Scientific Cruise Report of the Kara Sea Expedition with RV „Akademik Boris Petrov“ in 2003 within the frames of the Russian-German project „SIRRO“ and the Russian-Norwegian project „MAREAS“

Wissenschaftlicher Fahrtbericht über die Karasee-Expedition mit FS „Akademik Boris Petrov“ 2003 im Rahmen des russisch-deutschen Projektes „SIRRO“ und des russisch-norwegischen Projektes „MAREAS“

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1. Introduction

M.A. Levitan[1] and F. Schoster[2]

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In August 2003 a joint German-Russian-Norwegian expedition into the Kara Sea was carried out. It was the sixth expedition with RV "Akademik Boris Petrov" within the framework of the Russian-German project on "The nature of continental run-off from the Siberian rivers and its behavior in the Adjacent Arctic Basin (Siberian River Run-Off – SIRRO)" and was based on the results of the former expeditions in 1997, 1999, 2000, 2001, and 2002 (Matthiessen and Stepanets 1998, Stein and Stepanets 2000, 2001, 2002, Schoster and Levitan 2003). The overall goals of the project are the understanding of the oceanographical, biological, geochemical, and geological processes in the inner Kara Sea and the Yenisei Estuary. Especially, the aims of this expedition in 2003 were the recovery of the sediment trap, which was deployed in 2002, profiling with the new Parasound-System on board of RV "Akademik Boris Petrov", in order to get information about the sediment structure in a better resolution than with the former ELAC-System, and collecting additional oceanographical, biological and geochemical data.

Closely connected to the SIRRO-Project is the Norwegian-Russian joint project MAREAS ("Material fluxes from the Russian Rivers Ob and Yenisey: Interactions with climate and effects on Arctic Seas"), for which it is the first expedition with RV "Akademik Boris Petrov" into the Kara Sea. The main goal of the project is to conduct a process-oriented investigation of the flux and biogeochemical behavior of important river-derived constituents to the adjacent Arctic marginal sea. The flux assessments of DOC, nutrients and organic contaminants and the linkage between DOC, UV light regimes, primary production and contaminant discharges are of main interest.

The scientific program of the expedition covered a wide range of objectives:

(1) to characterize the supply of the Yenisei River with respect to their dissolved and suspension load, to identify processes modifying the river supply in the estuaries and the inner shelf sea, and finally to analyse the dispersal and deposition of the river supply in the Kara Sea;
(2) to study the response of the planktic and benthic biota on variations in the river supply along the salinity gradient from the estuaries to the inner shelf;
(3) to study the geochemistry of dissolved and particulate organic matter and hydrocarbon gases in the water column and the sediments, and
(4) to study the dispersal and distribution pattern of contaminants, and
(5) to determine the UV light regimes in the Kara Sea and to compare to satellite data.

The research institutes involved in this expedition were from the Russian side the Vernadsky Institute of Geochemistry and Analytical Chemistry (GEOKHI) Moscow, the Murmansk Marine Biological Institute (MMBI) Murmansk, and the "Nuklear Forschung" Vladivostok, and from the German side the Alfred Wegener Institute for Polar and Marine Research (AWI) Bremerhaven, the Research Center for Marine Geosciences (GEOMAR) Kiel, and the Institute for Biogeochemistry and Marine Chemistry (IFBM) Hamburg. From the Norwegian side the University of Oslo, Department of Biology, Akvaplan-niva Tromsø, the Nansen Environmental and Remote Sensing Center Bergen, and Norwegian University of Science and Technology, Department of Physics Trondheim were involved in this expedition.

This report presents the scientific program and initial results of the expedition and outlines future research to be performed on the material obtained during the expedition. In addition, some results from studies of the material, which was obtained in former expeditions with RV "Akademik Boris Petrov", are also presented.

The success of our expedition is mainly based on the excellent cooperation between crew and scientists. We would like to thank captain Igor A. Vtorov and his crew for their untiring and able support during work onboard RV "Akademik Boris Petrov".

2. Itinerary

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The sixth expedition of RV „Akademik Boris Petrov" within the frame of the SIRRO-Project started in the evening of July 30, 2003, in Bremerhaven, Germany. In this first part of the expedition the new Parasound-System on board of RV „Akademik Boris Petrov" should be tested and calibrated. Therefore, only three Russian scientists, two participants from Atlas Hydrographics (manufacturer of the Parasound-System), five German scientists and 36 crew members participated in this part of the cruise. Between July 31, 2003, and August 08, 2003, the testing and calibration of as well as the training on the Parasound-System took place on the way to and in the Lofoten Basin. After finishing this procedure RV „Akademik Boris Petrov" went to Kirkenes, Norway, which was reached on August 09, 2003. The participants of Atlas Hydrographics and three German scientists disembarked, and the equipment of the Norwegian group is loaded onto the ship.

The second part of this expedition began August 10, 2003, in Murmansk, which was the next stop of RV „Akademik Boris Petrov". After loading the equipment of the Russian groups and embarking of additionally 13 Russian, one German and three Norwegian scientists, RV „Akademik Boris Petrov" left Murmansk on August 14, 2003. On August 17, 2003, the working area in the Kara Sea was reached. We began immediately with station work and profiling of the sea bottom with the Parasound-System. RV „Akademik Boris Petrov" headed eastwards to the position of the mooring, which was deployed during the former expedition in 2002. The following recovery of the sediment trap was managed without any problems on August 18, 2003. On the way to this position we passed one sea-ice field. According to the available sea-ice charts, the central and the northeastern part of the Kara Sea was ice-covered. In order to profile the central and the northern Kara Sea, RV „Akademik Boris Petrov" headed to north, then to west. But in western direction the ice margin occurred, and the course had to be changed into southern direction. After some days profiling (see Fig. 2.2), a transect from northwestern Kara Sea into the southern Yenisei Mouth was investigated with the normal station work like water and sediment sampling, UV radiation measurements and oceanographical data collecting. On August 24, 2003, RV „Akademik reached the most southern location in the Yenisei River on this expedition. In order to finish our work in the Kara Sea, we headed northwest, and did the last station in the working area on August 26, 2003. The whole expedition ended on August 30, 2003, in Arkhangelsk.

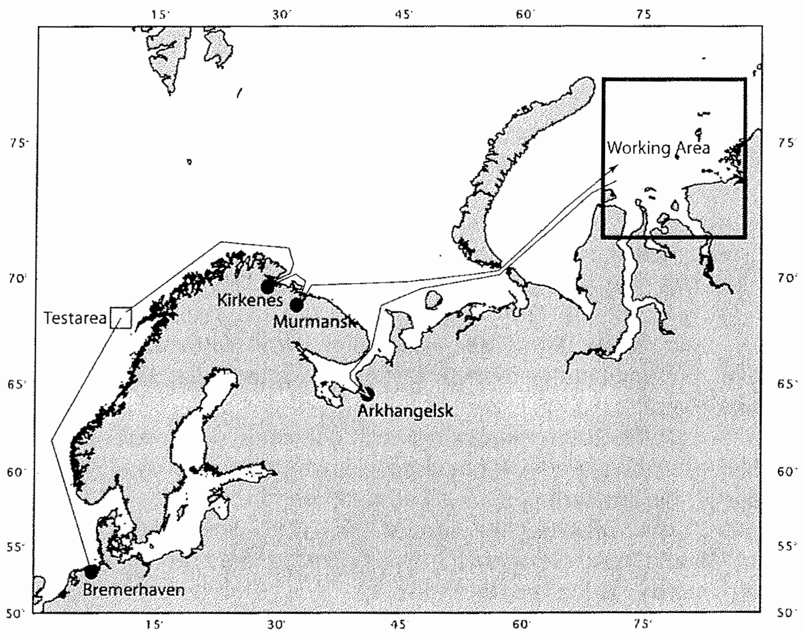

Figure 2.1: Schematic plot of the cruise of RV "Akademik Boris Petrov" from the start of the Kara Sea Expedition 2003 in Bremerhaven to the working area in the Kara Sea and the way back to Arkhangelsk, where the expedition was finished.

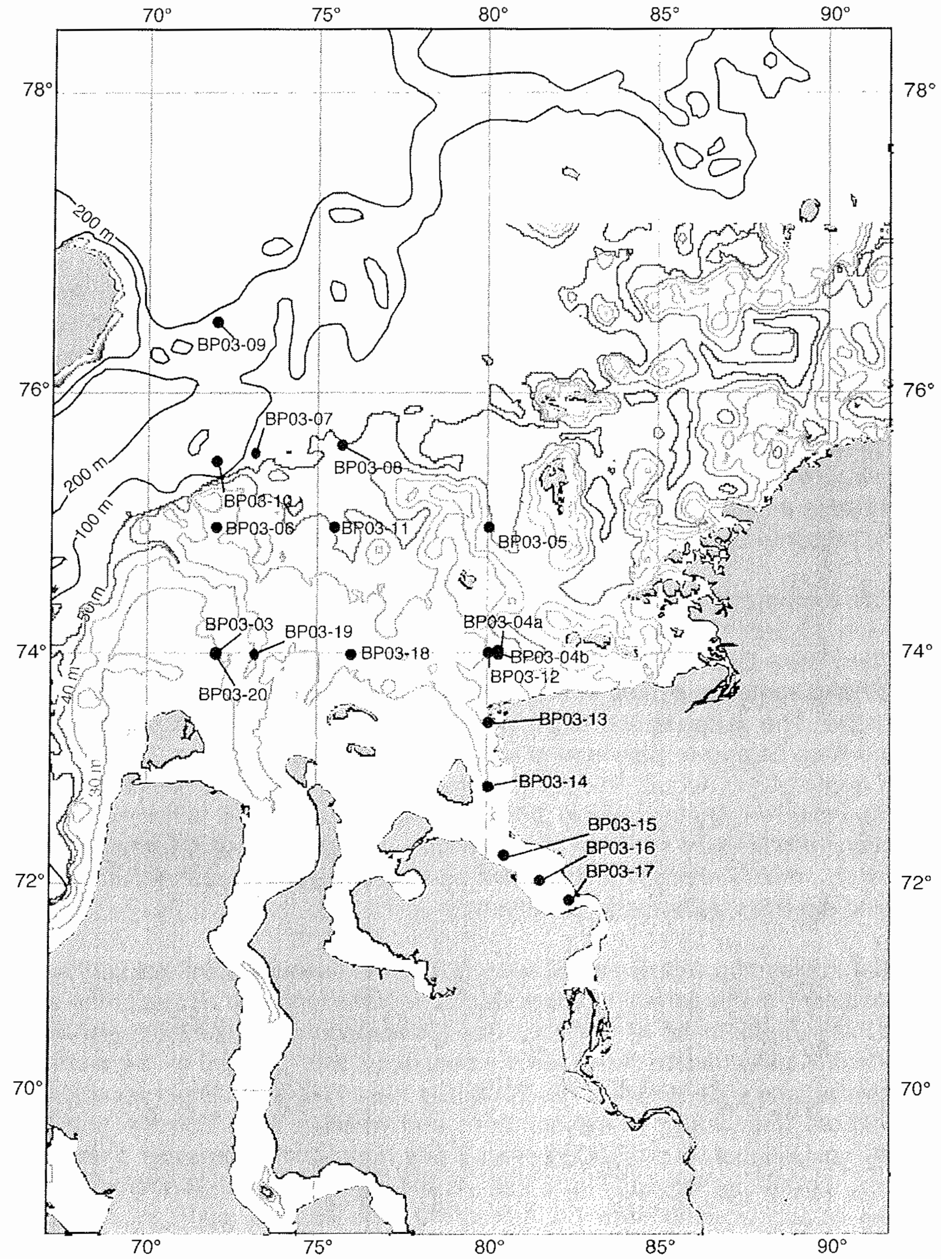

Figure 2.2: Stations of Kara Sea Expedition 2003.

3. Meteorological Data and Ice Conditions

F. Schoster and K. Dittmers

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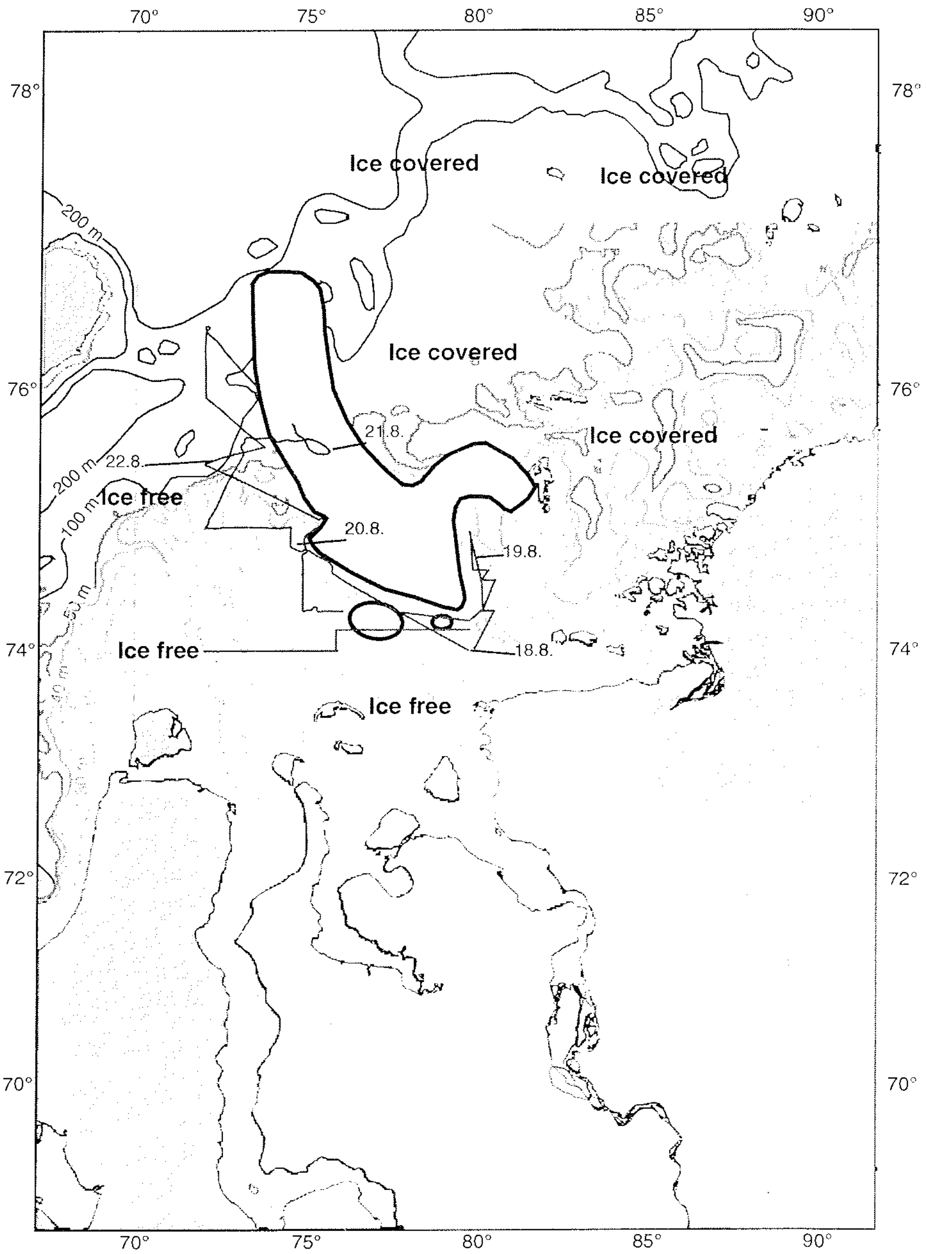
The meteorological data was taken at each station during the Kara Sea Expedition 2003 with RV "Akademik Boris Petrov", measured by ship sensors. Table 3.1 shows the surface water temperature, the air temperature, the wind speed and the wind direction. Due to the begin of the expedition in Arctic summer, open-water conditions in the southern and central Kara Sea were expected. Unfortunately, this summer was a cold one in the Kara Sea, and the sea-ice conditions were severe, compared to the former expeditions in the years 1997 to 2002. The central Kara Sea was ice-covered, and at the margin the ice fields were mainly dense. RV „Akademik Boris Petrov“ moved along the ice margin in the Kara Sea (Fig. 3.1). The margin is comparable to the results of the satellite images. For some days the distribution of the sea ice in the Kara Sea is presented in Figure 3.2 (http:/www.sea-ice.de, Kaleschke et al. 2001).

The air temperatures were between 4.5 and 10.5 °C in the Kara Sea and between 11 and 15.6 °C in the Yenisei River (Table 3.1). In the central and southern Kara Sea the weather was almost all the time foggy, while it was cloudy and sometimes rainy in the Yenisei River during the time of working in the areas. The water temperature was changing from 3.4 °C in the central, marine Kara Sea to a maximum of +13.8 °C in the Yenisei River (Table 3.1). From August 17 to August 20, southwesterly winds with speeds between 2 and 10 m/s occurred. During August 20, the wind was changing to southeasterly direction with speeds between 2 and 6 m/s. For the rest of the cruise until August 26, mainly wind directions from south, southeast or east occurr, while the wind speeds vary between 3 and 8 m/s.

In order to plan and coordinate the work during the expedition the status of sea-ice conditions are important to know. Because of the hindered retreat of the sea ice in this summer in the central Kara Sea, observing the sea-ice extension was important. A daily update of the sea-ice conditions was reported on the website http://www.seaice.de. On July 02, 2003, the Kara Sea was almost completely ice-covered (Fig. 3.2a). In the southern and western Kara Sea the sea ice melted until August 03, but in the central and northern/northeastern Kara Sea the sea ice still remained (Fig. 3.2b). At the arrival of RV „Akademik Boris Petrov“ in the working area on August 17, the sea-ice distribution hasn't changed in the central Kara Sea (Fig. 3.2c). The retreatment of the sea ice during the expedition was not much (Fig. 3.2d), so the extension of the ice-coverage is almost stable since end of July (http://www.seaice.de).

Table 3.1: Meteorological data recorded at the stations of the Kara Sea Expedition 2003 with RV "Akademik Boris Petrov" (Air: Air Temperature, Water: Water Temperature).

Station	Date	Time [UTC]	Latitude °N	Longitude °E	Air [°C]	Water [°C]	Wind Speed [m/s]	Wind Direction
BP03-03	17.08.03	23:12	74°00.12	72°00.85	10.4	8.4	6.3	111°
BP03-04b	18.08.03	14:22	74°01.49	80°18.78	5.6	7.8	10	100°
BP03-05	19.08.03	1:26	74°59.88	80°00.46	4.7	3.4	7.5	132°
BP03-06	20.08.03	5:30	74°59.88	72°01.34	8.4	7.0	2.7	135°
BP03-07	20.08.03	12:40	75°33.61	73°07.64	8.4	8.7	2	214°
BP03-08	21.08.03	0:10	75°37.11	75°42.32	5.2	7.0	n.d.	n.d.
BP03-09	21.08.03	12:00	76°30.01	72°00.18	7.3	7.3	5.9	227°
BP03-10	22.08.03	0:48	75°30.0	72°00.3	8.8	8.8	4.6	196°
BP03-11	22.08.03	9:14	75°00.03	75°27.97	4.9	7.6	6.9	155°
BP03-12	22.08.03	21:36	74°00.22	79°59.63	7.5	8	5	280°
BP03-13	23.08.03	2:42	73°25.00	80°00.84	7.1	7.9	3.4	290°
BP03-14	23.08.03	16:00	75°50.07	80°04.95	13.6	11.2	4	210°
BP03-15	24.08.03	4:01	72°14.99	80°29.99	13.7	12.4	3.5	214°
BP03-16	24.08.03	8:17	72°02.2	81°30.8	15.2	13.1	7.8	178°
BP03-17	24.08.03	12:23	71°50.98	82°25.38	15.6	13.8	6.3	172°
BP03-18	25.08.03	19:30	74°00.00	76°00.33	8.8	8.4	6	277°
BP03-19	26.08.03	4:10	73°59.86	73°08.08	8.0	9.1	7.3	250°
BP03-20	26.08.03	10:00	74°00.5	71°59.27	n.d.	n.d.	n.d.	n.d.



Ice fields or ice margin, noticed by RV „Akademik Boris Petrov" in 2003

Cruise track of RV „Akademik Boris Petrov" in the central Kara Sea

Figure 3.1: Noticed ice fields and ice margins by RV „Akademik Boris Petrov" in 2003. In the southern and western part no sea ice was recognised („ice free"), the northern and eastern part there was probably ice-covered (according to http://www.seaice.de).

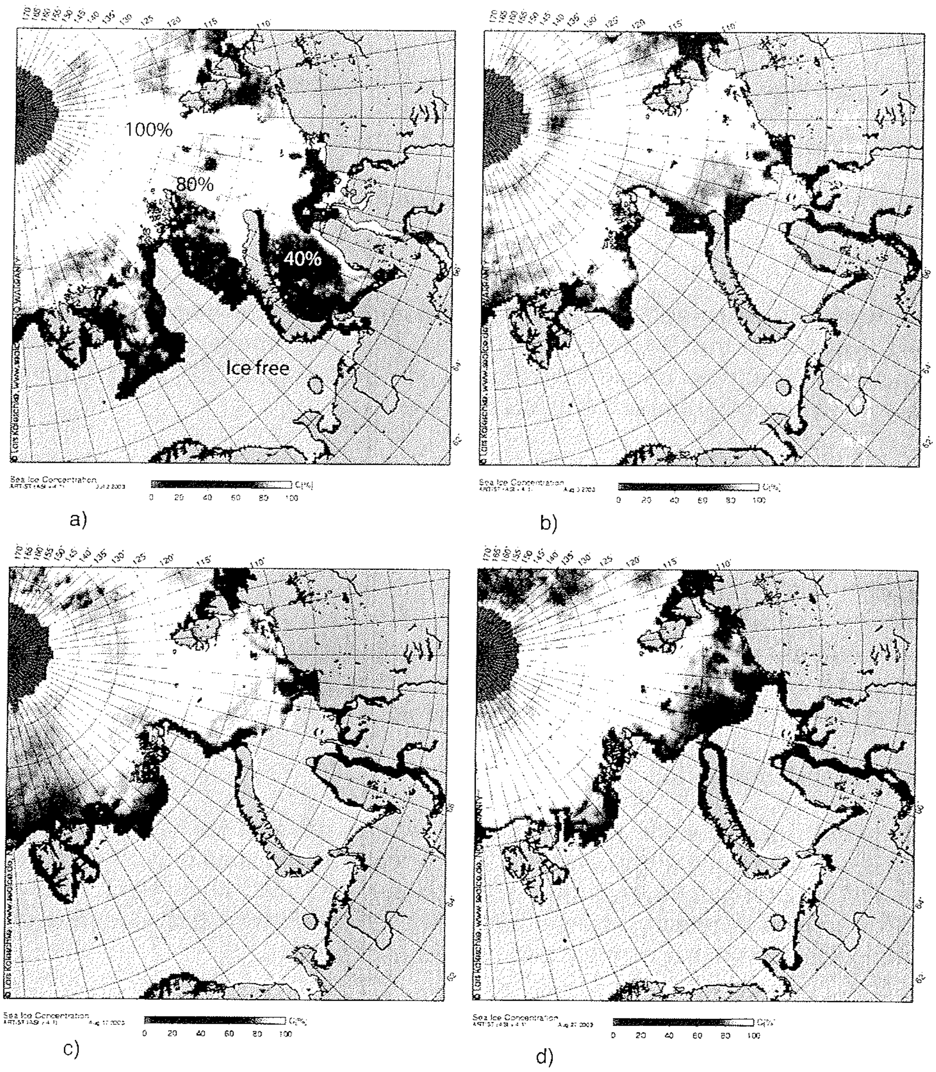


Figure 3.2a - d: Ice conditions in the Kara Sea from July 02, 2003 until August 27, 2003 (Source (in colour): http://www.seaice.de; due to maps are printed in black and white, examples of ice concentrations (100%, 80%, 40%, ice free) are given in Figure 3.2a).

4. Physical and Chemical Oceanography

4.1. Hydrological conditions in the Kara Sea in summer 2003

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Introduction

The working area in the Kara Sea reached from 74° to 76°30'N and from 72° to 80°E, including the Yenisei Gulf. The hydrological measurements were conducted during the period from August 18th until August 26th, 2003. There were 17 hydrological stations (Fig. 4.1).

For salinity and temperature measurements and for subsequent water sampling on selected depths a rosette sampler (21 bottles, volume 1.7 L), including CTD-probe "MARK-3B" of the "EG and G OCEAN PRODUCTS" company was used. Characteristics of the probe are described, for example, in Shmelkov and Latko (2003).

In general, the water samples were taken from surface water, from near bottom water and from the picnocline layer. The horizons for sampling were selected based on the profiles and absolute values of water temperature and salinity.

Results and discussion

During this expedition the Kara Sea, there was an offset of ice fields from the northeastern part of the Kara Sea into the central part, because of northeasterly winds. The air temperature in that time was between +5°C and +10°C. These factors and the increasing sea-ice melting are responsible for some features of hydrological facts in the northern part of the working area.

In Fig. 4.2a,b the distributions of surface-water temperature and salinity for the region of the Kara Sea from 74° to 76°N and from 72° to 81°E are represented. By comparing the obtained allocations with multiyear mean values of surface water temperature and salinity in summer time (Shmelkov et al. 2002), the surface water temperature in August 2003, as a whole, was higher than the multiyear mean (with a difference between 2°C and 4°C) in that area, except for the northeastern part. The salinity of the near surface water was much below the multiyear mean (with a difference of up to ~ 9 ppt) in the whole investigated area.

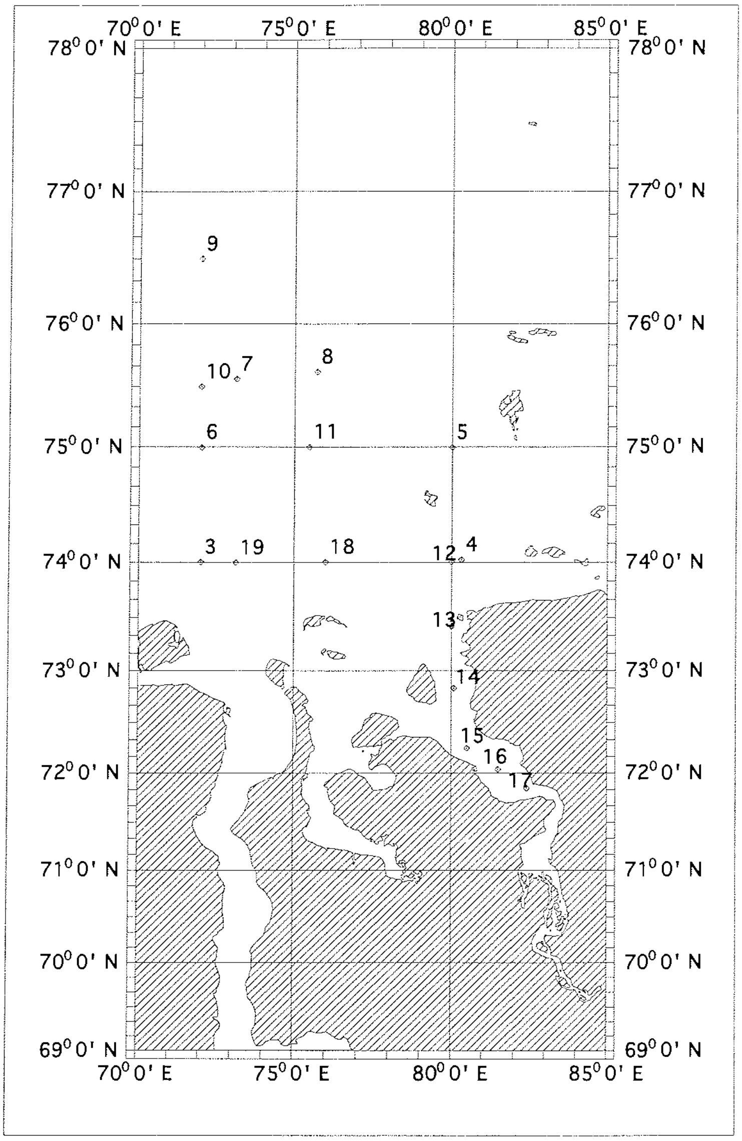
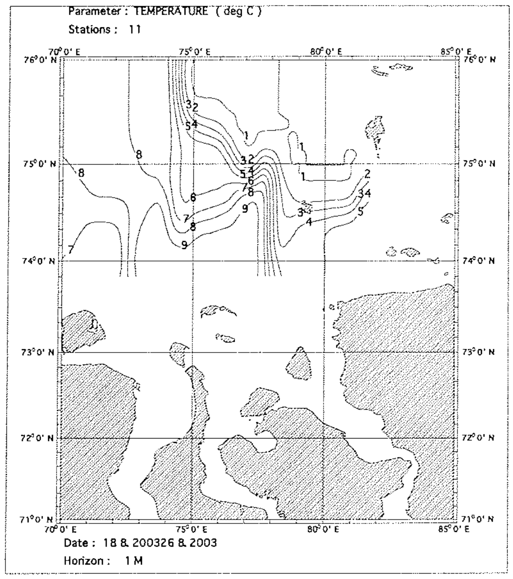
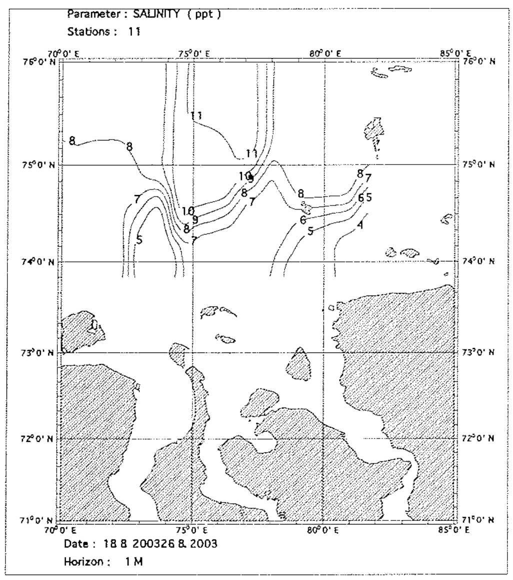


Figure 4.1: Hydrological stations of the Kara Sea Expedition 2003 with RV "Akademik Boris Petrov".



a)

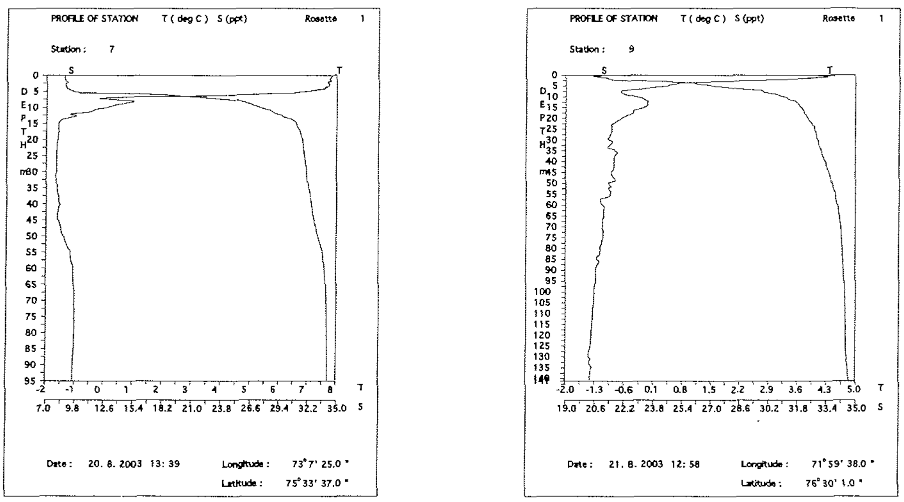


b)

Figure 4.2: Spatial distribution of the surface temperature (a) and salinity (b) in August 2003 (74° - 76°N, 72° - 81°E).

A comparison of our results from 2003 (Fig. 4.2a,b) with distributions of temperature and salinity of surface water, obtained during the 36th cruise of RV "Akademik Boris Petrov" in 2001 (Shmelkov et al. 2002) is possible due to sampling approximately in the same season (end of August - beginning of September). The water temperature in the upper layer of the sea water in 2003 were close to the values obtained in 2001, except for the northeastern part of the region, where they are lower than in summer 2001. In 2003 surface water salinity was much lower than in 2001 and also than the multiyear mean. One of the influencing factors is probably the presence of the ice fields in the northeastern part of the working area in 2003. In 2001, the whole Kara Sea, where were conducted investigations, was ice-free. It is necessary to mention, that the comparison of surface water temperature and salinity obtained in 2001 and 2003 is rather rough due to the spatial and temporal allocation of the small amount of hydrological stations.

In the deep-water part of the northwestern edge of the working area a temperature inversion in the water column in a depth of 10m were observed (Fig. 4.3a,b). The value of fluctuations reached about 1°C per 2m water depth. A similar appearance with greater amplitudes was observed in the same region, and also in northern direction, in 2001 during the 36th cruise of RV "Akademik Boris Petrov" and can be explained by the topographic amplification of the internal waves (Stanovoy and Shmelkov 2002).

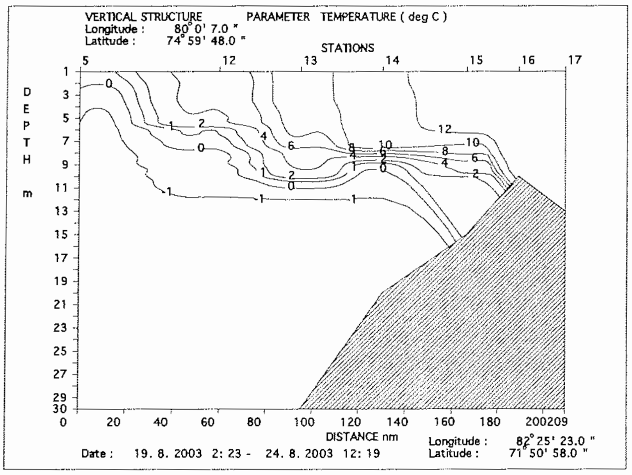


a) b)

Figure 4.3: CTD profiles at stations BP03-07 (a) and BP03-09 (b).

In Figure 4.4a,b the vertical distributions of water temperature and salinity, obtained from CTD-measurements, along the Yenisei Bay are represented. The stations BP03-14, BP03-15 and BP03–16 are examples for vertical profiles of temperature and salinity in the water column of the Kara Sea (Fig. 4.5a,b,c). The profiles for stations BP03-14 and -15 are characteristic for the mixing zone of river water (1 ppt) and seawater. The vertical gradient within the picnocline layer on these stations reached 9°C/m and 10 ppt/m water depth.

a)



b)

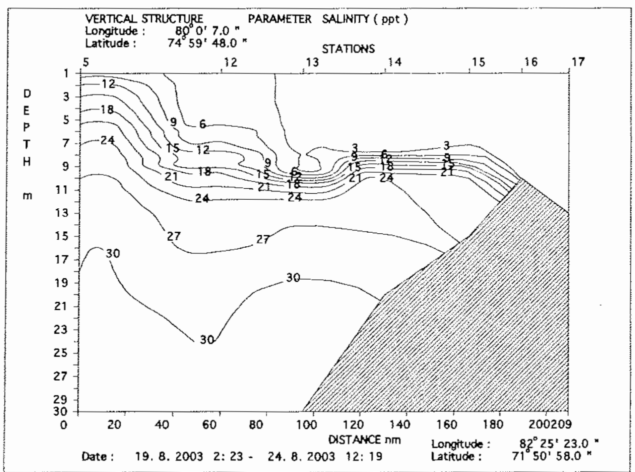
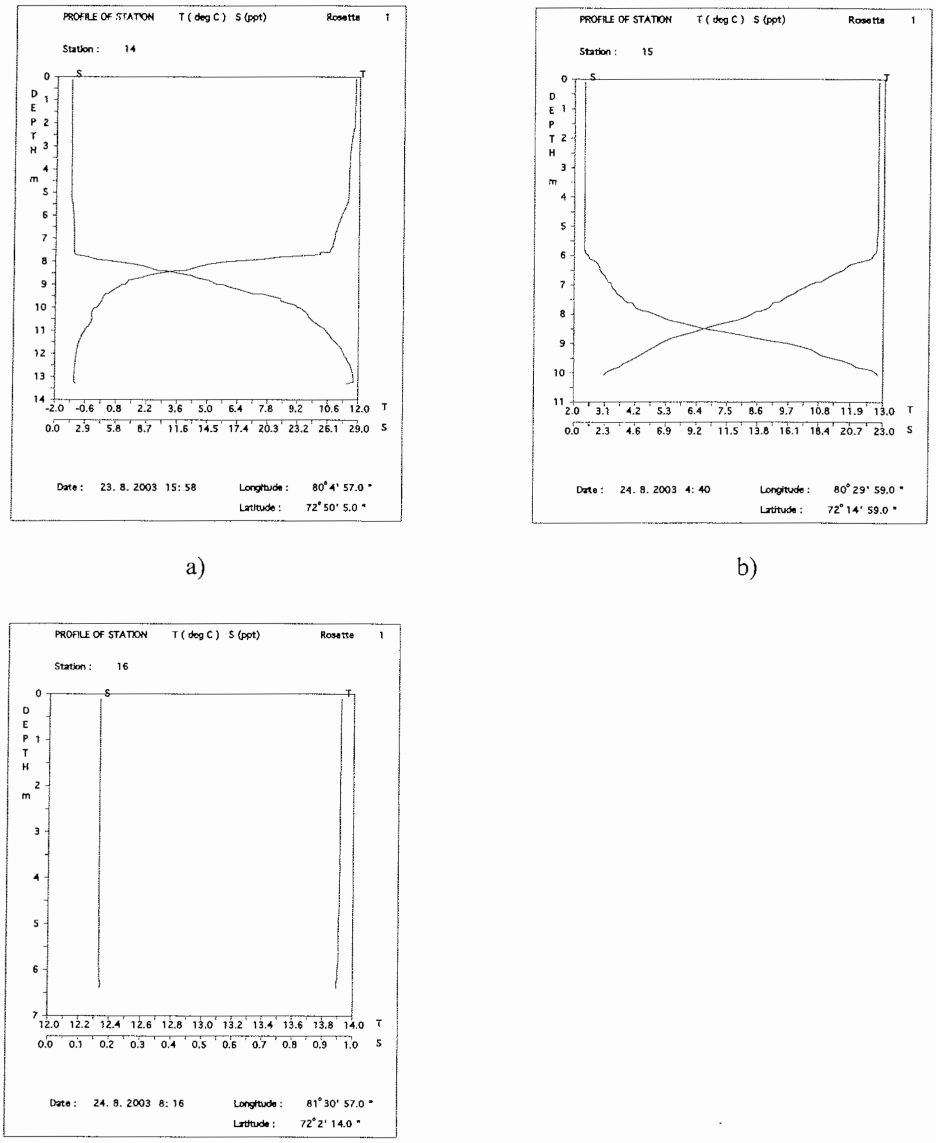


Figure 4.4: Vertical distribution of the water temperature (a) and salinity (b) at a section along Yenisei Bay.



c)

Figure 4.5: CTD profiles at stations BP03-14 (a), BP03-15 (b) and BP03-16(c).

In August 2003, the boundaries between fresh and saline water near the bottom were located between the stations BP03-16 and BP03-15. That boundary in the surface water lay in between stations BP03-15 and BP03-14. This is in agreement with results obtained in 2001 (Shmelkov et al. 2002). However it is necessary to mark, that the surface salinity in the Yenisei Bay in August 2003 was lower than in August 2001 (approximately on 3 ppt). The vertical gradients of salinity within the picnocline layer were essentially less, too, compared to that in 2001 (5-8 ppt on 10cm in 2001). The temperature of surface water in the Yenisei Bay was higher than the multiyear mean values.

4.2. Measurements of the short-period internal waves in the Kara Sea

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[2] Vernadsky Institute of Geochemistry and Analitical Chemistry, RAS, Moscow, Russia

Introduction

Within the framework of the joint Russian-German expedition 2001 onboard of the RV "Akademik Boris Petrov" the measurements of temporal variability of water temperature and salinity using CTD-sonde "Neil Brown-MKIII" were executed. At 22 stations the CTD-sonde was deployed for long-term measurements from the anchored vessel directly within the pycnocline layer or within the layer with some peculiarity of the vertical thermohaline structure. The mean duration of these records was about 1 hour.

The analysis of the long-term records of water temperature and salinity demonstrated the existence of well-pronounced short-period internal waves at all CTD-stations. The main periods of these waves were about 8-12, 5-6 and 2-3 minutes and its amplitudes were from 0.5 to 3 m (Stanovoy and Shmelkov 2002).

Data

Within the framework of the last summer joint Russian-German expedition 2003 onboard of the RV "Akademik Boris Petrov" the measurements of temporal variability of water temperature and salinity with CTD-sonde "Neil Brown-MKIII" were continued.

CTD-sonde was deployed from the anchored vessel within the pycnocline layer at 2 stations only owing to the limited time and intensive working plan. The duration of these records was about 30 minutes (Table 4.1). The locations of CTD-stations are presented in this volume (Shmelkov et al. 2004, compare also the station list in the Annex).

Table 4.1: The long-term measurements of the water temperature and salinity.

