest and the sedimentary record was considered to be most complete and encompassed all Baltic Sea stages. At this station, a 30cm x 30cm kasten corer (IOW#20048-1) and a gravity corer (IOW#20048-4), each recovering approximately 10 m of sediment, have been recovered. The sedimentary sequences in both cores are not exactly the same, probably because of different coring efficiency of the two techniques. We used magnetic susceptibility records (core IOW#20048-1 was analysed by T. Saarinen, pers. comm. 1995) of both cores for correlation; the proposed correlation scheme is tabulated in the CD ROM folder for that location. Two contributions describe geochemical and floral indicators of variations in the Baltic Sea environment since the ice lake stage based on these cores: KOHLY (this volume) analysed diatoms and presents his preliminary data in tabulated form. SCHÖNER et al. (this volume) describe first results of organic geochemical reconstructions of temperature and salinity using long-chain ketones produced by certain algae.

## Outlook

A primary goal of GOBEX was to bring scientists together who have an interest in interdisciplinary studies of the Baltic Sea. Field studies and collaboration after the expeditions have been stimulating and fruitful. A practical result of the pilot study was the formation of an international consortium of geologists, biologists, and geochemists as Subgroup 7 of the Baltic Sea System Study (BASYS) dedicated to studying the paleo-environment based on the study of deep basin sediments. In this research project, which is funded by the European Commission under the Marine Science and Technology Program, other sedimentary basins are currently under investigation with the aim of reconstructing environmental fluctuations in the entire Baltic Sea.

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## 2. Inventory and Description of Sediment Cores taken during GOBEX

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**Methods:**

Four different tools were used to obtain sediment samples during the GOBEX expeditions: The Niemistö-Lot, a short gravity corer with a plastic tube of 8 cm diameter and 50 cm length, was used to obtain samples to log physical properties of surface sediments.

A multicorer (MUC), which provides up to eight sediment cores from an area of 1.5 $m^2$ to a depth of 45 cm and ideally recovers bottom water, was used to sample surface sediments for high-resolution studies. Several of these sub-cores were sliced in 1 cm thick discs on board and either stored frozen for shorebased analyses, or centrifuged to obtain porewater samples. Other subcores were left intact for dating (CHRISTIANSEN and KUNZENDORF, this volume).

Table 1: Core locations and status of analyses of GOBEX multicores.

| IOW # | Cruise | Latitude | Longitude | WD | Dated | Isotopes | Chemistry | Other |
|---|---|---|---|---|---|---|---|---|
| 20000-7 | A.v.Humboldt | 57 ° 15.17 ´N | 20 ° 33.64 ´E | 112 | X | X | X | Pore waters |
| 20001-5 | Aug 94 | 57 ° 18.33 ´N | 20 ° 03.00 ´E | 243 | X | X | X | |
| 20003-6 | | 57 ° 17.53 ´N | 20 ° 17.69 ´E | 196 | | | | |
| 20004-1 | | 57 ° 18.28 ´N | 20 ° 13.66 ´E | 236 | X | | X | Pore waters |
| 20005-1 | | 57 ° 17.49 ´N | 20 ° 19.57 ´E | 188 | | | | |
| 20007-1/-2 | | 57 ° 23.14 ´N | 20 ° 15.60 ´E | 225 | X | X | X | |
| 20008-3/-4 | | 57 ° 27.60 ´N | 21 ° 09.60 ´E | 68 | X | | X | Pore waters |
| 20009-2 | | 57 ° 29.04 ´N | 21 ° 15.52 ´E | 60 | | | | |
| 20030-1 | | 57 ° 12.48 ´N | 20 ° 36.52 ´E | 106 | X | | | |
| 20053-1 | POSEIDON Feb 95 | 57 ° 23.14 ´N | 20 ° 15.51 ´E | 241 | | | | |
| 201301-4 | POSEIDON | 57 ° 20.10 ´N | 19 ° 57.500 ´E | 237 | X | | | |
| 201302-6 | Feb 96 | 57 ° 15.28 ´N | 20 ° 11.830 ´E | 249 | X | | | |
| 201303-1 | | 57 ° 11.09 ´N | 19 ° 55.680 ´E | 237 | X | | | |
| 201308-2 | | 54 ° 49.87 ´N | 19 ° 18.940 ´E | 117 | X | | X | Gdansk Basin |

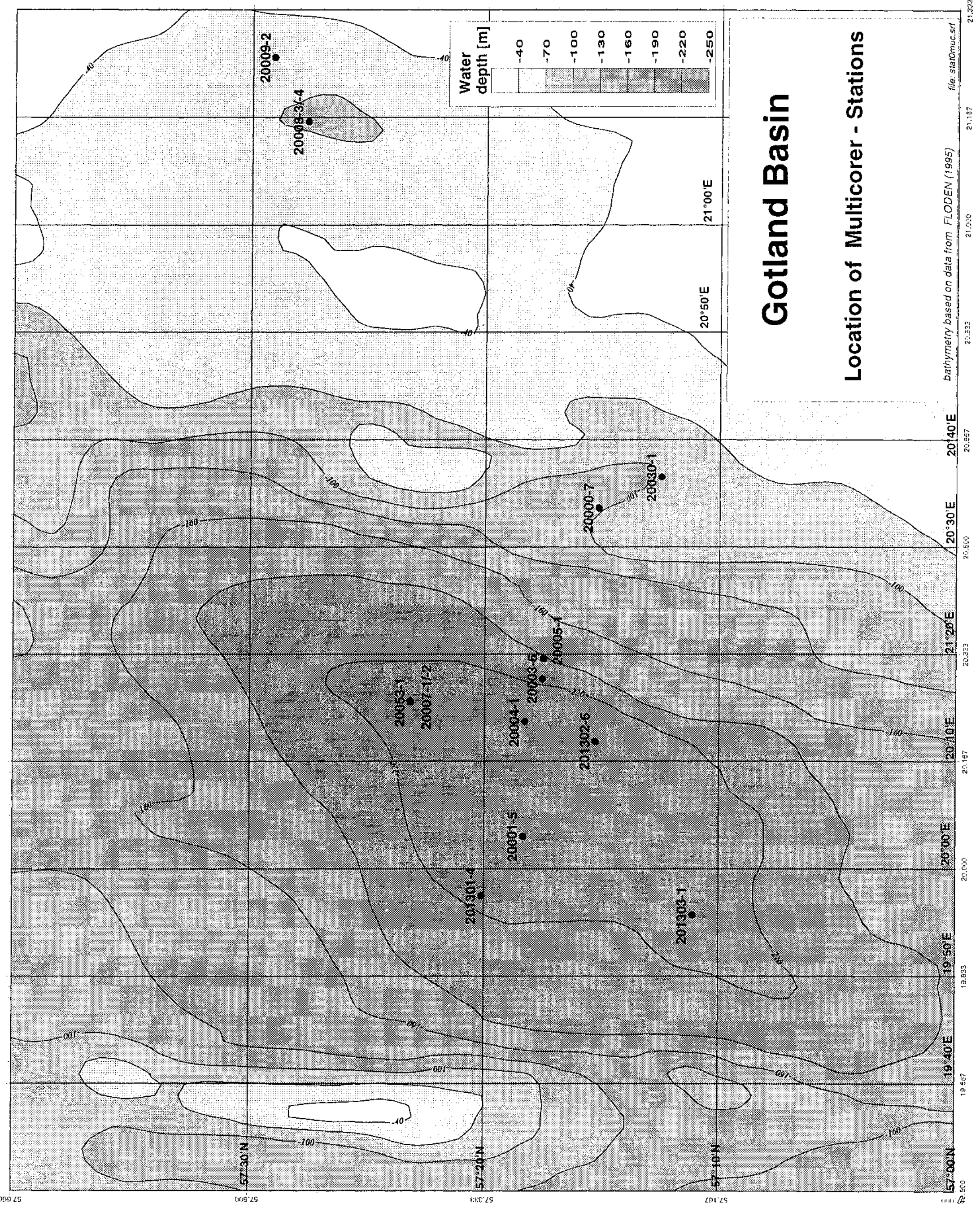


Figure 1: Location of multicores obtained during GOBEX on the map of ENDLER and FLODÉN (this volume).

A gravity corer (Schwerelot, SL) with an inner plastic liner and a top weight of 1200 kg to 850 kg. A maximum length of 10 m sediment was recovered with this weight, which was found to be sufficient for penetrating the soft sediment of the Gotland Basin. The liners were cut into sections of 1 m length, capped, and stored for shorebased logging and digital imaging (see MEYER, this volume; ENDLER, this volume). After cutting the cores in the shorebased laboratory, the 1-m-sections were described after visual examination and logged using the software Applecore. The logs are given in the on the CD ROM in the folder for the respective cores in pict-format..

A Kastenlot (KL) of 15x15cm or 30x30cm diameter and variable length, weighted by 1200 to 3500 kg of lead. The longest core recovered was 1070 cm. These cores were opened on board. In some cases, slabs and u-channels were taken over the entire length for x-ray photography (STRUCK and REHDER, this volume) and magnetic measurements, and the cores were described after visual examination. In addition, discrete samples were taken for porewater and sediment analyses.

Tables 1 and 2 give locations of multicorer stations and long sediment cores obtained during the GOBEX expedition. Figures 1 and 2 show these sampling stations in relation to seismic lines that have been obtained. Also indicated in Tables 1 and 2 are the types of data that have been obtained in shorebased studies and that are, in part, archived in this volume under the appropriate chapters.

Table 2: Core locations and status of analyses of GOBEX gravity cores and kasten cores.

| IOW # | Expedition | Latitude | Longitude | WD | Type | Penetration | Recovered | Description | X-ray | MSCL | Scans | PP | Carbon |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20001-6 | A.v.Humboldt | 57 ° 18.33 N | 20 ° 03.00 ´E | 243 | SL | 6.4 | 5.8 | X | X | | | | |
| 20002-1 | Aug 94 | 57 ° 18.04 N | 20 ° 14.02 ´E | 236 | SL | 6.5 | 5.6 | X | | X | X | | |
| 20007-3 | | 57 ° 23.14 N | 20 ° 15.60 ´E | 225 | SL-F | 6.5 | 2.4 | X | | | | | |
| 20007-4 | | 57 ° 23.19 N | 20 ° 15.50 ´E | 225 | SL | 6.5 | 5.8 | | | X | X | | |
| 20008-10 | | 57 ° 27.60 N | 21 ° 09.62 ´E | 68 | SL-F | 6.5 | 3.8 | X | | | | | |
| 20030-2 | | 57 ° 12.52 N | 20 ° 36.91 ´E | 106 | SL-F | 6.5 | 5.7 | X | | | | | |
| 20030-3 | | 57 ° 12.41 N | 20 ° 36.56 ´E | 106 | SL | 6.5 | 5.8 | | | X | X | | |
| 20031-1 | | 57 ° 17.40 N | 20 ° 20.06 ´E | 190 | | 6.5 | 5.7 | X | | | | | |
| 20048-1 | POSEIDON | 57 ° 23.14 N | 20 ° 15.51 ´E | 241 | KL | 11.0 | 10.4 | X | X | | | | |
| 20048-4 | Feb 95 | 57 ° 23.14 N | 20 ° 15.51 ´E | 241 | SL | 12.0 | 10.4 | X | | X | X | X | X |
| 20049-1 | | 57 ° 17.41 N | 20 ° 20.01 ´E | 197 | SL | 10.0 | 8.5 | | | | | | |
| 20050-1 | | 57 ° 18.76 N | 20 ° 08.53 ´E | 252 | SL | 12.0 | 10.0 | X | | X | X | | |
| 20051-1 | | 57 ° 20.27 N | 19 ° 56.69 ´E | 239 | SL | 11.5 | 10.0 | X | | X | | | |
| 20052-1 | | 57 ° 21.47 N | 19 ° 46.63 ´E | 197 | SL | 11.0 | 10.0 | | | | | | |
| 201301-5 | POSEIDON | 57 ° 20.10 N | 19 ° 57.50 ´E | 237 | KL | 12.0 | 10.70 | | X | | | | |
| 201302-5 | Feb 96 | 57 ° 15.14 N | 20 ° 11.99 ´E | 249 | KL | 12.0 | 7.00 | | X | | | | |
| 201304-1 | | 57 ° 11.14 N | 19 ° 55.69 ´E | 241 | SL | 12.0 | 10.1 | | | X | X | | |
| 201305-3 | | 57 ° 15.08 N | 20 ° 11.84 ´E | 248 | SL | 12.0 | 9.0 | X | | X | X | | |
| 201306-1 | | 57 ° 22.66 N | 20 ° 17.85 ´E | 235 | SL | 12.0 | 9.0 | X | | X | X | | |
| 201307-1 | | 57 ° 00.00 N | 19 ° 26.99 ´E | 182 | SL | 12.0 | 10.0 | | | X | | | |
| 201308-1 | | 54 ° 49.87 N | 19 ° 18.94 ´E | 117 | SL | 12.0 | 10.7 | | | X | | X | |

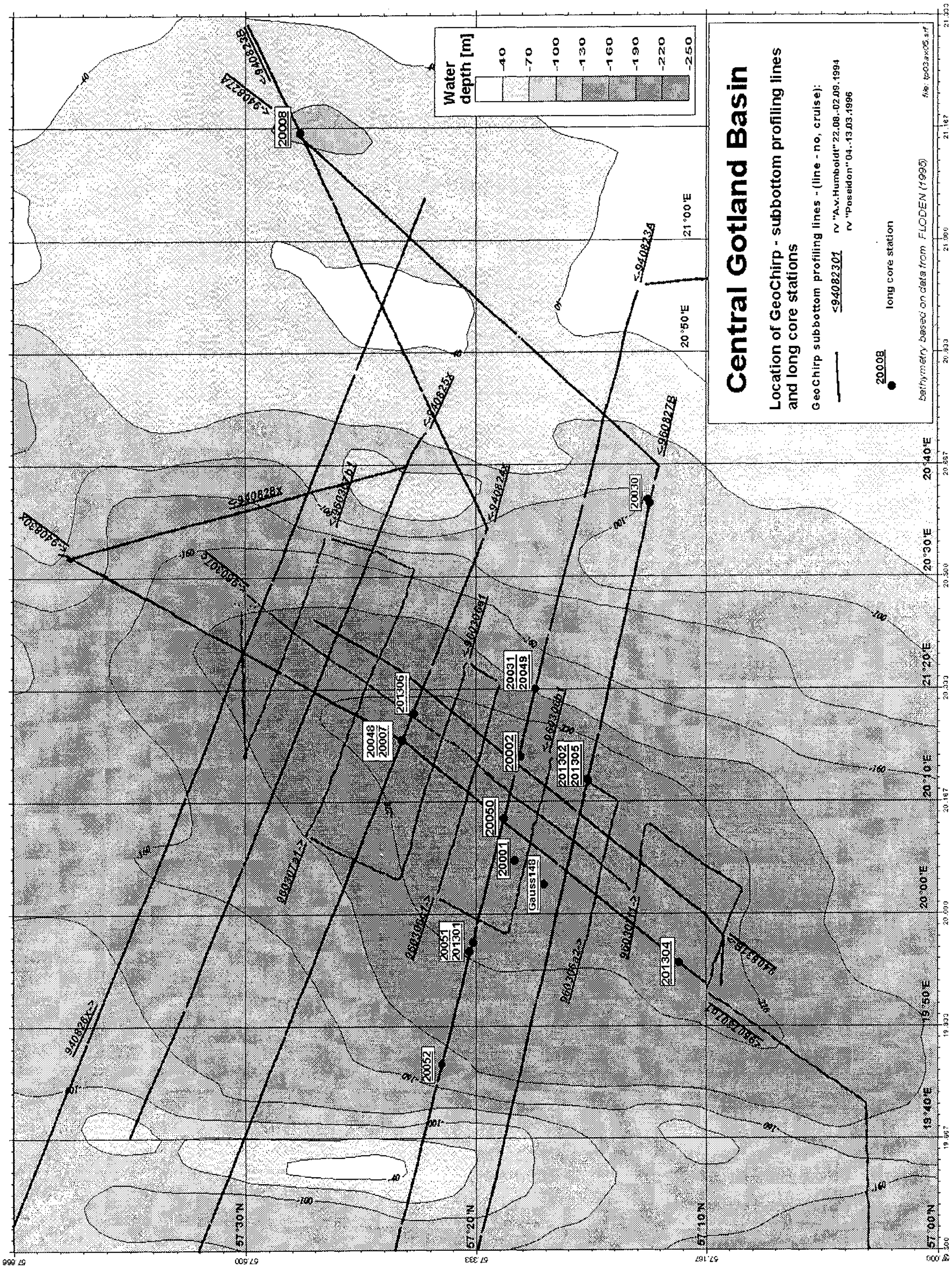


Figure 2: Location of gravity and kasten cores obtained during GOBEX on the track map of ENDLER and FLODÉN (this volume).

# 3. Bathymetry

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The Gotland Basin, located in the Central Baltic, east of Gotland, is the largest basin in the Baltic Sea (Figure 1). It consists of several depressions separated by sills. The GOBEX activity was focused on Gotland Deep, east of Klints Bank (marked as rectangle in Figure 1). Figure 2 shows the generalized bathymety of the GOBEX working area. The map is based on digital water depth data from FLODÉN (1995). Different grids and bathymetric maps were created using the PC – program SURFER™. Water depth data were smoothed in order to highlight the main morphological features. As depicted in Figure 2 the Gotland Deep extends to SW in two basins (western and eastern Gotland Depression according separated by the Klints Bank and its southward continuation.

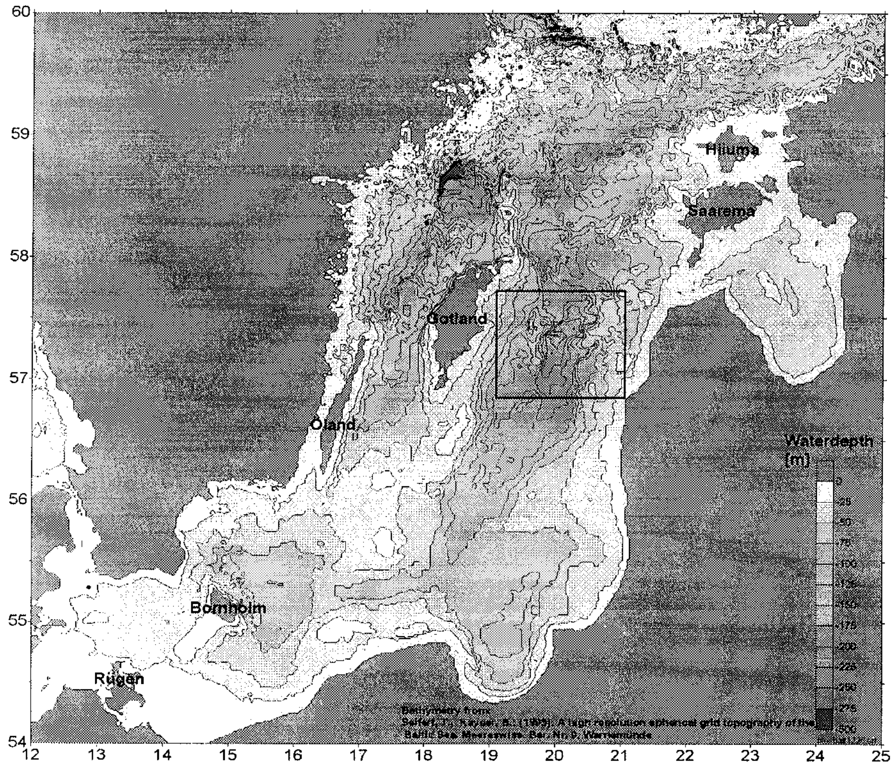


Figure 1: General Bathymetry of the Baltic Sea - Location of the GOBEX working area

Acoustic subbottom profiling were performed during two cruises with RV "A.v.Humboldt" 22.08.-02.09.1994 and RV"Poseidon" 04.03.-13.03.1996 using a GeoChirp profiler. The tracks are marked as dotted lines in Figure 2. Using these water depth data a more detailed bathymetric map of the Gotland deep was created (Figure 3). CTD – measurements (Figure 4) giving a mean sound velocity of the water column of about 1440 m/s were used for acoustic traveltime-to-depth conversion causing an error of less than 0.5 m. The acoustic transducers of the GeoChirp were housed in a towed fish. Its towing depth was estimated from the traveltime of the ghost reflection from the water surface. Special attention was paid to the detection of the very weak acoustic reflections of the soft sea bottom surface in the central part of the Gotland Deep. In summary the error of the GeoChirp water depth data (dotted lines in Figure 3) is about +/- 0.8 m. Because of the limited density of the available water depth data, small-scale morphological features (e.g. channels, ridges) in the depth profiles were smoothed during the gridding process and do not appear in the bathymetric map (Figure 3). For mapping of small scale morphological details more densely spaced echosounding profiles are needed.

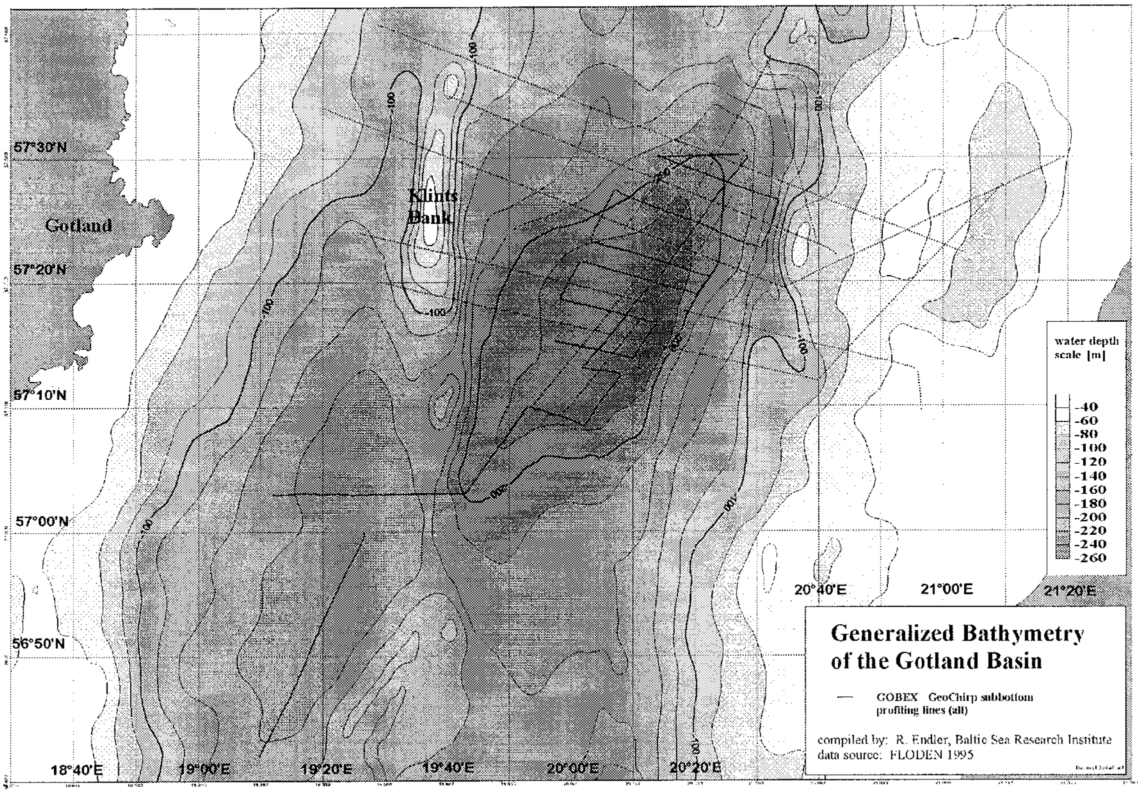


Figure 2: General bathymetry of the Central Gotland Basin and location of the subbottom profiling lines

The 2m - depth contours in Figure 3 show the asymmetric, SW – NE prolonged shape of the Gotland Deep. The rather flat central part with water depths from -240 m to -244 m is bordered to the SE by a steep slope. To the NE-, to the N-, and to the NW-directions, the slope of the sea bottom is more gentle. To the SW, the Gotland Deep continues to the "eastern Gotland Depression" ( GELUMBAUSKAITE and GRIGELIS, 1995).

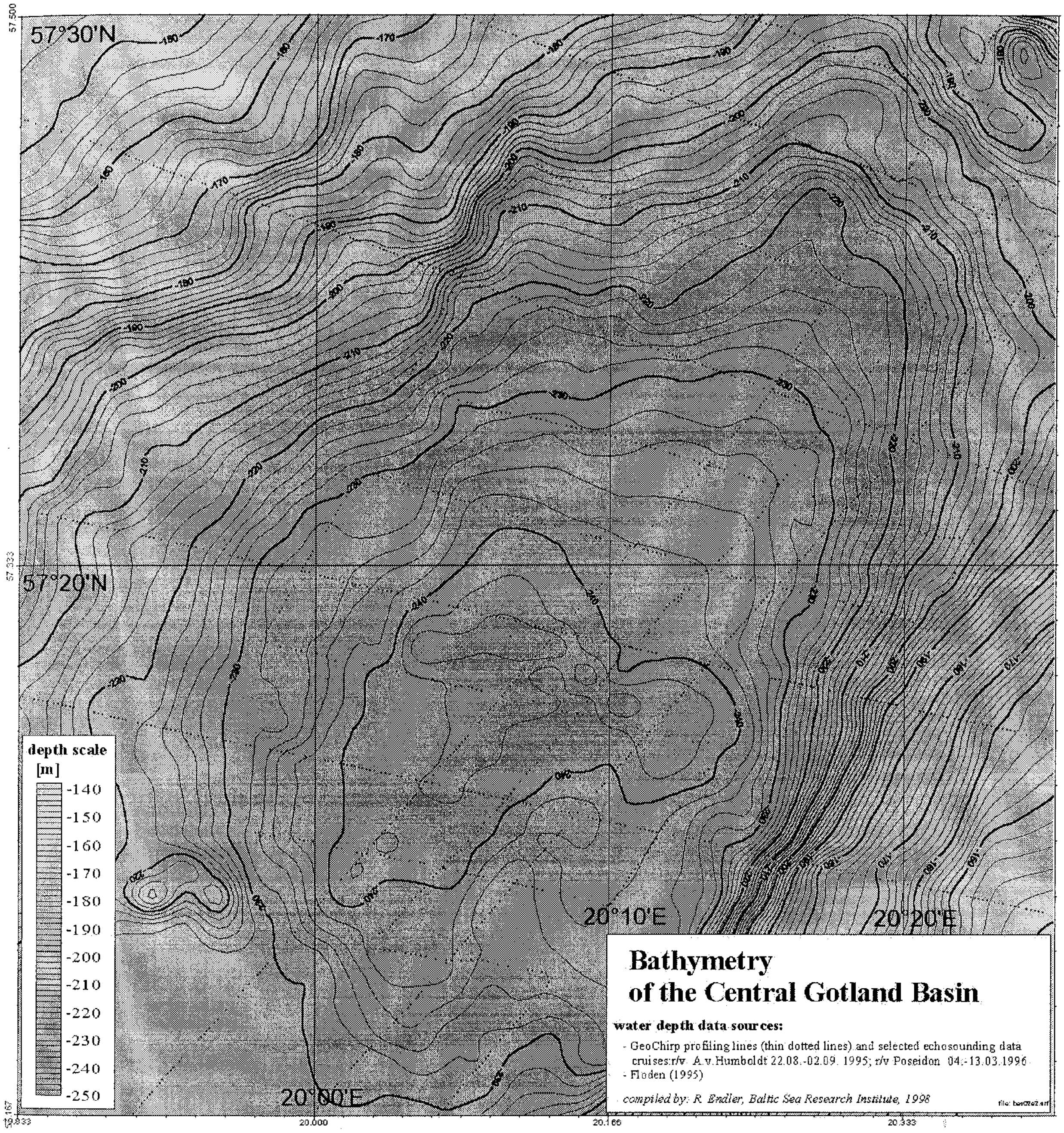


Figure 3: Bathymetry of the Gotland Deep

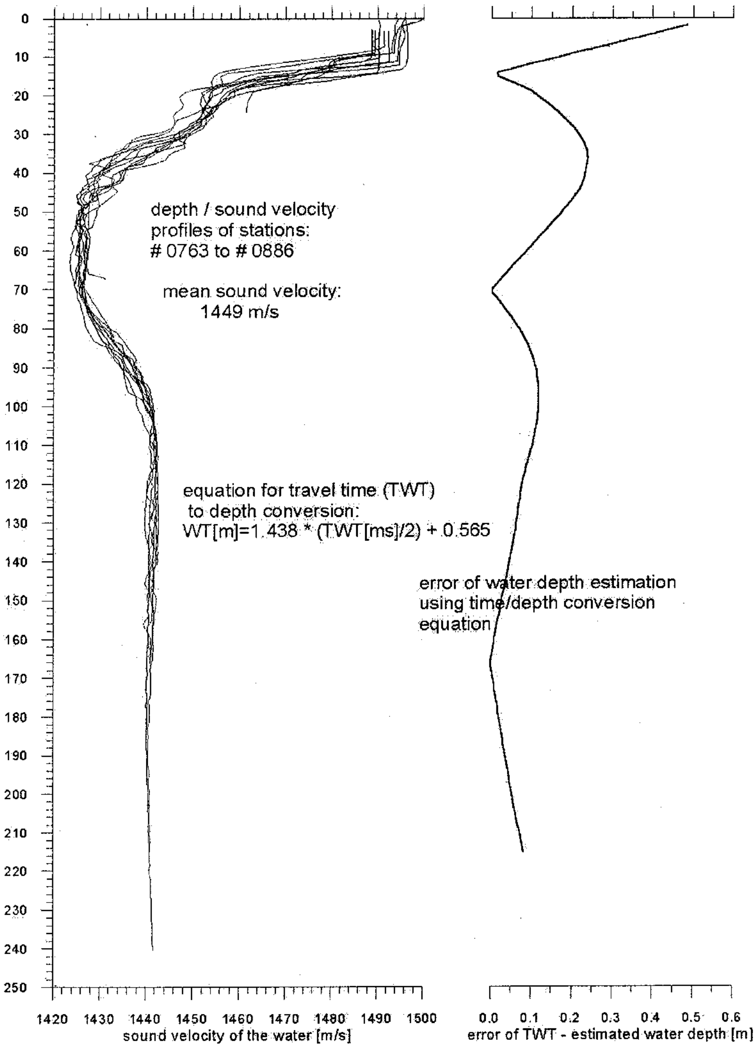


Figure 4: Estimation of sound velocity for traveltime to depth conversion of GeoChirp - data

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# 4. Acoustic Studies

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## Methods

In the frame of the GOBEX activity one expedition with R/V "A.v.Humboldt" (1994) and two with R/V "Poseidon" (1995, 1996) were performed to collect acoustic profiling data and sediment samples (Figure 1). A GeoChirp subbottom profiling system (GeoAcoustics) consisting of the tow fish (transmitter, receiver), the chirp-processor, a Sonar Enhancement System (SES) and a thermo-recorder (Wideline 200/138, Ultra Electronics) was used for acoustic surveys. The bandwidth of the transmitted acoustic pulses was 2 - 8 kHz with a duration of 32 ms. Reflected acoustic signals were received by a ministreamer (which was attached to the end of the tow fish), amplified and sent to the chirp-processor for matched filtering (signal compression). Further onboard processing, online printing and digital storing (SEGY - format, 8 mm ExaByte) were performed with the Sonar Enhancement System. Navigation data were collected from a GPS receiver (Sercel NR51, WGS84). During profiling, the tow fish was towed at a depth of about 20 m (due to limited cable length) and with a speed of about 5 knots. The firing rate was 2 per second giving a firing distance of about 1.3 m (at 5 knots). Depending on the sediment type, a penetration down to 40 m was achieved with a vertical resolution of about 0.3 - 0.5 m. Later on, postprocessing using an extended SeismicUnix - package (COHEN and STOCKWELL, 1994) was performed on an IBM R6000 workstation.

## General morphology

A rough image of the morphology is drawn in Figure 2. The shape of the Gotland Deep is NE-SW elongated, bordered to the West by the steep Klints Bank and to the East by smaller about N-S striking sills. Smaller mud-filled (often gas charged) basins were found at the eastern shoulder of the Gotland Deep. The asymmetric sea bottom relief follows pre-Quaternary structures. Along the longitudinal basin axis the water depth slowly increases from about -140 m in the North to about -240 m (max. -244 m) in the central part. Further to the South the basin is bordered by an elevation of about -230 m. A similar asymmetric sea bottom relief is displayed in the cross section of Figure 3. The sea bottom slowly rises up from the center towards WNW. Towards ESE the deep is bordered by a steep slope.

The bottom of the central Gotland Deep (water depth of about -240 m) consists of very soft mud with a flat surface. It is disturbed in the southern part by an uplifted subbottom structure. The muddy sea floor is slightly depressed in the western and northern parts whereas the

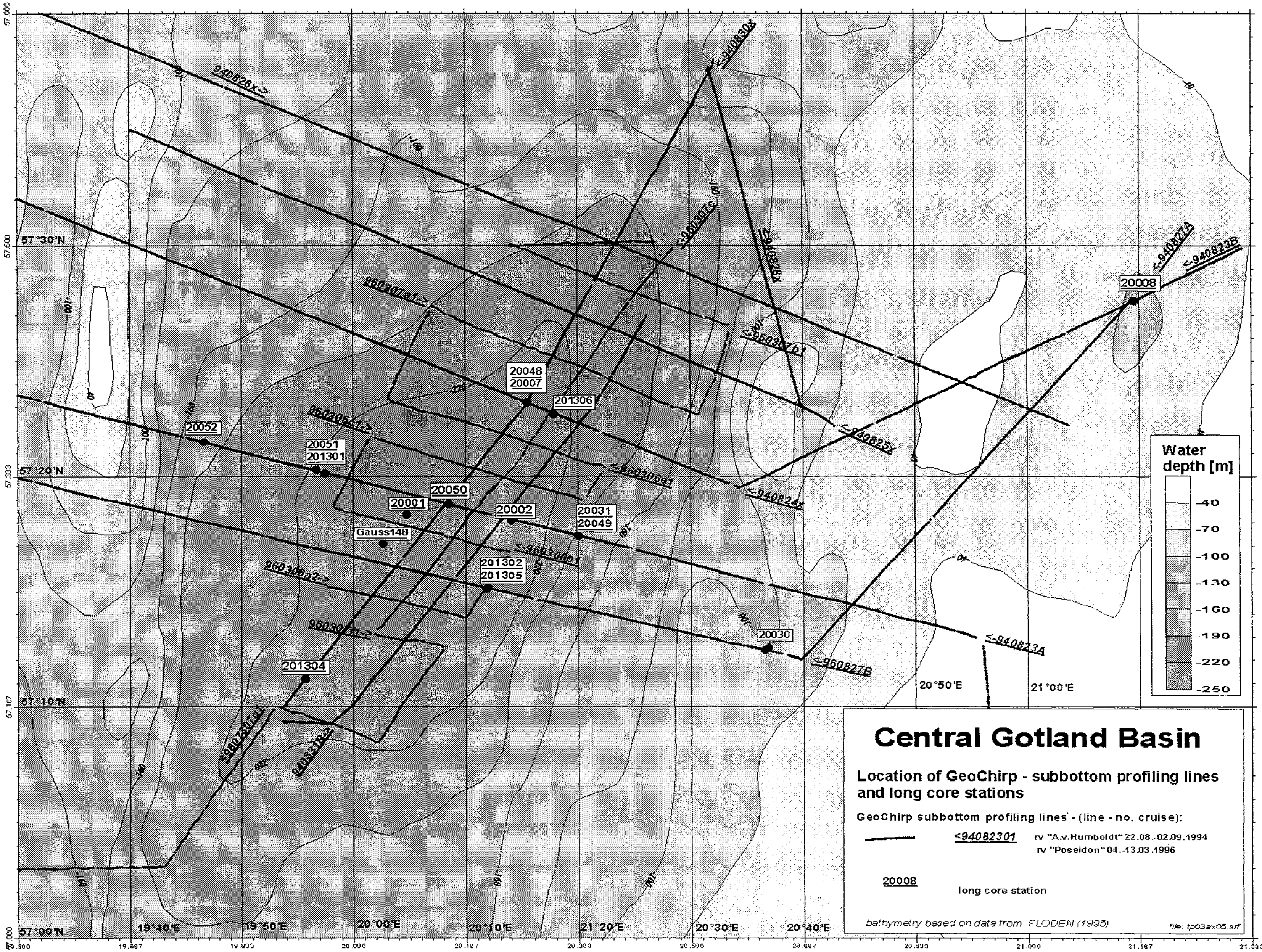


Figure 1: Location of GeoChirp – subbottom profiling lines and long core stations

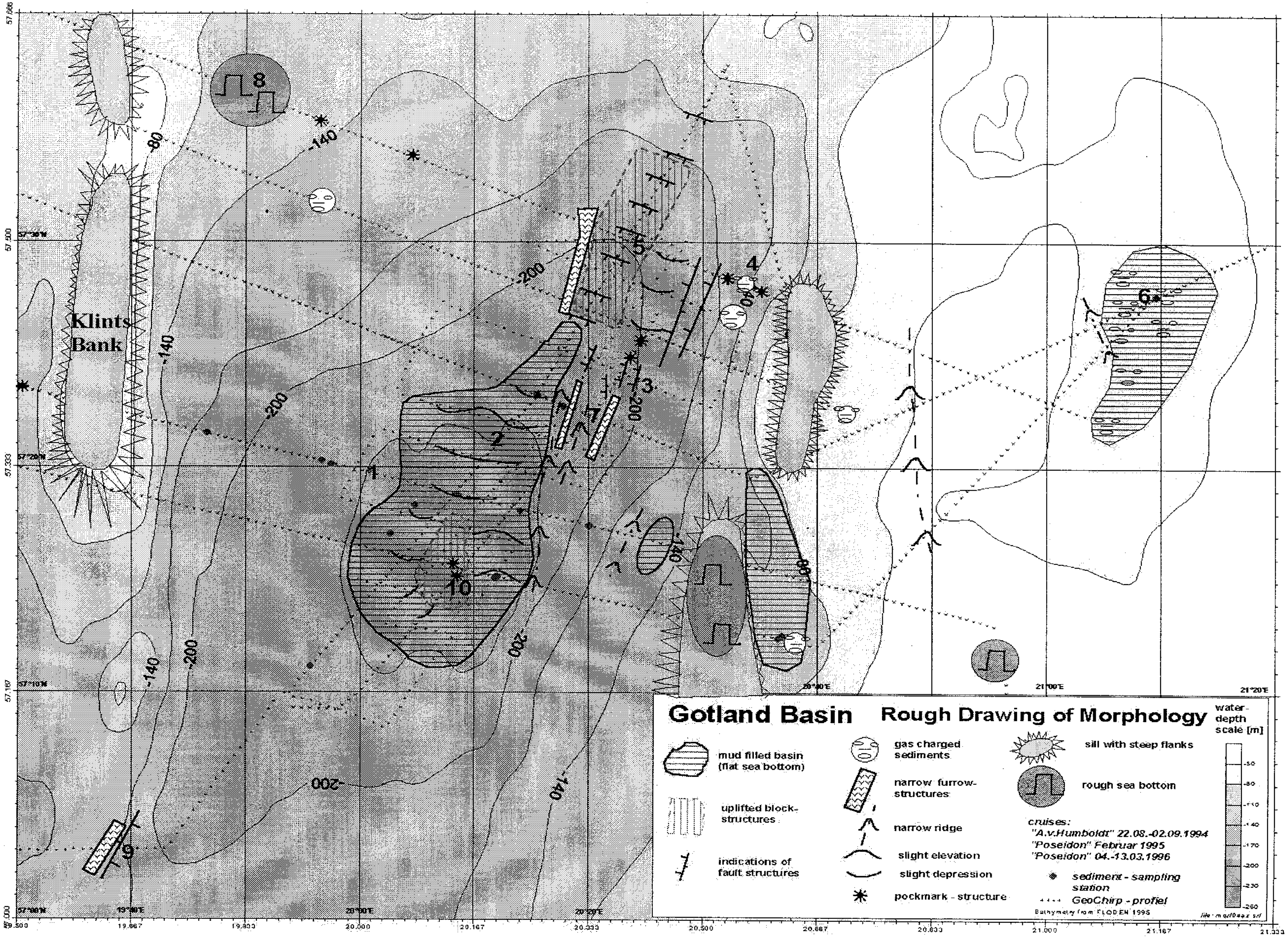


Figure: 2 Rough drawing of Gotland Deep morphology.

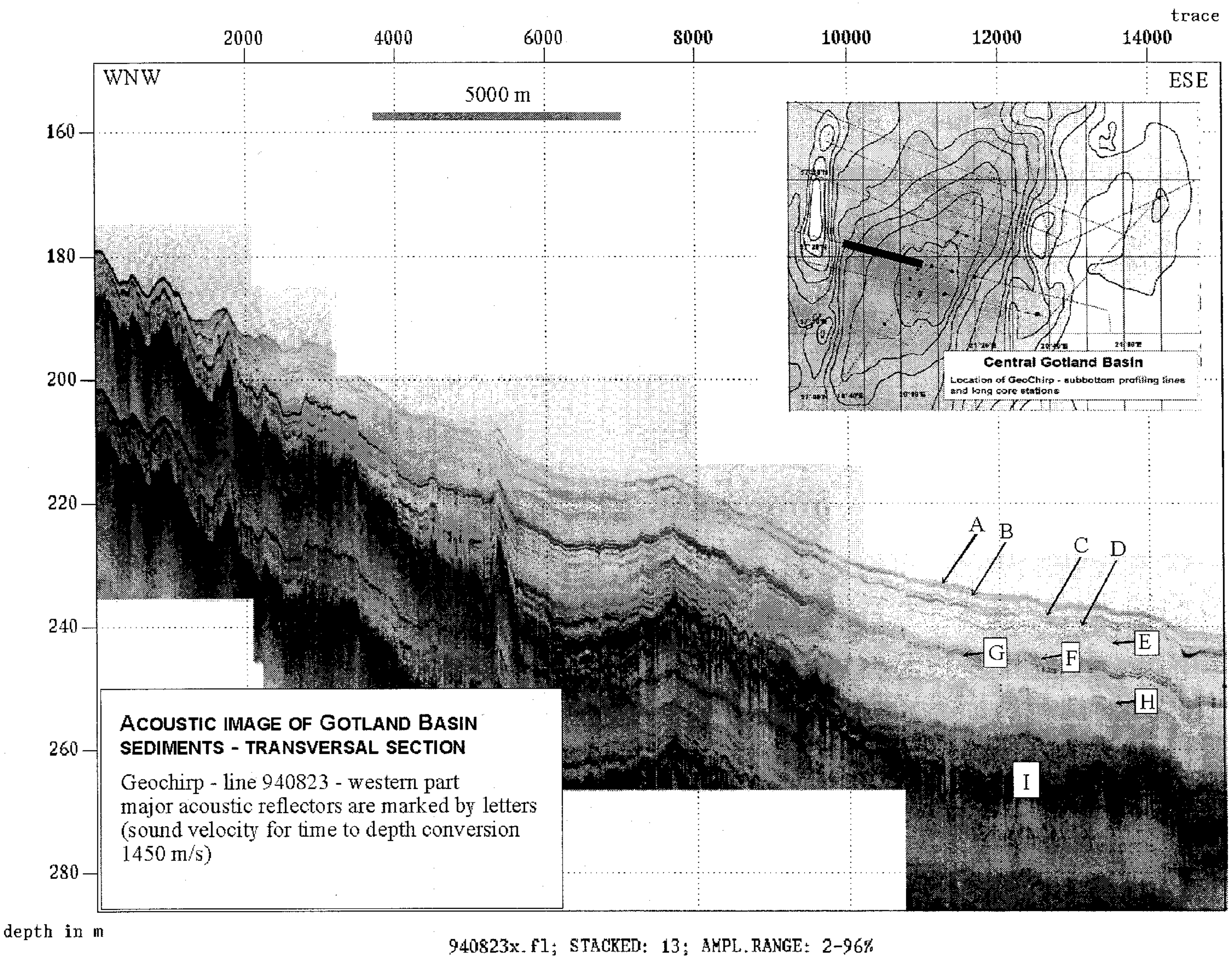


Figure 3a: Acoustic image of layered sediments – Transversal section through the Gotland Deep – western part; thick line in the inserted map indicates the location of the profile.

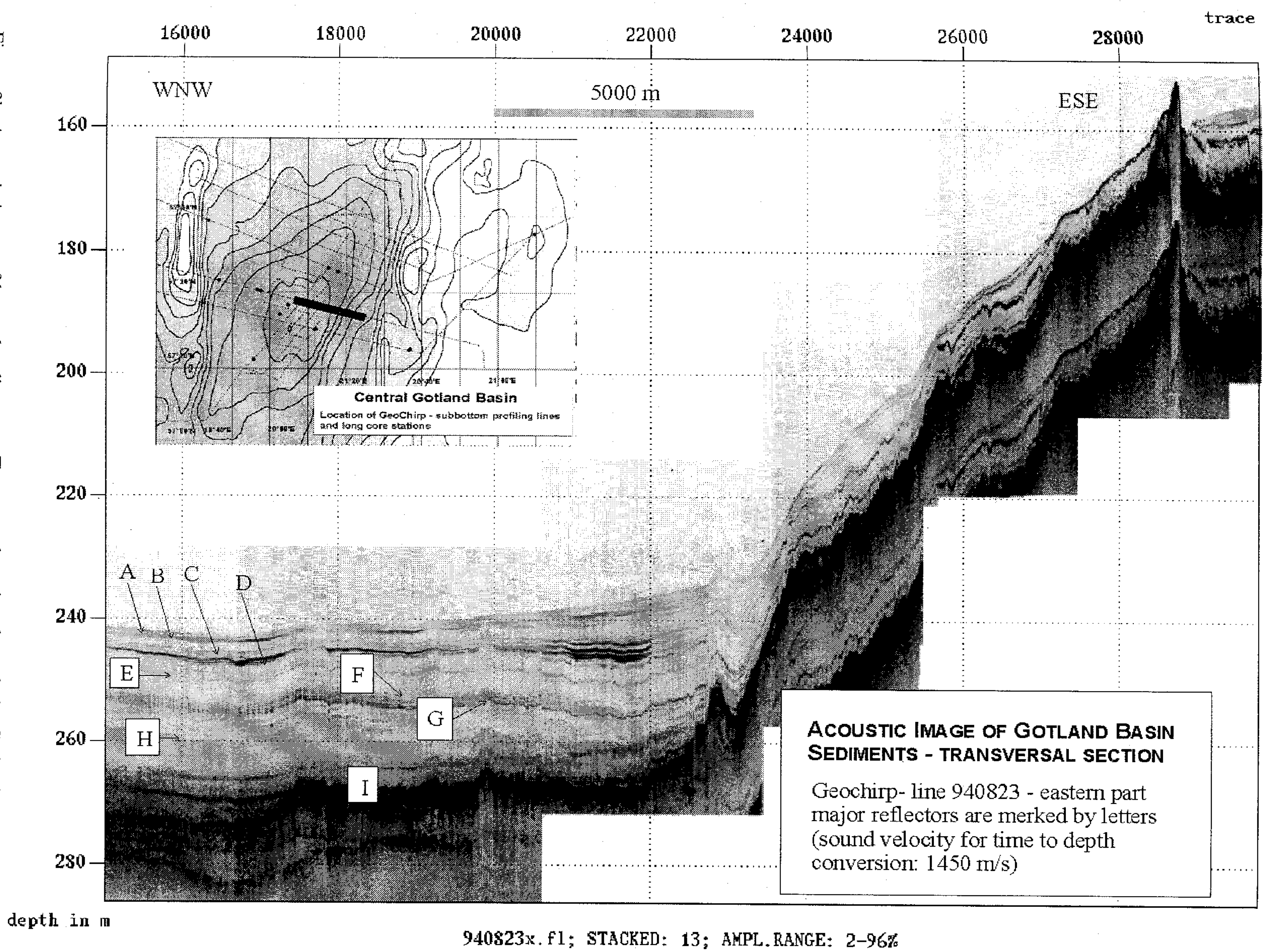


Figure 3b: Acoustic image of layered sediments – Transversal section through the Gotland Deep – eastern part; thick line in the inserted map indicates the location of the profile.

south-eastern part a small elevation occurs bordered to the East by a narrow NNE-SSW striking ridge. Comparing with subbottom profiles those slight elevations and depressions of the modern mud layer can be interpreted as the result of modern sedimentation processes in the deepest parts of the Gotland Basin.

Several morphological and sedimentary structures are marked in Figure 2 by signatures and numbers. Examples of acoustic images will be presented and discussed below.

**Layering of sediments**

The structure of the late glacial and postglacial basin fill (which is well penetrated by the acoustic signals) is reflected in transversal and longitudinal sections in Figure 3 and in Figure 4. In general, sediments are well layered and major acoustic reflector sequences can be traced over long distances in the rather flat and deep (-240 m) central part of the basin. With some exceptions, the acoustic characteristics of these reflectors do not change very much in horizontal direction. This suggests that this region can be considered as a rather uniform area of sedimentation.

Based on the acoustic characteristics, a number of major reflectors was chosen, marked by letters. The letter I marks the very rough surface of the glacial deposits (sand, gravel, till). The next sequence up to reflector D contains the varved clays of the Baltic Ice Lake. The thickness of this sequence is approximately 20 m and is nearly constant over the entire central basin. During that time sedimentation was rapid whithout lateral transport (no near bottom currents). By the acoustic image, the varved clays of the Baltic Ice Lake can be subdivided into several units separated by the reflectors H, G, E. This set of reflectors in the varved clays suggests that the sedimentation during the Baltic Ice Lake was not only influenced by seasonal variations (varves), but also by depositional, possibly climatic changes of longer duration. The sediments below reflector H show an acoustically turbulent image in the very central basin, whereas a band of reflections appear in the more distal regions. A very prominent reflector is G (by the signal strength) which is the lower boundary of a strong reflection sequence. This reflector can be traced over the entire basin. The reflection band is bounded at the upper end by the reflector F. A rather transparent region follows up to reflector E indicating continuous sedimentation during this period. In the intervall between reflectors G and E, black and irregularly distributed dots appear over the entire basin. It is unclear whether these spots are caused by diagenetic processes or local anomalies during sedimentation. Most prominent changes in the acoustic properties occur in the subbottom depth of about 5 m (reflectors D and C) indicating the transition from typical Baltic Ice Lake sedimentation (varved clays) to the younger Littorina environment (transition clays of Yoldia and Ancylus stages according to WINTERHALTER, 1992). The reflector D also marks a change in the sedimentation regime. As a result of strong lateral sediment transport (start of the near bottom circulation), the thickness of the sediments overlying reflector D continuously increases from west towards the steep eastern

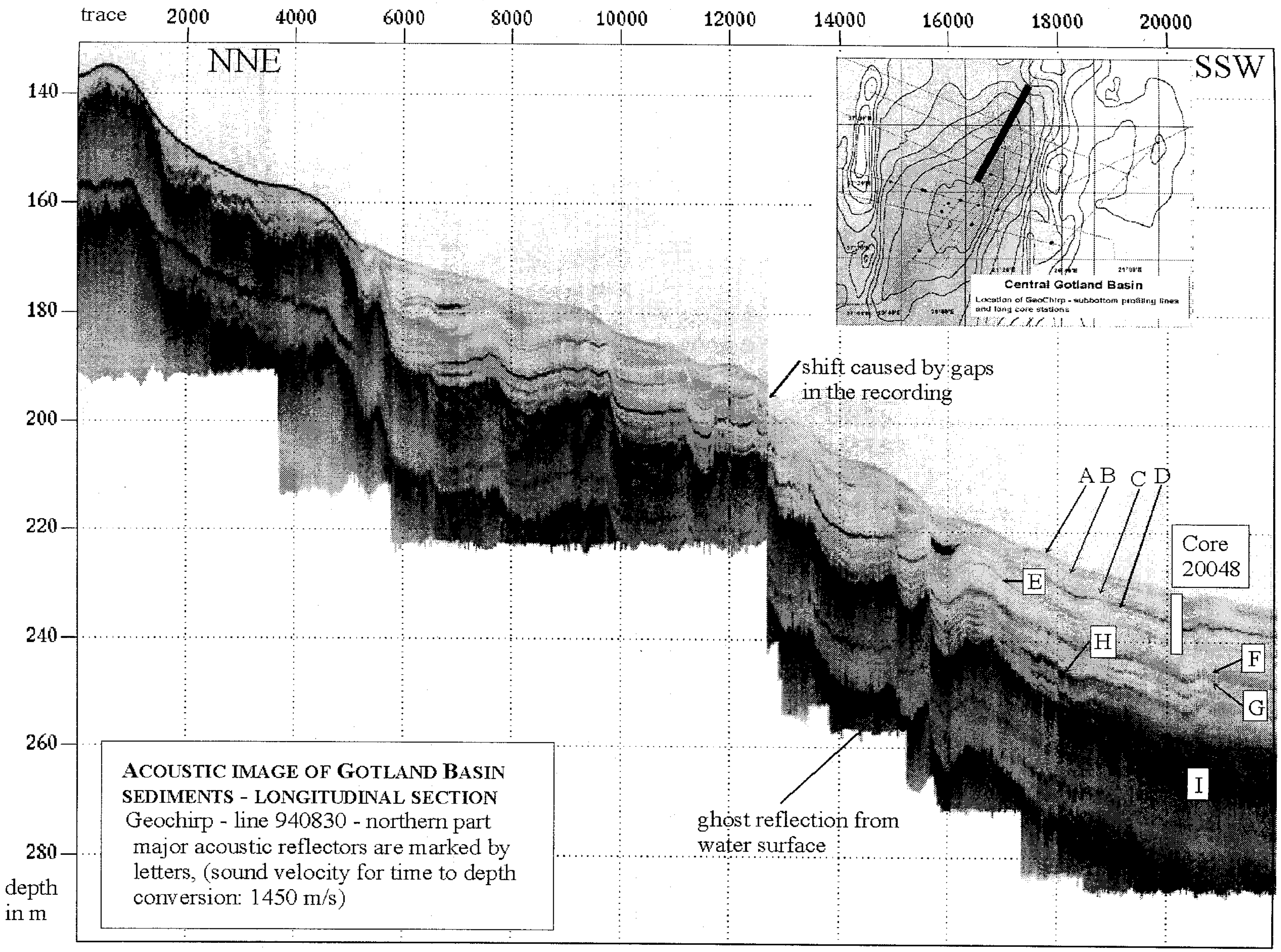


Figure 4a: Acoustic image of layered sediments – Longitudinal section through the Gotland Deep – northern part, thick line in the inserted map indicates the location of the profile.