Station	Horizon, m	Duration, min	Note
BP03-06	7.6	29	Pycnocline, long-periodic trend
BP03-14	8.9	29	Pycnocline, long-periodic trend

The depth of sensors varied because the sound was put down from the vessel board. We assumed that the oscillations of values of water temperature and salinity are a linear superposition of oscillations caused by vertical displacements of sensors and by internal waves. Using data of registration of immersion depth of the sensors and data of sounding on CTD-station executed before record, the oscillations caused by vertical displacements of sensors were filtered.

Results and discussion

Station BP03-14 was located in the northern part of the Yenisey Gulf, in the Eastern Strait, where significant internal waves with tidal and sub-tidal periods were usually observed (Gribanov et al., 1999). On Figure 4.6, vertical distribution of the water temperature, salinity, Brunt-Vaisala frequency and temporal variability of the temperature and salinity at the marked horizon (8.9 m) are presented. The long-period oscillation with period of a few hours is well pronounced. Temperature decreased from 1.5 to –0.5 °C and salinity increased from 15 to 23 psu during 10 minutes.

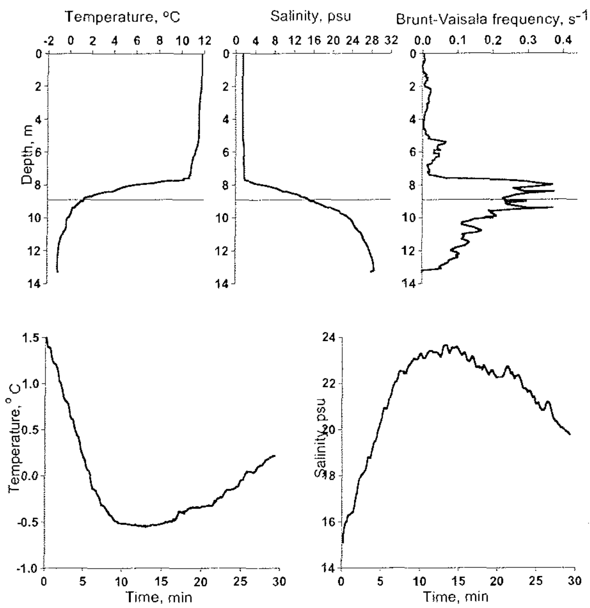

Figure 4.6: Vertical distribution of the water temperature, salinity, Brunt-Vaisala frequency and temporal variability of the temperature and salinity at the station 14 (8.9 m).

To obtain the short-period internal waves we filtered out the long-period component. The analysis of the filtered records of water temperature and salinity has shown the existence of well-pronounced short-period internal waves (Fig. 4.7). The salinity variations were about 0.8 psu per 10 min and temperature variations reach values up to 0.2 °C per 10 min. The main period of these waves is about 12-13 minutes and amplitudes are about 0.2-0.3 m. Also it were observed (particularly, on the salinity record) oscillations with periods of 2-3 minutes (Fig. 4.7)

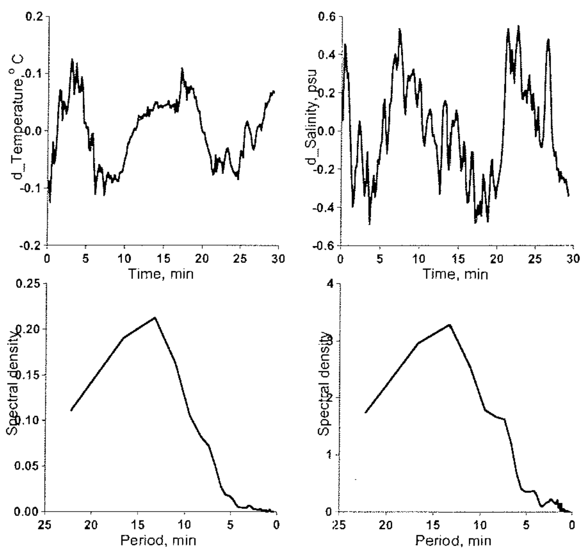

Figure 4.7: Filtered oscillations of the water temperature and salinity at the station BP03-14 (8.9 m) and spectra of these oscillations.

The second long-term record was made at station BP03-06 located in the central part of the Kara Sea, north of the Ob Gulf (Shmelkov et al. 2004). The vertical distribution of the water temperature, salinity, Brunt-Vaisala frequency and temporal variability of the temperature and salinity at horizon 7.6 m are presented on Figure 4.8. Also at this station the long-period oscillation with a period of a few hours is observed. Temperature decreased from 3.5 to 1.0 °C and salinity increased from 16 to 23 psu during several minutes.

On Figure 4.9, filtered records of temperature and salinity and their spectra are presented.

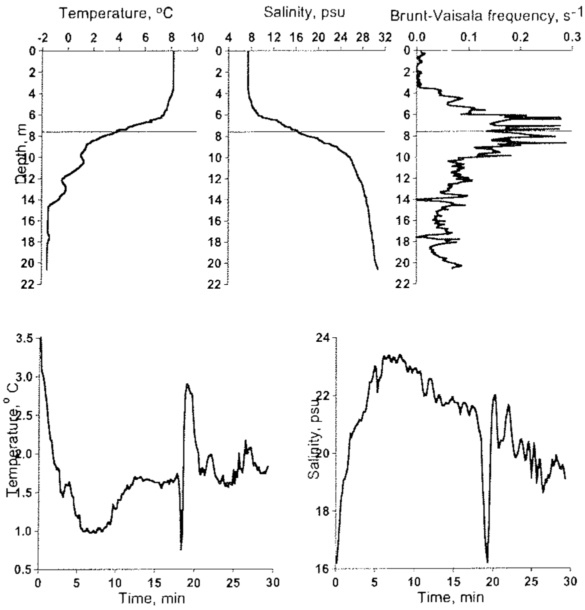

Figure 4.8: Vertical distribution of the water temperature, salinity, Brunt-Vaisala frequency and temporal variability of the temperature and salinity at station BP03-06 (7.6 m).

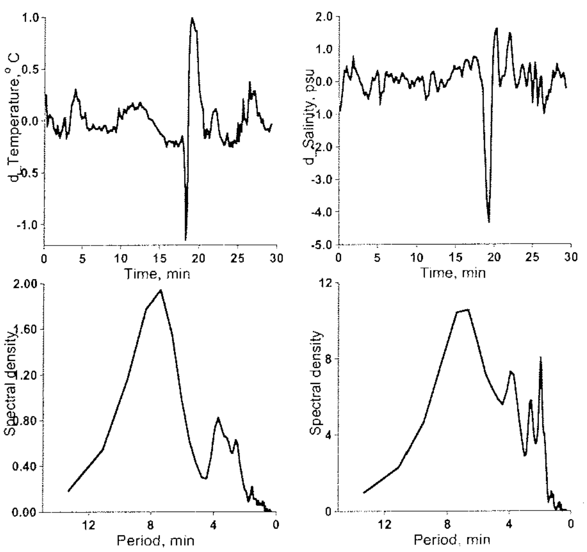

Figure 4.9: Filtered oscillations of the water temperature and salinity at the station BP03-06 (7.6 m) and spectra of these oscillations.

The salinity variations were about 0.5-0.8 psu and temperature variations reach values up to 0.2-0.5 °C in a few min. The main periods of these waves are about 7-8 and 2-3 minutes and amplitudes are about 0.3-0.5 m (Fig. 4.9).

Distinctive feature of these records is a very sharp and significant oscillation. One of the most probable reasons of this phenomenon is the unexpected starting of the ship engine. Consequence of this mechanical reason is a sharp increase of the current shear that stimulate the shear instability in the pycnocline. But another possible reason is a topographical feature causes the soliton-like waves appearance. On Figure 4.10, the long-term observations obtained in summer 2001 at the station BP01-68 (Stanovoy and Shmelkov, 2002) were located very close to station BP03-06.

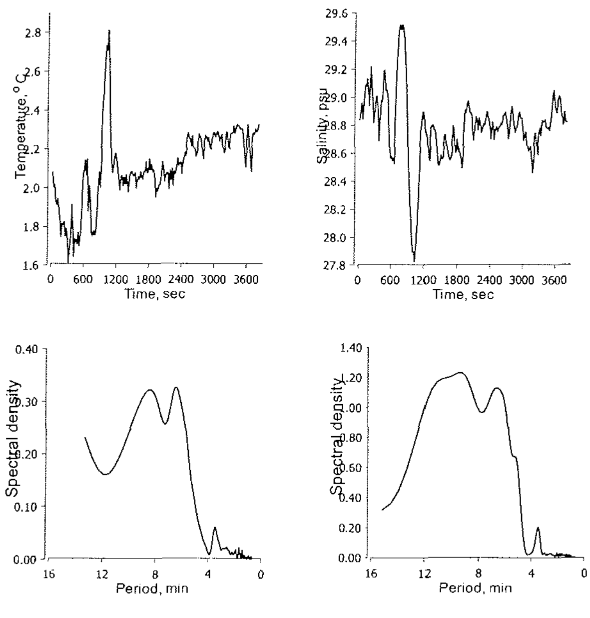

Figure 4.10: Oscillations of the water temperature and salinity at station BP01-68 (11.6 m) and spectra of these oscillations.

The comparison of the figures 4.9 and 4.10 shows the close similarity of the records and spectra at both stations. This suggests that the topographical feature is a main reason of such oscillations in this region. We hope very much that in the nearest future observations in this region will be continued with ADCP measurements.

Thus, the results of measurements of the short-period internal waves in summer cruise 2003 and estimations of the main periods and amplitudes of these waves are in the good agreement with the previous results (Stanovoy and Shmelkov, 2002).

5. Sediment Trap Investigations in the Kara Sea Expedition 2003

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Introduction

The transition zone between riverine and marine water masses represents one of the most important environments for studying biogeochemical cycles. Terrestrially derived organic and lithogenic components are transported by rivers across landmasses to the shelf and continental margin where both soluble and particulate components are eventually deposited in marine sedimentary basins. About 25 % of the total terrestrial water mass reaching the Arctic Ocean is transported by the Siberian rivers Ob and Yenisei. Therefore, the Kara Sea plays a key role in understanding biogeochemical cycles such as sources, alteration, and transport processes in the Arctic. Seasonal and all the year round investigations concerning the sediment load and its composition, however, are still very scarce in such high latitudes due to ice cover and logistic problems.

Aim of this study is to investigate the magnitude and seasonal variation of the transport of particulate organic and inorganic matter in the transition zone between the terrestrial and marine environment in the Arctic and the subsequent incorporation of particulate matter into the sedimentary record of the Kara Sea. Moored time-series sediment traps in concert with current-meters provide a powerful tool to obtain a detailed record of the seasonal fluctuation of particulate matter fluxes into as well as cycling in the Arctic Ocean.

At the "YEN" station (see Fig. 5.1), sediment trap investigations have also been carried out since the year 2000/2001 and represent the first long-term multi-year particle flux record in the Kara Sea (Gebhardt et al. 2002, Lahajnar et al. 2003). Within the Russian-German project SIRRO, a detailed evaluation of the particulate matter load, the bulk composition and its chemical compounds is being carried out. An annual cycle of sediment trap samples provides new insights into particulate matter transport in high latitudes, which is of special interest during the ice-covered winter times. These experiments contribute to carbon and nitrogen budget estimates in the Kara Sea and thus have great relevance for our understanding of Arctic Ocean biogeochemistry and its reaction to global change.

Sampling

Recovery of YEN 04

A sediment trap mooring (YEN 04 - see Figs. 5.1, 5.2; Tab. 5.1) was deployed during the cruise BP-02 with the Russian R/V "Akademik Boris Petrov" in fall 2002 (Lahajnar et al. 2003). The mooring was retrieved at station BP03-04a (74°00.1145'N 80°19.4613'E) on Aug. 18th. The BENTHOS release was located exactly at this position; the top-float came to the surface at 65 m far away from the ship's stern. The mooring was externally in good condition with no entanglement and no mechanical damages. However, one shackle below the sediment trap was severely corroded and would have been broken in the near future.

The sediment trap HYDROBIOS MST-24 was recovered at bottle 11 instead of the "open hole" position after completion of 24 samples. This means that the electronic unit executed the given rotation schedule correctly for bottle 1-10 (from Oct. 07th 2002 until Apr. 21st 2003) but ceased working some time after April 21st 2003. The given schedule for bottle 11-24 could not be executed.

Both, the electronic timer housing and the battery housing were not water-tight; both housings were recovered with water inside. A detailed inspection on board revealed that the connectors to the housings were severely corroded. This problem had already occurred during BP-01 (YEN-02) and BP-02 (YEN-03); the reasons behind this failure are still being discussed with the manufacturer from HYDROBIOS as this problem has only been observed in the Kara Sea but in no other marine environments around the world.

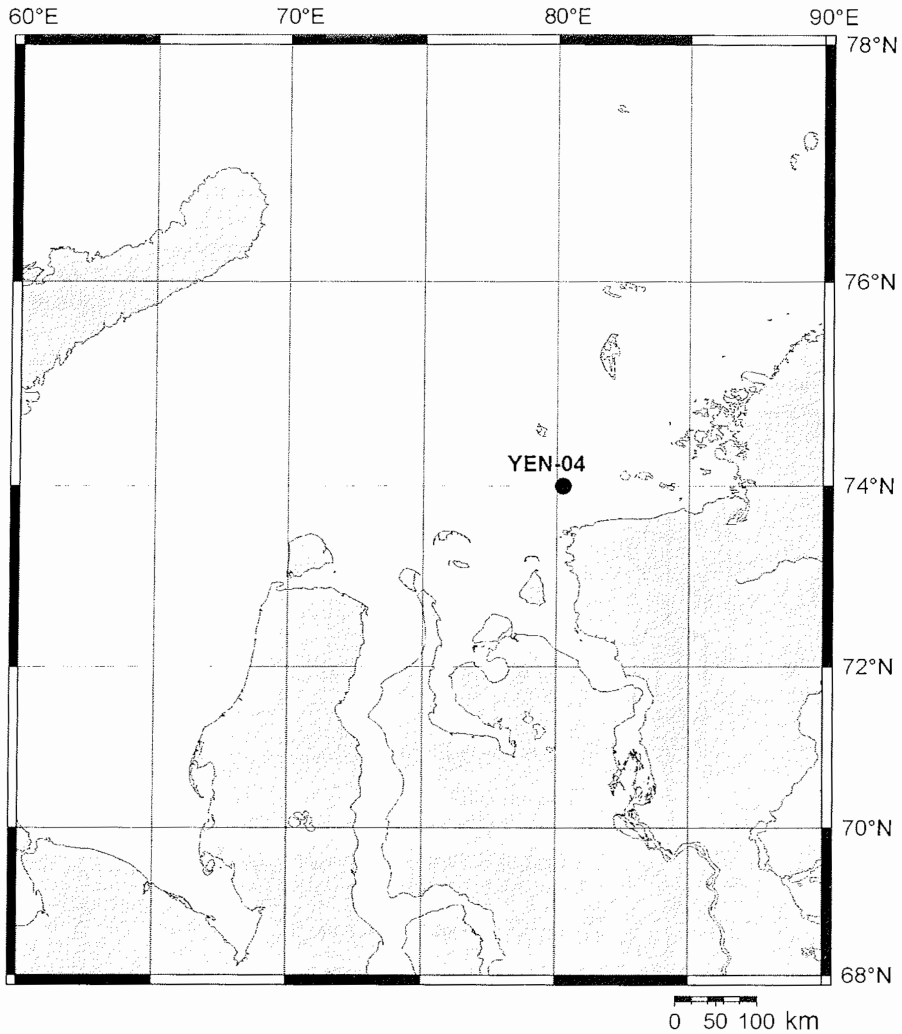


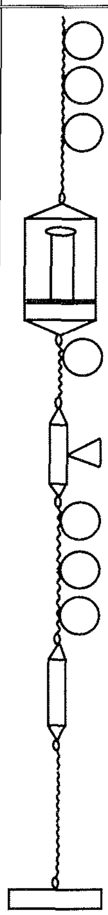
Figure 5.1: Position of sediment trap mooring YEN-04

Mooring System Information

Mooring-I.D.: YEN-04

Release Code:	Enable: 1 C Release: 1 A	Deployment Date:	07.10.02
Radio Frequency:	*none*	Start:	01:10 UTC
Deployment Position:	74°00.1145' N, 80°19.4613' E	System under water:	02:07 UTC
Water Depth:	39.7 m	Recovery Date:	18.08.03
		Start:	13:30 UTC
		System on deck:	14:00 UTC

Average temperature in water: -1.35 °C



Mooring Diagram m.a.b.	m.b.s.	Mooring Description	Deployment Time [UTC]	Recovery Time [UTC]
19	21	Nautlius Float on chain (red)	01:45	13:45
		Nautlius Float on chain (yellow)		
		Nautlius Float on chain (red)		
		Chain 3/8" 7m		
11	29	Sediment Trap Hydrobios MST-24	01:57	13:48
		Benthos 17" Float on chain (yellow)		
		Chain 3/8" 1m		
8	32	Aanderaa Current Meter RCM 9 MKII SN 626 Current speed/direction, Temperature, Turbidity	01:59	13:52
		Benthos 17" Float on chain (yellow)		
		Benthos 17" Float on chain (yellow)		
		Benthos 17" Float on chain (yellow)		
4	36	Benthos Release 865A SN 756 (13 V) Enable Code: 1 C; Release Code 1 A Release armed: 02:01 UTC (Niko Lahajnar, Birgit Nagel)	02:04	13:59
		Chain 3/8" 2m		
		Chain 3/8" 1m		
0	40	Anchor (1 Railroad Wheel)	02:07	

Figure 5.2: Mooring system deployment and recovery of YEN-04

Table 5.1: Rotation scheme for YEN-04

Cup No.	Start of Interval [UTC]	Duration	Recovery Status
Cup 01	07.10.2002 12:00	6.5 days (156 h)	done
Cup 02	14.10.2002 00:00	7 days (168 h)	done
Cup 03	21.10.2002 00:00	7 days (168 h)	done
Cup 04	28.10.2002 00:00	7 days (168 h)	done
Cup 05	04.11.2002 00:00	14 days (336 h)	done
Cup 06	18.11.2002 00:00	14 days (336 h)	done
Cup 07	02.12.2002 00:00	14 days (336 h)	done
Cup 08	16.12.2002 00:00	14 days (336 h)	done
Cup 09	30.12.2002 00:00	56 days (1344 h)	done
Cup 10	24.02.2003 00:00	56 days (1344 h)	done
Cup 11	21.04.2003 00:00	28 days (672 h)	active
Cup 12	19.05.2003 00:00	14 days (336 h)	waiting
Cup 13	02.06.2003 00:00	14 days (336 h)	waiting
Cup 14	16.06.2003 00:00	14 days (336 h)	waiting
Cup 15	30.06.2003 00:00	14 days (336 h)	waiting
Cup 16	14.07.2003 00:00	14 days (336 h)	waiting
Cup 17	28.07.2003 00:00	14 days (336 h)	waiting
Cup 18	11.08.2003 00:00	14 days (336 h)	waiting
Cup 19	25.08.2003 00:00	14 days (336 h)	waiting
Cup 20	08.09.2003 00:00	7 days (168 h)	waiting
Cup 21	15.09.2003 00:00	7 days (168 h)	waiting
Cup 22	22.09.2003 00:00	7 days (168 h)	waiting
Cup 23	29.09.2003 00:00	7 days (168 h)	waiting
Cup 24	06.10.2003 00:00	14 days (336 h)	waiting

The AANDERAA current meter, which was moored just below the HYDROBIOS sediment trap, was equipped with a current, temperature, and turbidity sensor. The current meter retrieved data from Oct. 7th 2002 until May 9th 2003. On May 10th the battery pack broke apart due to power overstraining. The reason for this unexpected error was a software problem on the current meter main board while using the current meter with "burst mode". A software update is now installed on the main board to solve this problem.

First Results

The daily current speed during the time of deployment at station YEN-04 ranged between 2 and 31 cm s^{-1} (Fig. 5.3). The average current speed was 7.65 cm s^{-1}. Both, the absolute range as well as the annual mean were a little lower than during YEN-03 (Lahajnar et al. 2003). The mean current direction (corrected for the magnetic deviation at station YEN-04) was approximately 186° (Fig. 5.4). Tidal influences and other short-term variations, however, led to current directions with a range from 30 to 330° on a daily basis.

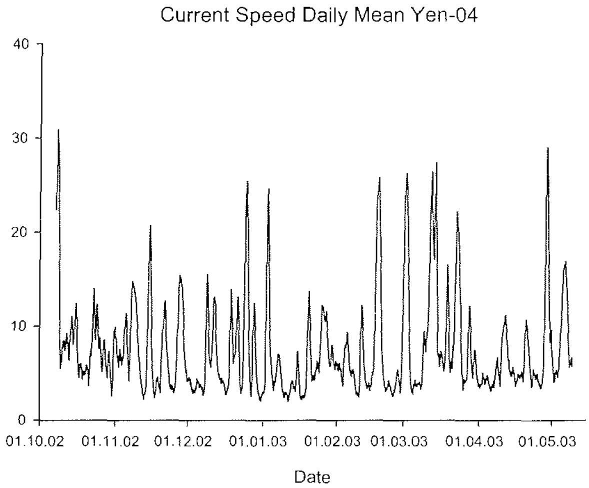


Figure 5.3: Current speed (daily mean) at station YEN-04

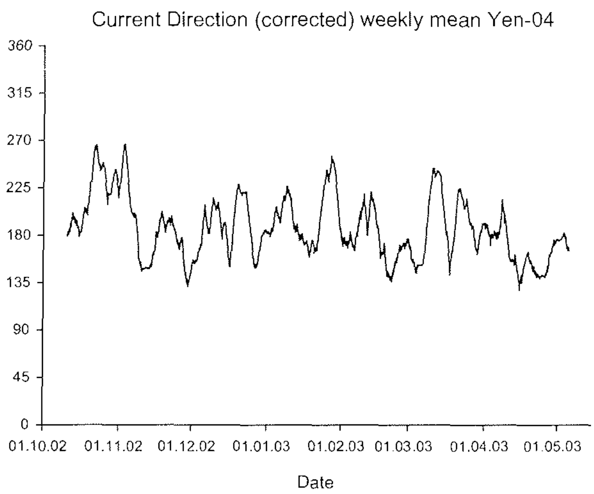


Figure 5.4: Current direction (weekly mean, corrected for magnetic deviation)

The mean water temperature at station YEN-04 was -1.35°C (Fig. 5.5) and thus slightly reduced in comparison to YEN-03 with -1.18°C. The temperature variability was very moderate with an absolute range between -1.27 and -1.50°C.

The turbidity at station YEN-04 remained almost constant throughout the period of deployment with values between 0.6 and ~ 2 NTU (Fig. 5.6). All current meter measurements took place during surface water glaciation. Due to the malfunctioning mentioned above, the period of melting and ice-free conditions were not covered by our measurements.

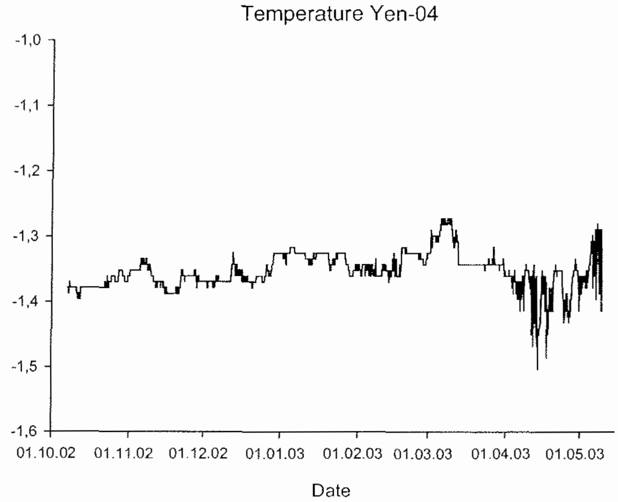


Figure 5.5: Water temperature at station YEN-04

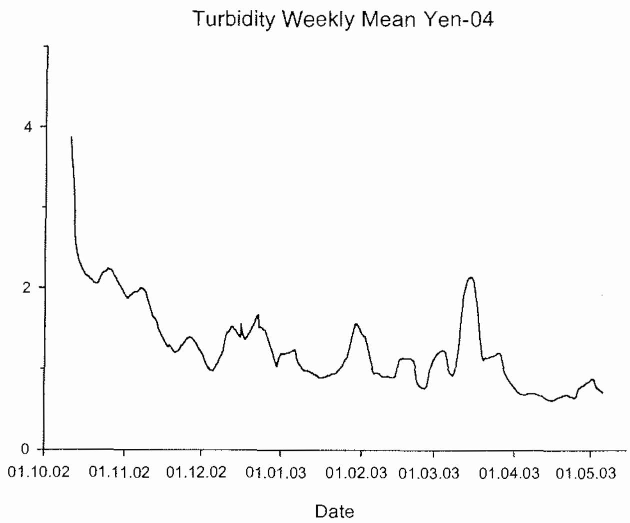


Figure 5.6: Turbidity (weekly mean) at station YEN-04

6. Marine Biology

6.1. Planktonic and macrobenthic investigations in the southern Kara Sea

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Introduction

The main goals of biological investigations in the Kara Sea Expedition 2003 with RV "Akademik Boris Petrov" were the determination of planktonic and macrobenthic fauna in the southern Kara Sea and analyzing of content of radionuclides in specific animals. A possible unusual high incorporation of radionuclides in animals in the Kara Sea may have two different sources:

1. The Kara Sea was used to bury radioactive wastes in the past; and
2. the large rivers Ob and Yenisei mainly supply the Kara Sea, and in the drainage area of these rivers nuclear power plants etc. are located.

A group from Murmansk Marine Biological Institute participated in the 39th cruise of RV "Akademik Boris Petrov" according to an agreement between the MMBI, RAS and Institute of Geochemistry, RAS, in the frame of the International project "ESTABLISH" (for further details see Stein and Stepanets 2002). This work was carried out in accordance with the scientific program on the research topic "Investigations of artificial radionuclides distribution along the trophic chain of the Kara Sea and the Yenisey bay", with the aims of studying the artificial radionuclides contents in phyto- and zooplankton as well as in the benthic organisms; and of estimating the benthic biological diversity.

Material and methods

Fourteen plankton samples and three benthos samples were collected for radionuclides analysis during the Kara Sea expedition carried out on board of RV "Akademik Boris Petrov" in August 2003 (Table 6.1). The stations were located in the area affected by a strong river run-off of the Ob and the Yenisei rivers (Fig. 6.1).

Table 6.1: Latitude, longitude, depth at each station.

Station	Date	Time (GMT)	Latitude °N	Longitude °E	Depth (m)	Activity
BP03-03	18.08.03	0:18	73°59.90	72°01.04	22.1	**PN**
BP03-03	18.08.03	1:30	74°00.12	72°01.05	22.1	**BT**
BP03-04b	18.08.03	15:29	74°02.11	80°16.20	39	**PN**
BP03-05	19.08.03	2:05	75°00.48	80°00.85	41.5	**PN**
BP03-06	20.08.03	6:00	74°59.94	72°02.14	30	**PN**
BP03-06	20.08.03	7:22	75.00.29	72°03.59	30	**BT**
BP03-07	20.08.03	13:27	75°33.63	73°09.00	104	**PN**
BP03-07	20.08.03	15:50	75°33.61	73°07.64	108	**GC**
BP03-09	21.08.03	13:40	76°30.20	72°05.20	174	**PN**
BP03-10	22.08.03	1:24	75°29.87	72°01.69	133	**PN**
BP03-11	22.08.03	10:03	75°00.35	75°28.51	38	**PN**
BP03-12	22.08.03	21:57	74°00.21	79°59.89	36	**PN**
BP03-13	23.08.03	3:43	73°24.73	80°01.72	36	**PN**
BP03-14	23.08.03	20:55	75°50.07	80°04.95	20	**PN**
BP03-15	24.08.03	9:00	72°14.99	80°29.99	15	**PN**
BP03-16	24.08.03	9:34	72°02.60	81°31.60	9.4	**BT**
BP03-18	25.08.03	20:19	73°58.92	76°02.63	27	**PN**
BP03-19	26.08.03	5:00	73°59.13	73°11.24	33	**PN**
BP03-19	26.08.03	7:57	73°59.99	73°07.81	34	**GC**

Legend: **PN** – Plankton net, **GC** – Gravity Corer, **BT** – Bottom trawl.

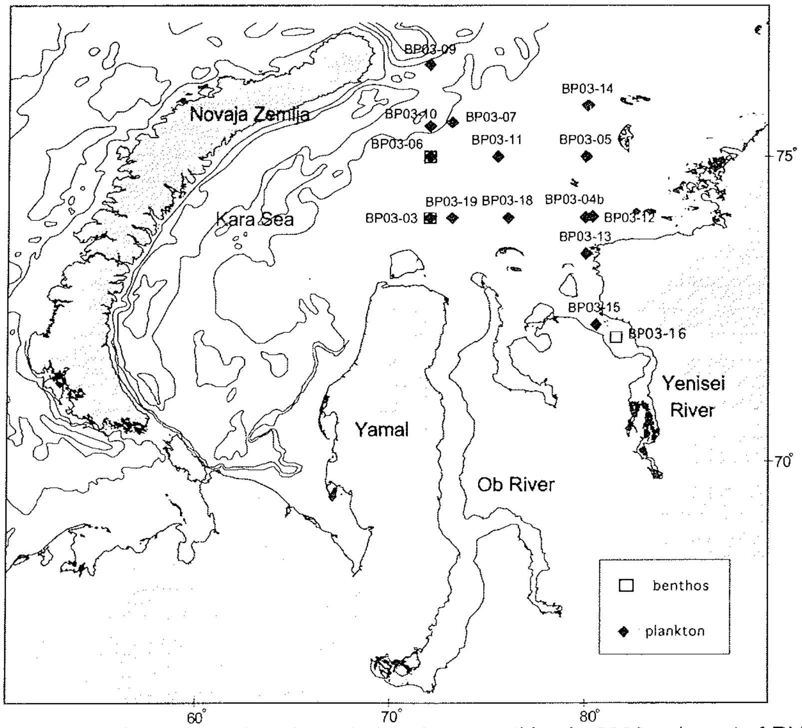

Figure 6.1: Investigated stations during the expedition in 2003 onboard of RV "Akademik Boris Petrov" in the southwestern Kara Sea.

Plankton was sampled by plankton net (Fig. 6.2) applying repeated vertical catch in the whole photic zone of the water column for an hour. Plankton samples were filtered through a nylon sieve and dried on filtration paper, before they were deep-frozen.

Figure 6.2: Collecting of Plankton samples on board of RV "Akademik Boris Petrov".

Benthos sampling was carried out by a Sigsby trawl (bottom trawl) during 15 minutes trawling at low speed (Fig. 6.3).

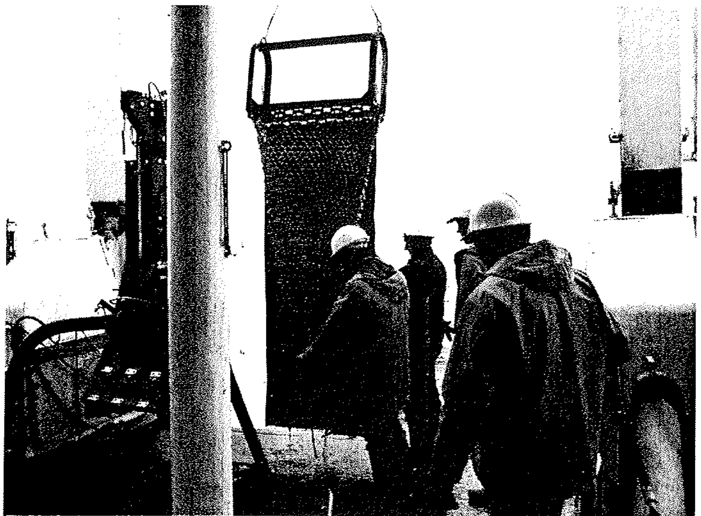

Figure 6.3: Bottom trawling on board of RV "Akademik Boris Petrov".

The catch was washed out on the washing table with a mesh size of 2 mm (Fig. 6.4). One to two dominant species were selected for the radionuclides analysis. These animals were determined into species, inserted into packets and frozen. The other animals were fixed with 4% formaldehyde for the subsequent taxonomical identification.

Figure 6.4: Cleaning and sorting of the catch on the washing table on board of RV "Akademik Boris Petrov".

The photos made by Dr. A. Borisov and Dr. G. Christensen.

Results of the expedition work

13 zooplankton samples, 1 phytoplankton sample and 4 zoobenthos samples were collected during the Kara Sea Expedition 2003. Phytoplankton was sampled on station BP03-15, which was the most southern station in the Yenisei Estuary and transferred to the GEOKHI, RAS, Moscow, for further analysis.

The identification of Polychaetes was carried out by Dr. E. Frolova, that of amphipods by Dr. O. Lyubina, hydroids and bryozoans by Dr. N. Panteleeva (Table 6.3).

In the Sigsby trawl on station BP03-03 in the estuarine zone, where sea and fresh waters are mixed, with a water temperature in the near bottom layer of -1.39°C and a salinity of 29.54 ‰ large isopods *Saduria sibirica* dominated, which were registered in large amounts in the re-freshened areas of the Kara Sea. In addition the bivalves *Serripes groenlandicus, Astarte elliptica, Macoma* sp. and brittle stars *Ophiocten sericeum* were found. *Saduria sibirica and Serripes groenlandicus* were collected as samples for radionuclides analysis.

On station BP03-06 brittle stars *Ophiocten sericeum* dominated at water temperature in the near bottom layer of -1.59°C and a salinity of 30.81‰ (Fig. 6.5). Besides, there were also star - fishes *Urasterial linckii* (Fig. 6), holothurians, large polychaetes belonging to family *Polynoidae*, amphipods, gastropods

Margarites sp., *Lunatia pallida*, isopods *S. sibirica*, *S. sabini*, soft corals on the tubes *Pectinaria hyperborea*, prawns, actin, sponges, bryozoens, cumaceans, and nudibrachan mollusks. Brittle stars *Ophiocten sericeum* were sampled for the analysis of radionuclides.

Figure 6.5: *Ophiocten sericeum* - a dominating species in the catch of the bottom trawling on station BP03-06 in the Kara Sea in August 2003.

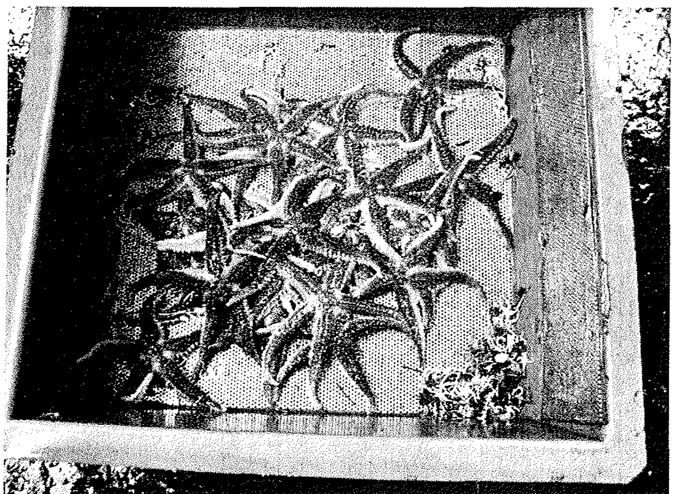

Figure 6.6: Star-fishes *Urasterias linkii* in the catch of the bottom trawling on station BP03-06 in the Kara Sea in August 2003.

On station BP03-16 (water temperature: 13.89°C, salinity: 0.17‰) isopods *Saduria entomon* prevailed (Fig. 6.7). Other species of the *Saduria* genus, some brittle stars *O. sericeum*, and some soft corals on the tubes *Pectinaria hyperborea* were also determined. The brackish- water isopods *S. entomon* were collected for the radionuclides analysis.

Figure 6.7: Isopods of *Saduria entomon* in the catch of the bottom trawling on station BP03-16 in the Kara Sea in August 2003.

At two stations the samples were collected within sediment cores, taken by a gravity corer. In these sediment cores the following mollusks valves were found in different depths. The identification was carried out by Dr. E. Frolova (Table 6.2).

In the materials collected on station BP03-07 a discrepancy occurs between the water depth of the sample site (150m) and the presence of a deep water species together with the species inhabiting both, upper and middle sub-littoral. According to Dr. M. A. Levitan opinion this might be the consequence of resedimentation (sliding down from small depths on the steep slope).

Portlandia arctica is a very changeable species forming a set of varieties and forms. In this case we speak quite probably on the form P. arctica var. siliqua Reeve which occurs in the shallow water areas of the coastal zone in conditions of the low salinity.

Species caught on station BP03-19 inhabit in it at the moment. According to the trophic classification of bottom organisms given by A. P. Kuznetsov (1976), mollusks of *Musculus* genus belong to immovable seiston fags and *P. arctica*, *Y. hyperborea* -to the collecting detritus fags .*Criptonatica, Buccinum, Lunatia pallida* are predators (carnivorous).

Table 6.2: The list of mollusks from the Gravity corer samples

Station	Depth, m	Species	Zoogeography	Distribution
BP03-07	0.11	*Cuspidaria arctica* (M. Sars, 1859)	b-a atl	
BP03-07	0.44	*Macoma moesta* (Dashayes, 1855)	b-a ws	
BP03-07	1.03	*Buccinum hydrophanum* Hancock, 1846	a atl	Deep water
BP03-07	1.82	*Macoma moesta* (Dashayes, 1855)		
BP03-07	2.00	*Yoldia hyperborea* (A.A. Gould, 1841)	b-a ws	Upper sub-littoral
BP03-07	2.30	*Lunatia pallida* (Broderip & Sowerby, 1829)	b-a ws cp	50-100m mainly
BP03-07	2.43	*Nuculoma tenuis* (Montagu, 1808)	b-a ws	Up to 100 m mainly
BP03-07	2.48	*Yoldia hyperborea* (A.A. Gould, 1841)		
BP03-07	3.00	*Macoma calcarea* (Gmelin,1791)	b-a ws	Middle sub-littoral
BP03-07	3.76	*Yoldia hyperborea* (A.A. Gould, 1841)		
BP03-19	0.10	*Musculus niger* (Gray, 1824)	b-a ws	Along the coasts on the silty- sand grounds
BP03-19	1.08	*Macoma moesta* (Dashayes, 1855)		
BP03-19	1.43	*Portlandia arctica* (Gray, 1842)	a?	Shallow-water areas of the coastal zone and the off-sea area
BP03-19	1.51	*Portlandia arctica* (Gray, 1842)		
BP03-19	2.09	*Portlandia arctica* (Gray, 1842)		
BP03-19	2.15	*Portlandia arctica* (Gray, 1842)		
BP03-19	2.35	*Portlandia arctica* (Gray, 1842)		
BP03-19	2.52	*Portlandia arctica* (Gray, 1842)		
BP03-19	2.70	*Portlandia arctica* (Gray, 1842)		
BP03-19	3.50	*Portlandia arctica* (Gray, 1842)		
BP03-19	3.83	*Portlandia arctica* (Gray, 1842)		
BP03-19	3.96	*Portlandia arctica* (Gray, 1842)		
BP03-19	4.32	*Portlandia arctica* (Gray, 1842)		
BP03-19	4.40	*Musculus niger* (Gray, 1824)		
BP03-19	4.65	*Portlandia arctica* (Gray, 1842)		
BP03-19	5.00	*Portlandia arctica* (Gray, 1842)		
BP03-19	5.56	*Portlandia arctica* (Gray, 1842)		
BP03-19	6.05	*Criptonatica* sp.		
BP03-19	6.05 – 6.08	Portlandia arctica *(Gray, 1842)*		

Legend: a – arctic; a atl – arctic atlantic; b-a atl – boreal – arctic atlantic; b-a ws – boreal – arctic widespread; b-a ws cp – boreal – arctic widespread circumpolar.

Conclusions

Fourteen plankton samples and three benthos samples were collected for radionuclides analysis during the Kara Sea expedition carried out onboard of RV "Akademik Boris Petrov" in August 2003.

Sixty four taxa (where 57 were species) were identified in the investigated area. Ten taxa (where 9 were species) were identified per mollusks valves from gravity corer.

The data received in the cruise will allow to estimate:
the species composition of the benthos part of communities;
radioactive contamination levels in the biological component of the marine ecosystem.

Table 6.3: Species list of benthic fauna sampled in the Kara Sea, 2003.

Order	Family	Species	Station	BP03-	
			03	06	16
Porifera		Porifera g. sp.	-	x	-
Antozoa					
Alcyonacea	Nephthyidae	*Gersemia* sp.	-	x	x
Actiniaria		Actiniaria g.sp.	-	x	-
Hydrozoa					
Thecaphora	Campanulinidae	*Lafoeina maxima* Levinsen, 1893	-	x	-
		Calycella syringa (L., 1767)	-	x	-
		Cuspidella sp.	-	x	-
	Campanulariidae	*Rhizocaulus verticillatus* (L., 1758)	-	x	-
		Obelia longissima (Pallas, 1766)	-	x	-
	Lafoeidae	*Lafoea fruticosa* (M. Sars, 1850)	-	x	-
Athecata	Pandeidae	*Halitholus yoldia-arcticae* (Birula, 1897)	-	x	-
	Eudendriidae	*Eudendrium capillare* Alder, 1856	-	x	-
Polychaeta					
Phyllodocida	Phyllodocidae	*Paranaitis wahlbergi* (Malmgren, 1865)	-	x	-
		Phyllodoce groenlandica Örsted, 1842	-	x	-
	Polynoidae	Bylgides promamme (Malmgren, 1867)	-	x	-
		Harmothoe imbricata (L., 1767)	-	x	-
		Melaenis loveni Malmgren, 1865	-	x	-
Flabelligerida	Flabelligeridae	*Brada villosa* (Rathke, 1843)	-	x	-
Opheliida	Scalibregmatidae	*Scalibregma inflatum* Rathke, 1843	-	x	-
Terebellida	Terebellidae	*Pista flexuosa* (Grube, 1860)	-	x	-
		Pista maculata (Dallyell, 1853)	-	x	-
Sabellida	Sabellidae	*Branchiomma arctica* (Ditlevsen, 1937) Knight-Jones, 1994	-	x	-
		Euchone papillosa (M. Sars, 1851)	-	x	-
Sipunculidea		*Sipunculidea g. sp.*	-	x	-
Artropoda - Malacostraca					
Decapoda	Crangonidae	*Sabinea*	-	x	-

		septemcarinata (Sabine, 1821)			
Cumacea	Diastylidae	*Diastylis glabra typica* Zimmer, 1926	-	x	-
		Diastylis lepechini Zimmer, 1926	-	x	-
		Diastylis oxyrhyncha Zimmer, 1926	-	x	-
		Diastylis spinulosa Heller, 1875	-	x	-
Isopoda	Idotheidae	*Synidothea bicuspida* (Owen, 1839)	-	x	-
		Saduria entomon (L., 1758)	-	-	x
		Saduria sabini (Krøyer, 1849)	-	x	-
		Saduria sibirica (Birula, 1896)	x	x	-
Amphipoda	Aoridae	*Arctolembos arcticus* (Hansen, 1887)	-	x	-
	Atylidae	*Atylus carinatus* (Fabricius, 1793)	-	x	-
	Acanthonotozomatidae	*Acanthonotozoma inflatum* (Krøyer, 1842)	-	x	-
	Acanthostepheia	*Acanthostepheia malmgreni* (Goës, 1866)	-	x	-
	Stegocephalidae	*Stegocephalus inflatus* Kroyer, 1842	-	x	-
	Calliopiidae	*Rosinante fragilis* (Go_s, 1886)	-	x	-
	Eusiridae	*Rhachotropis aculeate* (Lepechin, 1780)	-	x	-
	Pleustidae	*Pleustes panoplus tuberculatus* Bate, 1858	-	x	-
	Ampeliscidae	*Ampelisca macrocephala* Lillijeborg, 1852	-	x	-
		Haploops laevis Hoek, 1882	-	x	-
	Lysianassidae	*Anonyx debruyni* (Hoek, 1882)	-	x	-
		Anonyx nugax (Phipps, 1774)	-	x	-
		Socarnes bidenticulatus (Bate, 1858)	-	x	-
Mollusca - Gastropoda					
Trochiformes	Trochidae	*Margarites* sp.	-	x	-
Coniformes	Naticidae	*Lunatia pallida* (Broderip & Sowerby,	-	x	-

		1829)			
Nudibranchia		Nudibranchia g. sp.	-	x	-
Mollusca - Bivalvia					
Luciniformes	Astartidae	*Astarte elliptica* (Brown, 1827)	x	-	-
Veneroida	Clinocardiidae	*Serripes groenlandicus* (Bruguière, 1789)	x	-	-
	Tellinidae	*Macoma* sp.	x	-	-
	Mytilidae	*Dacrydium vitreum* (Møller, 1842)	-	x	-
Bryozoa					
Cheilostomida	Scrupariidae	*Eucratea loricata* (L., 1758)	-	x	-
	Calloporidae	*Tegella armifera* Hincks, 1880	-	x	-
		Tegella arctica var. retroversa (D'Orbiny, 1850)	-	x	-
		Callopora craticula (Alder, 1857)	-	x	-
	Hippopodinidae	*Cheiloporina sincera* (Smitt, 1868)	-	x	-
	Escharellidae	*Escharelloides cancellatum* (Smitt, 1872)	-	x	-
		Escharella ventricosa Hassall, 1842	-	x	-
Ctenostomata	Alcyonidiidae	*Alcyonidium gelatinosum var. pachydermatum* Kluge, 1962	-	x	-
		Alcyonidium mamillatum var. erectum Andersson, 1902	-	x	-
Echinodermata - Asteroidea					
Forcipulatidae	Asteriidae	*Urasterias linckii* (Müller & Troschel, 1842)	-	x	-
Echinodermata - Ophiuroidea					
Ophiurida	Ophiuridae	*Ophiocten sericeum* (Forbes, 1852)	x	x	x
Echinodermata -Holothuroidea					
Dendrochirotida	Phillophoridae	*Ekmania barthi* (Troschel, 1846)	-	x	-
Apodida	Myriotrochidae	*Myriotrochus rinkii* Steenstrup, 1851	-	x	-

7. Marine Geology

7.1. Geological sampling program

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The main objectives of this expedition of RV "Akademik Boris Petrov" in 2003 were the recovering of the mooring and the sediment profiling using Parasound-System. So the sediment sampling program was strictly reduced compared to the expeditions in the years 1997, 1999, 2000 and 2001 (Matthiessen and Stepanets 1999, Stein and Stepanets 2000, 2001, 2002). Surface and near surface samples were taken by Van-Veen-Grab, and giant box corer. The working area reached ca. from 72° E until 80° E and from 76° N down to 69° N. After recovering the mooring water and sediment samples were taken in the central and southern Kara Sea mainly without anchoring. Changes in the position due to drifting were documented in the stationlist (Annex 10.1). In the Yenisei Estuary water and sediment sampling were done after anchoring. In the southern region of the working area the samples were taken along the salinity gradient from the outer estuary of Yenisei down to the fresh water endmember. In general, the water column and the sediments were sampled at the same stations in order to study the relationship between modern processes in the surface waters and their reflection in the surface sediments. After the water sampling the geological sampling started generally with Van-Veen-Grab and Giant Box Corer in order to take samples from the surface and near-surface sediments.

Van-Veen-Grab

The Van-Veen-Grab is of light weight, and therefore, needs less time to get a small amount of surface sediment. It was used 18 times successfully.

Giant Box Corer

The Giant Box Corer (weight of ca. 500 kg; volume of sample 50*50*60 cm; manufactured by Fa. Wuttke, Henstedt-Ulzburg, Germany) was successfully used 7 times on 7 stations. The box cores were sampled for the following investigations:

surface sediments

- benthic foraminifera and stable isotopes (Shirshov-Institute)
1-3 times 10*10 from the upper 1 cm (100 cm^3) fixed with bengal-rose-methanol-solution
- organic geochemistry (Vernadsky-Institute)
- clay minerals, grain-size composition (AWI-Geology)

1 tube, 10 – 20 cm^3
- palynology (AWI-Geology)
1 tube, 10 – 20 cm^3
- biomarkers and $\delta^{13}C$ of specific biomarkers (AWI-Geology)
1 tube, 10 – 20 cm^3, stayed frozen at –20°C
- organic geochemical bulk parameter (TOC, C/N, Rock Eval pyrolysis, $CaCO_3$), inorganic geochemistry (AWI-Geology); 1 tube, 10 – 20 cm^3
- heavy minerals, lithology (Vernadsky-Institute)
- radio-geochemical studies (Vernadsky-Institute)

profiles (tubes 120 mm in diameter)

- organic geochemistry, radio-nuclides (Vernadsky-Institute)

7.2. First results of the sediment studies

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Introduction

During our joint Russian-German work within frames of SIRRO-project we managed to sample sediments from the surface layer and from the sediment sequence at many stations. Nevertheless, the more scale of investigation, the more new stations we need. Many serious scientific problems in the Kara Sea still wait their solution. That is why we fulfilled short sedimentological program during BP03 cruise of RV "Akademik Boris Petrov".

Facts and methods

To achieve our goals we took sediments by means of a giant box corer, a Van-Veen-Grab, and a gravity corer (in variants 5-m and 8-m lengths). Positions to retrieve the sediment core have been chosen according to Parasound data (Dittmers and Schoster, this issue). In the ship laboratory sediments have been described (V.V. Krupskaya and M.A. Levitan), smear-slides have been prepared and examined under microscope (V.V. Krupskaya), as well as mollusk shells have been determined (E.A. Frolova). Also we investigated water content and bulk density of sediments by weight method using narrow syringe (L.N. Vlasova) and steel rings (M.A. Levitan). Surface-layer sediments have been underwent to wet sieving in order to separate the grain fraction >125 μm (V.V. Krupskaya). Then the fraction was examined under the binocular microscope (M.A. Levitan).

Sediment descriptions are given in the Annex (11.2.). Results of the fraction >125 μm examination one can see in Table 7.1, smear-slide examination results in Table 7.4. The results of physical properties' measurement by means of the steel rings' method are given in Table 7.2. Comparison of both methods of the determination of physical properties showed that results fit very well for fine sediments, but for more coarse-grained sediments the results of the syringe method are the preferable ones. At last, lists of mollusks species determinations (for Bivalvia and Gastropoda) are given in Table 7.3.

Table 7.1: Composition of fraction >125 μm from surface-layer sediments (rel %).

Station	Biogenic remains					
	Aggl BtF	Secr BtF	Polychaet	Ostracods	Spicules	Gastropod
BP03-03	2	tr.	5	tr.	1	0
BP03-05	3	0	2	2	0	0
BP03-06	0	0	tr.	0	0	0
BP03-07	0	0	50	0	0	0
BP03-08	3	0	8	3	0	0
BP03-09	0	0	20	tr.	0	0
BP03-10	0	2	0	1	0	0
BP03-11	5	0	0	1	0	0
BP03-13	1	0	2	0	2	0
BP03-16	0	0	0	0	0	0
BP03-18	tr.	0	tr.	0	0	tr.
BP03-19	5	5	0	0	0	0

Station	Biogenic remains					
	Bivalvia	Mollusk clutch	Amphipod	Isopoda	Bryozoa	Wood
BP03-03	0	0	0	0	0	0
BP03-05	5	2	0	0	0	0
BP03-06	0	0	0	0	0	tr.
BP03-07	2	0	0	0	0	0
BP03-08	5	2	0	0	5	0
BP03-09	5	0	0	0	0	0
BP03-10	10	2	0	0	0	0
BP03-11	0	0	0	0	0	0
BP03-13	0	2	0	0	0	10
BP03-16	0	0	tr.	0	0	85
BP03-18	0	0	0	2	0	0
BP03-19	50	0	0	10	0	0

Station	Rock frag.	Minerals				
		Quartz	FeldSp	Coloured	Opaque	Mica
BP03-03	3	75	6	5	1	2
BP03-05	10	48	18	7	2	1
BP03-06	20	55	18	5	0	2
BP03-07	20	15	5	5	2	1
BP03-08	25	38	5	5	3	1
BP03-09	10	35	22	4	1	3
BP03-10	22	30	10	2	20	1
BP03-11	10	47	25	8	2	2
BP03-13	5	40	23	3	8	4
BP03-16	5	0	0	0	0	10
BP03-18	5	53	35	4	1	tr.
BP03-19	1	15	9	3	1	1

Preliminary results and discussion

Locations of the studied stations are given in the station list (Annex, 11.1.). First results of the study of the fraction >125 μm in the surface-layer sediments of the eastern Kara Sea have been published in our former papers (Levitan 2002, Levitan and Krupskaya 2003). Our new data (Table 7.1) fit well with published data. We would like to pay attention at three peculiarities: 1) high amount of rock fragments for stations BP03-05, 06, 07, 08, 09, 10, 11; 2) high amount of opaque minerals (magnetite) for station BP03-10; 3) extremely high concentration of plant remains (wood) and mica in fluvial sediments of station BP03-16. First event is due to a combination of dropstones and small grains of rocks from sediment matrix, and latter are dominant (see discussion in Levitan and Krupskaya 2003). The location of station BP03-10 coincides with those areas of magnetite enrichment of sediments, which have been described in Levitan and Krupskaya (2003). At last, that high amount of wood in surface-sediments of the southern Yenisei Gulf once more confirm the role of this component as a proxy for the discharge of Yenisei River (Levitan 2002).

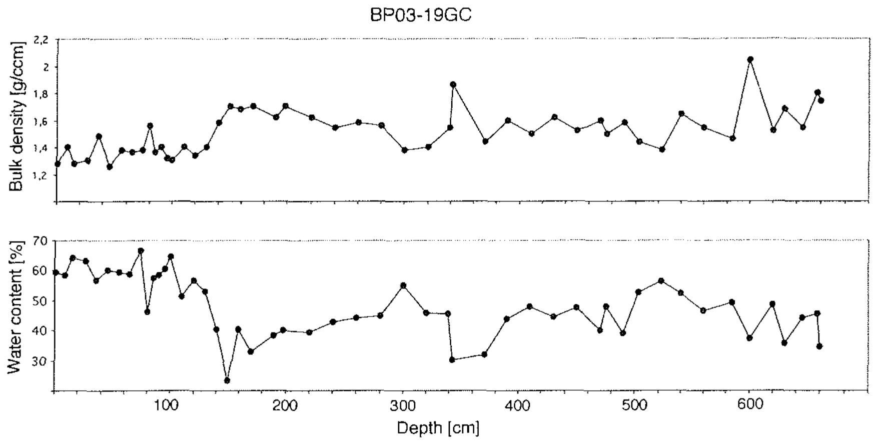

Figure 7.1: Bulk density and water content in sediment core BP03-19.

According to smear-slides examination (Table 7.4), studied samples belong mainly to siliciclastic terrigenous sediments of different grain-size composition. Only sediments of stations BP03-13, 14, 15, and 16 from the Yenisei Estuary can be determined as mud enriched by diatoms (diatomaceous mud). Recently we described this type of sediments in the southern Ob Estuary as well (Krupskaya and Levitan 2003). Quartz and feldspars dominate in the composition of different types of sands and mixtites, and clay minerals prevail in silty clays and muds.

Table 7.2: Physical properties of sediments from sediment core BP03-19.

Horizon, cm	Water content, wt.%	Bulk density, g/cm3
56	62.5	1.28
84	62.9	1.32
197	42.8	1.59
248	40.1	1.53
301	55.4	1.36
335	53.3	1.39
412	35.6	1.41
463	34.8	1.37
509	34.4	1.43
551	37.7	1.42
585	31.7	1.45
645	31.5	1.49

Our data on physical properties together with lithological descriptions (see Annex 11.2.) and smear-slides examination (Table 7.4) allowed us to reveal two sediment units in both studied sediment cores, BP03-07 and BP03-19, respectively. Unit I consists of relatively fine sediments with high water content (ca. 60%) and low bulk density (1.3-1.4 g/cm^3). It's thickness is 108 cm in sediment core BP03-07 and 138 cm in sediment core BP03-19. Below Unit I we described sediments of Unit II which are represented by intermediate layers of more coarse-grained silts, sandy silts, sands with clayey silts and silty clay. In general sediments of Unit II are characterized by relatively low water content (30-40%) and high bulk density (1.5-1.6 g/cm^3) (Fig. 7.1). The thickness of Unit II is more than 270 cm in sediment core BP03-07 and more than 530 cm in sediment core BP03-19. There are mollusk shells Yoldia hyperborea at the level of 200 cm and below in sediment core BP03-07 (within Unit II) (Table 7.3). At the present this mollusk lives in environments of upper sublittoral zone with water depths no more than 20 meters. Such way we can propose that the boundary between both sediment units is due to a radical change in the form of sedimentation and, therefore, in environment. Both obtained sediment cores are located along the Ob transect in channels (ancient pre-Ob river valleys). We compared them with sediment core DM4397 (Polyak et al. 2002), which is AMS ^{14}C-dated and is located close to sediment core BP03-07. According to this preliminary comparison, the age of the boundary between Unit I and Unit II in sediment core BP03-07 is in bteween 8.0-8.2 ka of ^{14}C age (B.P.). If this idea is correct it means that sedimentation rate of Unit I (which consists of marine shelf sediments) is 14-17 cm/ka. Keeping in mind the general trend of southward spreading of sea transgression during latest Pleistocene-Early Holocene in the Kara Sea (Stein et al. 2002), one can suppose that the age of the boundary between Unit I and Unit II in sediment core BP03-19 should be older than 8.0-8.2 ka B.P. We interpret the sediments of Unit II as river-influenced fluvial-marine sediments (with plant remains at a depth of 630 cm – see Table 7.4), and the enrichment of shells at the level 605-608 cm (see Annex, description of sediment core BP03-19) means coastal zone environment. According to

Parasound data, sediment core BP03-19 represents filling of second (younger) generation of pre-Ob river valley. Probably, it means that base of the core is younger that 10 ka B.P. (ca. 8.5-9.0 ka?) and sedimentation rate of Unit II was much higher than the sedimentation rate of Unit I (reached at least several hundreds cm/ka). In general sediment cores, taken within the SIRRO-Project, and from the expedition in 1993 with RV "Dmitry Mendeleev" allow to perform the high resolution study of Ob riverine discharge history during the Holocene.

Table 7.3: List of shells from sediment cores BP03-07 and BP03-19.

BP03-07

Horizon, cm	Species	Class
11	Cuspidaria arctica	Bivalvia
44	Macoma moesta	Bivalvia
103	Buccinum hydrophanum	Gastropoda
200	Yoldia hyperborea	Bivalvia
230	Lunatia pallida	Gastropoda
243	Leionucula tenuis	Bivalvia
248	Yoldia hyperborea	Bivalvia
300	Macoma calcarea	Bivalvia
376	Yoldia hyperborea	Bivalvia

BP03-19

Horizon, cm	Species	Class
10	Musculus niger	Bivalvia
108	Macoma moesta	Bivalvia
143	Portlandia arctica	Bivalvia
151	Same	Same
209	Same	Same
215	Same	Same
235	Same	Same
252	Same	Same
270	Same	Same
350	Same	Same
383	Musculus niger	Bivalvia
396	Portlandia arctica	Bivalvia
432	Same	Same
440	Musculus niger	Bivalvia
465	Portlandia arctica	Bivalvia
500	Same	Same
556	Same	Same
605	Criptonatica sp.	Gastropoda
608	Portlandia arctica	Bivalvia

Of great interest are numerous findings of ikaite in sediments of sediment core BP03-07 below 170 cm within Unit II (see Appendix). These are the first findings in the Kara Sea along the Ob (paleo-) valley. They were reported earlier only along the Yenisei (paleo-) valley (Kodina et al. 2001, 2002, Levitan et al. 1994). It was proved that ikaite formation there was due to diagenetic reactions related to methane cycle, sulphate reduction and so on (Kodina et al. 2001, 2002). But the relative role of paleoenvironment is not studied in details yet. Based on our knowledge about sedimentation history of sediment core DM 4401 (Polyak et al. 2002, Levitan et al. 1994) and the proposed age of Unit II in sediment core

BP03-07, we can suppose that this style of early diagenesis with ikaite formation occurs within sediments with strong riverine influence and very high sedimentation rate which were accumulated in close distance northward from the mixing zone of fresh and sea water during the Early Holocene. Of course, we need much more data to prove this idea.

Acknowledgements

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Table 7.4: Smear slide estimates from sediments taken from RV "Akademik Boris Petrov" in 2003

NN	Station	Depth, cm	grain size: sand	grain size: silt	grain size: clay	minerals: quarts	minerals: feldspar	minerals: heavy minerals: colored	minerals: heavy minerals: opaque	minerals: clay	minerals: mica: muscovite	minerals: mica: biotite	minerals: volcanic glass	rock fragments	Fe-clayey aggregates	biogenic remains: forams	biogenic remains: diatoms	biogenic remains: sponge spicules	biogenic remains: silicoflaggelats	biogenic remains: spores & pollens	biogenic remains: plant remains	lithology
1	03BC	1	25	60	15	54	20	10	1	15	+	-	+	+	+	+	+	-	-	-	-	sandy silt
2	04bBC	23	1	25	74	11	7	6	1	74	<1	-	1	+	+	+	+	+	-	-	-	silty clay
3		1	25	30	45	34	10	10	1	45	+	+	+	+	+	+	+	+	-	-	-	sandy silty clay
4		6	10	35	55	24	10	10	1	55	+	-	+	+	+	+	+	+	-	-	-	silty clay
5		35	10	30	60	23	5	5	2	40	1	+	4	+	20	+	+	-	-	-	-	silty clay
6	05BC	1	15	25	60	28	5	5	2	40	+	-	+	+	20	+	-	+	-	-	-	silty clay
7		4	10	35	55	19	10	5	1	50	+	-	+	+	15	+	+	-	-	-	-	silty clay
8		20	5	25	70	15	10	5	+	50	+	-	+	+	20	+	+	-	-	-	-	silty clay
9	06Gr	1	<1	10	90	10	<1	<1	+	90	-	-	+	+	+	-	+	+	-	-	-	clay
10	07BC	1	10	20	70	20	5	5	+	70	+	-	+	+	10?	+	+	+	-	-	-	silty clay
11		4	30	20	50	30	10	10	+	50	+	-	+	+	+	+	+	+	-	-	-	silty sandy clay
12		9	40	30	30	40	20	10	+	30		-	+	+	+	-	-	<1	-	-	-	silty clayey sand
13		13	10	30	60	20	10	5	+	50	1	-	3	+	10	-	-	1	-	-	-	silty clay
14		11	20	30	50	35	5	5	+	30	1	-	3	+	20	-	-	1	-	-	-	silty clay
15		30	50	30	20	59	8	7	1	15	1	+	3	+	5	-	-	1	-	-	-	clayey silty sand
16	07GC	6	20	30	50	32	5	5	1	47	1	-	5	+	3	-	-	1	-	-	-	sandy silty clay

17		20	40	30	30	44	10	5	1	20	1	1	5	+	10	-	-	3	-	-	-	mixtite
18		50	30	30	40	40	10	5	+	30	+	+	5	+	10	-	+	+	-	-	-	mixtite
19		50 (hydr)	30	30	40	27	20	5	3	10	+	-	5	+	30	+	+	+	-	-	-	mixtite
20		70	30	40	30	29	30	5	1	20	-	-	5	+	10	-	-	-	-	-	-	mixtite
21		115	20	60	20	40	30	5	1	15	+	-	3	+	5	-	-	1	-	-	-	clayey sandy silt
22		140	20	50	30	23	30	10	3	25	+	-	3	+	5	-	-	1	-	-	-	clayey sandy silt
23		180	40	30	30	22	30	10	3	25	1	-	3	+	5	-	-	1	-	-	-	mixtite
24		220	40	30	30	29	20	10	3	25	1	+	5	+	5	-	-	2	-	-		mixtite
25		240	30	40	30	31	20	10	2	25	1	+	5	+	5	+	+	1	-	-	-	mixtite
26		260	30	40	30	33	25	10	1	20	+	+	1	+	10	-	-	-	-	-	-	mixtite
27		300	30	40	30	26	20	15	5	10	1	+	3	+	20	+	+	+	-	-	-	mixtite
28		320	25	25	50	40	25	15	5	10	-	-	+	+	5	-	-	-	-	-	-	sandy silty clay
29		340	50	30	20	40	20	15	5	20	-	-	+	+	+	-	-	-	-	-	-	clayey silty sand
30		350	30	40	30	36	20	10	4	30	-	-	+	+	+	-	-	-	-	-	-	mixtite
31		370	20	40	40	30	15	10	5	40	-	-	+	+	+	-	-	-	-	-	-	mixtite
32		386	20	50	30	37	20	10	3	25	-	-	+	+	5	-	-	-	-	-	-	sandy clayey silt
33		386	60	20	20	40	25	15	+	20	-	-	+	+	+	-	-	-	-	-	-	clayey silty sand
34	08Gr	1	5	20	75	15	5	5	+	70	-	-	+	+	+	+	5	+	-	-	-	silty clay
35		1	5	20	75	15	5	5	+	70	-	-	+	+	+	+	5	+	-	-	-	silty clay
36		5	<1	35	65	29	5	1	+	65	-	-	+	+	+	-	-	-	-	-	-	silty clay
37	09Gr	1	20	20	60	26	5	2	1	55	-	-	+	+	5	-	5	1	-	-	-	sandy silty clay
38	10Gr	1	5	30	65	12	10	5	2	45	-	-	+	+	20	-	5	1	-	-	-	silty clay

39	11Gr	1	60	30	10	45	20	20	5	10	-	-	+	+	+	-	-	-	-	-	-	silty sand
40	13Gr	1	10	30	60	10	5	5	1	34	-	-	+	+	20	+	20	5	+	-	-	silty clay
41	13BC	3	5	35	60	22	5	5	3	45	-	-	5	+	10	+	5	+	+	-	-	silty clay
42		12	5	35	60	21	5	5	2	50	-	-	+	+	10	-	5	2	-	-	-	silty clay
43		25	10	30	60	19	7	5	2	55	-	-	+	+	5	-	5	2	+	-	-	silty clay
44		50	3	30	67	21	5	5	2	53	-	-	+	+	10	-	3	1	-	-	-	silty clay
45	14BC	1	2	38	60	13	2	5	+	55	-	-	+	+	+	-	20	5	-	-	-	silty clay
46		9	3	37	60	10	2	2	1	50	-	-	+	+	10	-	20	5	-	-	-	silty clay
47		20	5	45	50	11	2	2	+	40	-	-	+	+	10	-	35	+	-	-	-	silty clay
48		35	5	45	50	15	7	3	+	40	-	-	+	+	10	-	25	+	-	-	-	silty clay
49		62	5	45	50	15	7	3	+	30	-	-	+	+	10	-	35	+	-	-	-	silty clay
50	15Gr	1	10	60	30	24	4	2	+	20	-	-	+	+	+	-	50	-	-	-	-	clayey silt
51	16BC	1	10	65	25	21	7	5	2	15	+	1	2	+	+	-	45	2	+	-	-	clayey silt
52		5	20	60	20	27	15	7	3	20	2	1	5	+	+	-	20	-	-	-	-	sandy clayey silt
53		9	20	60	20	33	20	10	4	20	2	1	5	+	+	-	5	-	-	-	-	sandy clayey silt
54		12	20	60	20	30	20	10	4	15	1	+	5	+	+	-	15	-	-	-	-	sandy clayey silt
55		15	25	60	15	36	20	10	2	15	1	1	5	+	+	-	10	-	-	-	-	sandy silt
56		17	10	40	50	13	5	5	2	35	+	+	+	+	+	-	40	-	-	-	-	silty clay
57		19	10	50	40	11	5	3	1	27	+	+	5	+	3	-	45	-	-	-	+	clayey silt
58		23	20	60	20	28	15	13	2	10	1	1	5	+	10	-	15	-	-	-	-	sandy clayey silt
59		36	20	60	20	22	15	15	2	10	1	1	4	+	10	-	20	-	-	-	-	sandy clayey silt
60	17Gr	1	20	40	40	10	5	5	1	25	+	+	+	+	5	-	40	9	-	-	-	sandy silty clay

61	18Gr	1	7	28	65	20	5	5	+	60	+	+	+	+	5	-	5	+	-	-	-	silty clay
62	19BC	0.5	10	40	50	30	10	10	+	40	+	+	+	+	10	-	+	-	-	+	-	silty clay
63		4	10	40	50	39	5	5	1	40	+	+	+	+	10	-	+	+	-	-	-	silty clay
64		15	5	30	65	25	5	5	+	60	+	+	+	+	5	+	+	+	-	-	-	silty clay
65	19GC	4	<1	30	70	20	5	5	+	70	+	-	+	+	+	-	+	-	-	-	-	silty clay
66		15	<1	30	70	17	5	5	2	60	-	-	+	+	10	-	1	-	+	-	-	silty clay
67		28	<1	35	65	18	10	5	1	50	-	-	+	1	15	-	-	-	-	-	-	silty clay
68		40 (light)	2	48	50	37	5	5	3	35	+	-	+	+	15	-	+	-	-	-	-	silty clay
69		40 (black)	5	55	40	42	10	5	3	20	-	-	+	+	20	-	+	-	-	-	-	clayey silt
70		50	20	50	30	42	15	10	3	10	+	-	+	+	20	-	+	-	-	-	-	sandy clayey silt
71		80	<1	25	75	13	5	5	2	65	-	-	+	+	10	-	-	-	-	-	-	silty clay
72		98	<1	30	70	18	5	5	2	60	-	-	+	+	10	-	-	-	-	-	-	silty clay
73		101	5	30	65	17	10	5	3	50	+	+	+	+	15	-	+	-	-	-	-	silty clay
74		110	30	40	30	39	20	10	1	25	-	-	+	+	5	-	-	-	-	-	-	mixtite
75		120	<1	30	70	19	5	5	1	65	-	-	+	+	5	-	-	-	-	-	-	silty clay
76		157 (light)	10	40	50	29	15	5	1	45	+	-	+	+	5	-	-	-	-	-	-	silty clay
77		160 (black)	10	50	40	38	10	10	2	30	-	-	+	+	10	-	-	+	-	-	-	clayey silt
78		180 (dark)	10	60	30	47	10	10	1	20	+	-	+	+	10	-	2	-	-	-	-	clayey silt
79		226 (layer)	2	38	60	23	7	7	1	40	1	+	+	+	20	-	1	-	-	-	-	silty clay
80		272 (dark)	3	47	50	28	10	7	2	30	-	-	+	+	20	-	3	-	-	-	-	silty clay
81		293 (light)	20	40	40	28	20	10	2	30	+	+	+	+	10	-	+	-	-	-	-	sandy silty clay
82		336	5	30	65	13	10	10	1	55	-	-	+	+	10	-	1	-	-	-	-	silty clay

83		340 (sand)	60	30	10	55	20	15	+	5	-	-	+	+	5	-	+	-	-	-	-	silty sand
84		359	20	35	45	23	20	10	1	35	+	-	+	+	10	-	1	-	-	-	-	sandy silty clay
85		378	15	55	30	43	15	10	1	25	-	-	+	+	5	-	1	-	-	-	-	clayey silt
86		423	10	60	30	43	15	10	2	20	+	+	+	+	10	-	+	-	-	-	-	clayey silt
87		445	5	65	30	43	15	10	2	10	-	-	+	+	20	-	-	-	-	-	-	clayey silt
88		475	10	50	40	33	15	10	1	25	-	-	+	+	15	+	1	-	-	-	-	clayey silt
89		500	30	50	20	43	25	10	2	17	-	-	+	+	3	-	-	-	-	-	-	clayey sandy silt
90		515	15	55	30	27	20	20	2	25	-	-	+	+	5	+	1	-	-	-	-	clayey silt
91		525	7	58	35	36	15	10	2	35	+	+	1	1	+	-	-	-	-	-	-	clayey silt
92		542 (layer)	60	30	10	49	20	20	1	10	-	-	+	+	+	+	+	-	-	-	-	silty sand
93		565 (light)	5	35	60	21	10	5	4	35	-	-	+	+	25	+	+	-	-	-	-	silty clay
94		580	<1	30	70	13	10	5	1	65	-	-	+	+	5	1	+	-	-	-	-	silty clay
95		620	10	30	60	26	7	5	2	40	+	+	+	+	20	-	-	-	-	-	-	silty clay
96		630	40	40	20	41	20	15	4	10	+	+	+	+	10	-	-	-	-	-	+	clayey sandy silt
97		658	20	40	40	36	10	10	4	20	+	-	+	+	20	-	+	+	-	-	-	sandy silty clay
98		663	10	65	25	40	15	15	4	24	-	-	+	+	1	-	+	1	-	-	-	clayey silt
99		670	10	60	30	35	20	10	4	29	-	-	+	+	1	-	+	1	-	-	-	clayey silt

7.3. Acoustic facies in the southern Kara Sea: new results by PARASOUND echosounding

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Introduction

In the frame of the SIRRO (Siberian River Run-Off) Project several expeditions into the southern and central Kara Sea were carried out (Stein and Stepanets 2000, 2001, 2002, Schoster and Levitan 2003). During these expeditions echosounding surveys were conducted with different systems in order to select geological sampling stations, to characterize the sea floor topography and to get information about the structure and thickness of the upper sediment layer on the Kara Sea shelf (Dittmers et al. 2003, Stein et al. 2002). For this purpose, the hull-mounted ELAC echosound system as well as a towed CHIRP system were used (Stein et al. 2000, Dittmers and Stein 2001, Niessen and Dittmers 2002).

During the Kara Sea Expedition in 2003, a new hull-mounted PARASOUND III system (Atlas Hydrographics, Germany) was used onboard of RV "Akademik Boris Petrov" for the first time in real working conditions. Here we present the first, high quality data obtained by the new system and our experiences with the PARASOUND system.

Objective

During the Kara Sea Expedition 2003 a new parametric ATLAS PARASOUND III system was employed very successfully, after a successful test cruise to the Lofoten basin on the first part of the expedition. Onboard of RV "Akademik Boris Petrov" the system is the successor of the ELAC system (ELAC echograph LAZ 72, Honeywell-Nautik, Kiel, Germany) which operated at 12 kHz. During the expedition in 2001 it was modified by Niessen and Dittmers (2001) to enable sediment echosounding survey with digital data storage including GPS navigation data.

The configuration of software and hardware components of the new ATLAS PARASOUND III system onboard of Boris Petrov is unique (Fig 7.2). Sound transmission is now steered online with the recently developed ATLAS HYDROMAP CONTROL unit. The receiving part of the system is controlled by ATLAS PARASTORE 3.0; last modifications were finished during the first part of the expedition (Fig. 7.2). Besides having some "teething problems" both systems enabled us steady work and data storage.

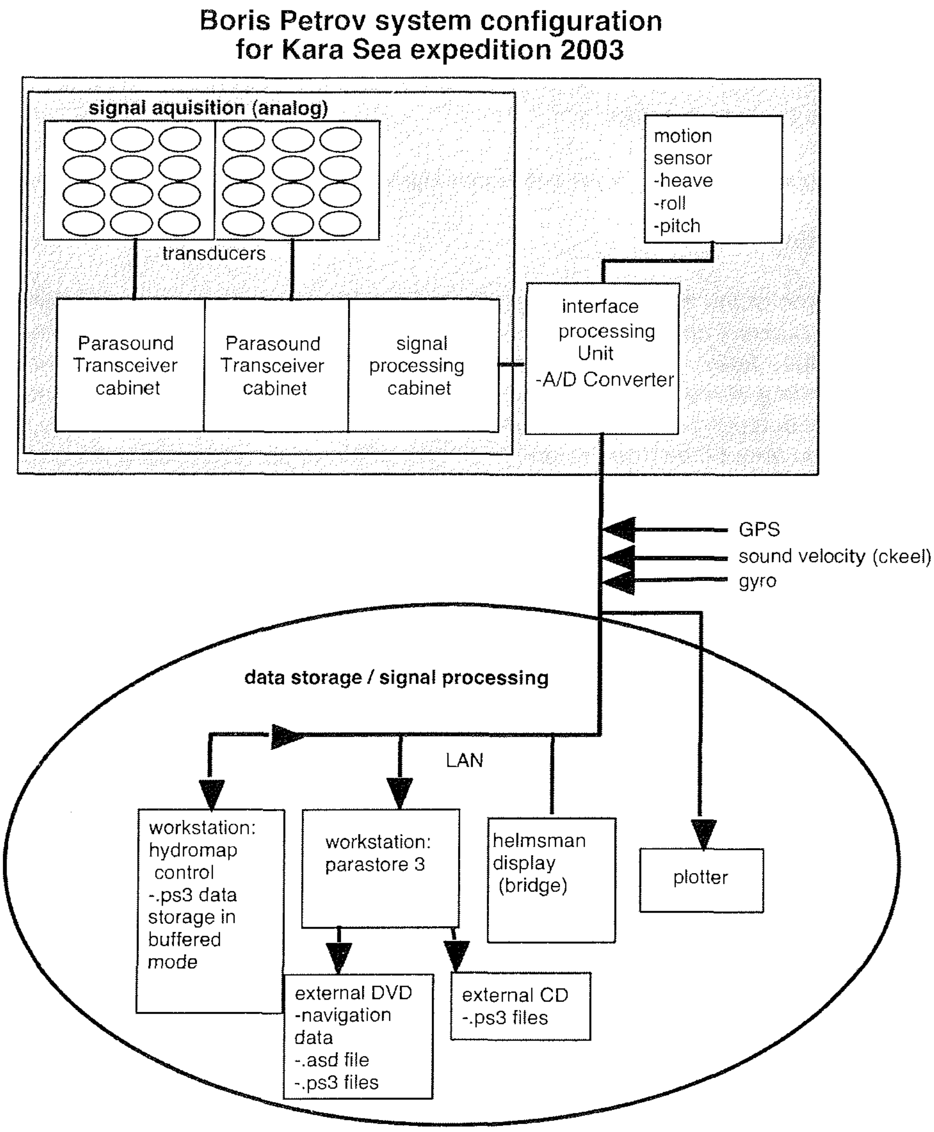

Figure 7.2: Software and hardware configuration of the PARASOUND system on RV "Akademik Boris Petrov": Connection diagram of different system components.

The System

The Atlas PARASOUND III sediment echosounder is a narrow-beam system that utilizes the parametric effect (Westervelt 1963) for acoustic signal generation and emission, that is a non linear interaction of high amplitude sinuoidal wave(lets). Two signals with a fixed lower frequency of 18 kHz and an operator selectable higher frequency of 20.5–23.5 kHz are emitted by the hull-mounted transducers, primarily.

The secondary parametric signal with frequency equal to the difference frequency, between 2.5–5.5 kHz, and variable length between 1 and 8 sine wave periods duration (Grant and Schreiber 1990, Rostek et al. 1991, Spiess 1993).

These signals are emitted within a narrow cone of 4° opening angle. The resulting footprint on the sea floor has a diameter of 7% of the water depth, so that generation of diffraction hyperbolae is significantly reduced compared to conventional 3.5 kHz sediment echosounder systems. One major drawback of this method, dependent on the narrow footprint is, that sea floor reflections are restricted to slopes below 4° inclination. For the data presented here, a sinuoidal wavelet of 3.5 kHz frequency and (sine wave) period duration (0.25 ms) was chosen as source signal; resulting in a vertical resolution of less than 28.6 cm (1 wavelength) for a sound velocity of 1500 m/s(Hamilton 1972). The received data were printed, recorded and digitized (sampling rate: 50 kHz) with PARASTORE 3.0 and georeferenced by the systems digital GPS. Seismic images were depth corrected using a sound velocity of 1500 m s^{-1} for water.

Table 7.5: Atlas HYDROMAP CONTROL settings used during Kara Sea Expedition 2003

Parameter	**a) normal mode**	**b) penetration mode**
Modus	PAR	PAR
Parametric Frequency	3.5 kHz	3.5 kHz
no. of periods per pulse	2	3
Receiver mode		
Pre-gain	shallow water	shallow water
Window/bottom TVG	off	off
A/D converter sensitivity	0 dB	20 dB
beam steering	off	off
C-mean	1500 m/s	1500 m/s

Setup

The general technical setup of all system components is summarized in Figure 7.2. We have used one computer as steering unit using ATLAS HYDROMAP CONTROL. For safety PARASTORE 3.0 was run simultaneously with data storage in a 4 GB buffered mode (ca. 2 hours of online operation) as backup for the main storage computer. One additional computer was used for the main data storage, running with PARASTORE 3.0 and equipped with a large hard disk and a DVD burner.