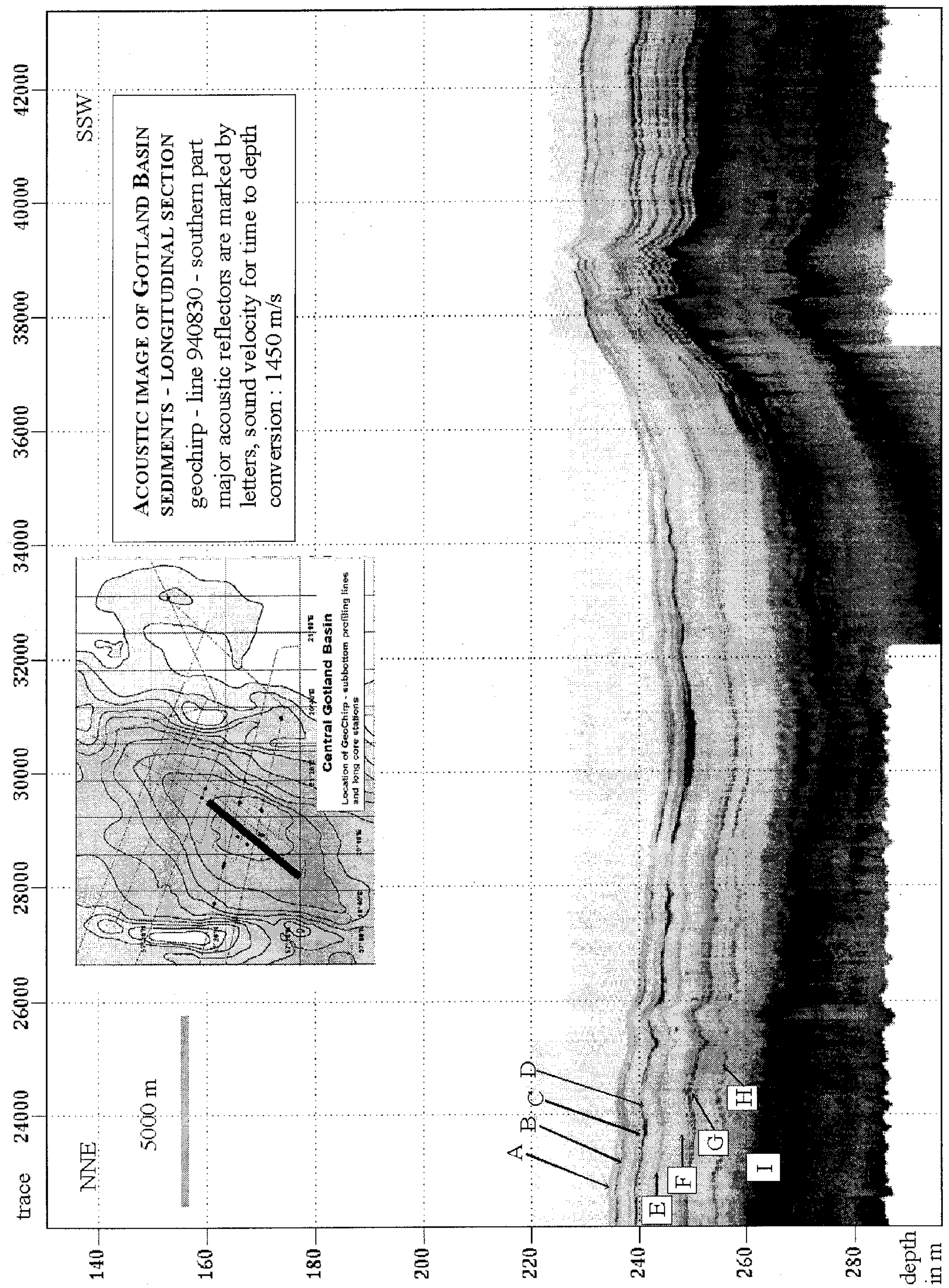


Figure 4b: Acoustic image of layered sediments – Longitudinal section through the Gotland Deep – eastern part; thick line in the inserted map indicates the location of the profile.

slope of the basin (Figure 3). A maximum thickness of about 12 m is reached just at the base of the eastern slope. The uppermost band of reflections bounded by reflectors B and A (surface of the recent mud) shows the transition from well laminated gyttja clays of the Littorina stage to the Recent very soft, black sulfidic mud. Because of the high water content the uppermost mud is easily transported by lateral currents.

### Channels, ridge- and sill-structures, indications of neotectonic movements

Several channel structures were found in the acoustic records. Figure 5 shows a channel crossing the southward extension of Klints Bank connecting the Gotland Deep with a second basin to the west (Western Gotland Depression, GELUMBAUSKAITE and GRIGELIS, 1995). Because of the vertical shift in the layering (about 10 m) the channel structure might be caused by neotectonic movements (e.g. uplifting of the right part). These activities must have taken place at the end of the Baltic Ice Lake stage or later. Later on erosional processes formed the recent shape of the channel and leveled out the sea bottom relief. Similar channel structures but combined with block structures occur at the upper NE slope (no 5 in Figure 5) of the Gotland Deep (Figure 6, Figure 7). Comparing the relief of the sea bottom in NE-SW- direction (Figure 4a, northern part) with the sea bottom profile in WNW-ESE direction (Figure 7), the following conclusions can be drawn: The surface of the moraine deposits has a step-like form in down slope direction. This can be interpreted as an result of coastal erosion (coastal terraces) during different stages of the Baltic Ice Lake (see also Figure 8). In WNW-ESE direction the moraine deposits are of rough, partly blocked structure. This can be the result of erosional processes from strong meltwater currents (filling up the Baltic Ice Lake) during ice retreat. Shifts/disturbances of the layering (see Figure 6) indicate a later influence of neotectonic aktivities (compare Figure 5). The strike of the channels in the NE part of the Gotland deep is about NE – SW, following the subbottom structures. The shape of the channels and cut layers (Figure 6 between trace no 800 – 1000 are the result of erosion by recent local bottom currents entering the Gotland Deep from the northern Gotland Basin.

### Gas charged-sediments

Gas in sediments was found either dispersed in the upper soft sediment layers (Figure 9) and/or as local pockmarks (Figure 10). The soft bottom of the central Gotland Deep is mainly free of gas. Pockmarks were only found in the SW part above an uplifted subbottom block-structure (for location see Figure 2, no 10). This suggests that the source of the (thermogenic) gas is located in the sedimentary bedrock. The occurrence of gas-charged sediments concentrates on the northern and north-eastern slope (Figure 9) as well as local mud filled basins at the shoulders of the Gotland Deep (Figure 11, see Figure 2 for locations). The dispersed gas is concentrated in the upper layers (subbottom depth of about 1 –

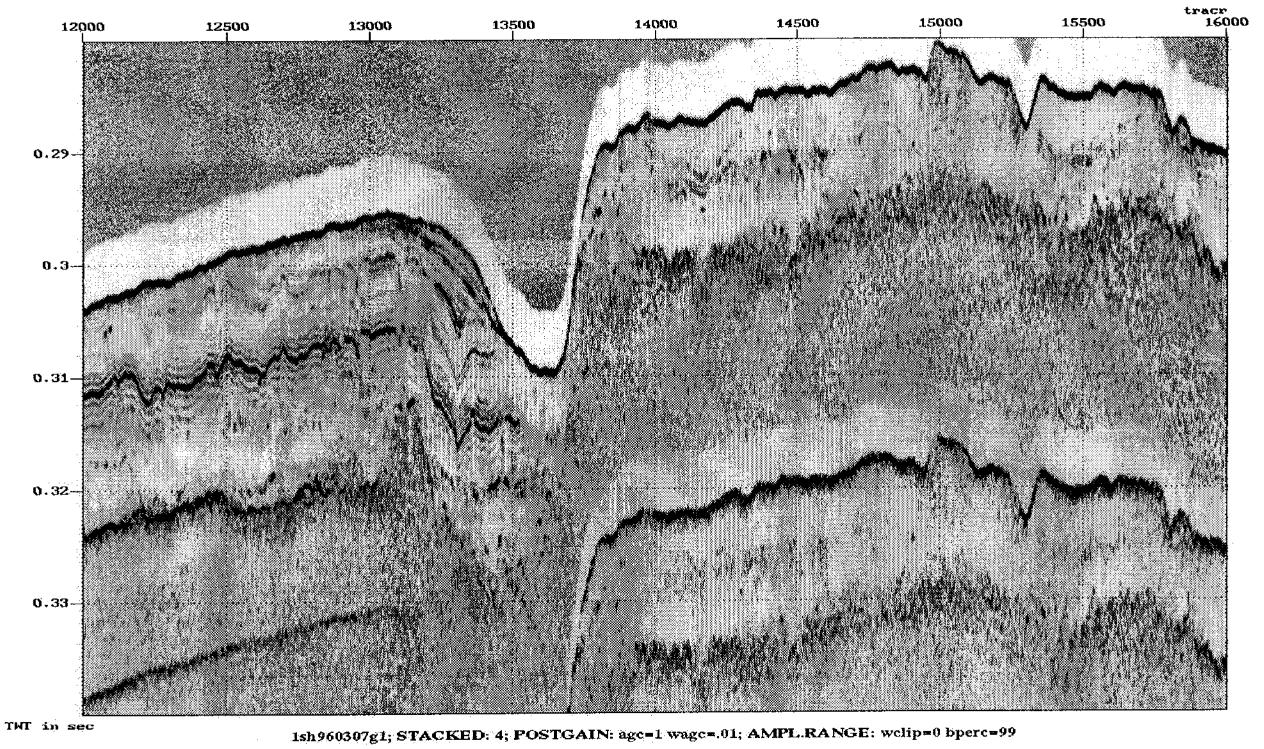


Figure 5: Channel caused by neotectonics – crossing the southwards extension of the Klints Bank, Geochirp – profile 960307g1, from E (left) to W (right), for location see no. 9 in Figure 2.

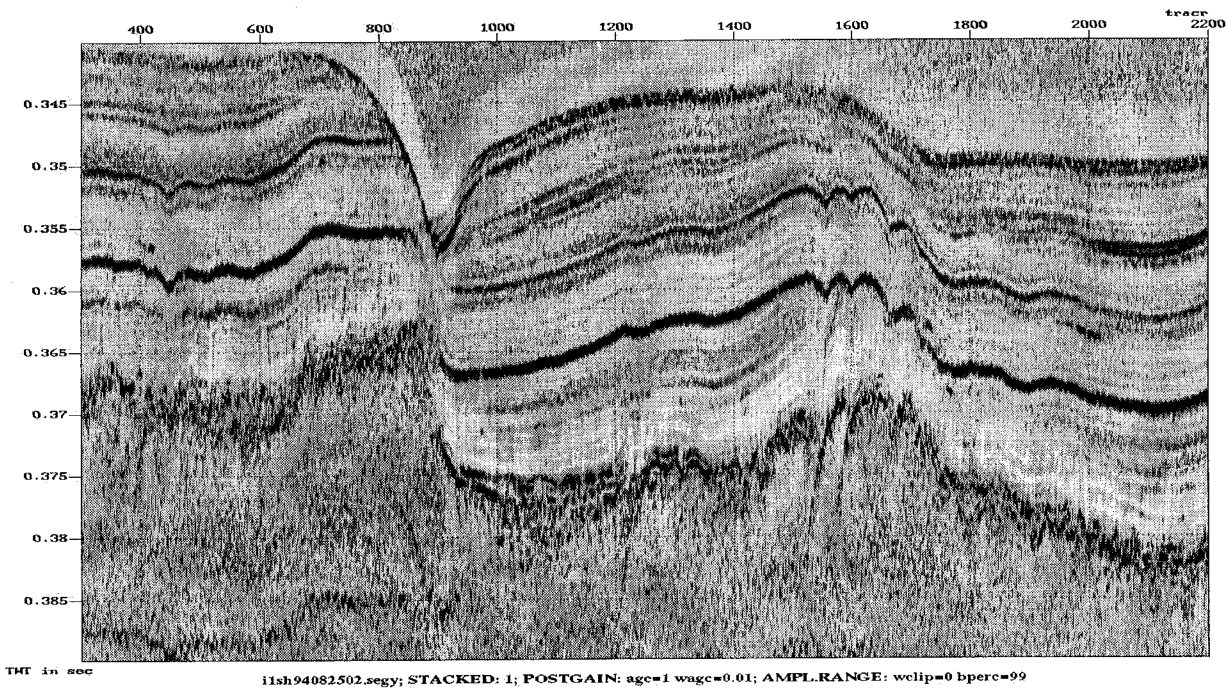


Figure 6: Similar channel-structure as in Figure 5 in the NE-part of the Gotland Deep, GeoChirp – profile 94082502, from ESE (left) to WNW (right).

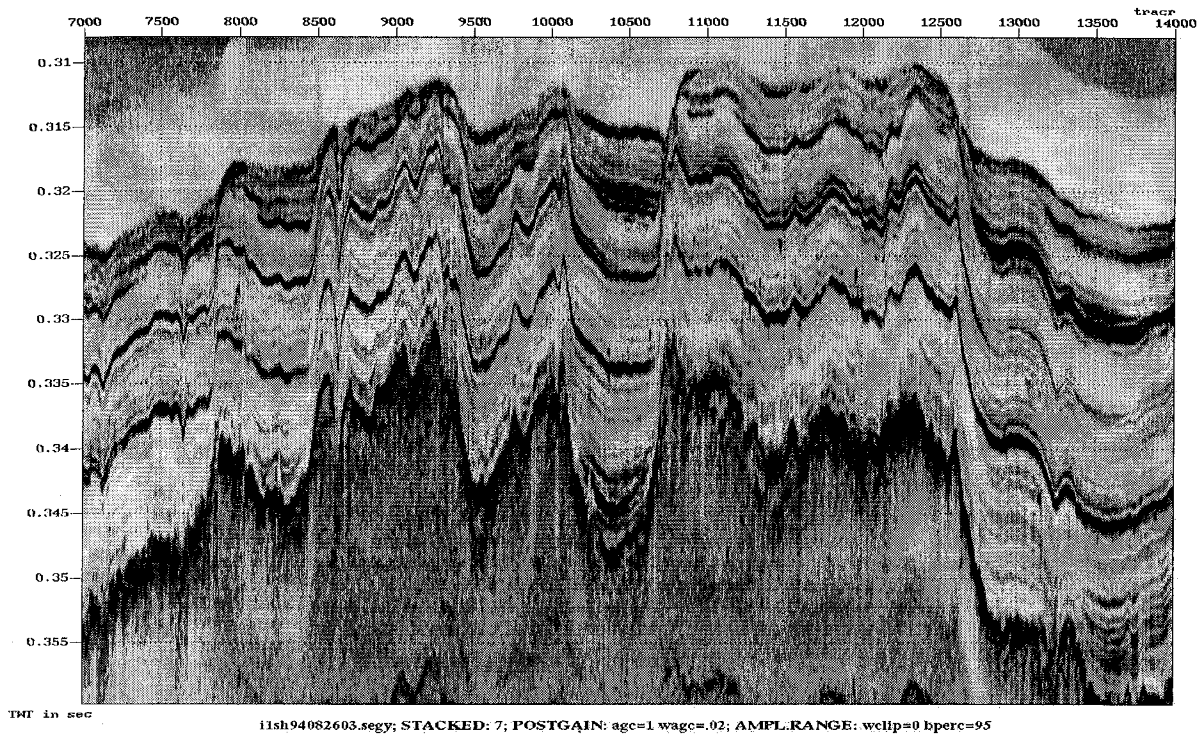


Figure 7: WNW(left)-ESE(right) section through Block – structures with NNE-SSW striking channels in the northern part of the Gotland Deep, GeoChirp-profile 94082603, for location see Figure 2 no. 5.

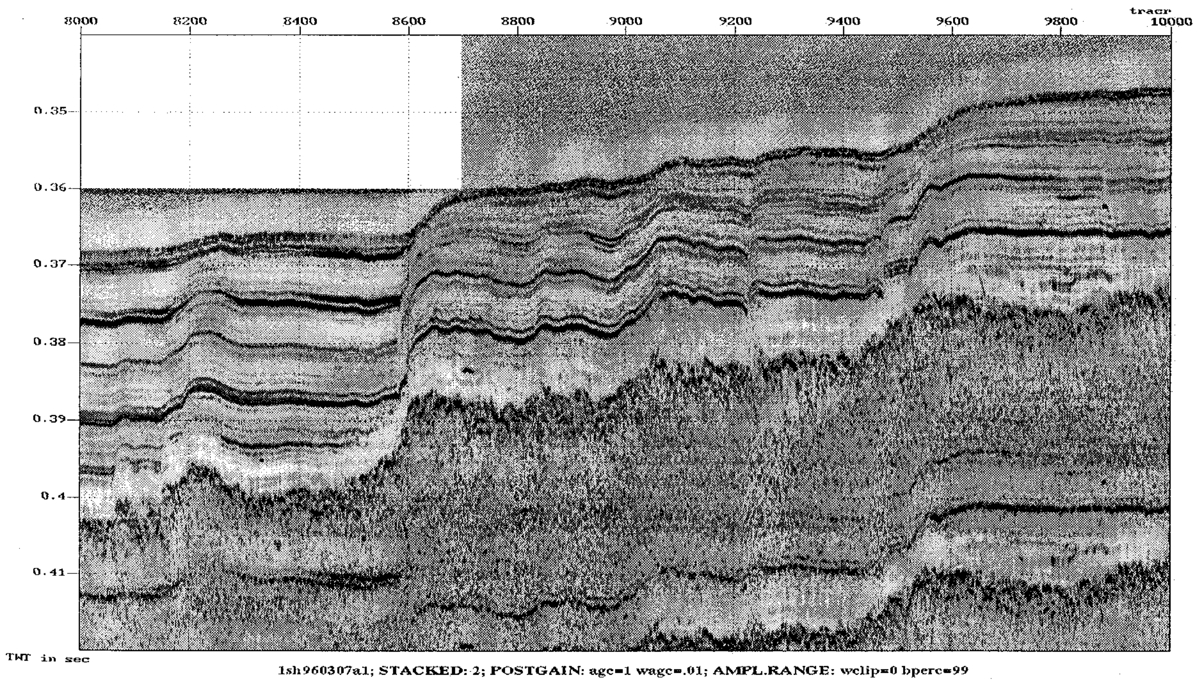


Figure 8: Step-structures at the NE-slope of the Gotland Deep, WNW(left)-ESE(right) striking GeoChirp-profile 960307a1, for location see Fig. 2 no. 3, compare with the NE-part of Line 940830 in Figure 4a.

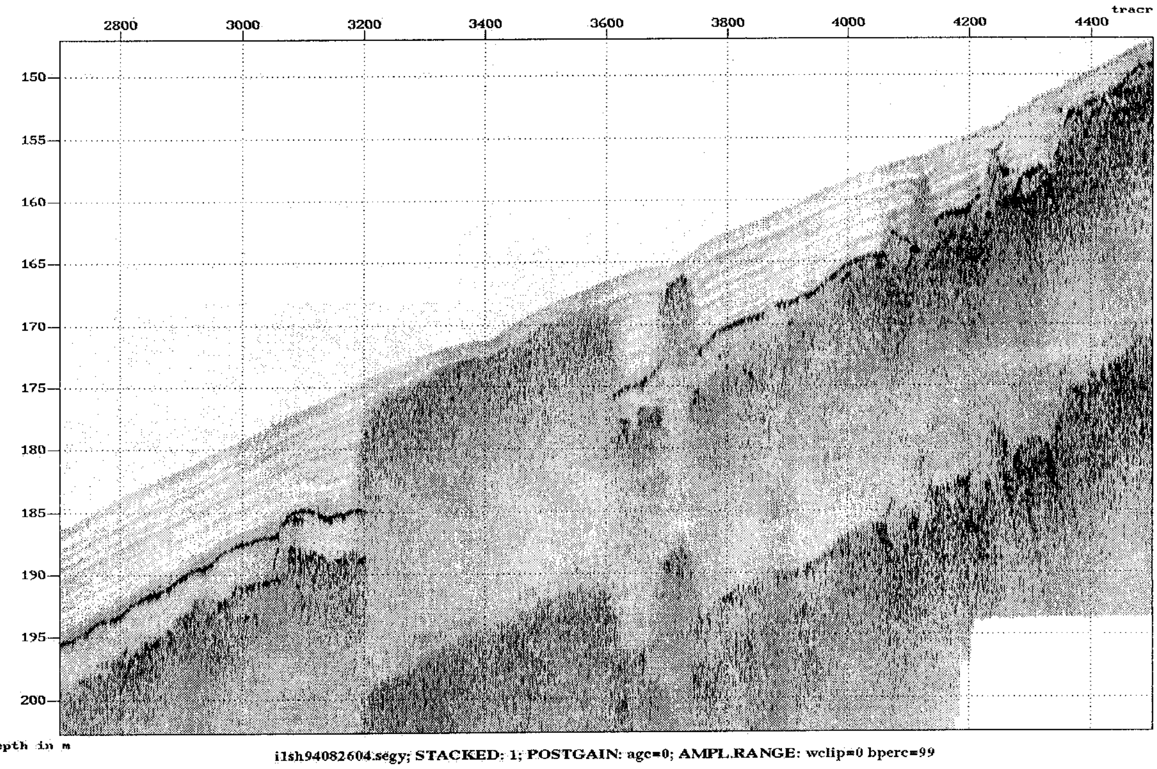


Figure 9: Gas charged sediments at the NE-slope of the Gotland Deep, WNW(left)-ESE(right) striking GeoChirp-profile 94082604, for location see Figure 2 no. 4.

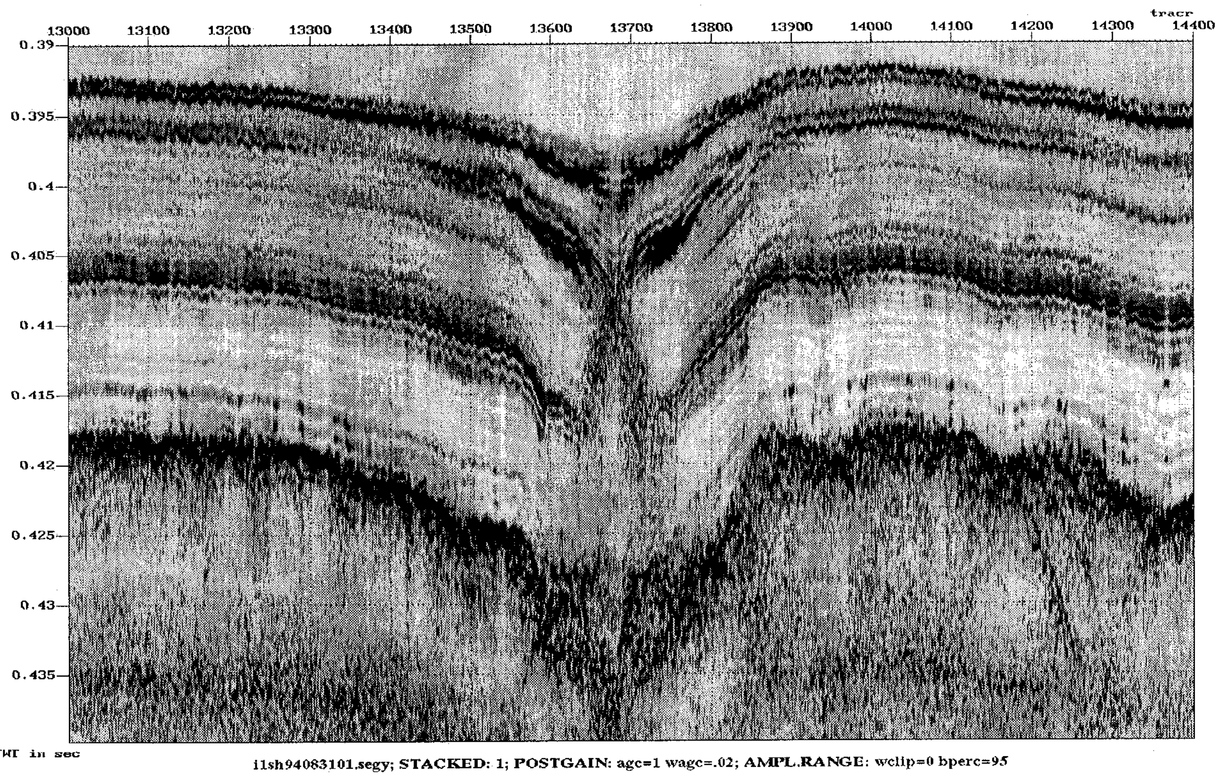


Figure 10: Pockmark-structure in the central part of the Gotland Deep, SSW(left)-NNE(right) striking GeoChirp-profile 94083101, for location see Fig. 2 no. 10.

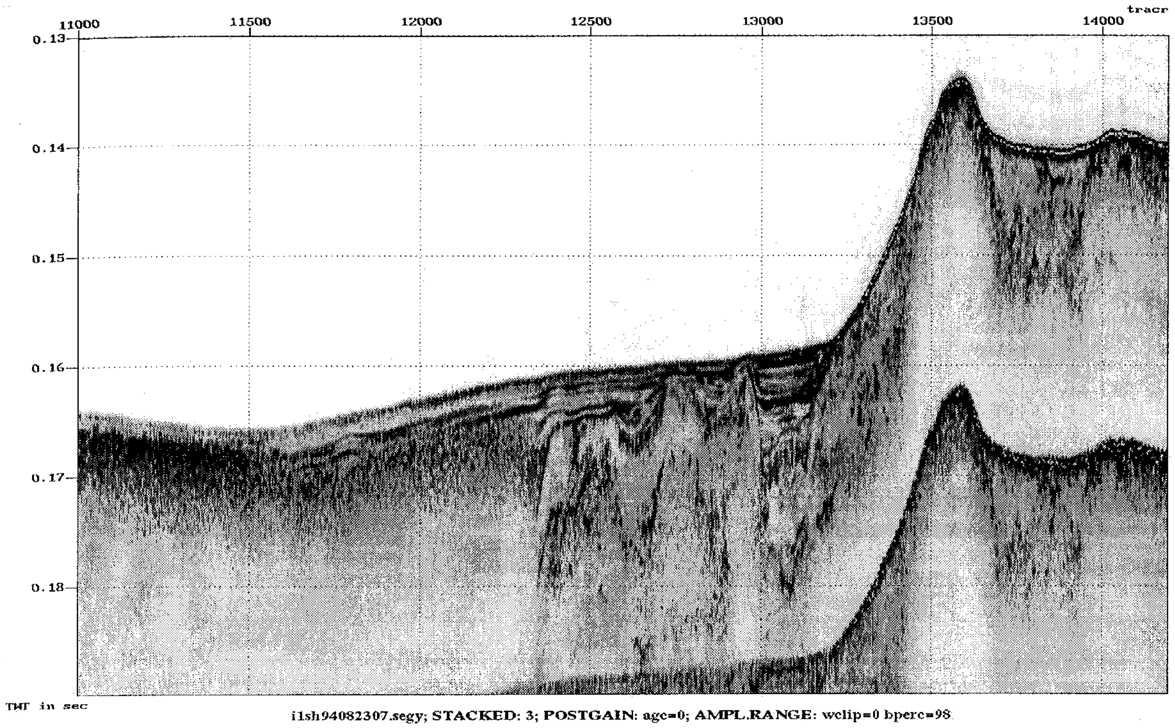


Figure 11: Gas charged sediments in a local basin on the NE – shoulder of the Gotland Deep, NE(left)-SW(right) striking GeoChirp-profile 94082307, for location see Fig. 2 no. 6.

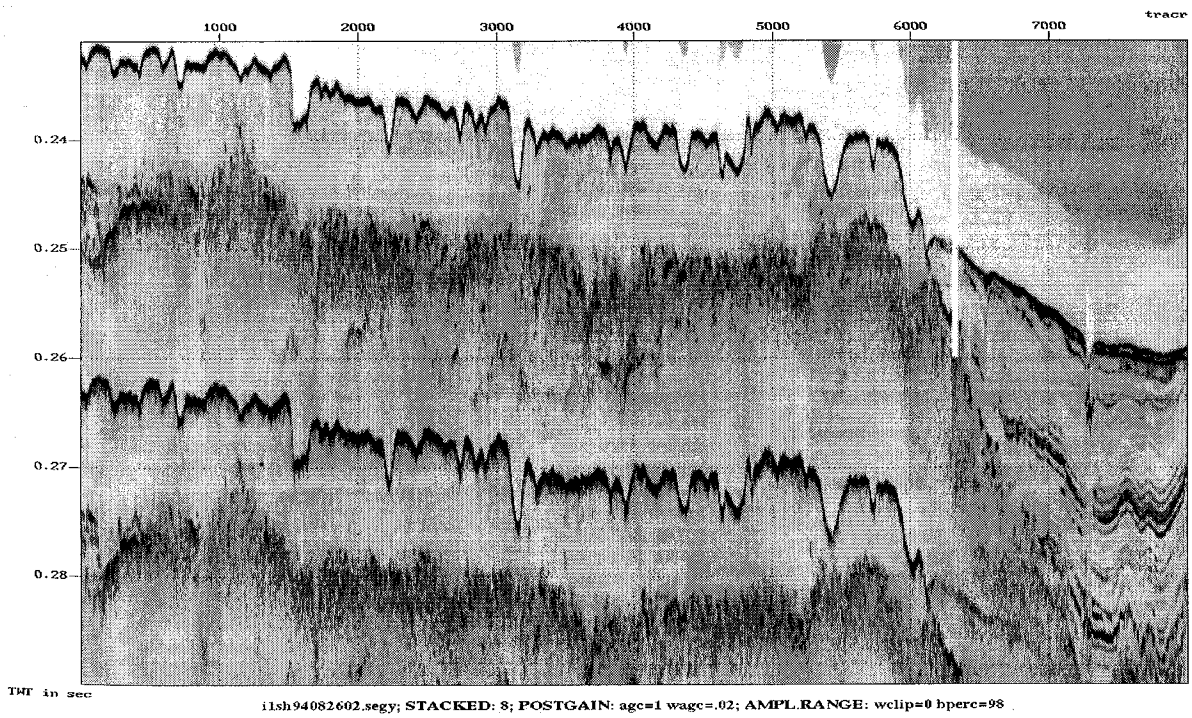


Figure 12: Erosional structures in late glacial clay – sea bottom at the NW shoulder of the Gotland Deep, WNW(left)-ESE(right) striking GeoChirp-profile 94082602, for location see Fig. 2 no. 8.

3m). Its origin appears to be mainly biogenic. Small depressions in the sea floor surface can be interpreted as initial stages of pockmarks (Figure 9). Pockmark–shaped sea floor structures were found on the outer NE – slope of the Gotland Deep (Figure 12, at trace no. 7300). Their origin is difficult to explain, because neither fault structures nor dispersed gas were observed in the subbottom.

## Rough sea bottom

In general the sea floor of the Gotland Deep has a rather smooth surface. This is the result of the postglacial sedimentation processes. At the shoulders of the basin, in regions were the sea bottom consists of moraine deposits with big boulders the sea floor surface is of irregular, rough shape. Erosional structures in the late glacial clay occur in the NW - outer slope near Klints Bank (Figure 12). The scraped shape of the sea floor surface is very similar to iceberg scour marks, but more likely is an explanation by erosional processes during the drainage of the Baltic Ice Lake.

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# 5. Results of Studies on Long Sediment Cores

## 5.1. Radiographies

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During GOBEX cruises with FS Alexander von Humboldt in 1994 and FS Poseidon 1995 and 1996, long sediment cores were retrieved from Gotland Deep sediments. Five cores were selected for X-ray radiography (Table 1). Slab samples were taken continuously in boxes (250x120x5mm) from the entire sedimentary sequence of the cores during the expedition. X-ray photographies of the slab samples were then performed with the radiography equipment at the Geological Institute of Kiel University.

In Appendix (CD ROM) all X-ray radiographs are stored as Bitmap-files (Windows Bitmap .BMP) in high resolution. The X-ray photographs are all black and white photos where dark areas represent areas of greater density. The sediments of the different stages of the Baltic Sea (Ice-Lake, Yoldia, Ancylus, Littorina and Lymnea) have typical structures and components exposed in the X-ray radiographs.

In deeper parts of the cores, which are deposited during the Ice Lake stage of the Baltic Sea, the sediments are commonly well layered or laminated (varved clay),. Typically one light and one dark layer mark a varve which represents a one year cycle of sedimentation. Dark spots are common and are ice rafted drop stones in these sediments. The sediments of Yoldia and Ancylus stages are usually homogenous to layered. Black spots and layers in these sediments originate often from mineral components (pyrite or greigite) in the sediments.

The sediments of the Littorina and Lymnea stage are commonly very thinly laminated (black/white) or bioturbated. Dark to black laminae may originate from thin layers of manganese-iron carbonates, which are often reported from the Littorina sediments of the Gotland Deep.

Table 1: Cores, sampled for X-Ray radiography.

| Core No | Equipment | Date of Retrieval | Core Length |
|---|---|---|---|
| 20001-5 | Gravity Corer | 1994 | 5.75m |
| 20048-2 | Kasten Corer | 1995 | 10.30m |
| 201301-3 | Multi Corer | 1996 | 10.19m |
| 201301-5 | Kasten Corer | 1996 | 0.50m |
| 201302-5 | Kasten Corer | 1996 | 6.82m |

## 5.2 Digital images of GOBEX cores

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Sediment cores are records of the environmental history in the Eastern Gotland Basin, and analyses of sedimentary features permit the reconstruction of changes in that history. Aside from classical core descriptions (EMEIS, this volume), we have used high-resolution methods to log the physical and sedimentological properties of cores taken during the GOBEX expeditions (ENDLER, this volume) and in addition, we have compiled digital images of the cores, which may be used in future studies for correlation purposes or evaluation of grey-scale time series.

The gravity cores taken were stored at 4°C in sections of 1m length after the three expeditions. These sections were subsequently cut lengthwise to ¾ of the original diameter using a cutting device with rotating metal saw blades. The newly created core face was carefully smoothed, watered, and covered with a clear plastic cover for the determination of density, magnetic susceptibility and P-wave velocity (ENDLER, this volume) using a GEOTECH multi-sensor core logger (MSCL). After MSCL logging, the plastic cover was removed and the core face was again cleaned and smoothed. Color scales of 10 cm length were placed at the top of each section to aid later sizing and color adjustment.

The scanner camera is mounted on the MSCL track and is run by a PC. The camera is calibrated in terms of illumination, brightness and distance from core with a calibration core. The software driving the scanner also adjusts the focus for each analysed section, which is most important for the production of good-quality scans.

The individual sections resting on the MSCL track are moved underneath the scanner, which records the image over a width of 8 cm at a resolution of 12 pixels per mm. During a scan, the data are recorded in RAM and are then stored on disc as 24-bit bitmap files (Windows-BMP). For each section of 100 cm, 6 files of 6MB each are created and stored. In order to compile an image of the entire section, these portions are later copiled using a newly developed tool mkcore. We use a Pentium II computer with 64 MB RAM and 1 GB hard drive running under Windows 95 and using the software PaintShop Pro (http://www.jasc.com) for further graphical layout and enhancement of the core images. After scanning, the cores are packaged in D-tubes and are then stored in the IOW core repository for future sampling.

As a next step in the generation of core images, a scale is fitted to each individual section based on the coring record and curated section length, because the use of a an external scale during the scanning process results in insufficient illumination of either the core surface, or the scale bar. Using an external scale also reduces the scanned surface area of the core. The graphic display including the scale is then stored in JPEG format, which reduces the file size from 36 MB to approximately 2MB per section. For an image of all sections of each core, the JPEG images are reduced by 50% in size and compiled in a joint JPEG file in the appropriate sequence. These JPEG files are appended on the CD-ROM for all GOBEX cores.

The digital images of high spatial resolution lend themselves to correlations between cores. For this purpose, we used grey-scale distribution curves created from the digital core image. The original BMP-files (6 per section) were converted to 8-bit grey-scale images using PaintShop Pro and were then loaded into the software Scion-Image (http:\\www.scioncorp.com), which produces tables of gray-scale values from the images which are then stored in ASCII-format and compiled for the entire core.

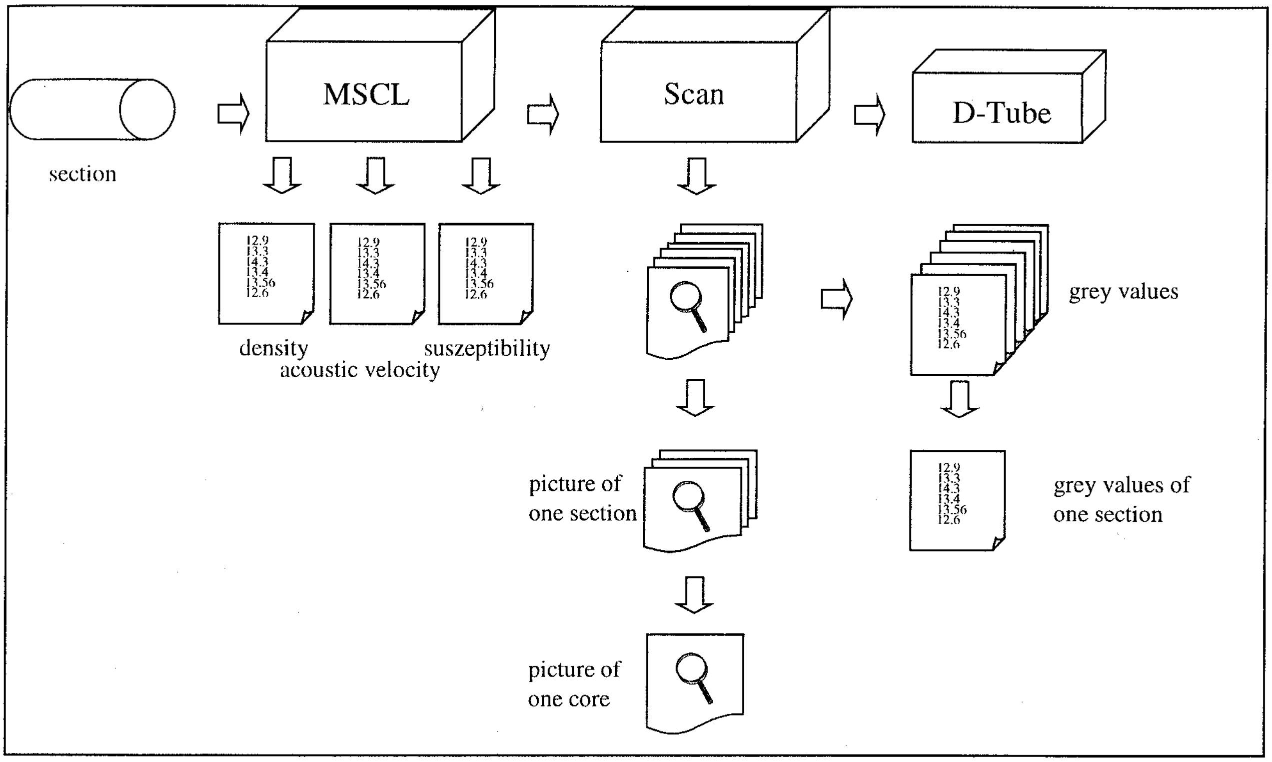


Figure 1: Schematic flow diagram of core handling and and image generation

## 5.3. Multi-sensor core logs of GOBEX gravity cores

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### Methods

Nondestructive logging of sediment cores was performed using a multi-sensor core logger (MSCL) from GEOTEK Ltd. UK (Figure 1). The system consists of following main units:

A.) Motorized core conveyor system:

The conveyor system pushes each core section past the sensor unit, which scans the core as it passes. The conveyor is driven by a stepper motor which can position a core with an accuracy of better than 0.5mm. The computer controlling the conveyor also controls the sensors, so that all the data are automatically correlated. The down core sampling intervall (typically 1 cm) is user-controlled. The computer also measures the length of each core section and can automatically subtract the thickness of the end caps. This allows the sections to follow sequentially, producing an unbroken stream of data.

B) Compressional wave velocity and core diameter measurement system

A pair of 500 kHz compressional wave transducers (piezo-ceramic thickness mode crystals potted in stainless steel houses) are used to measure P-wave velocity (traveltime of ultrasonic pulses, pulse timing resolution: 50 ns). These sensors are spring-loaded against the sides of the core and require water drops to provide good acoustic coupling. Both traveltime and the pulse amplitude are measured. A pair of displacement transducers measure the diameter of the core by following the motion of the spring loaded P-wave trancducers. Variations in core diameter are required for accurate calculation of P-wave velocity and sediment density.

C) Gamma-ray attenuation measurement system

Source: 10 mCi, $^{137}C$ capsule housed in lead shielding/collimator providing gamma rays with a principal energy at 0.662 MeV

Detector: Lead shielded and collimated detector assembly with 38 mm dia * 38 mm thick NaI(TI) crystal gamma detector with photomultiplier tube

D) Magnetic susceptibility measurement system

A magnetic suszeptibility sensor (Bartington Instruments Ltd. loop sensor& MS2 meter) determines the concentration of magnetic material present in the sediment.

E) Colour line scan core imaging imaging system

A colour line scan camera delivers colour pictures of split cores (12 dots per mm, colour depth 3*8 bit, file format: bmp). The image data are synchronized via the stepper motor drive of the MSCL conveyor. This means that image data can be correlated with other sensor data such as sediment density and P-wave velocity.

F) Sediment temperature sensor

The sediment temperature is measured using a thermocouple probe placed to one end of the section during logging.

G) Sensor electronics and external controlling computer

An Intel 8052AH Basic Microprocessor with on-board BASIC language interpreter provides all the interfacing between the control and sensor systems and the external controlling computer (IBM compatible). It is housed within the main P-wave electronics unit and enables the user to control all the major control and logging functions from the external controlling computer.

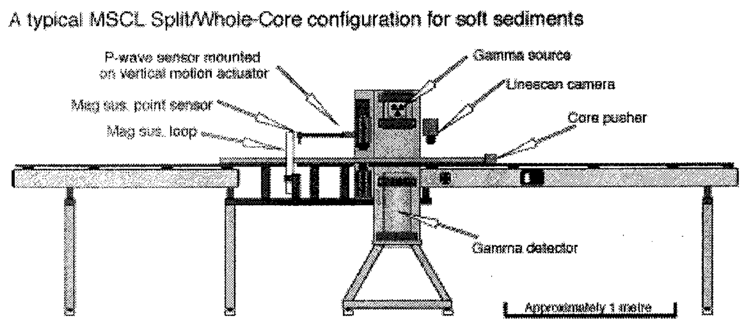


Figure 1: The Geotek Ltd. – Multi-sensor core logger (MSCL)

The MCSL can be used to log whole as well as split cores. Whole core logging gives good results only if the liner sections are filled with sediments and pore water. In general a loss of sediment and pore water occurs (near the end caps) during the cutting of the long core-liner in 1 m sections. This leads to spurious logging data. In order to avoid this problem, split cores were logged. The cores were cut in longitudinal direction with a special cutting device. Then, the exposed sediment surface was carefully smoothed and prepared for optical scanning during the first pass through the MSCL. After this, the sediment surface was covered by a 4 mm thick plastic plate making a flat and rigid surface needed by the P-wave sensor. (Whitout this plate the spring loaded trancducer would penetrate into the sediment during the measurements. The coupled core diameter sensor would deliver wrong core diameter data for density calculation.) During the following second pass through the MSCL, all the other properties (P-wave velocity, wet bulk density, magnetic susceptibility) were measured.

Calibration (including correction for electronic drifts, liner materials) was achieved by logging a special calibration piece before and at the end of each sediment core. The calibration of the density-sensor was supported by taking small sediment samples and estimating wet bulk density by conventional volume/weight method. Measured sound velocity was corrected to "in situ temperature" of 4°C using a velocity gradient of 3.4 m/s deg. For more detailed information about multi-sensore core logging see BOYCE (1973); GUNN and BEST (1998); SCHULTHEISS and WEAVER (1992).

**Results**

All logging data are depicted in the Appendix for the GOBEX gravity cores. The basis for core correlation by logging data is the assumption that the used features are deterministic and not random. In Figure 2 a simple attempt to correlate sediment cores from the central Gotland Deep is made using physical property data. The numbered horizonal correlation lines connect typical changes / characteristics of the logging curves. An impression about what features can be used for correlation is given in Fig. 3. Two sediment cores were taken at different times at about the same location (1994: 20007-4SL; 1996: 20048-2SL). The comparison of the logging results in Fig. 3 prove that the major peaks and gradients of the logging curves can be reproduced quite well and can be used for correlation. It further shows that the loss of the uppermost very soft mud during coring can be more than half a meter.

MSCL-logs of the long cores are depicted in Fig. 4 to Fig. 14. The locations of the coring sites and of the acoustic profiling lines are given in Endler, Acoustic studies, this volume (Figure 1).

In principle, the correlation lines are related to acoustic reflectors (see ENDLER, Acoustic studies, this volume). However, because of the known problems with gravity coring (loss of sediments, compaction, the change of the acoustic properties due to pressure release, dewatering ....), simple matching of acoustic profiling data and logging data did not lead to satisfying results. For accurate connection of coring data with acoustic profiling results a better correction to in-situ values is needed.

Analysing the shapes of the different core logging curves, a first discrimination of different sedimentation areas can be made: the central part with nearly identical logging curves (20048-2SL, 20007-4SL, 20050-1SL); the SE – border with rather thick postglacial sediment layers (201306-1SL, 20002-1SL, 201305-3SL) and the SW and NW border with much less postglacial sediments (201304-1SL, 20051-1SL, 20052-1SL ).

The first correlation line (no. 1 in Figure 2) marks a layer with low density (1.1 g/cm³) and high water content. This uppermost well laminated layer is of similar structure as those found between correlation lines no. 2 and no. 3. It is mainly present in the SE border of the central basin (core 201306-1SL, 201305-SL, 20002-1SL)

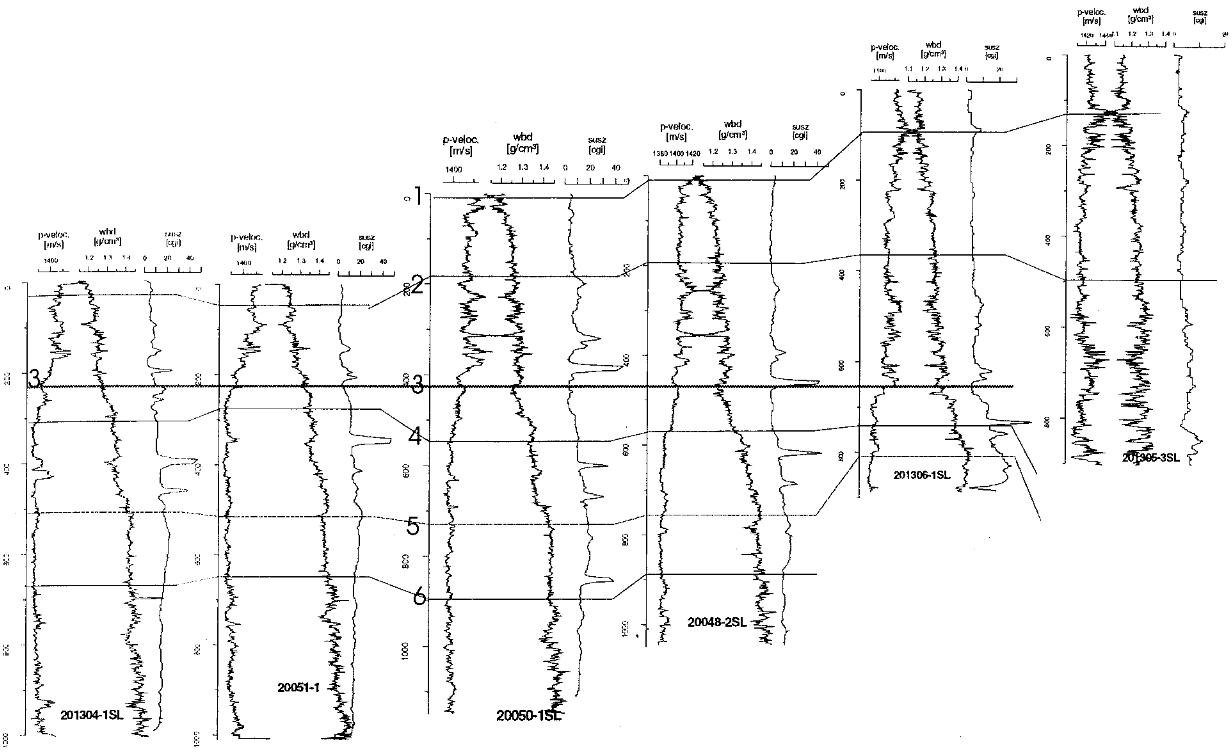


Figure 2: Correlation of Gotland Basin sediment cores by physical properties (multi-sensor core logging data)

The most evident sequence is enclosed by the correlation lines no. 2 and no. 3. This layer is well laminated. The rather high variations in wet bulk density (1.1 – 1.3 g/cm³) and in sound velocity (1400 – 1430 m/s) mainly reflect changes in the water content. This layer roughly corresponds to the acoustic reflector-sequence C – D reflectors (see ENDLER, Acoustic studies, this volume). The thickness of this layer increases to the NE-direction from about 2.5m (core 20050-1SL) up to about 2.8 m (core 20048-2SL) and to the SE-direction up to about 3 m (core 201306-1SL) and more (core 201305-3SL). Three typical peaks in the susceptibility curves are observed. The highest peak is located at the lower part just above line no. 3.

A nearly continuous increase of the wet bulk density occurs below the correlation line no. 3. This density increase reflects the normal compaction of the fine grained sediments. The sedimentation rate was probably lower than before and there was enough time for the pore water to migrate upwards. During this early diagenetic stage, rather high quantities of black sulfur-minerals were formed. The sound velocity drops down to values of about 1390 – 1400 m/s. This decrease of the sound velocity is probably caused by the increase in wet bulk density, whereas the elastic compressibility of the sediment remains constant.

The density gradient becomes low again below correlation line no 5 (which is in the depth range of the acoustic reflector E). This might be caused by an increase in sedimentation rate of the clay particles. The low scatter in wet bulk density and sound velocity data indicates the homogeneous structure of the sediment deposited in a calm deepwater environment far away from the ice margin. The magnetic susceptibility curve has a very flat maximum near correlation line no 5. This is probably caused by diagenetically formed minerals (the same holds true for the other maxima). The only susceptibility increase caused by terrestrial input was observed in the lowermost part of core 20052-1SL.

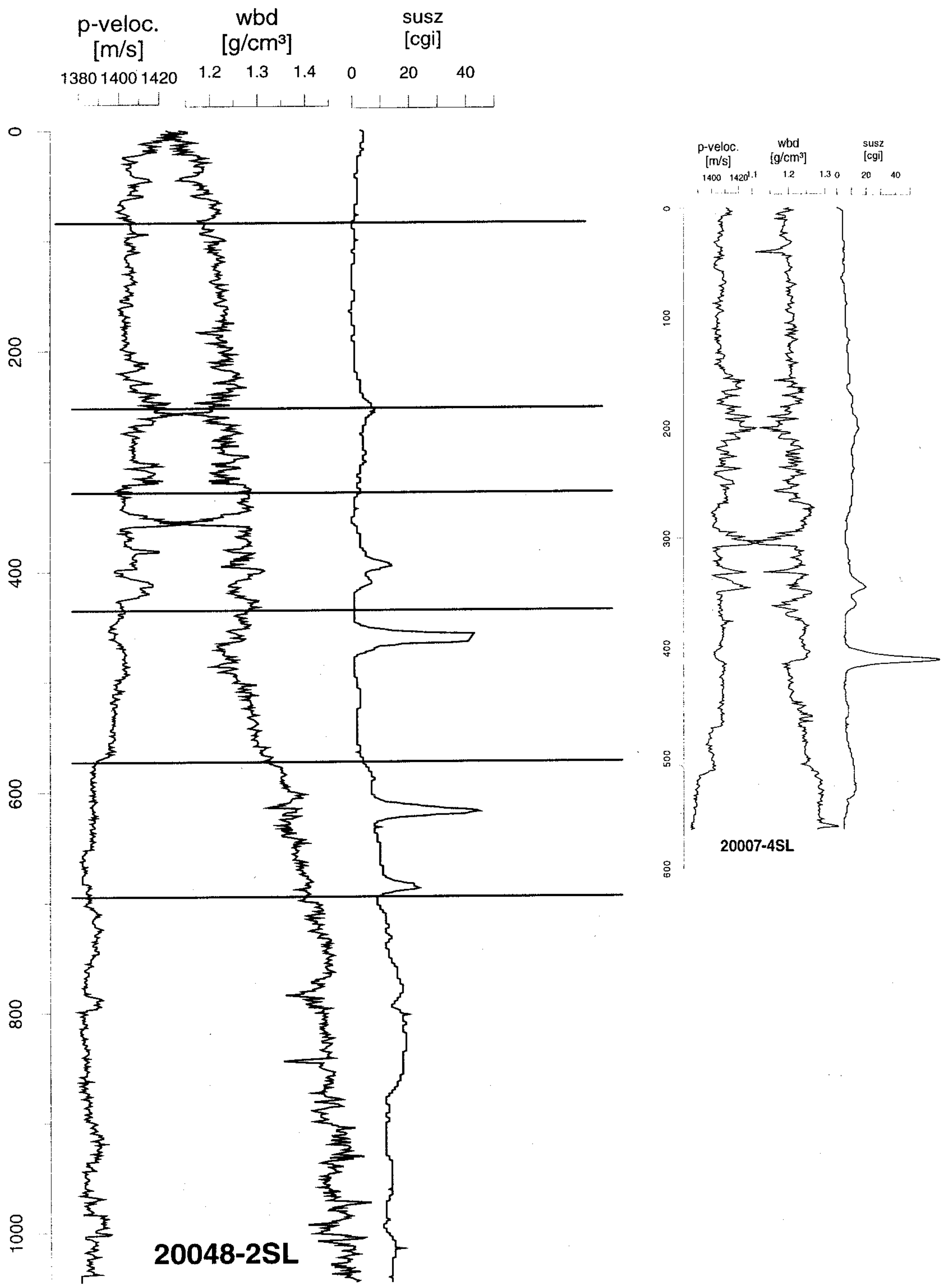


Figure 3: Comparison of logging data of sediment cores from about the same location

The higher fluctuations in wet bulk density and sound velocity below correlation line no. 6 are caused by embedded coarser material (sand and gravel). The most evident example for this varved late glacial clays was found in core 20052-1SL.