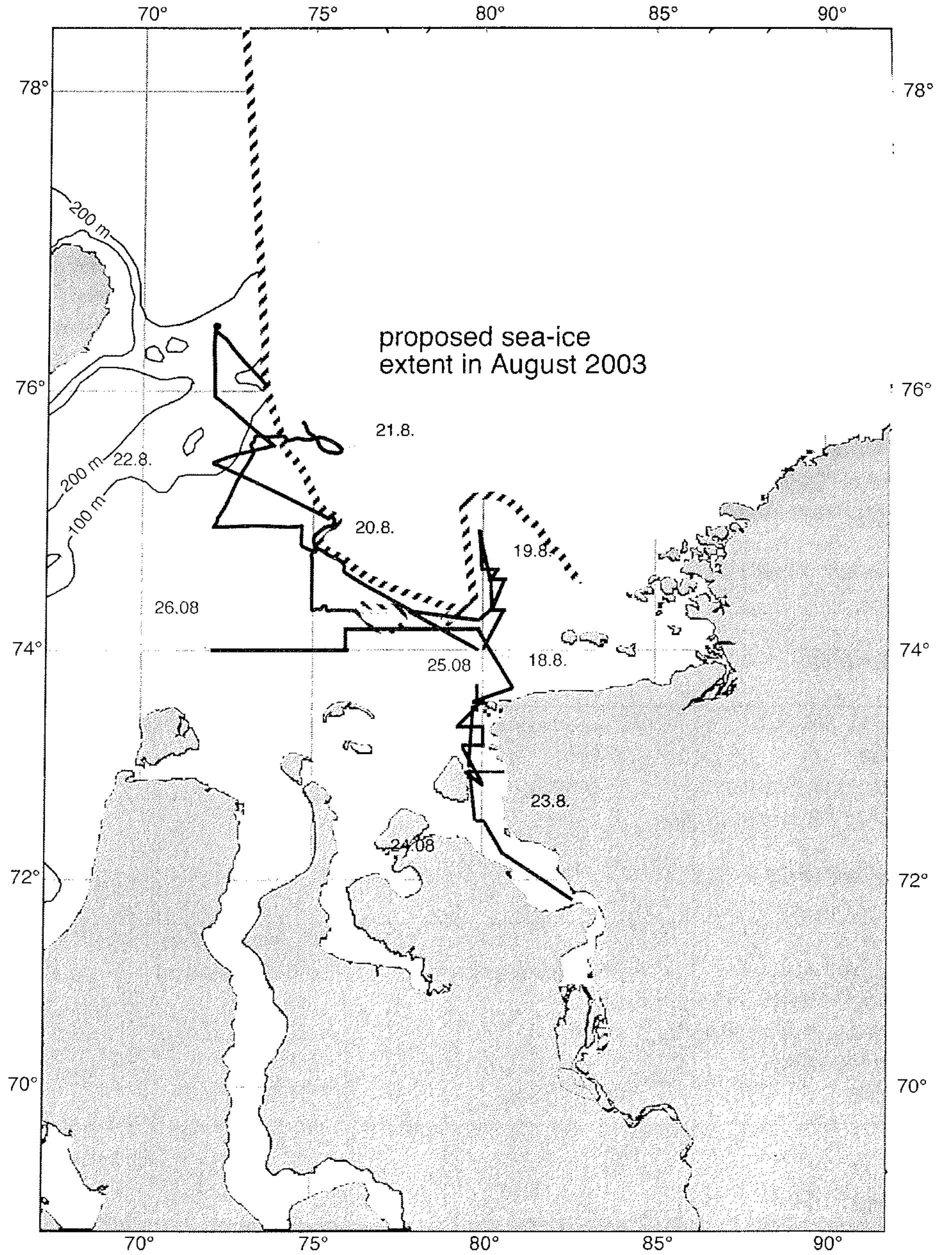

Figure 7.3: Map of PARASOUND profiles recorded during Kara Sea Expedition 2003 with RV "Akademik Boris Petrov".

The characteristics of the new system were carefully tested at stations, when the vessel did not move. So we tested and modified HYDROMAP CONTROL settings such as different secondary frequencies, A/D converter sensitivity (gain), and number of periods per pulse (pulse length). As a result two very expedient setups emerged (Table 7.5):

a) normal mode
b) penetration mode

A parametric frequency of 3,5 kHz proved to be the best compromise between resolution and penetration.

Most of the surveys were conducted in the "normal" mode. The "penetration" mode was used if water depths exceeded 100 meters. These water depths coincided with glacially overprinted terrain in most cases. Here beam attenuation was very high because of the high relief energy in this hummocky terrain (Fig. 7.13), with the result that even the penetration mode produced relatively weak backscatter. Another occasion, where we employed the "penetration" mode, was the Yenisei Estuary in order to visualize thick sediment packets in the recent depocentre (Dittmers et al. 2003; "marginal filter" of Lisitzin 1995). The relatively weak signal was probably related to the water depth of ca. 20 meters, so that PARASOUND did not fully develop the parametric pulse.

In PARASTORE 3.0 our default setting for processing was:

- subtract mean
- band pass; with low-cut at 2, high-cut at 6 kHz; one iteration
- clip at 500 mV
- subtract negative flanks

We used this processing setting all the time, which allowed optimal display of sedimentary structures. Unfortunately, PARASTORE was not able to read the GPS data telegram correctly, so that only timelines - no exact positions - could be displayed in PS3-data-files and on online prints. But the navigation data were stored correctly in the NAV files.

Data were stored contemporaneously as:

1. ASD: raw data containing all unprocessed information
2. PS3: processed data with possibly several processing steps and only a certain cutout depth window
3. NAV: navigational data including information of PARASOUND system settings
4. INF: meta data recorded all manipulation fulfilled by the watch such as changes in windows
5. NBS: optional! ASD files of Narrow Beam Sounder signal that determines the water depth; this signal is sent before parametric signal.

In general, the software ran stable, but problems occurred when parameters were changed online, either on PARASTORE 3.0 or ATLAS HYDROMAP CONTROL, and often resulted in system crashes.

In some cases online plotting was problematic, because the plotter did not always get the window delay correctly. In the configuration used onboard of RV "Akademik Boris Petrov" there is no output for a thermal printer like the DESO system on Polarstern, for example. So everything is dependent on the LAN and no "analouge" data storage or visualisation is possible.

In general, the tasks of the system during the cruise were:

1. testing of all software and hardware components in operation
2. resampling of certain "key-profiles" for comparison of previously collected data obtained by ELAC, CHIRP and 3.5 kHz systems (ref. to citations in Fig. 7.4)
3. filling of gaps in acoustic lines --> completion of Holocene sediment thickness map (e.g. Dittmers et al. 2003)
4. characterisation of sea floor topography --> identification of palaeochannels, the extensions of recent Ob and Yenisei rivers onto the shelf during LGM sea level lowstand
5. selection of sediment sampling stations

Despite being hindered by harsh ice conditions of an unusual far southward sea-ice extent of a closed pack-ice field (Fig. 7.3) associated with several small drifting ice fields we were able to record 66 acoustic lines, summing up to 1333.4 nautical miles of soundings (Table 7.6, Fig. 7.3). Ship's speed varied from 6 knots for high resolution along "key profiles" to ten knots during passages of known shelf areas.

Results

A. Data obtained by PARASOUND compared to former echosounding data

Echograms of the new system proved to be of excellent quality, which partly outmatched all former results, including processed examples of the CHIRP profile of the central Yenisei Estuary (Dittmers et al. 2003). They displayed both: higher resolution and internal sediment stratification as well as deeper penetration as shown in Figures 7.4 and 7.8 (see part B below for details). Quantitative comparison of the images of the different profiling systems shows that penetration is approximately the same up to the prominent basal reflector (base of Holocene; see Dittmers et al. 2003 for details), with the exception that often PARASOUND penetrates into strata below. In some examples from the central shelf and the estuaries (Figs. 7.5-7.7) PARASOUND reveals some interesting structures below this surface, which have not been identified in such detail by the former studies. In general, visualisation of sediment stratification by PARASOUND is more precisely, while ELAC and CHIRP produce more diffusive acoustic images. The CHIRP system (2-8 kHz) enables higher resolution than ELAC system, suitable for subdivision of Unit I although penetration of both systems is about the same (Fig. 7.3). Both have in common

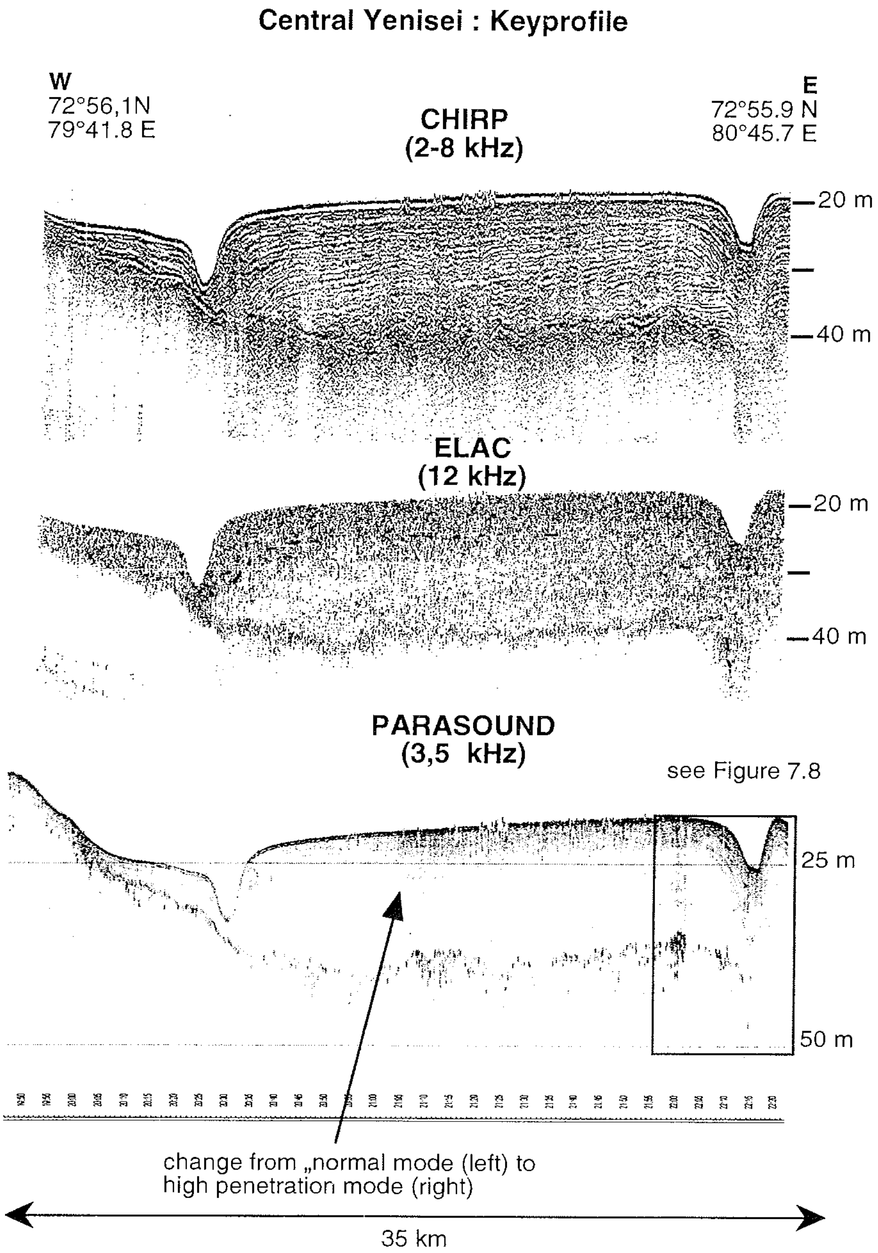

Figure 7.4: Comparison of different Echosounding systems used during several expeditions of the SIRRO project (CHIRP (Niessen and Dittmers 2001) and ELAC system (Weiel & Stein 1999, Dittmers & Stein 2000, Niessen & Dittmers 2001)).

that they can pick up prominent reflectors below the soft sediment such as the top of Unit II. Basically, the PARASOUND system enables higher energy transmission resulting in deeper penetration and better resolution of strata.

Therefore, the PARASOUND data reveal detailed information about the stratification of the sediments, but the results of the former used echosounding systems and their interpretation still have validity (e.g. Dittmers et al. 2003, Stein et al 2003, Stein et al. 2002). In addition, some new features have been discovered with the new system.

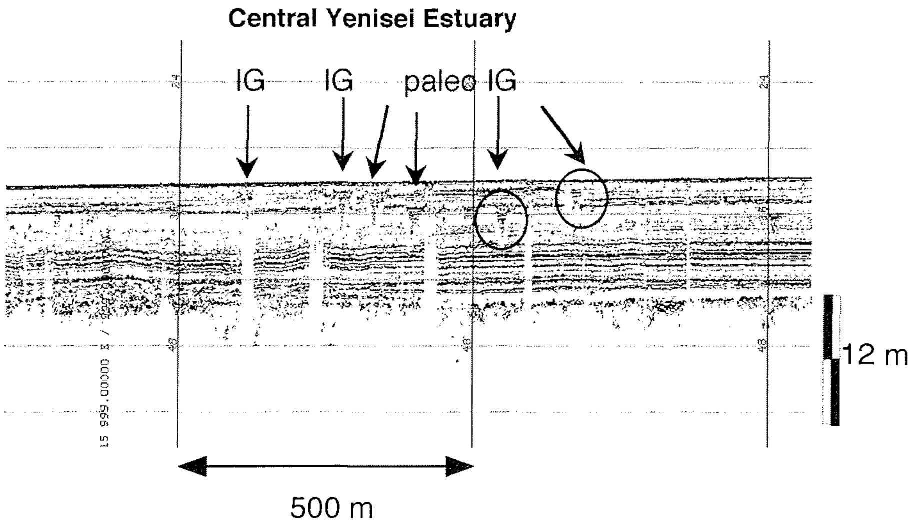

Figure 7.5: A section of the Yenisei Estuary with typical characteristics of Facies I. At the top of the succession well stratified sediments are disturbed by some v-shaped incisions, which are filled with even reflectors, interpreted as paleo ice gouges (paleo IG).

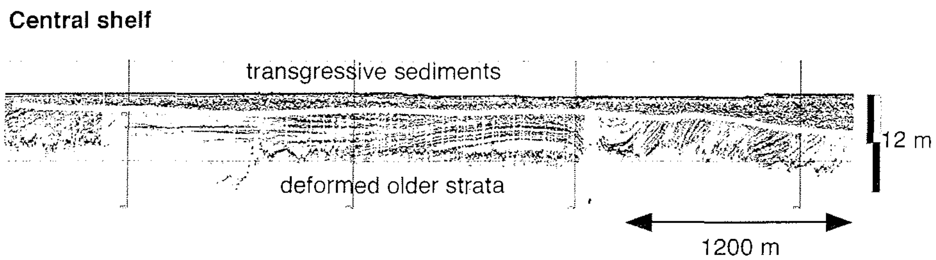

Figure 7.6: A section of central shelf area. Here, some Holocene sediments lie unconformably above older strata (grey line delineates unconformity). Well-stratified older strata show intense folding. The deformation/dislocation could be related to glaciotectonic ground moraine deformation during mid-Weichselian ice-sheet advance.

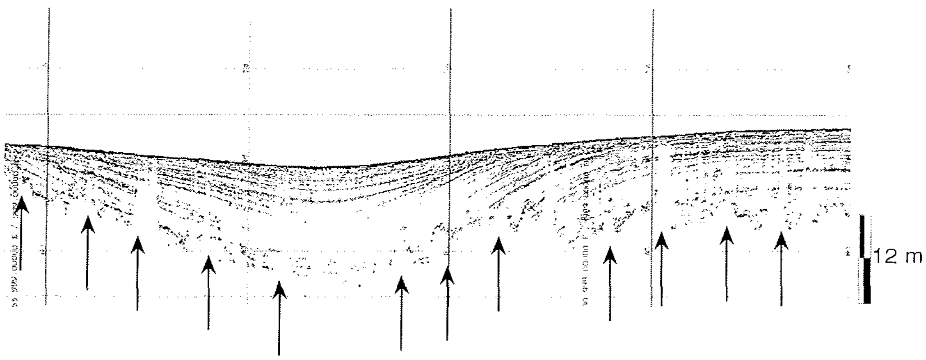

Figure 7.7: A filled channel in the Yenisei Estuary. Note disturbances at the bottom of the younger sedimentary sequence. In this case the prominent reflector is not visible clearly. Note the occurrence of an acoustic transparent front migrating into the sediments, ignoring bedding or other structures. The strong backscatter at this front (displayed by arrows) implies a major difference in acoustic impedance and suggest the transit to a less dense material due to gas loading or the existence of (perma)frozen sediments and thus resulting in a total attenuation of acoustic energy.

B. Typical (acoustic) facies types in the southern Kara Sea: Types, characteristics, and their paleoenvironmental implications

In general, three major different acoustic facies could be distinguished based on sediment penetration, backscatter characteristics, internal reflection pattern, sea bottom roughness and external morphology of seismic units:

Facies I: the outer areas of the Ob and Yenisei estuaries up to 74° N are characterized by relatively thick muds up to 20 meters in thickness (Figs. 7.4 and 7.9), associated with channel-overbank morphologies, consisting of subparallel to parallel reflectors with draping character in the upper meters (Figs 7.8 –7.10).

Facies II: shelf areas extending to the shelf break approximately at the 50 m isobath with large areas of little deposition and minor Holocene sediment penetration; here the relief is relatively smooth but cut by several channels (active and filled, Fig. 7.12) with a broad variety of geometries, where sediment thickness increases drastically. In general this facies is irregular with great lateral variability (Figs. 7.11 and 7.12).

Facies III: shelf break and deeper lying areas with irregular morphology in the north-western part of the working area, many deeply incised channels and in parts areas of soft sediment accumulation with high thickness associated with fluvial activity (Figs. 7.13 and 7.14).

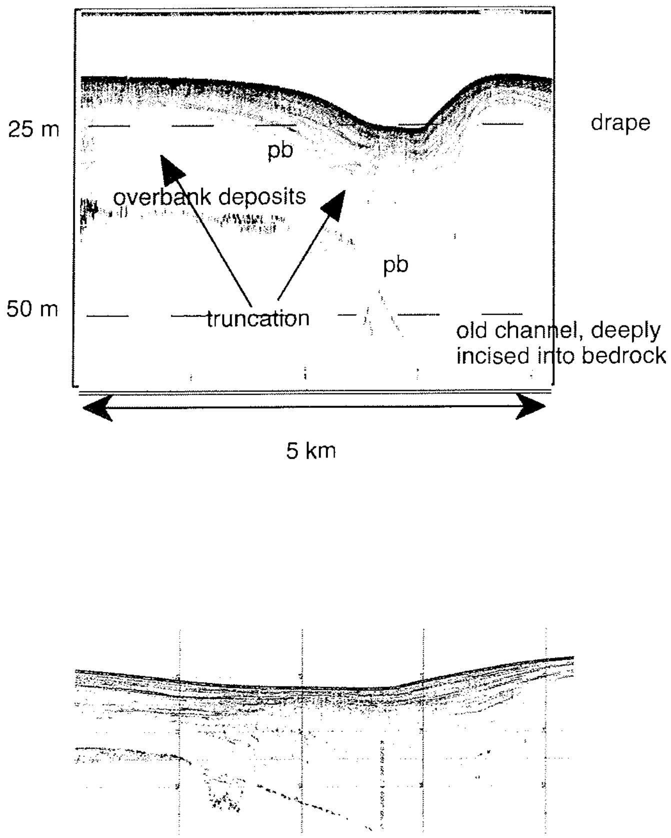

Figure 7.8: Enlargement of PARASOND profile of Figure 7.4. with excellent representation of reflectors. In the lower part the reflectors display a typical fluvial environment with a channel axis (right) associated with an overbank facies to the left; pb refers to "point bar" deposits; to the top they grade into drapes, resembling the modern estuariane/marine conditions.

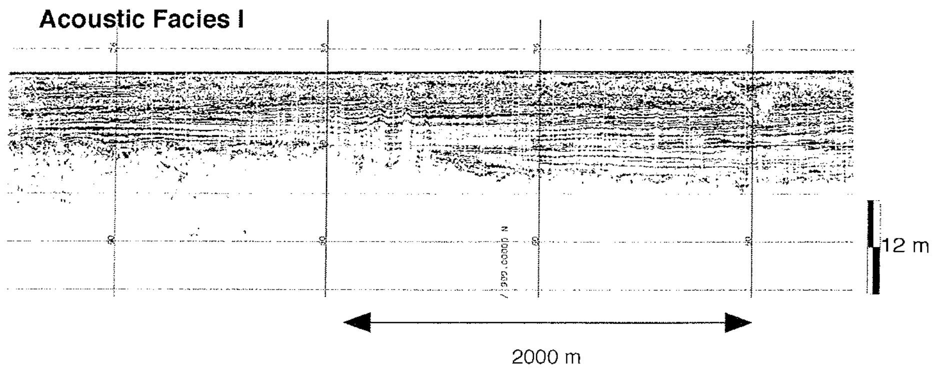

Figure 7.9: Typical section of central Yenisei area. Thick sediment packets (mud) overlay strong, erosive basal reflector (unconformity). In the lower part of well defined continuous reflectors a probable fluvial dominated fill deposit with onlaping reflectors (arrow) onto an unsteady reflector is visible. Underneath this reflector due to high attenuation there is little penetration, besides some weak stratification. Here soundings display strikingly the threefold division of Holocene sediments as concluded by Dittmers et al. (2003).

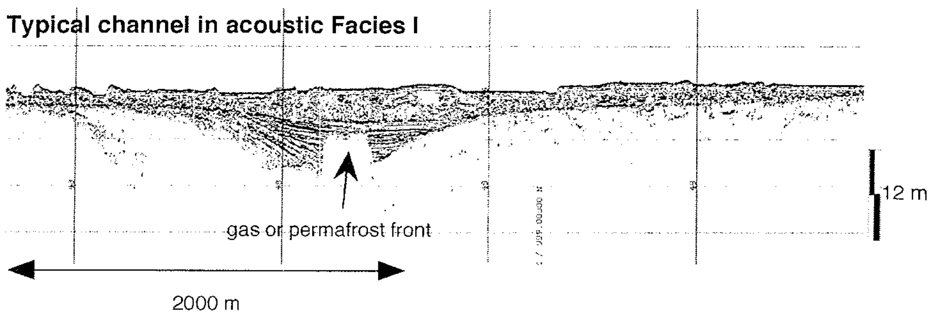

Figure 7.10: Buried channel in outer Yenisei estuary (north of 73°39'N). Prominent reflector at the base of sedimentary sequence delineates channel paleo-profile. Weak reflection below this reflector on the left hand indicate longer persistence of fluvial activity; channel fill consists of well stratified sediments overlain by acoustic diffusive layer, that possibly reflects sediment reworking during Holocene transgression. The irregular sea floor could arise from grounded press-ice ridges ploughing through the sediment surface in the winter months. White blanket in the channel axis indicates existence of shallow gas or potentially permafrost.

Acoustic Facies II: middle shelf

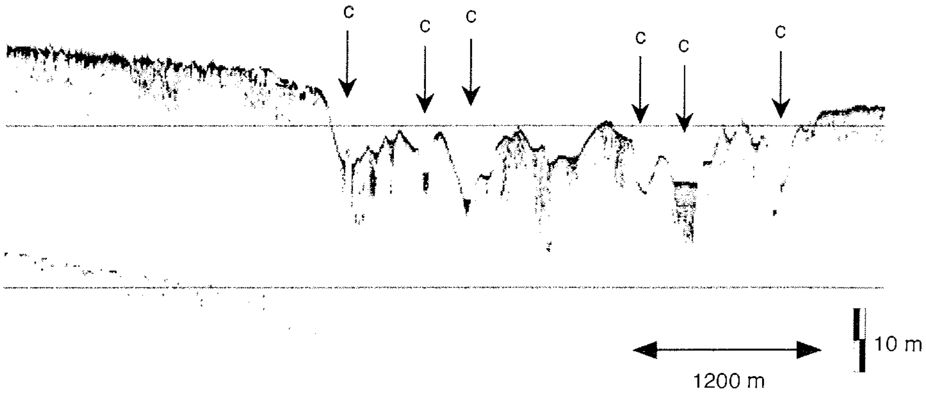

Figure 7.11: Facies II at (74°00'N 78° 20'E); representative section of the middle shelf facies. Note strong backscatter of the sea floor in the left part of the profile. Here little sediment accumulation above the unconformity takes places. Several channels with different levels of sediment filling (c) have cut in into this area of the shelf; their prevalence suggests a paleo-extent of the Ob River (Stein et al. 2003).

Channels in acoustic Facies II

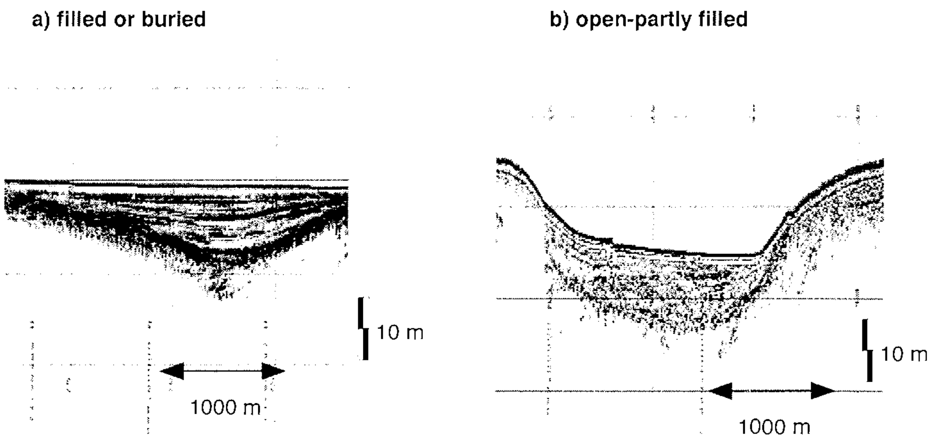

Figure 7.12: a) A filled channel at 30 m water depth, characterized by a deflection of the strong basal reflector overlain by younger, well-stratified sediments, consisting of at least three sequences. In the lower part these fill sequence seems to be current dominated because the old relief is not levelled. To the top the whole succession grades into draping deposits leaving no relief difference with the surroundings.

C. Paleoenvironmental implications

Each differentiated key facies reflects the reaction of a specific sedimentary environment to forced external changes. The factors (often influencing each other) of controlling the sedimentation are:
- the LGM and the eastern extent of the Barents-Kara Sea Ice Sheet,
- sea-level fluctuations, especially the post-LGM transgression,
- variability of river run-off.

Acoustic Facies III: shelf break; glacially overprinted terrain

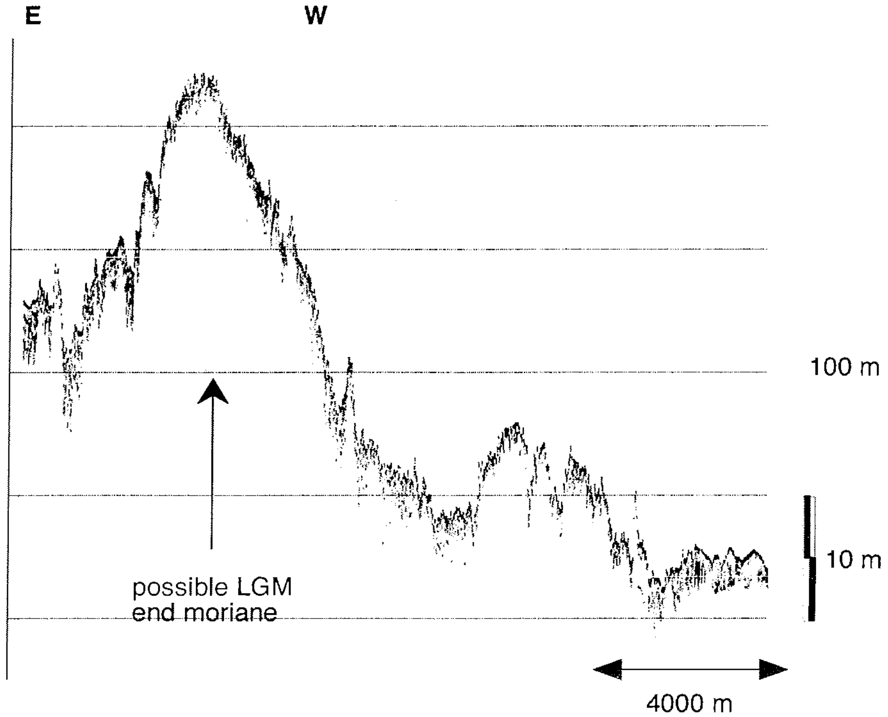

Figure 7.13: Facies III: Hummocky relief characterized by high diffuse acoustic backscatter and no penetration below. Note high relief energy and distinct peak in the left part of the image, possibly formed by an end moraine. Morphology resembles classical glacial overprinted terrain, that is formed by the drag and strain of a moving ice sheet.

Facies I mainly represents modern and late Holocene sediment accumulation in an estuarine environment with strong fluvial influences at its base. Facies II is characterized by low sedimentation rates, with the exception for areas of numerous channels, previously incised into the shelf. These channels probably supplied sediments during sea-level lowstand to Facies III, where thick sediment sequences accumulated. They probably are of fluvial origin. In the lower parts of the sections facies often resemble fluvial conditions. In a way all facies types show not only a lateral shift in the depositional environment, but each contains to certain amounts to all facies types in a vertical succession as postulated by Walthers law for time transgressive systems. For the same reason fluvial features encountered in all facies types are the product of similar processes.

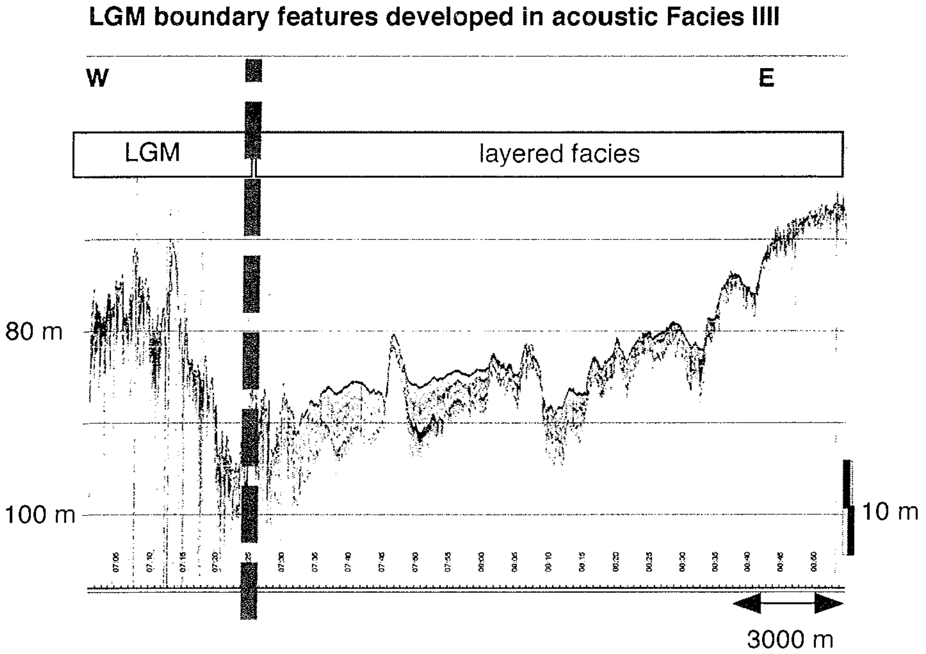

Figure 7.14: Glacial facies neighbouring thick sediment sequences of probably fluvial originated sediments. The layered sediments seem to border to the glacial influenced facies. There is a distinct change in the relief energy, the glaciated terrain being more hummocky. The acoustic layeredl facies seems to accumulate in depressions.

Outlook

The recently obtained high-resolution echosounding data allow a detailed sequence-stratigraphical interpretation of depositional history in the Kara Sea in terms of:

- sediment dynamics and evolution, and
- sedimentary (Holocene) sediment budget

Table 7.6: PARASOUND profiles recorded during BP03

No	Start		End		Distance		
	Latitude°(N)	Longitude°(E)	Latitude°(N)	Longitude°(E)	[nm]	Date	comment
1	74°00	80°00	74°20.026	80°44.210	23,50	17,08	
2	74°20.026	80°44.210	74°20.580	80°25.670	5,40	18,08	start at BP03-04b
3	74°20°	80°25	74°35	80°45	15,50	18,08	
4	74°35	80°45	74°35	80°25	5,30	18,08	
5	74°35	80°25	74°40.038	80°34.294	5,50	18,08	
6	74°40.038	80°34.294	74°40.069	80°07.224	7,40	18,08	
7	74°40.069	80°07.224	74°59.724	80°00.067	20,00	18,08	
8	74°59.724	80°00.067	74°57.316	80°06.336	2,90	19.08.	start at BP03-05
9	74°57.316	80°06.336	74°50.303	80°07.094	7,00	19.08.	
10	74°50.303	80°07.094	74°26.559	80°26.624	24,30	19.08.	
11	74°26.559	80°26.624	74°25.925	80°25.168	0,80	19.08.	
12	74°25.925	80°25.168	74°20.653	80°25.069	5,30	19.08.	
13	74°20.653	80°25.069	74°15.030	79°59.603	8,90	19.08.	
14	74°15.030	79°59.603	74°15.253	79°15.611	61,40	19.08.	
15	74°15.253	79°15.611	74°19.221	78°11.845	17,70	19.08.	
16	74°19.221	78°11.845	74°20.014	77°59.642	3,80	19.08.	
17	74°20.014	77°59.642	74°20.032	75°24.764	41,80	19.08.	
18	74°20.032	75°24.764	74°21.276	75°23.245	1,00	19.08.	
19	74°21.276	75°23.245	74°20.160	75°01.215	6,00	19.08.	
20	74°20.160	75°01.215	74°48.931	74°59.345	28,90	19.08.	
21	74°48.931	74°59.345	74°49.978	74°52.135	2,10	19.08.	
22	74°49.978	74°52.135	74°59.986	74°38.839	10,50	20.08.	
23	74°59.986	74°38.839	75°00.091	72°01.047	40,80	20.08.	ice margin end at BP03-06

No	Start		End		Distance			
	Latitude°(N)	Longitude°(E)	Latitude°(N)	Longitude°(E)	[nm]	Date	comment	
24	75°00.091	72°01.047	75°33.321	73°11.088	37,60	20.08.	ice margin	
25	75°33.321	73°11.088	75°41.937	73°11.998	8,00	20.08.		start at BP03-07
26	75°41.937	73°11.998	75°40.891	74°46.767	23,80	20.08.		
27	75°40.891	74°46.767	75°38.276	75°31.284	52,70	20.08.		
28	75°38.276	75°31.284	75°37.039	75°42.630	3,00	21.08.		
29	75°37.039	75°42.630	75°41.185	74°58.651	11,60	21.08.	icefield/packice	start at BP03-08
30	75°41.185	74°58.651	76°30.078	71°59.234	65,20	21.08.	icefield/packice	
31	76°30.078	71°59.234	76°30.854	72°9.376	2,20	21.08.	icefield/packice	start at BP03-09
32	76°30.854	72°09.376	75°59.652	72°1.803	2,40	21.08.	icefield/packice	
33	75°59.652	72°01.803	75°38.110	73°49.385	34,00	21.08.	icefield/packice	
34	75°38.110	73°49.385	75°29.952	71°59.848	28,50	21.08.	icefield/packice	
35	75°29.952	71°59.848	75°2.941	75°34.986	60,00	21.08.	icefield/packice	start at BP03-10
36	75°02.941	75°34.986	75°01.417	75°32.945	1,50	22.08.	icefield/packice	
37	75°01.417	75°32.945	74°56.738	75°08.636	7,80	22.08.	icefield/packice	start at BP03-04b
38	74°56.738	75°08.636	74°53.255	75°02.120	3,80	22.08.	icefield/packice	
39	74°53.255	75°02.120	74°49.227	75°07.294	4,30	22.08.		
40	74°49.227	75°07.294	74°41.861	75°51.770	13,80	22.08.		
41	74°41.861	75°51.770	74°39.770	75°51.546	2,00	22.08.		
42	74°39.770	75°51.546	74°00.336	79°58.207	72,10	22.08.	small icefields	
43	74°00.336	79°58.207	73°41.320	79°58.988	20,15	23.08.		start at BP03-12
44	73°41.320	79°58.988	73°25.016	80°02.844	16,30	23.08.		
47	73°20.011	79°23.743	73°20.395	80°11.981	13,90	23.08.		
48	73°20.395	80°11.981	73°09.965	80°10.265	10,50	23.08.		
49	73°09.965	80°10.265	73°09.836	79°34.249	23,50	23.08.		

No	Start latitude°(N)	Start Longitude°(E)	End Latitude°(N)	End Longitude°(E)	Distance (nm)	Date	comment
50	73°09.836	79°34.249	72°50.356	80°05.306	23,40	23.08.	
51	72°50.356	80°05.306	72°56.036	79°36.639	10,30	23.08.	start at BP03-14
52	72°32	79°55	72°58	79°47	26,00	23.08.	Yenisei key profile
53	72°58	79°47	72°14.99	80°29.99	40,88	24.08.	end at BP03-15
54	72°14.99	80°29.99	72°02.2	81°30.8	22,60	24.08.	end at BP03-16
55	72°02.2	81°30.8	71°50.98	82°25.38	20,30	24.08.	end at BP03-17
56	71°50.98	82°25.38	72°32.5	79°56.1	61,70	24.08.	
57	72°32.5	79°56.1	73°28.5	79°51.6	56,00	24.08.	
58	73°28.5	79°51.6	73°32.9	80°07.5	6,30	24.08.	
59	73°32.9	80°07.5	73°32.6	79°50.7	4,80	25.08.	
60	73°32.6	79°50.7	73°39.9	80°59.5	20,80	25.08.	
61	73°39.9	80°59.5	74°10	79°54	35,10	25.08.	
63	74°10	79°54	74°10	76°	63,80	25.08.	
64	74°10	76°	74°	76°	10,00	25.08.	
65	74°	76°	73°59.86	73°08.08	47,40	25.08.	start at BP03-18
66	73°59.86	73°08.08	74°00	71°56.9	19,60	26.08.	start at BP03-19
					1333,43		

8. Geochemistry

8.1. Organic carbon distribution within two ikaite-bearing sediment cores in the Kara Sea

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Introduction

One of the SIRRO aims was to determine organic carbon content (TOC) and isotope composition in time and space. Distribution of organic carbon concentration and C/N ratio in sediments of two cores obtained during R/V "Akademik Boris Petrov" cruise in August-September 2001 is presented. Core BP01-26 was obtained on the continuation of Yenisey Estuary at 74°N, core BP01-55 is located seaward at 77°N (Fig. 8.1) (Kodina et al. 2002). One giant ikaite crystal (15-cm length) and numerous smaller well-shaped crystals were present in core BP01-55. In core BP01-26 radial cluster (<5 cm in diameter) of small ikaite crystals and three individual crystals were observed (Kodina et al. 2003).

Results and discussion

According to lithology and geochemistry of the sediment two cores were formed under different sedimentological environments. Accumulations observed at station BP01-26 reflect higher river activity. Trend to higher TOC accumulation (1.0-2.8%) manifested itself more clearly within the stiff sandy silty clay interval (190-450cm) with the maximal C/N ratio of 12.9 being observed at the depth of 184-264 cm. The upper part of the core is much less enriched with TOC (0.8-1.5) and C/N ratio is lower ranging between 7.5 and 9.9 (Table 8.1, Fig. 8.2a). Marine sedimentation was probably prevailing in the upper part of the core. TOC distribution pattern throughout sedimentary succession appeared to be related to the postglacial sea level rise (Stein et al. 2003). Two stratigraphic units (Unit I and Unit II) were recognized within core BP01-26 (Dittmers et al. 2003), with the boundary being at 190-200 cm.

Sediments of core BP01-55 taken further northward are characterized by lower TOC values (from 0.35% to 1.2%) and C/N ratios changing from 7.4 to 12.0 (Table 8.2., Fig. 8.2b). Organic carbon distribution in this case is more uniform and clearly related to the core lithology. The most significant deviation to lowermost values (0.35-0.82) is observed at the core bottom in sandy intervals (230-510 cm) (Fig. 8.2b). Most of the analyzed sediment samples show C/N ratios varying around 11. Relatively low organic carbon content in the core with mean TOC value 0.79 enables to suppose marine sedimentation environment. Nevertheless, the influence of terrestrial input marked by relatively high C/N ratio, was rather significant. The location of northern station BP01-55 suggests that some Yenisey-derived sediment supply as well as terrigenous material resulted from coastal and sea-floor abrasion could be deposited there (Stein et al. 2003).

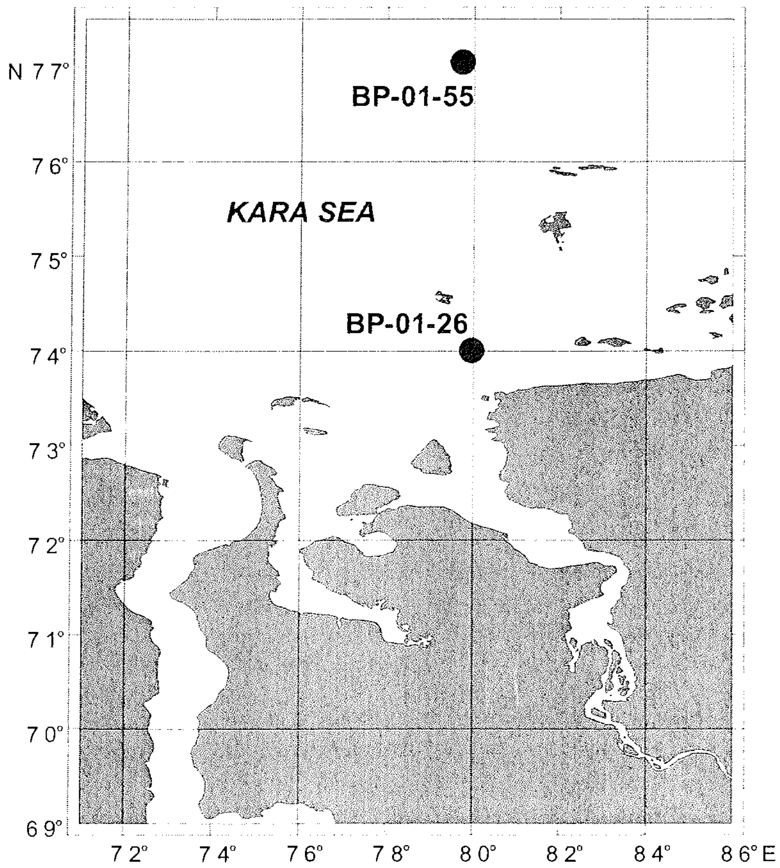

Figure 8.1: Location map with the positions of cores BP-01-26 and BP-01-55.