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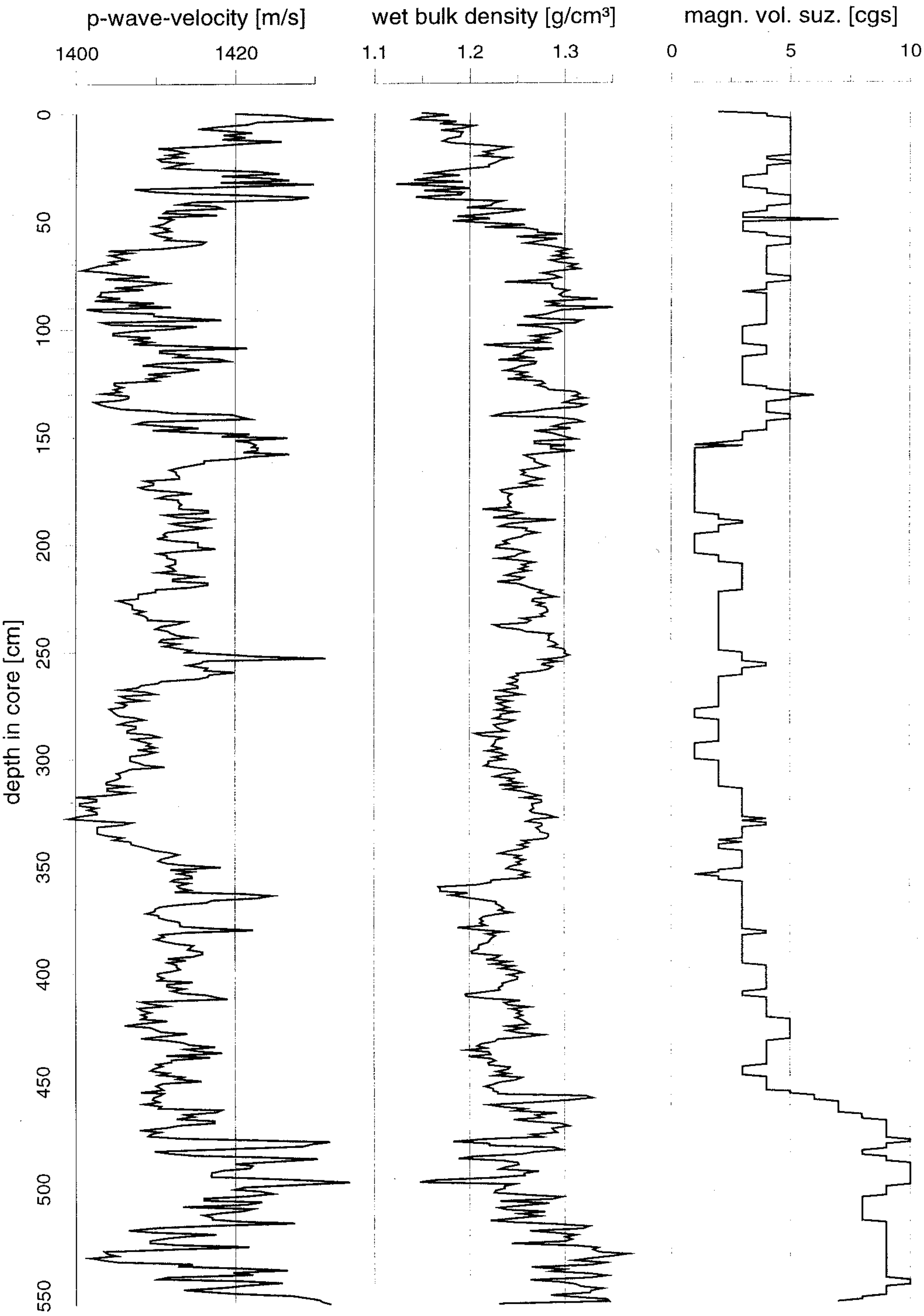
## APPENDIX: Figures of results of core loggings with the MSCL.

# Results of Multi-Sensor-Core-Logging

**cruise:** ***rv A.v.Humboldt, 1994*** **core:** ***20002-SL***

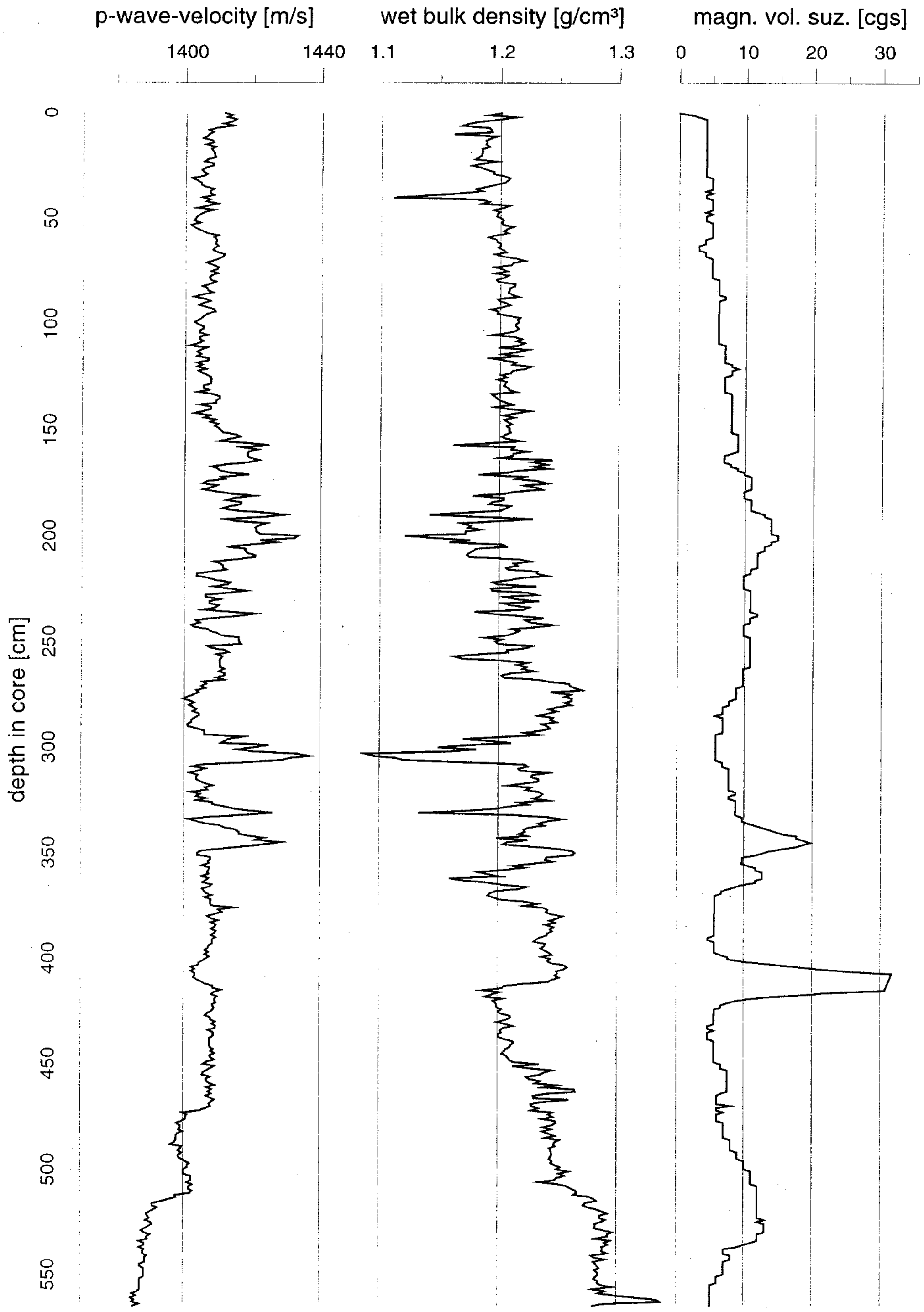
Remarks:



# Results of Multi-Sensor-Core-Logging

**cruise:** ***rv A.v.Humboldt, 1994*** **core:** ***20007-4SL***

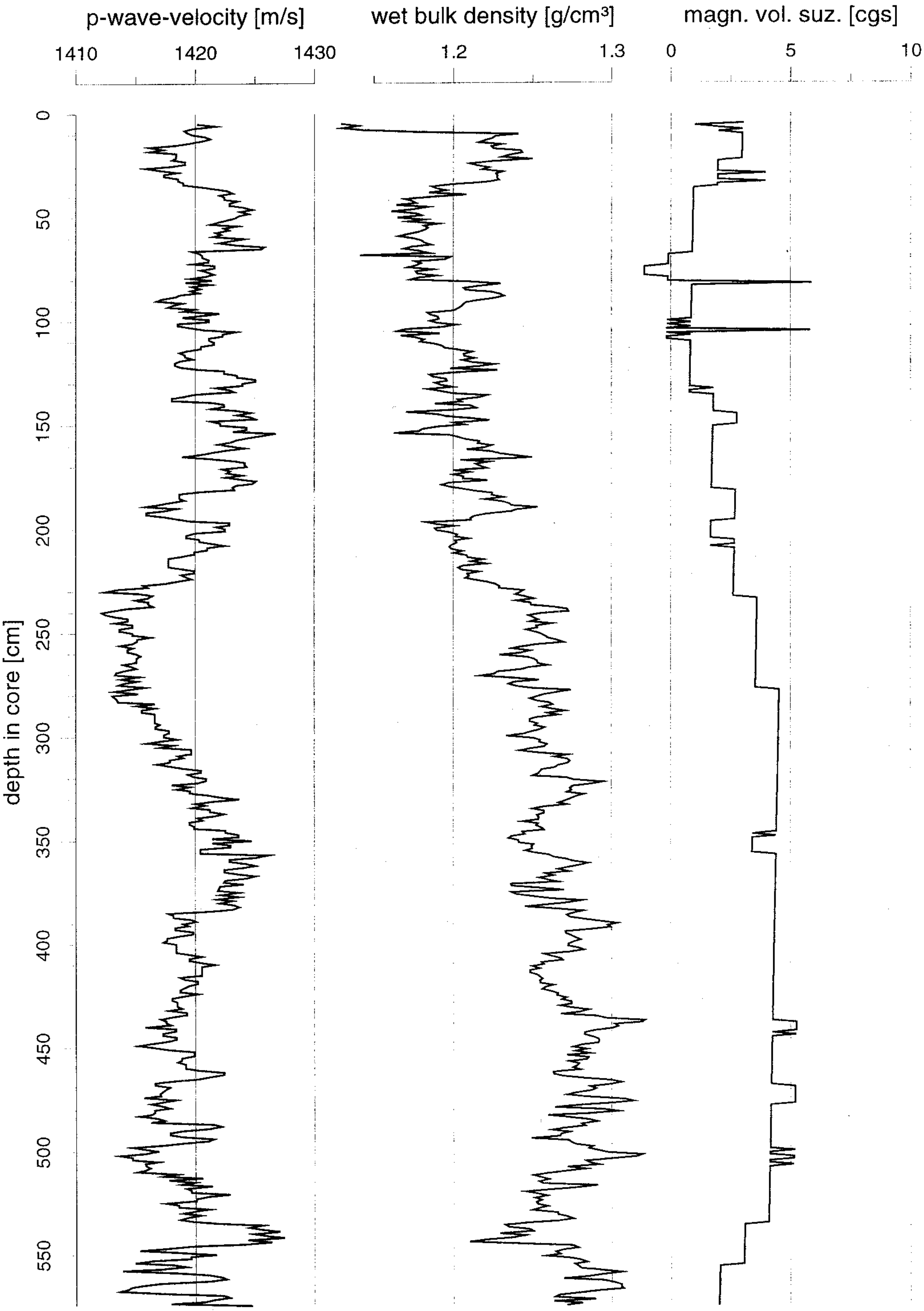
Remarks:



# Results of Multi-Sensor-Core-Logging

**cruise:** *rv A.v.Humboldt, 1994* **core:** *20030-3SL*

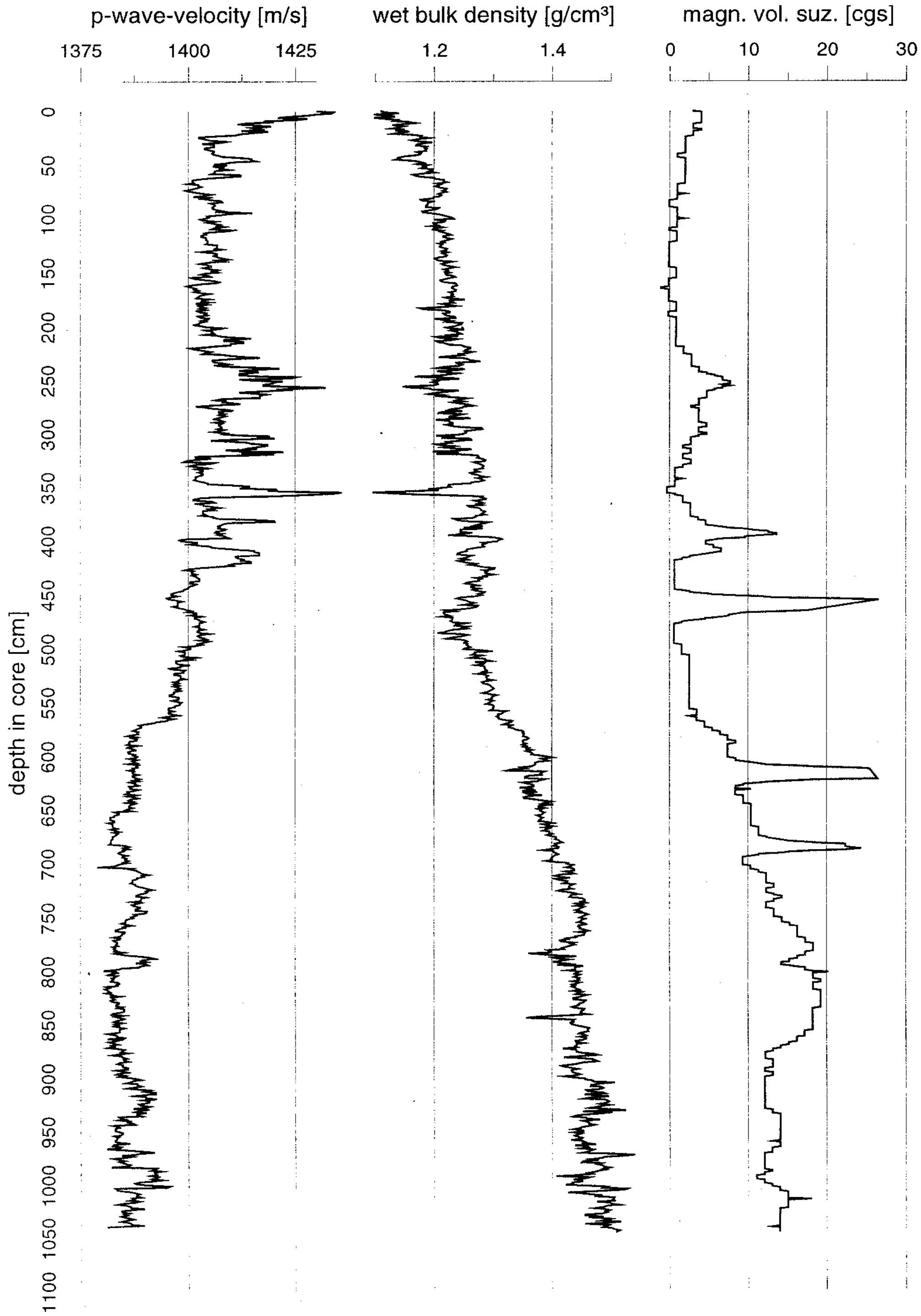
Remarks:



## Results of Multi-Sensor-Core-Logging

**cruise/ship:** ***rv Poseidon, 1995*** **core:** ***20048-2SL***

Remarks:

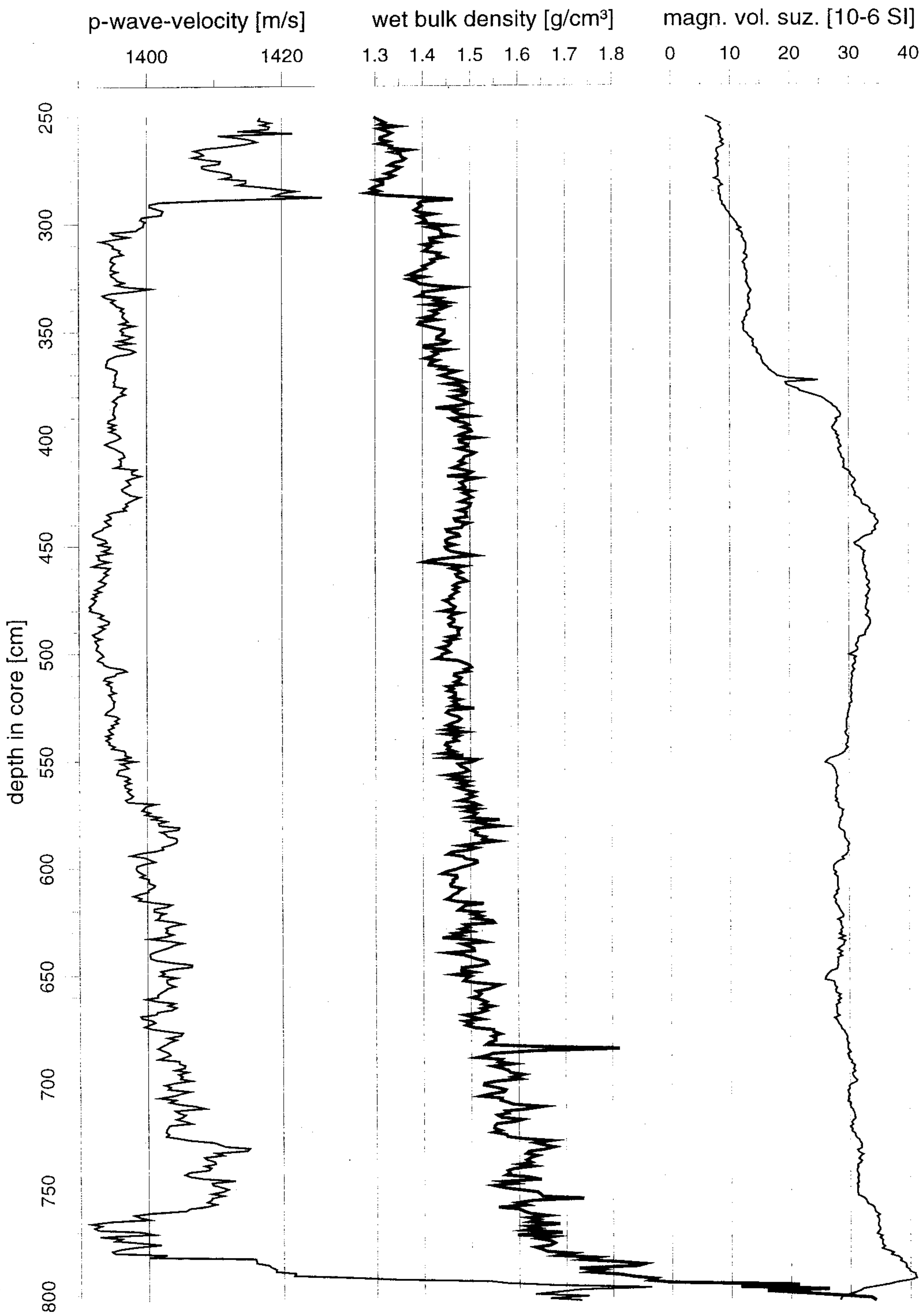


# Results of Multi-Sensor-Core-Logging

**cruise:** ***rv Poseidon, 1995*** **core:** ***20049-1SL***

Remarks:

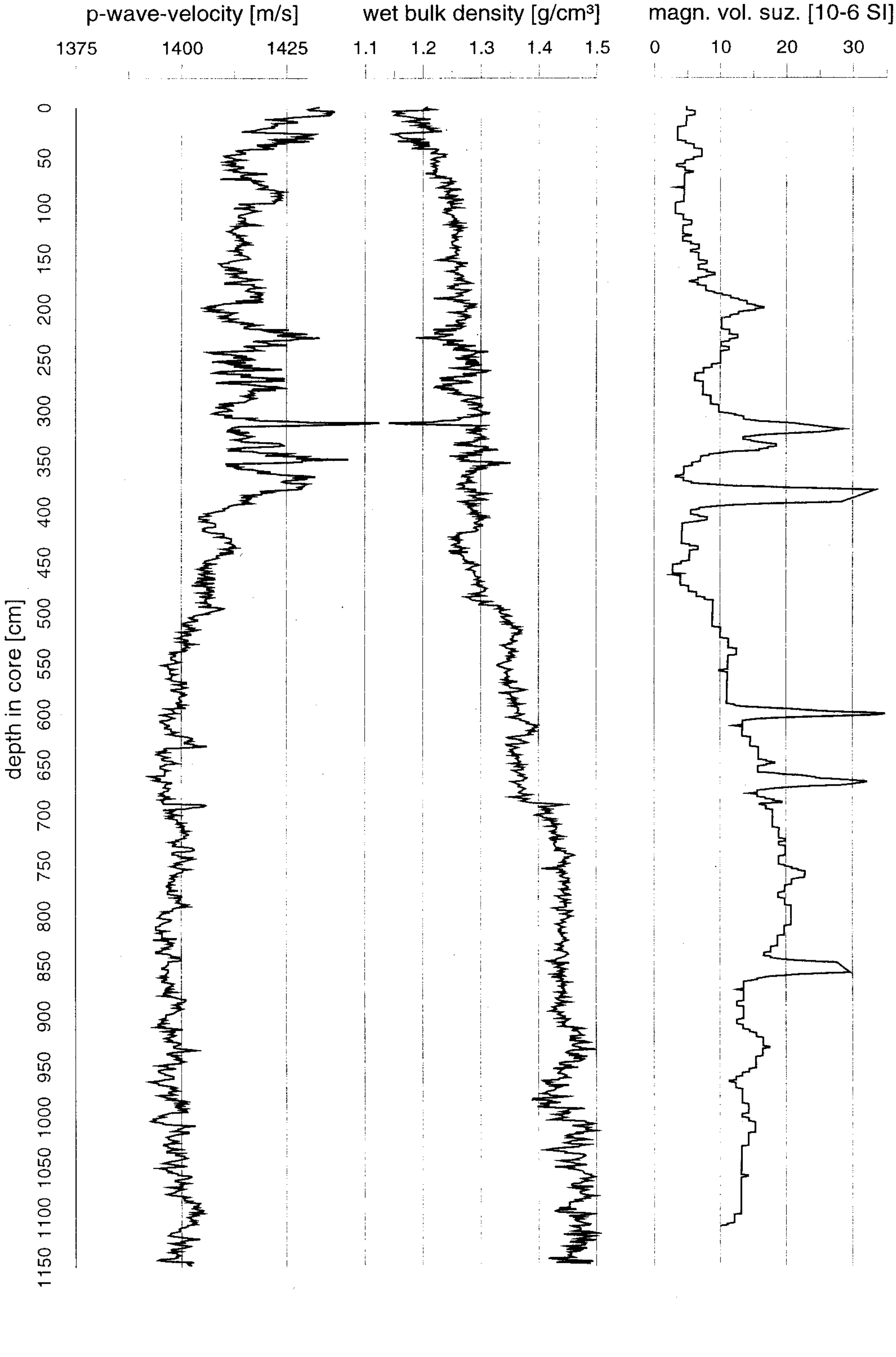
loss of uppermost (about 2.5 m) sediments



# Results of Multi-Sensor-Core-Logging

**ship/cruise:** ***rv Poseidon, 1995*** **core:** ***20050-1SL***

Remarks:



## Results of Multi-Sensor-Core-Logging

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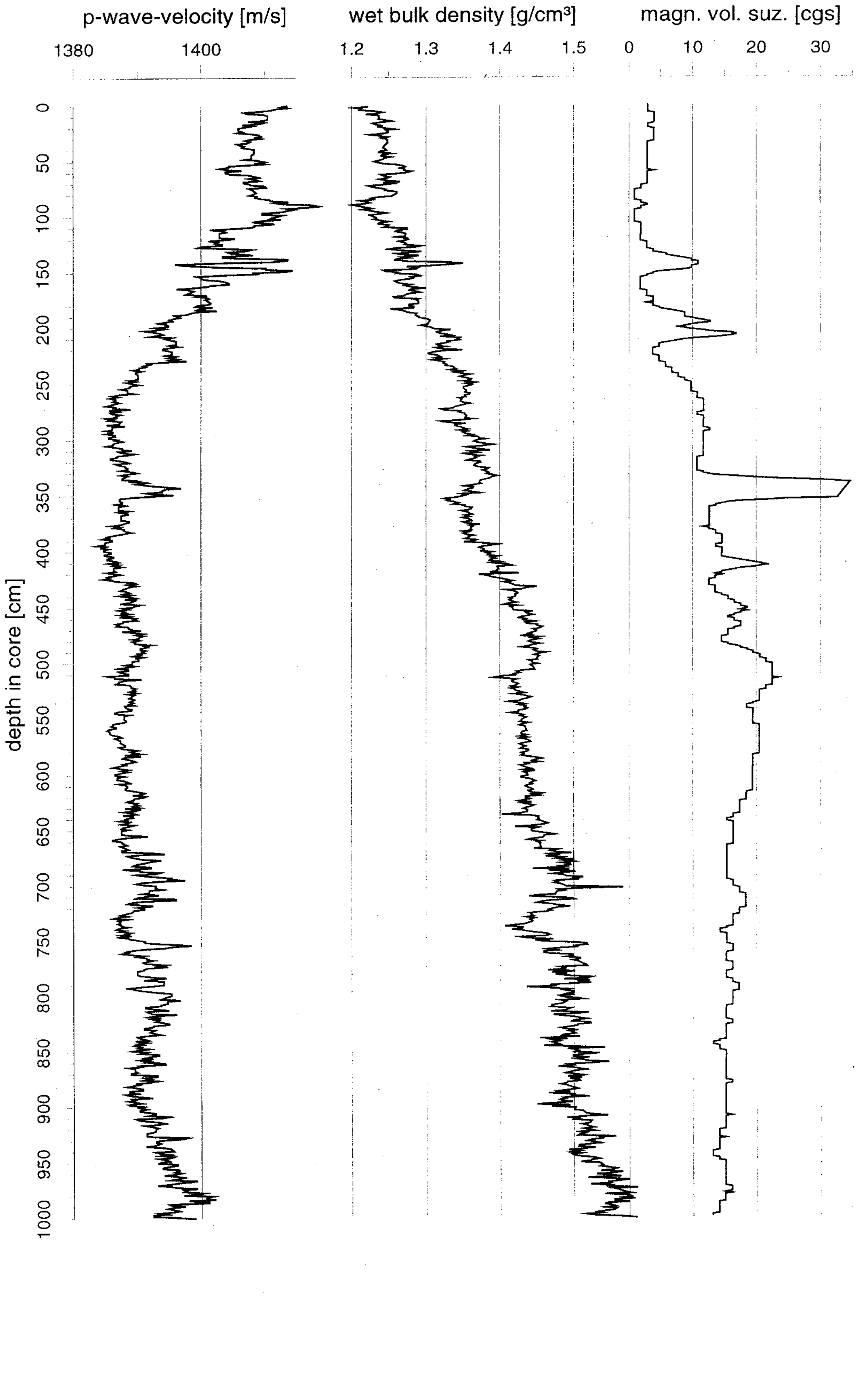
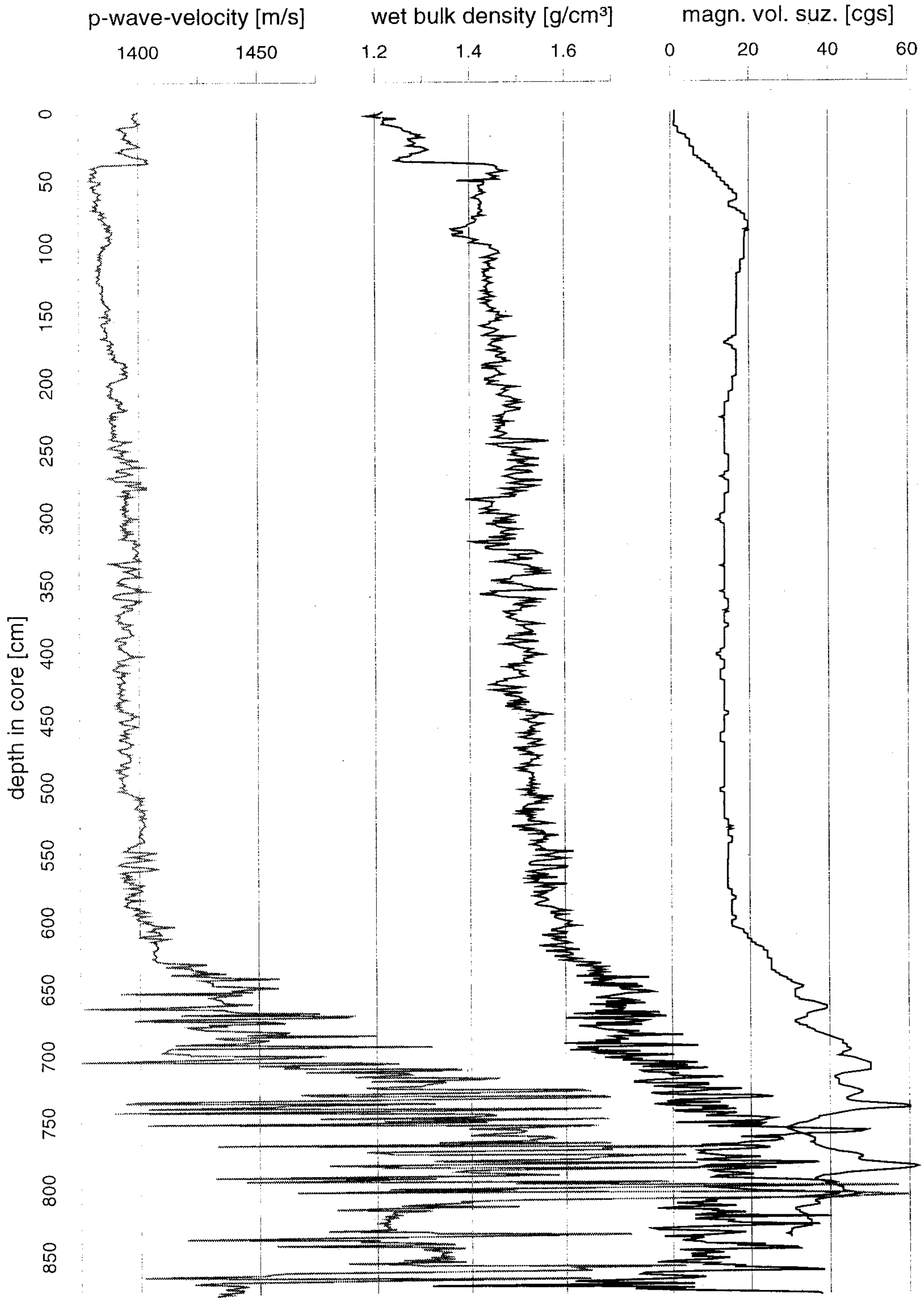
Remarks:



# Results of Multi-Sensor-Core-Logging

**cruise:** ***rv Poseidon, 1995*** **core:** ***20052-1SL***

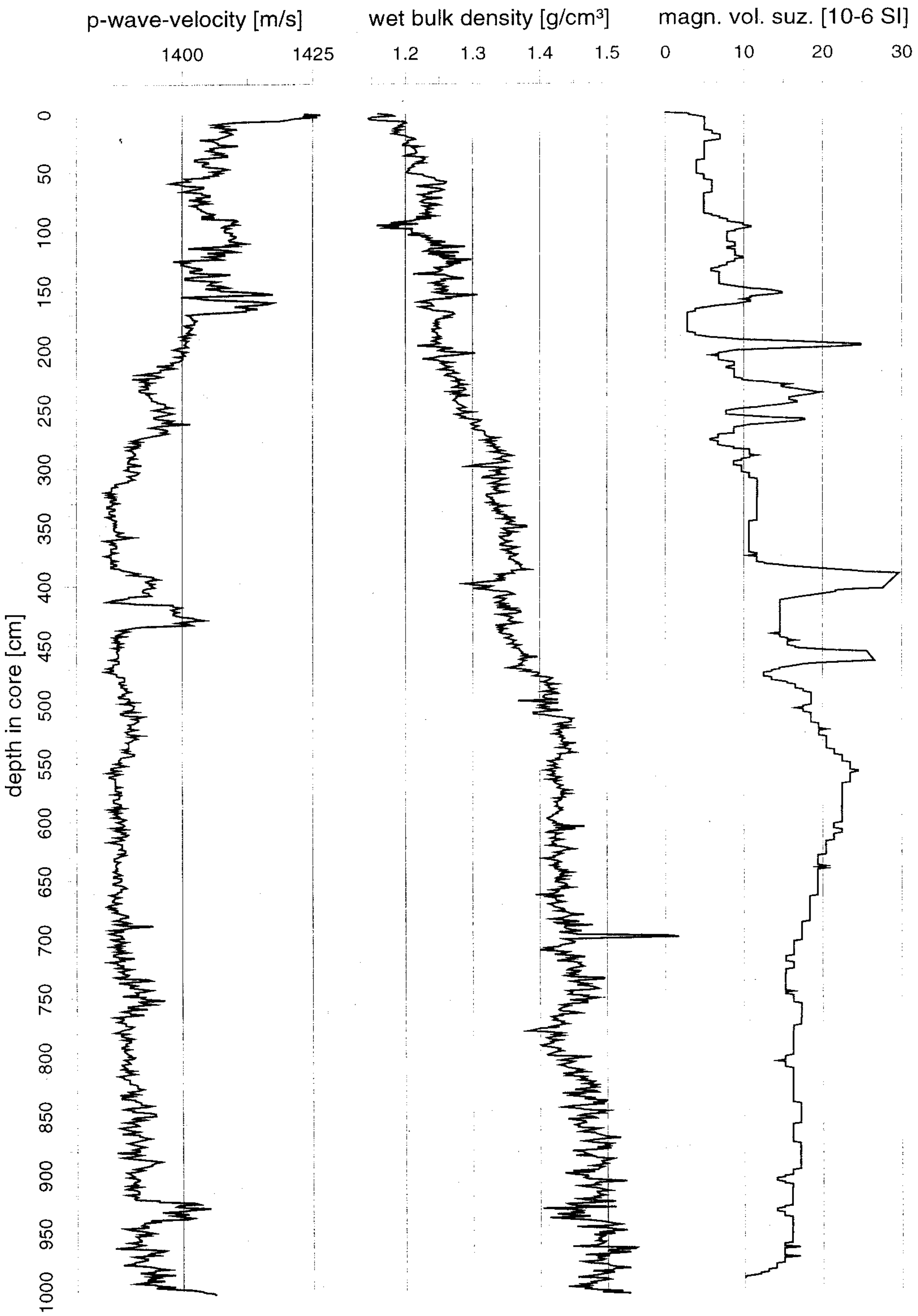
Remarks:



# Results of Multi-Sensor-Core-Logging

**cruise:** ***rv Poseidon, 1996*** **core:** ***201304-1SL***

Remarks:



## Results of Multi-Sensor-Core-Logging

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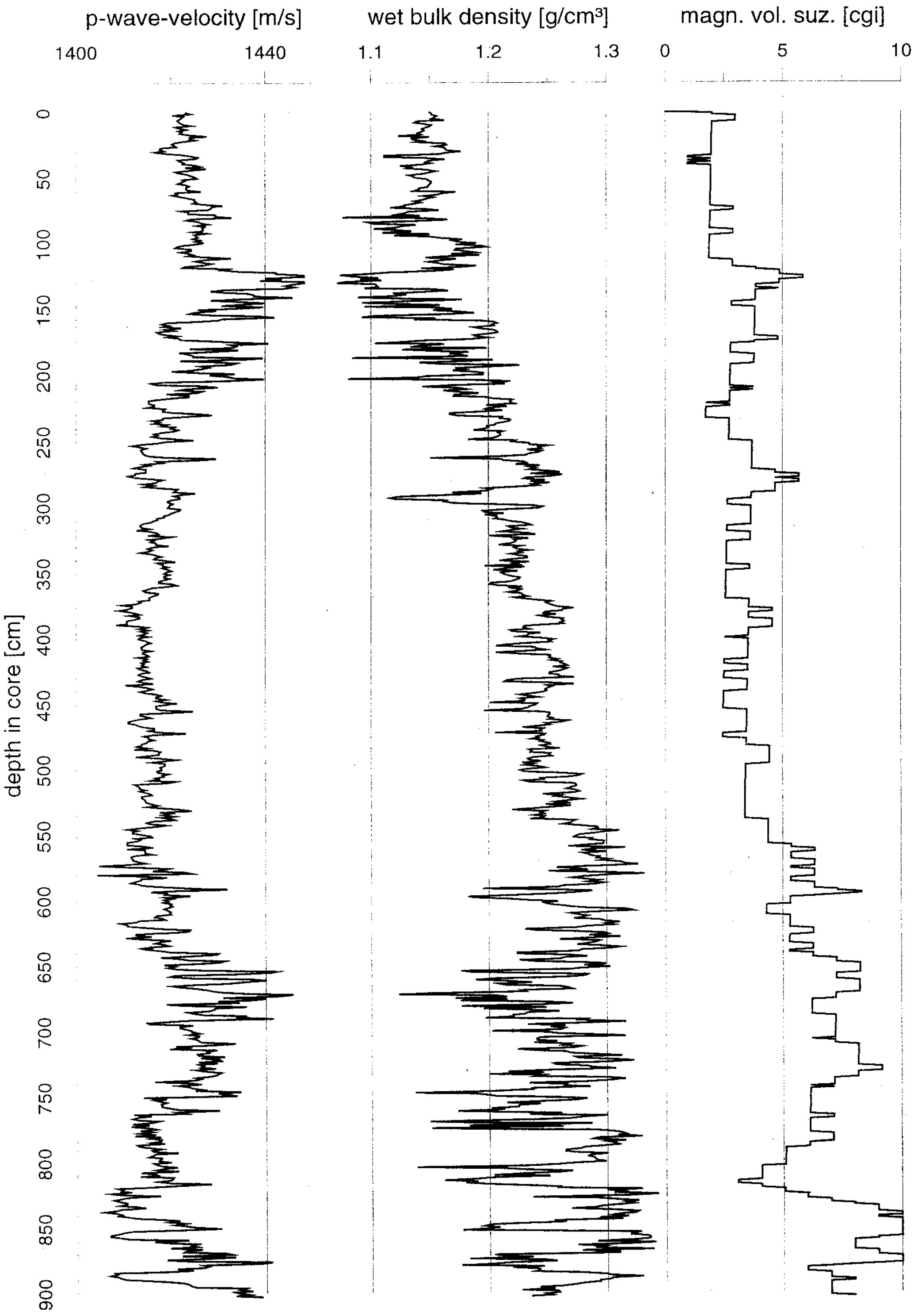
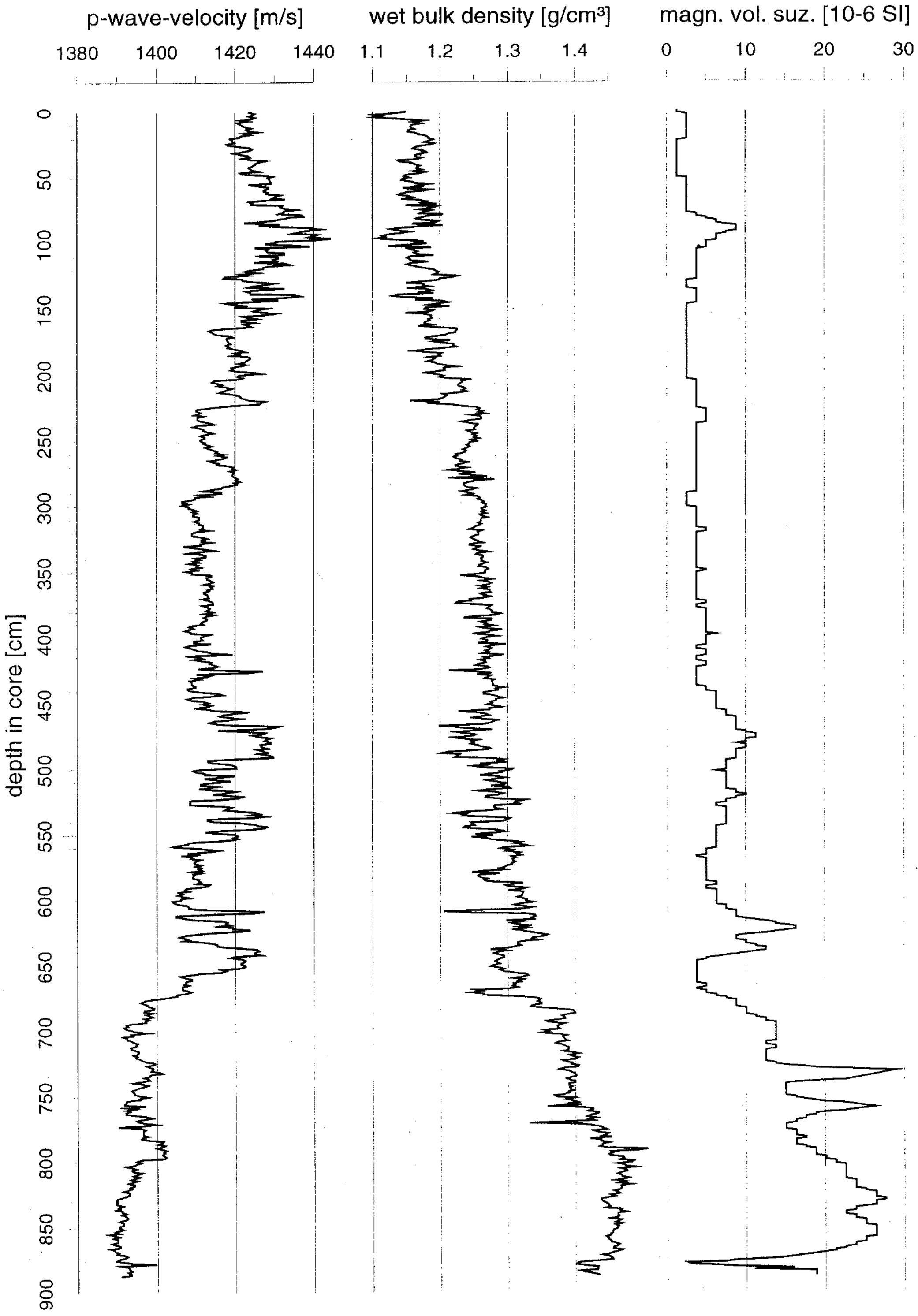
Remarks:



## Results of Multi-Sensor-Core-Logging

**cruise:** ***rv Poseidon, 1996*** **core:** ***201306-1SL***

Remarks:



# 6. Results of Studies on Short Sediment Cores

## 6.1 Datings and sedimentation rate estimations during GOBEX. A summary.

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### Abstract

During GOBEX, a number of methods have been used to estimate past and present sedimentation rates. Since the Littorina transgression some 7800 years ago the long term sedimentation rate in the basin has been asymmetric with higher rates (0.75 mm/a) in the SE part of the basin than in the NW part of the basin (0.23 mm/a). Present rates have great variabilities and range from 0 to possibly more than 30 mm/a. In general, present rates are 2 times higher than observed 25 years ago. This may be due to both eutrophication and more shallow-water erosion because of increased storminess.

### Introduction

The benthic working group under GOBEX defined three main research areas: 1) Biogeochemical cycling in historic times; 2) Partial reconstruction of flux rates of natural and anthropogenic materials into and out of the depositional system; 3) Environmental records and their diagenetic overprint. Essential for all three research areas is a knowledge on past and present sedimentation rates. During GOBEX such rates were estimated using a number of methods: $^{14}C$ dating of layers in long cores, layer thickness from Chirp Sonar data, estimations from suspended matter concentrations, estimations from sediment traps, and datings and sedimentation rate estimations from short cores using $^{210}Pb$ and $^{137}Cs$ (e.g. KUNZENDORF et al., 1998). While reporting results from all methods, priority will be given to results from $^{210}Pb$ datings.

### Study area

The location of Geochirp profiling lines and sampling sites in the Gotland Basin is shown in ENDLER (this volume). One additional sample was taken in the Gdansk Basin (IOW core #201308; 54° 49.870' N; 19° 18.940' E) at a water depth of 117 m.

**Methods**

Two $^{14}C$ datings (AAR 6008-09) on samples from the long cores were carried out at the AMS (Accelerator Mass Spectrometry) Laboratory at the Institute of Physics and Astronomy, University of Aarhus. The datings were performed, respectively, on chitinous remains of Cladocera and fish bones using a method previously described by ANDERSEN et al. (1989). The datings are given in conventional $^{14}C$ years corrected for reservoir effect. The common reservoir age in Danish waters is 400 years according to KROGH and TAUBER (1973). These years are subtracted from the present datings in order to compare with datings from terrestrial material and to apply the datings on a chronostratigraphical framework (e.g., MANGERUD et al., 1974). Results from $^{14}C$ dating of layers were used to estimate long term sedimentation rates from long cores and from GeoChirp profiles (CHRISTIANSEN et al., submitted; ENDLER et al., this volume).

Recent net sedimentation rates were determined from dating of multicores using low-level gamma-spectrometry using the method described by KUNZENDORF et al. (1998). Unsupported lead activity is used to estimate linear sedimentation rates for the cores using the constant initial concentration (CIC) model of interpretation (ROBBINS, 1978) assuming constant compaction or constant bulk density. The historical profiles were constructed using physical core data (density and/or porosity) and the constant rate of supply (CRS) model for $^{210}Pb$ (ROBBINS, 1978).

GeoChirp profiling was carried out by the method outlined in CHRISTIANSEN et al. (submitted) and described in detail in ENDLER (this volume). Sedimentation fluxes to the sea floor were calculated from suspended matter (CHRISTIANSEN et al., submitted; see SIVKOV et al., this volume). Results of an automatic sediment trap applied during the period from 23.2.95 to 23.3.95 at a water depth of 120 m are used as supplementary information on present day sedimentation flux rates (CHRISTIANSEN et al., submitted).

## Results

### Long term sedimentation rates

Samples from two cores were $^{14}C$ dated during GOBEX. These datings indicate that sedimentation has been unevenly distributed in the Gotland Basin since about 5500 $^{14}C$ years BP. The 499-500 cm layer in core 20048 (AAR-6008; sample provided by U. Struck) yielded 5200±75 BP (about 4800 conventional years BP) which compares to a sedimentation rate of 1 mm $a^{-1}$. The 203 cm layer in core 20001 (AAR-6009; sample provided by U. Struck) yielded 5540±50 BP (about 5140 conventional years BP) which compares to a sedimentation rate of 0.4 mm $a^{-1}$. The above rates include effects of compaction and different coring efficiency of box and gravity corers.

The acoustic profiling data give a clear image of the postglacial to recent sedimentation in the eastern Gotland Basin. As an example, Fig. 1 shows a typical NW-SE cross section of the central basin. Typical bands of reflectors (indicating major changes in the sedimentation) can be identified and traced over the entire basin (ENDLER et al., 1996; ENDLER, this volume). In general, there is an asymmetry in the recent morphology and in the subbottom structure. The older layers are of more or less constant thickness, whereas the thickness of the uppermost (Littorina to recent) sediments clearly increases from WNW towards ESE reaching the maximum thickness near the steep ESE slope of the basin. The asymmetry therefore must be a reflection of a deep circulation system in the Gotland Basin, which induces sediment winnowing and accumulation, and which results in spatially heterogeneous sediment records at the deep basin floor. From comparison of acoustic profiling data with core data the reflector "C" (see Figure 1) was identified as onset of the Littorina transgression. Hence, asymmetric deposition in the deep basin was initiated at the transition from the Ancylus Lake to the Littorina Sea, 7800 years ago (EMELYANOV et al., 1995).

| | | Core data | | | Acoustic profiling data | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Station | Latitude/ Longitude | subbottom depth (m) Littorina/ Ancylus | proposed age (a) of Littorina/ Ancylus Transition | estimated sediment. rate (mm/a) | water depth (m) | nearest distance to profiling line (m) | subbottom depth of reflector C (m) | proposed age of refl ector C (a) | resulting mean sediment rate (mm/a) |
| 20001-5 MUC | 57°18.33'N/ 20°03.00'E | | | | 240 | 2033 | 1.85 | 8000 | 0.23 |
| 20001-6 SL | 57°18.33'N/ 20°13.66'E | | | | 242 | 1684 | 2.31 | 8000 | 0.29 |
| 20004-1 MUC | 57°18.30'N | | | | 238 | 239 | 6.03 | 8000 | 0.75 |
| 200048-2 SL | 57°18.28'N/ 20°15.51'E | | | | 232 | 71 | 4.20 | 8000 | 0.53 |
| 20050-1 SL | 57°23.14'N/ 20°08.53'E | | | | 242 | 40 | 2.64 | 8000 | 0.33 |
| PS2510 | 57°18.75'N/ 20°08.00'E | 2.44 | 7800 | 0.28 | 242 | 314 | 2.44 | 8000 | 0.31 |
| Sohlenius 1996 | 57°18.82'N/ 20°08.42'E | 4.18 | 8000 | 0.50 | 240 | 91 | 2.44 | 8000 | 0.31 |

Table 1. Variation of mean (Littorina to Recent) sedimentation rates in the Eastern Gotland Basin.

Examining the high-resolution seismic record of the uppermost layers (subbottom depth of reflector "C"), mean sedimentation rates for the last 8000 years were estimated (Table 1). These rates vary from 0.23 mm $a^{-1}$ in the north-western part of the deep basin over 0.33 mm $a^{-1}$ in the central part of the basin to 0.75 mm $a^{-1}$ in the south-eastern part.

## Recent sedimentation rates from datings

The sedimentation rates calculated from $^{210}Pb$ profiles and physical properties are highly variable and reflect very different sedimentation rates (Table 1; all data are shown in Appendix 1). However, we are confident that they represent true trends and rates, because the $^{137}Cs$ profiles resulting from the Chernobyl accident corroborate the $^{210}Pb$ datings in all cores and none had irregular features that indicate hiatuses. In fact, Gotland Basin sediments seem to be supplied from three major $^{137}Cs$ sources: The atmospheric bomb testing in the beginning of the 1960'ies, the Sellafield accident in the 1970'ies, and the Chernobyl disaster in 1986 (Figure 2).

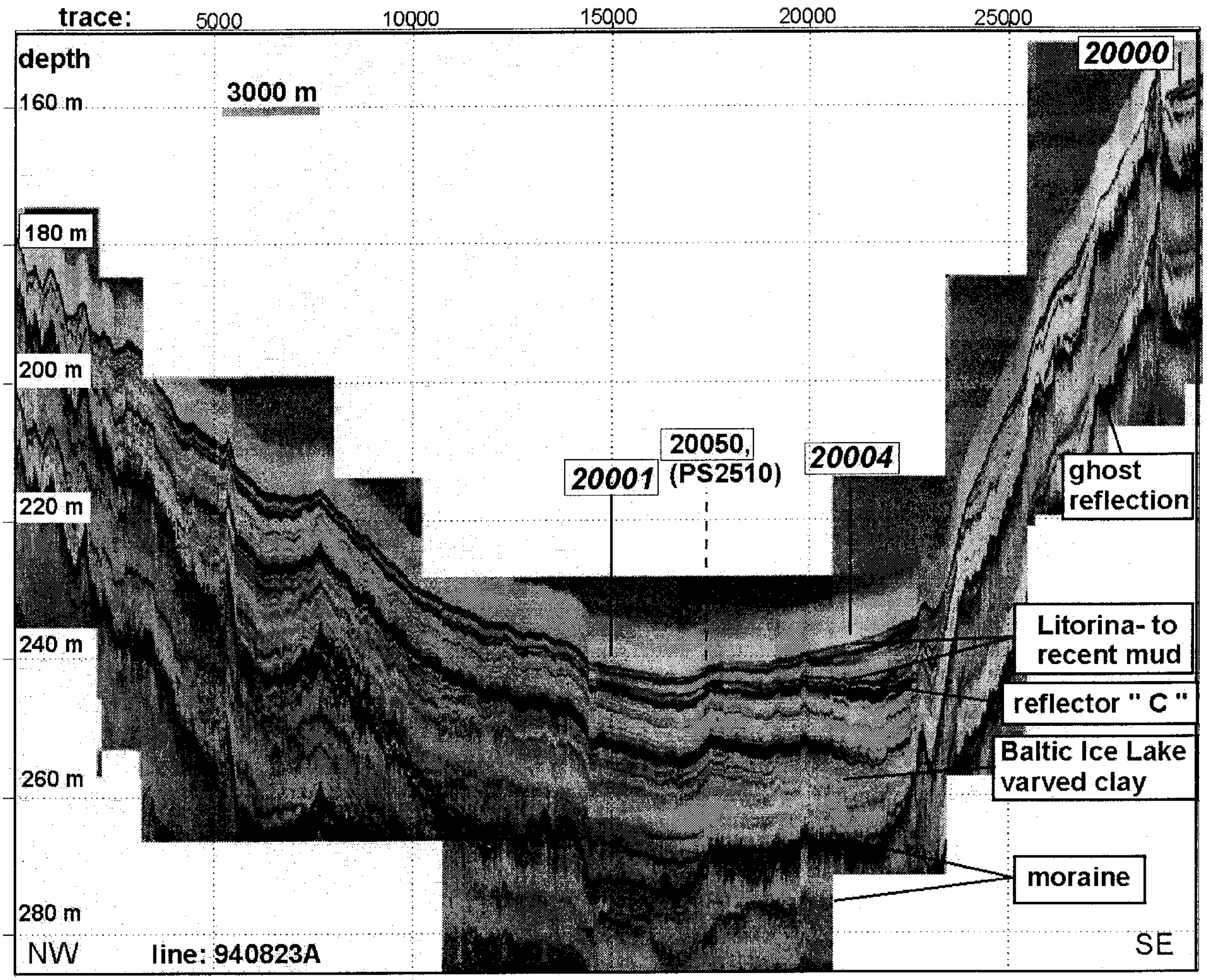



Figure 1: Environmental interpretation (right hand part) based on WNW-ESE GeoChirp subbottom profiling line 960823A across the Gotland Basin. The stratigraphy is based on core correlations. For location of profiling line see ENDLER (this volume).

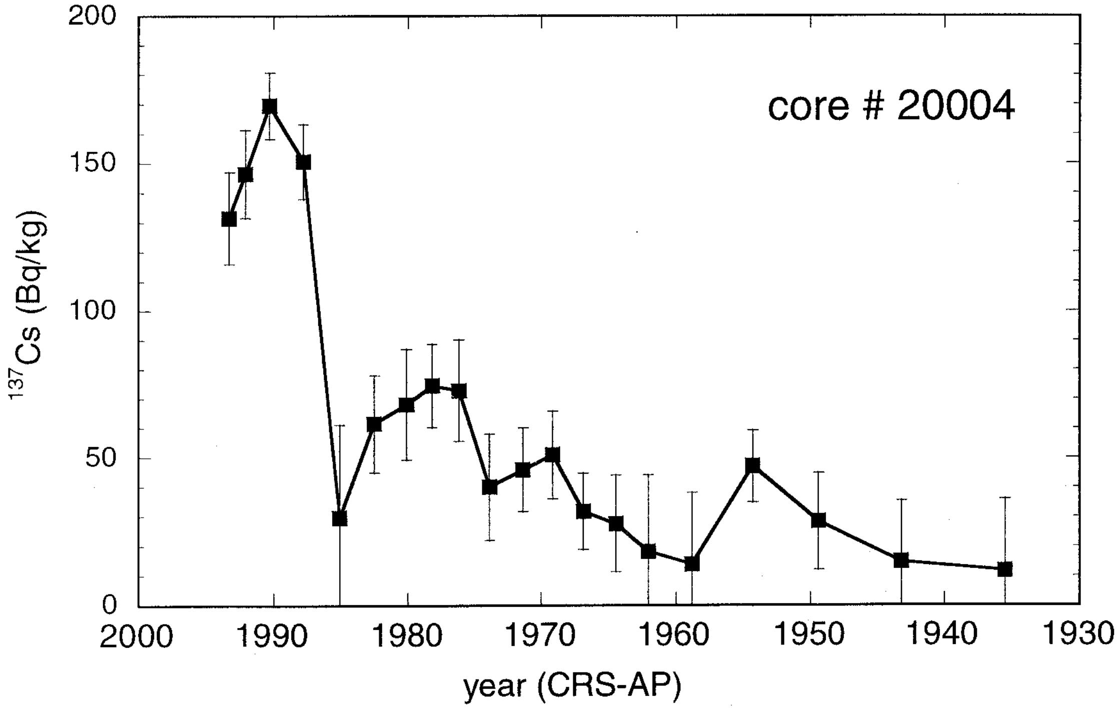
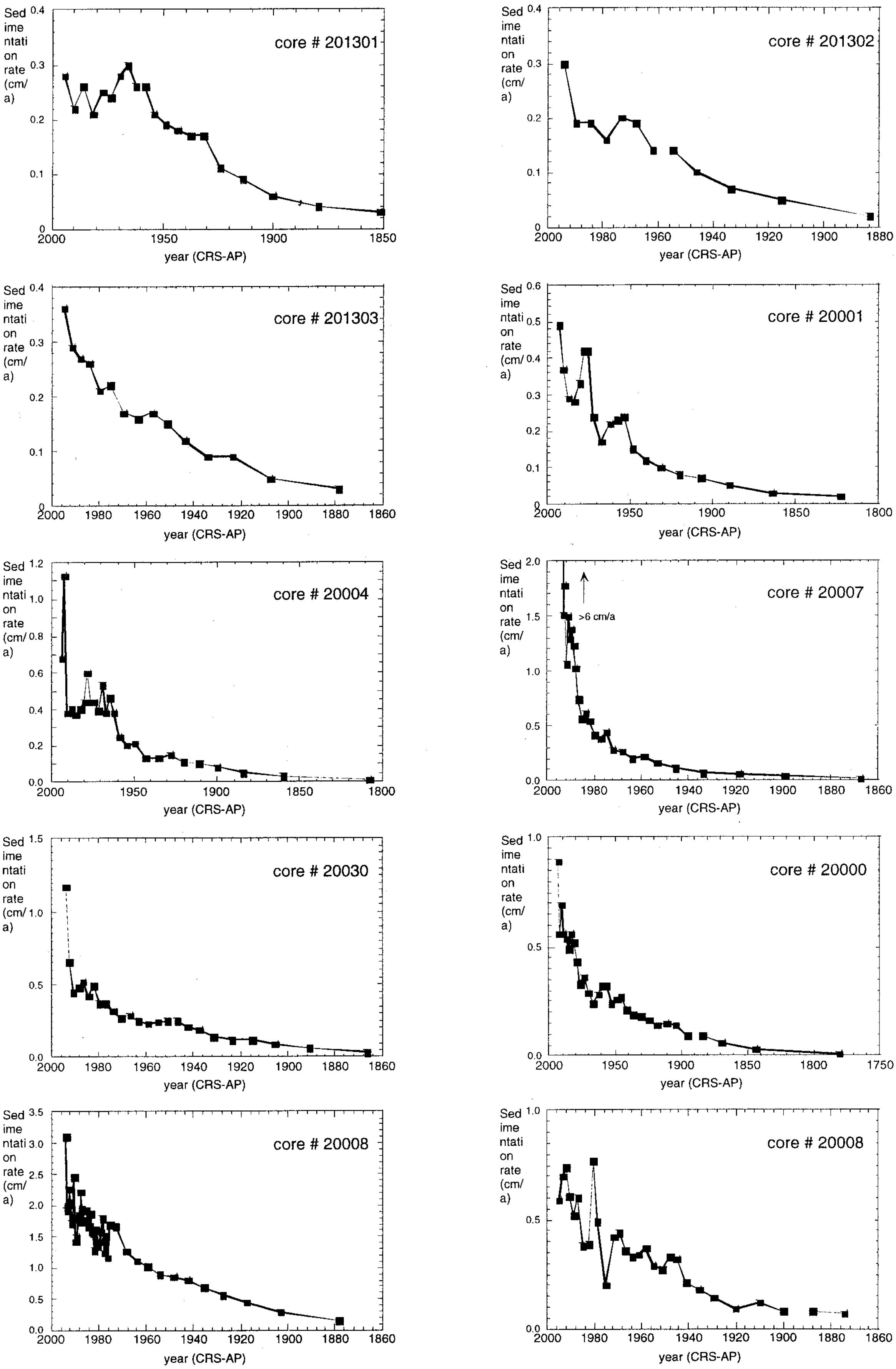



Figure 2: Downcore variations in $^{137}Cs$ activity in core 20004.

At the deep basin stations, recent sedimentation rates range from 2 to 6-7 mm $a^{-1}$ (Figure 3) and the sediments accumulate with rates varying between 220 and 600 g $m^{-2}$ $a^{-1}$ (Appendix). Stations on the steep eastern slope of Gotland Basin have disturbances in the depth profiles of both $^{210}Pb$ and $^{137}Cs$ activity in the upper centimeters of the sediment There is no decrease in $^{210}Pb$ activity suggesting sediment mixing and the $^{137}Cs$ activity increases towards the top which indicates that the mixed layer is settled from suspension. Further, grain-size analysis from station 20000 corroborate such observations in that a general fining-upward sequence in the upper layer is abruptly interrupted twice by sediment coarsening. These observations together indicate that the sediment disturbance is not due to bioturbation but caused by physical mixing processes. The Chernobyl peak in the $^{137}Cs$ distribution is displaced with depth indicating that the disturbance has taken place in recent years. Fitting the $^{210}Pb$ profile below the disturbed interval suggests accumulation rates of 900-1100 g $m^{-2}$ $a^{-1}$ and sedimentation rates of 5-7 mm $a^{-1}$.

Figure 3 (following page): Sedimentation rate variabilities in the short GOBEX cores. Note that the Y-axes have different scales!.



Station 20008 in a small intraslope basin (68 m water depth) has uncharacteristically high sedimentation and accumulation rates: The data suggest that the sediment accumulates at a rate of 6100 g $m^{-2}$ $a^{-1}$ and has a sedimentation rate of 20 mm $a^{-1}$. Using wave prediction formula, storm with winds from the west in the area of this intraslope basin may reach the following characteristics : height ~5 m, length ~100 m and period ~8 s. Near-bottom maximum orbital velocities for such waves in areas with a depth of 40-50 m can reach 20-30 cm $s^{-1}$. Such orbital velocities exceed the threshold velocity for grains with sizes of up to 60 µm (CHRISTIANSEN and EMELYANOV, 1995). Therefore, the very high sedimentation rate in the basin most probably reflects intensive shallow water erosion along the rim of the basin. For comparison, high sedimentation rates (10-12 mm $a^{-1}$) were also observed at the relatively shallow water station (GOBEX #201308) in the Gdansk Basin. Here the sediments accumulate with rates of 1000 g $m^{-2}$ $a^{-1}$.

## Short term accumulation rates from suspended matter

Sedimentation fluxes in the trap during 36 hour periods (CHRISTIANSEN et al., submitted) fluctuated strongly between 14 and 676 mg $m^{-2}$ $d^{-1}$ (Table 2) with an average rate of 151 mg $m^{-2}$ $d^{-1}$. Previously, also from sediment trap studies, SAARSO (1995) observed that at the clear-water layer (90-120 m) just above the benthic nepheloid layer the sedimentation flux of the sedimentary matter was 294 mg $m^{-2}$ $d^{-1}$ in summer and 93.5 mg $m^{-2}$ $d^{-1}$ in winter. So, taking the present relatively short observation period as representative for a year, a sedimentation flux of 51 g $m^{-2}$ $a^{-1}$ is deduced.

Table 2: Sedimentation flux rates from traps measured in 36 hour periods from 23. Februar to 23. March 1995 (CHRISTIANSEN et al., submitted).

| Sample No | Date | Period (hours) | Total flux mg $m^{-2}$ $d^{-1}$ |
|---|---|---|---|
| 1 | 23.2.95 | 36 | 124 |
| 2 | | 72 | 105 |
| 3 | | 108 | 305 |
| 4 | | 144 | 40 |
| 5 | | 180 | 85 |
| 6 | | 216 | 92 |
| 7 | | 252 | 49 |
| 8 | | 288 | 45 |
| 9 | | 324 | 34 |
| 10 | | 360 | 14 |
| 11 | | 396 | 273 |
| 12 | | 432 | 102 |
| 13 | | 468 | 62 |
| 14 | | 504 | 143 |
| 15 | | 540 | 188 |
| 16 | | 576 | 676 |
| 17 | | 612 | 285 |
| 18 | | 648 | 110 |
| 19 | | 684 | 209 |
| 20 | 23.3.95 | 720 | 81 |
| | | Min. | 14 |
| | | Max. | 676 |
| | | Average | 151 |

Following CHRISTIANSEN et al. (submitted) and SIVKOV et al. (this volume) the vertical distribution

$$C_z = C_0 e^{-\alpha z}$$

of total particulate matter (TPM) is characterized by an exponential profile:

where $\alpha = w_s/\mathcal{D}_v$; $w_s$= settling velocity; $\mathcal{D}_v$= vertical turbulent eddy diffusivity; $C$= TPM concentration and z= vertical coordinate pointing upward.

By regression analysis of TPM data from the Gotland Deep observed during the last decade (CHRISTIANSEN et al., submitted) the following exponential equation was derived: $C_z = 0.92e^{-0.012z}$ ($R^2$= 0.45).

Taking $\mathcal{D}_v$ as equal to 1 and 2 $cm^2$ $s^{-1}$ (RAHM, 1985), it then follows that the average perennial sedimentation flux of TPM at the bottom ($w_s c_0$) ranges from 92 to 184 mg $m^{-2} d^{-1}$. Assuming the average density of surficial deposits (ρ) as being equal to $1.2 \cdot 10^6$ g $m^{-3}$ , we may obtain the rate of sedimentation from TPM data ($\mathcal{W}$):

$\mathcal{W} = w_s c_0/\rho \bullet$ 0.03-0.06 (mm $a^{-1}$).

## Discussion

Deep basin sedimentation rates from datings are an order of magnitude higher than can be estimated from sediment trap fluxes and water column particulate matter concentrations. This indicates that a substantial amount of the material deposited on the deep basin sea floor is derived from near bottom lateral advection

Table 3: 210-Pb dating results for the multicores taken during GOBEX.

| Core | Average sedimentation rate (mm $a^{-1}$) | Average sediment accumulation rate (g $m^{-2}$ $a^{-1}$) | Remarks |
|---|---|---|---|
| 20001 | 2.1 ± 0.1 | 322 ± 79 | |
| 20004 | 2.5 ± 0.1 | 279 ± 37 | |
| 20007 | 4.3 ± 0.6 | 238 ± 19 | Disturbed surface |
| 20000 | 2.5 ± 0.5 | 340 ± 30 | Disturbed surface |
| 20030 | 3.5 ± 0.3 | 399 ± 32 | Disturbed surface |
| 20008 | 30 ± 6 | 6099 ± 1860 | Very high rate |
| 201301 | 1.6±0.2 | 350±46 | |
| 201302 | 1.7±0.1 | 226±83 | |
| 201303 | 1.6±0.1 | 259±26 | |
| 201308 | 4.7±0.7 | 966±131 | |

Recent net sedimentation rates from the present study generally are increasing and seem to be about 2 times higher than observed from $^{210}$Pb datings 20-25 years ago (IGNATIUS et al., 1971; NIEMISTÖ and VOIPIO, 1974). The present study thereby corroborates the findings by JONSSON et al. (1990) from varve counting in recent laminated sediments. A number of factors may explain this increase in sedimentation rate: 1) It may be quite accidental in that only a few number of datings are involved and the regional variability seems to be high. 2) An increase in organic matter is observed in the upper parts of the present cores (see also CHRISTIANSEN and KUNZENDORF, 1996; NEUMANN et al., 1997). Such observations corroborate the estimates made by JONSSON and CARMAN (1994) that in general, a more than 1.7-fold increase in sediment organic matter content has taken place in the Baltic proper between the late 1920's and the late 1980's. This may be explained by higher primary production in connection with the present eutrophication. ROSENBERG et al. (1990) observed that winter nutrient concentrations in the Gotland Deep increased by a factor 2-3 in the period from 1970 to 1990. 3) A recent 16 year long period of bottom water anoxia (MATTHÄUS and LASS, 1995) may have contributed to better preservation of organic matter and authigenetic mineral production (NEUMANN et al., 1997).

4) Erosion of shallow water sediments seems to be the major source for additional sedimentation in the Gotland Basin. In their nutrient budget for the Baltic proper, JONSSON et al. (1990) found that as much as 85% of the organic matter and nutrients sequestered in the laminated sediments in the Baltic deeps may have originated from shallow water erosion. Such observations have been corroborated by resuspension studies (CHRISTIANSEN and EMELYANOV, 1995). Shallow-water erosion may have been enhanced in recent years. This is apparently the case in the southern Kattegat where a shift in the wind regime has caused increased coastal and shallow water erosion (CHRISTIANSEN et al., 1993) and induced higher sedimentation rates since the beginning of the 1970'ies (CHRISTIANSEN et al., 1996). It should also be mentioned that the number of storm surges at the German Baltic coast has increased in the last decades (BAERENS and HUPFER, 1995).

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**Appendix**

Data tables of results for all short cores dated during GOBEX (also reproduced on CD-ROM as Excel 97 files)

Gamma Dating Center SYSTEM0

Core: **GOBEX798 (IOW #20000) core taken: August 1994**

Date: 971029

| Depth (mm) | Pb-210tot (Bq/kg) | s (%) | Pb-210sup (Bq/kg) | s (%) | Pb-210uns (Bq/kg) | s (%) | Cs-137 (Bq/kg) | s (%) |
|---|---|---|---|---|---|---|---|---|
| 5 | 536.4 | 11.3 | 78.5 | 36.0 | 457.8 | 37.8 | 249.4 | 10.4 |
| 15 | 554.7 | 9.6 | 78.9 | 26.4 | 475.8 | 28.1 | 245.8 | 10.2 |
| 25 | 560.3 | 11.4 | 82.6 | 34.1 | 477.7 | 36.0 | 209.9 | 10.6 |
| 35 | 558.8 | 13.0 | 84.0 | 40.9 | 474.8 | 42.9 | 210.0 | 10.9 |
| 45 | 550.9 | 11.0 | 64.4 | 57.6 | 486.5 | 58.7 | 148.0 | 10.8 |
| 55 | 525.6 | 9.8 | 78.6 | 27.4 | 446.9 | 29.1 | 150.2 | 10.4 |
| 65 | 547.3 | 10.6 | 73.8 | 37.0 | 473.5 | 38.5 | 179.3 | 10.5 |
| 75 | 481.1 | 15.7 | 88.5 | 39.9 | 392.6 | 42.9 | 220.2 | 10.9 |
| 85 | 554.3 | 11.4 | 73.9 | 28.3 | 480.4 | 30.6 | 275.3 | 10.3 |
| 95 | 610.0 | 12.0 | 80.0 | 39.0 | 530.0 | 40.8 | 182.9 | 10.9 |
| 105 | 519.2 | 11.0 | 81.4 | 30.3 | 437.8 | 32.2 | 133.8 | 10.7 |
| 115 | 598.6 | 9.4 | 76.7 | 30.3 | 521.9 | 31.7 | 100.7 | 10.8 |
| 125 | 601.8 | 9.3 | 71.8 | 35.1 | 530.0 | 36.3 | 89.8 | 11.1 |
| 135 | 456.8 | 13.9 | 78.0 | 42.9 | 378.7 | 45.1 | 76.2 | 13.1 |
| 145 | 364.1 | 13.0 | 78.7 | 33.1 | 285.4 | 35.6 | 67.8 | 12.1 |
| 155 | 303.1 | 19.3 | 69.5 | 58.6 | 233.6 | 61.7 | 51.3 | 14.1 |
| 165 | 347.7 | 12.1 | 72.3 | 33.1 | 275.5 | 35.3 | 47.0 | 12.3 |
| 175 | 293.6 | 13.0 | 77.8 | 28.3 | 215.8 | 31.2 | 34.9 | 13.0 |
| 185 | 266.9 | 13.9 | 80.8 | 26.4 | 186.1 | 29.9 | 26.2 | 14.1 |
| 195 | 278.9 | 13.0 | 78.1 | 26.4 | 200.8 | 29.5 | 15.6 | 16.4 |
| 205 | 247.6 | 17.5 | 67.9 | 47.8 | 179.8 | 50.9 | 13.9 | 21.5 |
| 255 | 171.0 | 17.5 | 82.4 | 24.6 | 88.5 | 30.1 | 10.3 | 18.9 |
| 305 | 125.7 | 21.2 | 76.3 | 27.4 | 49.4 | 34.6 | 7.8 | 20.6 |

| Slice measured | Depth Top (cm) | Depth Bottom (cm) | Slice Depth (cm) | Year (CRS-AP) | Sed.rate (cm/a) | Accu.rate ($g/m^2/a$) | Dry weight (g) | Rhob ($g/cm^3$) | Pb-210uns (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|
| * | 0 | 1 | 0.5 | 1993.4 | 0.89 | 1268.0 | 11.14 | 0.142 | 457.8 |
| * | 1 | 2 | 1.5 | 1992.0 | 0.56 | 1155.8 | 16.21 | 0.206 | 475.8 |
| * | 2 | 3 | 2.5 | 1990.4 | 0.69 | 1101.4 | 12.56 | 0.160 | 477.7 |
| * | 3 | 4 | 3.5 | 1988.8 | 0.56 | 1050.0 | 14.65 | 0.187 | 474.8 |
| * | 4 | 5 | 4.5 | 1986.9 | 0.54 | 968.8 | 14.11 | 0.180 | 486.5 |
| * | 5 | 6 | 5.5 | 1985.0 | 0.49 | 991.3 | 15.99 | 0.204 | 446.9 |
| * | 6 | 7 | 6.5 | 1983.1 | 0.56 | 886.6 | 12.36 | 0.157 | 473.5 |
| * | 7 | 8 | 7.5 | 1981.2 | 0.52 | 1008.6 | 15.32 | 0.195 | 392.6 |
| * | 8 | 9 | 8.5 | 1979.1 | 0.43 | 768.9 | 13.96 | 0.178 | 480.4 |
| * | 9 | 10 | 9.5 | 1976.4 | 0.33 | 637.0 | 15.12 | 0.193 | 530.0 |
| * | 10 | 11 | 10.5 | 1973.5 | 0.36 | 709.5 | 15.55 | 0.198 | 437.8 |
| * | 11 | 12 | 11.5 | 1970.4 | 0.29 | 537.3 | 14.60 | 0.186 | 521.9 |
| * | 12 | 13 | 12.5 | 1966.6 | 0.24 | 468.7 | 15.21 | 0.194 | 530.0 |
| * | 13 | 14 | 13.5 | 1962.8 | 0.28 | 590.9 | 16.41 | 0.209 | 378.7 |
| * | 14 | 15 | 14.5 | 1959.5 | 0.32 | 715.4 | 17.34 | 0.221 | 285.4 |
| * | 15 | 16 | 15.5 | 1956.3 | 0.32 | 796.1 | 19.65 | 0.250 | 233.6 |
| * | 16 | 17 | 16.5 | 1952.7 | 0.24 | 598.8 | 19.22 | 0.245 | 275.5 |
| * | 17 | 18 | 17.5 | 1948.8 | 0.26 | 683.8 | 20.34 | 0.259 | 215.8 |
| * | 18 | 19 | 18.5 | 1945.1 | 0.27 | 711.8 | 20.48 | 0.261 | 186.1 |
| * | 19 | 20 | 19.5 | 1940.8 | 0.21 | 573.5 | 21.74 | 0.277 | 200.8 |
| * | 20 | 21 | 20.5 | 1935.7 | 0.19 | 549.2 | 23.01 | 0.293 | 179.8 |
| | 21 | 22 | 21.5 | 1930.3 | 0.18 | 529.2 | 23.17 | 0.295 | 159.0 |
| | 22 | 23 | 22.5 | 1924.3 | 0.16 | 504.7 | 25.38 | 0.323 | 139.0 |
| | 23 | 24 | 23.5 | 1917.6 | 0.14 | 484.4 | 26.53 | 0.338 | 119.0 |
| | 24 | 25 | 24.5 | 1910.7 | 0.15 | 479.4 | 25.93 | 0.330 | 99.0 |
| * | 25 | 26 | 25.5 | 1903.8 | 0.14 | 440.7 | 24.10 | 0.307 | 88.5 |
| | 26 | 27 | 26.5 | 1894.8 | 0.09 | 363.8 | 31.22 | 0.398 | 80.0 |
| | 27 | 28 | 27.5 | 1883.6 | 0.09 | 297.2 | 26.97 | 0.343 | 72.0 |
| | 28 | 29 | 28.5 | 1868.9 | 0.06 | 214.9 | 30.15 | 0.384 | 64.0 |
| | 29 | 30 | 29.5 | 1843.9 | 0.03 | 120.8 | 30.39 | 0.387 | 57.0 |
| * | 30 | 31 | 30.5 | 1780.5 | 0.01 | 35.2 | 26.25 | 0.334 | 49.4 |

Gamma Dating Center SYSTEM0
Core: **GOBEX799 (IOW #20001) core taken: August 1994**
Date: 971030

| Depth (mm) | Pb-210tot (Bq/kg) | s (%) | Pb-210sup (Bq/kg) | s (%) | Pb-210uns (Bq/kg) | s (%) | Cs-137 (Bq/kg) | s (%) |
|---|---|---|---|---|---|---|---|---|
| 5 | 1124.7 | 15.7 | 197.9 | 41.9 | 926.7 | 44.7 | 127.2 | 16.4 |
| 15 | 1171.2 | 15.7 | 137.3 | 54.7 | 1033.8 | 56.9 | 151.0 | 14.9 |
| 25 | 1301.6 | 9.9 | 104.2 | 43.9 | 1197.4 | 45.0 | 171.2 | 11.6 |
| 35 | 1114.8 | 11.0 | 160.2 | 27.4 | 954.6 | 29.5 | 113.0 | 12.9 |
| 45 | 875.7 | 14.8 | 202.4 | 25.5 | 673.4 | 29.5 | 67.8 | 18.0 |
| 55 | 807.7 | 9.9 | 333.1 | 11.2 | 474.6 | 15.0 | 45.5 | 14.1 |
| 65 | 645.0 | 10.6 | 300.3 | 11.6 | 344.7 | 15.7 | 43.6 | 14.1 |
| 75 | 546.9 | 10.7 | 133.8 | 19.1 | 413.1 | 21.9 | 44.4 | 13.5 |
| 85 | 645.0 | 9.9 | 113.8 | 22.7 | 531.2 | 24.8 | 33.6 | 14.1 |
| 95 | 518.6 | 10.9 | 138.5 | 18.2 | 380.1 | 21.2 | 26.6 | 15.6 |
| 105 | 389.5 | 10.3 | 127.8 | 14.0 | 261.7 | 17.3 | 2.3 | 29.7 |
| 115 | 297.9 | 11.3 | 118.7 | 14.0 | 179.1 | 18.0 | 2.0 | 29.7 |
| 125 | 322.6 | 10.2 | 117.2 | 14.0 | 205.4 | 17.3 | 10.7 | 18.0 |
| 135 | 343.7 | 13.0 | 133.8 | 19.1 | 209.9 | 23.1 | 10.7 | 21.5 |
| 145 | 293.0 | 12.1 | 127.2 | 15.6 | 165.8 | 19.8 | 12.6 | 18.0 |
| 155 | 332.7 | 12.2 | 181.0 | 13.2 | 151.8 | 18.0 | 21.9 | 14.9 |
| 165 | 246.2 | 12.2 | 137.6 | 12.5 | 108.7 | 17.5 | 12.4 | 16.4 |
| 175 | 235.7 | 13.0 | 130.6 | 11.9 | 105.1 | 17.7 | 7.9 | 19.7 |
| 185 | 212.1 | 13.0 | 133.4 | 12.5 | 78.7 | 18.0 | 9.7 | 17.2 |
| 205 | 208.0 | 12.2 | 137.8 | 11.4 | 70.2 | 16.7 | 7.8 | 18.9 |
| 255 | 202.9 | 12.2 | 124.0 | 13.1 | 78.9 | 17.9 | 8.5 | 18.9 |
| 305 | 213.7 | 12.2 | 136.7 | 11.8 | 76.9 | 17.0 | 8.8 | 18.0 |

| Slice measured | Depth Top (cm) | Depth Bottom (cm) | Slice Depth (cm) | Year (CRS-AP) | Sed.rate (cm/a) | Accu.rate ($g/m^2/a$) | Dry weight (g) | Rhob ($g/cm^3$) | Pb-210uns (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|
| * | 0 | 1 | 0.5 | 1993.0 | 0.49 | 304.6 | 4.87 | 0.062 | 926.7 |
| * | 1 | 2 | 1.5 | 1990.6 | 0.37 | 251.8 | 5.35 | 0.068 | 1033.8 |
| * | 2 | 3 | 2.5 | 1987.5 | 0.29 | 196.0 | 5.40 | 0.069 | 1197.4 |
| * | 3 | 4 | 3.5 | 1984.0 | 0.28 | 221.1 | 6.24 | 0.079 | 954.6 |
| * | 4 | 5 | 4.5 | 1980.6 | 0.33 | 286.2 | 6.86 | 0.087 | 673.4 |
| * | 5 | 6 | 5.5 | 1977.9 | 0.42 | 378.3 | 7.02 | 0.089 | 474.6 |
| * | 6 | 7 | 6.5 | 1975.6 | 0.42 | 485.3 | 8.97 | 0.114 | 344.7 |
| * | 7 | 8 | 7.5 | 1972.3 | 0.24 | 358.7 | 11.67 | 0.149 | 413.1 |
| * | 8 | 9 | 8.5 | 1967.4 | 0.17 | 236.5 | 10.69 | 0.136 | 531.2 |
| * | 9 | 10 | 9.5 | 1962.2 | 0.22 | 289.8 | 10.28 | 0.131 | 380.1 |
| * | 10 | 11 | 10.5 | 1957.8 | 0.23 | 371.6 | 12.43 | 0.158 | 261.7 |
| * | 11 | 12 | 11.5 | 1953.6 | 0.24 | 480.3 | 15.83 | 0.202 | 179.1 |
| * | 12 | 13 | 12.5 | 1948.1 | 0.15 | 345.4 | 18.50 | 0.236 | 205.4 |
| * | 13 | 14 | 13.5 | 1940.4 | 0.12 | 267.2 | 17.86 | 0.227 | 209.9 |
| * | 14 | 15 | 14.5 | 1931.3 | 0.10 | 259.3 | 19.93 | 0.254 | 165.8 |
| * | 15 | 16 | 15.5 | 1920.1 | 0.08 | 203.3 | 20.14 | 0.256 | 151.8 |
| * | 16 | 17 | 16.5 | 1907.1 | 0.07 | 200.2 | 21.12 | 0.269 | 108.7 |
| * | 17 | 18 | 17.5 | 1890.1 | 0.05 | 126.4 | 20.34 | 0.259 | 105.1 |
| * | 18 | 19 | 18.5 | 1864.1 | 0.03 | 85.1 | 21.10 | 0.269 | 78.7 |
|  | 19 | 20 | 19.5 | 1823.0 | 0.02 | 52.0 | 20.69 | 0.263 | 50.0 |

| Gamma | Dating | Center | SYSTEM0 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Core: | **GOBEX802 (IOW #20004) core taken: August 1994** | | | | | | | | |
| Date: | 971030 | | | | | | | | |
| Depth (mm) | Pb-210tot (Bq/kg) | s (%) | Pb-210sup (Bq/kg) | s (%) | Pb-210uns (Bq/kg) | s (%) | Cs-137 (Bq/kg) | s (%) | |
| 5 | 1038.5 | 15.7 | 97.1 | 71.5 | 941.4 | 73.2 | 131.5 | 15.6 | |
| 15 | 1152.1 | 14.8 | 123.2 | 52.7 | 1028.9 | 54.7 | 146.4 | 14.9 | |
| 25 | 1255.5 | 9.2 | 91.1 | 38.0 | 1164.4 | 39.1 | 169.5 | 11.2 | |
| 35 | 1157.9 | 11.3 | 112.0 | 37.0 | 1045.8 | 38.7 | 150.6 | 12.7 | |
| 45 | 1056.0 | 13.0 | 129.7 | 34.1 | 926.2 | 36.5 | 29.5 | 31.6 | |
| 55 | 986.1 | 11.4 | 108.6 | 37.0 | 877.6 | 38.7 | 61.5 | 16.4 | |
| 65 | 891.9 | 14.8 | 154.8 | 31.2 | 737.2 | 34.5 | 68.1 | 18.9 | |
| 75 | 688.8 | 13.9 | 192.0 | 19.1 | 496.8 | 23.6 | 74.5 | 14.1 | |
| 85 | 867.8 | 15.7 | 127.0 | 43.9 | 740.8 | 46.6 | 72.9 | 17.2 | |
| 95 | 593.2 | 13.0 | 99.3 | 35.1 | 493.9 | 37.4 | 40.0 | 18.0 | |
| 105 | 619.7 | 11.1 | 100.0 | 28.3 | 519.6 | 30.4 | 45.9 | 14.1 | |
| 115 | 530.8 | 13.9 | 111.2 | 29.3 | 419.6 | 32.4 | 51.0 | 14.9 | |
| 125 | 483.2 | 9.6 | 110.2 | 15.6 | 373.0 | 18.3 | 31.7 | 13.0 | |
| 135 | 379.8 | 13.9 | 114.1 | 21.8 | 265.7 | 25.8 | 27.6 | 16.4 | |
| 145 | 412.6 | 18.4 | 115.7 | 31.2 | 296.9 | 36.2 | 18.2 | 26.0 | |
| 155 | 365.2 | 13.9 | 122.8 | 19.1 | 242.4 | 23.6 | 13.9 | 24.2 | |
| 165 | 347.7 | 12.1 | 72.3 | 33.1 | 275.5 | 35.3 | 47.0 | 12.3 | |
| 205 | 347.8 | 12.2 | 135.9 | 16.4 | 211.9 | 20.5 | 28.3 | 16.4 | |
| 265 | 199.8 | 15.7 | 128.3 | 15.6 | 71.6 | 22.1 | 14.8 | 20.6 | |
| 326 | 196.4 | 21.2 | 145.0 | 14.0 | 51.4 | 25.4 | 11.8 | 24.2 | |
| Slice measured | Depth Top (cm) | Depth Bottom (cm) | Slice Depth (cm) | Year (CRS-AP) | Sed.rate (cm/a) | Accu.rate (g/m$^2$/a) | Dry weight (g) | Rhob (g/cm$^3$) | Pb-210uns (Bq/kg) |
| * | 0 | 1 | 0.5 | 1993.3 | 0.68 | 431.2 | 4.87 | 0.062 | 926.7 |
| * | 1 | 2 | 1.5 | 1992.1 | 1.13 | 384.0 | 5.35 | 0.068 | 1033.8 |
| * | 2 | 3 | 2.5 | 1990.3 | 0.38 | 313.8 | 5.40 | 0.069 | 1197.4 |
| * | 3 | 4 | 3.5 | 1987.8 | 0.40 | 323.9 | 6.24 | 0.079 | 954.6 |
| * | 4 | 5 | 4.5 | 1985.1 | 0.37 | 337.1 | 6.86 | 0.087 | 673.4 |
| * | 5 | 6 | 5.5 | 1982.5 | 0.40 | 330.1 | 7.02 | 0.089 | 474.6 |
| * | 6 | 7 | 6.5 | 1980.1 | 0.44 | 366.8 | 8.97 | 0.114 | 344.7 |
| * | 7 | 8 | 7.5 | 1978.2 | 0.60 | 517.3 | 11.67 | 0.149 | 413.1 |
| * | 8 | 9 | 8.5 | 1976.2 | 0.44 | 323.8 | 10.69 | 0.136 | 531.2 |
| * | 9 | 10 | 9.5 | 1973.9 | 0.44 | 453.4 | 10.28 | 0.131 | 380.1 |
| * | 10 | 11 | 10.5 | 1971.4 | 0.39 | 398.8 | 12.43 | 0.158 | 261.7 |
| * | 11 | 12 | 11.5 | 1969.2 | 0.53 | 466.2 | 15.83 | 0.202 | 179.1 |
| * | 12 | 13 | 12.5 | 1966.9 | 0.38 | 485.0 | 18.50 | 0.236 | 205.4 |
| * | 13 | 14 | 13.5 | 1964.5 | 0.46 | 637.5 | 17.86 | 0.227 | 209.9 |
| * | 14 | 15 | 14.5 | 1962.1 | 0.38 | 526.9 | 19.93 | 0.254 | 165.8 |
| * | 15 | 16 | 15.5 | 1958.8 | 0.25 | 573.8 | 20.14 | 0.256 | 151.8 |
| * | 16 | 17 | 16.5 | 1954.3 | 0.20 | 437.1 | 21.12 | 0.269 | 108.7 |
| * | 17 | 18 | 17.5 | 1949.4 | 0.21 | 402.7 | 20.34 | 0.259 | 105.1 |
| * | 18 | 19 | 18.5 | 1943.2 | 0.13 | 345.3 | 21.10 | 0.269 | 78.7 |
| | 19 | 20 | 19.5 | 1935.5 | 0.13 | 296.8 | 20.69 | 0.263 | 50.0 |
| * | 20 | 21 | 20.5 | 1928.4 | 0.15 | 268.0 | | | |
| | 21 | 22 | 21.5 | 1920.6 | 0.11 | 232.4 | | | |
| | 22 | 23 | 22.5 | 1910.9 | 0.10 | 196.8 | | | |
| | 23 | 24 | 23.5 | 1899.7 | 0.08 | 162.2 | | | |
| | 24 | 25 | 24.5 | 1884.2 | 0.05 | 117.7 | | | |
| * | 25 | 26 | 25.5 | 1859.9 | 0.03 | 79.5 | | | |
| | 26 | 27 | 26.5 | 1807.8 | 0.01 | 33.5 | | | |

Gamma Dating Center SYSTEM0
Core: **GOBEX805 (IOW #20007) core taken: August 1994**
Date: 971030

| Depth (mm) | Pb-210tot (Bq/kg) | s (%) | Pb-210sup (Bq/kg) | s (%) | Pb-210uns (Bq/kg) | s (%) | Cs-137 (Bq/kg) | s (%) |
|---|---|---|---|---|---|---|---|---|
| 5 | 162.0 | 34.7 | 244.5 | 201.2 | | | 96.6 | 23.3 |
| 15 | 464.2 | 23.1 | 125.1 | 300.1 | 339.1 | 301.0 | | |
| 25 | 891.9 | 16.6 | 242.3 | 31.2 | 649.7 | 35.3 | 121.6 | 16.4 |
| 35 | 778.5 | 17.5 | 221.9 | 46.8 | 556.7 | 50.0 | 113.1 | 18.0 |
| 45 | 959.8 | 13.9 | 266.9 | 45.8 | 692.9 | 47.9 | 105.1 | 15.6 |
| 55 | 857.1 | 17.5 | 197.9 | 55.7 | 659.3 | 58.3 | 111.8 | 18.0 |
| 65 | 727.2 | 16.6 | 174.2 | 33.1 | 553.0 | 37.0 | 69.7 | 18.0 |
| 75 | 908.3 | 16.6 | 257.8 | 49.8 | 650.5 | 52.4 | 269.8 | 16.4 |
| 85 | 899.7 | 16.6 | 273.9 | 60.6 | 625.9 | 62.8 | 122.2 | 16.4 |
| 95 | 737.5 | 15.7 | 149.9 | 47.8 | 587.5 | 50.3 | 159.0 | 13.5 |
| 155 | 772.5 | 13.0 | 198.2 | 24.6 | 574.3 | 27.8 | 66.7 | 16.4 |
| 205 | 606.0 | 11.6 | 148.3 | 18.2 | 457.6 | 21.6 | 30.2 | 18.9 |
| 255 | 311.3 | 12.2 | 116.9 | 14.0 | 194.4 | 18.6 | 12.9 | 20.6 |
| 315 | 205.4 | 22.1 | 146.7 | 22.7 | 58.7 | 31.7 | 11.8 | 31.6 |

| Slice measured | Depth Top (cm) | Depth Bottom (cm) | Slice Depth (cm) | Year (CRS-AP) | Sed.rate (cm/a) | Accu.rate ($g/m^2/a$) | Dry weight (g) | Rhob ($g/cm^3$) | Pb-210uns (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|
| * | 0 | 1 | 0.5 | 1993.9 | 6.66 | 1076.7 | 1.27 | 0.016 | 300.0 |
| * | 1 | 2 | 1.5 | 1993.7 | 4.65 | 946.5 | 1.60 | 0.020 | 339.0 |
| * | 2 | 3 | 2.5 | 1993.3 | 1.51 | 483.8 | 2.52 | 0.032 | 649.7 |
| * | 3 | 4 | 3.5 | 1992.7 | 1.78 | 555.0 | 2.45 | 0.031 | 556.7 |
| * | 4 | 5 | 4.5 | 1991.9 | 1.06 | 433.2 | 3.20 | 0.041 | 692.9 |
| * | 5 | 6 | 5.5 | 1991.1 | 1.50 | 446.0 | 2.33 | 0.030 | 659.3 |
| * | 6 | 7 | 6.5 | 1990.4 | 1.29 | 519.2 | 3.16 | 0.040 | 553.0 |
| * | 7 | 8 | 7.5 | 1989.7 | 1.38 | 431.7 | 2.46 | 0.031 | 650.5 |
| * | 8 | 9 | 8.5 | 1988.9 | 1.23 | 437.5 | 2.80 | 0.036 | 625.9 |
| * | 9 | 10 | 9.5 | 1988.0 | 1.03 | 452.4 | 3.46 | 0.044 | 587.5 |
| * | 10 | 11 | 10.5 | 1986.8 | 0.74 | 439.8 | 4.65 | 0.059 | 580.0 |
| * | 11 | 12 | 11.5 | 1985.3 | 0.57 | 417.0 | 5.75 | 0.073 | 580.0 |
| * | 12 | 13 | 12.5 | 1983.6 | 0.62 | 397.2 | 5.01 | 0.064 | 580.0 |
| * | 13 | 14 | 13.5 | 1981.9 | 0.54 | 378.9 | 5.47 | 0.070 | 575.0 |
| * | 14 | 15 | 14.5 | 1979.8 | 0.42 | 352.8 | 6.58 | 0.084 | 575.0 |
| * | 15 | 16 | 15.5 | 1977.3 | 0.38 | 326.5 | 6.75 | 0.086 | 574.3 |
| * | 16 | 17 | 16.5 | 1974.8 | 0.44 | 318.2 | 5.73 | 0.073 | 550.0 |
| * | 17 | 18 | 17.5 | 1971.9 | 0.28 | 297.4 | 8.44 | 0.107 | 529.0 |
| * | 18 | 19 | 18.5 | 1968.1 | 0.26 | 279.7 | 8.48 | 0.108 | 502.0 |
| | 19 | 20 | 19.5 | 1963.7 | 0.20 | 258.2 | 10.23 | 0.130 | 470.0 |
| * | 20 | 21 | 20.5 | 1958.8 | 0.22 | 231.8 | 8.43 | 0.107 | 457.6 |
| | 21 | 22 | 21.5 | 1953.3 | 0.16 | 220.9 | 11.18 | 0.142 | 400.0 |
| | 22 | 23 | 22.5 | 1945.6 | 0.11 | 197.7 | 13.79 | 0.176 | 350.0 |
| | 23 | 24 | 23.5 | 1933.8 | 0.07 | 157.7 | 18.41 | 0.234 | 300.0 |
| | 24 | 25 | 24.5 | 1918.5 | 0.06 | 127.1 | 15.68 | 0.200 | 250.0 |
| * | 25 | 26 | 25.5 | 1899.1 | 0.04 | 95.2 | 17.21 | 0.219 | 194.4 |
| | 26 | 27 | 26.5 | 1867.5 | 0.02 | 48.3 | 15.26 | 0.194 | 170.0 |

Gamma Dating Center SYSTEM0
Core: **GOBEX806 (IOW #20008) core taken: August 1994**
Date: 971030

| Depth (mm) | Pb-210tot (Bq/kg) | s (%) | Pb-210sup (Bq/kg) | s (%) | Pb-210uns (Bq/kg) | s (%) | Cs-137 (Bq/kg) | s (%) |
|---|---|---|---|---|---|---|---|---|
| 5 | 439.8 | 15.7 | 86.4 | 39.9 | 353.4 | 42.9 | 260.9 | 10.7 |
| 15 | 424.5 | 14.8 | 78.2 | 43.9 | 346.4 | 46.3 | 243.4 | 10.6 |
| 25 | 357.5 | 20.3 | 87.8 | 38.0 | 269.7 | 43.1 | 211.8 | 11.2 |
| 35 | 390.9 | 10.7 | 72.8 | 29.3 | 318.1 | 31.2 | 162.8 | 10.4 |
| 45 | 424.8 | 15.7 | 83.8 | 41.9 | 341.0 | 44.7 | 181.9 | 11.2 |
| 55 | 382.3 | 10.3 | 66.5 | 33.1 | 315.9 | 34.7 | 191.4 | 10.2 |
| 65 | 392.3 | 10.6 | 56.6 | 66.6 | 335.8 | 67.4 | 218.6 | 10.2 |
| 75 | 400.5 | 10.9 | 75.4 | 28.3 | 325.1 | 30.4 | 242.5 | 10.2 |
| 85 | 412.5 | 13.9 | 82.0 | 33.1 | 330.5 | 35.9 | 234.1 | 10.5 |
| 95 | 375.8 | 11.7 | 62.7 | 50.7 | 313.1 | 52.1 | 203.1 | 10.3 |
| 105 | 420.6 | 13.0 | 70.5 | 46.8 | 350.0 | 48.6 | 216.0 | 10.5 |
| 115 | 424.4 | 11.3 | 68.5 | 41.9 | 355.9 | 43.4 | 209.2 | 10.4 |
| 125 | 359.0 | 15.7 | 77.5 | 41.9 | 281.5 | 44.7 | 132.0 | 11.3 |
| 135 | 346.4 | 12.0 | 71.6 | 32.2 | 274.8 | 34.3 | 100.1 | 10.9 |
| 145 | 323.5 | 11.7 | 69.9 | 31.2 | 253.6 | 33.3 | 91.8 | 10.8 |
| 155 | 363.2 | 13.9 | 80.6 | 32.2 | 282.6 | 35.1 | 126.8 | 11.2 |
| 175 | 347.3 | 14.8 | 72.8 | 39.9 | 274.5 | 42.6 | 101.3 | 11.8 |
| 205 | 329.5 | 11.6 | 68.3 | 34.1 | 261.2 | 36.0 | 113.0 | 10.7 |
| 225 | 365.9 | 12.0 | 62.2 | 52.7 | 303.8 | 54.1 | 120.8 | 10.8 |
| 255 | 343.9 | 11.2 | 65.6 | 38.0 | 278.3 | 39.6 | 98.2 | 10.7 |
| 275 | 304.9 | 15.7 | 71.2 | 40.9 | 233.7 | 43.8 | 59.4 | 13.3 |
| 314 | 340.2 | 11.6 | 71.7 | 31.2 | 268.5 | 33.3 | 58.0 | 11.9 |