An interesting point of TOC distribution was observed within ikaite-containing layer. Samples taken at 233-cm depth in core BP01-26 and at 150 cm in core BP01-55 are characterized by low TOC content as well as by low nitrogen value and by low C/N ratio (See arrows at Fig. 8.2). Observed fluctuations in TOC content and C/N values tightly related to ikaite occurrence in the sediment. They might be resulted from the short-term climate fluctuations during deglaciation period (Stein et al. 2003). It is well known that ikaite precipitation under temperature control and corresponds to cooling periods in the Earth climate history. ^{14}C dating of the ikaite-bearing accumulations can provide better understanding of the sedimentation history in the Arctic Basin.

Acknowledgements

This study was supported by Otto Schmidt Laboratory fellowship program. Authors are grateful to Heads of OSL, to Dr. Jens Hoelemann and to Vladimir Churun for help with elemental analysis.

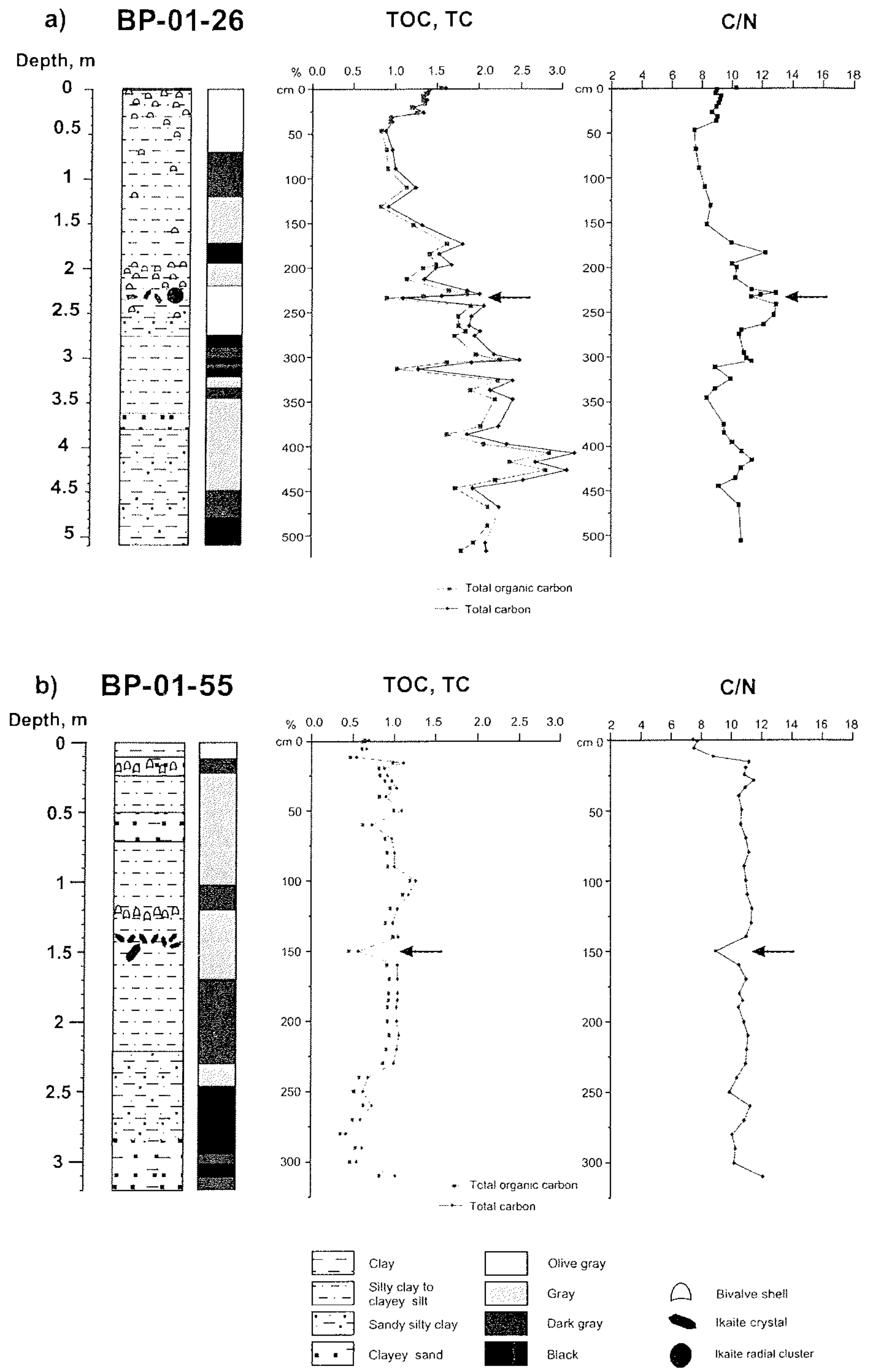

Fig. 8.2. Total organic carbon, total carbon and C/N ratio in cores BP-01-26 (a) and BP-01-55 (b).

Table 8.1. Total carbon, total organic carbon, total nitrogen contents and C/N ratio in sediments of core BP-01-26.

Depth, cm	TC	TOC	N	C/N
0	1.601	1.548	0.151	10.25
2	1.406	1.397	0.156	8.96
6	1.387	1.367	0.154	8.88
9	1.344	1.329	0.144	9.23
13	1.376	1.329	0.145	9.17
17	1.355	1.353	0.149	9.08
21	1.224	1.197	0.134	8.93
27	1.338	1.262	0.146	8.64
32	0.957	0.944	0.105	8.99
37	0.962	0.936	0.105	8.91
47	0.884	0.828	0.111	7.46
68	0.966	0.89	0.118	7.54
89	1.002	0.909	0.117	7.77
110	1.248	1.134	0.139	8.16
131	0.917	0.822	0.096	8.56
152	1.326	1.22	0.147	8.30
173	1.806	1.618	0.163	9.93
184	1.528	1.413	0.116	12.18
196	1.673	1.495	0.15	9.97
200	1.488	1.337	0.13	10.28
212	1.353	1.141	0.112	10.19
225	1.86	1.645	0.146	11.27
229	2.014	1.866	0.145	12.87
231	1.56	1.342	0.113	11.88
233	1.098	0.899	0.08	11.24
242	2.065	1.907	0.148	12.89
254	1.915	1.757	0.138	12.73
264	1.89	1.761	0.146	12.06
270	2.017	1.846	0.174	10.61
275	1.953	1.713	0.164	10.45
296	2.185	1.969	0.183	10.76
302	2.489	2.251	0.206	10.93
305	1.917	1.622	0.144	11.26
312	1.285	1.027	0.116	8.85
325	2.411	2.233	0.226	9.88
336	2.142	1.902	0.215	8.85
346	2.413	2.197	0.265	8.29
376	2.241	2.026	0.215	9.42
385	1.867	1.624	0.172	9.44
396	2.336	2.066	0.207	9.98
406	3.162	2.854	0.269	10.61
416	2.686	2.374	0.21	11.30
425	3.067	2.808	0.266	10.56
436	2.538	2.205	0.216	10.21
445	1.936	1.726	0.19	9.08
466	2.249	2.117	0.203	10.43
487		2.115		
506	2.09	1.945	0.184	10.57
515	2.104	1.798		

Table 8.2. Total carbon, total organic carbon, total nitrogen contents and C/N ratio in sediments of core BP-01-55.

Depth, cm	TC	TOC	N	C/N
0	0.691	0.647	0.087	7.437
1	0.649	0.617	0.080	7.713
6	0.666	0.607	0.081	7.494
12	0.539	0.466	0.053	8.792
16	1.112	0.982	0.088	11.159
20	0.878	0.809	0.074	10.932
25	0.917	0.824	0.076	10.842
29	0.971	0.885	0.077	11.494
34	1.028	0.949	0.087	10.908
40	0.897	0.817	0.078	10.474
50	1.090	0.993	0.093	10.677
60	0.728	0.615	0.058	10.603
70	0.972	0.886	0.081	10.938
80	1.005	0.913	0.082	11.134
90	1.004	0.921	0.085	10.835
100	1.264	1.193	0.109	10.945
110	1.174	1.104	0.100	11.040
120	1.039	0.953	0.084	11.345
130	0.983	0.893	0.079	11.304
140	1.049	0.986	0.090	10.956
150	0.565	0.447	0.050	8.940
160	1.041	0.913	0.087	10.494
170	1.043	0.942	0.086	10.953
180	1.045	0.936	0.089	10.517
185	1.044	0.935	0.087	10.747
190	1.030	0.921	0.088	10.466
200	1.033	0.919	0.085	10.812
210	1.060	0.941	0.085	11.071
220	1.034	0.902	0.082	11.000
230	0.998	0.863	0.079	10.924
240	0.685	0.579	0.056	10.339
250	0.628	0.513	0.052	9.865
260	0.733	0.628	0.056	11.214
270	0.593	0.498	0.046	10.826
280	0.418	0.351	0.035	10.029
290	0.617	0.533	0.052	10.250
300	0.546	0.467	0.046	10.152
310	1.016	0.820	0.068	12.059

8.2. Variations of hydrochemical parameters throughout the water masses in the Kara Sea in August 2003

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Introduction

In order to continue the study of the influence of the river discharge onto the Kara Sea water hydrochemistry, the sampling and first analyzes have been carried out during the 39th cruise of R/V "Akademik Boris Petrov" in August 2003. In this paper shipboard data of hydrochemical parameters are presented.

Material and methods

Water sampling was performed at stations, when the ship was drifting, by using the Rosette water sampler equipped with the hydrophysical CTD complex. Water samples were taken from three horizons at each station – surface layer, pycnocline and near- bottom water. Water samples were prefiltered through a paper blue-tape filter. pH, salinity and oxygen concentration were measured with the combined ORION electrode, total alkalinity was analyzed titrimetrically, phosphate was determined colorimetrically. All procedures were carried out onboard of RV "Akademik Boris Petrov".

Results and discussion

Two quasimeridional sections of several stations are compared (Fig. 8.3). The hydrochemical parameters throughout the Kara Sea water mass are presented in Table 8.3 and in Figs. 8.4 – 8.7. Section I covers the Yenisei Estuary (Stations BP03-13 and BP03-17) and the adjacent Kara Sea water area (St. BP03-04 and BP03-05). Section II comprises several stations (BP03-03 ÷ BP03-09) in the southeastern Kara Sea northward of the Ob Estuary.

As expected, the water mass along section I is characterized by higher temperature and lower salinity than the second one. The lowermost pH-values (pH < 8) and TAlk (0.8 mM) were measured along section I (Fig. 8.4). The influence of marine water of high salinity was extended southward up to Station BP03-15. Dissolved oxygen is rather deficient in the near- bottom and pycnocline water of the estuary (6.4 mg/L). Oxygen concentration increases northwards. (Fig. 8.5). Maximum phosphate concentration (1.78 μM) was observed in the top layer of the southern estuarine water (Station BP03-16) and was probably associated with a rather intensive remineralization of organic material.

Stations of the Section II were situated in areas with deeper water depths (from 22 to 160 m) comparing with Section I. The salinity was ranging from 4.9 to 20.3 ‰ in the surface water and from 29.1 to 34.2‰ in the near-bottom water. The water temperature is lower and shows negative values near bottom sometimes (Fig. 8.6).

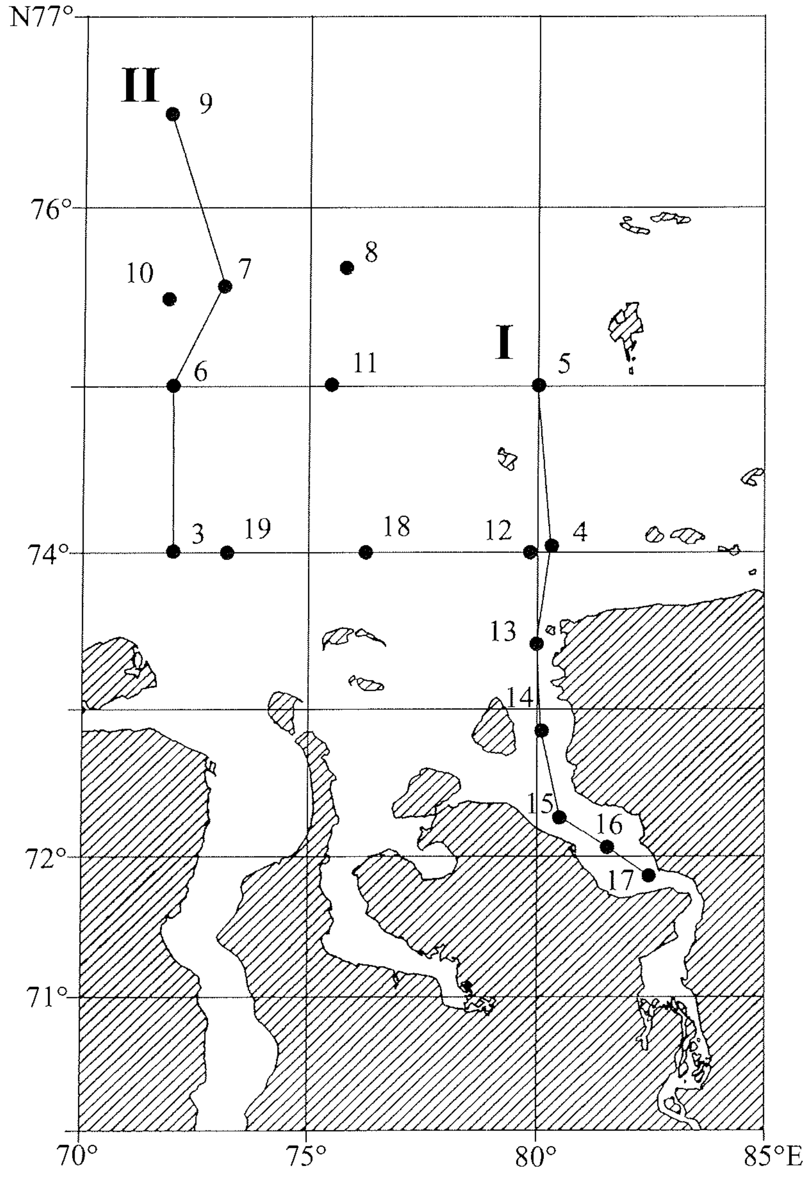

Figure 8.3: Stations on the 39th cruise of RV "Akademik Boris Petrov" in 2003.

The hydrochemical parameters distribution pattern along the Section II is shown in Figs. 8.6 and 8.7. Oxygen concentration in seawater is higher than that in the Yenisei Estuary. Unusual distribution pattern of inorganic phosphate in the seawater area was revealed (Fig. 8.7). Usually phosphate concentration decreases northward over the Kara Sea shelf because of phosphate consumption by phytoplankton and progressive dilution of transformed riverine water with saline seawater. In August 2003, phosphate concentrations were very high (up to 0.97 μM) in the open sea and the spatial distribution of phosphate did not show any interconnection with water salinity (Table 8.3, Fig. 8.7). This phenomenon as well as the decreasing salinity and alkalinity of the seawater in the studied area might be concerned with the sea-ice regime in this year: numerous thawing "dirty" ice were present in sea water between 75 and 76.5° N.

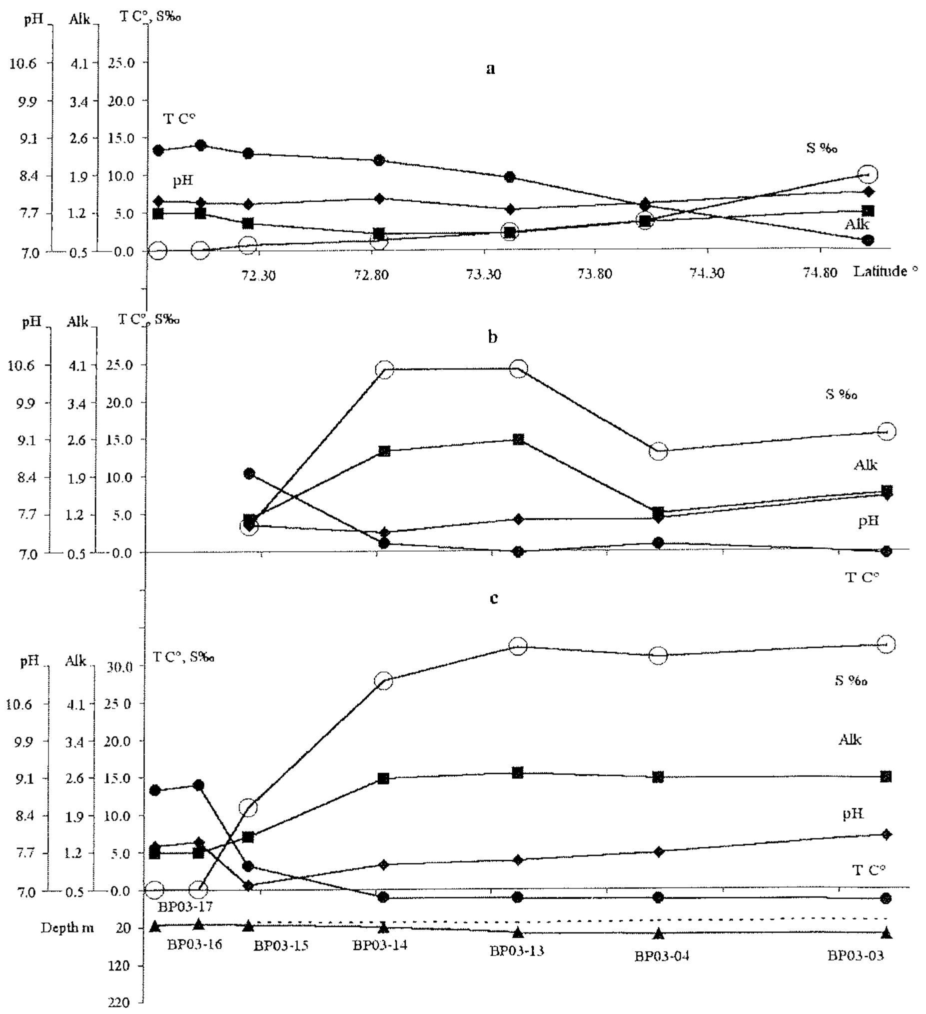

Figure 8.4: Hydrochemical parameters throughout the Kara Sea water mass along the meridional profile I.

a Surface water

b pycnocline horizon

c near bottom water

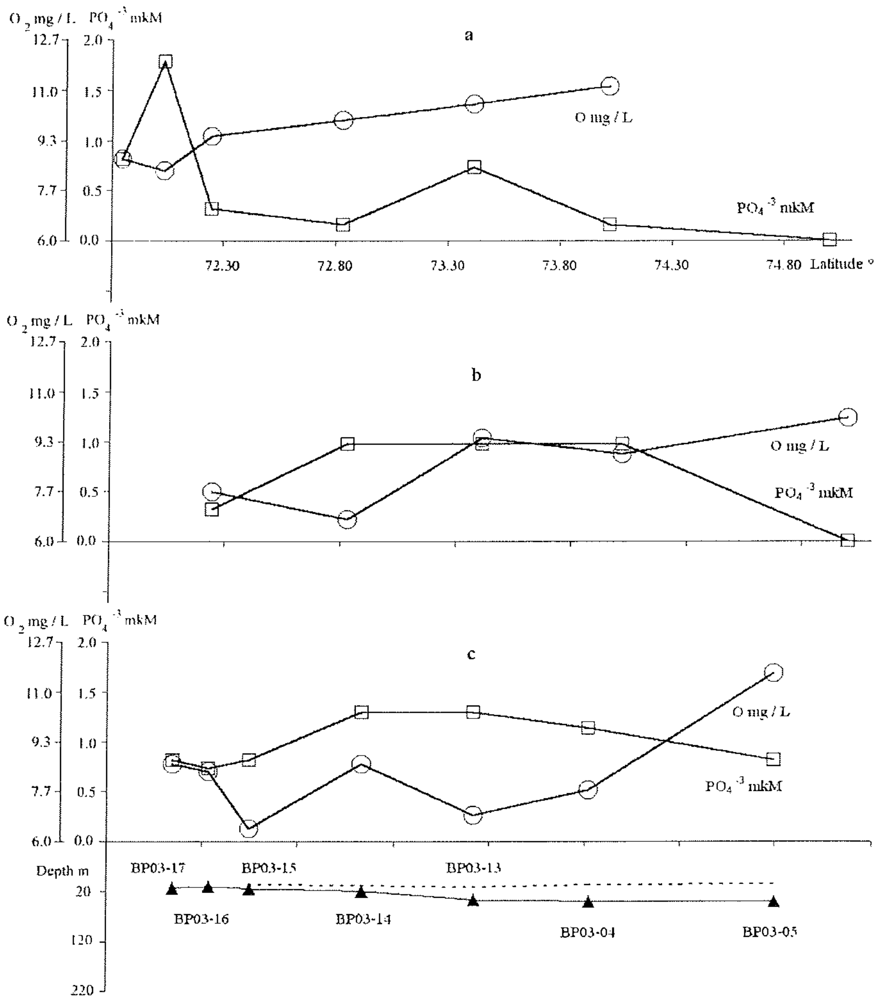

Figure 8.5: Hydrochemical parameters throughout the Kara Sea water mass along the meridional profile I.

a Surface water

b pycnocline horizon

c near bottom water

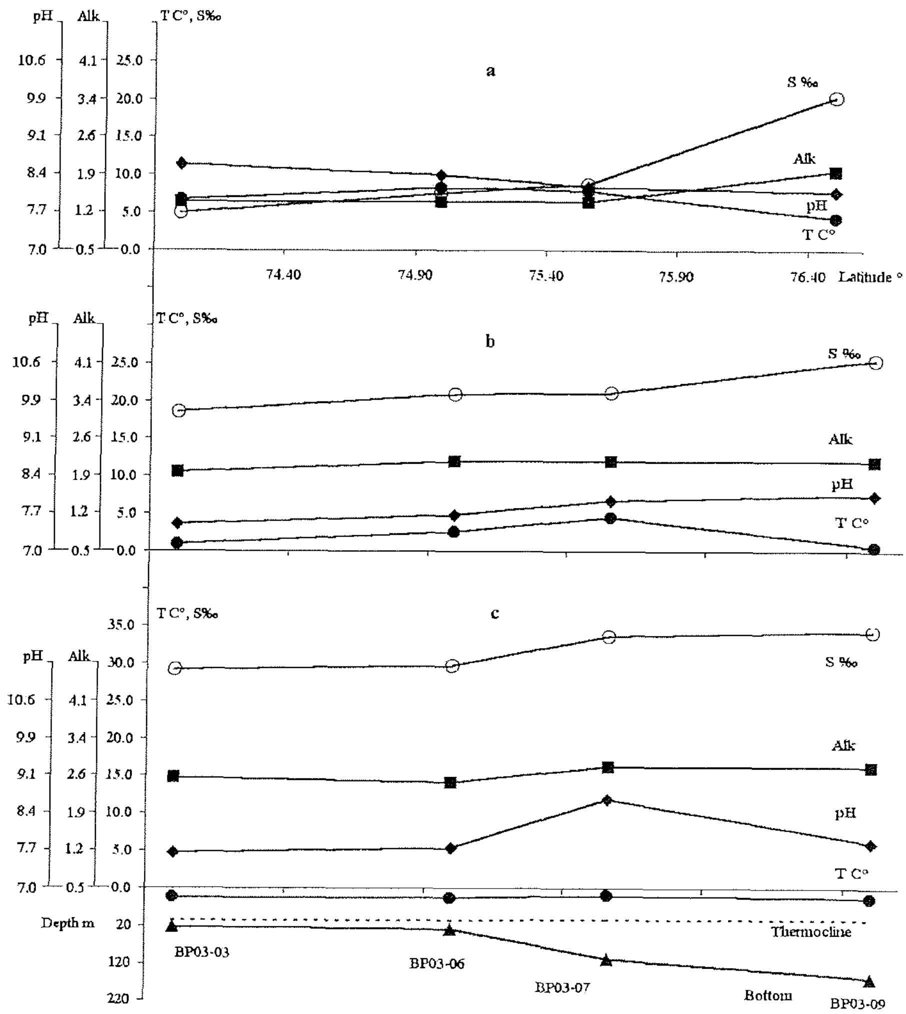

Figure 8.6: Hydrochemical parameters throughout the Kara Sea water mass along the meridional profile II.

- a Surface water
- b pycnocline horizon
- c near bottom water

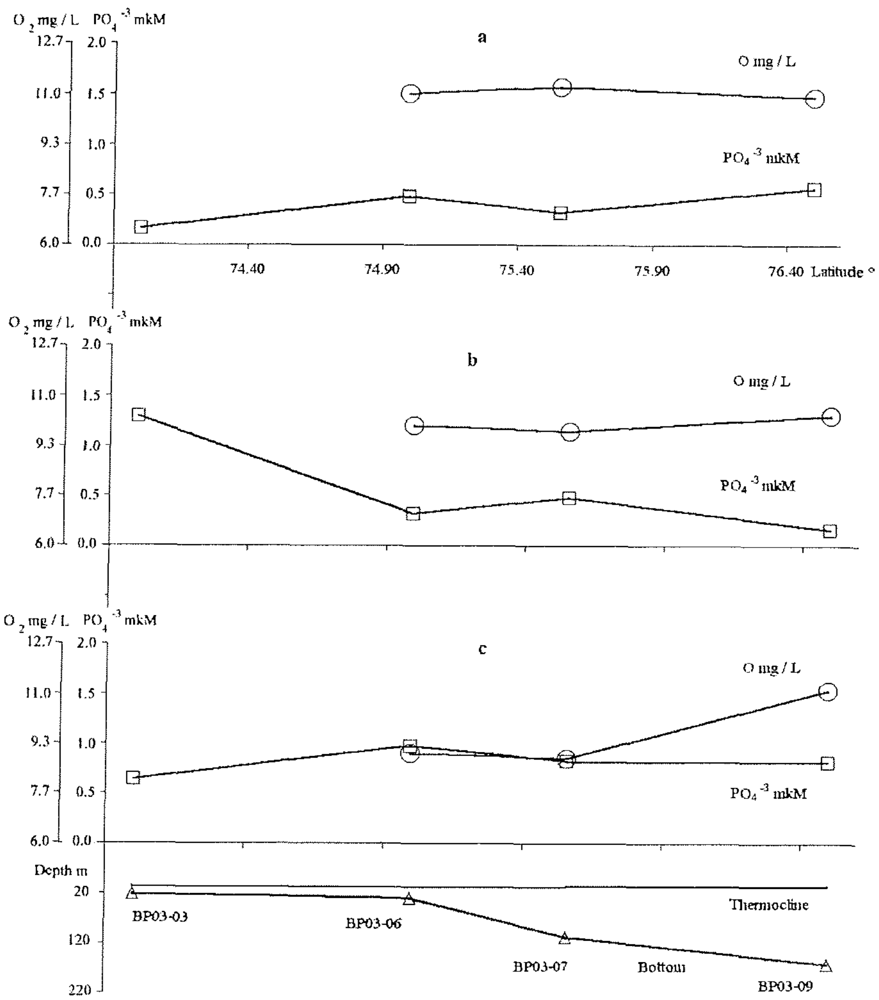

Figure 8.7: Hydrochemical parameters throughout the Kara Sea water mass along the meridional profile II.

- a Surface water
- b pycnocline horizon
- c near bottom water

Table 8.3: Hydrochemical parameters of the water mass in the study Kara Sea water area. (RV "Akademik Boris Petrov" 39th cruise. August 2003.)

Station number, latitude *longitude*	Water depth, m	Sampling horizon, m	T, C°	S, ‰	pH	TAlk mM	Oxygen		Phosphate μM
							% satur.	mg / L	
BP03-03	22	0	6.7	4.9	8.62	1.4	-	-	0.16
74° 00'09" N		7	0.9	18.5	7.5	2.0	-	-	1.29
72° 00'40" E		14	-1.3	29.1	7.66	2.6	-	-	0.64
BP03-04	40	0	5.7	3.7	7.86	1.0	101.2	11.1	0.16
74° 01'28" N		7.5	0.9	13	7.61	1.2	89.7	8.9	0.97
80° 18'50" E		30	-1.4	30.9	7.68	2.6	65	7.7	1.13
BP03-05	41	0	1	9.7	8.06	1.2	-	-	0.00
74° 59'48" N		5	-0.4	15.6	8.03	1.6	73.3	10.1	0.00
80° 00'70" E		30	-1.6	32.3	8	2.6	82.4	11.6	0.81
BP03-06	30	0	8.2	7.5	8.42	1.4	101.1	11.0	0.48
74° 59'48" N		8	2.6	20.8	7.69	2.2	80	10.0	0.32
72° 01'12" E		20	-1.4	29.7	7.77	2.5	70.2	9.0	0.97
BP03-07	108	0	7.8	8.7	8.2	1.4	101.8	11.2	0.32
75° 33'37" N		6	4.4	21.1	7.95	2.2	76.9	9.8	0.48
73° 07'25" E		94	-1	33.6	8.68	2.8	69.2	8.8	0.82
BP03-08	55	0	0.9	9.8	8.13	1.5	84.2	11.2	0.97
75° 37'06" N		4	-1	27.4	8.06	2.4	83.1	11.3	0.16
75° 42'19" E		44	-1.5	32.5	7.79	2.6	68.1	8.9	0.81
		—	-	2.2	-	0.5	-	-	0.00
BP03-09	160	0	4.2	20.3	8.09	2.0	85.5	10.9	0.56
76° 30'01" N		5	0.5	25.4	8.07	2.2	82.3	10.3	0.16
71° 59'38" E		140	-1.4	34.2	7.86	2.8	83.4	11.1	0.81
BP03-11	39	0	5.8	10.6	8.11	1.5	90.5	11.7	0.00
75° 00'00" N		6.5	0.1	22	8.16	2.2	83.1	11.2	0.08
75° 27'55" E		29	-1.6	30.7	7.95	2.8	75	9.8	0.32

BP03-13 73° 25'03" N 80° 00'02" E	37	0 11 26	9.5 -0.2 -1.3	2.2 24.1 32.2	7.74 7.58 7.54	0.8 2.6 2.7	93 74.5 54.5	10.5 9.4 6.9	0.73 0.97 1.29
BP03-14 72° 50'05" N 80° 04'57" E	20	0 9 13	11.8 1 -1.1	1.2 24.1 27.7	7.97 7.34 7.46	0.8 2.4 2.6	92.7 54.1 70	10.0 6.7 8.6	0.16 0.97 1.29
BP03-15 72° 14'59" N 80° 29'59" E	15	0 6.5 10	12.8 10.4 3.1	0.6 3.3 10.9	7.88 7.49 7.07	1.0 1.1 1.5	90.3 70.6 58.4	9.5 7.7 6.4	0.32 0.32 0.81
BP03-16 72° 02'14" N 81° 30'57" E	10	0 6	13.9 13.9	0 0	7.9 7.9	1.2 1.2	80.4 83.2	8.3 8.3	1.78 0.73
BP03-17 71° 50'58" N 82° 25'23" E	13	0 8	13.3 13.2	0 0	7.94 7.82	1.2 1.2	82.9 84.7	8.7 8.6	0.81 0.81
BP03-18 74° 00'06" N 75° 59'59" E	25	0 6 18	9.2 -0.2 -1.5	6.6 17.6 29.8	8.33 7.69 7.56	1.4 1.9 2.7	99.8 89.5 87.4	11.3 11.8 9.5	0.16 0.40 0.40
BP03-19 73° 59'55" N 73° 07'49" E	34	0 7 24	9.3 4.9 -1.6	4.5 14 30	8.37 7.31 7.72	1.5 1.8 2.7	100.7 70.4 87.1	11.4 8.6 10.6	0.16 0.40 0.40

8.3. The technogenic pollution of the Yenisei Estuary and adjacent part of the Kara Sea based on the data of the expeditions 2002-2003

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Introduction

The main tasks of our investigations were to study the horizontal and vertical distribution of anthropogenic pollutants such as radionuclides and heavy metals in the water column and surface sediments and to find the interaction between natural environmental parameters and behavior and migration of pollutants.

There are several sources of anthropogenic pollution the Kara Sea. But at present the large Siberian rivers are the most important potential source of the Kara Sea and further of the Arctic basin. It is known, that the pollution by waste water from Krasnojarsk Minning and Chemical plant and Mayak plant is observed good in the Yenisei and Ob Bays, but also in the Kara Sea, far away from the discharge sites.

Sampling and Analytical Methods for radionuclides

Sediments were sampled with a box corer (50x50x60 cm), with subsequent subsampling with a plastic tube having an inner diameter of 10 cm. The cores were cut in 2 cm slices, and samples were dried at a temperature of 60 - 80^0 C. Water was sampled with a large volume sampler (200 l Batomat) or taken by a pump through a plastic tube system, and filled in storage tanks. Before analysis the samples were filtered through a cartridge filter to remove suspended matter >0.45 μm.

For the analysis of ^{137}Cs in sediments we used direct γ-measurements without decomposition of the sample. ^{137}Cs was determined in water samples of 200 l volume using the sorption method under dynamic conditions with subsequent γ-spectrometer measurements on concentrates.

The determination of ^{90}Sr in the water samples included precipitation of strontium carbonate, which then was finally precipitated as strontium oxalatum.

For the analysis of plutonium in water samples Pu was precipitated with iron hydroxide with subsequent radiochemical cleaning and adsorption of Pu on LaF_3. To analyze Pu concentrations in sediment cores Pu was extracted by boiling of the sediment sample in 7M HNO_3 with $KBrO_3$. Afterwards the sample was treated like the water samples for Pu analysis.

Within the framework of SIRRO samples of bottom deposits from surface layer (0-2 cm) from the stations of the expeditions between 2001 und 2003 were selected and analyzed for heavy metals. The contents of heavy metals are determined by a method with usage of a X-ray spectrometer, which one allows to determine chemical elements from Ti up to Sr till C-linium and from Ba up to U on a L-line on fluorescent radiation. The power in a central portion of the spectrum (~30 Ev) allows to supply a sharp response for a analysis with minimum errors of measurements. The determination of the contents of elements is carried out by using of external standards. Onboard of RV «Akademik Boris Petrov» approximately 150 samples from surface sediments (0-2 cm) were analyzed for 12-19 elements during the expeditions 2001-2003.

Results and discussion

1. The distribution of ^{137}Cs and $^{239,240}Pu$ in the surface sediments (0-2 cm) collected during the 2002-2003 expeditions campaign was studied in detail. The data of the ^{137}Cs radionuclide concentration are presented in table 8.4, the results of concentration of radionuclide ^{90}Sr are in table 8.5.

Table 8.4: The data on ^{137}Cs distribution in the upper layer (0-2cm.) of the bottom sediments measured in the 39th cruise of RV "Akademik Boris Petrov"

	Station	Concentration of ^{137}Cs, Bq/kg (P=0.95)
1	BP03-03	1.2 ± 0.4
2	BP03-04	13.8 ± 3.0
3	BP03-05	7.5 ± 2.0
4	BP03-06	4.1 ± 1.7
5	BP03-07	3.7 ± 1.1
6	BP03-08	5.4 ± 0.9
7	BP03-09	6.6 ± 1.2
8	BP03-10	14 ± 2
9	BP03-11	1.8 ± 0.7
10	BP03-12	20.4 ± 3.5
11	BP03-13	35.3 ± 8.8
12	BP03-14	53 ± 8
13	BP03-15	47 ± 9
14	BP03-16	37 ± 5
15	BP03-17	4.7 ± 1.3
16	BP03-18	7.7 ± 1.6
17	BP03-19	13 ± 3

Table 8.5: The results of ^{90}Sr in the water samples of the cruise of RV «Akademik Boris Petrov».

Station	Depth, m	Salinity, ‰	Activity, Sr-90, Bq/m^3
BP02-01*	3	26.9	1.7±0.7
BP02-01	3	26.9	2.3±0.9
BP02-02	3	11.0	1.5±0.6
BP02-06	3	0.05	7.2±2.0
BP02-12	3	8.0	5.1±2.0

The study of horizontal distribution of radionuclides in upper layer of bottom sediments in studied areas shows that the ^{137}Cs concentration varied between 1.4-50.0 Bq/kg, with the mean 12.4 Bq/kg, ^{90}Sr concentration have interval 5-10 Bq/kg, the $^{239,240}Pu$ concentration varied between 0.1-1.0 Bq/kg.

There is a connection between of radioactivity ^{137}Cs and clay content in samples (Fig. 8.8). In this figure we have added our previous data received in several parts of the Kara Sea.

You can see that in places, where the sediments consist mainly of clay, a rather high content of ^{137}Cs was observed in samples. The influence of the geochemical parameters of the upper sedimentary layer on the activity distribution patterns is recorded to a certain extent in the lateral distribution of $^{239,240}Pu$, though quantity of the analyzed samples was very less (Fig. 8.9).
Thus, the horizontal distribution of radionuclides is irregular and their concentration depends on lithology and structure of sediments, which provides the necessity to carry out combined investigations of radioactivity and geochemical parameters in the study area.

2. Our investigations of vertical distribution of man-made radionuclides ^{137}Cs in sediments showed that specific concentration of this radionuclide shows significantly variations with depth in some sediment columns. The distribution of the radionuclide in the upper sedimentary layer shows that the observed fluctuations are not controlled by the vertical heterogeneity in the sedimentary sequence and may be explained by a variable influx of radioactive components to sediments at different time intervals. It allows to use the determination of the ages of recent sediments using measurements of trace radioactivity for evaluation of time intervals of massive fluvial input from radiochemical plants of Ural and Siberia into the marine area in the past (Hewitt 2000).

For example, a detailed consideration of ^{137}Cs distribution with depth reveals, that in some samples from Yenisei Bay we observed a peak in depths of 12-13 cm (Fig. 8.10). It corresponds approximately to 1960-1967. It may be related to activity of the Krasnoyarsk mineral processing plant, when after accident the greatest amount of radioactivity entered the Yenisei River and then the Yenisei Bay. The estimation of sedimentation rate for modern sediments in Yenisei Bay and the open part of Kara Sea basin coincide with data of other investigators for this region (Stepanets at al. 2000, Dahle et al. 1994).

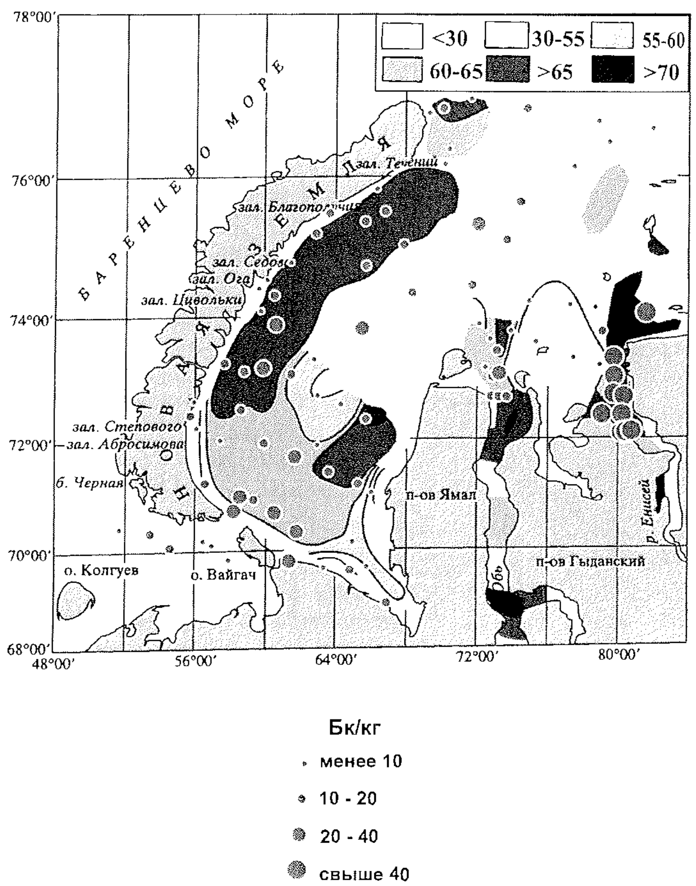


Figure 8.8: ^{137}Cs-radioactivity (in Bq/kg, in intervals of <10, 10 – 20, 20 – 40, >40) and clay content (in %) of upper layer of the bottom sediments.