Gamma Dating Center SYSTEM0
Core: **GOBEX806 (IOW #20008) core taken: August 1994**
Date: 971030

| Slice measured | Depth Top (cm) | Depth Bottom (cm) | Slice Depth (cm) | Year (CRS-AP) | Sed.rate (cm/a) | Accu.rate ($g/m^2/a$) | Dry weight (g) | Rhob ($g/cm^3$) | Pb-210uns (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|
| * | 0 | 1 | 0.5 | 1993.8 | 3.11 | 5753.4 | 14.52 | 0.185 | 353.4 |
| * | 1 | 2 | 1.5 | 1993.4 | 1.92 | 5776.2 | 23.58 | 0.300 | 346.4 |
| * | 2 | 3 | 2.5 | 1992.9 | 2.02 | 7306.3 | 28.40 | 0.362 | 269.7 |
| * | 3 | 4 | 3.5 | 1992.4 | 2.27 | 6110.7 | 21.17 | 0.270 | 318.1 |
| * | 4 | 5 | 4.5 | 1992.0 | 2.05 | 5614.8 | 21.56 | 0.275 | 341.0 |
| * | 5 | 6 | 5.5 | 1991.4 | 1.72 | 5953.3 | 27.14 | 0.346 | 315.9 |
| * | 6 | 7 | 6.5 | 1990.9 | 1.80 | 5505.4 | 24.00 | 0.306 | 335.8 |
| * | 7 | 8 | 7.5 | 1990.4 | 2.46 | 5615.5 | 17.93 | 0.228 | 325.1 |
| * | 8 | 9 | 8.5 | 1989.8 | 1.42 | 5405.0 | 29.94 | 0.381 | 330.5 |
| * | 9 | 10 | 9.5 | 1989.2 | 1.50 | 5589.3 | 29.28 | 0.373 | 313.1 |
| * | 10 | 11 | 10.5 | 1988.6 | 1.86 | 4917.9 | 20.73 | 0.264 | 350.0 |
| * | 11 | 12 | 11.5 | 1988.0 | 1.73 | 4750.6 | 21.62 | 0.275 | 355.9 |
| * | 12 | 13 | 12.5 | 1987.5 | 2.21 | 5922.6 | 21.09 | 0.269 | 281.5 |
| * | 13 | 14 | 13.5 | 1987.0 | 1.94 | 5971.1 | 24.18 | 0.308 | 274.8 |
| * | 14 | 15 | 14.5 | 1986.5 | 1.76 | 6357.9 | 28.34 | 0.361 | 253.6 |
| * | 15 | 16 | 15.5 | 1985.9 | 1.92 | 5614.5 | 22.93 | 0.292 | 282.6 |
|  | 16 | 17 | 16.5 | 1985.4 | 1.93 | 5576.8 | 22.67 | 0.289 | 280.0 |
| * | 17 | 18 | 17.5 | 1984.8 | 1.75 | 5589.2 | 25.06 | 0.319 | 274.5 |
|  | 18 | 19 | 18.5 | 1984.3 | 1.67 | 5578.3 | 26.24 | 0.334 | 270.0 |
|  | 19 | 20 | 19.5 | 1983.7 | 1.87 | 5590.2 | 23.53 | 0.300 | 265.0 |
| * | 20 | 21 | 20.5 | 1983.1 | 1.58 | 5561.7 | 27.72 | 0.353 | 261.2 |
|  | 21 | 22 | 21.5 | 1982.5 | 1.55 | 5274.5 | 26.70 | 0.340 | 270.0 |
| * | 22 | 23 | 22.5 | 1981.8 | 1.28 | 4576.7 | 28.00 | 0.357 | 303.8 |
|  | 23 | 24 | 23.5 | 1981.1 | 1.61 | 4703.4 | 22.97 | 0.292 | 290.0 |
|  | 24 | 25 | 24.5 | 1980.4 | 1.35 | 4761.6 | 27.69 | 0.353 | 280.0 |
| * | 25 | 26 | 25.5 | 1979.7 | 1.42 | 4687.6 | 26.00 | 0.331 | 278.3 |
|  | 26 | 27 | 26.5 | 1979.0 | 1.58 | 5117.6 | 25.38 | 0.323 | 250.0 |
| * | 27 | 28 | 27.5 | 1978.4 | 1.80 | 5381.7 | 23.43 | 0.298 | 233.7 |
|  | 28 | 29 | 28.5 | 1977.7 | 1.24 | 5112.2 | 32.32 | 0.412 | 240.0 |
|  | 29 | 30 | 29.5 | 1977.0 | 1.51 | 4808.8 | 24.95 | 0.318 | 250.0 |
|  | 30 | 31 | 30.5 | 1976.2 | 1.16 | 4682.7 | 31.81 | 0.405 | 250.0 |
| * | 31 | 32 | 31.5 | 1975.5 | 1.69 | 4281.2 | 19.89 | 0.253 | 268.5 |
|  | 32 | 40 | 36 | 1972.8 | 1.67 | 4350.1 |  |  | 230.0 |
|  | 40 | 45 | 42.5 | 1968.4 | 1.27 | 4457.7 |  |  | 200.0 |
|  | 45 | 50 | 47.5 | 1964.2 | 1.11 | 4011.5 |  |  | 195.0 |
|  | 50 | 55 | 52.5 | 1959.5 | 1.02 | 3769.7 |  |  | 180.0 |
|  | 55 | 60 | 57.5 | 1954.3 | 0.89 | 3399.8 |  |  | 170.0 |
|  | 60 | 65 | 62.5 | 1948.6 | 0.86 | 3261.4 |  |  | 150.0 |
|  | 65 | 70 | 67.5 | 1942.6 | 0.81 | 3155.9 |  |  | 130.0 |
|  | 70 | 75 | 72.5 | 1935.8 | 0.69 | 2674.9 |  |  | 125.0 |
| * | 75 | 80 | 77.5 | 1927.7 | 0.56 | 2179.2 |  |  | 120.0 |
|  | 80 | 85 | 82.5 | 1917.6 | 0.44 | 1754.5 |  |  |  |
|  | 85 | 90 | 87.5 | 1903.3 | 0.29 | 1199.6 |  |  |  |
|  | 90 | 95 | 92.5 | 1878.3 | 0.15 | 621.2 |  |  |  |

| Gamma | Dating | Center | SYSTEM0 |
|---|---|---|---|
| Core: | **GOBEX828 (IOW #20030) core taken: August 1994** | | |
| Date: | 971030 | | |

| Depth (mm) | Pb-210tot (Bq/kg) | s (%) | Pb-210sup (Bq/kg) | s (%) | Pb-210uns (Bq/kg) | s (%) | Cs-137 (Bq/kg) | s (%) |
|---|---|---|---|---|---|---|---|---|
| 5 | 515.7 | 13.9 | 89.6 | 37.0 | 426.1 | 39.5 | 255.2 | 10.7 |
| 15 | 498.2 | 8.1 | 68.9 | 21.8 | 429.4 | 23.2 | 243.2 | 10.0 |
| 25 | 533.3 | 11.0 | 73.3 | 41.9 | 460.0 | 43.3 | 230.2 | 10.4 |
| 35 | 519.6 | 13.0 | 77.1 | 43.9 | 442.5 | 45.8 | 209.7 | 10.8 |
| 45 | 496.3 | 13.0 | 78.3 | 41.9 | 418.0 | 43.9 | 424.9 | 10.3 |
| 55 | 505.5 | 13.9 | 84.1 | 39.0 | 421.4 | 41.4 | 146.9 | 11.6 |
| 65 | 492.3 | 12.2 | 75.8 | 39.9 | 416.5 | 41.8 | 108.3 | 11.6 |
| 75 | 509.6 | 13.0 | 95.0 | 28.3 | 414.6 | 31.2 | 98.8 | 12.1 |
| 85 | 513.7 | 12.0 | 65.8 | 56.7 | 447.8 | 57.9 | 92.2 | 11.7 |
| 95 | 507.9 | 13.0 | 81.6 | 37.0 | 426.3 | 39.3 | 80.7 | 12.7 |
| 105 | 507.1 | 11.5 | 69.5 | 45.8 | 437.6 | 47.2 | 72.5 | 12.4 |
| 115 | 452.5 | 15.7 | 74.2 | 50.7 | 378.3 | 53.1 | 80.0 | 13.8 |
| 125 | 450.2 | 12.2 | 74.1 | 37.0 | 376.1 | 39.0 | 76.1 | 12.0 |
| 135 | 403.5 | 10.0 | 72.5 | 27.4 | 331.0 | 29.2 | 58.8 | 11.4 |
| 145 | 321.5 | 12.2 | 78.9 | 28.3 | 242.6 | 30.9 | 41.7 | 13.3 |
| 155 | 310.0 | 13.0 | 81.1 | 28.3 | 229.0 | 31.2 | 29.8 | 14.9 |
| 165 | 247.8 | 13.9 | 72.4 | 32.2 | 175.4 | 35.1 | 20.7 | 16.4 |
| 175 | 242.9 | 13.9 | 65.9 | 40.9 | 177.0 | 43.2 | 14.5 | 18.9 |
| 185 | 243.3 | 13.9 | 75.7 | 28.3 | 167.6 | 31.6 | 14.6 | 18.0 |
| 195 | 244.9 | 13.9 | 76.0 | 28.3 | 168.9 | 31.6 | 17.8 | 16.4 |
| 205 | 216.5 | 19.3 | 56.5 | 89.4 | 159.9 | 91.5 | 11.9 | 24.2 |
| 255 | 193.6 | 17.5 | 84.5 | 29.3 | 109.1 | 34.1 | 9.1 | 26.9 |
| 305 | 185.2 | 20.3 | 81.0 | 32.2 | 104.1 | 38.0 | 6.2 | 30.7 |
| 355 | 77.3 | 28.9 | 74.6 | 30.3 | 2.7 | 41.8 | 7.0 | 22.4 |
| 395 | 102.5 | 21.2 | 64.5 | 43.9 | 38.1 | 48.7 | 11.4 | 19.7 |

| Slice measured | Depth Top (cm) | Depth Bottom (cm) | Slice Depth (cm) | Year (CRS-AP) | Sed.rate (cm/a) | Accu.rate ($g/m^2/a$) | Dry weight (g) | Rhob ($g/cm^3$) | Pb-210uns (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|
| * | 0 | 1 | 0.5 | 1993.6 | 1.17 | 1117.6 | 7.48 | 0.095 | 426.1 |
| * | 1 | 2 | 1.5 | 1992.4 | 0.66 | 1059.1 | 12.58 | 0.160 | 429.4 |
| * | 2 | 3 | 2.5 | 1990.5 | 0.45 | 924.9 | 16.08 | 0.205 | 460.0 |
| * | 3 | 4 | 3.5 | 1988.4 | 0.48 | 902.4 | 14.91 | 0.190 | 442.5 |
| * | 4 | 5 | 4.5 | 1986.4 | 0.52 | 901.7 | 13.52 | 0.172 | 418.0 |
| * | 5 | 6 | 5.5 | 1984.2 | 0.42 | 833.1 | 15.45 | 0.197 | 421.4 |
| * | 6 | 7 | 6.5 | 1982.0 | 0.49 | 792.5 | 12.71 | 0.162 | 416.5 |
| * | 7 | 8 | 7.5 | 1979.7 | 0.37 | 734.5 | 15.56 | 0.198 | 414.6 |
| * | 8 | 9 | 8.5 | 1976.9 | 0.37 | 626.6 | 13.47 | 0.172 | 447.8 |
| * | 9 | 10 | 9.5 | 1974.0 | 0.32 | 599.3 | 14.86 | 0.189 | 426.3 |
| * | 10 | 11 | 10.5 | 1970.6 | 0.27 | 523.4 | 15.24 | 0.194 | 437.6 |
| * | 11 | 12 | 11.5 | 1967.0 | 0.29 | 546.9 | 14.77 | 0.188 | 378.3 |
| * | 12 | 13 | 12.5 | 1963.3 | 0.25 | 489.8 | 15.2 | 0.194 | 376.1 |
| * | 13 | 14 | 13.5 | 1959.2 | 0.23 | 491.1 | 16.5 | 0.210 | 331.0 |
| * | 14 | 15 | 14.5 | 1955.0 | 0.24 | 594.5 | 19.06 | 0.243 | 242.6 |
| * | 15 | 16 | 15.5 | 1951.0 | 0.25 | 561.0 | 17.37 | 0.221 | 229.0 |
| | 16 | 17 | 16.5 | 1947.0 | 0.25 | 649.9 | 20.8 | 0.265 | 175.4 |
| * | 17 | 18 | 17.5 | 1942.6 | 0.21 | 560.8 | 20.98 | 0.267 | 177.0 |
| | 18 | 19 | 18.5 | 1937.6 | 0.19 | 510.5 | 20.63 | 0.263 | 167.6 |
| | 19 | 20 | 19.5 | 1931.5 | 0.14 | 415.5 | 22.96 | 0.292 | 168.9 |
| * | 20 | 21 | 20.5 | 1923.8 | 0.12 | 347.4 | 23.08 | 0.294 | 159.9 |
| | 21 | 22 | 21.5 | 1915.4 | 0.12 | 316.1 | 20.35 | 0.259 | 140.0 |
| * | 22 | 23 | 22.5 | 1905.5 | 0.09 | 249.6 | 22.91 | 0.292 | 130.0 |
| | 23 | 24 | 23.5 | 1890.9 | 0.06 | 174.9 | 24.1 | 0.307 | 120.0 |
| | 24 | 25 | 24.5 | 1866.3 | 0.03 | 96.1 | 23.88 | 0.304 | 110.0 |

Gamma Dating Center SYSTEM 2
Core: **GOBEX (IOW #201301) core taken: March 1996**
Date: 961125

| Depth (mm) | Pb-210tot (Bq/kg) | s (%) | Pb-210sup (Bq/kg) | s (%) | Pb-210uns (Bq/kg) | s (%) | Cs-137 (Bq/kg) | s (%) |
|---|---|---|---|---|---|---|---|---|
| 5 | 369.8 | 8.0 | 42.8 | 14.9 | 327.0 | 13.6 | 74.2 | 5.4 |
| 15 | 332.5 | 7.8 | 51.7 | 14.1 | 280.8 | 12.7 | 52.7 | 5.7 |
| 25 | 229.9 | 8.3 | 58.8 | 14.0 | 171.0 | 12.8 | 71.7 | 4.7 |
| 35 | 209.9 | 8.1 | 56.7 | 13.8 | 153.2 | 12.5 | 19.3 | 8.2 |
| 45 | 156.1 | 8.5 | 56.6 | 13.8 | 99.6 | 12.8 | 11.5 | 10.4 |
| 55 | 137.0 | 8.9 | 55.0 | 13.9 | 82.0 | 13.1 | 6.2 | 15.5 |
| 75 | 121.4 | 9.2 | 57.2 | 13.8 | 64.2 | 13.2 | 3.2 | 22.1 |
| 85 | 118.3 | 9.4 | 60.4 | 13.8 | 57.9 | 13.3 | 2.9 | 22.5 |
| 95 | 121.8 | 9.2 | 66.3 | 13.7 | 55.5 | 13.1 | 0.0 | |
| 125 | 110.7 | 9.6 | 70.1 | 13.7 | 40.5 | 13.4 | 0.0 | |
| 155 | 104.0 | 9.7 | 69.1 | 13.7 | 34.9 | 13.5 | 0.0 | |
| 205 | 88.2 | 10.5 | 70.7 | 13.6 | 17.5 | 14.0 | 0.0 | |
| 255 | 95.4 | 10.1 | 68.9 | 13.7 | 26.5 | 13.7 | 0.0 | |
| 305 | 100.9 | 9.8 | 59.1 | 13.8 | 41.8 | 13.7 | 0.0 | |

| Slice measured | Depth Top (cm) | Depth Bottom (cm) | Slice Depth (cm) | Year (CRS-AP) | Sed.rate (cm/a) | Accu.rate ($g/m^2/a$) | Dry weight (g) | Rhob ($g/cm^3$) | Pb-210uns (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|
| * | 0 | 1 | 0.5 | 1994.2 | 0.28 | 292.9 | | | |
| * | 1 | 2 | 1.5 | 1990.2 | 0.22 | 298.4 | | | |
| * | 2 | 3 | 2.5 | 1986.0 | 0.26 | 438.3 | | | |
| * | 3 | 4 | 3.5 | 1981.7 | 0.21 | 426.9 | | | |
| * | 4 | 5 | 4.5 | 1977.4 | 0.25 | 583.8 | | | |
| * | 5 | 6 | 5.5 | 1973.3 | 0.24 | 627.9 | | | |
| * | 6 | 7 | 6.5 | 1969.4 | 0.28 | 661.7 | | | |
| * | 7 | 8 | 7.5 | 1965.9 | 0.30 | 652.6 | | | |
| * | 8 | 9 | 8.5 | 1962.3 | 0.26 | 645.2 | | | |
| * | 9 | 10 | 9.5 | 1958.4 | 0.26 | 599.9 | | | |
| | 10 | 11 | 10.5 | 1954.1 | 0.21 | 580.6 | | | |
| | 11 | 12 | 11.5 | 1949.0 | 0.19 | 552.9 | | | |
| * | 12 | 13 | 12.5 | 1943.5 | 0.18 | 522.8 | | | |
| | 13 | 14 | 13.5 | 1937.8 | 0.17 | 470.3 | | | |
| | 14 | 15 | 14.5 | 1931.8 | 0.17 | 406.4 | | | |
| * | 15 | 16 | 15.5 | 1924.2 | 0.11 | 335.9 | | | |
| | 16 | 17 | 16.5 | 1913.9 | 0.09 | 278.2 | | | |
| | 17 | 18 | 17.5 | 1900.2 | 0.06 | 206.5 | | | |
| | 18 | 19 | 18.5 | 1879.3 | 0.04 | 133.1 | | | |
| | 19 | 20 | 19.5 | 1851.4 | 0.03 | 82.8 | | | |

Gamma Dating Center SYSTEM 3
Core: **GOBEX (IOW #201302) core taken: March 1996**
Date: 961121

| Depth (mm) | Pb-210tot (Bq/kg) | s (%) | Pb-210sup (Bq/kg) | s (%) | Pb-210uns (Bq/kg) | s (%) | Cs-137 (Bq/kg) | s (%) |
|---|---|---|---|---|---|---|---|---|
| 5 | 520.9 | 9.2 | 69.1 | 15.0 | 451.9 | 17.5 | 93.7 | 5.4 |
| 15 | 425.6 | 10.0 | 61.2 | 16.3 | 364.4 | 19.1 | 79.0 | 7.4 |
| 25 | 346.3 | 9.3 | 53.1 | 14.7 | 293.2 | 17.4 | 50.5 | 6.1 |
| 35 | 320.1 | 10.0 | 49.7 | 16.2 | 270.3 | 19.0 | 29.1 | 10.1 |
| 45 | 224.1 | 9.8 | 50.8 | 14.9 | 173.3 | 17.8 | 10.4 | 10.0 |
| 55 | 169.2 | 11.3 | 42.7 | 16.8 | 126.5 | 20.3 | 10.3 | 13.3 |
| 65 | 161.2 | 9.8 | 40.3 | 14.9 | 120.9 | 17.8 | 3.4 | 11.2 |
| 75 | 154.5 | 11.4 | 54.8 | 16.4 | 99.7 | 20.0 | 6.1 | 13.6 |
| 85 | 148.7 | 9.9 | 45.6 | 14.7 | 103.1 | 17.7 | 2.0 | 11.3 |
| 125 | 109.2 | 12.9 | 50.7 | 17.6 | 58.5 | 21.8 | 0.8 | 18.4 |
| 155 | 91.9 | 11.2 | 57.7 | 15.6 | 34.3 | 19.2 | 0.0 | |
| 195 | 94.9 | 10.2 | 52.9 | 14.7 | 42.0 | 17.9 | 0.7 | 10.3 |
| 245 | 108.4 | 10.1 | 64.9 | 14.6 | 43.5 | 17.7 | 0.0 | |
| 295 | 100.6 | 10.3 | 60.2 | 14.7 | 40.5 | 17.9 | 0.0 | |
| 345 | 120.4 | 9.8 | 67.9 | 14.3 | 52.5 | 17.4 | 0.0 | |
| 425 | 123.4 | 14.5 | 78.8 | 18.7 | 44.6 | 23.7 | 0.0 | |

| Slice measured | Depth Top (cm) | Depth Bottom (cm) | Slice Depth (cm) | Year (CRS-AP) | Sed.rate (cm/a) | Accu.rate ($g/m^2/a$) | Dry weight (g) | Rhob ($g/cm^3$) | Pb-210uns (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|
| * | 0 | 1 | 0.5 | 1994.3 | 0.30 | 215.1 | | | |
| * | 1 | 2 | 1.5 | 1990.0 | 0.19 | 228.7 | | | |
| * | 2 | 3 | 2.5 | 1984.8 | 0.19 | 244.7 | | | |
| * | 3 | 4 | 3.5 | 1979.0 | 0.16 | 221.5 | | | |
| * | 4 | 5 | 4.5 | 1973.3 | 0.20 | 298.2 | | | |
| * | 5 | 6 | 5.5 | 1968.0 | 0.19 | 350.0 | | | |
| * | 6 | 7 | 6.5 | 1961.8 | 0.14 | 299.8 | | | |
| * | 7 | 8 | 7.5 | 1954.7 | 0.14 | 298.2 | | | |
| * | 8 | 9 | 8.5 | 1946.1 | 0.10 | 218.6 | | | |
| | 9 | 10 | 9.5 | 1933.7 | 0.07 | 169.0 | | | |
| | 10 | 11 | 10.5 | 1915.5 | 0.05 | 113.8 | | | |
| | 11 | 12 | 11.5 | 1883.6 | 0.02 | 57.3 | | | |

Gamma Dating Center SYSTEM 2
Core: **GOBEX (IOW #201303) core taken: March 1996**
Date: 961129

| Depth (mm) | Pb-210tot (Bq/kg) | s (%) | Pb-210sup (Bq/kg) | s (%) | Pb-210uns (Bq/kg) | s (%) | Cs-137 (Bq/kg) | s (%) |
|---|---|---|---|---|---|---|---|---|
| 5 | 673.8 | 9.8 | 76.5 | 15.8 | 597.3 | 15.7 | 276.6 | 2.9 |
| 15 | 794.0 | 9.8 | 64.3 | 16.3 | 729.7 | 16.2 | 231.5 | 3.4 |
| 25 | 655.5 | 9.7 | 54.4 | 16.0 | 601.1 | 15.8 | 213.5 | 3.1 |
| 35 | 496.2 | 9.7 | 56.7 | 15.5 | 439.5 | 15.3 | 118.1 | 3.9 |
| 45 | 455.6 | 9.7 | 55.7 | 15.2 | 399.9 | 15.0 | 91.1 | 4.0 |
| 55 | 334.6 | 9.7 | 53.4 | 15.0 | 281.2 | 14.8 | 56.7 | 4.6 |
| 65 | 308.3 | 9.6 | 51.7 | 14.8 | 256.6 | 14.5 | 37.3 | 5.3 |
| 75 | 229.6 | 9.8 | 52.9 | 14.7 | 176.7 | 14.6 | 16.8 | 8.5 |
| 85 | 183.5 | 10.3 | 53.3 | 14.9 | 130.2 | 15.0 | 12.9 | 10.7 |
| 95 | 198.4 | 12.7 | 65.4 | 16.3 | 133.0 | 18.1 | 8.6 | 29.2 |
| 125 | 139.2 | 10.7 | 68.8 | 14.5 | 70.3 | 15.0 | 0.0 | |
| 155 | 121.7 | 13.5 | 68.1 | 15.1 | 53.5 | 17.6 | 0.0 | |
| 205 | 101.5 | 10.4 | 68.5 | 14.4 | 33.0 | 14.6 | 0.0 | |
| 255 | 128.6 | 11.2 | 75.6 | 14.6 | 53.0 | 15.4 | 0.0 | |
| 305 | 118.8 | 9.8 | 92.4 | 14.3 | 26.4 | 14.1 | 0.0 | |

| Slice measured | Depth Top (cm) | Depth Bottom (cm) | Slice Depth (cm) | Year (CRS-AP) | Sed.rate (cm/a) | Accu.rate ($g/m^2/a$) | Dry weight (g) | Rhob ($g/cm^3$) | Pb-210uns (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|
| * | 0 | 1 | 0.5 | 1994.6 | 0.36 | 240.1 | | | |
| * | 1 | 2 | 1.5 | 1991.5 | 0.29 | 177.2 | | | |
| * | 2 | 3 | 2.5 | 1987.9 | 0.27 | 192.7 | | | |
| * | 3 | 4 | 3.5 | 1984.1 | 0.26 | 235.0 | | | |
| * | 4 | 5 | 4.5 | 1979.8 | 0.21 | 225.5 | | | |
| * | 5 | 6 | 5.5 | 1975.1 | 0.22 | 280.2 | | | |
| * | 6 | 7 | 6.5 | 1969.8 | 0.17 | 258.5 | | | |
| * | 7 | 8 | 7.5 | 1963.7 | 0.16 | 315.0 | | | |
| * | 8 | 9 | 8.5 | 1957.7 | 0.17 | 362.4 | | | |
| * | 9 | 10 | 9.5 | 1951.4 | 0.15 | 338.4 | | | |
| | 10 | 11 | 10.5 | 1943.9 | 0.12 | 310.1 | | | |
| | 11 | 12 | 11.5 | 1934.4 | 0.09 | 272.0 | | | |
| * | 12 | 13 | 12.5 | 1923.5 | 0.09 | 246.0 | | | |
| | 13 | 14 | 13.5 | 1907.7 | 0.05 | 156.6 | | | |
| | 14 | 15 | 14.5 | 1878.6 | 0.03 | 80.9 | | | |

Gamma Dating Center SYSTEM 2
Core: **GOBEX (IOW #201308) core taken: March 1996 (Gdansk Basin)**
Date: 961129

| Depth (mm) | Pb-210tot (Bq/kg) | s (%) | Pb-210sup (Bq/kg) | s (%) | Pb-210uns (Bq/kg) | s (%) | Cs-137 (Bq/kg) | s (%) |
|---|---|---|---|---|---|---|---|---|
| 5 | 254.9 | 10.7 | 6.3 | 23.7 | 248.6 | 26.0 | 294.9 | 6.2 |
| 15 | 216.9 | 9.5 | 5.4 | 14.1 | 211.5 | 17.0 | 333.0 | 5.5 |
| 25 | 171.7 | 11.5 | 6.6 | 19.5 | 165.2 | 22.6 | 287.4 | 6.0 |
| 45 | 184.4 | 9.2 | 8.5 | 9.0 | 175.9 | 12.9 | 281.1 | 5.4 |
| 55 | 199.8 | 9.6 | 7.5 | 13.1 | 192.4 | 16.2 | 454.4 | 5.4 |
| 65 | 224.0 | 9.0 | 8.8 | 8.0 | 215.2 | 12.1 | 310.0 | 5.4 |
| 85 | 221.7 | 9.4 | 12.1 | 12.7 | 209.6 | 15.8 | 3810.1 | 5.2 |
| 95 | 201.9 | 9.0 | 10.2 | 7.3 | 191.8 | 11.6 | 167.2 | 5.5 |
| 125 | 98.8 | 9.9 | 13.3 | 6.6 | 85.5 | 11.9 | 57.8 | 6.3 |
| 155 | 134.7 | 9.5 | 9.5 | 8.3 | 125.2 | 12.6 | 69.5 | 6.2 |
| 205 | 115.7 | 10.7 | 7.5 | 11.2 | 108.2 | 15.5 | 54.5 | 6.7 |
| 305 | 39.1 | 10.0 | 14.0 | 3.7 | 25.1 | 10.7 | 0.0 | 7.7 |
| 536 | 19.3 | 11.4 | 15.2 | 4.5 | 4.1 | 12.3 | | |

| Slice measured | Depth Top (cm) | Depth Bottom (cm) | Slice Depth (cm) | Year (CRS-AP) | Sed.rate (cm/a) | Accu.rate ($g/m^2/a$) | Dry weight (g) | Rhob ($g/cm^3$) | Pb-210uns (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|
| * | 0 | 1 | 0.5 | 1995.2 | 0.59 | 842.9 | | | |
| * | 1 | 2 | 1.5 | 1993.6 | 0.70 | 958.1 | | | |
| * | 2 | 3 | 2.5 | 1992.2 | 0.74 | 1176.8 | | | |
| * | 3 | 4 | 3.5 | 1990.7 | 0.61 | 1032.2 | | | |
| * | 4 | 5 | 4.5 | 1988.9 | 0.52 | 908.4 | | | |
| * | 5 | 6 | 5.5 | 1987.1 | 0.60 | 755.5 | | | |
| * | 6 | 7 | 6.5 | 1985.0 | 0.38 | 716.1 | | | |
| * | 7 | 8 | 7.5 | 1982.4 | 0.39 | 736.9 | | | |
| * | 8 | 9 | 8.5 | 1980.4 | 0.77 | 1583.3 | | | |
| * | 9 | 10 | 9.5 | 1978.8 | 0.49 | 1012.6 | | | |
| | 10 | 11 | 10.5 | 1975.3 | 0.20 | 700.3 | | | |
| | 11 | 12 | 11.5 | 1971.6 | 0.42 | 852.9 | | | |
| * | 12 | 13 | 12.5 | 1969.3 | 0.44 | 1126.6 | | | |
| | 13 | 14 | 13.5 | 1966.8 | 0.36 | 902.5 | | | |
| | 14 | 15 | 14.5 | 1963.8 | 0.33 | 719.7 | | | |
| * | 15 | 16 | 15.5 | 1960.9 | 0.34 | 595.2 | | | |
| | 16 | 17 | 16.5 | 1958.0 | 0.37 | 567.2 | | | |
| | 17 | 18 | 17.5 | 1954.9 | 0.29 | 529.9 | | | |
| | 18 | 19 | 18.5 | 1951.3 | 0.27 | 477.5 | | | |
| | 19 | 20 | 19.5 | 1948.0 | 0.33 | 455.0 | | | |
| * | 20 | 21 | 20.5 | 1944.9 | 0.32 | 431.9 | | | |
| | 21 | 22 | 21.5 | 1940.9 | 0.21 | 414.7 | | | |
| | 22 | 23 | 22.5 | 1935.7 | 0.18 | 387.1 | | | |
| | 23 | 24 | 23.5 | 1929.3 | 0.14 | 342.1 | | | |
| | 24 | 25 | 24.5 | 1920.0 | 0.09 | 295.9 | | | |
| | 25 | 26 | 25.5 | 1910.1 | 0.12 | 260.2 | | | |
| | 26 | 27 | 26.5 | 1900.1 | 0.08 | 207.6 | | | |
| | 27 | 28 | 27.5 | 1887.8 | 0.08 | 189.5 | | | |
| | 28 | 29 | 28.5 | 1874.4 | 0.07 | 157.3 | | | |

# 6.2 Major and trace-element composition of surface sediments and pore waters from cores in the Eastern Gotland Basin – A Data Report

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## Introduction

A series of surface sediment cores have been taken during the expeditions related to GOBEX and we have determined the chemical composition of sediments and pore waters in the Eastern Gotland Basin. Furthermore, several of the cores have been dated by non-destructive Pb-210-dating (Christiansen and Kunzendorf, this volume). The compositional data reflect changes in trace element accumulation in different water depths (ranging from 68 to 243 m) corresponding to predominantly oxic and anoxic conditions at the sea floor. When used in combination with the age determinations and determinations of physical properties, the time series permit detailed reconstructions of flux rates from natural and anthropogenic sources, which was one of the major objectives of the GOBEX work plan. This manuscript is a data report on the geochemistry of GOBEX multicores IOW# 20000-4/5, 20001-4, 20004-1/2, 20007-4, and 20008-4/5 and tabulates analytical results of sediment geochemistry and pore water composition. The data have in part been published and discussed elsewhere (EMEIS et al., 1996; NEUMANN et al., 1997; EMEIS et al., 1998).

## Material and Methods

Sediment sampling was conducted aboard R/V ALEXANDER VON HUMBOLDT using a Multi-Corer device in August of 1994. Sampling locations are given in Table 1 and are shown on a map of the Gotland Basin in Figure 1 of EMEIS (this issue). This corer takes up to 8 short cores from an area of about 1.5$m^2$ on the seafloor. All subcores contained bottom water, an intact sediment surface, and between 200 and 600 mm of underlying sediment. The cores were sliced into 5 or 10 mm thick discs during extrusion. The slices were stored in polyethylene bottles, frozen and lyophilized. Pore water sampling was performed immediately after retrieval: sediment cores within the liners were transferred into an argon-flushed glove box to prevent oxidation, extruded and sliced into 10 mm discs. The slices were stored in pre-cleaned polyethylene centrifuge bottles. After centrifugation, the supernatant water was filtered through 0.45 mm nucleopore filters. Aliquots were used to determine chloride and sulfate by HPLC-technique at the University of Aarhus (see also MATTHIESEN, this volume). Subsamples of pore water were acidified with suprapure $HNO_3$ and kept frozen until analysis in the laboratories of the Institute of Baltic Sea Research at Warnemünde.

Table 1: Location and water depths of cores

| Core # | Expedition | Latitude | | | | Longitude | | | | Water depth |
|---|---|---|---|---|---|---|---|---|---|---|
| 20000 | GOBEX II | 57 | ° | 15.17 | 'N | 20 | ° | 33.64 | 'E | 112 |
| 20001 | A.v.Humboldt | 57 | ° | 18.33 | 'N | 20 | ° | 20.03 | 'E | 243 |
| 20004 | | 57 | ° | 18.28 | 'N | 20 | ° | 13.66 | 'E | 236 |
| 20007 | | 57 | ° | 23.14 | 'N | 20 | ° | 15.60 | 'E | 225 |
| 20008 | | 57 | ° | 27.60 | 'N | 21 | ° | 09.62 | 'E | 68 |

Chemical analyses were performed on the <63 µm sieved fractions after homogenisation of the size fraction. Procedures for the chemical analysis of the sediments onshore have been described by EMEIS et al. (1998), NEUMANN et al. (1997) and NEUMANN et al. (1996). Total carbon and total nitrogen were determined with a Foss-Heraeus CHN-analyser. The sample splits (20-200 mg) were oxidized in a pure $O_2$ atmosphere at 950° C and measured by a thermal conductivity detector as $N_2$ and $CO_2$ after reduction of $NO_x$ on elemental copper. Sulfur and organic carbon were determined with an Eltra CS-Analyser. Prior to analysis, 0.1N HCl was added to the sample splits to remove carbonates. The samples were then oxidized at 1400°C and the evolving gases determined by infra-red detection.

Weighed splits of the <63 mm fractions were completely dissolved in a combination of HF/HCl and $HClO_4/HNO_3$-reagents. Concentrations of elements in the solutions were determined by an ICP-AES (Varian Liberty 200) instrument. The solutions were introduced into the plasma by a pneumatic nebulizer. The operating conditions were optimized for each element. Data quality was controlled by repeatedly analysing reference materials ABSS, MBSS and MAG-1. Certified multi-element standard solutions were used for calibration. Standard deviations for each element revealed precisions that were generally below 3%, except for Co, Cu, Ni and Pb, which were below 10%, and for Cd, which were below 20%. Detection limits for trace elements are below 2 ppm. Ages given in Tables 2 to 6 are derived from Pb-210 determinations described in CHRISTIANSEN and KUNZENDORF (this volume). Data tables on chemical conditions are given in the Tables 2 to 6, which are also reproduced on the DC-ROM.

**References**

EMEIS, K. C., T. NEUMANN, R. ENDLER, U. STRUCK, H. KUNZENDORF, C. CHRISTIANSEN (1998): Geochemical records of sediments in the Gotland Basin - products of sediment dynamics in a not-so-stagnant anoxic basin? **Applied Geochemistry 13** : 349-359.

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NEUMANN, T., C. CHRISTIANSEN, S. CLASEN, K.-C. EMEIS, H. KUNZENDORF (1997). Geochemical records of salt-water inflows into the deep basins of the Baltic Sea. **Cont. Shelf Res. 17** (1): 95-115.

Table 2: Composition of sediment samples and pore waters from core IOW-2008-4

| | Pore Water | | | | Sediment | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dept (cm) | Fe (µM/L) | Mn (µM/L) | $SO_4$ (mM/L) | Cl (mM/L) | Age (years) | TC (%) | TS (%) | TN (%) | TOC (%) | Al (%) | P (%) | Mg (%) | K (%) | Ca (%) | Fe (%) | Mn (µg/g) | Li (µg/g) | Cr (µg/g) | Co (µg/g) | Ni (µg/g) | Cu (µg/g) | Zn (µg/g) | Mo (µg/g) | Cd (µg/g) | Pb (µg/g) |
| 1 | n.d. | n.d. | 7.11 | 140 | 0.3 | 6.80 | 0.45 | 0.86 | 6.74 | 5.11 | 0.36 | 1.40 | 2.36 | 1.25 | 3.98 | 442 | 21.1 | 72.4 | 15.8 | 39.0 | 35.6 | 139 | 18.4 | 1.46 | 73.8 |
| 2 | 494 | 27.5 | 5.36 | 121 | 0.8 | 4.93 | 0.30 | 0.57 | 4.97 | 4.70 | 0.12 | 1.42 | 2.48 | 1.85 | 2.29 | 304 | 30.8 | 63.4 | 13.6 | 27.0 | 26.8 | 109 | 15.7 | 1.09 | 58.0 |
| 3 | 372 | 28.8 | 5.15 | 131 | 1.39 | 4.27 | 0.26 | 0.45 | 4.13 | 5.02 | 0.10 | 1.33 | 2.49 | 1.48 | 2.39 | 286 | 33.8 | 70.2 | 14.8 | 31.2 | 31.3 | 127 | 16.4 | 1.19 | 65.1 |
| 4 | 209 | 32.2 | 4.27 | 130 | 1.83 | 4.47 | 0.56 | 0.51 | 4.32 | 4.88 | 0.10 | 1.17 | 2.44 | 1.17 | 2.50 | 259 | 32.4 | 66.8 | 14.8 | 30.5 | 30.3 | 128 | 16.4 | 1.17 | 65.6 |
| 5 | 55 | 35.1 | 3.14 | 136 | 2.28 | 5.71 | 1.75 | 0.70 | 5.61 | 5.35 | 0.11 | 1.27 | 2.45 | 0.94 | 3.80 | 332 | 41.0 | 81.1 | 17.5 | 41.7 | 39.1 | 164 | 19.0 | 1.6 | 81.9 |
| 6 | 4 | 34.9 | 1.21 | 128 | 2.85 | 5.28 | 0.79 | 0.56 | 4.89 | 5.23 | 0.10 | 1.38 | 2.48 | 1.43 | 2.87 | 349 | 38.2 | 73.4 | 15.7 | 34.9 | 34.3 | 138 | 17.8 | 1.41 | 77.0 |
| 7 | 6 | 36.6 | 0.48 | 132 | 3.35 | 4.82 | 0.58 | 0.56 | 4.78 | 5.27 | 0.10 | 1.37 | 2.52 | 1.40 | 2.68 | 344 | 37.3 | 50.9 | 15.9 | 33.5 | 33.3 | 137 | 18.2 | 1.27 | 74.1 |
| 8 | 3 | 36 | 0.18 | 128 | 3.72 | 3.50 | 1.56 | 0.38 | 3.44 | 4.98 | 0.09 | 1.15 | 2.45 | 1.06 | 3.16 | 328 | 33.6 | 71.4 | 16.3 | 32.0 | 29.8 | 132 | 17.1 | 1.31 | 70.4 |
| 9 | 6 | 36.6 | 0.10 | 138 | 4.35 | 4.72 | 1.67 | 0.54 | 4.77 | 5.43 | 0.10 | 1.35 | 2.49 | 0.10 | 3.55 | 379 | 40.9 | 82.9 | 17.0 | 38.3 | 40.0 | 169 | 18.9 | 1.7 | 86.7 |
| 10 | 8 | 38.6 | 0.09 | 127 | 4.96 | 4.79 | 1.74 | 0.50 | 4.65 | 5.10 | 0.10 | 1.42 | 2.41 | 1.45 | 3.60 | 396 | 38.8 | 76.1 | 16.8 | 36.8 | 38.1 | 159 | 19.0 | 1.67 | 84.4 |
| 11 | 7 | 37.9 | 0.13 | 128 | 5.39 | 4.94 | 1.66 | 0.54 | 4.91 | 5.43 | 0.10 | 1.41 | 2.48 | 1.40 | 3.67 | 391 | 41.3 | 81.4 | 18.4 | 41.5 | 40.2 | 172 | 20.8 | 2.08 | 92.4 |
| 12 | 16 | 38.6 | 0.13 | 135 | 5.84 | 4.52 | 1.16 | 0.48 | 4.53 | 5.53 | 0.10 | 1.41 | 2.54 | 1.45 | 3.41 | 367 | 41.1 | 83.0 | 17.7 | 39.7 | 37.7 | 174 | 20.8 | 1.6 | 91.3 |
| 13 | 49 | 40.8 | 0.00 | 126 | 6.28 | 4.92 | 0.73 | 0.49 | 4.86 | 5.52 | 0.11 | 1.53 | 2.53 | 1.92 | 3.18 | 373 | 39.9 | 64.9 | 17.1 | 38.7 | 37.5 | 161 | 21.6 | 1.62 | 88.2 |
| 14 | 58 | 42.2 | 0.00 | 123 | 6.79 | 4.95 | 0.76 | 0.52 | 4.90 | 5.65 | 0.14 | 1.53 | 2.59 | 1.76 | 3.33 | 409 | 41.8 | 84.9 | 17.7 | 40.3 | 39.7 | 174 | 21.8 | 1.7 | 93.7 |
| 15 | 86 | 43.7 | 0.00 | 130 | 7.38 | 4.03 | 1.01 | 0.39 | 4.02 | 5.32 | 0.11 | 1.49 | 2.50 | 1.89 | 3.15 | 374 | 36.7 | 73.4 | 16.8 | 34.6 | 34.0 | 150 | 20.4 | 1.53 | 82.3 |
| 16 | 90 | 44.6 | 0.00 | 130 | 7.86 | 4.46 | 0.99 | 0.47 | 4.42 | 5.64 | 0.11 | 1.47 | 2.59 | 1.54 | 3.45 | 360 | 41.0 | 83.3 | 17.3 | 37.9 | 38.6 | 170 | 21.5 | 1.62 | 90.8 |
| 17 | 85 | 44.6 | 0.00 | 124 | 8.33 | 3.93 | 1.08 | 0.41 | 3.99 | 5.45 | 0.09 | 1.47 | 2.57 | 1.70 | 3.24 | 369 | 37.8 | 76.1 | 17.0 | 35.3 | 35.2 | 157 | 20.1 | 1.54 | 84.3 |
| 18 | 95 | 45.9 | 0.00 | 131 | 8.85 | 4.47 | 1.15 | 0.51 | 4.41 | 5.74 | 0.11 | 1.46 | 2.62 | 1.46 | 3.67 | 387 | 42.4 | 84.2 | 18.2 | 38.9 | 39.7 | 177 | 22.3 | 1.76 | 94.4 |
| 19 | 117 | 48.1 | 0.00 | 127 | 9.4 | 4.70 | 0.75 | 0.66 | 4.56 | 5.68 | 0.19 | 1.51 | 2.63 | 1.55 | 3.42 | 446 | 42.3 | 55.5 | 18.1 | 39.3 | 39.5 | 169 | 21.9 | 1.69 | 96.7 |
| 20 | 58 | 46.6 | 0.00 | 128 | 9.89 | 4.37 | 0.97 | 0.44 | 4.22 | 5.56 | 0.11 | 1.50 | 2.60 | 1.73 | 3.33 | 384 | 39.5 | 70.9 | 17.4 | 36.7 | 35.6 | 160 | 21.2 | 1.63 | 87.6 |
| 21 | 25 | 46.2 | 0.00 | 129 | 10.47 | 3.95 | 1.44 | 0.40 | 3.93 | 5.33 | 0.10 | 1.36 | 2.45 | 1.42 | 3.53 | 370 | 39.7 | 76.6 | 16.9 | 36.3 | 36.0 | 165 | 20.5 | 1.67 | 90.9 |

Table 3: Composition of sediment samples and pore waters from core IOW-20000-4

| | Pore Water | | | | Sediment | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (cm) | Fe (µM/L) | Mn (µM/L) | SO4 (mM/L) | Cl (mM/L) | Age (years) | TC (%) | TS (%) | TN (%) | TOC (%) | Al (%) | P (%) | Mg (%) | K (%) | Ca (%) | Fe (%) | Mn (µg/g) | Li (µg/g) | Cr (µg/g) | Co (µg/g) | Ni (µg/g) | Cu (µg/g) | Zn (µg/g) | Mo (µg/g) | Cd (µg/g) | Pb (µg/g) |
| 1 | 2.33 | 4.91 | 7.91 | 168 | 0.8 | 7.97 | 0.83 | 0.93 | 7.29 | 4.89 | 0.11 | 1.12 | 2.23 | 0.68 | 2.61 | 215 | 38.2 | 66.9 | 14.3 | 35.4 | 51.7 | 137 | 21.8 | 1.64 | 72.6 |
| 2 | 1.74 | 5.64 | 7.30 | 169 | 0.8 | 6.46 | 0.84 | 0.77 | 5.97 | 5.42 | 0.10 | 1.09 | 2.49 | 0.61 | 2.79 | 232 | 42.1 | 73.1 | 15.4 | 36.5 | 52.6 | 142 | 22.2 | 1.37 | 81.2 |
| 3 | 2.18 | 5.82 | 6.22 | 167 | 0.8 | 4.86 | 1.15 | 0.54 | 4.52 | 5.74 | 0.09 | 1.01 | 2.59 | 0.42 | 3.06 | 241 | 44.9 | 77.0 | 16.2 | 38.4 | 51.8 | 149 | 22.7 | 1.26 | 84.9 |
| 4 | 1.07 | 8.01 | 5.54 | 170 | 0.8 | 3.51 | 1.48 | 0.36 | 3.27 | 6.01 | 0.08 | 0.99 | 2.70 | 0.46 | 3.34 | 256 | 44.1 | 78.2 | 16.3 | 38.5 | 48.5 | 138 | 23.7 | 0.99 | 79.7 |
| 5 | 1.68 | 8.55 | 5.10 | 165 | 0.8 | 3.69 | 1.02 | 0.37 | 3.46 | 5.91 | 0.08 | 1.08 | 2.71 | 0.65 | 3.00 | 250 | 46.2 | 69.9 | 16.3 | 36.2 | 46.9 | 128 | 22.4 | 0.90 | 81.1 |
| 6 | 0.82 | 8.55 | 4.86 | 167 | 0.8 | 4.38 | 0.90 | 0.43 | 4.03 | 6.08 | 0.08 | 1.16 | 2.75 | 0.79 | 3.04 | 266 | 49.0 | 71.2 | 16.7 | 37.8 | 50.3 | 140 | 21.9 | 1.00 | 84.5 |
| 7 | 0.66 | 8.01 | 4.03 | 168 | 0.9 | 4.19 | 1.06 | 0.42 | 3.87 | 5.91 | 0.08 | 1.17 | 2.62 | 0.81 | 3.17 | 268 | 49.0 | 79.8 | 16.5 | 38.5 | 52.2 | 144 | 21.6 | 1.10 | 85.8 |
| 8 | 1.36 | 7.83 | 3.23 | 160 | 2.7 | 4.68 | 1.06 | 0.49 | 4.38 | 6.07 | 0.09 | 1.18 | 2.66 | 0.76 | 3.13 | 274 | 50.0 | 78.3 | 16.5 | 39.6 | 55.8 | 157 | 23.2 | 1.21 | 93.2 |
| 9 | 1.27 | 6.55 | 2.82 | 165 | 4.7 | 5.34 | 1.09 | 0.60 | 5.03 | 6.15 | 0.09 | 1.20 | 2.58 | 0.72 | 3.22 | 276 | 48.3 | 67.7 | 16.6 | 40.5 | 56.8 | 163 | 23.8 | 1.45 | 94.8 |
| 10 | 1.24 | 6.92 | 2.18 | 164 | 7.4 | 6.08 | 1.09 | 0.73 | 5.70 | 5.53 | 0.09 | 1.13 | 2.45 | 0.71 | 3.03 | 259 | 42.2 | 69.3 | 15.4 | 39.2 | 54.6 | 151 | 22.1 | 1.33 | 87.6 |
| 11 | 4.42 | 6.01 | 1.81 | 161 | 10.1 | 6.22 | 1.10 | 0.75 | 5.75 | 5.31 | 0.09 | 1.13 | 2.38 | 0.75 | 3.01 | 265 | 43.2 | 75.3 | 15.7 | 37.7 | 54.7 | 150 | 20.6 | 1.48 | 88.3 |
| 12 | 1.56 | 4.55 | 1.63 | 166 | 13.4 | 5.98 | 1.18 | 0.68 | 5.54 | 5.26 | 0.09 | 1.15 | 2.33 | 0.86 | 2.96 | 271 | 39.6 | 66.0 | 15.1 | 37.6 | 51.0 | 143 | 24.0 | 1.54 | 85.1 |
| 13 | 1.00 | 5.28 | 1.40 | 165 | 17.1 | 6.27 | 1.31 | 0.69 | 5.71 | 5.37 | 0.09 | 1.13 | 2.42 | 0.66 | 3.17 | 270 | 42.8 | 73.4 | 15.0 | 38.8 | 56.3 | 154 | 23.6 | 1.52 | 93.8 |
| 14 | 1.18 | 4.91 | 1.23 | 162 | 20.5 | 6.60 | 1.06 | 0.75 | 6.08 | 5.35 | 0.09 | 1.09 | 2.42 | 0.53 | 2.94 | 260 | 42.4 | 79.0 | 15.6 | 39.4 | 60.2 | 173 | 26.5 | 1.88 | 94.5 |
| 15 | 1.63 | 4.55 | 1.07 | 166 | 23.4 | 5.90 | 1.10 | 0.68 | 5.47 | 5.56 | 0.10 | 1.07 | 2.45 | 0.47 | 3.15 | 267 | 43.3 | 84.1 | 17.6 | 43.0 | 69.0 | 195 | 27.1 | 1.94 | 106.0 |
| 16 | 1.36 | n.d. | 1.29 | 166 | 26.1 | 5.35 | 1.02 | 0.62 | 5.03 | 5.22 | 0.09 | 1.00 | 2.32 | 0.49 | 2.89 | 253 | 38.3 | 77.1 | 16.1 | 39.2 | 61.3 | 180 | 24.5 | 1.93 | 108.0 |
| 17 | 1.22 | 4.55 | 1.26 | 161 | 29.2 | 4.90 | 1.24 | 0.56 | 4.58 | 5.48 | 0.09 | 1.05 | 2.51 | 0.48 | 3.18 | 265 | 44.2 | 73.0 | 18.1 | 41.1 | 62.3 | 184 | 25.8 | 1.96 | 109.0 |
| 18 | 1.84 | 3.64 | 0.89 | 161 | 32.8 | 4.36 | 1.11 | 0.47 | 4.01 | 5.67 | 0.08 | 1.05 | 2.39 | 0.52 | 3.09 | 251 | 42.7 | 79.4 | 16.8 | 39.0 | 56.3 | 175 | 24.5 | 1.54 | 98.6 |
| 19 | 1.45 | 3.82 | 1.47 | 164 | 36.3 | 4.37 | 1.42 | 0.45 | 4.02 | 5.86 | 0.08 | 1.13 | 2.48 | 0.66 | 3.43 | 267 | 45.2 | 80.3 | 17.5 | 40.7 | 55.9 | 178 | 25.1 | 1.49 | 100.0 |
| 20 | 0.64 | 3.46 | 1.42 | 172 | 40.5 | 4.70 | 1.47 | 0.48 | 4.32 | 5.77 | 0.09 | 1.17 | 2.47 | 0.77 | 3.41 | 310 | 43.8 | 80.0 | 16.7 | 39.7 | 57.1 | 175 | 23.9 | 1.45 | 104.0 |
| 21 | n.d. | 3.28 | 1.26 | 165 | 44.7 | 3.81 | 1.16 | 0.42 | 3.75 | 6.05 | 0.08 | 1.15 | 2.54 | 0.64 | 3.26 | 280 | 45.1 | 81.0 | 17.3 | 38.4 | 52.8 | 154 | 23.8 | 1.33 | 87.0 |
| 23 | n.d. | 2.73 | 1.36 | 163 | 52.0 | 3.50 | 1.63 | 0.37 | 3.45 | 5.88 | 0.08 | 1.16 | 2.54 | 0.88 | 3.57 | 290 | 45.3 | 77.2 | 17.5 | 36.9 | 46.6 | 138 | 22.9 | 1.28 | 80.6 |
| 25 | n.d. | 2.91 | 1.45 | 168 | 63.8 | 3.09 | 2.40 | 0.32 | 3.11 | 6.08 | 0.08 | 1.20 | 2.57 | 0.90 | 4.02 | 330 | 45.0 | 79.5 | 18.9 | 39.4 | 43.6 | 132 | 26.1 | 1.08 | 78.0 |
| 27 | 1.20 | 2.37 | 1.22 | 162 | 70.8 | 3.23 | 1.76 | 0.38 | 3.29 | 6.23 | 0.08 | 1.16 | 2.57 | 0.82 | 3.70 | 310 | 46.5 | 80.0 | 18.2 | 39.4 | 43.2 | 131 | 24.5 | 0.97 | 76.9 |
| 29 | 1.36 | 2.55 | 1.43 | 165 | 79.8 | 3.22 | 2.42 | 0.41 | 3.25 | 5.36 | 0.07 | 1.09 | 2.38 | 0.74 | 3.94 | 291 | 42.4 | 75.4 | 19.3 | 39.7 | 41.1 | 122 | 24.2 | 1.44 | 65.0 |
| 31 | n.d. | 2.55 | 1.89 | 166 | 87.8 | 3.21 | 1.76 | 0.40 | 3.23 | 5.92 | 0.08 | 1.12 | 2.45 | 0.68 | 3.53 | 275 | 45.5 | 79.1 | 18.8 | 41.0 | 42.1 | 121 | 21.5 | 1.10 | 61.7 |
| 33 | 1.29 | 2.91 | 1.78 | 166 | 99.8 | 3.00 | 1.64 | 0.34 | 2.98 | 6.14 | 0.08 | 1.18 | 2.52 | 0.76 | 3.59 | 280 | 47.7 | 82.1 | 18.4 | 41.7 | 43.0 | 122 | 25.7 | 0.93 | 61.3 |
| 35 | 2.49 | 2.91 | 2.18 | 166 | 109.8 | 3.03 | 2.03 | 0.36 | 3.09 | 5.90 | 0.08 | 1.15 | 2.48 | 0.88 | 3.69 | 287 | 44.5 | 76.4 | 18.6 | 39.6 | 41.1 | 113 | 25.9 | 0.92 | 56.6 |
| 37 | 3.10 | 3.09 | 2.33 | 171 | 113.8 | 3.04 | 2.23 | 3.60 | 3.07 | 5.91 | 0.08 | 1.16 | 2.42 | 0.79 | 3.86 | 294 | 44.0 | 78.6 | 19.0 | 40.1 | 41.7 | 108 | 26.1 | 1.24 | 54.9 |
| 39 | 4.15 | 3.46 | 2.77 | 182 | 122.8 | 3.10 | 2.32 | 0.35 | 3.09 | 5.61 | 0.07 | 1.08 | 2.43 | 0.76 | 4.01 | 288 | 42.0 | 74.8 | 18.8 | 37.3 | 40.2 | 104 | 26.4 | 1.27 | 54.8 |