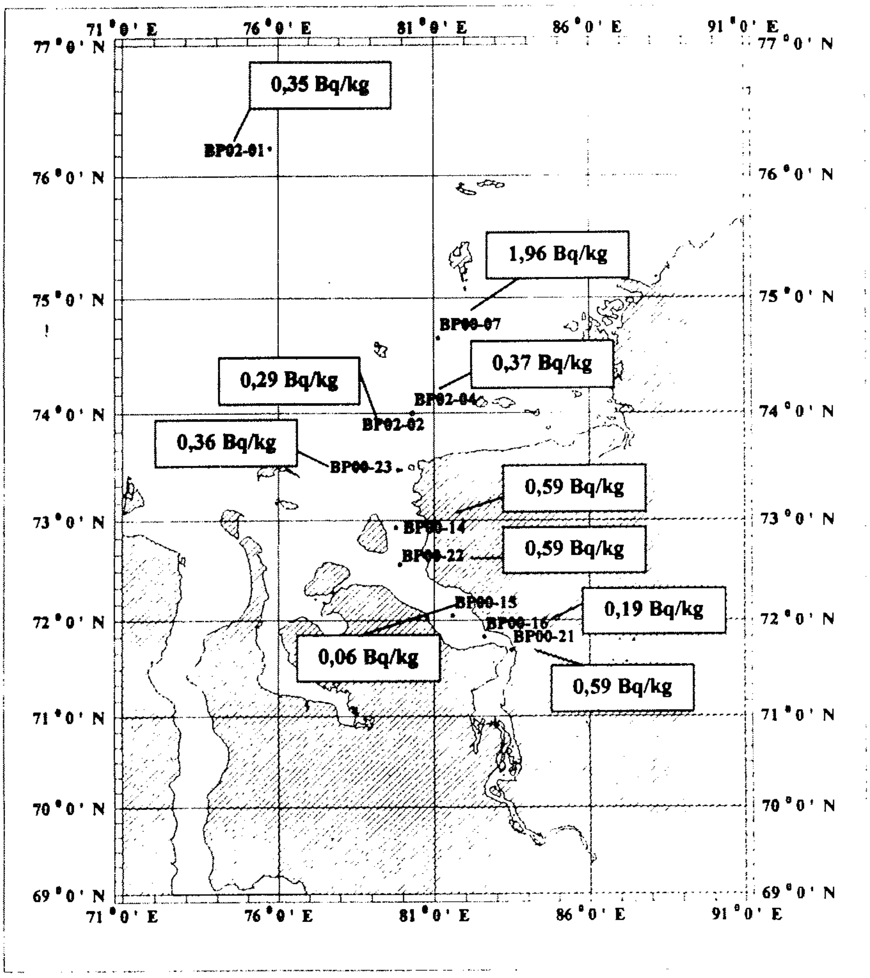


Figure 8.9: Distribution of $^{239,240}Pu$ in upper layer of bottom sediments.

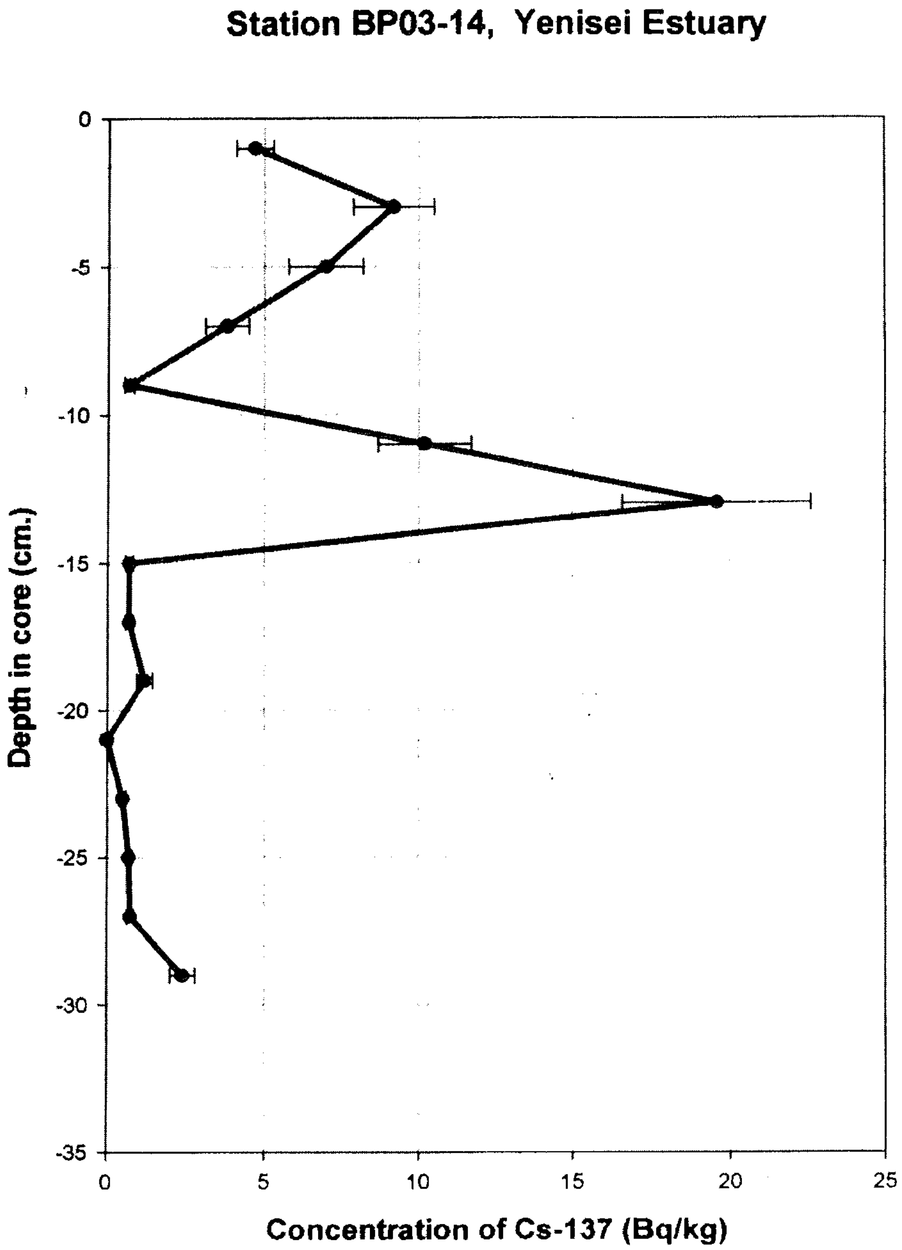


Figure 8.10: Concentration of ^{137}Cs vs. depth in sediment core BP03-14.

3. The concentrations of water-soluble species ^{137}Cs increase with increasing salinity, in opposite the concentration of strontium decrease with increasing salinity.

Table 8.6: Activity of ^{137}Cs in bottom sediments.

Station	Depth [m]	Salinity [‰]	Volume [l]	Concentration of ^{137}Cs (P=0.95) [Bq/m^3]
BP03-01	100	34.6	195	3.5 ± 0.7
BP03-02	85	34.5	169	7.5 ± 1.8
BP03-03	3	8.4	195	1.2 ± 0.4
BP03-04	3	5	158	0.8 ± 0.3
BP03-07	95	34.5	182	8.6 ± 2.1
BP03-09	145	34.6	155	4.0 ± 1.4
BP03-10	3	9.8	170	2.1 ± 0.5
BP03-11	3	11.9	175	3.9 ± 1.1
BP03-13	3	3	130	0.7 ± 0.3
BP03-14	3	1.5	205	0.8 ± 0.3
BP03-15	3	1.0	168	0.6 ± 0.3
BP03-17	3	0.1	180	0.6 ± 0.3
BP03-18	3	7.9	190	1.2 ± 0.4

It may be related with several behaviour of these radionuclides and their stable isotopes in river and sea water and influence of several sources of radioactive contamination on this basin. The similar results for ^{137}Cs were observed former by other investigators (Nikitin at al. 1992).

Table 8.7: The results of ^{90}Sr in the water samples, selected in 2002-cruise.

Station	Depth [m]	Salinity [‰]	Activity ^{90}Sr [Bq/m^3]
BP02-01*	3	26.9	1.7±0.7
BP02-01	3	26.9	2.3±0.9
BP02-02	3	11.0	1.5±0.6
BP02-06	3	0.05	7.2±2.0
BP02-12	3	8.0	5.1±2.0

Table 8.8: The results of ^{90}Sr in the water samples, selected in 2003-cruise.

Station	Depth [m]	Salinity [‰]	Activity ^{90}Sr [Bq/m^3]
BP03-01	85	34.5	1.3±0.3
BP03-03	3	8.4	6.8±1.4
BP03-04	3	6.0	5.9±1.2
BP03-07	95	34.5	1.6±0.3
BP03-09	145	34.5	2.3±0.5
BP03-11	3	11.9	4.9±1.0
BP03-14	3	1.5	4.3±0.9
BP03-17	3	0.1	5.1±1.0

It means, that the main source of radioactivity in this area is the global fallout. Nevertheless, taking into account the potential sources of radioactivity, which may influence the pollution of Siberian rivers, we believe that the monitoring studies of radioecological conditions in the Ob and Yenisei estuaries and adjacent part of the Kara Sea are important and should involve geoecological data on the environments of these regions, too.

Thus, our studies yielded to rather objective characteristics of radioecological conditions in the estuaries of the Ob and Yenisei rivers and the adjacent regions of the Kara Sea.

4. Statistic parameters of the distribution of chemical elements in the surface sediments and the different rock types are presented in Table 8.9. – 8.11. The surface sediments of the study area are rich in elements such as Fe, Mn, Cu, Zn, Pb, As and Br relative to both, the average composition of the Earth's crust and the mentioned sedimentary rocks. Most studied samples differ much from the average composition of deep-water clays because they are depleted in most elements. This reflects the geological structure of the catchment area of Ob and Yenisei, which are tundra and taiga landscapes with permafrost. Thus, high contents of Fe and Mn in the muds are related to their accumulation in dead plants. Then, owing to low activity of microorganisms under low temperatures, dead plants are accumulated at the soil surface and are washed into the rivers in spring (Lisitsyn 1995). Elevated contents of Cu, Zn, Pb, As and Br are primarily related to the presence of large copper-pyrite and copper-zink deposits, ores of the Siberian trapp basalts and rocks of the Taimyr Peninsula, which are characterized by granitophylic associations of chemical elements.
The large difference in chemical composition between the surface sediments from the Ob and Yenisei estuaries and the oceanic sediments (red oozes) shows that the sediments were formed in the shallow littoral zone of the inner shelf. The main parameter responsible for the variability is iron which is characterized by a bimodal distribution curve. Prominent are two maxima with the average contents of 7.9% and 4.3%, respectively; the differences are statistically important. The relationship between the variable contents of Fe and other elements will be considered in more detail.

The analysis of the contents of Fe and associated chemical elements revealed two different sediment groups (Fig. 8.11): the first one with Fe > 6.0% (average content) and the second one with Fe < 6.0%. Each group is characterized by statistic significant distribution of elements and correlation dependencies. The correlation between the contents of chemical elements and the two sediment groups, tested by the Student t-criterion, revealed that most elements show statistically important differences. The differences are statistically insignificant only for Ba. The sediment group with low contents of Fe also shows high values of dispersion of the contents of chemical elements.

Two groups of elements can be distinguished because of the character of correlation with Fe (Fig. 8.12). The first group includes Co, V, Ni, Ti, Cr, Cu, Zn and Ba and shows a bit high statistically significant correlation with Fe. The second group includes Mn and Pb and shows low insignificant or negative correlation to Fe. Correlated with sediments with low contents of Fe (< 6.0%), whereas it is statistically insignificant correlated with sediments with high contents of Fe (> 6.0%). Ba showing low correlation coefficients with Fe for the second sediment group is the exception.

The regional distribution of the two sediment groups in the investigation area of the Ob and Yenisei estuaries is shown in Figure 8.12. A well-defined zonation is observed: The inner zone presented mainly by sediments with high contents of iron (> 6.0%) is replaced northwestward by sediments with low contents of iron (< 6.0%). The observed zonation corresponds to the distribution of river waters in the marginal filter zone. These data are similar of our earlier results from 1999-2000 expeditions.

Two geochemical types of sediments can be clearly distinguished based both on absolute contents of chemical elements and the structure of their correlation with Fe. The first type is characterized by high contents of Fe, Ti, V, Cr, Ni, Co, and Zn by the lack of any correlation between these elements and Fe. This type is spatially confined to the inner zone of the marginal filter characterized by subsaline waters with maximum influence of fresh waters (Fig. 8.12). According to Lukachin et al. (1999) the main process responsible for the composition of these sediments is their mechanical differentiation that is supported by the lack of correlation coefficients between elements in this geochemical sediment type.

The second geochemical type of surface sediments with low contents of Fe, Ti, V, Ni, Co, Zn, Ba and significant positive correlation with Fe reflects sedimentation in the marine environment where chemical elements are accumulated due to their sorption from sea water by Fe- and Mn-hydroxides. This type occurs in the outer zone of the marginal filter where saline waters are associated with low suspension concentrations (Lukashin et al. 1999).

The zonation of geochemical types in the surface sediments distinctly reflects the influence of Yenisei water which is drifting westward, and the penetration of sea waters into the Ob Bay. Therefore, the first geochemical type of the surface sediments has a widespread westward distribution.

The regular distribution of Pb and Mn, and the absence of any correlation with Fe in surface sediments of the study area may indicate different sources of the elements appearance in the water area, and their presence in water mainly in dissolved form.

The data on Fe content in the upper layer of sediments show, that the influence of discharge of the Yenisei River into the Kara Sea is noticed far in the northeast direction.

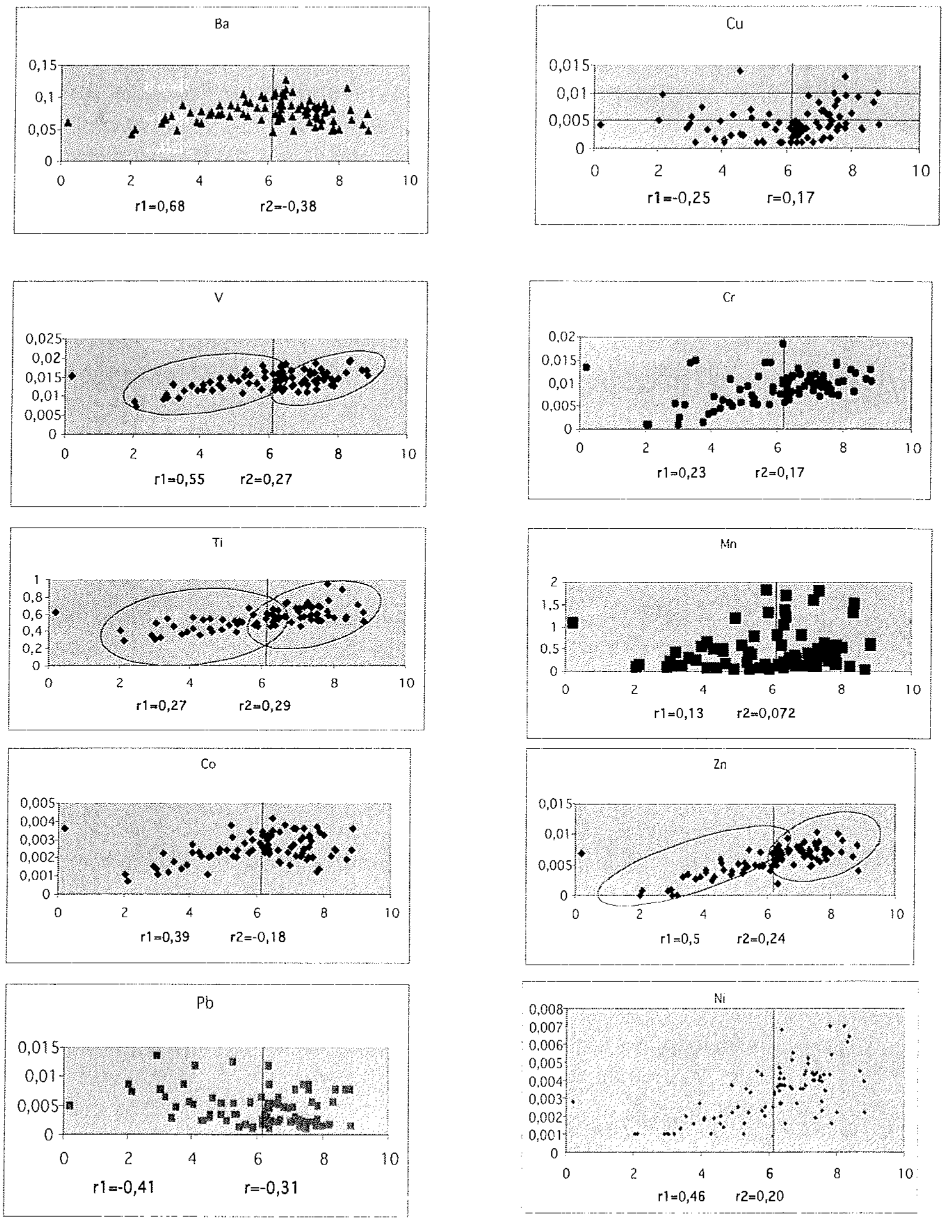
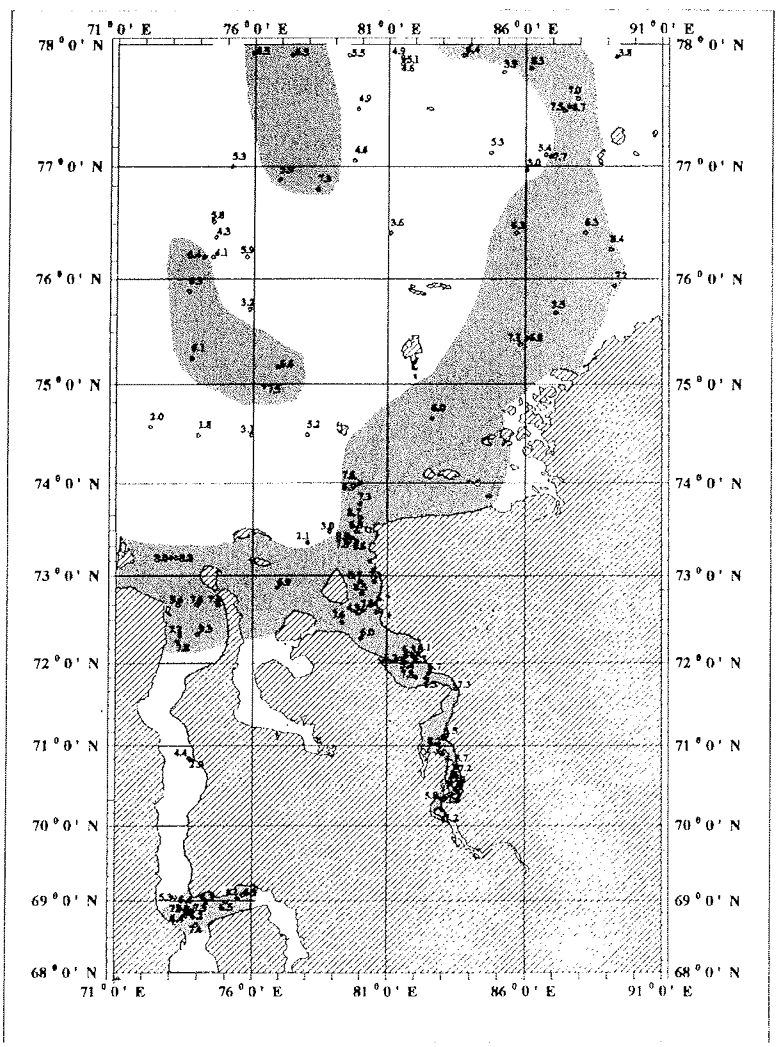


Figure 8.11: Correlation between contents of different elements and iron.

Thus, the preliminary results show significant differences in the contents of several elements in the sediments of Ob and Yenisei estuaries, that can be explained by a various geochemical nature of bottom sediments of these rivers.

The consequent X-ray-fluorescent analysis of samples in stationary conditions of laboratory with use of ratio of various elements to a "reference" element will allow in more detail to evaluate influence of a geological nature of the rivers to an element structure of deposits of a mixing zone and to reveal the possible contribution of anthropogeneous effect of heavy elements on this water area.



- <6 %   - >6 %

Figure 8.12: Spreading of the Yenisei River material into the Kara Sea (on example of the iron content in top layer of the bottom sediments).

Conclusions and Outlook

The distribution of ^{137}Cs in the top layer (0-2cm) of the bottom sediments on all stations is irregular. In the Yenisei Bay high concentrations of this radionuclide are observed. If we consider the data on ^{137}Cs radioactivity, which we obtained in this expedition, in combination with the lithology and geochemical activity of the sediments we can estimate the peculiarities in the distribution of this radionuclide in the Yenisei Estuary. Thus, the reduced sediments are represented by sandy mud that don't absorb cesium, consequently, the ^{137}Cs concentration is very low. On the contrary, if the bottom sediments are characterized by a high fraction of partially oxidized clays, with high capabilities of absorbing ^{137}Cs, the specific activity of ^{137}Cs is higher in the bottom sediments.The influence of the geochemical parameters of the upper sedimentary layer on Pu-radionuclides activity distribution is recorded, although we have for this radionuclide a low number of analyzed samples.

The investigation of the distribution of cesium and strontium radionuclides in water samples shows that the concentration of these two radionuclides is low in filtered samples of water. The results of Cs- and Sr-radionuclides distribution between solution and suspended matter show that for sea water the suspended matter may absorb up to 1-10% of ^{137}Cs and ^{90}Sr, for the water samples of rivers these value can reach 15-30%. This means, that the coefficient of ^{137}Cs concentration (the first time) by suspended matter may be as high as 10^1-10^2. Therefore suspended matter, together with mobile clay phase of the upper layer of bottom sediments may transfer considerable amounts of ^{137}Cs (and other isotopes). For ^{90}Sr and $^{239,240}Pu$ radionuclides we found that these radionuclides are able to form complexes with dissolved organic matter, especially in solutions with low salinity.

Our further investigations were to obtain information about contents and distribution of heavy elements, including presence of anthropogenous heavy metals, which enter the Kara Sea in consequence of the working of the mining plants.We have confirmed in this cruise the investigations on determination of heavy metals in bottom sediments by X-Ray fluorescent method.

In our opinion, these investigations are important for the understanding of behavior and transfer of radioactive elements – as marker of processes in the river-estuaries-sea geochemical system.
Thus, our studies yielded the rather objective characteristics of technogenic situation in estuary of the Yenisei River and adjacent part of the Kara Sea in 2003.

Table 8.9: Results of the heavy metals determination in the surface bottom sediments [%].

Station	Pb	Sc	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti	Ba
BP-01-01	0.001	<0.01	0.0085	0.01	0.004	0.0019	7.48	0.65	0.0092	0.0172	0.6	0.055
BP-01-03	0.0015	<0.01	0.0068	0.0038	0.004	0.003	7.3	0.52	0.0104	0.0162	0.7	0.053
BP-01-04	0.0018	<0.01	0.01	0.0094	0.007	0.0021	8.22	0.13	0.013	0.0161	0.88	0.114
BP-01-05	0.0018	<0.01	0.005	0.0034	0.0045	0.0028	5.66	0.09	0.0144	0.0133	0.67	0.084
BP-01-06	0.0018	0.05	0.0074	0.0128	0.007	0.0012	7.8	0.18	0.0144	0.013	0.95	0.047
BP-01-07	0.0054	<0.05	0.0047	0.0046	0.0043	0.0023	5.78	0.17	0.0054	0.0118	0.59	0.065
BP-01-08	0.0031	<0.05	0.0063	0.0019	0.0049	0.0036	7.16	0.13	0.0119	0.0156	0.68	0.094
BP-01-09	0.0051	<0.05	0.0038	0.0014	0.0018	0.0023	4.08	0.09	0.007	0.0117	0.56	0.078
BP-01-10	0.0051	<0.05	0.0074	0.0062	0.0051	0.0018	6.66	0.16	0.0077	0.0127	0.72	0.071
BP-01-11	0.0031	<0.05	0.0072	0.0048	0.0041	0.003	6.3	0.15	0.0091	0.0138	0.59	0.088
BP-01-12	0.0026	<0.05	0.005	<0.001	0.0033	0.0032	6.16	0.18	0.0106	0.0139	0.61	0.102
BP-01-13	0.0026	0.015	0.0075	0.0096	0.0055	0.0017	6.7	0.14	0.0119	0.0129	0.74	0.047
BP-01-14	0.0026	<0.015	0.0068	<0.001	0.0037	0.003	6.32	0.09	0.0111	0.0146	0.66	0.09
BP-01-15	0.0026	<0.015	0.0075	0.0095	0.0054	0.0014	7.84	0.19	0.0102	0.0139	0.76	0.051
BP-01-16	0.0026	<0.015	0.0068	0.0061	0.0044	0.0021	7.28	0.12	0.007	0.014	0.74	0.086
BP-01-17	0.0021	<0.015	0.008	0.0037	0.0043	0.0026	7.04	0.15	0.0106	0.0143	0.67	0.073
BP-01-18	0.0021	0.02	0.0103	0.0086	0.0039	0.0026	7.56	0.37	0.009	0.0141	0.7	0.076
BP-01-19	0.0021	<0.02	0.0087	0.0058	0.0043	0.0029	7.62	0.25	0.0085	0.0151	0.68	0.08
BP-01-20	0.0021	<0.02	0.0062	0.0048	0.0044	0.0025	7.4	0.35	0.0116	0.0145	0.68	0.086
BP-01-21	0.0021	<0.02	0.0071	0.002	0.0035	0.0034	6.66	0.34	0.0086	0.0148	0.57	0.108
BP-01-22	0.0072	0.04	0.0008	0.0098	<0.001	0.0007	2.12	0.18	<0.001	0.0072	0.29	0.049
BP-01-23	0.0077	<0.04	<0.0005	0.0056	<0.001	0.0011	3.04	0.16	0.0025	0.0095	0.49	0.065
BP-01-24	0.0077	<0.04	0.0063	0.0083	0.0045	0.0019	8.68	0.06	0.0109	0.0168	0.71	0.057
BP-01-25	0.0077	<0.04	0.0082	0.0099	0.0039	0.0024	8.81	0.61	0.0128	0.0167	0.62	0.074
BP-01-26	0.0077	<0.04	0.0076	0.0039	0.0028	0.0032	7.57	0.36	0.0081	0.0158	0.52	0.091
BP-01-28	0.0077	<0.04	0.0088	0.0067	0.0052	0.0021	7.16	1.62	0.0099	0.0164	0.57	0.06
BP-01-29	0.0077	<0.04	0.009	0.0033	0.0064	0.0024	8.36	1.54	0.0121	0.0193	0.57	0.064
BP-01-30	0.0022	<0.04	0.005	0.0036	0.0047	0.0026	6.31	1.07	0.0081	0.016	0.51	0.072
BP-01-31	0.0022	0.017	0.0074	0.0083	0.0035	0.0016	7.01	0.42	0.0117	0.0171	0.63	0.078
BP-01-32	0.0022	0.013	0.0082	0.0076	0.0042	0.002	7.51	0.46	0.0081	0.0161	0.61	0.064
BP-01-33	0.0062	<0.013	0.0042	0.0023	0.0014	0.0021	4.65	0.2	0.0051	0.0119	0.39	0.074
BP-01-34	0.0086	0.012	0.0026	0.0017	0.0016	0.0014	3.77	0.27	0.0014	0.0126	0.37	0.076

Station	Pb	As	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti	Ba
BP-01-35	0.0086	<0.012	0.0082	0.0028	0.0068	0.0022	6.37	1.25	0.0076	0.0156	0.47	0.087
BP-01-36	0.0055	<0.012	0.003	0.0049	0.0027	0.0016	3.94	0.57	0.0034	0.0113	0.39	0.06
BP-01-37	0.0055	<0.012	0.007	0.0036	0.0061	0.0025	8.31	1.34	0.008	0.0191	0.55	0.08
BP-01-38	0.0055	<0.012	0.0055	0.004	0.0034	0.002	7.65	0.59	0.0076	0.0161	0.52	0.078
BP-01-39	0.0035	<0.012	0.0047	0.0043	0.0022	0.002	5.4	0.4	0.0052	0.0133	0.52	0.07
BP-01-40	0.0035	<0.012	0.0057	0.0027	0.0036	0.0023	6.25	0.62	0.0057	0.0158	0.46	0.062
BP-01-41	0.0048	<0.012	0.0034	0.0033	0.002	0.0018	3.54	0.34	0.0149	0.0113	0.45	0.087
BP-01-42	0.0048	<0.012	0.0049	<0.001	0.0027	0.0038	6.82	0.83	0.0094	0.0112	0.51	0.082
BP-01-43	0.0048	<0.012	0.007	0.0014	0.0037	0.0036	7.08	0.38	0.0083	0.0112	0.46	0.083
BP-01-44	0.0077	<0.012	0.0009	0.0044	<0.001	0.0014	3.01	0.25	0.0009	0.0105	0.3	0.068
BP-01-45	0.0053	<0.012	0.0042	<0.001	0.0016	0.0031	5.29	0.46	0.0055	0.0153	0.39	0.074
BP-01-46	0.0053	<0.012	0.0059	<0.001	0.0016	0.0035	6.48	0.34	0.0116	0.0184	0.55	0.112
BP-01-47	0.0053	<0.012	0.0073	0.0023	0.0044	0.0027	6.33	0.11	0.0077	0.0178	0.51	0.095
BP-01-48	0.0053	<0.012	0.0034	0.007	0.0037	0.0023	4.9	0.08	0.0085	0.0148	0.42	0.07
BP-01-49	0.0024	<0.012	0.0052	<0.001	0.0025	0.0024	5.1	0.62	0.0093	0.014	0.47	0.083
BP-01-50	0.0029	0.013	0.0058	0.014	0.0016	0.0011	4.56	0.48	0.0059	0.013	0.55	0.072
BP-01-51	0.0013	<0.013	0.0074	0.0062	0.0033	0.0024	5.46	0.82	0.0115	0.0156	0.51	0.091
BP-01-52	0.0035	<0.013	0.004	0.0055	0.0022	0.0025	4.92	1.22	0.0059	0.0143	0.53	0.087
BP-01-55	<0.0035	<0.013	0.0053	0.0026	0.002	0.002	4.58	0.54	0.011	0.0145	0.43	0.087
BP-01-56	<0.0035	<0.013	0.0053	0.0042	0.0035	0.0021	5.33	0.07	0.0065	0.0167	0.48	0.093
BP-01-57	0.0013	<0.013	0.0049	<0.001	0.0025	0.0024	5.89	0.08	0.0091	0.015	0.46	0.099
BP-01-58	<0.0013	<0.013	0.0074	0.0061	0.0043	0.0021	7.33	1.82	0.0094	0.0186	0.58	0.07
BP-01-59	0.0055	<0.013	0.007	<0.001	0.0023	0.0034	5.8	1.84	0.0145	0.018	0.47	0.103
BP-01-60	0.0024	<0.01	0.0025	0.0023	<0.001	0.0023	4.29	0.54	0.0045	0.0135	0.36	0.072
BP-01-61	0.001	<0.01	0.0047	<0.001	0.002	0.003	5.88	1.35	0.0081	0.0163	0.49	0.083
BP-01-62	0.001	<0.01	0.0058	0.0023	0.0037	0.0023	6.38	1.73	0.0063	0.0166	0.53	0.066
BP-01-63	0.0118	<0.01	0.0041	0.0011	0.0019	0.0027	4.09	0.69	0.0038	0.0129	0.43	0.058
BP-01-64	0.0118	<0.01	0.0019	0.0025	0.0027	0.0032	6.34	1.38	0.0104	0.0179	0.53	0.082
BP-01-65	0.0064	<0.01	<0.0005	<0.001	<0.001	0.0022	3.19	0.45	0.0053	0.013	0.33	0.07
BP-01-66	0.0064	<0.01	0.0093	0.0035	0.0036	0.0024	6.63	0.37	0.0132	0.0169	0.57	0.088
BP-01-67	0.0064	<0.01	0.004	0.0035	0.0025	0.0028	6.12	0.84	0.0075	0.0158	0.54	0.046
BP-01-68	0.0086	<0.01	<0.0005	0.005	<0.001	0.0011	2.04	0.12	<0.001	0.0087	0.4	0.042
BP-01-69	0.0086	<0.01	0.005	0.0019	0.0019	0.0036	7.38	0.37	0.0104	0.0144	0.53	0.066
BP-01-70	0.0086	<0.01	0.0059	0.0032	0.0023	0.0031	7.57	0.42	0.0095	0.0145	0.55	0.09

Station	Pb	As	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti	Ba
BP-01-71	0.0027	<0.01	0.003	0.0074	0.0013	0.0012	3.38	0.15	0.0145	0.0095	0.55	0.048
BP-01-72	0.0136	<0.01	0.0008	0.0036	<0.001	0.0015	2.91	0.12	0.0055	0.0092	0.35	0.058
BP-01-73	0.0045	<0.01	0.0076	0.0046	0.0027	0.0025	6.36	0.22	0.011	0.0114	0.57	0.106
BP-01-74	0.0045	<0.01	0.0078	0.0041	0.0034	0.0031	6.31	0.23	0.0069	0.0125	0.6	0.09
BP-01-75	0.0045	<0.01	0.008	0.0047	0.0035	0.0023	6.94	0.15	0.0103	0.0132	0.67	0.088
BP-01-76	0.0018	<0.01	0.0048	0.0018	0.0033	0.0034	6.17	0.15	0.01	0.0116	0.59	0.106
BP-01-77	0.0022	<0.01	0.0066	0.003	0.0037	0.0042	6.47	0.27	0.0115	0.0147	0.57	0.128
BP-01-78	0.0023	<0.01	0.0072	0.0051	0.0043	0.0023	7.35	0.38	0.0095	0.0133	0.67	0.074
BP-01-79	0.0125	<0.01	0.0036	0.0013	<0.001	0.0038	5.26	0.23	0.0074	0.0107	0.52	0.104
BP-01-80	0.005	<0.01	0.0059	0.0045	0.0016	0.0034	7.84	0.62	0.0074	0.0126	0.58	0.062
BP-01-81	0.005	<0.01	0.0068	0.0043	0.0028	0.0036	0.2	1.11	0.0133	0.0152	0.62	0.061
BP-01-82	0.0015	<0.01	0.0068	0.0064	0.0022	0.0032	8	0.56	0.0105	0.0144	0.56	0.05
BP-01-83	0.0015	<0.01	0.0039	0.0042	0.0022	0.0036	8.84	0.63	0.0105	0.0156	0.52	0.048
BP-01-73/1	0.0015	<0.01	0.0067	0.0035	0.0043	0.0037	7.8	0.36	0.0138	0.0147	0.63	0.082
BP-01-73/2	0.0023	<0.01	0.0048	0.0043	0.004	0.0031	7.35	0.36	0.0092	0.0116	0.59	0.084
BP-01-73/3	0.0023	<0.01	0.0068	0.0046	0.0032	0.0026	6.17	0.16	0.0186	0.0122	0.61	0.074
BP-01-73/4	0.0023	<0.01	0.007	0.0041	0.0041	0.0032	6.44	0.21	0.0082	0.0119	0.64	0.102
BP-01-73/5	0.0023	<0.01	0.0074	0.0067	0.0045	0.0027	7.09	0.27	0.0097	0.013	0.56	0.076
BP-01-72 A	0.0023	<0.01	0.003	0.0061	0.0019	0.0021	4.37	0.1	0.0064	0.0114	0.53	0.076

Table 8.10: Results of the heavy metals determination in the samples selected in 2002-cruise [%].

Station	Nb	Zr	Y	Sr	Rb	Th	Pb	As	Zn	Cu	Ni	Fe	Mn
BP-02-01	0.0016	0.0126	0.0027	0.0225	0.0088	0.0064	0.0007	0.0009	0.0118	0.0014	0.005	3.35	0.76
BP-02-02	0.0017	0.0123	0.0035	0.021	0.0085	0.0021	0.0017	0.0008	0.0087	0.0015	0.006	4.53	0.11
BP-02-05	0.0014	0.0206	0.003	0.0188	0.0068	0.0093	0.0005	0.0022	0.0071	0.0011	0.0047	4.51	0.17
BP-02-06	0.0014	0.0172	0.0028	0.0153	0.0078	0.0014	0.001	0.0022	0.009	0.0049	0.0064	7.42	0.36
BP-02-07	0.0013	0.021	0.0031	0.0159	0.0092	0.002	0.0025	0.0013	0.0051	0.0067	0.0068	6.39	0.19
BP-02-08	0.0012	0.02	0.0035	0.0184	0.0079	0.0036	0.0026	0.0018	0.0066	0.0032	0.0046	5.58	0.14
BP-02-09	0.0014	0.0262	0.0027	0.0241	0.0086	0.0051	0.0011	0.0027	0.0076	0.0039	0.0045	4.84	0.17
BP-02-12	0.0019	0.0152	0.003	0.0207	0.0091	0.0027	0.0011	0.0014	0.0069	0.0043	0.0074	5.76	0.1

Station	Co	Cr	V	Ce	La	Ti	Ba	Ca	Ga	Se	Nd	Bi	U
BP-02-01	0.0022	0.0097	0.0143	0.0052	0.0051	0.44	0.059	0.65	0.0013	0.003	0.0055	0.0011	0.0002
BP-02-02	0.0026	0.011	0.0167	0.0037	0.0022	0.47	0.044	1.1	0.0013	0.0035	0.0062	0.0007	0.0002
BP-02-05	0.0024	0.0071	0.0093	0.0052	0.0038	0.36	0.061	0.76	0.0014	0.0027	0.0045	<___	0.0004
BP-02-06	0.0013	0.0116	0.0153	0.006	0.0044	0.53	0.075	1.14	0.0013	0.0028	0.0041	0.0004	0.0006
BP-02-07	0.0027	0.0131	0.0126	0.0043	0.003	0.53	0.06	0.77	0.0014	0.0047	0.0036	<___	0.0001
BP-02-08	0.0022	0.0104	0.0116	0.0055	0.0032	0.51	0.062	0.63	0.0017	0.0051	0.0048	<___	0.001
BP-02-09	0.002	0.0081	0.011	0.0054	0.0035	0.51	0.073	1.05	0.0016	0.0058	0.0025	<___	0.0007
BP-02-12	0.0027	0.0112	0.0148	0.0056	0.0039	0.51	0.061	0.69	0.001	0.0064	0.0032	0.0019	0.0005

Table 8.11: The heavy metals concentration in samples selected in the 2003-cruise (St: Station BP03-..; all [ppm] except the elements Mn, Ti, Ba, Ca).

St.	Nb	Zr	Y	Sr	Rb	Th	Pb	As	Zn	Cu	Ni	Co	Fe
03	12	225	22	222	57	1	53	5	20	4	12	23	7.82
04	14	94	27	219	79	8	103	73	98	87	55	17	5.61
05	16	158	29	228	75	38	111	61	68	37	36	12	4.92
06	11	427	15	165	44	2	23	25	24		19	15	1.45
07	10	219	32	205	87		72	35	169	56	32	13	3.99
08	13	159	25	199	80	16	55	9	42	24	31	7	3.12
09	13	190	34	196	82	48	64	32	67	49	51	13	3.93
10	4	152	34	269	103	14	214	84	111	88	66	24	6.90
11	14	313	20	215	43	33	28	16	32	11	6	3	1.09
12	16	143	25	175	90	28	69	128	80	43	56	15	5.71
13	17	131	34	264	103	18	149	30	110	40	62	41	7.42
14	12	119	29	246	79	9	49	36	195	63	74	24	6.74
15	10	108	28	237	69	20	19	20	107	88	74	31	6.06
16	14	143	30	432	6	44	40	22	85	35	62	25	5.82
17	11	87	17	194	31	33	48	8	30	2	22	12	2.13
18	12	327	21	180	46	53	55	35	43	7	25	3	2.75
19	13	147	30	221	95	67	101	31	69	61	27	19	5.34

St.	Mn%	Cr	V	Ce	La	Ti%	Ba%	Ca%	Ga	Sc	Nd	Bi	U
03	034	47	42	54	40	0.19	.057	.57	12	9	40	6	7
04	.217	110	179	50	62	.45	.053	.85	17	19	44	17	5
05	.229	86	169	49	38	.46	.053	.90	16	14	42	3	5
06	.094	75	89	64	44	.34	.067	.062	15	11	51	11	3
07	.414	90	148	61	74	.45	.068	.62	11	13	43	20	4
08	.203	73	154	55	28	.42	.057	.71	10	12	31	28	3
09	.286	83	161	71	55	.48	.072	.66	17	15	51	4	3
10	1.20	110	228	66	54	.57	.072	.59	11	18	28	7	5
11	.158	97	97	59	45	.32	.06	.63	17	9	30	1	3
12.	.322	105	160	57	38	.51	.038	.79	8	15	31	3	3
13	.22	133	228	40	46	.64	.06	.60	7	.18	30	7	5
14	.906	121	18.298	48	30	.62	.051	1.36	10	16	35	11	3
15.	.228	124	165	64	46.	.66.	.055	1.54	16	16	33	13	3
16	.174	110	183	48	34	.64	.061	2.39	11	18	29	16	3
17	.079	51	95	59	44	.25	.057	1.16	13	3	17	11	7
18	.195	.40	122	51	43	.37	.052	.58	12	12	29	23	4
19	.298	93	196	50	75	.49	.059	.59	16	14	46	14	4

9. Material fluxes from the Russian Rivers Ob and Yenisey: Interactions with climate and effects on Arctic Seas (MAREAS)

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Abstract

Understanding the long-term consequences of future changes on river material fluxes, marine cycles, productivity and the numerous feedback loops leading to long-term ecosystem impacts will require knowledge of current conditions. To this end, a field expedition was carried out on the Kara Sea shelf in August 2003 to examine the governing relationships between DOC light (PAR and UV), primary productivity and nutrient availability. This work is expected to help elucidate the role of changing climate, focusing on riverine fluxes on nutrients and dissolved organic carbon (DOC) and the effect of productivity and UV-regimes in Arctic marine waters, and finally to determine the role of these major Arctic Rivers in the transfer of land sources of anthropogenic contaminants to Arctic marine systems. The project will lead to a better representation of present-day and potential future impacts of this major Arctic river system on a local, regional and Pan-Arctic scale.

Introduction

The Arctic seas receive a freshwater input of approximately 4,200 km^3 yr^{-1} (AMAP 1998)), corresponding to about 10% of the global river runoff (Aagaard & Carmack 1989). The Russian rivers Ob and Yenisey are two of the four largest rivers flowing into the Arctic. The Yenisey River is ranked 1^{st} (603 km^3/yr) and the Ob River is ranked 3^{rd} (404 km^3/yr) among Arctic rivers with respect to freshwater discharges (AMAP 1997). These rivers supply the shelf seas with nutrient-rich terrestrial and riverine material. However, they are also carriers of water- and particulate-borne contaminants such as heavy metals, radionuclides and organic contaminants where dissolved organic carbon (DOC) may be a major mediator of contaminant transport from terrestrial and freshwater environments to marine habitats (Opsahl et al. 1999).

Vigorous transformations of organic matter occur on the extensive continental shelves with off-shelf export to the deeper waters of the interior Arctic basin. The flux of DOC from northern areas may range from 1 to 8 tonnes $km^{-2}y^{-1}$ (Hessen 1999) and this flux of DOC strongly depends on soil temperature and hydrology. DOC may also be a main determinant of annual fluxes of nitrogen and iron that fuels marine productivity. In addition, river discharge is central in the establishment of the Arctic Ocean's halocline (Aagaard et al. 1981; Rudels et al. 1996; Schauer et al. 1997; Steele et al. 1995)) and in the inter-hemispheric transport of freshwater (Wijffels et al. 1992).

Climate models predict significant warming in the Arctic in the 21^{st} century, which will impact the functioning of terrestrial and aquatic ecosystems as well as alter land-ocean interactions in the Arctic (IPCC 1998). It has been predicted that the region will experience amplified effects of global climatic changes (Manabe & Stouffer 1994; Rind et al. 1995; Weller & Lange 1999). Arctic ecosystems' limited biodiversity, short food chains, and specialized adaptations to the local environment (e.g. lipid storage) render them particularly susceptible to environmental perturbations. Contamination from either local or far-afield sources, long-term climatic changes, and variations in ultraviolet radiation (UVB) are the most likely factors to significantly impact the Arctic ecosystems.

Climate induced effects on mass transport of DOC to Arctic marine waters, notably the Barents Sea, may profoundly affect the ecosystem in two ways:

1) The flux of DOC and nutrients provide mineral nutrients like phosphorus, nitrogen, silicate or iron that fuels marine primary production. It also supports heterotrophic bacteria with a major source of DOC that may fuel the microbial food web.
2) The flux of DOC has profound effects on light penetration, and especially on the attenuation of ultraviolet radiation (UV-R) (Aas et al. 2001). The export of DOC from Russian rivers causes rather low UV-R exposure for pelagic biota in the Arctic areas, and shifts in levels of DOC will probably have greater effects on the marine UV-attenuation and UV-R effects than the predicted decrease in stratospheric ozone over Arctic areas (Hessen 2001 and articles herein).

The first of two planned research expeditions was carried out during August 2003 to evaluate the spatial extent to which the Ob and Yenisey material discharges influence the adjacent coastal ecosystems. A second expedition is scheduled for August 2004. Project results give perspective on the present-day which will help toward identifying potential future impacts of this major Arctic river system on a local, regional and Pan-Arctic scale under a changing climate.

Field programme

During the cruise from 14^{th} to 29^{th} of August 2003, 19 stations were occupied on the Ob-Yenisey shelf (Fig. 9.1, Table 9.1). Emphasis was given to covering a transect from the Yenisey river mouth northwards across a salinity gradient from 0-35ppt. The main field programme consisted of 5 different activities: I. satellite image collection; II. ultra-violet radiation measurements; III. hydrochemistry; IV. pigments / biological measurements; and V. river-borne contaminants. For reference purposes, CTD profiles and Secchi-depths were recorded at each station and samples were collected for the determination of suspended sediment concentrations and salinity at all sampling depths.

Table 9.1: Norwegian sampling programme in 2003.

Station	Date	Latitude (N)	Longitude (E)	Cont	Hydro	Pigments	UV
BP03-03	18.08	74°00'09"	72°00'40"	+	+	+	+
BP03-4b	18.08	74°01'28"	80°18'50"	+			+
BP03-05	19.08	74°59'48"	80°00'07"	+			
BP03-06	20.08.	74°59'48"	72°01'12"	+			
BP03-09	21.08	76°30'01"	72°02'49"	+	+	+	+
BP03-10	22.08	71°59'53"	71°59'53"		+	+	+
BP03-11	22.08	75°00'00"	75°27'55"	+	+	+	+
BP03-12	23.08	74°00'12"	79°59'34"		+	+	+
BP03-13	23.08	73°25'03"	80°00'02"	+	+	+	+
BP03-13b	23.08	73°20'17"	80°11'45"				+
BP03-14	23.08	72°50'05"	80°04'57"	+	+	+	+
BP03-15	24.08	72°14'59"	80°29'59"		+	+	+
BP03-16	24.08	72°02'14"	81°30'57"	+	+	+	+
BP03-17	24.08	71°50'58"	82°25'23"	+	+	+	+
BP03-17a	25.08	73°37'07"	80°29'54"				+
BP03-17b	25.08	73°48'35"	80°45'35"				+
BP03-18	25.08	74°00'06"	75°59'59"	+	+	+	
BP03-19	26.08	73°59'55"	73°07'49"		+	+	+
BP03-20	26.08	74°00'30"	71°59'16"				+

Cont: Contaminants- 1 composite sample per station
Hydro: Hydrochemistry- salinity, nutrients+Fe, suspended sediment concentration.
Pigments: Pigments/Biology- TSM, DOC, TOC, particulate P, N, C, Yellow stuff, chla, algae, bacteria
UV: UV-measurements- spectrophotometry (310nm)

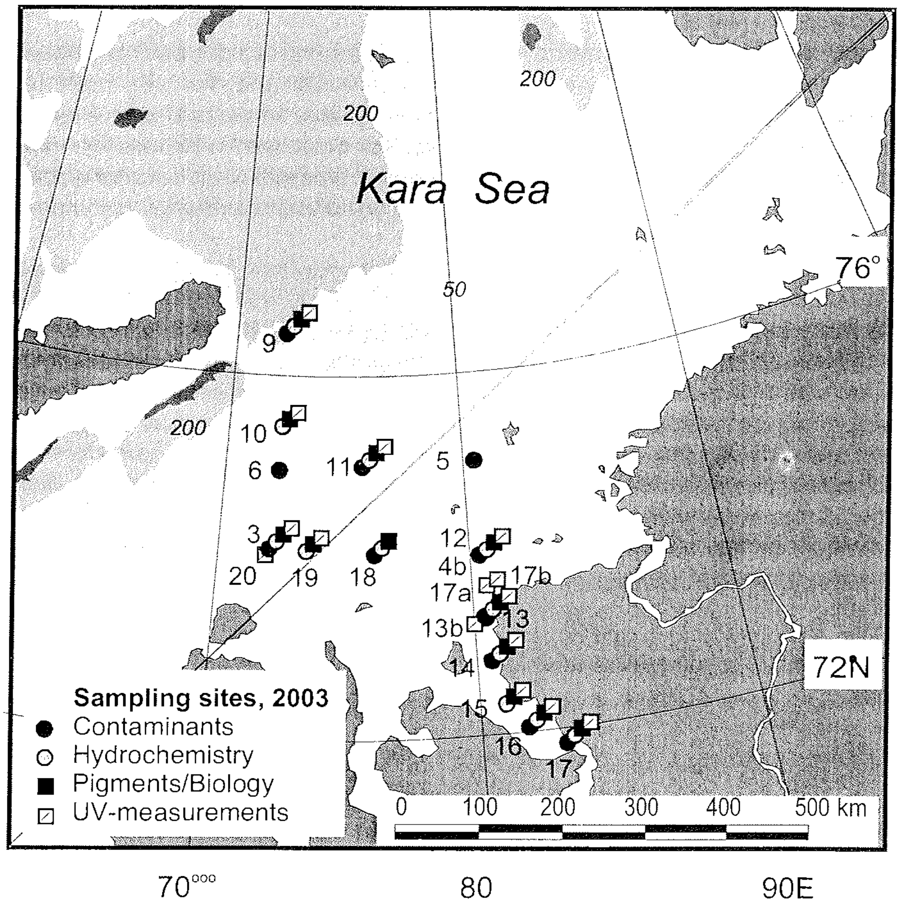

Figure 9.1: Station map August 2003.

Results and Discussion

I. Satellite ocean color image analysis

Satellite ocean color images (SeaWIFS, MERIS, MODIS data) for the Kara Sea were collected in tandem with the 2003 expedition. The analysis of satellite images is dependent upon ship-borne measurements of colour producing agents (CPAs), i.e. chlorophyll, suspended minerals (SMs), humic substances (HSs) and DOC, concentrations in surface waters. These data were collected and will be used for purposes of ground-truthing algorithms essential for the establishment of a hydro-optical model for the area. Together with the measurements of CPAs, data on sub-surface volume reflectance or above surface remote sensing reflectance were collected. These are also critical toward the development of site-specific hydro-optical models.

II. Ultraviolet radiation and PAR distribution

Radiation profiles from multichannel radiometer at 4 UV wavelengths (308nm, 320nm, 340nm, and 380nm) and PAR were measured at all stations except BP03-18 and BP03-05. Sea surface light penetration was observed to diminish rapidly on the shelf. Light penetration diminished within 3-5 meters below sea surface at most stations. Station BP03-09 (the northernmost station) is the most UV transparent station. Diffuse attenuation coefficients were extremely high; in the range between 17 and 30 at 320 nm, between 13.7 and 21.1 at 340 nm and between 7.6 and 11.5 at 380 nm. This indicates the predominant influence of river supplies of organic and inorganic matter on the Kara Sea shelf during this period of the annual river discharge cycle.

III. Hydrochemistry

Nutrient fluxes from land to ocean integrate changes in terrestrial ecosystems, in land use, and in other human activities. The Ob and Yenisey Rivers which contribute about 34% of the annual freshwater discharge into the Arctic Ocean also provide a huge supply of bio-reactive materials (nutrients, trace elements, DOC etc) that together with light intensity stimulate primary production in the adjacent coastal seas (Holmes et al. 2000). As yet, we have only an incomplete understanding of the fluxes of nutrients and other materials brought into the Arctic Ocean by rivers as well as by processes of coastal erosion (Rachold et al. 2000; Gordeev et al. 1996; Reimnitz et al. 1994).

The hydrochemistry sampling program consisted of samples for total and dissolved nutrient concentrations and DOC. Nutrient samples were collected from three different water layers (surface, middle and bottom). Exact sample depths were chosen based on water mass changes with depth identified in the CTD profiles. Water samples were then collected directly from Niskin bottles mounted on the CTD unit. For the nutrient analyses, both filtered and unfiltered samples were collected for the analysis of NH_4, NO_3+NO_2 PO_4, SiO_2 and Fe. To obtain the dissolved sample fractions, sub-samples were immediately filtered through individual 47 mm, 0.2μm PCMB filters. The volume of water passed through a filter varied from 1000 – 2000 ml. Sample filters were then dried and stored at room temperature. Fe samples were preserved with HNO_3, SiO_2 samples were preserved with chloroform, PO_4, NH_4 and NO_3+NO_2 samples were preserved with H_2SO_4. The Fe, SiO_2, PO_4, NH_4 and NO_3+NO_2 were stored at 5 – 10 degrees Celsius. For measuring dissolved organic carbon (DOC), 3 ampoules (2ml) of filtered surface water were collected and stored frozen for later analysis. As a back-up, 250 ml of surface water were filtered through a 0.2μm Al_2O_3-filter and stored for later analysis at 4 degrees Celsius.

Table 9.2: Dissolved phosphate, ammonium, nitrate+nitrite, silica, and iron in the Yenisey River mouth and Kara Sea shelf, August 2003.

Station ID Date	Lat.	Long.	Total depth (m)	Secchi depth (m)	Salinity surface (‰)	Salinity bottom (‰)	Sample Depth (m)	PO_4 (µg/l)	NH_4 (µg/l)	NO_3+ NO_2 (µg/l)	SiO_2 (µg/l)	Fe (mg/l)
BP03-09 8/21	76°30'	72°02'	150	4.5	21	35	0	1	10	4	1470	0.010
							6	3	5	4	398	0.010
							140	23	8	140	327	0.009
BP03-10 8/22	75°29'	71°59'	135	11.5	10	34	0	3	33	4	4050	0.017
							8	7	10	4	832	0.006
							125	25	11	122	706	0.020
BP03-11 8/22	75°00'	75°27'	39	5.0	10	32	0	3	5	3	3200	0.015
							7	6	6	3	1240	0.007
							29	19	7	57	614	0.007
BP03-03 8/18	74°00'	72°00'	22	3.0	8	30	0	3	18	8	5320	0.057
							7	4	11	15	2020	0.035
							14	27	13	96	1775	0.021
BP03-18 8/25	74°00'	75°59'	25	3.0	6.5	30	0	3	11	71	4210	0,018
							6	13	10	63	2840	0.010
							18	37	12	160	2410	0.005
BP03-19 8/26	73°59'	73°07'	34	4	4.5	30	0	2	11	11	4840	0.019
							7	3	18	16	3510	0.017
							24	30	9	98	1675	0.004
BP03-12 8/23	74°00'	79°59'	34	3.0	4	30	0	2	8	4	1950	0.011
							7	2	8	19	3250	0.020
							24	20	8	71	1330	0.031
BP03-13 8/23	73°25'	80°00'	35	3.0	3	33	0	2	7	4	2020	0.046
							11	24	6	109	2880	0.008
							26	42	<5	144	2020	<0.003
BP03-14 8/23	72°50'	80°04'	20	2.5	2	28	0	3	6	3	890	0.056
							9	12	23	96	3350	0.016
							13	35	25	150	3030	0.017
BP03-15 8/24	72°14'	80°29'	15	3.0	0.6	23	0	6	8	5	2090	0.049
							8	7	35	27	2410	0.026
							10	29	64	143	3590	0.143
BP03-16 8/24	72°02'	81°30'	10	3.0	0	0	0	6	6	21	3030	0.028
							3	7	6	15	3350	0.025
							6	7	8	15	3260	0.028
BP03-17 8/24	71°50'	82°25'	13	3.0	0	0	0	5	11	11	3580	0.026
							3	6	10	104	3780	0.021
							8	6	24	2750	3820	0.022

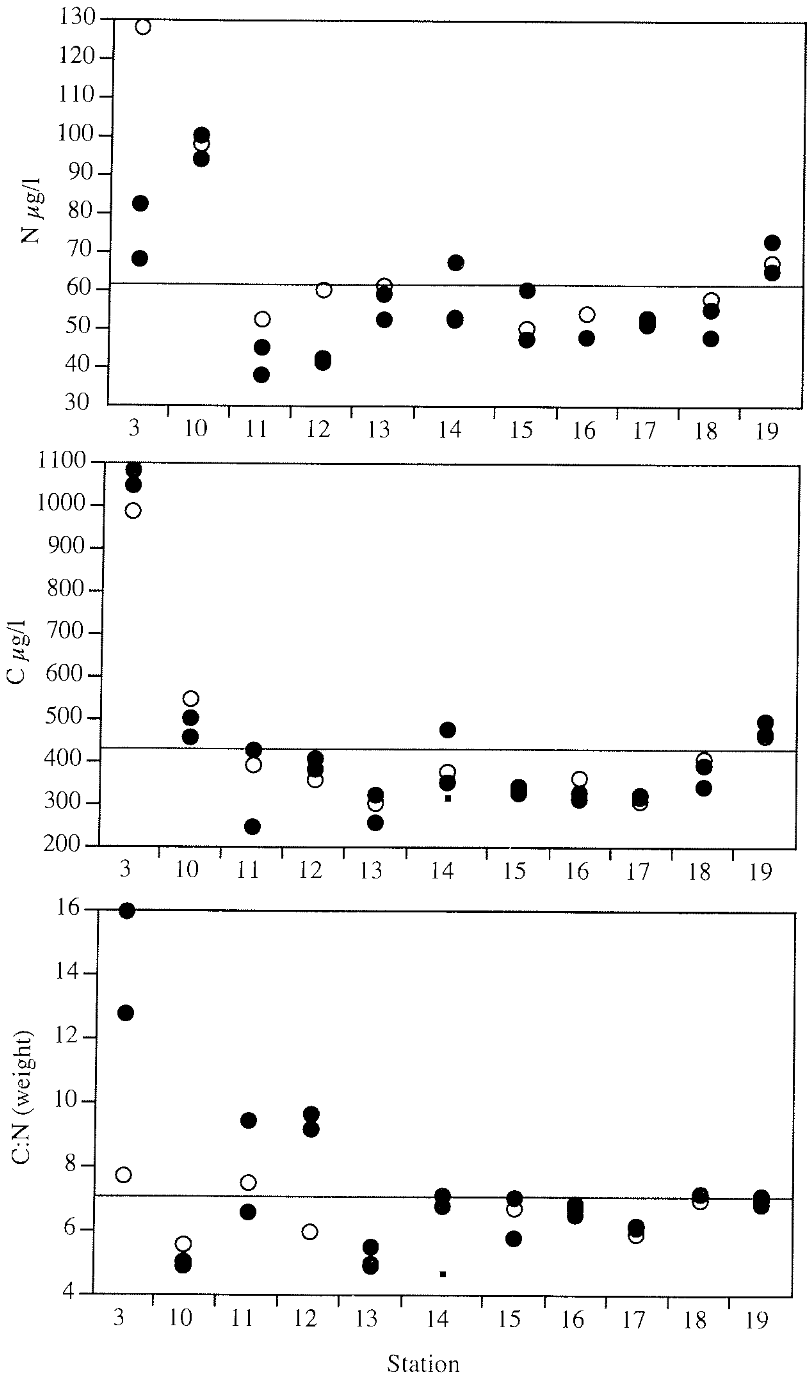

Figure 9.2: Particulate N (μg/l) and C (μg/l) and C:N ratios for in surface waters of the Yenisey River mouth and Kara Sea shelf, August 2003.

During this period of the river discharge cycle, freshwater and constituent fluxes are near their annual maximums. Dissolved phosphate and nitrate+nitrite concentrations (Table 9.2) are low in surface waters and high in bottom waters due to nutrient regeneration on the seafloor. Surface seawater concentrations of SiO_2 are fairly uniform throughout. While concentrations decrease with depth on the Kara Sea shelf, in the Yenisey river mouth concentrations increase with depth. Regeneration of SiO_2 from coastal sediments is likely responsible for the observed increase with depth in the Yenisey River. No clear trend is observed for NH_4 in either the shelf or river mouth zones. While for Fe, 30-50% is associated with the dissolved phase. DOC concentrations are on the order of 5-9 mg/l in near-shore areas (Table 9.3).

IV. Pigments/ biological measurements

As previously noted, satellite image analysis requires the field collection of colour producing agents (CPAs). Water samples of chl a, suspended minerals (SMs), humic substances (HSs) were collected from Niskin bottles attached to the CTD. Samples were collected from the water surface (0.5 m), 0.5 and 1 Secchi-depth and subsequently stored frozen at –20 °C until analyses.

Total suspended matter (SM) samples were prepared by filtering 2000 ml of water through a pre-weighted 47 mm GFF filter. These filters were also stored at 4 degrees Celsius. Samples for chlorophyll analysis were taken from the sea surface only. These 2000 ml sub-samples were filtered through 47 mm GFF filters and stored in liquid nitrogen. Yellow substances, which is a good proxy of the presence of humic material in seawater as well as optical properties of the water column, are being quantified on unfiltered water samples (100 ml) taken from the surface only. Samples for yellow substances were stored at 5 – 10 degrees Celsius.

To assess the presence of algae and bacteria in seawater, 5 ml of seawater were preserved with 100 μl of glutaraldehyde and stored in the dark at 5 – 10 degrees Celsius for biomass determination by flow-cytometry after staining. In addition, particulate fractions of water samples for the analysis of particulate C, N and P were filtered through 25 mm GFF filter. The volume filtered varied between 500 – 1500 ml depending on the particle load at each station. The filter was dried and stored at room temperature. Seston deviation from Redfield ratio indicates prevailing nutrient limitation, and also food quality for pelagic grazers (Fig. 9.2).

Water samples from the river mouth were brought to the laboratory for biological assays on biodegradation, bacterial and phytoplankton responses on DOC.

Combining discharge data with DOC concentrations we intend to calculate the entire export of C to the Kara Sea - this will be some thousands tons of C. Further the results will be linked with estimates of primary production in the catchment to estimate net retention of C in this catchment, and the fraction which is annually exported to the sea. The fate of this C will have strong bearings on ocean C-budgets.

V. River-borne contaminants

In many parts of the world, coastal ecosystems are experiencing unfavorable changes in water quality, some of which can be linked directly to the transport of waterborne constituents from land. The Ob-Yenisey Rivers are recognized as major transporters of contaminants from land to sea (AMAP 1998). Although considered relatively pristine by most standards, contaminants found in remote Arctic areas include persistent organic contaminants, heavy metals (Pb, Cd, Hg etc), acidifying gases, and radionuclides (Macdonald et al. 2000; AMAP 1998).

For the contaminant program, large volume water samples were collected at 11 of the 19 stations using an Infiltrex II unit. One hundred litres of water were collected in 50-litre steel barrels at 5 meters depth. Each sample was first filtered through a GFF filter to remove water-borne particulates followed by exchange through a pre-conditioned resin column designed for the efficient removal of selected persistent organic pollutants in coastal waters. Particle filters were kept frozen while the extraction columns were stored at 4 degrees Celsius for transport to the analytical laboratory. Contaminant analyses are being performed on the list of constituents presented in Table 9.4 by AXYS Analytical Services, British Columbia, CANADA.

Table 9.3: Dissolved organic carbon (DOC) in surface waters of the Yenisey River mouth and Kara Sea shelf, August 2003.Concentrations are given mg/l.

Station ID	Lat.	Long.	Total depth (m)	Sample salinity (psu)	DOC (mg/l)
BP03-09	75°29'	71°59'	135	21.1	2.6
BP03-10	75°00'	75°27'	39	-	4.6
BP03-11	74°00'	72°00'	22	11	5.7
BP03-03	76°30'	72°02'	150	4.6	8.7
BP03-18	72°14'	80°29'	15	6.7	7.2
BP03-19	72°02'	81°30'	10	4.5	7.0
BP03-13	74°00'	75°59'	25	2.2	6.7
BP03-13	71°50'	82°25'	13	2.2	7.6
BP03-14	73°59'	73°07'	34	1.2	6.6
BP03-15	74°00'	79°59'	34	0.6	7.3
BP03-16	73°25'	80°00'	35	0	5.6
BP03-17	72°50'	80°04'	20	0	6.2

Summary

The transport of organic matter from terrestrial and freshwater environments to marine habitats on Arctic continental shelves is known to influence marine primary productivity, light penetration, and potentially mediates contaminant behavior. An investigation of supplies and mixing behaviors for DOC, nutrients, and persistent organic pollutants across the Kara Sea shelf was carried out in August 2003 to evaluate the spatial extent to which river supplies of DOC influences material distributions in the adjacent coastal ecosystem during late summer. In-situ data are combined with satellite imagery analysis (MERIS and SeaWiFS) in order to map distributions of chlorophyll, sediments and DOC on the shelf. These data sets are complimented with in-situ measurements of ultraviolet radiation (UV-R) penetration using a high resolution (1nm) spectroradiometer to determine sea surface light intensity and light attenuation in the water column across the shelf. During this period of the river discharge cycle, freshwater and constituent fluxes are near their annual maximums with DOC concentrations of 5-9 mg/l in near-shore areas. Sea surface light penetration diminishes rapidly with depth on the shelf (ca. < 3 meters below the sea surface) indicating the predominant influence of major supplies of organic and inorganic matter transported by rivers to the Kara Sea shelf and ultimately to deeper waters of the interior Arctic basin. These present-day observations provide a context within to evaluate expected future changes in land-ocean interactions where in the Arctic, it has been predicted that the region will experience amplified effects of global climatic changes.

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Table 9.4: Forthcoming contaminant analyses by AXYS Analytical Services, British Columbia, CANADA.

Polychlorinated biphenyls (congener #)	*Dioxins/Furans*	*Polyaromatic hydrocarbons*	*Polybrominated Diphenyl Ethers*	*Pesticides*
1	$^{13}C_{12}$ 2.3.7.8-TCDD	Naphthalene	$^{13}C_{12}$-4-mono-BDE	$^{13}C_6$-Mono-Cl-Benzene (RT
3	$^{13}C_{12}$ 2.3.7.8-TCDF	2-Methylnaphthalene	$^{13}C_{12}$-4.4'-di-BDE	$^{13}C_6$-1.4-DiCl-Benzene
4	$^{13}C_{12}$ 1.2.3.7.8-PCDD	Acenaphthylene	$^{13}C_{12}$-2.4.4'-tri-BDE	$^{13}C_6$-1.2.3-TriCl-Benzene
15	$^{13}C_{12}$ 1.2.3.7.8-PCDF	Phenanthrene	$^{13}C_{12}$-2.2'.4.4'-tetra-BDE	$^{13}C_6$-1.2.3.4-TetCl-Benzene
19	$^{13}C_{12}$ 2.3.4.7.8-PCDF	Fluoranthene	13C12-3,3',4,4'-tetra-BDE	$^{13}C_6$-PentaCl-Benzene
37	$^{13}C_{12}$ 1.2.3.4.7.8-HxCDD	Benz[a]anthracene	$^{13}C_{12}$ -2.2'.4.4'.5-penta-BDE	$^{13}C_6$-HexaCl-Benzene
54	$^{13}C_{12}$ 1.2.3.6.7.8-HxCDD	Chrysene	$^{13}C_{12}$ -2.2'.4.4'.6-penta-BDE	$^{13}C_6$-beta BHC
81	$^{13}C_{12}$ 1.2.3.4.7.8-HxCDF	2,6-Dimethylnaphthalene	$^{13}C_{12}$-3.3'.4.4'.5-penta-BDE	$^{13}C_6$-gamma BHC
77	$^{13}C_{12}$ 1.2.3.6.7.8-HxCDF	Benzo[b,k]fluoranthene	$^{13}C_{12}$ -2.2'.4.4'.5.5'-hexa-BDE	$^{13}C_{10}$-Heptachlor
104	$^{13}C_{12}$ 1.2.3.7.8.9-HxCDF	Benzo[a]pyrene	$^{13}C_{12}$-2.2'.4.4'.5.6'-hexa-BDE	$^{13}C_{12}$-Aldrin
123	$^{13}C_{12}$ 2.3.4.6.7.8-HxCDF	Perylene	$^{13}C_{12}$-2.2'.3.4.4'.5'.6-hepta-BDE	$^{13}C_{10}$-trans-Chlordane
118	$^{13}C_{12}$ 1.2.3.4.6.7.8-HpCDD	Indeno[1,2,3-cd]pyrene	$^{13}C_{12}$-22'33'44'55'66'-deca-BDE	$^{13}C_{10}$-trans-Nonachlor
114	$^{13}C_{12}$ 1.2.3.4.6.7.8-HpCDF	Dibenzo[ah]anthracene		$^{13}C_{10}$-Oxychlordane (RT marker)
105	$^{13}C_{12}$ 1.2.3.4.7.8.9-HpCDF	Benzo[ghi]perylene		$^{13}C_{12}$-pp'-DDE
126	$^{13}C_{12}$ OCDD	Biphenyl		$^{13}C_{12}$-pp'-DDT
155				$^{13}C_{12}$-op'-DDT (RT marker)
167				d_4-alpha-Endosulphan
156/157				
169				
188				
189				
202				
205				
208				
206				
209				

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11.1 Station list

Abbreviations of activities:

50 l WS	50 l Watersampler
UVR	Ultraviolet-Radiation
PN	Plankton Net
LBC	Large Box Corer
VVG	Van-Veen-Grabsampler
GC	Gravity Corer
WP	Water pumping
BT	Bottom Trawl
ST	Sediment Trap

Station	Date	Time (GMT)	Latitude ° N	Longitude ° E	Depth (m)	Gear No.	Activity
BP03-01	15.08.2003	1:40	69°52.0	36°40.0	138	/01	CTD/Rosette
		2:45	69°53.6	36°38.2	137	/02	Batomat
BP03-02	16.08.2003	6:24	70°07.09	52°07.45	111	/01	CTD/Rosette
		6:45	70°07.14	52°06.30	111	/02	Batomat
BP03-03	17.08.2003	23:12	74°00.12	72°00.85	22,2	/01	CTD/Rosette
		0:18	73°59.90	72°01.51	22,1	/02	50 l WS
		0:10	73°59.99	72°01.52	22,1	/03	Batomat
		0:18	73°59.90	72°01.04	22,1	/04	PN
		0:56	73°53.88	72°01.05	22,1	/05	LBC
		1:30	74°00.12	72°01.05	22,1	/06	BT
BP03-04a	18.08.2003	13:00	74°00.11	80°19.46	39		ST Recovery
BP03-04b	18.08.2003	14:22	74°01.49	80°18.78	39	/01	CTD/Rosette
		14:30	74°02.08	80°16.43	39	/02	UVR
		14:40	74°01.68	80°18.02	39	/03	50 l WS
		14:40	74°01.68	80°18.02	39	/04	Batomat
		15:29	74°02.11	80°16.2	39	/05	PN
		16:55	74°01.68	80°12.2	39	/06	LBC
BP03-05	19.08.2003	1:26	74°59.88	80°00.46	41,5	/01	CTD/Rosette
		1:51	75°00.25	80°00.52	41,5	/02	50 l WS
		1:51	75°00.25	80°00.52	41,5	/03	Batomat
		2:05	75°00.48	80°00.85	41,5	/04	PN
		3:28	75°01.50	80°04.01	41,5	/05	LBC
BP03-06	20.08.2003	5:30	74°59.88	72°01.34	30	/01	CTD/Rosette
		5:40	74°59.94	72°02.36	30	/02	UVR
		5:48	74°59.93	72°01.83	30	/03	50 l WS
		5:48	74°59.93	72°01.83	30	/04	Batomat
		6:00	74°59.94	72°02.14	30	/05	PN
		6:46	75°00.17	72°03.25	30	/06	VVG
		7:22	75°00.29	72°03.59	30	/07	BT
BP03-07	20.08.2003	12:40	75°33.61	73°07.64	107	/01	CTD/Rosette
		12:45	75°33.64	73°08.75	102	/02	UVR
		12:59	75°33.61	73°08.23	102	/03	Batomat
		13:27	75°33.63	73°09.0	104	/04	PN
		14:34	75°33.68	73°11.27	92	/05	LBC
		15:50	75°33.61	73°07.64	108	/06	GC
BP03-08	21.08.2003	0:10	75°37.11	75°42.32	55	/01	CTD/Rosette
		0:20	75°36.84	75°42.32	55	/02	Batomat
		0:22	75°36.84	75°42.32	55	/03	VVG
BP03-09	21.08.2003	12:00	76°30.01	72°00.18	162	/01	CTD/Rosette
		12:10	76°30.04	72°02.29	162	/02	UVR
		12:21	76°29.98	72°01.26	163	/03	50 l WS
		12:46	76°30.03	72°02.54	164	/04	Batomat
		13:40	76°30.20	72°05.20	174	/05	PN
		16:59	76°30.83	72°08.57	175	/06	VVG

BP03-10	22.08.2003	0:48	75°30.0	72°00.3	140	/01	CTD/Rosette
		1:00	75°29.85	72°01.98	140	/02	UVR
		1:42	75°29.86	72°02.36	125	/03	Batomat
		1:24	75°29.87	72°01.69	133	/04	PN
		2:38	75°29.88	72°05.26	125	/05	VVG
BP03-11	22.08.2003	9:14	75°00.03	75°27.97	38	/01	CTD/Rosette
		9:25	75°00.27	75°28.34	38	/02	UVR
		9:36	75°00.19	75°28.27	38	/03	50 l WS
		9:25	75°00.19	75°28.27	38	/04	Batomat
		10:03	75°00.35	75°28.51	38	/05	PN
		11:00	75°00.65	75°29.83	38	/06	VVG
BP03-12	22.08.2003	21:36	74°00.22	79°59.63	35	/01	CTD/Rosette
		21:45	74°00.22	80°00.02	36	/02	UVR
		21:57	74°00.21	79°59.89	36	/03	PN
BP03-13	23.08.2003	2:42	73°25.00	80°00.84	37	/01	CTD/Rosette
		2:50	73°24.84	80°01.54	37	/02	UVR
		3:01	73°24.96	80°00.84	37	/03	50 l WS
		3:17	73°24.90	80°01.35	37	/04	Batomat
		3:43	73°24.73	80°01.72	36	/05	PN
		4:42	73°24.65	80°03.24	33	/06	LBC
BP03-14	23.08.2003	16:00	72°50.07	80°04.95	20	/01	CTD/Rosette
			anchoring			/02	UVR
						/03	50 l WS
						/04	Batomat
						/05	PN
						/06	WP
						/07	LBC
BP03-15	24.08.2003	4:01	72°14.99	80°29.99	15	/01	CTD/Rosette
			anchoring			/02	UVR
						/03	Batomat
						/04	PN
						/05	VVG
BP03-16	24.08.2003	8:17	72°02.2	81°30.8	9,4	/01	CTD/Rosette
			anchoring			/02	UVR
						/03	50 l WS
						/04	VVG
						/05	LBC
		9:34	72°02.6	81°31.6	9,4	/06	BT
BP03-17	24.08.2003	12:23	71°50.98	82°25.38	17	/01	CTD/Rosette
			anchoring			/02	UVR
						/03	50 l WS
						/04	Batomat
						/05	VVG
BP03-18	25.08.2003	19:30	74°00.00	76°00.33	27	/01	CTD/Rosette
		19:43	73°59.42	76°01.26	27	/02	50 l WS
		20:19	73°58.92	76°02.63	27	/03	PN
		20:31	73°58.73	76°03.17	27	/04	VVG

BP03-19	26.08.2003	4:10	73°59.86	73°08.08	33	/01	CTD/Rosette
		4:30	73°59.29	73°10.55	33	/02	UVR
					33	/03	Batomat
		5:00	73°59.13	73°11.24	33	/04	PN
		6:41	73°59.92	73°07.79	34	/05	LBC
		7:57	73°59.99	73°07.81	34	/06	GC
BP03-20	26.08.2003	10:00	74°00.5	71°59.27		/01	UVR

11.2

Geological Core Descriptions

R/V "AKADEMIK BORIS PETROV" - 2003

GEOLOGICAL CORE DESCRIPTIONS

Legend

Lithology

- clay
- silty clay
- sandy silty clay
- sandy clay
- silty clay with clay clasts
- silt
- clayey silt
- sandy silt
- clayey sand
- silty sand
- sand
- clay clasts
- spots and lenses

- sharp boundary
- gradational boundary
- transition zone

Structure

- lamination, bending
- bioturbation
- drop stones
- shell debris
- tubes of polychaets
- h hydrotroilite
- plant remains
- Crystals of ikaite
- bivalves or gastrapodes
- burrows filled by clay
- Coarsening downcore
- Fining downcore

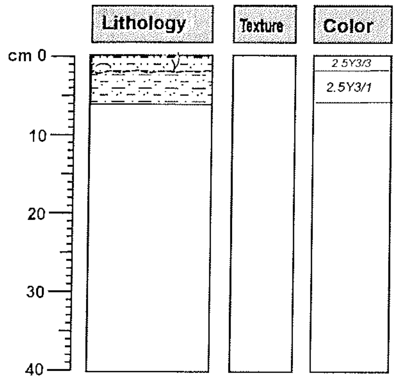
BP03-03BC

BORIS PETROV 2003

Kara Sea

75°59.88' N
72°01.05' E

Water depth: 21.1m
Recovery: 6 cm



Description

0-2 cm: dark olive brown (2.5Y3/3) liquid clayey silt with sand admixture some amount of bivalves and tubes of polychaets on the surface

2-6 cm: very dark gray (2.5Y3/1) clayey silt, some amount of sand

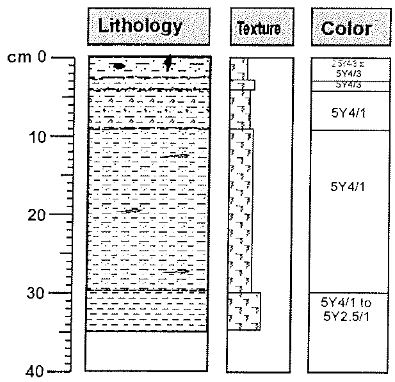
BP03-04bBC

BORIS PETROV 2003

Kara Sea

74°02.9' N
80°12.2' E

Water depth: 38.6m
Recovery: 35 cm



Description

0-3 cm: olive brown (2.5Y4/3) to olive (5Y4/3) liquid clayey silt with sand; black lithified tubes of polychaets (up to 100 mm in length) which are filled with olive (5Y4/3) silty clay. Fe-Mn nodules up to 7*20*100 mm

3-4 cm: olive (5Y4/3) silty clay with clay clasts, some amount of fine sand; bioturbated

4-9 cm: dark gray (5Y4/1) stiff silty clay with clay clasts, density is increased downcore; bioturbated

9-30 cm: dark gray (5Y4/1) stiff clay with silt admixture; color and density are variable; abundant black spots of hydrotroilite, bioturbation; density is decreased downcore, transitional boundary by color and density

30-35 cm: dark gray (5Y4/1) to black (5Y2.5/1) soft clay with hydrotroilite

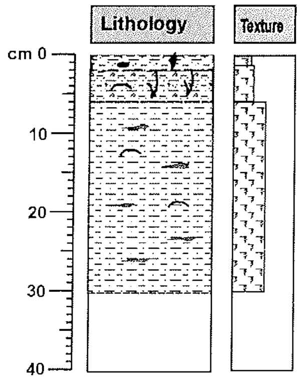
BP03-05BC

BORIS PETROV 2003

Kara Sea

75°01.50' N
80°04.01' E

Water depth: 43.2 m
Recovery: 30 cm



Color

2.5Y3/3 to 5Y4/3
5Y4/3
5Y4/3

Description

0-1.5 cm: dark olive brown (2.5Y3/3) to olive (5Y4/3) liquid silty clay with some sand; brown (7.5Y4/4) to black (10Y2/1) lithified tubes of polychaetes (up to 100 mm in length). Fe-Mn nodules up to 30 mm in length

1.5-6 cm: olive (5Y4/3) silty clay with clay clasts (up to 5 mm in diameter) and fine sand admixture; density is variable; bioturbated; polyhaets up to 3*70 mm; shell detrite

6-30 cm: olive (5Y4/3) stiff silty clay with hydrotroilite and shell detrite

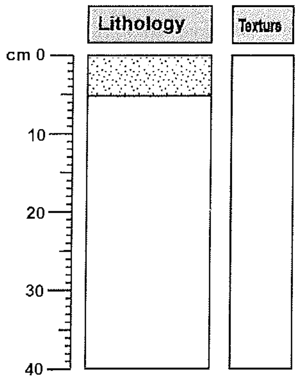
BP03-06Gr

BORIS PETROV 2003

Kara Sea

75°00.17' N
72°03.24' E

Water depth: 30.7 m
Recovery: 5 cm



Color

2.5Y3/3

Description

0-5 cm: dark olive brown (2.5Y3/3) sand with admixture of silt and clay

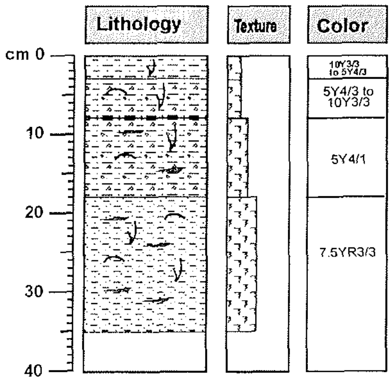
BP03-07BC

BORIS PETROV 2003

Kara Sea

75°33.69' N
73°11.38' E

Water depth: 92.6 m
Recovery: 35 cm



Description

0-3 cm: dark brown (10Y3/3) to olive (5Y4/3) liquid silty clay, some amount of sand; tubes of polychaets

3-8 cm: olive (5Y4/3) to dark brown (10Y3/3) silty clay with clay clasts (up to 5 mm in diameter), soft; tubes of polyhaets up to 70 mm in length

8-18 cm: dark gray (5Y4/1) stiff silty clay with clay clasts; rare small spots of hydrotroilite up to 5 mm in diameter; shell detrite; tubes of polyhaets up to 20 mm in length; lenses (up to 15*20*40 mm) of dark gray (5Y4/1) clay with dark brown (7.5YR3/3) clasts (1-4 mm) and with lithified tube in the center of lens; bioturbated; shell detrite; silt and sand content and density are increased downcore

18-35 cm: very dark gray (7.5YR3/3) silty clay with sand admixture; spots of hydrotroilite; bioturbation; fining downcore below 26 cm; shell debris; polyhaet tubes up to 10 mm in length