Table 4: Composition of sediment samples and pore waters from core IOW-20004-1

| | Pore Water | | | | Sediment | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (cm) | Fe (µM/L) | Mn (µM/L) | $SO_4$ (mM/L) | Cl (mM/L) | Age (years) | TC (%) | TS (%) | TN (%) | TOC (%) | Al (%) | P (%) | Mg (%) | K (%) | Ca (%) | Fe (%) | Mn (µg/g) | Li (µg/g) | Cr (µg/g) | Co (µg/g) | Ni (µg/g) | Cu (µg/g) | Zn (µg/g) | Mo (µg/g) | Cd (µg/g) | Pb (µg/g) |
| 1 | 8.81 | 210 | 8.41 | 200 | 2.26 | 12.46 | 2.03 | 1.44 | 12.04 | 4.09 | 0.02 | 1.1 | 1.74 | 0.58 | 3.57 | 133 | 29.5 | 52.0 | 21.8 | 43.9 | 127 | 338 | 176 | 5.37 | 69.2 |
| 2 | 6.09 | 214 | 6.59 | 195 | 3.48 | 13.67 | 1.75 | 1.72 | 14.11 | 3.06 | 0.02 | 0.95 | 1.35 | 0.52 | 3.01 | 716 | 22.2 | 41.3 | 14.9 | 42.4 | 149 | 325 | 89.7 | 6.24 | 55.1 |
| 3 | 2.81 | 221 | 5.98 | 195 | 6.39 | 17.44 | 1.71 | 2.05 | 16.28 | 3.51 | 0.18 | 1.07 | 1.58 | 0.6 | 2.78 | 681 | 25.6 | 35.1 | 14.6 | 47.5 | 137 | 348 | 122 | 5.55 | 60.6 |
| 4 | 1.22 | 220 | 4.6 | 186 | 9.32 | 15.31 | 1.22 | 2.03 | 14.74 | 3.7 | 0.14 | 1.08 | 1.64 | 0.61 | 2.38 | 667 | 27.0 | 40.5 | 13.8 | 53.8 | 124 | 335 | 149 | 4.63 | 70.4 |
| 5 | n.d. | 208 | 5.08 | 187 | 12.61 | 14.54 | 1.23 | 1.90 | 14.11 | 3.73 | 0.13 | 1.1 | 1.61 | 0.63 | 2.35 | 667 | 27.2 | 43.5 | 13.6 | 54.8 | 118 | 347 | 157 | 4.37 | 73.3 |
| 6 | 1.45 | 202 | 4.76 | 190 | 15.55 | 13.89 | 1.32 | 1.70 | 13.54 | 3.85 | 0.13 | 1.09 | 1.65 | 0.64 | 2.52 | 652 | 28.4 | 51.9 | 14.8 | 57.6 | 120 | 396 | 182 | 4.87 | 83.8 |
| 7 | 2.42 | 194 | 3.77 | 181 | 18.55 | 14.25 | 1.45 | 1.66 | 13.71 | 3.91 | 0.13 | 1.13 | 1.68 | 0.67 | 2.6 | 884 | 28.8 | 54.4 | 15.4 | 59.7 | 127 | 442 | 201 | 5.47 | 93.1 |
| 8 | 1.47 | 180 | 3.95 | 190 | 21.65 | 13.75 | 1.47 | 1.57 | 13.22 | 4.23 | 0.13 | 1.13 | 1.76 | 0.71 | 2.81 | 765 | 31.0 | 58.3 | 15.8 | 60.6 | 139 | 486 | 205 | 6.08 | 103 |
| 9 | 1.34 | 175 | 3.47 | 188 | 24.29 | 13.16 | 1.66 | 1.51 | 12.71 | 4.23 | 0.13 | 1.15 | 1.84 | 0.72 | 3.05 | 1048 | 31.5 | 63.4 | 17.4 | 68.1 | 154 | 569 | 212 | 7.88 | 107 |
| 10 | n.d. | 160 | 3.04 | 184 | 28 | 12.48 | 2.18 | 1.47 | 12.11 | 3.91 | 0.13 | 2.12 | 1.68 | 0.95 | 3.37 | 9417 | 29.3 | 59.7 | 20.4 | 78.8 | 171 | 589 | 195 | 8.52 | 118 |
| 11 | 1.93 | 140 | 3.07 | 193 | 31.7 | 11.48 | 2.25 | 1.17 | 11.07 | 3.69 | 0.16 | 1.09 | 1.59 | 1.63 | 3.55 | 38120 | 28.3 | 57.7 | 25.1 | 80.1 | 152 | 515 | 145 | 8.43 | 113 |
| 12 | 2.02 | 141 | 3.01 | 192 | 32.01 | 10.87 | 2.33 | 1.04 | 10.62 | 3.61 | 0.18 | 1.05 | 1.5 | 2.17 | 3.62 | 61930 | 28.1 | 56.7 | 30.2 | 82.4 | 136 | 551 | 130 | 8.17 | 117 |
| 13 | 2.06 | 117 | 2.97 | 188 | 36.53 | 10.52 | 4.24 | 1.25 | 10.34 | 3.82 | 0.11 | 1.1 | 1.61 | 1.12 | 5.73 | 15500 | 28.6 | 60.6 | 43.2 | 94.2 | 182 | 797 | 225 | 11.1 | 126 |
| 14 | 1.92 | 113 | n.d. | n.d. | 41.5 | 9.28 | 4.38 | 0.88 | 9.11 | 3.79 | 0.14 | 1.08 | 1.6 | 1.81 | 5.78 | 44160 | 28.6 | 58.1 | 43.9 | 80.6 | 154 | 690 | 191 | 10.3 | 114 |
| 15 | 1.81 | 112 | 2.56 | 184 | 46.51 | 8.59 | 4.01 | 0.66 | 8.50 | 3.89 | 0.17 | 1.1 | 1.63 | 2.42 | 6.04 | 66950 | 30.8 | 55.3 | 42.4 | 81.3 | 112 | 540 | 168 | 9.05 | 119 |
| 16 | 1.58 | 114 | 2.42 | 188 | 54.71 | 6.99 | 3.87 | 0.69 | 6.94 | 5.24 | 0.12 | 1.24 | 2.22 | 1.37 | 6.31 | 23680 | 40.4 | 66.5 | 40.1 | 77.4 | 114 | 517 | 178 | 8.52 | 123 |
| 17 | 1.29 | 118 | 2.38 | 184 | 62.48 | 6.00 | 2.78 | 0.53 | 5.99 | 5.84 | 0.10 | 1.26 | 2.46 | 1.67 | 5.27 | 32460 | 45.7 | 67.9 | 38.5 | 68.6 | 69.7 | 376 | 75.8 | 4.70 | 105 |
| 18 | 1.68 | 123 | 2.1 | 183 | 69.42 | 5.46 | 2.41 | 0.54 | 5.42 | 6.69 | 0.10 | 1.36 | 2.75 | 1.16 | 5.45 | 18560 | 49.3 | 77.4 | 33.5 | 66.9 | 70.1 | 359 | 57.9 | 4.55 | 102 |
| 19 | 1.15 | 118 | 2.18 | 188 | 78.83 | 4.96 | 1.69 | 0.51 | 4.93 | 7.23 | 0.10 | 1.42 | 2.95 | 0.84 | 4.93 | 6900 | 53.1 | 76.5 | 29.4 | 62.6 | 69.6 | 356 | 61.8 | 3.64 | 102 |
| 20 | 1.2 | 129 | 1.85 | 187 | 86.97 | 4.22 | 1.31 | 0.41 | 4.18 | 7.83 | 0.10 | 1.49 | 3.21 | 0.7 | 4.78 | 3336 | 58.8 | 83.4 | 30.1 | 62.0 | 59.9 | 306 | 52.4 | 3.00 | 97.3 |
| 21 | 1.34 | 137 | 1.61 | 188 | 93.19 | 4.28 | 2.25 | 0.40 | 4.26 | 7.74 | 0.10 | 1.45 | 3.19 | 0.85 | 5.25 | 8496 | 58.2 | 84.8 | 36.8 | 66.3 | 58.2 | 276 | 55.1 | 2.96 | 96.1 |
| 23 | 1.58 | 145 | 1.68 | 188 | 100.3 | 4.67 | 1.82 | 0.39 | 4.65 | 6.79 | 0.10 | 1.41 | 2.89 | 1.28 | 4.94 | 24530 | 54.5 | 71.5 | 29.7 | 55.3 | 53.0 | 225 | 40.7 | 2.67 | 90.6 |
| 25 | 1.15 | 149 | 1.44 | 187 | 108.5 | 5.48 | 2.28 | 0.47 | 5.40 | 6.22 | 0.10 | 1.34 | 2.72 | 1.3 | 4.86 | 25910 | 50.6 | 72.8 | 31.2 | 59.7 | 69.0 | 259 | 73.7 | 4.71 | 90.6 |
| 27 | 1.15 | 154 | 0.93 | 177 | 117.5 | 4.66 | 1.89 | 0.40 | 4.63 | 6.77 | 0.10 | 1.42 | 2.89 | 1.07 | 4.81 | 16970 | 53.5 | 75.0 | 30.0 | 55.1 | 56.0 | 203 | 40.7 | 2.75 | 86.7 |
| 29 | 2.52 | 155 | 0.69 | 188 | 126.9 | 4.00 | 0.98 | 0.32 | 4.01 | 7.16 | 0.10 | 1.43 | 2.95 | 1.16 | 4.16 | 18690 | 57.7 | 75.9 | 25.1 | 50.4 | 46.9 | 158 | 38.0 | 1.78 | 81.2 |
| 31 | 2.31 | 160 | 0.53 | 190 | 135.8 | 3.71 | 1.34 | 0.35 | 3.71 | 7.47 | 0.09 | 1.51 | 3.2 | 0.78 | 4.81 | 6642 | 60.9 | 86.0 | 28.0 | 54.4 | 51.0 | 177 | 40.2 | 1.82 | 85.0 |
| 33 | 0.7 | 153 | 0.25 | 190 | 148.1 | 3.93 | 1.79 | 0.37 | 3.91 | 7.06 | 0.09 | 1.43 | 3.01 | 0.78 | 5.05 | 7621 | 56.3 | 80.3 | 28.7 | 54.8 | 50.4 | 161 | 40.7 | 1.87 | 82.9 |
| 35 | 1.54 | 149 | 0.09 | 192 | 160.4 | 3.69 | 0.90 | 0.38 | 3.67 | 7.22 | 0.09 | 1.45 | 3.13 | 0.61 | 4.3 | 1721 | 58.1 | 84.4 | 25.4 | 52.1 | 50.9 | 168 | 38.7 | 1.86 | 80.4 |
| 37 | 1.31 | 146 | n.d. | 193 | 172.8 | 3.80 | 1.15 | 0.40 | 3.76 | 7.28 | 0.09 | 1.47 | 3.14 | 0.61 | 4.55 | 2763 | 59.1 | 87.0 | 25.8 | 54.5 | 49.5 | 158 | 40.4 | 1.56 | 75.4 |

Table 5: Composition of sediment samples from core IOW-20001-4

| Depth (cm) | Sediment Age (years) | TC (%) | TS (%) | TOC (%) | Al (%) | P (%) | Mg (%) | Ca (%) | Fe (%) | Mn (µg/g) | Li (µg/g) | Cr (µg/g) | Co (µg/g) | Ni (µg/g) | Cu (µg/g) | Zn (µg/g) | Cd (µg/g) | Pb (µg/g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.75 | 0.5 | 11.30 | 1.56 | 9.61 | 3.15 | 0.17 | 1.34 | 1.06 | 2.88 | 17400 | 24.5 | 38.4 | 18.4 | 55.4 | 96.1 | 404 | 5.8 | 60.1 |
| 1.25 | 2.6 | 11.20 | 1.46 | 10.20 | 3.26 | 0.15 | 1.31 | 1.09 | 2.95 | 18900 | 25.2 | 27.6 | 18.4 | 57.4 | 96.5 | 422 | 5.3 | 63.7 |
| 1.75 | 4.5 | 10.30 | 1.46 | 9.82 | 3.19 | 0.17 | 1.24 | 1.56 | 3.27 | 40200 | 25.0 | 32.6 | 22.7 | 63.5 | 99.5 | 476 | 6.8 | 74.0 |
| 2.25 | 6.5 | 10.10 | 1.24 | 9.03 | 3.26 | 0.15 | 1.22 | 1.36 | 3.24 | 31300 | 24.9 | 36.4 | 19.8 | 54.4 | 92.5 | 428 | 5.8 | 69.1 |
| 2.75 | 8.6 | n.d. | n.d. | 9.81 | 3.18 | 0.14 | 1.27 | 1.30 | 3.10 | 27100 | 24.6 | 39.3 | 18.8 | 60.8 | 96.1 | 443 | 5.6 | 67.0 |
| 3.25 | 10.7 | 9.71 | 1.76 | 10.00 | 2.98 | 0.14 | 1.27 | 1.36 | 3.09 | 30200 | 23.0 | 29.3 | 19.5 | 56.3 | 94.4 | 432 | 6 | 68.6 |
| 3.75 | 12.5 | 10.30 | 1.44 | 9.40 | 3.03 | 0.15 | 1.27 | 1.36 | 2.76 | 30400 | 23.5 | 28.8 | 18.8 | 53.3 | 88.2 | 399 | 5.3 | 63.8 |
| 4.25 | 14.3 | 10.80 | 1.65 | 8.95 | 2.96 | 0.13 | 1.27 | 1.04 | 2.48 | 17100 | 22.8 | 33.1 | 15.2 | 52.5 | 86.3 | 371 | 4.7 | 63.8 |
| 4.75 | 16.2 | 10.60 | 1.47 | 5.23 | 3.32 | 0.15 | 1.21 | 1.29 | 3.04 | 28000 | 25.3 | 39.2 | 19.0 | 61.6 | 101.0 | 454 | 6 | 76.0 |
| 5.25 | 18.1 | 10.00 | 1.62 | n.d. | 2.88 | 0.15 | 1.24 | 1.56 | 2.96 | 39000 | 22.9 | 32.1 | 19.8 | 60.9 | 97.0 | 441 | 6.1 | 73.3 |
| 5.75 | 19.9 | 9.53 | 1.53 | 8.75 | 2.54 | 0.18 | 1.13 | 2.21 | 3.22 | 68900 | 20.5 | 36.0 | 25.7 | 67.4 | 86.7 | 483 | 6.9 | 72.6 |
| 6.25 | 21.7 | 9.86 | 1.39 | 10.40 | 2.08 | 0.23 | 1.01 | 2.71 | 3.07 | 99100 | 17.7 | 49.3 | 26.7 | 63.4 | 78.0 | 450 | 6.7 | 71.6 |
| 6.75 | 23.6 | 8.98 | 1.78 | 10.40 | 2.44 | 0.22 | 0.99 | 2.71 | 3.57 | 94500 | 20.0 | 47.5 | 28.2 | 62.2 | 73.2 | 466 | 6 | 70.5 |
| 7.25 | 25.5 | 8.10 | 1.95 | 6.50 | 2.84 | 0.19 | 1.05 | 2.30 | 4.04 | 74700 | 22.4 | 37.8 | 29.0 | 60.2 | 77.9 | 485 | 7.1 | 90.9 |
| 7.75 | 28.3 | 7.56 | 2.23 | 5.59 | 3.64 | 0.14 | 1.10 | 1.71 | 4.70 | 45200 | 28.6 | 49.8 | 32.3 | 61.8 | 99.4 | 516 | 7.6 | 87.2 |
| 8.25 | 31.1 | 6.85 | 1.95 | 4.99 | 3.87 | 0.13 | 1.16 | 2.04 | 4.42 | 52700 | 30.0 | 42.5 | 29.4 | 58.2 | 76.0 | 439 | 5.2 | 65.4 |
| 8.75 | 34.2 | 6.44 | 1.41 | 6.21 | 4.56 | 0.10 | 1.16 | 2.46 | 4.15 | 56000 | 34.9 | 48.5 | 26.7 | 50.0 | 55.5 | 358 | 4.3 | 60.9 |
| 9.25 | 37.4 | 6.36 | 1.13 | 4.29 | 4.84 | 0.10 | 1.16 | 2.57 | 3.86 | 56900 | 39.0 | 47.3 | 27.8 | 53.6 | 58.8 | 373 | 4.1 | 60.0 |
| 9.75 | 40.5 | 6.12 | 1.22 | 3.77 | 5.01 | 0.09 | 1.20 | 2.89 | 3.51 | 63600 | 39.1 | 54.4 | 24.1 | 50.5 | 49.1 | 314 | 3 | 55.8 |
| 10.25 | 43.7 | 5.31 | 1.16 | 4.23 | 5.90 | 0.10 | 1.30 | 2.17 | 3.97 | 47400 | 45.7 | 65.4 | 22.7 | 49.7 | 48.5 | 293 | 2.7 | 54.7 |
| 10.75 | 47 | 5.40 | 1.40 | 4.59 | 6.06 | 0.09 | 1.32 | 1.79 | 4.49 | 38000 | 46.2 | 68.4 | 24.9 | 55.5 | 55.6 | 312 | 3.7 | 51.5 |
| 11.25 | 50.3 | 5.13 | 1.74 | 4.65 | 6.61 | 0.09 | 1.37 | 1.20 | 4.48 | 19500 | 48.9 | 75.8 | 33.0 | 58.6 | 69.4 | 302 | 4 | 58.3 |
| 11.75 | 54 | 5.87 | 0.67 | 5.18 | 6.30 | 0.11 | 1.29 | 2.27 | 3.46 | 52000 | 46.9 | 61.3 | 22.5 | 47.2 | 52.7 | 233 | 2.5 | 45.8 |
| 12.25 | 57.6 | 5.53 | 0.92 | 3.19 | 6.17 | 0.11 | 1.28 | 2.12 | 3.79 | 49000 | 47.2 | 62.0 | 23.5 | 51.5 | 49.0 | 216 | 2.5 | 52.0 |
| 12.75 | 61.5 | 5.60 | 0.87 | 4.01 | 5.95 | 0.11 | 1.24 | 2.42 | 3.47 | 59400 | 46.5 | 66.3 | 21.3 | 47.6 | 43.8 | 183 | 2.1 | 50.6 |
| 13.25 | 65.4 | 4.38 | 1.18 | 3.75 | 6.59 | 0.13 | 1.37 | 1.49 | 4.27 | 33400 | 50.2 | 63.7 | 24.0 | 48.2 | 40.1 | 159 | 1.5 | 45.8 |
| 13.75 | 69.2 | 4.10 | 1.03 | 3.66 | 6.39 | 0.12 | 1.41 | 1.08 | 4.41 | 20100 | 53.6 | 77.8 | 25.4 | 49.2 | 41.8 | 170 | 1.5 | 45.8 |
| 14.25 | 73 | 3.90 | 0.74 | 3.94 | 7.04 | 0.10 | 1.46 | 0.85 | 4.26 | 10200 | 57.0 | 76.8 | 22.3 | 49.7 | 46.9 | 177 | 1.5 | 49.4 |
| 14.75 | 77.2 | 4.17 | 0.88 | 3.97 | 6.75 | 0.12 | 1.40 | 1.08 | 4.10 | 19800 | 55.4 | 77.7 | 21.1 | 47.7 | 45.0 | 173 | 1.5 | 52.9 |
| 15.25 | 81.4 | 4.33 | 1.08 | 5.64 | 6.57 | 0.11 | 1.39 | 1.06 | 4.25 | 19300 | 54.0 | 75.3 | 22.5 | 53.5 | 46.9 | 171 | 1.5 | 51.2 |
| 15.75 | 84.9 | 4.34 | 0.75 | 4.41 | 7.18 | 0.10 | 1.40 | 1.22 | 3.98 | 24000 | 56.1 | 79.8 | 22.5 | 50.2 | 47.7 | 171 | 1.5 | 54.7 |
| 16.25 | 88.4 | 4.72 | 0.73 | 4.00 | 6.84 | 0.11 | 1.36 | 1.67 | 3.74 | 39200 | 52.4 | 74.0 | 22.1 | 50.8 | 44.6 | 163 | 1.5 | 45.9 |
| 16.75 | 94.8 | 4.25 | 1.32 | 5.08 | 7.04 | 0.11 | 1.40 | 1.25 | 4.62 | 26000 | 53.7 | 74.4 | 24.1 | 51.0 | 44.6 | 165 | 1.5 | 39.4 |
| 17.25 | 101.3 | 3.91 | 1.33 | 4.13 | 6.99 | 0.09 | 1.45 | 0.90 | 4.92 | 11400 | 57.6 | 81.2 | 24.6 | 52.2 | 47.0 | 197 | 1.5 | 43.9 |
| 17.75 | 111.2 | 4.05 | 0.98 | 3.88 | 6.93 | 0.09 | 1.45 | 1.11 | 4.41 | 17900 | 57.9 | 82.5 | 23.1 | 49.1 | 47.0 | 153 | 1.5 | 37.9 |
| 18.25 | 121 | 4.35 | 0.66 | 4.60 | 7.14 | 0.10 | 1.41 | 1.52 | 3.82 | 30100 | 56.2 | 73.2 | 20.7 | 45.3 | 43.1 | 138 | 1.5 | 39.7 |
| 18.75 | 132.5 | 4.25 | 0.61 | 3.89 | 6.75 | 0.11 | 1.40 | 1.46 | 3.84 | 29500 | 55.4 | 78.0 | 20.5 | 47.0 | 43.7 | 138 | 1.5 | 42.0 |
| 19.25 | 144 | 3.89 | 0.87 | 3.83 | 6.77 | 0.11 | 1.45 | 1.07 | 4.41 | 18000 | 57.3 | 80.5 | 22.2 | 52.2 | 44.8 | 141 | 1.5 | 39.0 |
| 19.75 | 161.7 | 3.89 | 1.26 | 4.62 | 6.88 | 0.12 | 1.46 | 1.06 | 4.75 | 19800 | 56.7 | 80.9 | 23.5 | 56.6 | 46.4 | 144 | 1.5 | 34.3 |
| 20.5 | 179.4 | 4.20 | 1.04 | 4.30 | 6.87 | 0.12 | 1.42 | 1.23 | 4.25 | 27000 | 53.3 | 68.6 | 22.8 | 51.3 | 47.4 | 137 | 1.5 | 35.3 |
| 21.5 | 244.5 | 4.44 | 0.70 | 3.95 | 6.58 | 0.11 | 1.43 | 1.41 | 3.81 | 29300 | 53.6 | 76.8 | 23.2 | 52.5 | 47.4 | 135 | 1.5 | 36.1 |
| 22.5 | 309.6 | 4.35 | 1.09 | 3.85 | 6.55 | 0.11 | 1.44 | 1.34 | 4.08 | 28000 | 52.4 | 69.1 | 23.0 | 55.2 | 47.3 | 139 | 1.5 | 32.7 |
| 23.5 | 374.7 | 3.92 | 1.17 | 4.32 | 7.05 | 0.10 | 1.48 | 0.76 | 4.36 | 9000 | 56.8 | 81.8 | 25.6 | 54.7 | 50.0 | 146 | 1.5 | 33.3 |
| 24.5 | 439.8 | 4.35 | 1.64 | 4.61 | 6.75 | 0.10 | 1.43 | 1.01 | 4.57 | 18500 | 53.9 | 81.0 | 25.6 | 54.1 | 50.2 | 144 | 1.5 | 30.3 |
| 25.5 | 504.9 | 4.75 | 1.08 | 4.51 | 6.67 | 0.10 | 1.44 | 1.10 | 4.01 | 21600 | 53.4 | 76.4 | 21.5 | 56.2 | 53.2 | 144 | 1.5 | 36.0 |
| 26.5 | 570 | 4.90 | 0.86 | 4.41 | 6.76 | 0.11 | 1.36 | 1.52 | 3.69 | 36300 | 51.1 | 76.0 | 20.2 | 50.2 | 48.7 | 132 | 1.5 | 39.6 |
| 27.5 | 635.2 | 4.07 | 1.96 | 4.02 | 6.62 | 0.10 | 1.44 | 1.10 | 4.81 | 19200 | 53.3 | 76.5 | 28.2 | 57.5 | 45.3 | 125 | 1.5 | 30.0 |
| 28.5 | 700.3 | 3.62 | 0.87 | 3.99 | 6.16 | 0.09 | 1.34 | 0.67 | 4.05 | 6800 | 49.4 | 82.8 | 22.2 | 50.4 | 45.0 | 137 | 1.5 | 29.5 |
| 29.5 | 765.4 | 3.74 | 0.63 | 3.92 | 6.32 | 0.09 | 1.44 | 0.73 | 3.86 | 8100 | 55.4 | 83.2 | 21.4 | 48.2 | 44.5 | 139 | 1.5 | 30.1 |

Table 6: Composition of sediment samples from core IOW-20007 (composite of two multicores)

| Depth (cm) | Sediment Age (years) | TC (%) | TIC (%) | TOC (%) | Al (%) | P (%) | Mg (%) | Ca (%) | Fe (%) | Mn (µg/g) | Li (µg/g) | Cr (µg/g) | Co (µg/g) | Ni (µg/g) | Cu (µg/g) | Zn (µg/g) | Cd (µg/g) | Pb (µg/g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.50 | 0.7 | 6.61 | 0.00 | 6.61 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| 1.50 | 1.0 | 8.24 | 0.00 | 8.24 | 1.61 | 0.10 | 2.23 | 0.96 | 0.92 | 664 | 18.0 | 18.0 | 4.0 | 22.0 | 40.0 | 147 | n.d. | 18.0 |
| 2.50 | 1.3 | 6.64 | 0.39 | 6.25 | 2.02 | 0.16 | 2.03 | 0.89 | 1.35 | 850 | 21.0 | 24.0 | 9.0 | 26.0 | 49.0 | 177 | n.d. | 25.0 |
| 3.50 | 1.8 | 8.57 | 0.33 | 8.24 | 2.52 | 0.21 | 1.74 | 0.73 | 1.71 | 1378 | 26.0 | 30.0 | 10.0 | 31.0 | 63.0 | 182 | n.d. | 29.0 |
| 4.50 | 2.6 | 7.45 | 2.12 | 5.33 | 2.03 | 0.19 | 2.05 | 0.88 | 1.28 | 1492 | 21.0 | 23.0 | 7.0 | 26.0 | 48.0 | 185 | n.d. | 26.0 |
| 5.50 | 3.5 | 6.28 | 0.04 | 6.24 | 1.75 | 0.12 | 2.45 | 1.06 | 1.10 | 736 | 14.0 | 24.0 | 5.0 | 25.0 | 43.0 | 159 | n.d. | 31.0 |
| 6.50 | 4.5 | 7.47 | 0.00 | 7.47 | 1.89 | 0.13 | 2.39 | 1.03 | 1.19 | 756 | 15.0 | 26.0 | 6.0 | 28.0 | 44.0 | 179 | n.d. | 19.0 |
| 7.50 | 5.1 | 6.65 | 0.02 | 6.63 | 1.48 | 0.10 | 2.43 | 1.05 | 0.93 | 611 | 13.0 | 20.0 | 5.0 | 21.0 | 39.0 | 146 | n.d. | 16.0 |
| 7.75 | 5.4 | 6.65 | 0.02 | 6.63 | 1.28 | 0.08 | 2.28 | 0.90 | 0.89 | 577 | n.d. | 27.9 | n.d. | 27.9 | 55.9 | 223 | n.d. | 18.6 |
| 8.25 | 5.8 | 12.02 | 0.00 | 12.02 | 1.41 | 0.09 | 2.06 | 0.80 | 0.88 | 585 | 8.1 | 24.4 | n.d. | 28.4 | 48.7 | 211 | n.d. | 23.6 |
| 8.75 | 6.3 | 12.02 | 0.00 | 12.02 | 1.37 | 0.08 | 2.03 | 0.84 | 0.86 | 564 | 14.4 | 18.5 | n.d. | 22.6 | 45.3 | 202 | n.d. | 32.0 |
| 9.25 | 6.7 | 9.27 | 0.00 | 9.27 | 1.57 | 0.09 | 1.85 | 0.79 | 1.02 | 708 | 13.4 | 16.4 | n.d. | 25.3 | 49.0 | 207 | n.d. | 49.0 |
| 9.75 | 7.2 | 9.27 | 0.00 | 9.27 | 1.38 | 0.09 | 1.95 | 0.74 | 1.05 | 869 | 10.4 | 20.8 | 1.5 | 24.6 | 37.2 | 219 | n.d. | 50.0 |
| 10.25 | 7.7 | 7.33 | 0.00 | 7.33 | 1.65 | 0.10 | 1.96 | 0.81 | 1.20 | 742 | 14.0 | 23.9 | 6.0 | 29.9 | 53.8 | 231 | n.d. | 23.9 |
| 10.75 | 8.2 | 7.33 | 0.00 | 7.33 | 3.06 | 0.11 | 1.59 | 0.82 | 1.93 | 718 | 25.0 | 36.4 | 10.0 | 38.9 | 65.0 | 262 | 2.1 | 55.0 |
| 11.25 | 8.9 | 8.12 | 0.03 | 8.09 | 2.99 | 0.11 | 1.47 | 0.81 | 2.02 | 615 | 25.0 | 42.5 | 11.0 | 40.0 | 65.0 | 287 | 3.0 | 65.0 |
| 11.75 | 9.6 | 8.12 | 0.03 | 8.09 | 3.07 | 0.10 | 1.23 | 0.68 | 1.97 | 510 | 25.0 | 40.6 | 10.9 | 38.0 | 65.0 | 283 | 2.8 | 64.0 |
| 12.25 | 10.5 | 8.87 | 0.00 | 8.87 | 3.03 | 0.11 | 1.38 | 0.78 | 2.02 | 560 | 23.0 | 42.9 | 11.0 | 44.4 | 79.0 | 331 | 3.5 | 55.0 |
| 12.75 | 11.4 | 8.87 | 0.00 | 8.87 | 3.01 | 0.12 | 1.35 | 0.76 | 2.16 | 591 | 23.6 | 46.0 | 11.4 | 48.0 | 86.7 | 402 | 4.4 | 63.0 |
| 13.25 | 12.3 | 11.42 | 0.00 | 11.42 | 2.91 | 0.12 | 1.24 | 0.69 | 2.25 | 585 | 23.0 | 49.5 | 11.8 | 49.0 | 86.0 | 411 | 4.3 | 73.0 |
| 13.75 | 13.2 | 11.42 | 0.00 | 11.42 | 3.23 | 0.12 | 1.18 | 0.73 | 2.43 | 649 | 23.5 | 53.8 | 11.5 | 51.4 | 99.7 | 476 | 4.6 | 78.3 |
| 14.25 | 14.1 | 11.85 | 0.00 | 11.85 | 3.48 | 0.11 | 1.31 | 0.73 | 2.40 | 610 | 23.4 | 51.0 | 11.2 | 49.7 | 95.0 | 437 | 4.1 | 76.0 |
| 14.75 | 15.1 | 10.26 | 0.00 | 10.26 | 3.28 | 0.11 | 1.24 | 0.75 | 2.40 | 621 | 22.9 | 53.0 | 12.7 | 50.9 | 98.0 | 479 | 6.7 | 78.0 |
| 15.75 | 17.7 | 9.74 | 0.00 | 9.74 | 3.03 | 0.11 | 1.12 | 0.60 | 3.35 | 839 | 23.3 | 55.2 | 16.0 | 63.8 | 138.0 | 576 | 7.8 | 88.1 |
| 16.25 | 19.0 | 9.30 | 0.12 | 9.18 | 3.46 | 0.15 | 1.31 | 1.21 | 3.70 | 20810 | 24.4 | 54.2 | 20.6 | 75.5 | 134.0 | 632 | 8.6 | 87.3 |
| 16.75 | 20.3 | 8.27 | 1.65 | 6.62 | 2.88 | 0.23 | 1.20 | 2.38 | 3.56 | 72140 | 21.2 | 49.6 | 31.2 | 64.5 | 82.5 | 529 | 5.5 | 76.9 |
| 17.25 | 21.5 | 8.78 | 1.26 | 7.52 | 2.79 | 0.22 | 1.17 | 2.07 | 3.48 | 61170 | 19.8 | 47.5 | 26.2 | 60.0 | 93.7 | 525 | 5.6 | 75.3 |
| 17.75 | 22.8 | 9.42 | 0.51 | 8.91 | 3.00 | 0.14 | 1.21 | 1.17 | 4.57 | 21140 | 19.3 | 47.5 | 23.3 | 67.0 | 121.0 | 553 | 1.1 | 85.8 |
| 18.25 | 24.3 | 9.41 | 0.49 | 8.92 | 2.77 | 0.20 | 1.16 | 1.49 | 4.58 | 42640 | 22.6 | 40.0 | 33.3 | 79.0 | 125.0 | 739 | 9.6 | 97.5 |
| 18.75 | 25.9 | 8.65 | 0.75 | 7.90 | 2.36 | 0.20 | 1.15 | 1.93 | 4.31 | 62460 | 18.7 | 39.1 | 39.3 | 81.5 | 108.0 | 584 | 7.7 | 74.7 |
| 19.25 | 27.7 | 8.19 | 2.00 | 6.19 | 2.79 | 0.24 | 1.06 | 2.32 | 4.17 | 88290 | 22.9 | 47.0 | 45.0 | 81.6 | 93.0 | 634 | 7.8 | 84.0 |
| 20.50 | 33.0 | n.d. | n.d. | n.d. | 3.21 | 0.24 | 1.02 | 2.72 | 4.05 | 82300 | 24.0 | 45.0 | 31.0 | 64.0 | 64.0 | 417 | n.d. | 69.0 |
| 21.50 | 37.7 | n.d. | n.d. | n.d. | 3.04 | 0.14 | 1.03 | 2.49 | 5.04 | 67660 | 22.0 | 39.0 | 35.0 | 55.0 | 67.0 | 491 | n.d. | 67.0 |
| 22.50 | 42.9 | n.d. | n.d. | n.d. | 4.75 | 0.14 | 1.26 | 1.89 | 4.17 | 35430 | 38.0 | 59.0 | 27.0 | 57.0 | 81.0 | 358 | n.d. | 78.0 |
| 23.50 | 49.8 | n.d. | n.d. | n.d. | 5.08 | 0.15 | 1.26 | 2.24 | 4.09 | 53730 | 39.0 | 56.0 | 26.0 | 47.0 | 40.0 | 256 | n.d. | 55.0 |
| 24.50 | 58.2 | n.d. | n.d. | n.d. | 5.62 | 0.13 | 1.33 | 1.36 | 4.09 | 18100 | 43.0 | 69.0 | 23.0 | 53.0 | 51.0 | 278 | n.d. | 61.0 |
| 25.50 | 66.6 | 4.91 | 1.18 | 3.73 | 5.82 | 0.10 | 1.33 | 1.86 | 3.97 | 38760 | 49.0 | 72.7 | 25.0 | 51.0 | 56.2 | 346 | 2.5 | 53.9 |
| 26.50 | 75.7 | 4.73 | 1.50 | 3.23 | 6.29 | 0.10 | 1.35 | 2.05 | 4.13 | 42670 | 45.3 | 73.5 | 26.1 | 51.0 | 47.9 | 301 | 0.6 | 50.6 |
| 27.50 | 85.7 | 4.58 | 0.97 | 3.61 | 6.05 | 0.10 | 1.39 | 1.70 | 4.83 | 37190 | 46.3 | 71.9 | 29.7 | 48.9 | 45.4 | 321 | 1.7 | 58.3 |
| 28.50 | 95.0 | 4.63 | 0.49 | 4.14 | 6.13 | 0.09 | 1.38 | 1.23 | 4.88 | 20070 | 49.6 | 76.3 | 29.7 | 55.7 | 58.7 | 316 | 2.6 | 60.6 |
| 29.50 | 109.1 | 4.73 | 0.62 | 4.11 | 5.93 | 0.10 | 1.31 | 1.16 | 4.50 | 20620 | 49.3 | 77.6 | 32.4 | 56.3 | 56.6 | 292 | 1.9 | 57.5 |
| 30.50 | 136.9 | 4.25 | 0.50 | 3.75 | 6.46 | 0.11 | 1.44 | 1.11 | 4.53 | 20130 | 49.2 | 78.4 | 27.9 | 48.6 | 48.6 | 243 | 1.6 | 56.0 |
| 32.50 | n.d. | n.d. | n.d. | n.d. | 7.40 | 0.09 | 1.62 | 0.78 | 4.48 | 6546 | 56.4 | 91.5 | 21.9 | 49.8 | 46.5 | 235 | 0.8 | 42.3 |
| 33.50 | n.d. | 3.30 | 0.01 | 3.29 | 4.62 | 0.09 | 1.13 | 0.45 | 4.59 | 2562 | 47.0 | 85.0 | 26.5 | 55.0 | 42.0 | 213 | 0.8 | 42.7 |
| 34.50 | n.d. | 3.36 | 0.08 | 3.28 | 7.05 | 0.10 | 1.57 | 0.72 | 5.26 | 5360 | 55.0 | 87.4 | 27.6 | 50.9 | 45.9 | 215 | 0.4 | 43.4 |
| 35.50 | n.d. | 3.55 | 0.18 | 3.37 | 7.67 | 0.10 | 1.56 | 0.82 | 4.80 | 8656 | 52.5 | 81.8 | 26.2 | 48.5 | 44.5 | 203 | 0.7 | 51.0 |
| 36.50 | n.d. | 3.49 | 0.00 | 3.49 | 4.30 | 0.09 | 1.07 | 0.44 | 4.47 | 2396 | 48.2 | 80.9 | 26.0 | 48.8 | 46.0 | 199 | 0.3 | 49.5 |
| 37.50 | n.d. | 3.49 | 0.00 | 3.49 | 4.23 | 0.09 | 1.12 | 0.47 | 4.20 | 1611 | 52.2 | 83.2 | 27.3 | 49.0 | 48.4 | 213 | 0.9 | 42.2 |
| 38.50 | n.d. | 3.51 | 0.34 | 3.17 | 7.34 | 0.10 | 1.43 | 1.03 | 4.16 | 16120 | 56.2 | 85.9 | 22.9 | 48.9 | 46.8 | 220 | n.d. | 43.0 |
| 39.50 | n.d. | 3.18 | 0.00 | 3.18 | 6.95 | 0.09 | 1.54 | 0.62 | 5.07 | 2668 | 50.6 | 70.0 | 27.0 | 57.0 | 42.3 | 213 | 0.4 | 38.0 |
| 40.50 | n.d. | 3.51 | 0.00 | 3.51 | 6.21 | 0.09 | 1.49 | 0.61 | 4.90 | 1891 | 48.5 | 87.8 | 28.0 | 47.4 | 45.0 | 207 | n.d. | 32.0 |
| 41.50 | n.d. | 3.64 | 0.04 | 3.60 | 6.23 | 0.09 | 1.40 | 0.62 | 4.47 | 4045 | 47.4 | 86.2 | 24.6 | 51.3 | 46.3 | 214 | 1.6 | 46.5 |
| 42.50 | n.d. | 3.65 | 0.46 | 3.19 | 7.00 | 0.10 | 1.48 | 1.07 | 4.12 | 16100 | 50.8 | 85.4 | 22.2 | 48.5 | 46.2 | 209 | 0.3 | 39.9 |
| 43.50 | n.d. | 3.27 | 0.02 | 3.25 | 7.86 | 0.09 | 1.51 | 0.66 | 4.83 | 3805 | 51.8 | 90.0 | 25.0 | 55.0 | 45.7 | 199 | 0.3 | 37.2 |
| 44.50 | n.d. | n.d. | 0.02 | n.d. | n.d. | 0.08 | 1.38 | 0.64 | 5.33 | 3707 | 50.0 | 76.4 | 32.0 | 50.0 | 43.0 | 201 | 0.7 | 44.3 |
| 45.50 | n.d. | n.d. | 0.23 | n.d. | 6.18 | 0.09 | 1.29 | 0.84 | 4.92 | 10760 | 43.0 | 79.0 | 26.0 | 50.0 | 41.0 | 191 | 0.4 | 41.0 |
| 46.50 | n.d. | n.d. | 0.00 | n.d. | 6.94 | 0.09 | 1.37 | 0.80 | 4.40 | 9554 | 48.4 | 85.5 | 25.3 | 52.8 | 44.0 | 196 | 0.5 | 33.5 |
| 47.50 | n.d. | n.d. | 0.34 | n.d. | 7.23 | 0.10 | 1.47 | 1.05 | 4.95 | 16400 | 47.2 | 77.0 | 27.0 | 53.6 | 43.1 | 191 | 0.3 | 42.0 |
| 48.50 | n.d. | n.d. | 0.14 | n.d. | 6.99 | 0.10 | 1.47 | 0.80 | 4.99 | 9380 | 49.7 | 83.0 | 27.8 | 53.0 | 44.9 | 194 | 0.3 | 52.5 |
| 49.50 | n.d. | n.d. | 0.00 | n.d. | 6.80 | 0.10 | 1.44 | 0.62 | 4.29 | 3158 | 50.9 | 88.0 | 24.4 | 51.9 | 47.7 | 199 | 0.4 | 29.1 |

# 7. Studies on Suspended Matter

## 7.1 Observations of the nepheloid layers in the Gotland Deep (August 1994)

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### Introduction

The accumulations of suspended particulate matter in the water column of the Gotland Deep have been known for a long time (YAKUBOVICH et al., 1972; EMELYANOV and PUSTELNIKOW, 1976) as layers of elevated turbidity of the waters (or nepheloid layers) which are registered by light scattering experiments. Their role is very significant in the basinward transport of sedimentary matter and pollutants added to coastal areas of the Baltic Sea. They are results of a complicated interplay between the dynamical and thermohaline structures of sea water, the distinctive features of the bottom relief, the properties of sediments and suspended particles, and the existence of the deep-water redox boundaries which act as geochemical sources of suspended particulate matter (SIVKOV and ZHUROV, 1991). The variety and complexity of the processes forming the NL in the Gotland Deep require that the origin of the NL be ascertained in almost every observation.

The aim of this paper is to report observations of the NL made during the IOW expedition in the GOBEX area with R/V "Alexander von Humboldt" (August 1994), and to discuss the influence of the several processes on formation of the bottom and intermediate nepheloid layers (BNL and INL, respectively) in the Gotland Deep.

### Methods

We have registered *in situ* and continuously the light scattering (turbidity) and water temperature of the water column by an immersible nephelometer developed in Atlantic Branch of P.P. Shirshov Institute of Oceanology of Russian Academy of Sciences (KARABASHEV et al., 1988). The light scattering by the suspended particles is measured in the wavelength range from 580 to 700 nm at an angle of 90°.

The hydrographical data set gathered on the same stations during the GOBEX II expedition was used for the characterisation of the water column conditions. Hydrographic measurements were carried out using the CTD probe OM-87 of the IOW.

Table 1. The GOBEX stations occupied and registered nepheloid layers during this study

| NN | Stations | Dates/ Y:M:D | Average Time UTC/ H:M | Latitude/ Deg:Min N | Longit./ Deg:Min E | Depth/ m | Tools |
|---|---|---|---|---|---|---|---|
| *Northern section* | | | | | | | |
| 1 | 810 20012 | 94:08:28 | 07:55 | 57:31 | 19:58 | 149 | OM* |
| 2 | 811 20013 | 94:08:28 | 09:35 | 57:30 | 20:09 | 182 | N** |
| 3 | 812 20014 | 94:08:28 | 10:45 | 57:29 | 20:10 | 190 | OM, N |
| 4 | 813 20015 | 94:08:28 | 11:35 | 57:29 | 20:13 | 195 | OM, N |
| 5 | 814 20016 | 94:08:28 | 12:20 | 57:28 | 20:15 | 203 | OM, N |
| 6 | 815 20017 | 94:08:28 | 13:15 | 57:27 | 20:18 | 210 | OM, N |
| 7 | 816 20018 | 94:08:28 | 14:20 | 57:27 | 20:20 | 207 | OM, N |
| 8 | 817 20019 | 94:08:28 | 15:15 | 57:26 | 20:23 | 201 | OM, N |
| 9 | 818 20020 | 94:08:28 | 16:30 | 57:26 | 20:26 | 194 | OM, N |
| 10 | 819 20021 | 94:08:28 | 17:35 | 57:25 | 20:29 | 181 | OM, N |
| 11 | 820 20022 | 94:08:28 | 18:40 | 57:25 | 20:32 | 143 | OM, N |
| *Southern section (from E to W)* | | | | | | | |
| 1 | 799 20001 | 94:08:24 | 08:30 | 57:18 | 20:03 | 243 | N |
| 2 | 804 20006 | 94:08:26 | 10:30 | 57:18 | 20:13 | 239 | N |
| 3 | 801 20003 | 94:08:25 | 12:00 | 57:18 | 20:19 | 196 | N |
| 4 | 798 20000 | 94:08:23 | 12:40 | 57:15 | 20:35 | 112 | N |

* - IOW CTD probe OM-87, ** - ABIORAS nephelometer

## Results

The positions of stations occupied during the expedition are depicted in Figure 1. The 15 stations which provide nephelometric and hydrographic data are aligned in two transects across the Eastern Gotland Basin; their positions are listed in Table 1. According to FEISTEL and HAGEN (1996) annual atmospheric signals are rather weak in the Gotland

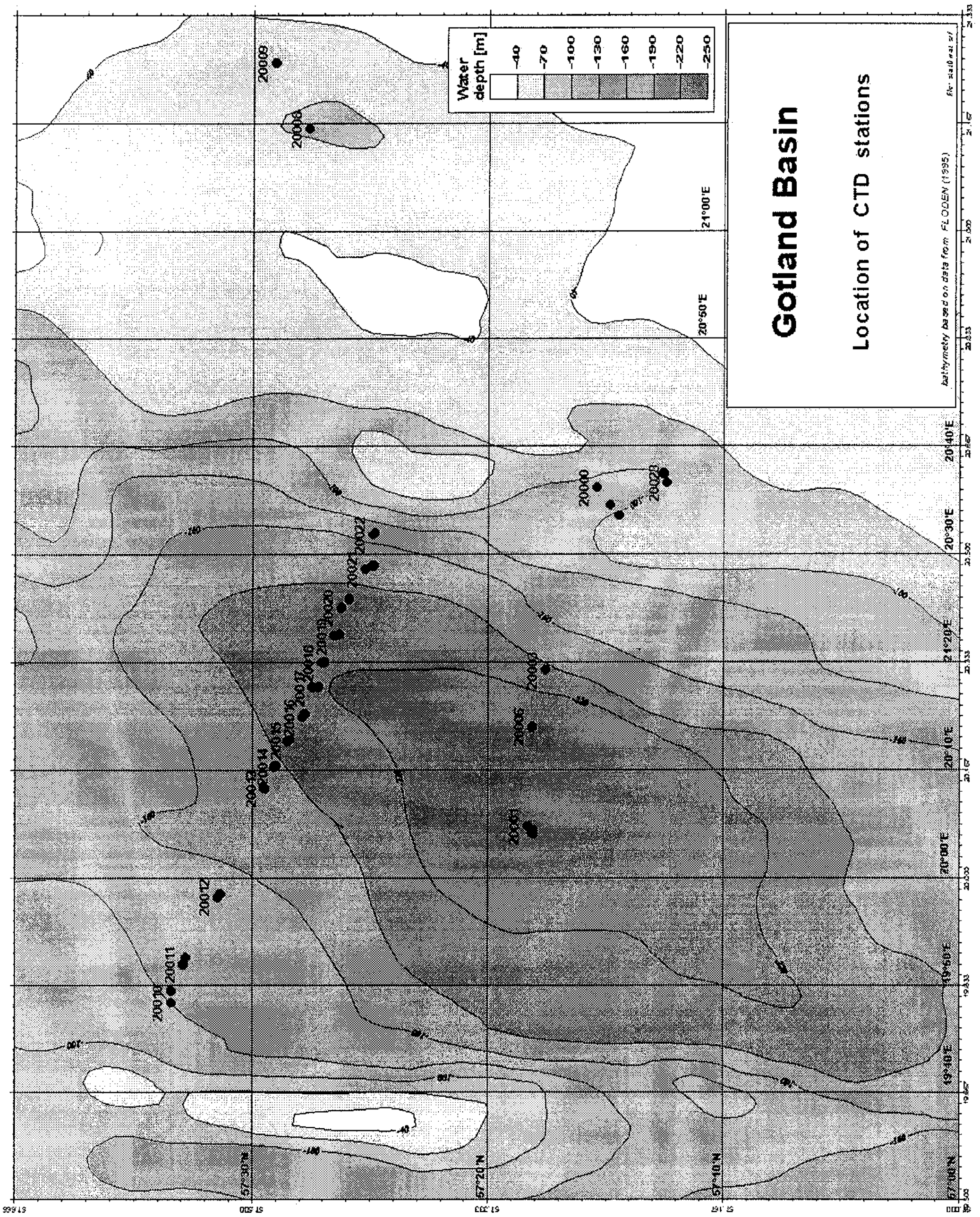
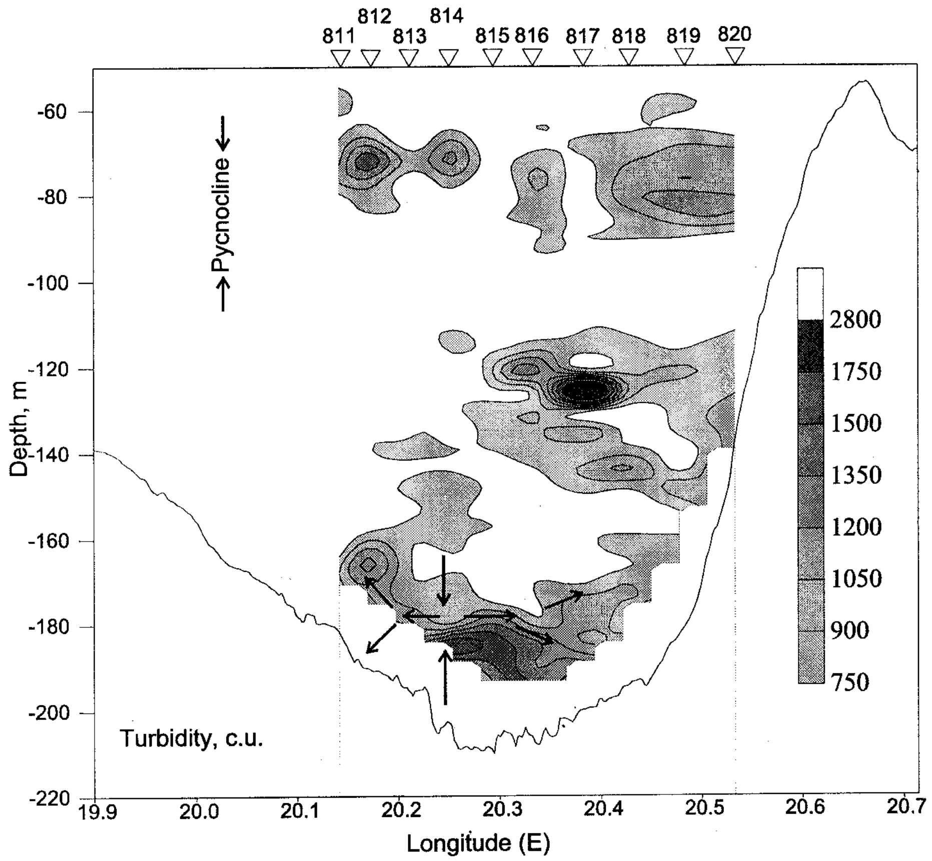


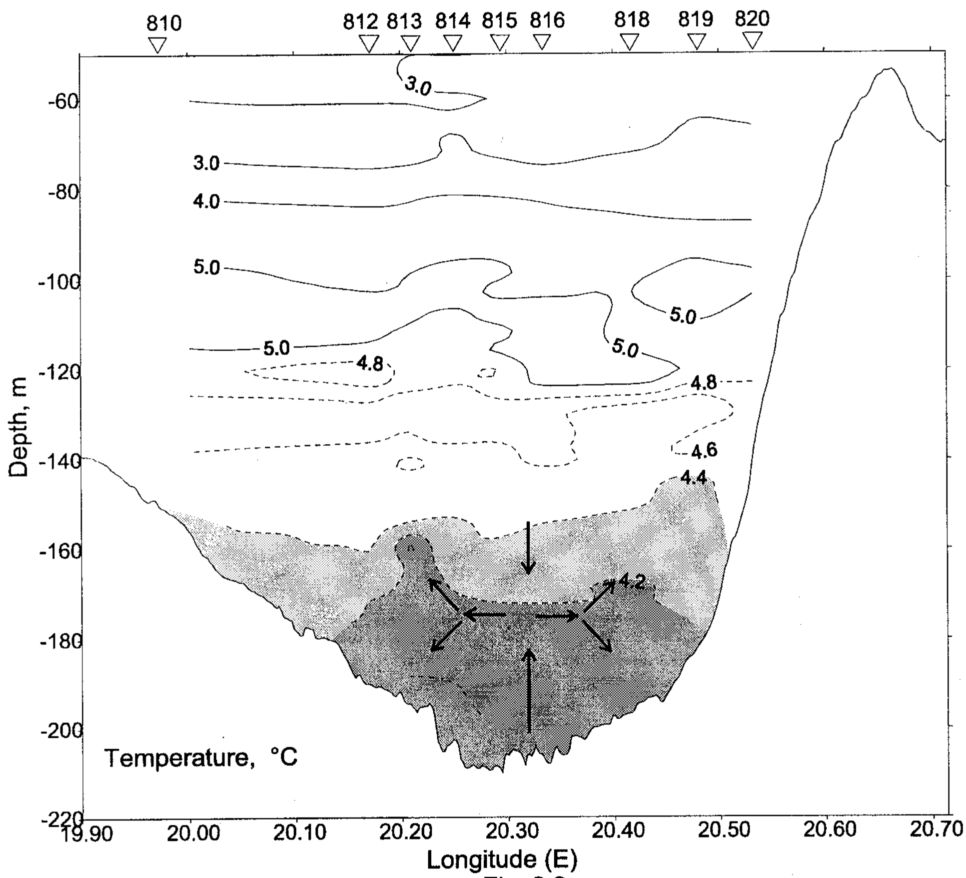

Figure 1. The nephelometric stations occupied during the GOBEX expedition in 1994.

Basin below 50 m depth and we thus only investigate the deep waters of the basin (depth >50 m). The general distribution of NLs, water temperature, salinity, density and dissolved oxygen in the two sections are summarised in Figures 2 and 3.



811
812
813
814
815
816
817
818
819
820
Pycnocline
Depth, m
Turbidity, c.u.
2800
1750
1500
1350
1200
1050
900
750
Longitude (E)


Fig. 2.1.



810
812
813
814
815
816
818
819
820
3.0
4.0
5.0
4.8
4.6
4.4
4.2
Depth, m
Temperature, °C
Longitude (E)


Fig. 2.2.

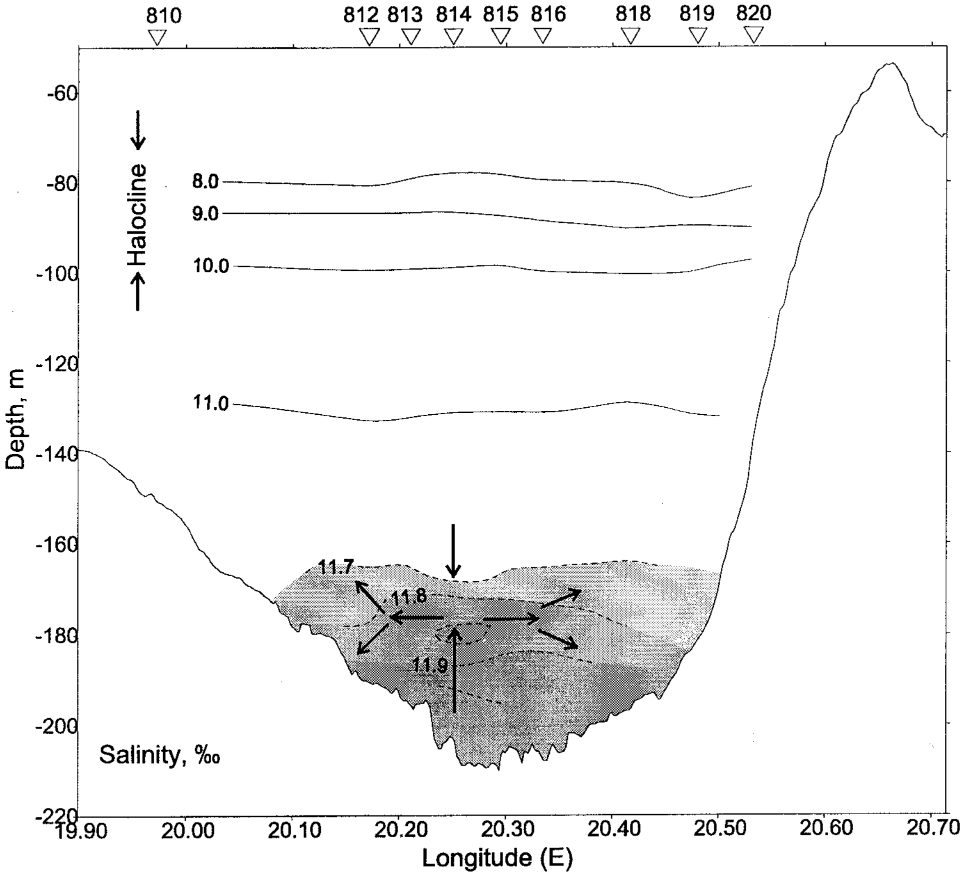

810 812 813 814 815 816 818 819 820
Halocline
8.0
9.0
10.0
11.0
11.7
11.8
11.9
Depth, m
-60
-80
-100
-120
-140
-160
-180
-200
-220
Salinity, ‰
19.90 20.00 20.10 20.20 20.30 20.40 20.50 20.60 20.70
Longitude (E)

Fig. 2.3.

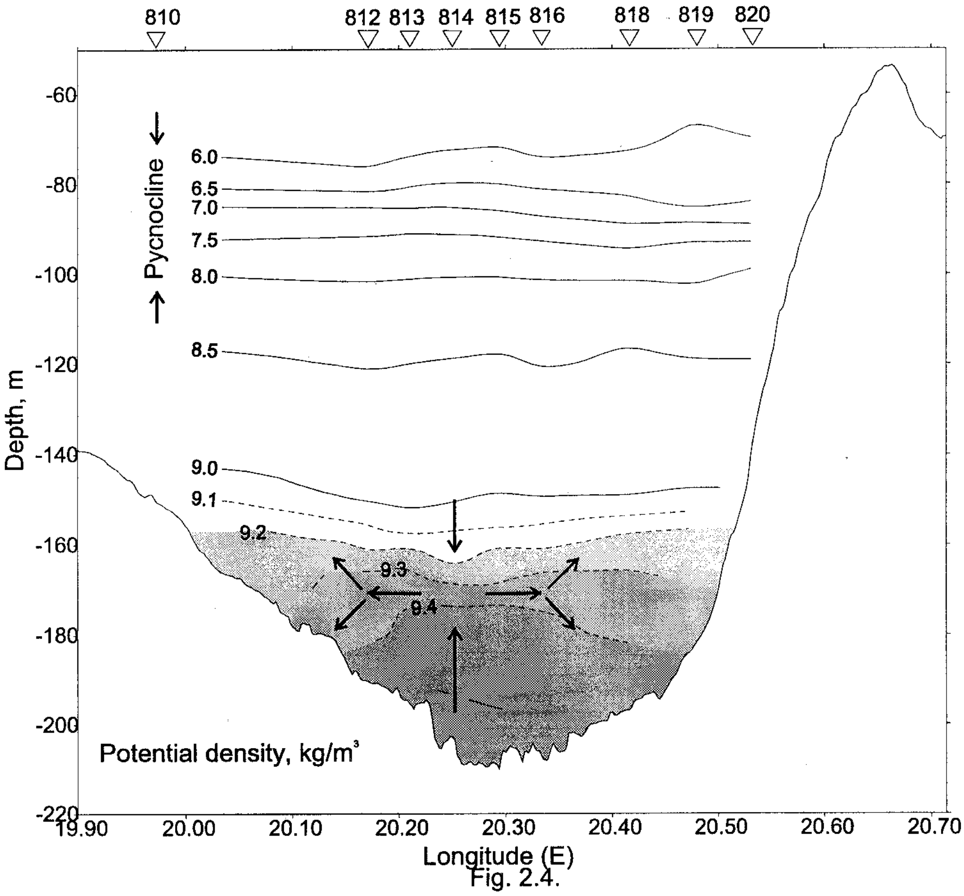

810 812 813 814 815 816 818 819 820
Pycnocline
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.1
9.2
9.3
9.4
Depth, m
-60
-80
-100
-120
-140
-160
-180
-200
-220
Potential density, kg/m³
19.90 20.00 20.10 20.20 20.30 20.40 20.50 20.60 20.70
Longitude (E)

Fig. 2.4.

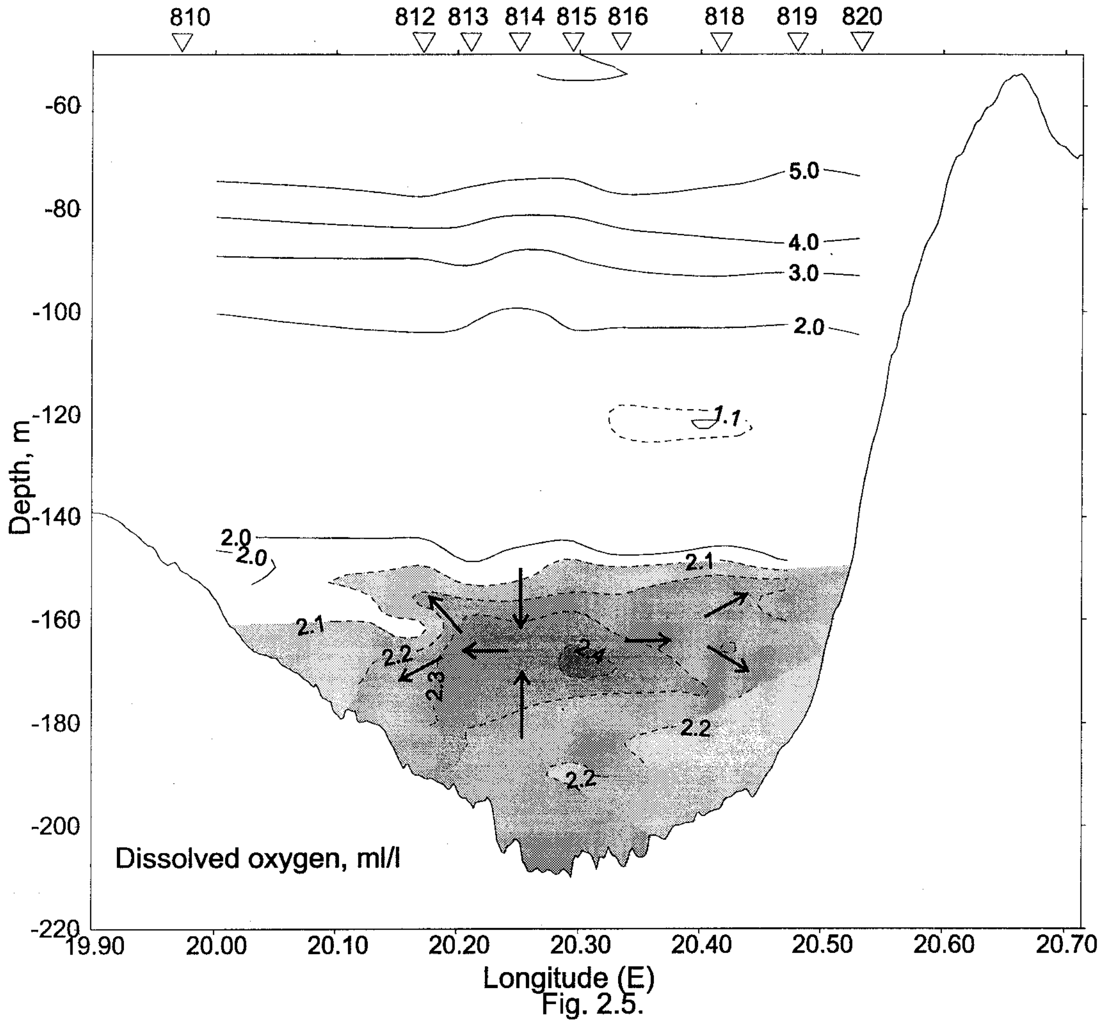



Figure 2. The nephelometric and hydrographical data combined with bottom relief on the northern section of the GOBEX II cruise: 1) turbidity, 2) temperature, 3) salinity, 4) potential density, 5) dissolved oxygen. The arrows outline a probable near-bottom poloid (vertical-radial) circulation (MONIN and FEDOROV, 1983).

## Discussion

Our observations show that the general trends in the turbidity profiles in the Eastern Gotland Basin differ from the classical profiles in open ocean waters, where the turbidity (and suspended matter concentration) decreases uniformly from the productive surface layer to a clear water minimum (CWM) and increases from the CWM towards the bottom (BISCAYE and EITTREIM, 1977). Secondary intermediate maxima of light scattering (which we term intermediate nepheloid layers, or INL) are observed in the Gotland Deep at all GOBEX stations. Such variability of the turbidity contrasts with the quasi-logarithmic mean trend of the classical profiles in the vicinity of the ocean floor. We can distinguish 3 types of NL in the GOBEX area. These are: 1) slope erosional INL, 2) deep erosional BNL and 3) chemoclinic INL. Comparison of the nephelometric data with hydrographical conditions and bottom relief was used for the identification of the nature of the nepheloid layers encountered during the expedition.

**Slope erosional INL**

The eastern near-slope area of the northern transect was characterised by high near-bottom turbidity and relatively sharp boundaries of the BNL. After MCCAVE (1983), we may explain the origin of INL with a lateral injection of particles in a bottom layer which detached upstream from the surrounding relief and was advected along an isopycnal surface into the basin center. It is likely that both local resuspension (or non-deposition) and advection along isopycnal surfaces interact and produce complicated patterns of turbidity. The slope-erosional INL are visible at depths of 75 to 95 m, 140-155 m, 160-175 m, and 215-230 m. Near-bottom currents flowing along slope of a basin have speeds that are proportional to the bed gradient (BOWDEN, 1960). This suggests some influence of slope inclination on the erosion (or non-deposition) of sediments and on formation of the INL in the Gotland Basin area.

The pattern of near-bottom turbidity on the southern section were generally similar to those measured on the northern section. However, sea-floor morphology of the northern transect is characterized by a steeper relief with sharp rises. The roughness of the slope relief focuses the energy of currents (for example, topographical eddies) and makes the erosion (non-deposition) of sediments more probable.

The permanent halocline which exists at depths of 70 to 100 m is a barrier for the exchange between deep waters and the surface layer, allowing only slow mixing. The sharp density gradient at the upper edge of the halocline prevents both downward transport of the suspended matter into deep waters and upward transport into surface waters. Concentrations of suspended particles in the waters at depths from 50 to 90 m were elevated in the vicinity of the upper part of the halocline. Their origin may be from resuspension as a result of the focused energy of currents, intrahaloclinal eddies and internal waves where the halocline intersects the slope of the basin.

**Deep erosional BNL**

High turbidity was measured in deep near-bottom waters at depths >170 m in the northern section and at depths >220 m on the southern section. Patchiness of the BNL structure suggests that local processes, combining vertical mixing and advection, may account for the turbidity profiles observed. Near-bottom turbidity in the deep part of basin was higher than turbidity near the slope and marks water depths where the most extensive resuspension occurs. We proposed that these turbid near-bottom waters derive from fine-grained sediments (muds of water content ~ 85% and with more than 70% particles with diameters <10m) that characterise the bottom in this area (EMELYANOV et al., 1995). Burst-like or periodical resuspension would be indicated by sharp near-bottom turbidity gradients.

We can evaluate the conditions required for resuspension using the logarithmic relation proposed by WIMBUSH and MUNK (1970) and from critical erosion conditions for cohesive sediments (grain-size less than 10 μm), reported by MCCAVE (1984) and DADE et al. (1992). If we assume a water content in bottom sediments of 85% (or a bed concentration of 150 kg/m$^3$), erosion would require near-bottom current velocities (at 5 m above the sea bed) of about 30 cm/s. If water content is 90%, the critical conditions for erosion are equivalent to velocities about of 15 cm/s.

Such near-bottom currents have been measured in the Gotland Deep (HAGEN and FEISTEL, 1996). According to NAUSCH and MATTHÄUS (1996) a water body with relatively high salinity (11 to 13 psu) and concentrations in oxygen (5 cm$^3$/dm$^3$) occupied the bottom of the southern part of the Eastern Gotland Basin in May 1994. This water body propagated further north into the direction of the Gotland Deep. HAGEN and FEISTEL (1996) reported the intrusion of relatively saline water (S > 12.2 psu) within the near bottom layer and a counter-clockwise mean circulation with mean vector speeds between 2 and 5 cm/s from a six week current-meter deployment in August and September of 1994. These measurements were carried out in the immediate vicinity of our station 799 and recorded sporadic events with peak velocities between 16 and 20 cm/s at 5 m above the sea bed. Such events are the likely cause for erosion of the surface sediment and the formation of deep erosional BNLs.

We also registered saline water (S > 12.0 PSU) near the sea floor on the northern section. The isopycnal surface of 9.4 kg/m$^3$ and isohalinal surface of 11.8 psu clearly show a dome-like shape. Its relative maximum lies about 30 m above the bottom (at a water depth of 210 m). The dome-like shape suggests a cyclonic rotation of a geostrophic current, which is trapped in the deep basin (HAGEN and FEISTEL, 1996) and may be an eddy-like feature trapping waters from the last inflow of salt-rich waters. The presence of such features is confirmed by the patterns of hydrographical parameters (Fig. 2, and Fig. 3.2) which correspond to patterns expected for poloid (vertical-radial) circulation in eddies (MONIN and FEDOROV, 1983). We are certain that such deep intrusions must have some impact on the temporal and spatial conditions for sedimentation and deposition. The frequent resuspension indicates that sediments are being recycled between the sea floor and overlying water and therefore may play a role in the removal of pollutants from the water column.

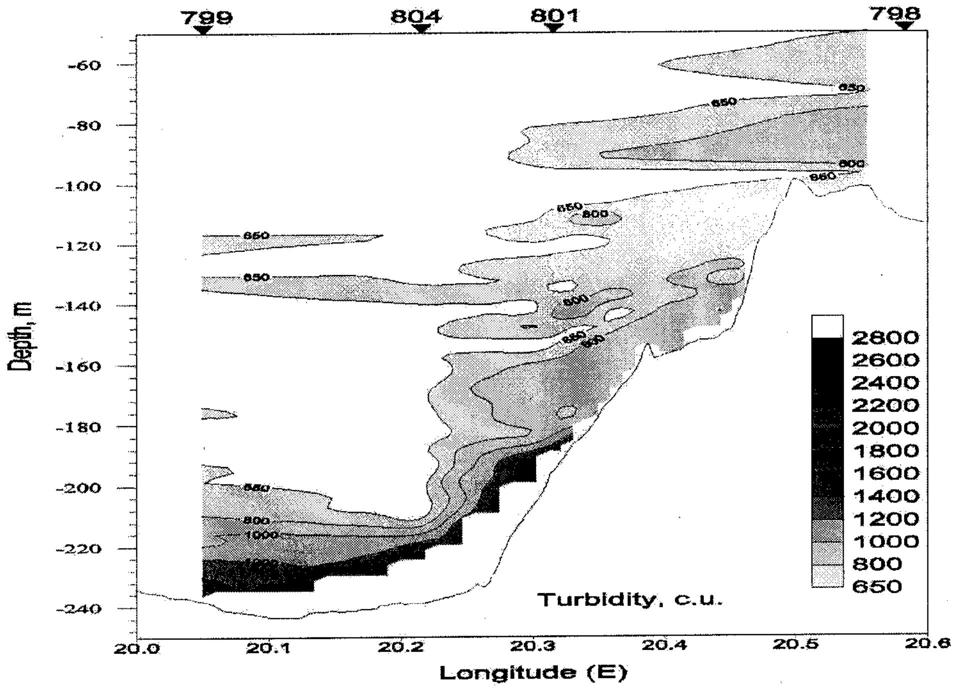



Fig. 3.1

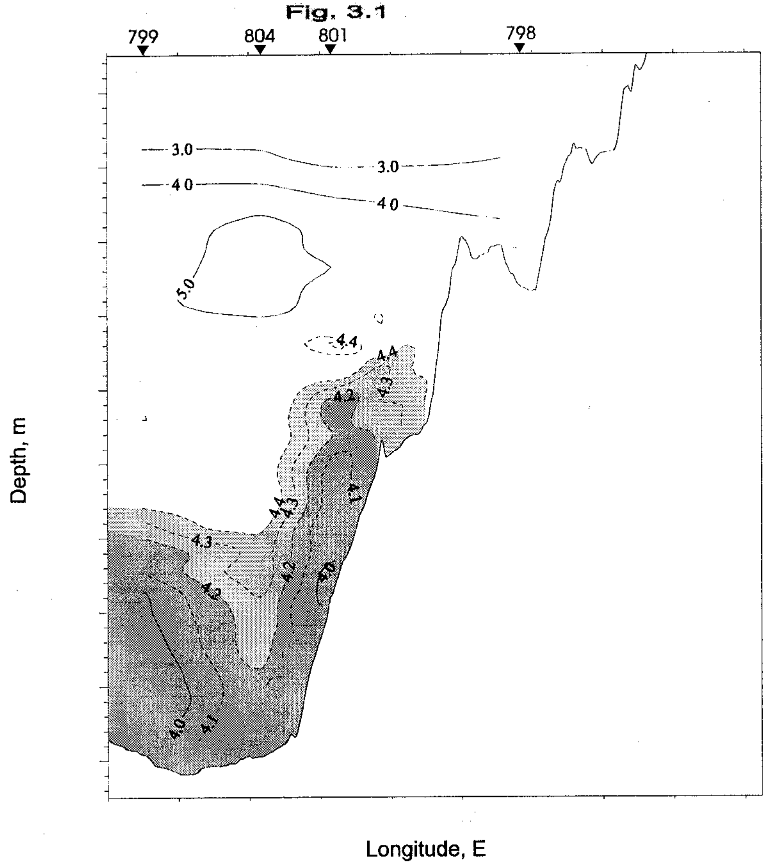



Fig 3.2.

Figure 3. The turbidity (3.1) and temperature (3.2) distribution combined with bottom relief on the southern section of the GOBEX II cruise. Temperature was registered by nephelometer.

**Chemoclinic INL**

A geochemical source of suspended particles in the water column of the Gotland Deep is the boundary between the layers of reducing and oxidising conditions (chemocline) (EMELYANOV, 1981). Dissolved Fe and Mn diffuse upwards from reducing bottom water into the overlying oxidising water and are transformed into particles. These particles accumulate in a comparatively narrow layer, since their upward movement is prevented by gravity and the weak vertical diffusion of the deep water, and their downward settling is

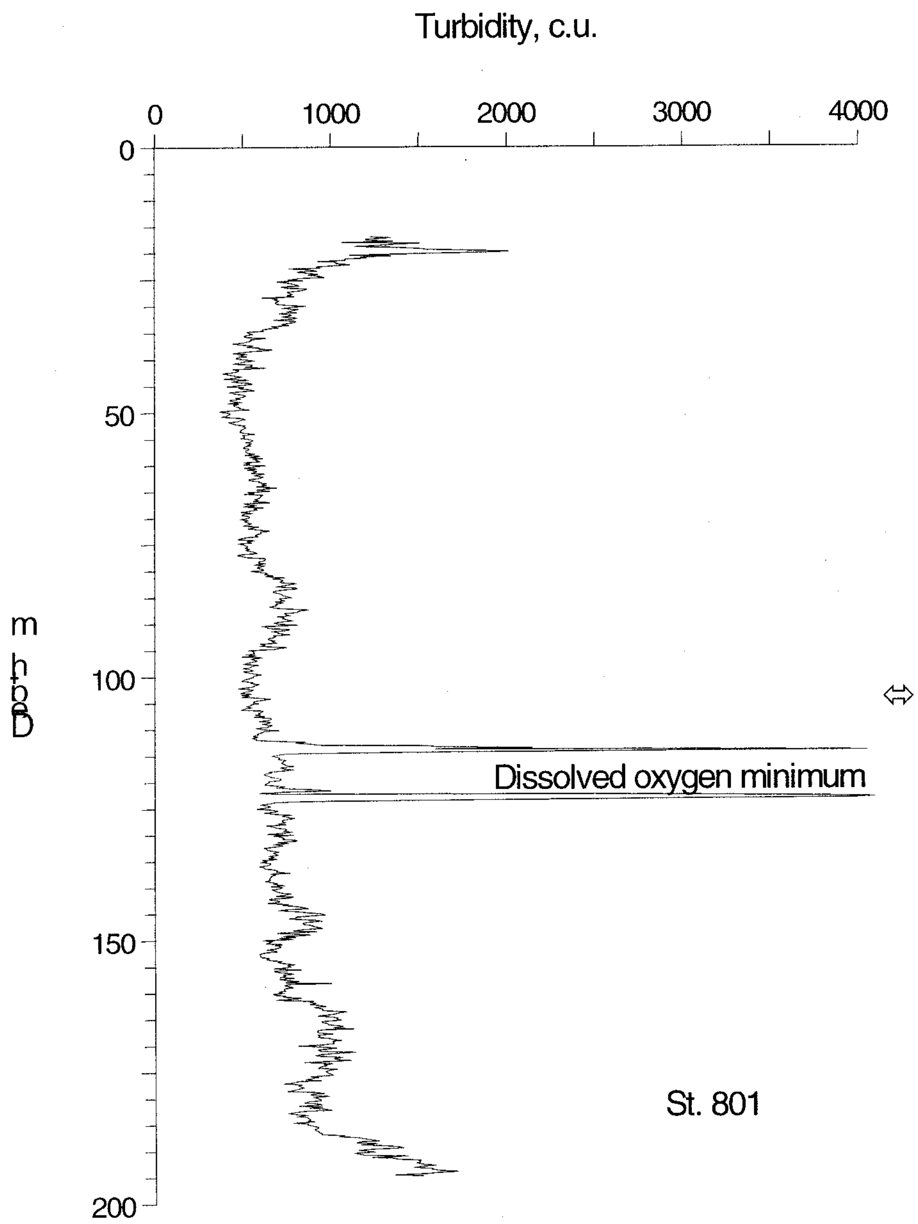



Figure 4. An example of the turbidity maximum registered at depths of 115-130 m (chemoclinic INL) with a fine layering structure and presence of the very sharp peaks.

prevented by solution in the reducing conditions below. Microbial biomass may further contribute to the increase of turbidity in the chemoclinic INL (LEIPE et al., 1996).

When water in the deep Gotland Basin is aging, salinity and temperature gradients are smoothed out and density differences decrease. Waters from the North Sea with high salinity and oxygen content may sporadically propagate into deeper layers of the Gotland Basin to form new bottom water, thereby replacing the former anoxic deep water. From 1976 to 1992 almost no deep water renewal took place (MATTHÄUS and LASS, 1995). As a consequence, the deep-water salinity dropped to minimum values on record, dissolved oxygen content became exhausted, and hydrogen sulphide accumulated in the deep water. The inflow event of January 1993 stopped this trend, salinity and oxygen were replenished, and $H_2S$ has practically disappeared. A new inflow event trough the Slupsk Furrow in the eastern Gotland Basin occurred at the end of March 1994 (NAUSCH and MATTHÄUS, 1996; ZÜLICKE and HAGEN, 1997). As a result, oxygen containing water was found in the bottom layer of the Gotland Deep in the time of May 1994 to January 1995. This water was located below a thin zone of minimal oxygen concentrations (< 1.0 $cm^3/dm^3$ in 120 m depth) during the GOBEX II cruise. The oxygen concentration was elevated from this depths downward to the bottom and reached values > 2.0 $cm^3/dm^3$ between 140 and more than 200 m. A turbidity maximum was registered only as a weak chemoclinic INL at mid-depths of 115-130 m and corresponded to minima in dissolved $O_2$ and to a local maximum of water temperature. This remnant of a chemoclinic INL had a finely layered structure with very sharp peaks (Figure 4). Similar patterns have also been noted earlier by KARABASHEV and YAKUBOVICH (1978) and SIVKOV and ZHUROV (1991).

## Conclusions

Near-bottom water in the central part of the Gotland Deep and over the eastern slope contained nepheloid layers composed of resuspended bottom sediment. Near-bottom currents were responsible for the resuspension. Local erosion of the bottom sediment on the heights, supplemented by advection and subsequent sedimentation, may explain the BNL and INL observed in the Gotland Deep. Both the pycnocline (halocline) and the roughness of the bottom relief focus the hydrodynamical energy and may be responsible for the increased resuspension.

An interesting feature during the August 1994 expedition of GOBEX was a local turbidity maximum of geochemical and microbiological origin at mid-depths between 115 and 130 m, which corresponds to minima in dissolved $O_2$ and to intermediate maxima of water temperature. This local turbidity maximum is related to redox cycling of Mn and Fe supplemented by bacterial biomass and may either be a remnant of a previously anoxic deep water body, or may signal the onset of reducing conditions in an intermediate depth interval after the inflow of new bottom water in 1993-1994.

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# 8.2. Particle quality in the bottom boundary layer of the Gotland Basin

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## Abstract

During a GOBEX cruise with R.V. 'Alexander von Humboldt' from August 21 to September 2 1994, bottom-water samples were retrieved with a bottom-water sampler (BWS). The stations were situated along a depth gradient from 68m to 243m. The oxygen saturation at the three deep stations (below 196m water depth) was between 10 and 80%, with an increase 5 cm above the bottom. Lowest values were observed at 10 cm above the sediment surface (1 - 20% oxygen saturation). These low values at 10 cm above the sediment were correlated with maximum amounts of total particulate matter (TPM, up to 45mgl$^{-1}$) probably caused by an observable increase in current velocity. Low values in TPM were related to high oxygen values and low current velocities. High amounts of particulate organic nitrogen (PON), particulate organic carbon (POC), and chlorophyll pigment equivalents (CPE) values were also positively correlated with higher current velocities and a corresponding higher resuspension efficiency. Low $\delta^{15}$N values of PON were found in the bottom nearest samples of the deep stations (>230m) whereas $\delta^{13}$C of POC was nearly uniformly distributed. Relatively light $\delta^{13}C_{(POC)}$ values at 10cm above the sediment surface give an indication for an increase of organic matter of bacterial origin in 10 cm above the sediment.

Only at the shallow station 20008 urea increased at the bottom due to macrofaunal activity. Bacterial numbers were positively correlated with TPM and increased (as well as mean bacterial biomass) towards the bottom.

## Introduction

A period of easterly winds followed by strong westerly winds has generated deep water inflow events in December 1993 and during 1994 into the Baltic, but did not fulfil the criteria for major Baltic inflows (NEHRING et al., 1995). Together with the inflow of highly saline water through the Sound, they led to an effective aeration of the central Baltic deep water accompanied by decreasing temperatures and increasing salinity.

Beginning with small concentrations of hydrogen sulphide in February 1994, the inflow events in December 1993 and March 1994 have improved oxygen conditions in the deep waters of the eastern Gotland basin significantly, whereas the increase in salinity and related decrease in temperature were only moderate compared to former major inflow situations (NEHRING et al., 1995). In May 1994 oxygen concentrations of 134-170 mmol l$^{-1}$ were observed below 170m depth (NEHRING et al., 1995). Similarly high concentrations have been found at that depth only in the 1930s (MATTHÄUS and LASS, 1995).

Little information is available about particle composition and concentrations in the benthic boundary layer (BBL) of the Gotland Deep before the inflow of 1993/1994. The thickness of the BBL in the Gotland Basin depends on the near bottom current velocity, on sediment roughness, and sediment distribution. The BBL is defined as the water-column above the sediment which has less than 99% of the free flow velocity. Little information is available about oxygen concentrations, chlorophyll and bacteria abundance and biomass down to 25 cm above the sediment from the Gotland Deep water column (GAST and GLOCKE, 1988).

We used a bottom water sampler to study the near bottom water column in the Gotland Deep. Our study focused on the composition of the particulate organic matter in the BBL and the influence of the hydrodynamic regime on their distribution.

## Material and Methods

*Area und investigation*

The study was carried out in August 1994 (21.08. - 02.09.1994) in Gotland Basin in the western Baltic (Figure 1 in EMEIS and STRUCK, this issue). Four stations were sampled (Figure 1 in EMEIS and STRUCK,this volume, Table 1) following a depth gradient into the basin.

*Sampling*

For sampling within the BBL the BIOPROBE (Fig. 2) bottom water sampler (BWS) was used (THOMSEN et al. 1994). Water samples were collected at 5, 10, 20 and 40 cm above the sediment surface. Water samples from 5 m above bottom were taken with Niskin bottles. BIOPROBE collects 10 litres of water at each of the four different heights above the seafloor. Flow velocity measurements with a thermistor probe in earlier deployments suggest that a waiting period of 10 minutes was adequate to prevent errors due to artificial resuspension during deployment.

Fig. 2

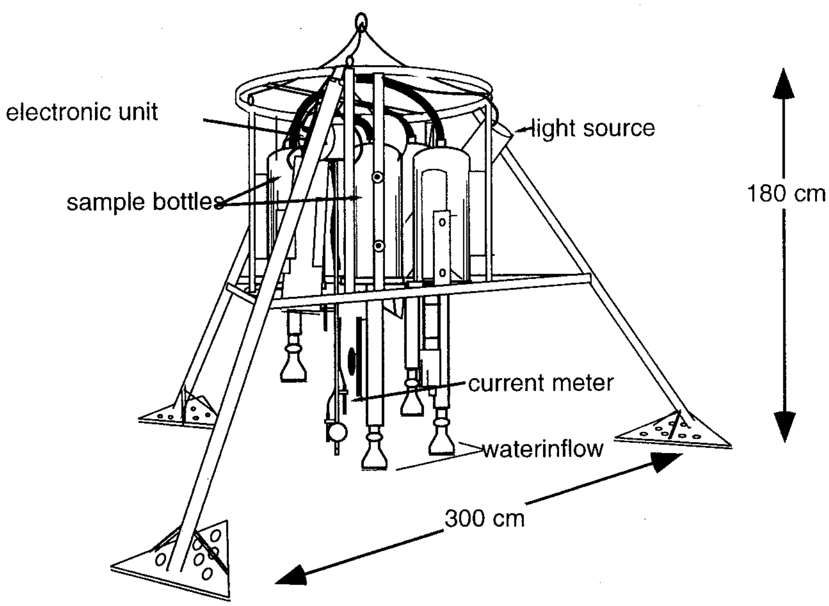


Figure 2: Sketch of Bottom Water Sampler (BIOPROBE) for the rerieval of bottom near water samples (5,10,20,40 cm above the sea floor)

**Analyses**

Water samples were filtered, and the filters were frozen onboard for later analyses of various parameters. 0.25 - 1.0 l of water was filtered onto precombusted glasfiber filters (GF/F, 500°C, 2h). For stable isotope analysis and the contents of particulate organic carbon (POC) and particulate organic nitrogen (PON), filters were treated with concentrated HCl for 24 hours to remove inorganic carbon. After drying at 60°C samples were wrapped in silver cups (Heraeus CHN cups). POC/PON and $\delta^{13}C_{(POC)}/\delta^{15}N$ were simultanously determined in a Carlo Erba/Fisons 1108 elementare analyzer connected to an isotope ratio mass spectrometer (Finnigan Delta S). The reference gas was pure $N_2$ nitrogen and $CO_2$ from a cylinder calibrated against air nitrogen as a standard (MARIOTTI, 1984) and against carbonate (NBS-18, 19, 20), respectively. Isotope data are given in the conventional delta notation as:

$$\delta^{13}C_{(POC)} \text{ or } \delta^{15}N = (R(sample)-R(reference)/R(reference)*1000$$

$R={}^{15}N/{}^{14}N$, ${}^{13}C/{}^{12}C$ of the sample and the reference gas, respectively. The standard deviation for replicate samples is less than 0.2‰.

Table 1: Station list of sampled stations during GOBEX-Cruise in August /September 1994.

| Station | Date | Coordinates | Depth (m) | Sediment type |
|---|---|---|---|---|
| **20001** | 24.8.1994 | 57°18.51'N, 20°04.63'E | 243 | mud |
| **20003** | 25.8.1994 | 57°17.43'N, 20°19.56'E | 196 | mud |
| **20004** | 26.8.1994 | 57°18.08'N, 20°13.97'E | 236 | mud |
| **20008** | 27.8.1994 | 57°27.84'N, 21°09.60'E | 68 | muddy sand |

Chlorophyll equivalents (CPE) were analysed with a Turner Fluorometer by using the extraction method of EDLER (1979). Total particulate matter (TPM) was determined according to LENZ (1971) by filtering 0.5 - 1l of sample water onto preweight glasfiber filters. This material was later ashed at 550°C to achieve total combusted material (TCM). Water samples (100 ml) for bacterioplankton were preserved with 4% buffered, 0.2 µm prefiltered formalin. Bacterial numbers were determined by the DAPI (4-6-Diamidino 2-Phenylindol) method described by HOBBIE et al. (1977) using a Zeiss Axiovert Epifluorescence microscope. Cell volumes of 100 to 150 bacteria of each sample were determined from photographs using a modified version of the method of THOMSEN (1991) using the image analysis program "Image 1.41" for Macintosh computers. Bacterial volumes were calculated from length and width measurements of bacterial images photographed in randomly selected fields. Coccoid- and rod-shaped bacteria were distinguished by the length/width ratio of < 2 for cocci and ≥ 2 for rods. Cocci volumes were calculated as ellipsoids of revolution: $V = (\pi l w^2)/6$, where V = volume ($\mu m^3$), l = length (µm) and w = width (µm). Rods were modeled as cylinders with added end caps: $V = (\pi/4)\, w^2\, (l-(w/3))$.

Because of small sample size non-parametric tests were used for statistical analyses. The Wilcoxon signed rank test was used for the analysis of paired data sets, the Kendall´s τ test for correlation of different parameters between and in the transects. Both tests were applied according to SOKAL AND ROHLF (1981) using the program StatView 4.1 for Macinthosh computers.

**Results and Discussion**

Nearly no data are available from the deeper part of the Gotland deep concerning distribution and composition of suspended particulate matter. Few data are published for dissolved components such as oxygen and some nutrients (NEHRING and MATTHÄUS, 1991; NEHRING et al., 1995) but only in the depth resolution of a CTD-Rosette sampler.

During the expedition, oxygen was observed down to the sea floor (Figure 3). At the deeper stations (20001, 20003 and 20004), between 10 and 30 % oxygen saturation was found. The more shallow station 20008 had 80% oxygen saturation at 5 m above the sediment. The oxygen distribution correlated negatively with the amount of TPM. Highest amounts in TPM at 10 cm above the bottom at stations 20001 and 20004 coincided with lowest amounts of oxygen. On the other hand a decrease in suspended matter at 5 cm above the sediment correlated with an increase of oxygen.

Absolute concentrations of TPM (Figure 4) were between 3 (stations 20003 and 20008) and 44 $mgl^{-1}$ (stations 20001 and 20004). The organic part of the TPM measured as TCM (total combusted material) showed highest values at 5 and 10 cm above the sediment; this increase could also be seen at station 20003 (Figure 5), but only at 5 cm above the sediment.

POC and PON also had highest concentrations directly above the sediment (Figure 6 and 7) but the maxima at stations 20001 and 20004 correlate with the maxima in TPM and the decrease in oxygen. C/N ratios (Fig. 8) show values between 7.5 and 12.5 and indicate relativeley fresh marine organic matter. At station 20003 the ratio was nearly uniformly distributed through the water column whereas an decrease close to the bottom could be seen at stations 20001 and 20004. An increase in the C/N ratio of the near bottom material could be seen at 5cm above ground at the shallow station 20008.

Delta$^{15}$N values of suspended particles from BBL-samples range between 2 to 8 ‰ (Figure 9). Lowest $\delta^{15}$N-values of particulate nitrogen were found in the two bottom nearest samples from the deepest part of the Gotland Basin (station 20001 and 20004; Figure 10). There is a clear tendency in $\delta^{15}$N of PON to heavier values with greater distance from the sediment surface. Delta$^{15}$N of PON of shallower stations 20003 and 20008 show low variations in the BBL: values are around 6 ‰ $\delta^{15}$N at station 20008 and 8 ‰ $\delta^{15}$N at station 20003 (Fig. 10) respectively. There is a small but significant excursion in $\delta^{15}$N towards lighter values in both profiles at 10cm above sediment surface.

Delta$^{13}$C of organic carbon of BBL-samples exhibit variations between -26.00 to -23.50‰ (Figure 10) and the variations are largest in samples from deep stations 20001 and 20004. Delta$^{13}$C of particulate organic carbon at the shallower stations 20003 and 20008 show low variations with increasing distance to the sea floor around -26.00 ‰ $\delta^{13}$C at station 20008 and at -25.00 ‰ $\delta^{13}$C at station 20003 (Figure 10). The excursion towards lighter values, seen in $\delta^{15}$N is also seen in $\delta^{13}$C in both profiles at 10cm above sediment surface.

The excursions may be indications for organic matter of bacterial origin. Bacterial biomass, which is formed near the sediment surface, has a much lighter carbon isotope composition than organic mattter from which derives formed in the euphotic zone because the carbon isotope composition of the deep water dissolved organic carbon is usually much lighter than that of the euphotic zone (FRY et al., 1991).

Increased concentrations of oxygen at 5 cm above the seafloor coupled with reduced amounts of suspended particulates could be a result of three different processes:

Fig. 3

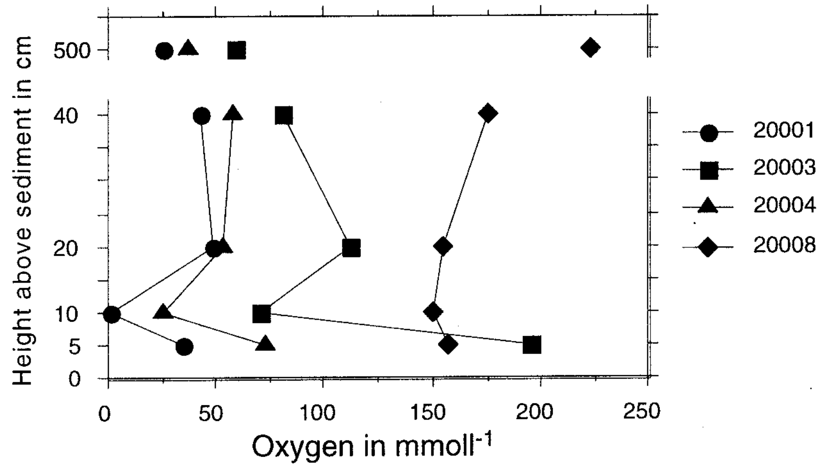


Fig. 4

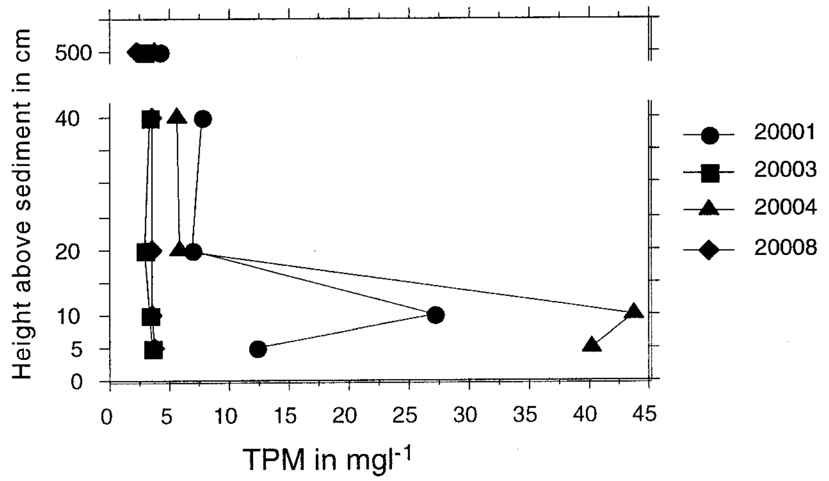


Fig. 5

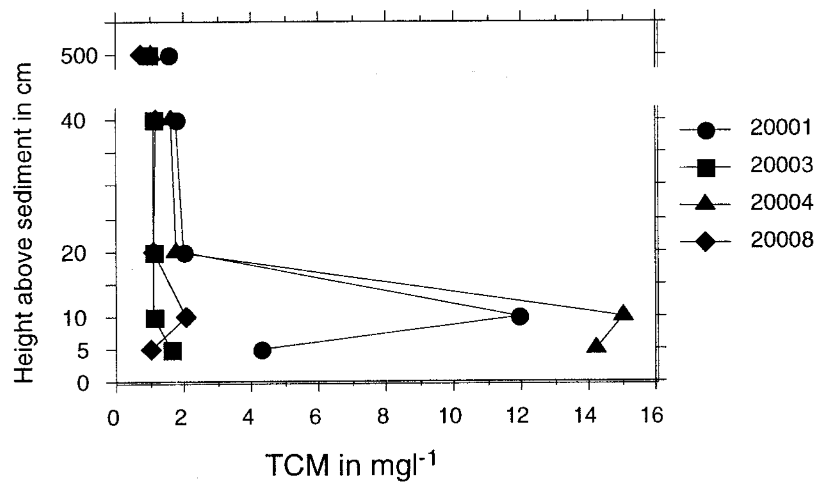


Figure 3: Oxygen concentrations in watersamples from all investigated sites.
Figure 4: Concentrations of total particulate matter (TPM) in watersamples from all investigated sites.
Figure 5: Concentrations of total combusted matter (TCM) in watersamples from all investigated sites.

- During the preceding stagnation period lasting 15 years the Gotland Basin, deep waters have become anoxic. During the inflow of oxygenated water, no aerobic bacterial community has been established. Therefore the increase of oxygen close to the bottom could reflect a lack of oxygen consumption which normally decreases the oxygen concentrations close to the bottom.

- Another possible explanation for consistently higher oxygen concentrations at 5 cm above sediment surface may be the repeated inflow of oxygenated and more saline water only in a very thin layer of a few centimeters.

- Thirdly, low oxygen concentrations found above 5cm may be the result of increased oxygen consumption by a bacteria community which is attached to particulate matter held in suspension by the hydrodynamic environment of the BBL. Relatively low $\delta^{13}C$-values in the particulate matter from 10cm above the sediment surface support the notion of additional bacterial biomass in these samples (see below and Figure 10). In addition light nitrogen isotope values, which may originate from new bacterial biomass in the BBL, are consistent with isotopically relatively light inorganic nitrogen source in the benthic boundary layer. Relatively low oxygen concentrations at the same level (10cm above sediment) in the profiles of station 20003 and 20008 support our interpretation that bacterial biomass formed near in the BBL contribute significantly to the particulate organic matter in the Gotland Basin.

The amount of CPE was very low at the station 20003 and 20008 all the way down to the sediment surface with values between 1 and 3 $\mu gl^{-1}$ (Figure 11). A sharp increase in CPE towards the sediment surface was found at station 20001 and 20004. This pattern is comparable to the increase of the other particulate components (TPM, POC, PON).

Bacteria counts showed values between 3 and 30 x $10^5$cells $ml^{-1}$ and increase towards the bottom at all deep stations (Figure 12). The bacteria abundance at the shallow station 20008 was nearly uniformly distributed above the sediment surface. Some data are available on the bacterial abundance and biomass in the Gotland Deep (GAST and GLOCKE, 1988). The authors sampled down to 25 cm above the sediment with an especially designed water sampler during a stagnation period. They found on average 11-14 x $10^5$ bacteria $ml^{-1}$ in the anoxic bottom water. Proceeding on the assumption that there was a bacteria community adapted to the anoxic situation during the last 15 years, a change in the bacteria population due to the bottom water renewal can be assumed. The overall amount of bacteria in the bottom water did not change, but counting does not give an indication about the activity of this population. Mean bacteria volume has a steep increasing gradient to the bottom at all stations (Figure 13). Mean cell volume was found around 0.1-0.2$\mu m^3$ at 5 m above the sediment and showed increasing values towards the bottom to up to 0.9$\mu m^3$ in 5 to 10 cm above the sediment. From bacterial volume and abundance the amount of bacterial organic carbon (BOC) was calculated by using a conversion factor of 0.110 $pg\mu m^{-3}$ (BRATBAK and DUNDAS, 1984). Mean cell volume of bacteria in the samples from the stagnation period was 0.3$\mu m^3$ (GAST and GLOCKE, 1988). Our results show increased cell sizes after the saltwater inflow to a mean cell volume of 0.56$\mu m^3$. This increase in mean cell volume also forms an increase in bacterial organic carbon (BOC) from 30$\mu gCl^{-1}$ near the sediment to 78$\mu gCl^{-1}$ in BBL samples.

Fig. 6

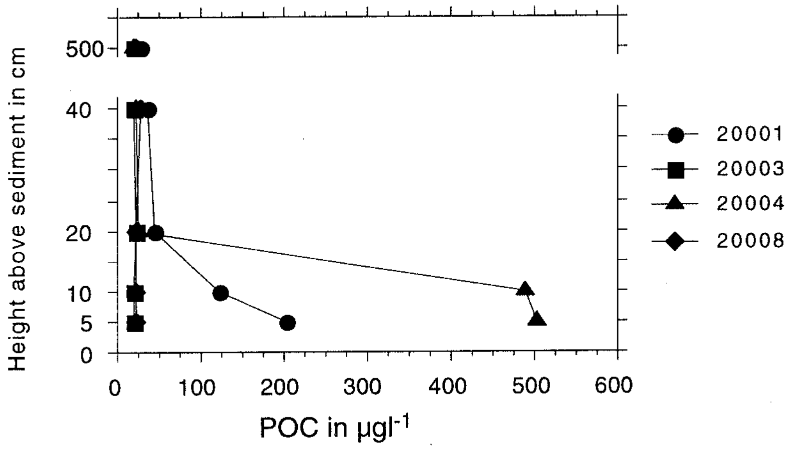


Fig. 7

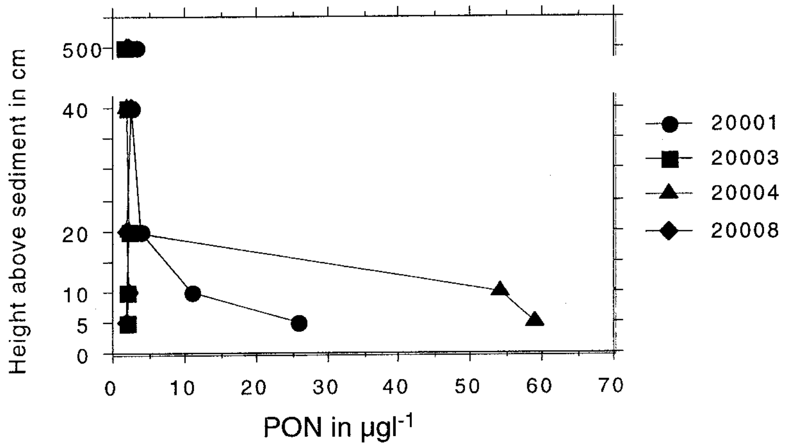


Fig. 8

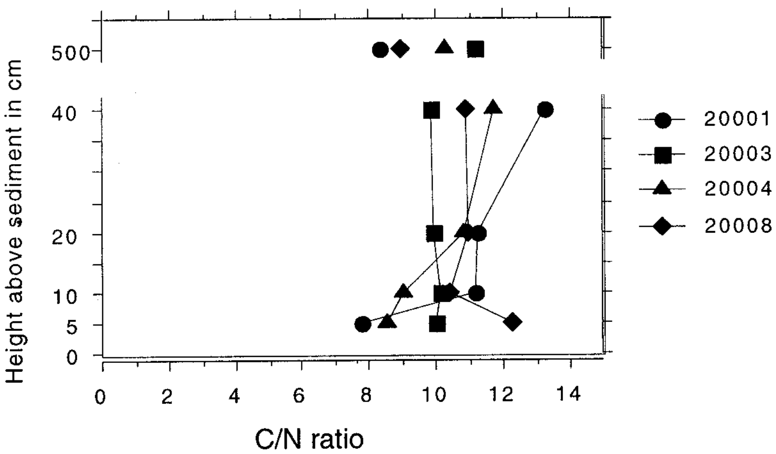


Figure 6: Concentrations of total particulate organic carbon (POC) in watersamples from all investigated sites.

Figure 7: Concentrations of total particulate organic nitrogen (PON) in watersamples from all investigated sites.

Figure 8: Ratios of particulate organic carbon and particulate organic nitrogen (C/N) in watersamples from all investigated sites.

Fig. 9

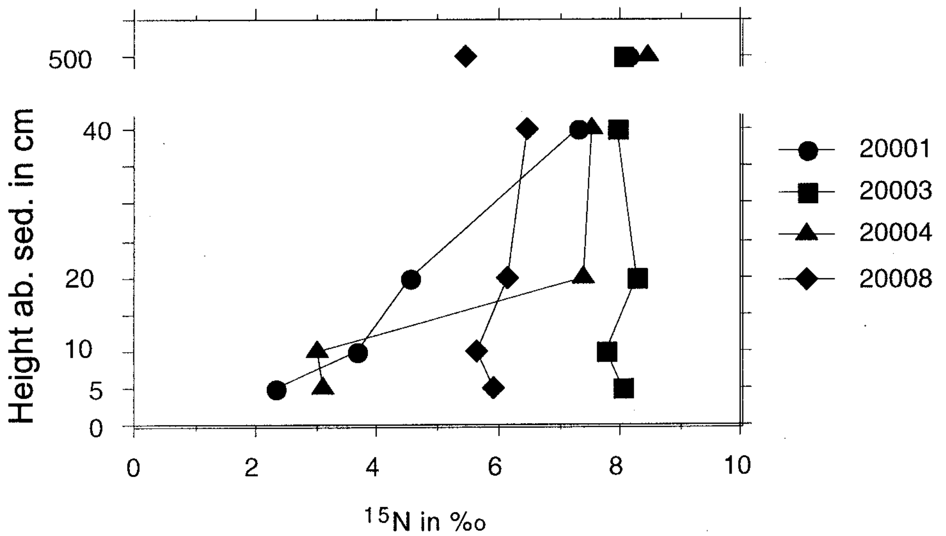


Fig. 10

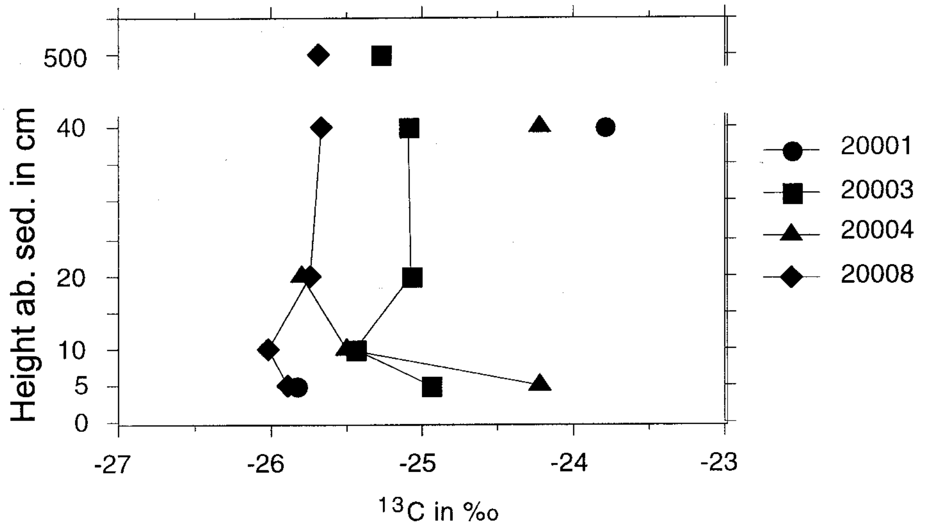


Figure 9: $\delta^{15}N$-distribution of suspended particulate organic matter in watersamples from all investigated sites.

Figure 10: $\delta^{13}C$-distribution of suspended particulate organic matter in watersamples from all investigated sites.

Fig. 11

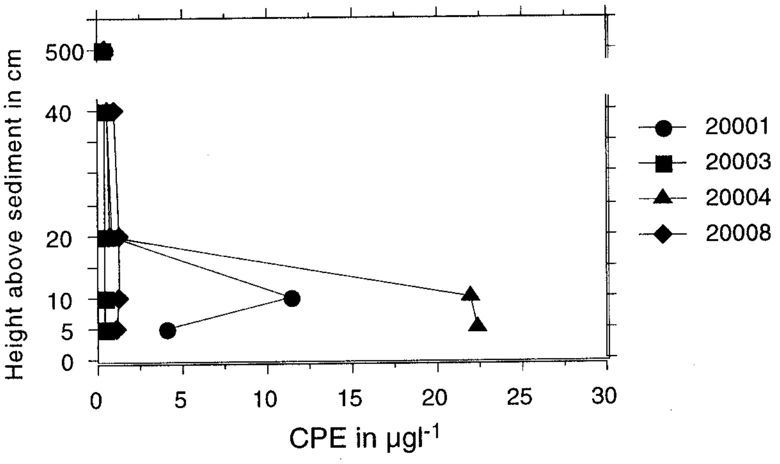


Fig. 12

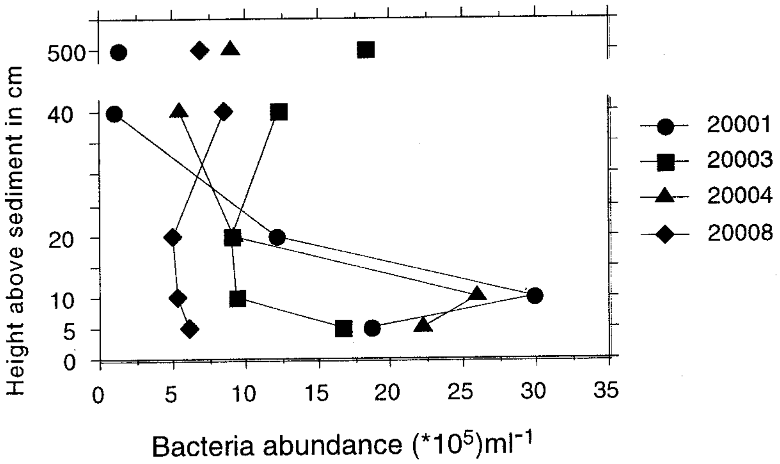


Fig. 13

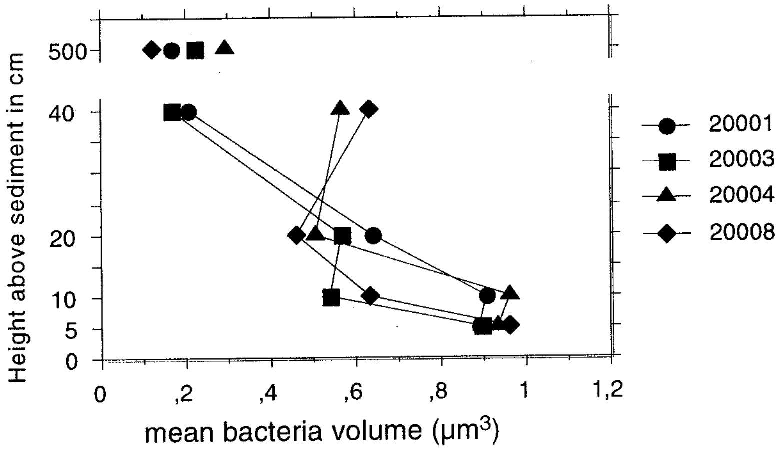


Figure 11: Concentrations of chlorophyll pigment equivalents (CPE) in watersamples from all investigated sites.

Figure 12: Bacterial abundance in watersamples from all investigated sites.

Figure 13: Bacterial cell volumes in watersamples from all investigated sites.

Mean bacteria volume has a steeply increasing gradient to the bottom at all stations (Figure 13). Mean cell volume was found around 0.1-0.2μm$^3$ at 5 m above the sediment and showed increasing values towards the bottom to up to 0.9μm$^3$ in 5 to 10 cm above the sediment. From bacterial volume and abundance the amount of bacterial organic carbon (BOC) was calculated by using a conversion factor of 0.110 pgμm$^{-3}$ (BRATBAK and DUNDAS, 1984).