30-35 cm: dark gray (5Y4/1) to black (5Y2.5/1) soft clay with hydrotroilite

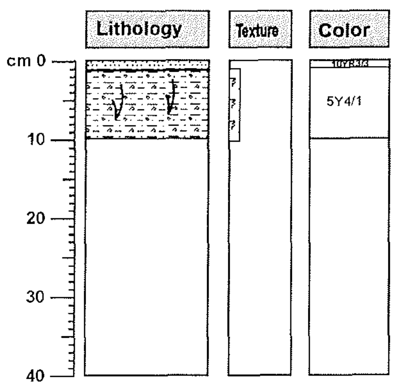
BP03-08Gr

BORIS PETROV 2003

Kara Sea

75°36.84' N
73°43.22' E

Water depth: 55.1 m
Recovery: 10 cm



Description

0-1 cm: dark brown (10YR3/3) silty sand, some amount of clay

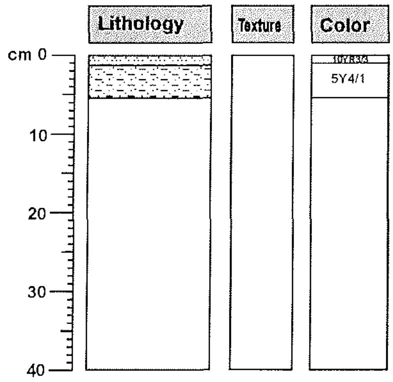
3-10 cm: dark gray (5Y4/1) silty clay with polychaets and clay clasts

BP03-09Gr BORIS PETROV 2003

Kara Sea

75°30.95' N
72°09.1' E

Water depth: 185.4 m
Recovery: 5 cm



Description

0-1 cm: dark brown (10YR3/3) clayey sand with silt admixture

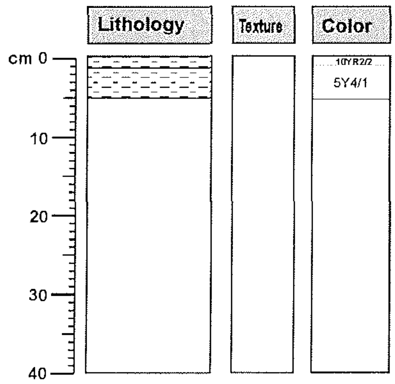
1-5 cm: dark gray (5Y4/1) silty clay, some amount of sand

BP03-10Gr BORIS PETROV 2003

Kara Sea

75°29.88' N
75°05.26' E

Water depth: 127.6 m
Recovery: 5 cm



Description

0-1 cm: very dark brown (10YR2/2) clay, some amount of sand

1-5 cm: dark gray (5Y4/1) clay, some amount of sand

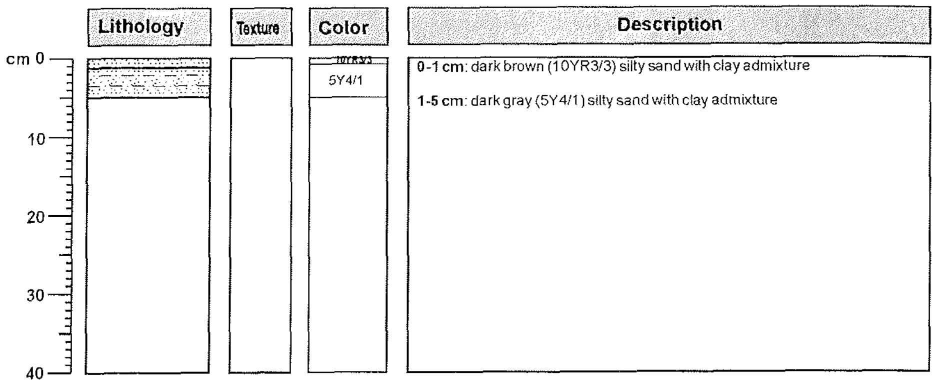
BP03-11Gr

BORIS PETROV 2003

Kara Sea

75°00.65' N
75°29.83' E

Water depth: 37.5 m
Recovery: 5 cm



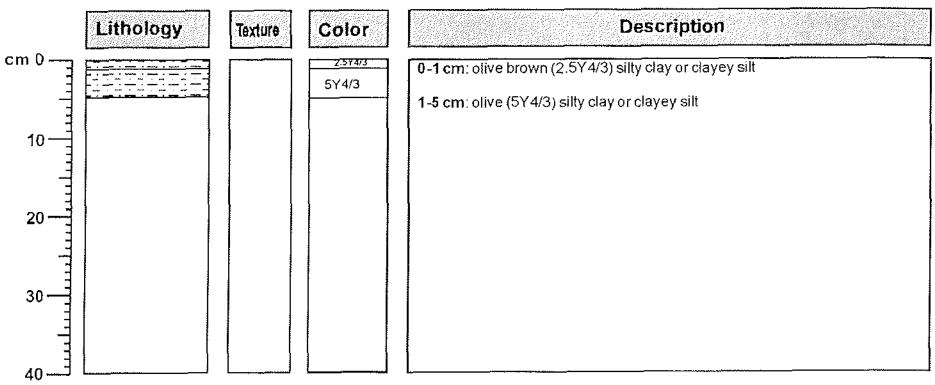
BP03-12Gr

BORIS PETROV 2003

Kara Sea

75°00.21' N
79°59.82' E

Water depth: 36.0 m
Recovery: 5 cm



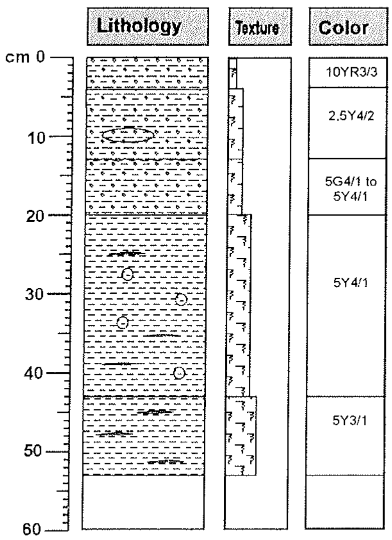
BP03-13BC

BORIS PETROV 2003

Yenisei Estuary

73°24.65' N
80°03.24'E

Water depth: 35.4 m
Recovery: 53 cm



Description

0-4 cm: liquid dark brown (10YR3/3) clay with clay clasts; sharp boundary

4-13 cm: soft and viscous dark grayish (2.5Y4/2) clay with clay clasts; 7-12 cm lense of stiff dark olive brown (2.5Y3/3); clay density is increased downcore; gradual boundary

13-20 cm: downcore dark greenish gray (5G4/1) to dark gray (5Y4/1) clay with clay clasts; gradual boundary

20-43 cm: stiff dark gray (5Y4/1) clay; burrows are filled by dark brown (10YR3/3) liquid clay; rare spots of hydrotroilite which are increased downcore; gradual boundary

43-53 cm: more soft very dark gray (5Y3/1) clay with spots of hydrotroilite

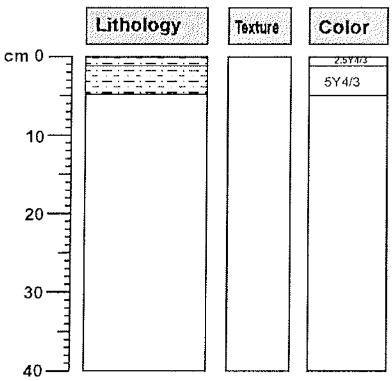
BP03-14BC

BORIS PETROV 2003

Kara Sea

75°50.07' N
80°04.95'E

Water depth: 20.6 m
Recovery: 5 cm



Description

0-1 cm: olive brown (2.5Y4/3) silty clay or clayey silt

1-5 cm: olive (5Y4/3) silty clay or clayey silt

BP03-15Gr

BORIS PETROV 2003

Yenisei Estuary

72°02.2' N
80°29.99' E

Water depth: 15.0 m
Recovery: 5 cm

Color	Description
2.5Y3/3	**0-5 cm**: dark olive brown (2.5Y3/3) clay

BP03-16BC

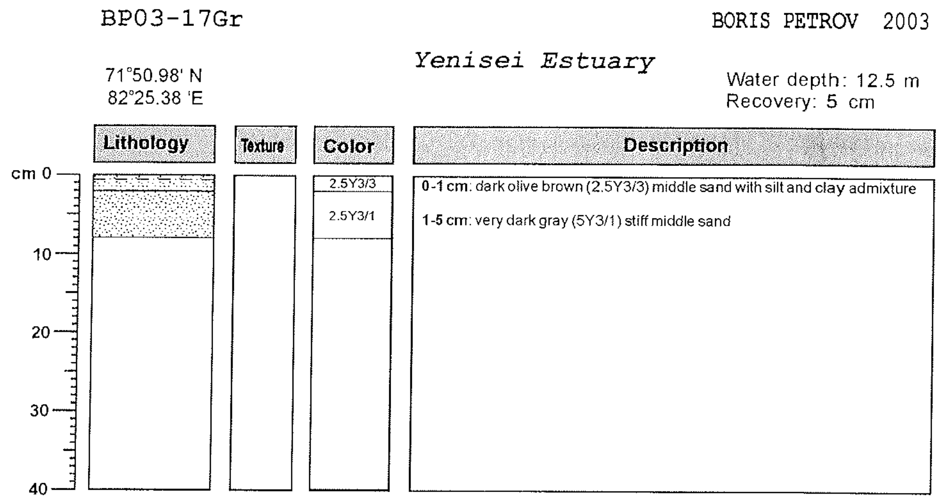
BORIS PETROV 2003

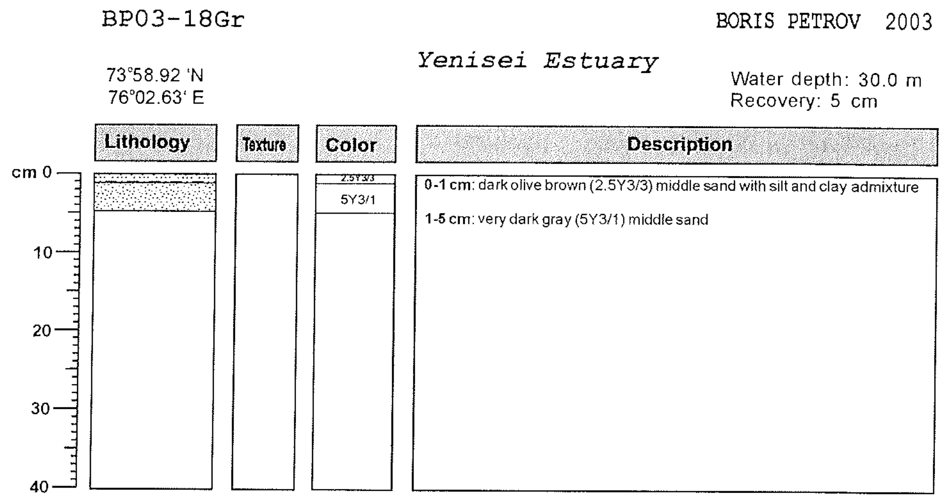
Yenisei Estuary

72°02.2' N
81°30.8 'E

Water depth: 10.6 m
Recovery: 40 cm

Color	Description
2.5Y3/3	**0-2 cm**: dark olive brown (2.5Y3/3) clay with sand admixture
2.5Y3/2	**2-8 cm**: very dark grayish brown (2.5Y3/2) soft clay
5Y3/2 5Y3/1 5Y2.5/2 5Y2.5/1 5Y2.5/1 to 5Y2.5/2	**8-25 cm**: laminated sediments: 8-11 cm - dark olive gray (5Y3/2) clay; 11-13 - very dark gray 5Y3/1 clay with silt; 13-17 cm - black (5Y2.5/2) silty clay; 17-20 cm - black (5Y2.5/1) clay; 20-25 cm - black (5Y2.5/1 to 5Y2.5/2) clay
5Y2.5/1	**25-40 cm**: black (5Y2.5/1) massive silty clay or clayey silt


BP03-17Gr
BORIS PETROV 2003
Yenisei Estuary
71°50.98' N
82°25.38 'E
Water depth: 12.5 m
Recovery: 5 cm
Lithology
Texture
Color
Description
cm 0
10
20
30
40
2.5Y3/3
2.5Y3/1
0-1 cm: dark olive brown (2.5Y3/3) middle sand with silt and clay admixture
1-5 cm: very dark gray (5Y3/1) stiff middle sand


BP03-18Gr
BORIS PETROV 2003
Yenisei Estuary
73°58.92 'N
76°02.63' E
Water depth: 30.0 m
Recovery: 5 cm
Lithology
Texture
Color
Description
cm 0
10
20
30
40
2.5Y3/3
5Y3/1
0-1 cm: dark olive brown (2.5Y3/3) middle sand with silt and clay admixture
1-5 cm: very dark gray (5Y3/1) middle sand

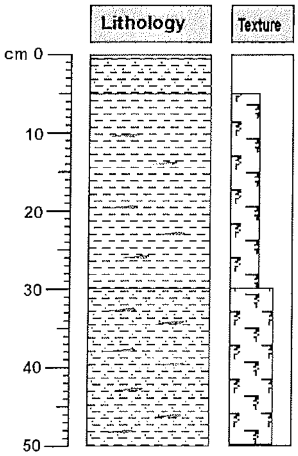
BP03-19BC

BORIS PETROV 2003

Yenisei Estuary

73°59.92' N
73°07.79' E

Water depth: 26.6 m
Recovery: 50 cm



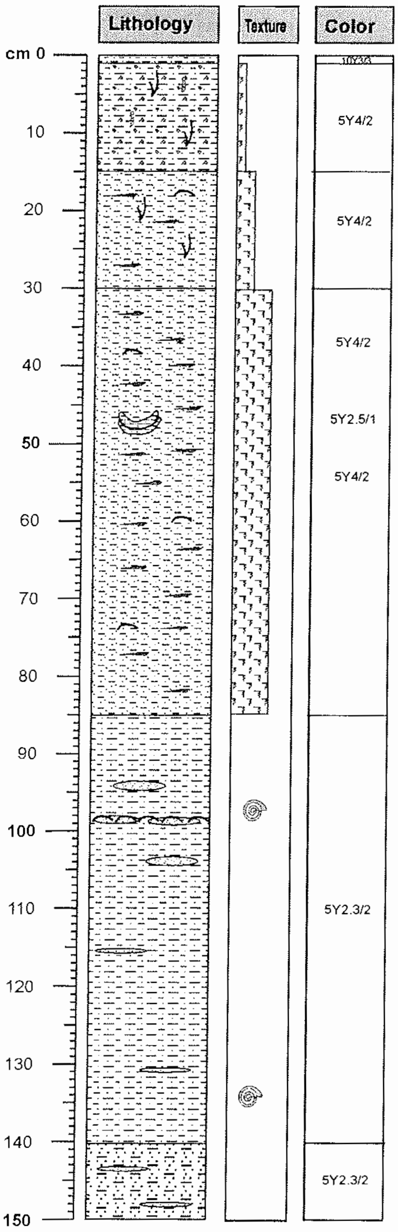
Color	Description
2.5Y3/3	**0-0.5 cm**: dark olive brown (2.5Y3/3) clay
5Y4/1	**0.5-5 cm**: dark gray (5Y4/1) clay with some silt; density is increased downcore; gradual boundary
5Y3/1	**5-30 cm**: very dark gray (5Y3/1) clay; abundant black spots of hydrotroilite below 18 cm; moderately to intensively (6-10 cm) bioturbated; gradual boundary
5Y4/1 to 5Y3/1 to 5Y2.5/1	**30-50 cm**: very dark gray (5Y4/1 to 5Y3/1) to black (5Y2.5/1) clay with sand admixture, mottled; dense; strongly bioturbated

BP03-07GC — BORIS PETROV 2003

Kara Sea

75°33.39' N
73°10.09' E

Water depth: 97.4 m
Recovery: 390 cm



Description

0-1 cm: dark brown (10Y3/3) liquid silty clay, some amount of sand

1-15 cm: olive gray (5Y4/2) silty clay with clay clasts (up to 5 mm), polyhaets tubes up to 70 mm in length; burrows are filled with stiff clay; gradual boundary

15-30 cm: olive gray (5Y4/2) silty clay with black (5Y2.5/1) spots; clay clasts; rare small spots of hydrotroilite; polyhaet tubes; bioturbated; shell detrite; gradual boundary

30-85 cm: olive gray (5Y4/2) silty clay with some amount of sand; black (5Y2.5/1) spots and lenses of hydrotroilite up to 10-70 mm; 47-52 cm lense of stiff silty clay with clay clasts; intensively bioturbated; shell debris; sharp boundary

85-140 cm: dark olive gray (5Y2.3/2) silty clay with lenses of fine sand; less dense than layer above; low viscosity; gradual boundary

BP03-07GC

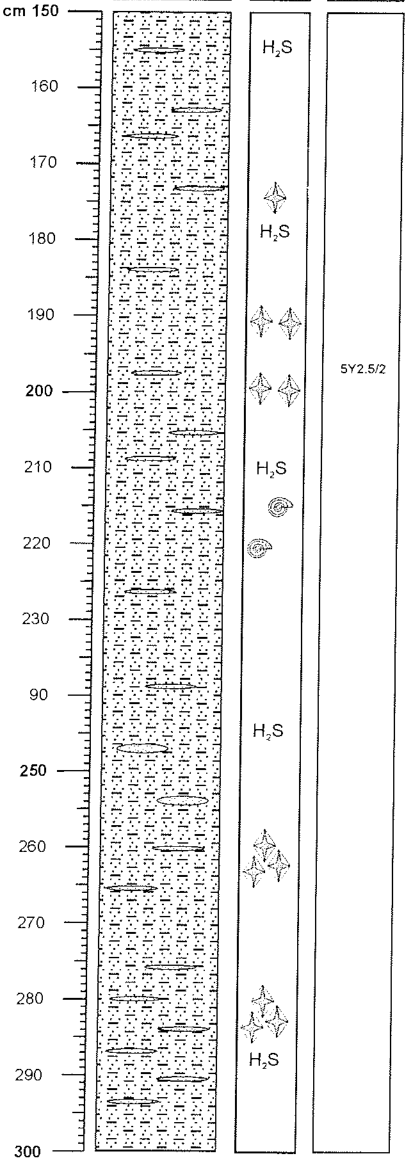
BORIS PETROV 2003

75°33.39' N
73°10.09' E

Kara Sea
continue

Water depth: 97.4 m
Recovery: 390 cm

Lithology	Texture	Color	Description



140-330 cm: dark olive gray (5Y2.3/2) sandy silty clay or clayey silt with lenses of fine sand and silt; content of sand and silt (especially lenses of silty sand and sand) is increased downcore; H_2S odor below 150 cm

likaite aggregates (up to 10 cm in length) at 175, 191, 199, 260-270, 280-285, 300-305, 315, 320 cm

bivalves / shell detrite at 99, 134 (gastropoda) cm;
97-98 cm level is enriched by shell detrite
bivalves at 215, 225 cm

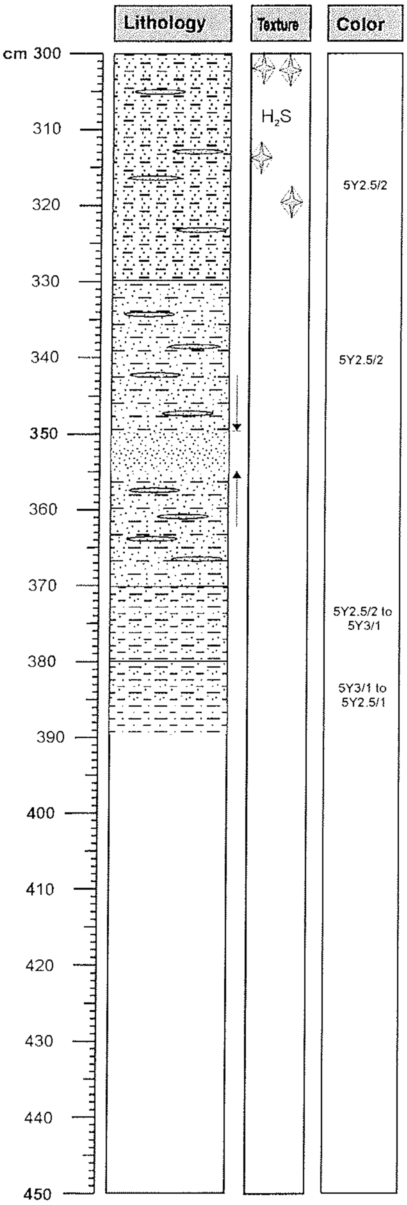
BP03-07GC

BORIS PETROV 2003

75°33.39' N
73°10.09' E

Kara Sea
continue

Water depth: 97.4 m
Recovery: 390 cm



Description

330-370 cm: dark olive gray (5Y2.3/2) heterogenous silty sand or sandy silt with clay admixture and numerous lenses of sand which content is increased below 350 cm and is decreased below 355 cm (350-355 cm sandy layer)

370-380 cm: dark olive gray (5Y2.3/2) to very dark gray (5Y3/1) silty clay with some amount of sand; fining downcore; sharp boundary

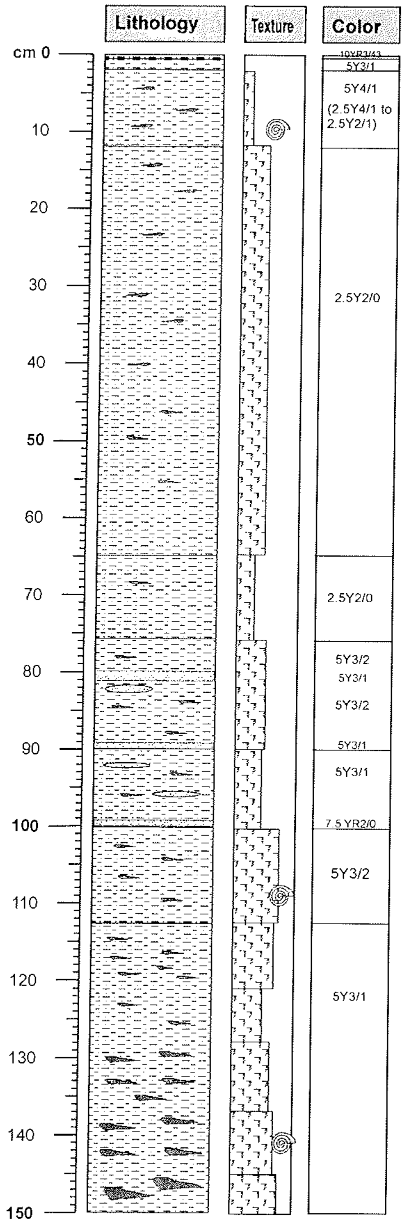
380-390 cm: very dark gray (5Y3/1) to black (5Y2.5/1) silty clay; finning downcore, intensive bioturbation; shell detrite

BP03-19GC — **BORIS PETROV 2003**

Yenisei Estuary

73°59.99' N
73°07.81' E

Water depth: 30.0 m
Recovery: 672 cm



Description

0-0.5 cm: dark olive brown (10YR3/43) liquid clay

0.5-2 cm: very dark gray (5Y3/1) soft clay with some silt

2-12 cm: heterogenous dark gray (5Y4/1) clay with some silt; mottled (2.5Y4/1 to 2.5Y2/1). Density is increased downcore; gradual boundary

12-65 cm: very dark gray (2.5Y2/0) clay; abundant black spots of hydrotroilite; moderately to intensively bioturbated; gradual boundary by character of bioturbation

65-76 cm: very dark gray (2.5Y2/0) clay with silt admixture; dense; lightly bioturbated

76-90: interlayering of heterogenous dark olive gray (5Y3/2) bioturbated clay with black spots (76-81cm, 82-89 cm) and with very dark gray (5Y3/1) sand (80-80.7 and 89-90 cm), lense of sand (82 cm)

90-100 cm: interlayering of very dark gray (5Y3/1) bioturbated clay or silty clay with black (5Y2.5/1) spots and lenses with irregular boundaries, and thin layer of gray (7.5 YR2/0) fine sand (100 cm)

103-113 cm: dark olive gray (5Y3/2) silty clay, strongly bioturbated with honeycombs

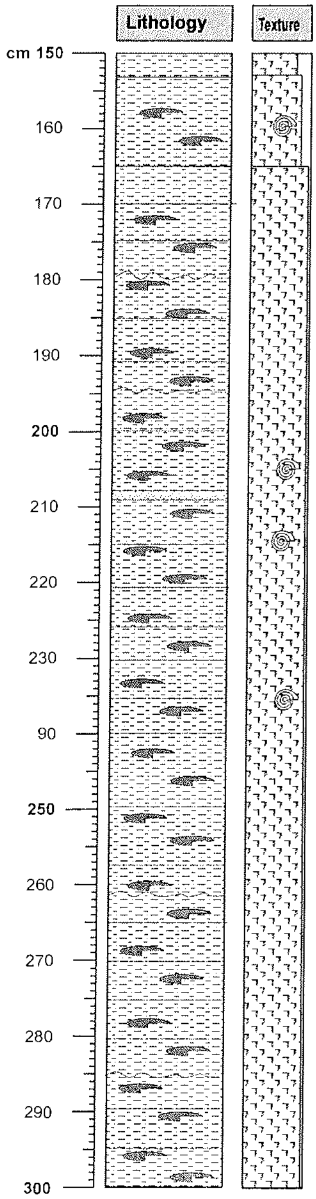
113-153 cm: very dark gray (5Y3/1) **mottled** silty clay with small black (5Y2.5/1) spots. Banding is due to bioturbation and diagenetic mottling:
113-121 cm - more intensive,
121-128 cm more uniform,
128-137 cm increase of size and number of black spots,
137-145 cm more large spots,
145-153 cm very large black spots

BP03-19GC **BORIS PETROV 2003**

73°59.99' N
73°07.81' E

Yenisei Estuary
continue

Water depth: 30.0 m
Recovery: 672 cm



Color	Description
5Y2.5/1 to 5Y4/2	**153-165** cm: heterogeneous black (5Y2.5/1 to 5Y4/2) sily clay, strongly bioturbated; fining downcore
5Y3/1-2 to 5Y2.5/1-2	**165-330 cm**: very dark gray (5Y3/1-2 to 5Y2.5/1-2) laminated clay with silt admixture, mottled, very strong bioturbation, layers from 5 to 6 mm with sharp and gradual boundaries, rarely is wavy boundary with pockets, 208 cm - sand layer, 300-310 cm - very stiff silty clay

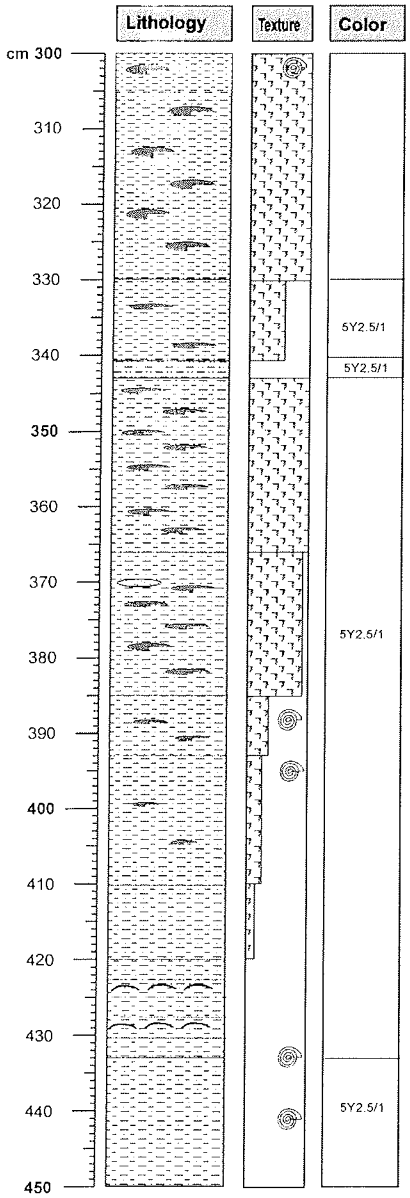
BP03-19GC — **BORIS PETROV 2003**

Yenisei Estuary

continue

73°59.99' N
73°07.81' E

Water depth: 30.0 m
Recovery: 672 cm



Description

165-330 cm: very dark gray (5Y3/1-2 to 5Y2.5/1-2) laminated clay with silt admixture, mottled, very strong bioturbation, layers from 5 to 6 mm with sharp and gradual boundaries, rarely is wavy boundary with pockets, 208 cm - sand layer.
300-310 cm - very stiff silty clay

330-341 cm: black (5Y2.5/1) silty clay, bioturbated, more massive downcore

341-343 cm: black (5Y2.5/1) silt or fine sand, faint boundary

343-433 cm: black (5Y2.5/1) banded silty clay, bioturbated. Banding is due to bioturbation and diagenetic mottling:

343-366 cm: intensive mottling, very intensive bioturbation,
366-385 cm intensive mottling, intensive bioturbation,
385-393 cm middle mottling, light bioturbation,
393-410 cm light mottling, light bioturbation,
410-420 cm massive texture, very light bioturbation,
420-433 cm slightly laminated with detrite.
370 cm lense of silt or sandy silt

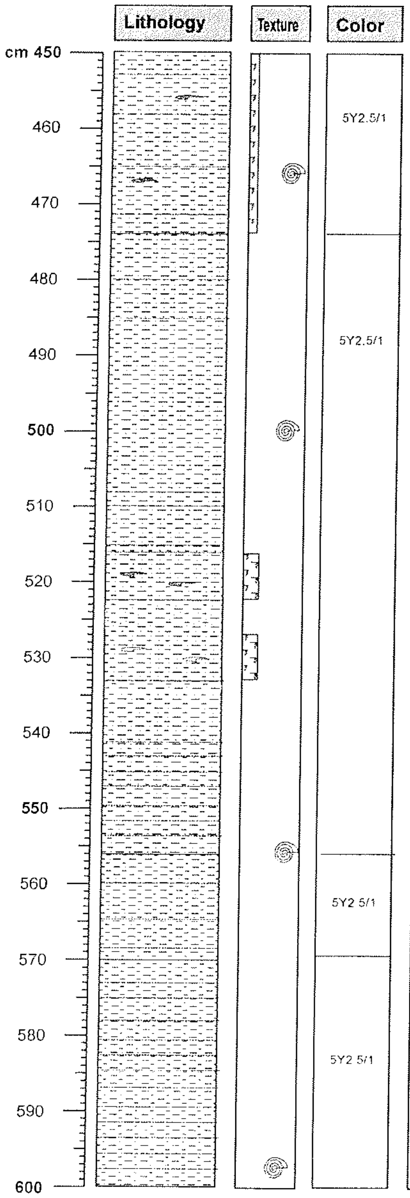
433-450 cm: black (5Y2.5/1) massive silty clay

BP03-19GC **BORIS PETROV 2003**

Yenisei Estuary
continue

73°59.99' N
73°07.81' E

Water depth: 30.0 m
Recovery: 672 cm



Description

450-474 cm: black (5Y2.5/1) silty clay, laminated (?), light bioturbation

474-556 cm: interlayering of thin layers of black and dark gray silty clay and silt, boundaries between layers are sharp but sometimes they are gradual
474-480 cm dark gray,
480-485 cm dark gray with thin diffusive black layers,
485-507 cm massive,
507-510 cm laminated, gray-black-gray layers up to 5-7 mm,
510-515 cm very dark, massive,
515-516 cm black layer,
516-522 cm dark gray, mottled, bioturbated,
522-526 cm black massive, fine sand admixture,
526-527 cm silt or fine sand layer,
527-536 cm mottled (?),
536-536.5 cm sandy silty clay layer,
536.5-541 cm massive, more dark,
541-556 cm thin layers of dark gray silty clays and homogenous black clays

556-570 cm: interlayering of silty clay, bioturbated and massive layers with thickness 4-5 cm and sharp boundaries

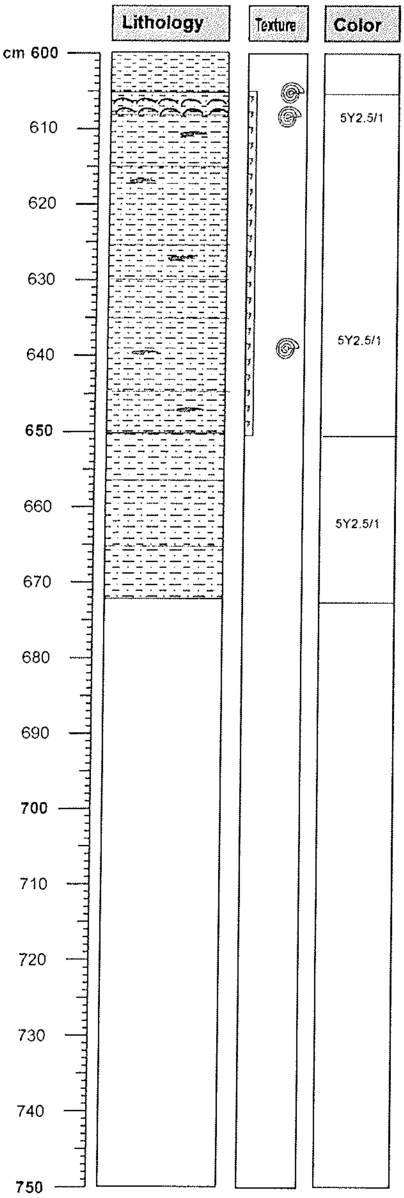
570-605 cm interlayering of very dark gray to black massive silty clay with thin more light layers of silty clay

BP03-19GC | BORIS PETROV 2003

Yenisei Estuary
continue

73°59.99' N
73°07.81' E

Water depth: 30.0 m
Recovery: 672 cm



Description

605-606 cm: enrichment of sediments by mollusk shell detrite

606-650 cm: banding is due to interlayering of very dark gray silty clay or silt, bioturbated, with more light layers up to 10 cm thickness, darkness is increased downcore, sharp boundary

650-672 cm: black clay or silty clay with rare thin (up to 1 cm thickness) more light layers of clayey silt

bivalves / shell detrite at 10, 108, 143, 209, 215, 235, 302, 383, 396, 432, 440, 465, 500, 556, 595, 605, 608, 640

11.3

Methods

11.3: Summary of biological, geochemical, and geological studies performed at Russian and German institutes on water and sediment samples obtained during the "Akademik Boris Petrov" Kara Sea Expedition 2002.

	Institute	Methods	Parameter
1. Water samples			
Sea (river) water	GEOKHI	Classical chemical analyses	Nutrients (PO4, NO3, NO2, SiO2), alkalinity, pH, chlorinity
Sea water	GEOKHI	GC	Concentration and distribution of CH4 and C2-C6 homologues
Dissolved organic matter	IFBM-AWI	HTC, HPLC, GC/MS, IRMS, CHN, NMR	DOC, DON; C, N; Amino acids, lignin phenols; structure
Carbon and silica cycle	IFBM	CN, HPLC, MS, Photometry	POC, PON, CaCO3, Opal, aminoacids, carbohydrates; ∂15N
Particulate organic matter	AWI	GC, GC/MS	Biomarkers (n-alkanes, fatty acids, sterols, hopanoids etc.)
Particulate organic matter	GEOKHI	CNS, MS	POC, PON; stable carbon and nitrogen isotopes
Particulate organic matter	GEOKHI	Radiochemistry	137-Cs and other radianuclides
Geochemistry	GEOMAR	MS	Stable inorganic carbon and oxygen isotopes
Geochemistry	GEOKHI	MS	Stable inorganic carbon isotopes
Phytoplankton	GEOKHI	MS	Stable carbon and nitrogen isotopes
Phytoplankton	MMBI	Microscopy, statistical analysis	Abundances, species composition, community structure
Zooplankton	AWI	Microscopy, REM, statistical analysis	Abundances, biomass, species composition, community structure

	Institute	Methods	Parameter
2. Sediments			
Benthos ecology	AWI	Microscopy, statistical analysis	Abundances, biomass, species composition, community structure
Benthos	GEOKHI	Gamma-spectrometry	Total radioactivity
Sedimentology/Mineralogy	AWI	XRD	Bulk and clay mineroiogy
Sedimentology/Mineralogy	IORAS	Microscopy	Heavy minerals; grain size
Organic geochemistry	AWI	CNS, Rock-Eval, GC, GC/MS; Microscopy	TOC, N, S, C/N, HI, OI; Biomarkers, ∂13C of biomarkers; Macerals
Organic geochemistry	IFBM	CN, HPLC, MS, Photometry	POC, PON, CaCO3, Opal, aminoacids, carbohydrates; ∂15N
Organic geochemistry	GEOKHI	CNS, Rock-Eval, GC, GC/MS	C, N, S; pyrolysis parameter; lignin; stable carbon and nitrogen isotopes
Hydrocarbon gases	GEOKHI	GC, GC/MS	Concentration and distribution of hydrocarbon gases; stable isotopes CH4
Pore-water chemistry	GEOKHI	classical chemistry analyses	Nutrients (PO4, NO3, NO2, SiO2), alkalinity, pH, chlorinity
Radio-geochemistry	GEOKHI	Radiochemistry, gamma-spectrometry	137-Cs, 90-Sr, 239-Pu, 240-Pu, 210-Pb
Radio-geochemistry	IGEM	Radiochemistry, gamma-spectrometry	137-Cs, 90-Sr, 239-Pu, 240-Pu, 210-Pb
Micropaleontology	AWI	Microscopy	Palynomorphs, diatoms; pollen stratigraphy
Micropaleontology	IORAS	Microscopy	Benthic foraminifera
Geochemistry	GEOMAR	MS	Stable inorganic carbon and oxygen isotopes
Inorganic geochemistry	AWI	RFA	Major and minor elements
Inorganic geochemistry	GEOKHI	XRS	Heavy elements
Core logging	AWI	Multi-sensor core logging	Magnetic susceptibility, density, velocity
Dating of sediment cores	AWI	AMS 14C	Chronology; flux rates
Sediment profiling	AWI	Sediment echograph, 3.5 khz profiling	sediment thickness, sediment structures

11.4

Participants

Research Participants

Name	Discipline	Institution
Levitan, Michael	Chief of Expedition	GEOKHI
Schoster, Frank	Co - chief Scientist	AWI
Blakely, Pal	Physics	Akvaplan-niva
Bogacheva, Margarita	Geochemistry	GEOKHI
Borisov, Alexander	Radio- Geochemistry	GEOKHI
Christensen, Guttorm	Organic Geochemistry	Akvaplan-niva
Dittmer, Martin	Geophysics	Atlas Hydrographics
Dittmers, Klaus	Geology	AWI
Evert, Jörn	Geophysics	Atlas Hydrographics
Frolova, Elena	Biology	MMBI
Janovitch, Evgeny	Radio-Physics	FEB RAS
Krupskaja, Viktoria	Sedimentology	GEOKHI
Kuhn, Gerhard	Geophysics	AWI
Lahajnar, Niko	Organic Geochemistry	IFBM
Ligaev, Alexander	Radio - Geochemistry	GEOKHI
Lom, Hanno von	Geophysics	Uni. Bremen
Nikitin, Alexander	Geology	GEOKHI
Osadchiy, Nikolay	Engineer	GEOKHI
Prusakov, Boris	Engineer	GEOKHI
Savinov, Vladimir	Organic Geochemistry	Akvaplan-niva
Schmelkov, Boris	Engineer	GEOKHI
Sizov, Yevgeniy	Radio – Geochemistry	GEOKHI
Solovjeva, Galina	Radio – Geochemistry	GEOKHI
Soyfer, Vladimir	Radio-Physics	FEB RAS
Stefantsev, Leonid	Hydrochemistry	GEOKHI
Usbeck, Regina	Geophysics	FIELAX/AWI
Vlasova, Ludmilla	Organic Geochemistry	GEOKHI

Ships Crew

Vtorov, Igor	Capitain
Dmitrenko, Peter	Chief mate
Moiseev, Alexey	2nd Mate
Opekunov, Viner	2nd Mate
Vtorov, Andrei	3rd Mate
Krytin, Alexey	Chief Radio
Horshev, Viktor	Scientific - Engineer
Latko, Alexander	Scientific - Engineer
Reutschkin, Anatoliy	Doctor
Moriz, Igor	Engineer
Abaturov, Evgeniy	Chief Mechanic
Penkauskas, Antanas	2nd Mechaniker
Boytikin, Alexander	3nd Mechaniker
Nikonorov, Alexander	4nd Mechaniker
Drosdov, Fedor	Elektro - Engineer
Ganoshenko, Anatoliy	2nd Elektro - Engineer
Golikov, Yuriy	Motorman
Nesterzuk, Yuriy	Boatswain
Petrov, Oleg	Seaman
Domrachev, Alexey	Seaman
Glebov, Vladimir	Seaman
Belousov, Pavel	Seaman
Petruschin, Sergey	Seaman
Popov, Andrey	Seaman
Smirnov, Vladimir	Seaman
Slepchenko, Vladimir	Motorman
Klimenko, Vjazeslav	Motorman
Lyatovizkiy, Oleg	Motorman
Saizev, Anatoliy	Motorman
Morosov, Yuriy	Cook
Morosova, Svetlana	Cook
Kramskaya, Ludmila	Cook
Dolmatova, Irina	Stewardess
Grizeshina, Irina	Stewardess
Korschenevskaya, Marina	Stewardess
Titova, Irina	Stewardess

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