There is no information about POC concentrations in the near bottom water during the stagnation period, but we may assume that the importance of bacteria after the saltwater inflow has increased. The BOC to POC ratio (%) ranged from 6 to 81% with a mean value 18%. However, no significant trend in the BOC/POC ratio was observed with decreasing distance from the sediment surface.

Urea concentration was analyzed to study the distribution of a dissolved organic matter component which originates in the sediment. The amount of urea and the distribution in the BBL may be also attributed to macrofaunal activity and abundance. At the deep stations (20001, 20003 and 20004) we found very low urea concentrations, and it was nearly uniformly distributed throughout the water column (Figure 14). Only the samples of the shallow station 20008 had an increase of urea towards the bottom. This finding indicates a greater abundance of benthic macrofauna compared to the deeper parts of the Gotland Basin.

Statistical analyses of the different variabled determined for the particulate substances showed a strong correlation between PON and CPE ($r^2$=0.9) as well as between POC and CPE ($r^2$=0.93). The amount of TPM also correlated with POC and PON ($r^2$=0.9/0.86) as well as with CPE ($r^2$=0.98). The amount of TPM was also correlated with bacteria abundance ($r^2$=0.56).

CPE/POC (%) ratio ranged from 1.4 to 9.4% with a mean value of 2%. It generally decreased from the seabed into the watercolumn (Spearman Rank, $p<0.01$). The POC/TPM (%) ratio ranged from 3.8 to 16.4% with a mean value of 7.2%. Only at the stations 20001 and 20004 there was decrease into the watercolumn.

The high POC/TPM ratios show a high amount of organic particles in the BBL. The largest carbon source seem to be bacteria with a BOC to POC ratio up to 80%.

The composition and amount of particulate matter is strongly correlated with current velocity. Higher flow velocities at stations 20001 (18 cms$^{-1}$) and 20008 (20 cms$^{-1}$) compared to stations 20003 (3 cms$^{-1}$) and 20008 (3 cms$^{-1}$) as result in higher amounts of TPM in the lower 10 cm of the watercolumn, and amounts of POC, PON and CPE (Table 2).

Up to 65% of the bacteria in the BBL are associated to particles (THOMSEN et al., 1994). Our data support the hypotheses that the increasing amount of particles resuspended at the sediment-water interface, provides more attachment places for bacteria and increases the availability of food for these bacteria (RITZRAU and GRAF, 1992). We plan to revisit the stations after anoxic conditions have again be established in the eastern Gotland Basin for a comparison of oxic and anoxic conditions in the BBL.

| Station | Depth ab.sedi-ment (cm) | $O_2$ (mmol/l) | TPM (mg/l) | TCM (mg/l) | Urea-N µmol/l | PON µmol/l | POC µmol/l | C/N ratio molar | $\delta^{15}N$ (‰) Air | $\delta^{13}C$ (‰) vs PDB | Bacteria ($ml^{-1}*10^5$) | Bact. Vol. ($\mu m^3$) | CPE ($\mu g l^{-1}$) | CPE/POC ratio (%) | BOC ($\mu g l^{-1}$) | BOC/POC ratio (%) | POC/TPM ratio (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **20001** | 500 | 25,64 | 4,22 | 1,57 | 0,193 | 3,29 | 27,50 | 8 | 8,16 | n.d. | 1,33 | 0,165 | 0,388 | 1,4 | 0,241 | 9,0 | 6,5 |
| | 40 | 43,02 | 7,80 | 1,77 | 0,174 | 2,75 | 36,55 | 13 | 7,31 | -25,84 | 1,02 | 0,208 | 0,592 | 1,6 | 0,233 | 6,0 | 4,7 |
| | 20 | 49,06 | 6,86 | 2,02 | 0,188 | 3,95 | 44,32 | 11 | 4,55 | n.d. | 12,14 | 0,639 | 0,842 | 1,9 | 8,533 | 19,3 | 6,5 |
| | 10 | 1,47 | 26,99 | 11,96 | 0,203 | 10,88 | 121,68 | 11 | 3,68 | -23,8 | 29,75 | 0,906 | 11,420 | 9,4 | 29,649 | 24,4 | 4,5 |
| | 5 | 34,46 | 12,30 | 4,28 | 0,227 | 25,80 | 201,39 | 8 | 2,32 | n.d. | 18,64 | 0,889 | 4,036 | 2,0 | 18,228 | 9,1 | 16,4 |
| **20003** | 500 | 58,68 | 2,97 | 0,99 | 0,174 | 1,76 | 19,64 | 11 | 8,04 | -25,28 | 18,31 | 0,223 | 0,346 | 1,8 | 4,491 | 22,9 | 6,6 |
| | 40 | 81,14 | 3,27 | 1,08 | 0,145 | 1,89 | 18,70 | 10 | 7,98 | -25,1 | 12,29 | 0,169 | 0,367 | 2,0 | 2,285 | 12,2 | 5,7 |
| | 20 | 112,71 | 2,97 | 1,13 | 0,184 | 2,25 | 22,36 | 10 | 8,31 | -25,08 | 9,12 | 0,569 | 0,435 | 1,9 | 5,708 | 25,5 | 7,5 |
| | 10 | 70,61 | 3,32 | 1,09 | 0,198 | 1,89 | 19,19 | 10 | 7,79 | -25,45 | 9,42 | 0,539 | 0,435 | 2,3 | 5,585 | 19,1 | 5,8 |
| | 5 | 195,48 | 3,56 | 1,60 | 0,275 | 2,01 | 20,14 | 10 | 8,04 | -24,95 | 16,65 | 0,893 | 0,412 | 2,0 | 16,355 | 81,2 | 5,7 |
| **20004** | 500 | 37,01 | 3,72 | 1,03 | 0,164 | 2,01 | 20,62 | 10 | 8,46 | -24,58 | 9,08 | 0,296 | 0,412 | 2,0 | 2,956 | 14,3 | 5,5 |
| | 40 | 58,24 | 5,61 | 1,65 | 0,179 | 1,82 | 21,40 | 12 | 7,53 | -25,8 | 5,51 | 0,567 | 0,589 | 2,8 | 3,437 | 16,1 | 3,8 |
| | 20 | 53,76 | 5,84 | 1,77 | 0,188 | 2,39 | 25,85 | 11 | 7,41 | -25,5 | 9,23 | 0,505 | 0,646 | 2,5 | 5,127 | 19,8 | 4,4 |
| | 10 | 25,77 | 43,7 | 15,03 | 0,208 | 53,99 | 488,43 | 9 | 3,01 | -24,22 | 25,91 | 0,963 | 21,884 | 4,5 | 27,446 | 5,6 | 11,2 |
| | 5 | 72,63 | 40,11 | 14,25 | 0,217 | 58,91 | 502,74 | 9 | 3,08 | n.d. | 22,13 | 0,931 | 22,416 | 4,5 | 22,663 | 4,5 | 12,5 |
| **20008** | 500 | 222,99 | 2,20 | 0,71 | 0,261 | 2,37 | 21,29 | 9 | 5,47 | -25,69 | 6,94 | 0,123 | 0,459 | 2,2 | 0,939 | 4,4 | 9,7 |
| | 40 | 176,02 | 3,44 | 1,19 | 0,435 | 2,56 | 27,89 | 11 | 6,48 | -25,66 | 8,63 | 0,634 | 0,958 | 3,4 | 6,021 | 21,6 | 8,1 |
| | 20 | 155,56 | 3,59 | 1,11 | 0,478 | 2,08 | 22,77 | 11 | 6,18 | -25,75 | 5,07 | 0,463 | 1,192 | 5,2 | 2,580 | 11,3 | 6,3 |
| | 10 | 150,03 | 3,61 | 2,06 | 0,625 | 2,24 | 23,30 | 10 | 5,65 | -26,02 | 5,31 | 0,623 | 1,253 | 5,4 | 3,692 | 15,8 | 6,5 |
| | 5 | 157,50 | 3,70 | 1,05 | 0,647 | 1,81 | 22,28 | 12 | 5,94 | -25,88 | 6,11 | 0,963 | 1,175 | 5,3 | 6,472 | 29,0 | 6,0 |

n.d. : not determined

Table 2: Analytical data of all samples discussed above.

Fig. 14

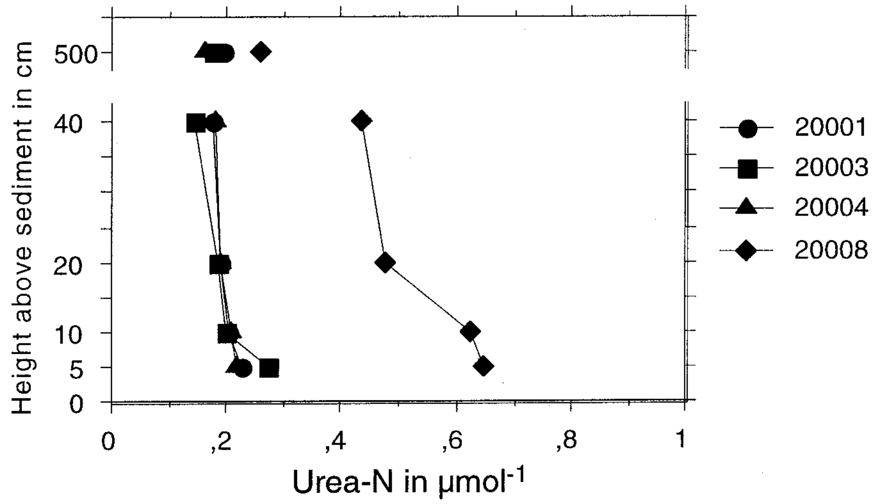


Figure 14: Concentrations urea in watersamples from all investigated sites.

**Conclusion**

Saltwater inflows from 1993 and 1994 reoxygenated the deep parts of the Gotland basin. Due to the change from an anoxic to an oxic environment the bacteria population changed in size and most likely in composition.The amount of suspended material and the quality of the particles in the BBL of the Gotland deep is a result of the hydrodynamic situation. Higher flow velocities lead to resuspension of the sediment surface and increases the amount of TPM as well as POC and CPE at the sediment-water interface.Stable isotope investigations of organic carbon and nitrogen of suspended particles in the BBL suggests indicate that remarkable amounts of the organic matter derives from bacterial new production.However, information available about the bottom near environment in the Gotland Basin from before the saltwater inflow, is too limited to study the change in the BBL due this inflow situation more in detail.

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# 8. Miscellaneous Data

## 8.1. Composition of pore water from three sediment cores in Eastern Gotland Deep:A Data Report.

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### Methods

Sediments were sampled during an expedition with R/V A.v.Humboldt in August 1994 in the framework of GOBEX. Three sampling stations were occupied in the Eastern Gotland Deep

Station 20000 ( 57°15.17'N 20°33.64'E, 112 m)

Station 20004 (57°18.28'N 20°13.66'E, 236 m)

Station 20008 (57°27.60'N 21°09.60'E, 68 m).

We used a multicorer (8 cores, diameter 10 cm) which retrieves 8 cores from an area of 1.5 $m^2$, usually recovering > 30 cm of sediment and overlying seawater with intact sediment surfaces. Upon retrieval, the cores were sealed and stored upright. Within a few hours after sampling, the cores were subsampled in a glovebox with an argon atmosphere. After centrifugation (7000 rpm for 30 min) the pore water supernatant was filtered (0.45 µm Millipore).

Dissolved sulphide was measured on board the ship using a Spectroquant®-kit from Merck based on the methylene-blue method (BUDD and BEWICK, 1952). The analyses were performed within a few hours after sampling in order to minimize the amount of analyte escaping as gaseous hydrogen sulphide.

Samples for sulphate analysis were transferred to glass vials and frozen at -20°C. Samples for analysis of dissolved iron, manganese, and ortophosphate were acidified with HCl to minimize oxidation of Fe(II) (ROEKENS and VAN GRIEKEN, 1983), and stored at 4°C in glass vials.

Dissolved iron was measured spectrophotometrically (COLLINS et al., 1959). Iron in filtered pore water is interpreted as Fe(II) because the solubility of Fe(III) is low ($<10^{-8}$ M) at natural conditions (6<pH<8). Iron oxidized to Fe(III) during storage was reduced to Fe(II) with $HONH_3Cl$ before analysis.

Ortophosphate was measured spectrophotometrically with the phosphomolybdate-method (KOROLEFF, 1976). Sulphate and chloride were measured by reversed phase ion pair chromatography (Perrone and Grant, no year). Manganese was measured by ICP-AES at the Baltic Sea Research Institute, the procedure is described by NEUMANN et al. (1997).

As primary standards for the iron, phosphate, sulphate, and chloride-measurements were used $(NH_4)_2Fe(SO_4)_2.6H_2O$, dried $KH_2PO_4$, dried $Na_2SO_4$, and dried NaCl, respectively. All chemicals were of analytical grade.

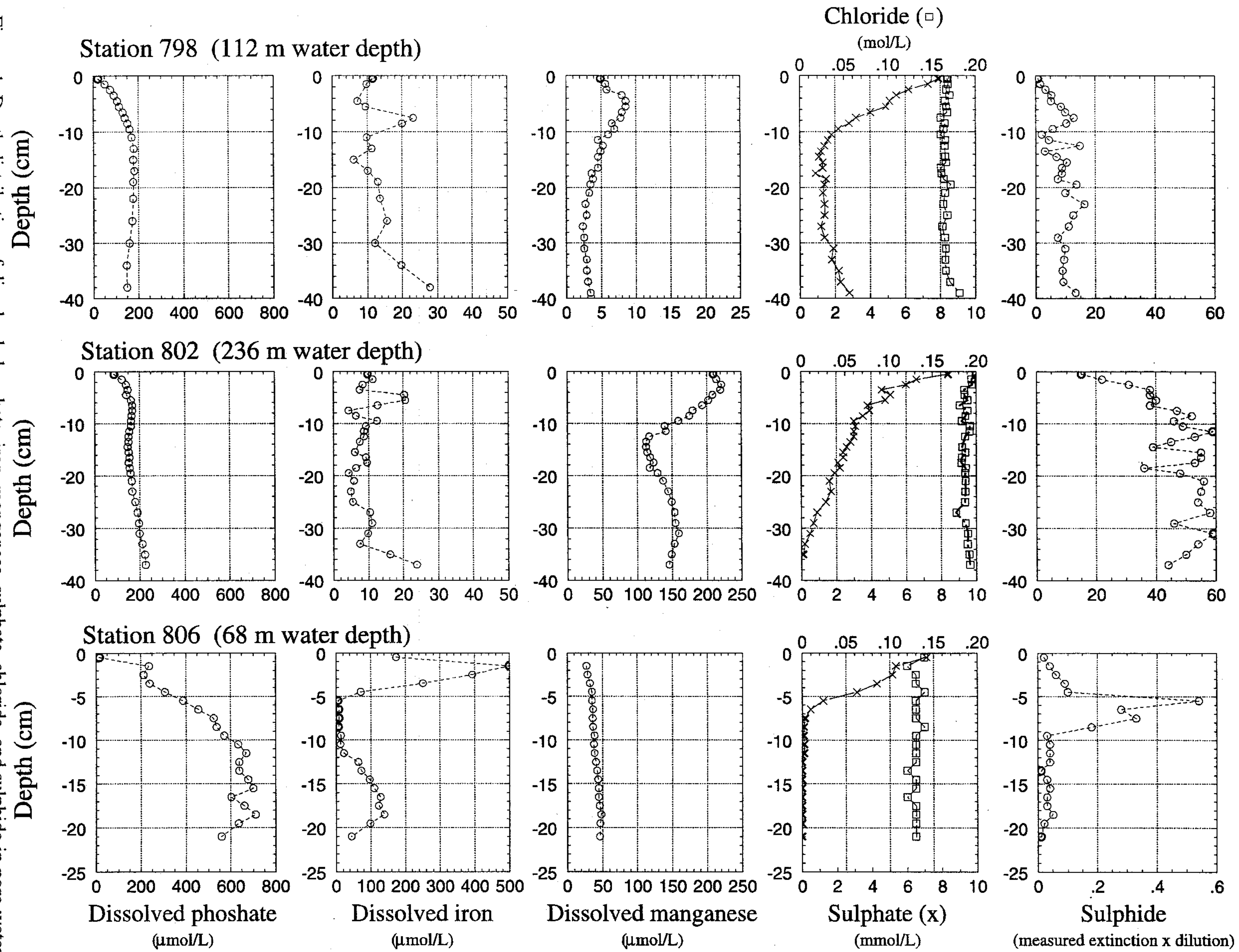


Figure 1: Depth distribution of dissolved phosphate, iron, manganese, sulphate, chloride, and sulphide in pore water from the three stations. Note different concentration scales for dissolved iron and sulphide measured at station 806, and for dissolved manganese at station 798.

**Results**

Figure 1 shows results of phosphate, iron, manganese, sulphate, chloride, and sulphide analyses of pore water. Only relative measurements for sulphide analyses are given (measured extinction x dilution) because no sulphide standard was available. Analyses of water samples taken near the bottom (20 cm above the sediment) showed no sulphide, 2-5 μM oxygen, less than 1 μM dissolved iron, and less than 2 μM phosphate at all three stations.

$^{210}$Pb dating of the cores showed accumulation rates of 34±3, 28±4, and 610±190 $mg.cm^{-2}.a^{-1}$ at station 798, 802, and 806, respectively (CHRISTIANSEN and KUNZENDORF, this volume). A detailed description of age model, mineralogy, lithology, and sediment analyses at station 802 is given by NEUMANN et al. (1997). Sediment from all three cores was analysed for Mo, Al, Ni, Fe, Cr, Mg, Mn, Zn, Ca, Cu, Pb, Li, Co, Cd, K, TC, TOC, TS, TN, and P at the Baltic Sea Research Institute (NEUMANN et al., this volume).

Table 1: Analyses of pore water from 3 sediment cores sampled August 1994 by the GOBEX project. Analyses performed by Henning Matthiesen, Aarhus University. Station 798 (IOW 20000) (57°15.17 N, 20°33.64 E), Station 802 (IOW 20004) (57°18.28 N, 20°13.66 E), Station 806 (IOW 20008) (57°27.60 N, 21°09.60 E)

Station 798 (#20000)

| Depth (cm) | $Cl^-$ (M) | SO42- (mM) | S(-II) (ext*dil) | Mn (mM) | (PO4-) (mM) | Fe (mM) |
|---|---|---|---|---|---|---|
| -0.5 | 0.168 | 7.9 | 0.6 | 4.91 | 20.3 | 11.6 |
| -1.5 | 0.169 | 7.3 | 1.5 | 5.64 | 50.4 | 9.8 |
| -2.5 | 0.167 | 6.21 | 3.3 | 5.82 | 74.3 | 7.2 |
| -3.5 | 0.17 | 5.53 | 5.2 | 8.01 | 91.3 | 9.6 |
| -4.5 | 0.165 | 5.1 | 5 | 8.56 | 106.6 | 23.2 |
| -5.5 | 0.167 | 4.86 | 8.4 | 8.56 | 114.6 | 20 |
| -6.5 | 0.168 | 4.03 | 9.8 | 8.01 | 131.2 | n.d. |
| -7.5 | 0.16 | 3.23 | 12.7 | 7.83 | 140 | n.d. |
| -8.5 | 0.165 | 2.82 | 10.2 | 6.55 | 151.6 | n.d. |
| -9.5 | 0.164 | 2.17 | 5.6 | 6.92 | 161 | n.d. |
| -10.5 | 0.16 | 1.81 | 2 | 6.01 | n.d. | n.d. |
| -11 | n.d. | n.d. | n.d. | n.d. | 170.4 | 9.8 |
| -11.5 | 0.166 | 1.62 | 4.4 | 4.55 | n.d. | n.d. |
| -12.5 | 0.165 | 1.39 | 14.8 | 5.28 | n.d. | n.d. |
| -13.5 | n.d. | 1.23 | 3 | 4.91 | n.d. | n.d. |
| -13 | n.d. | n.d. | n.d. | n.d. | 179.1 | 11.3 |
| -14.5 | 0.165 | 1.07 | 6.9 | 4.55 | n.d. | n.d. |
| -15 | n.d. | n.d. | n.d. | n.d. | 177 | 6.1 |
| -15.5 | 0.166 | 1.29 | 10.4 | n.d. | n.d. | n.d. |
| -16.5 | 0.16 | 1.26 | 8.7 | 4.55 | n.d. | n.d. |
| -17 | n.d. | n.d. | n.d. | n.d. | 181.2 | 10.1 |
| -17.5 | 0.161 | 0.89 | 8.7 | 3.64 | n.d. | n.d. |
| -18.5 | 0.164 | 1.47 | 7.2 | 3.82 | n.d. | n.d. |
| -19 | n.d. | n.d. | n.d. | n.d. | 176.2 | 13 |
| -19.5 | 0.172 | 1.41 | 13.6 | 3.46 | n.d. | n.d. |
| -21 | 0.165 | 1.26 | 9.8 | 3.28 | n.d. | n.d. |
| -22 | n.d. | n.d. | n.d. | n.d. | 175.4 | 13.6 |
| -23 | 0.163 | 1.37 | 16.3 | 2.73 | n.d. | n.d. |
| -25 | 0.168 | 1.44 | 12.5 | 2.91 | n.d. | n.d. |
| -26 | n.d. | n.d. | n.d. | n.d. | 171.8 | 15.6 |
| -27 | 0.162 | 1.21 | 11 | 2.37 | n.d. | n.d. |
| -29 | 0.165 | 1.43 | 7.3 | 2.55 | n.d. | n.d. |

| | | | | | | |
|---|---|---|---|---|---|---|
| -30 | n.d. | n.d. | n.d. | n.d. | 159.5 | 12.2 |
| -31 | 0.166 | 1.88 | 9.7 | 2.55 | n.d. | n.d. |
| -33 | 0.166 | 1.78 | 9.3 | 2.91 | n.d. | n.d. |
| -34 | n.d. | n.d. | n.d. | n.d. | 147.2 | 19.7 |
| -35 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| -37 | 0.171 | 2.33 | 9.1 | 3.09 | n.d. | n.d. |
| -38 | n.d. | n.d. | n.d. | n.d. | 148.6 | 27.8 |
| -39 | 0.182 | 2.77 | 13.2 | 3.46 | n.d. | n.d. |
| Station 802 (#20004) | | | | | | |
| -0.5 | 0.2 | 8.4 | 15.4 | 210 | 87.4 | 9.8 |
| -1.5 | 0.195 | 6.6 | 21.5 | 214 | 122 | 11.3 |
| -2.5 | 0.195 | 5.97 | 30.7 | 221 | 140.6 | 8.4 |
| -3.5 | 0.186 | 4.6 | 38.2 | 220 | 147.9 | 7.5 |
| -4.5 | 0.187 | 5.08 | 37.5 | 208 | 141.7 | 20.3 |
| -5.5 | 0.19 | 4.76 | 39.9 | 202 | 162.4 | 20.6 |
| -6.5 | 0.181 | 3.77 | 37.7 | 194 | 167.5 | 12.7 |
| -7.5 | 0.19 | 3.95 | 47.1 | 180 | 167.5 | 4.3 |
| -8.5 | 0.188 | 3.46 | 52.5 | 175 | 164.6 | 6.4 |
| -9.5 | 0.184 | 3.04 | 46 | 160 | 162.4 | 12.5 |
| -10.5 | 0.193 | 3.07 | 48.8 | 140 | 160.9 | 9.3 |
| -11.5 | 0.192 | 3.01 | 59.5 | 141 | 154.4 | 8.7 |
| -12.5 | 0.187 | 2.96 | 52.6 | 117 | 150.8 | 8.7 |
| -13.5 | n.d. | 2.8 | 45.4 | 113 | 150.1 | 7.5 |
| -14.5 | 0.184 | 2.56 | 39.4 | 112 | 147.2 | n.d. |
| -15.5 | 0.188 | 2.41 | 55.2 | 114 | 151.5 | 6.1 |
| -16.5 | 0.184 | 2.37 | 54.8 | 118 | 154.8 | 9.3 |
| -17.5 | 0.183 | 2.1 | 53.1 | 123 | 151.5 | 9.6 |
| -18.5 | 0.188 | 2.18 | 36.5 | 118 | 155.9 | 6.4 |
| -19.5 | 0.187 | 1.85 | 48.4 | 129 | 159.5 | 4.3 |
| -21 | 0.188 | 1.62 | 56.5 | 137 | 164.6 | 5.8 |
| -23 | 0.188 | 1.67 | 55.4 | 145 | 166.7 | 4.9 |
| -25 | 0.187 | 1.44 | 53.9 | 149 | 179.8 | 5.5 |
| -27 | 0.177 | 0.93 | 57.7 | 154 | 190 | 10.4 |
| -29 | 0.188 | 0.69 | 45.8 | 155 | 195.8 | 11 |
| -31 | 0.19 | 0.53 | 59.2 | 160 | 198.7 | 9.8 |
| -33 | 0.19 | 0.25 | 53.5 | 153 | 211.7 | 7.5 |
| -35 | 0.192 | 0.09 | 50.2 | 149 | 221.9 | 16.2 |
| -37 | 0.193 | n.d. | 44.5 | 146 | 225.1 | 23.8 |
| Station 806 (#20008) | | | | | | |
| -0.5 | 0.14 | 7.11 | 0.02 | n.d. | 15.4 | 174 |
| -1.5 | 0.121 | 5.36 | 0.04 | 27.5 | 235.7 | 499.1 |
| -2.5 | 0.131 | 5.15 | 0.064 | 28.8 | 212.4 | 393.1 |
| -3.5 | 0.13 | 4.27 | 0.088 | 32.2 | 239.3 | 250.9 |
| -4.5 | 0.136 | 3.14 | 0.104 | 35.1 | 306.2 | 71.7 |
| -5.5 | 0.128 | 1.21 | 0.544 | 34.9 | 387.8 | 5.5 |
| -6.5 | 0.132 | 0.48 | 0.28 | 36.6 | 454.9 | 7.8 |
| -7.5 | 0.128 | 0.17 | 0.332 | 36 | 523.9 | 8.7 |
| -8.5 | 0.138 | 0.11 | 0.184 | 36.6 | 537.5 | 6.4 |
| -9.5 | 0.127 | 0.1 | 0.032 | 38.6 | 571 | 13.9 |
| -10.5 | 0.128 | 0.13 | 0.036 | 37.9 | 632.7 | 12.5 |
| -11.5 | 0.135 | 0.12 | 0.044 | 38.6 | 668.9 | 22.6 |
| -12.5 | 0.126 | 0 | 0.04 | 40.8 | 637.8 | 64.4 |
| -13.5 | 0.123 | 0 | 0.012 | 42.2 | 637.8 | 72.5 |
| -14.5 | 0.13 | 0 | 0.028 | 43.7 | 677.7 | 97.1 |
| -15.5 | 0.13 | 0 | 0.044 | 44.6 | 699.5 | 110.2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| -16.5 | 0.124 | 0 | 0.032 | 44.6 | 601.6 | 129 |
| -17.5 | 0.132 | 0 | 0.028 | 45.9 | 659.6 | 123.2 |
| -18.5 | 0.127 | 0 | 0.052 | 48.1 | 710.4 | 139.2 |
| -19.5 | 0.127 | 0 | 0.02 | 46.6 | 634.2 | 98.6 |
| -21 | 0.129 | 0 | 0.008 | 46.2 | 558 | 44.1 |

## Discussion

The presented data has been used in combination with sediment data to show that:

Iron and sulphate reduction control the diffusive release of phosphate from sediment to the water during oxic bottom water conditions (MATTHIESEN et al., in press). Phosphate is currently released at a rate of 1-3 µmol $P.cm^{-2}.a^{-1}$ at the deep station 802 (MATTHIESEN et al., in press). The release rate has increased considerably between 1990 and the present study (1994) (MATTHIESEN, 1998).

Manganese oxides formed in the water column by the salt water inflows in 1993 and 1994 (MATTHÄUS and LASS, 1995) settle very slowly. The manganese had not reached the sediment surface by August 1994 (MATTHIESEN, 1998).

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## 8.2. Absolute and relative abundances of siliceous plankton organisms in the Gotland Sea

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### Abstract

Absolute abundances of diatoms, chrysophyte stomatocysts, silicoflagellates and ebriids were determined in samples from a 10.40 m long sediment core (# 20048) from the Gotland Basin. The sediments of the Baltic Ice Lake show a very scarse diatom record. In the marine to brackish sediments of the Yoldia Sea and the freshwater sediments of the Ancylus Lake increasing amounts of diatoms were determined. During the marine-brackish water Littorina Sea stage at least three marine ingressions were reconstructed by diatom species composition. Maximum abundances of about 240 million diatom valves per gram dry sediment were calculated for the Littorina stage.

### Methods

More than 180 samples were taken with a spatula (0.5 cm broad) crossing the sediment core to get representative samples. Routinely, all samples were freeze dried and weighed. The method for quantitative processing of sediment samples was adopted and follows the instructions of BATTARBEE (1973) and ABELMANN (1985). Chemical treatment with $H_2O_2$ (35%), and HCl (10%) dissolve organic matter and carbonate. Subsequently, the aliquots were cleaned from added chemicals and salts, using a settling procedure and change demineralized water after 12 hours. A unique adding of a solution of potasium-hexametaphosphate (0.3%) separate the clay particles, and after four hours (settling distance 6 cm) the supernatant water including particles • 2µm diameter were removed several times, using a water-jet filter pump. The residuals were sedimented on cover slips. For light microscopical examinations strewn slides were prepared with Mountex mounting medium ($n_D$= 1.68). Identification and counting were done with a Leitz Orthoplan microscope at magnification of 1250x. The counting procedure of (SCHRADER and GERSONDE, 1978) were adopted for diatom analysis and is the basis for calculation of relative and absolute abundances after the formula below, where C is the concentration of fossils per gram dry sediment; N is the number of fossils counted (usually more than 300 diatom valves were counted, while the number of other organisms were registrated simultaneously); A is the area of the sedimentation dish [$mm^2$]; D is the dilution of the sample; a is the area counted on the cover slip [$mm^2$] and g is the dry weight of the sample [g].

$$C = \frac{N * A * D}{a * g}$$

### Results

Interdisciplinary, geological, paleontological and geochemical investigations were made to reconstruct the environmental history of the Gotland Basin. This paper only deals with micropaleontological data. Differences in diatom species composition in comparison with downcore lithological variations results in ecostratigraphical classification of the sediment core.

Diatoms

Diatoms are present throughout the entire sediment core (Figure 1) and are the dominant plankton group. Ecological preferences of species (e.g. salinity tolerance, water temperature, nutrients) can be recognized from species composition. In the sediments of the Baltic Ice Lake diatoms are present but very scarce, but during Yoldia increasing amounts were recorded. In the Ancylus Lake maximum diatom amounts with 150 and $90*10^6$ valves/g sediment were calculated.

Mean values of up to $40*10^6$ valves/g were present during the Littorina Stage, but more than 90 (max. 240) $*10^6$ valves/g occurred during four distinct intervals. The Postlittorina stages are characterized by very low diatom amounts, but during the recent Mya stage between 10 and $30*10^6$ valves/g were calculated.

Chrysophyte stomatocysts

The first occurrence of chrysophyte cysts is during the Ancylus stage (Figure 2). At the Mastogloia-Littorina transition a remarkable increase of chrysophyte stomatocysts from below 2 $*10^6$ to about 10 $*10^6$ cysts/g were recorded due to a suggested incresing salinity of the surface water which were also reported by marine diatom species (Figures 4a-c). Maximum abundances were present during three narrow intervals with strong marine influence reaching 30-85* $10^6$ cysts/g. The ocurrence of chrysophyte stomatocysts results in changing marine environmental conditions.

Silicoflagellates

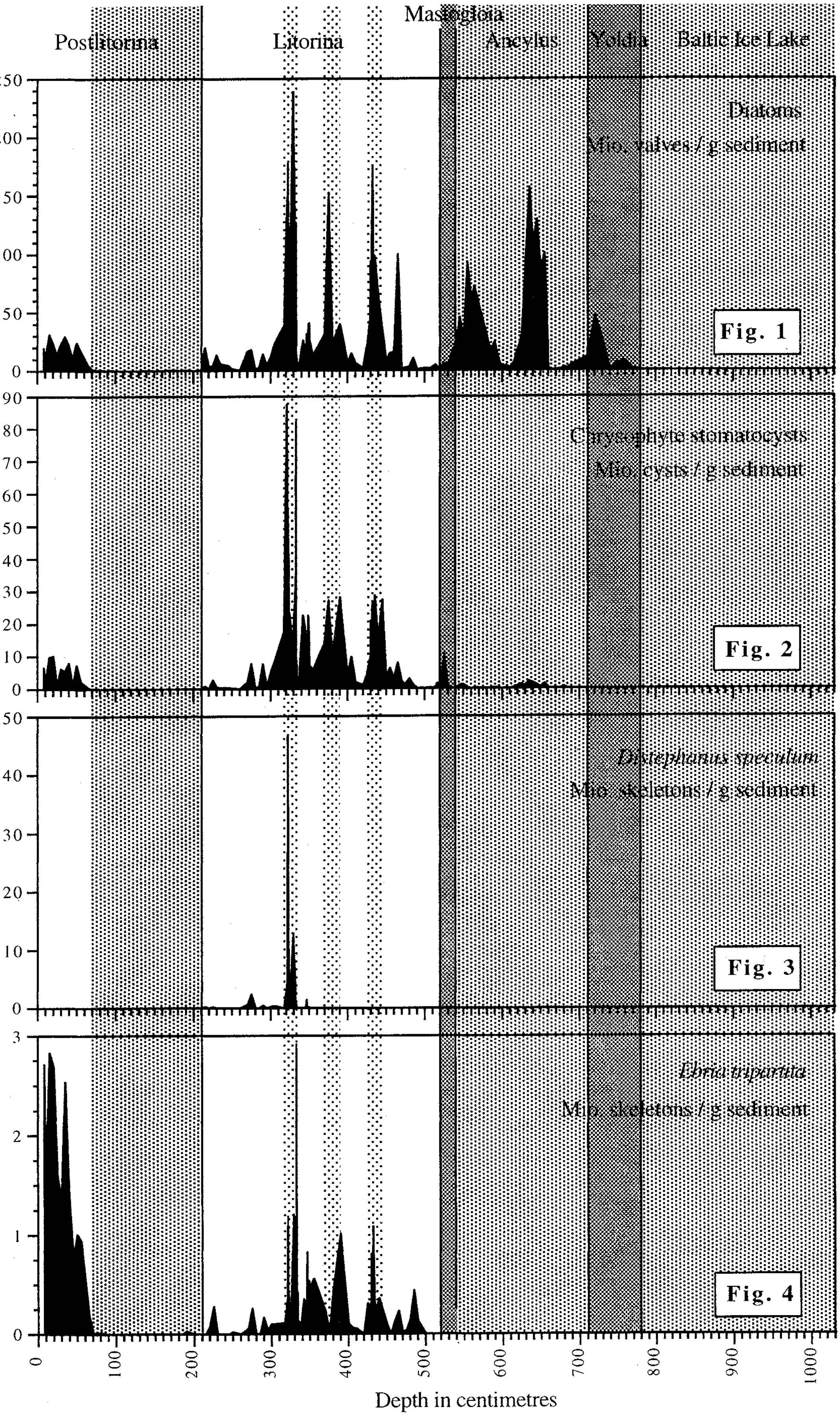
The silicoflagellate species *Distephanus speculum* only sporadically occure in the sediments of the Littorina stage. This species prefer cool water masses and higher salinities (27 ‰). In sediment core 20048 the record of *D. speculum* is restricted from 342-215 cm depth below sea floor. Peak abundance of 46 $*10^6$ skeletons/g were observed at 320 cm depth (Figure 3). The occurrence of this species may indicate an inflow of marine surface water masses into the Gotland Sea region.

Ebriids

The dinoflagellate *Ebria tripartita* is a species bearing a siliceous skeleton. It was found exclusively during the marine influenced Littorina and Mya stages (Figure 4). Highest abundances ( 3 $*10^6$ skeletons/g) were recorded in the uppermost part of the sediment core. (WITTKOWSKI and PEMPKOWIAK, 1995) suggested that the increase of *E. tripartita* is an indicator of the anthropogenic eutrophication of the Baltic Sea.

The diatom content in the sediments from the **Baltic Ice Lake** (> 10300 $^{14}C$ yr B.P.) is almost negligible. Sporadically, valves of *Stephanodiscus, Cyclotella, Aulacoseira,* some pennate diatoms and chrysophyte stomatocysts were present from 1030-780 cm depth (see Table 1, Figure 5).

The transition to the sediments of the **Yoldia Sea** (10300-9600 $^{14}C$ yr B.P.) is marked by an increase of the total diatom amount and composition. From 780-710 cm depth *Thalassiosira baltica, T. eccentrica, T. decipiens*-group, *Stephanodiscus rotula* and *S. minutulus* are most common (Figure 5). In the Gotland basin the Yoldia phase consists of typical brackish to marine species.


Postlitorina
Litorina
Mastogloia
Ancylus
Yoldia
Baltic Ice Lake
Diatoms
Mio. valves / g sediment
Fig. 1
Chrysophyte stomatocysts
Mio. cysts / g sediment
Fig. 2
Distephanus speculum
Mio. skeletons / g sediment
Fig. 3
Ebria tripartita
Mio. skeletons / g sediment
Fig. 4
0
100
200
300
400
500
600
700
800
900
1000
Depth in centimetres

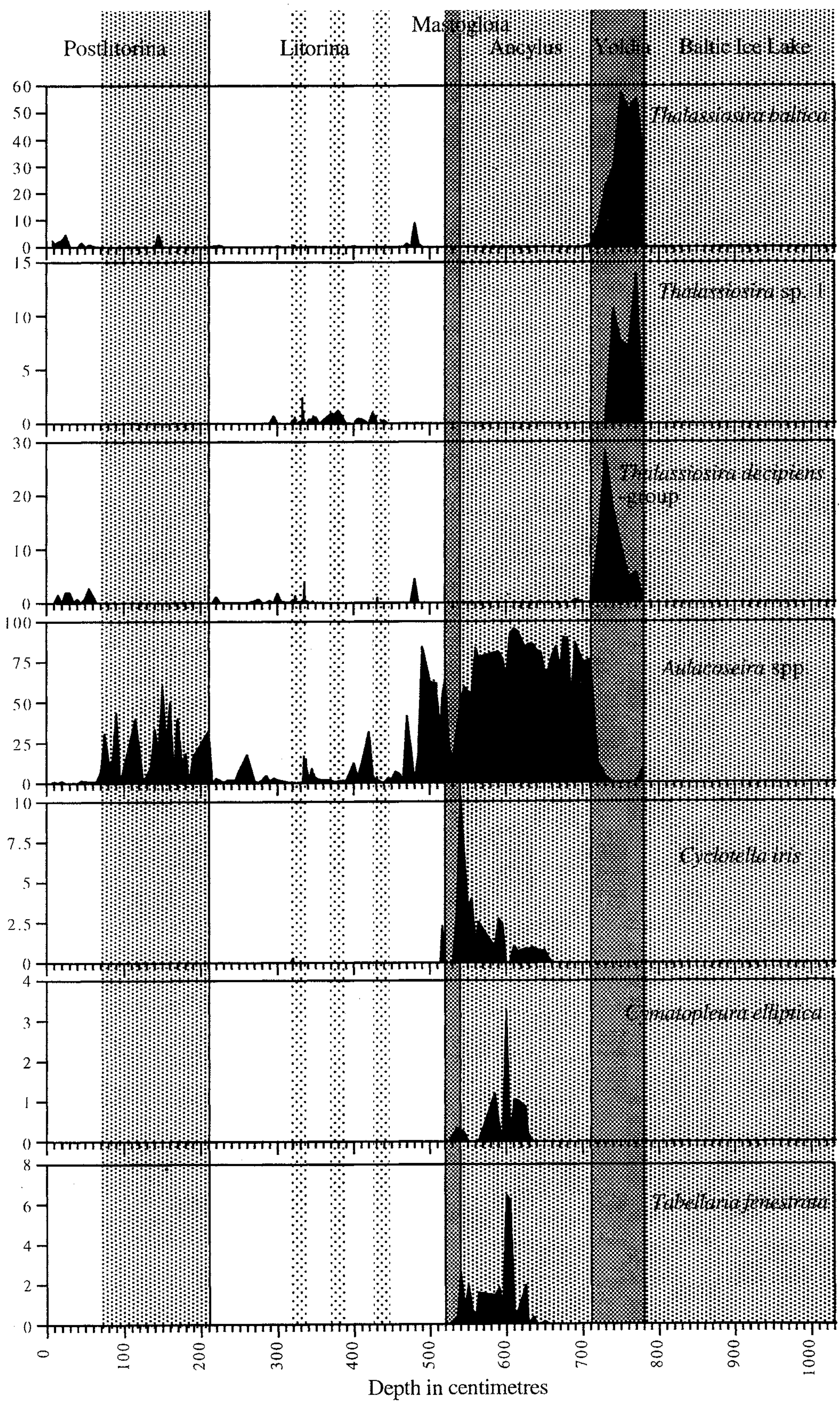



Fig. 5: Relative abundances of important diatoms. Freshwater and brackish species.

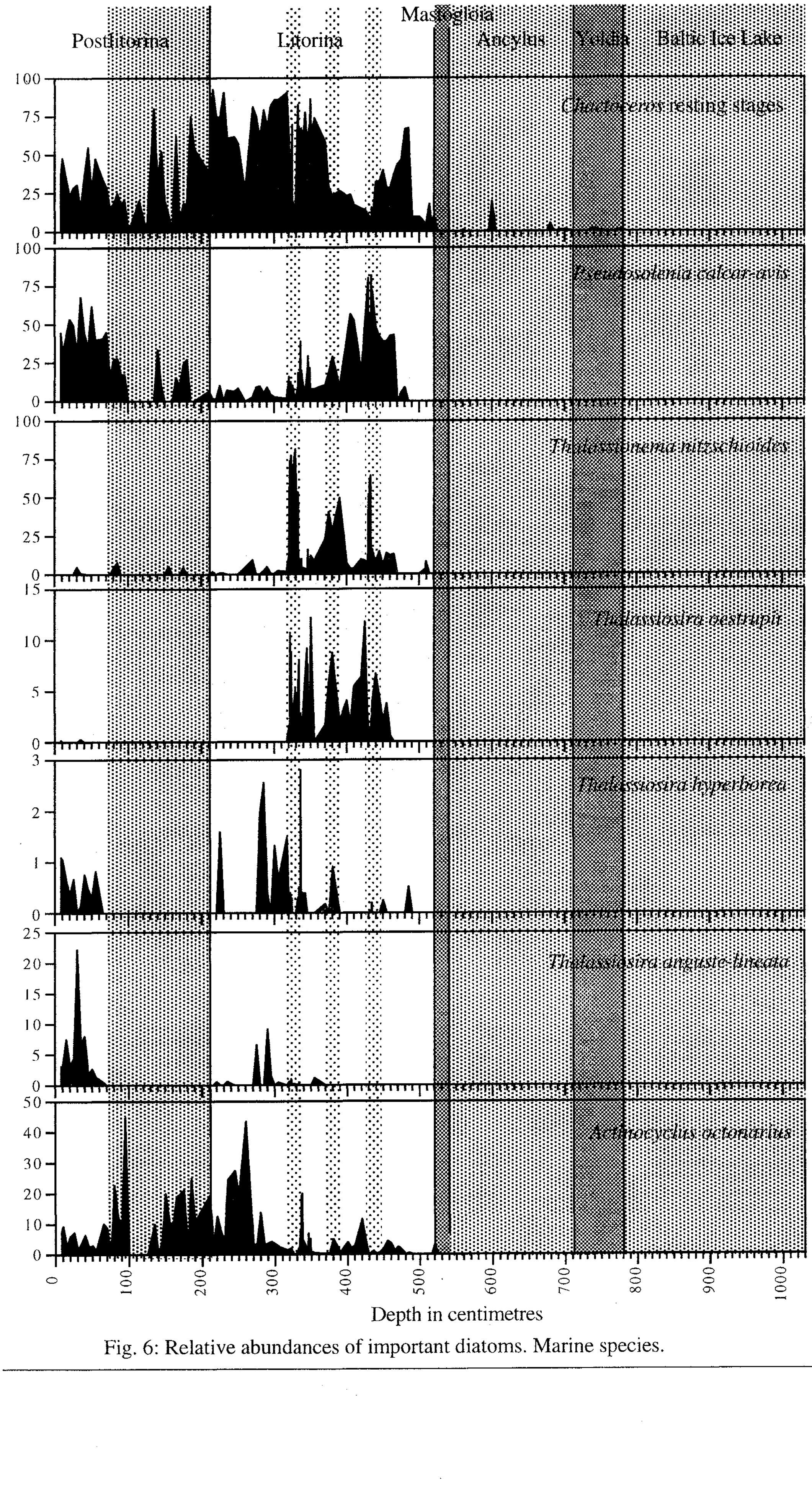



Fig. 6: Relative abundances of important diatoms. Marine species.

The diatoms of the freshwater **Ancylus Lake** (9600-8000 $^{14}$C yr B.P.) consists of about 50-93 % of *Aulacoseira* species. Other freshwater species such as *Tabellaria fenestrata, Cymatopleura elliptica,* as well as the brackish *S. rotula* and *S. minutulus* are also common from 710-540 cm depth (Figure 5).

Brackish and freshwater species such as *Aulacoseira, Stephanodiscus,* and *Cyclotella* are dominant from 540-520 cm depth. Due to the occurrence of *Mastogloia* in this offshore region this short intervall is related to the **Mastogloia Sea** (8000-7000 $^{14}$C yr B.P.) (see Figure 5).

The marine sediments of the **Littorina Sea** (7000-3000 14C yr B.P.) consists of *Actinocyclus octonarius* and resting stages of the genus *Chaetoceros* as the main contributors. *Hyalodiscus scoticus, Epithemia turgida,* and *Diploneis* spp. are of minor importance but present during the whole stage from 520-210 cm depth. At least during three time intervals sharp increases of marine, warm to temperate water adapted species such as *Thalassiosira oestupii, T. eccentrica, Thalassionema nitzschioides,* and *Pseudosolenia calcar-avis* reach peak abundances from 450-310 cm depth (Figure 6) when maximum abundance of more than $100*10^6$ valves/g were recorded. These intervals correlates exactely with dark olive grey, bioturbated but laminated sediments and were interpretated as three main Littorina ingressions. The occurrence of diatom species which were adapted to cold water temperatures and lowered salinity (*Thalassiosira anguste-lineata* and *T. hyperborea*) were present with increasing amounts from 300-210 cm depth (Figure 6).

With a sharp contrast the lower Postlittorina interval from 210-70 cm depth is characterized by a very low diatom content (< 0.5 * 106 valves / g). Mostly strongly silicified diatoms occure or valves were preserved badly. In this interval also freshwater algae (*Pediastrum* spp.) are present which persist the chemical preparation. Strong silica dissolution and/or sorting by bottom currents is another possible interpretation.

The sediments of the upper Postlittorina interval from 70-0 cm depth shows a species composition which is comparable to those of the Littorina stage. As a mean value relative abundances are: *Chaetoceros* resting stages (30%), *P. calcar-avis* (40%), *A. octonarius* (<10%), *T. anguste-lineata* (7%).

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## 8.3. Long-chain alkenones in Holocene Sediments of the Baltic Sea - A Status Report

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In an attempt to establish a molecular proxy of sea surface temperatures and salinity in the Baltic Sea, we analysed Baltic Sea surface sediments and suspended matter from the water column for long-chain alkenones. Their unsaturation ratio ($U^{K'}_{37}$ as defined in Table 1) is a well established proxy indicator of marine surface temperatures (e.g., BRASSELL, 1993). The field data have been supplemented by cultures of Baltic Sea algae under controlled conditions. The thus established Baltic Sea alkenone unsaturation index will be applied to reconstruct the paleoenvironment in the Baltic Sea during the Holocene.

### Alkenones in surficial sediments of the Baltic Sea and the Skagerrak

In Baltic Sea sediments, long-chain alkenones were first described by SCHULZ et al. (1997). Alkenone patterns in surficial sediments were found to differ in the sub-basins of the brackish marginal sea. In the Skagerrak, in the Kattegat, and in the Belt Sea, the concentration of tetraunsaturated $C_{37}$-alkenones ($C_{37:4}$) was low, and $C_{38}$-alkenones were present as methyl and ethyl ketones. Similar patterns have been reported in marine environments (SONZOGNI et al., 1997). Under brackish to marine conditions (with salinities ranging from 10-34) *Emiliania huxleyi* is the dominant prymnesiophyte, which is the class of haptophytes that synthesises the long-chain ($C_{37}$-$C_{40}$) ketones. In the Mecklenburg Bight, the Arkona Sea, the Bornholm Sea and the Gdansk Bight concentrations of $C_{37:4}$ alkenones were also low and only $C_{38}$ methyl ketones were detected. In the Gotland Deep and the Gulf of Finland, the surficial sediments did not contain any $C_{38}$ methyl ketones, but $C_{38}$ ethyl ketones. Concentrations of tetra-unsaturated $C_{37}$ alkenones were found to be low in the Gotland Deep and high in the Gulf of Finland. The variable patterns in surface sediments may reflect modern salinity gradients from south-east to north-west. Salinity determines the occurrence of different prymnesiophytes, which might be reflected in the ratios of the individual alkenones found in the Baltic Sea.

### Alkenones synthesised by Baltic Sea algae in culture experiments

In a first step towards identifying the producing organism and to test temperature and salinity dependence, we cultivated the algae *Chrysochromulina polylepis, Chrysochromulina aphelis, Pleurochrysis carterae, Prymnesium patelliferum,* and *Pavlova lutheri* at optimal growth temperature and analysed the cultures for their specific alkenone pattern. At the present time alkenones were detected in low concentrations in all algae, but sample sizes will be increased for optimal analyses.

Table 1 : Average results of alkenone analyses in Baltic Sea sediments (core 20048-1) and most abundant alkenone patterns in relation to the paleoenvironment; Σ alkenone includes all ketones with 37, 38, 39 and 40 carbon atoms. Results are means of 1cm layers sampled at distances of 10-20cm.

| Paleoenvironment | Stage/ Age y. BP (depths in core 20048-1) | n = number of samples | TOC % | Σ alkenone µg/gTOC | $U^{K'}_{37} = C_{37:2}/(C_{37:2} + C_{37:3})$ | $C_{37}$ pattern $C_{37:4} = 4$; $C_{37:3} = 3$; $C_{37:2} = 2$ | % $C_{37:4}$ in Σ $C_{37}$ | % $C_{37:3}$ in Σ $C_{37}$ | % $C_{37:2}$ in Σ $C_{37}$ |
|---|---|---|---|---|---|---|---|---|---|
| <10PSU, brackish | Mya/ 0-500 (0-65cm) | n = 5 | 5.6 | 1266 | 0.473 | alternating patterns 4<3>2 | 32 | 36 | 32 |
| <10PSU, brackish | Lymnea/ 500-2000 (65-202cm) | n = 11 | 3.3 | 1730 | 0.459 | alternating patterns 4<3>2 | 30 | 38 | 32 |
| >10, marine-brackish | Littorina/ 2000-5750 (202-520cm) | n = 23 | 3.9 | 1549 | 0.310 | alternating patterns 4<3>2 | 25 | 52 | 23 |
| >10, brackish atlant. climate-optimum | Mastogloia/ 5750-7800 (520-632cm) | n = 8 | 2.4 | 9169 | 0.278 | 4>2 4<3>2 | 31 | 63 | 20 |
| <2, freshwater, warm | Ancylus/ 7800-9250 (632-720cm) | n = 7 | 0.8 | 4698 | 0.399 | 4<<2 4<3>2 | 22 | 47 | 31 |
| >10, marine-brackish | Yoldia/ 9250-10000 (720-780cm) | n = 4 | 0.8 | 9622 | 0.217 | 4>>2 4<3>2 | 38 | 45 | 13 |
| <2, freshwater, cold | Baltic Ice Lake/>10000 (780-1037cm) | n = 15 | 0.6 | 1875 | 0.510 | 4<<2 4<3<2 | 18 | 37 | 45 |

## Alkenones in Holocene sediments of the Gotland Deep

In a second effort we investigated alkenone occurrence in a 10.29 m length core from the Gotland Deep (core 20048-1), which provides a continuous paleoceanographic and paleoclimatic record in the Baltic Sea. Alkenones have been detected in sediments from all Baltic Sea stages that represent lacustrine to fully marine conditions. Highest alkenone concentrations were detected in sediments from the brackish Yoldia and Mastogloia stages. The sediments from the freshwater Ancylus stage contained higher alkenone concentrations than those of the marine/brackish Littorina, the brackish Lymnea and Mya and also of the colder freshwater stage Baltic Ice Lake stages (see Table 1).

Specific $C_{37}$ alkenone patterns were identified in the sediments deeper than 4 m which included sediments from the Baltic Ice Lake, Yoldia, Ancylus, Mastogloia and basal Littorina stages. Sediments from freshwater stages were dominated by $C_{37:4}$ ketones , and were more abundant in Baltic Ice Lake sediments than in sediments of the warmer Ancylus Lake. All brackish and marine/brackish sediments are dominated by $C_{37:3}$ ketones. In the freshwater stages Baltic Ice Lake and Ancylus, $U^{K'}_{37}$ was relatively high (0.510 - 0.399; for a definition see Table 1). In Yoldia and Mastogloia sediments, $U^{K'}_{37}$ was calculated to be as low as 0.217 and 0.278. $U^{K'}_{37}$ increased from Littorina to Mya.

One reason for these differences might be that the algal community is dominated by different species depending on salinity. In addition, a given species produces different alkenone patterns if growth temperature changes.

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