Scientific Cruise Report of the Kara Sea Expedition of RV "Akademik Boris Petrov" in 1997

Wissenschaftlicher Fahrtbericht über die Karasee-Expedition von 1997 mit FS „Akademik Boris Petrov"

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Content

In Memoriam

Leonid Petrunin
(1949-1998)

The ultimately and sudden death of our colleague and friend Leonid Petrunin is a great loss to us all. Leonid will be remembered for his scientific contributions to the inorganic geochemistry of the polar regions, and the Atlantic and Pacific oceans. All participants of our expedition to the Kara Sea will miss him as a kind, warm-hearted friend who was always cooperative and helpful on our cruise.

Памяти

Леонида Петрунина
(1949-1998)

Внезапная и трагическая гибель нашего коллега и друга Леонида Петрунина - большая потеря для всех нас. Леонида, несомненно, будут помнить благодаря его значительному вкладу в неорганическую геохимию полярных районов, а также Атлантического и Тихого океанов. Нам, участникам рейса в Карское море, будет очень недоставать этого дружелюбного и открытого человека, на которого всегда можно было положиться во время непростых морских экспедиций.

1 Introduction

О.В.Степанец, доктор технических наук,
Институт геохимии и аналитической химии им. В.И. Вернадского
Российской Академии наук

В соответствии с Планом Российской Академии наук по изучению Мирового океана (председатель- вице-президент Российской Академии наук, академик Н.П.Лаверов) и в рамках совместного соглашения между Институтом геохимии и аналитической химии им.В.И. Вернадского РАН (ГЕОХИ РАН) (научный руководитель академик Э.М. Галимов) и Германским институтом полярных и морских исследований им. Альфреда Вегенера (AWI) (научный руководитель профессор Д.Футерер) в 1997 году была осуществлена международная экспедиция в Арктический бассейн.

Основная научная цель исследований - понять геохимические, геологические и биологические процессы, происходящие в водной среде полярных широт и оценить их влияние на проходящие глобальные процессы в Арктическом регионе.

Арктический бассейн играет существенную роль в формировании климата Земли. Баланс поглощённой и отращённой солнечной энергии в полярных районах в значительной мере определяет тепловой режим на поверхности Земли. Формирующиеся здесь массы холодной воды питают глубоководные течения в океане. В Арктическом бассейне замыкаются глобальные циклы атмосферной воды, CO_2, CH_4. Состояние газообмена здесь оказывает непосредственное влияние на озоновый слой Земли. В полярных районах сосредоточен огромный резервуар пресной воды. В свою очередь, изменение климата и параметров окружающей среды под влиянием как естественных причин, так и антропогенной нагрузки способно привести к резким нарушениям хрупкого равновесия, сложившегося в арктических экосистемах.

Великие сибирские реки вместе с северными морями образуют часть глобальной гидросферы, в пределах которой осуществляется процесс континентальной эрозии, выноса и накопления морских осадков, т.е. процесс геохимического взаимодействия "континент-океан". Масштабы и конкретное содержание этих процессов на территории северных рек и арктических морей и особенно в зоне их взаимодействия остаются ещё мало изученными.

Как известно, при контакте пресных речных и солёных морских вод (зона смешения) резко меняются гидрологические и гидрохимические условия среды, скорость перемещения водных масс, величина их водородного показателя, ионной силы, химического состава и т.д. Это приводит к интенсивной коагуляции и осаждению на дно (разгрузка) взвешенного материала, в том числе мельчайших взвесей и коллоидных частиц, что приводит к образованию полей повышенных значений концентрации химических и радиоактивных элементов, в первую очередь, искусственных радионуклидов антропогенного происхождения.

Процессы вариаций природных параметров среды, которые, в свою очередь, приводит к перераспределению и трансформации неорганических и органических веществ в зонах смешения "река-море", в настоящее время недостаточно изучены и требуют продолжения исследований.

28-я экспедиция НИС "Академик Борис Петров" является первой частью планируемых долгосрочных совместных российско-германских исследований в рамках проекта "Изучение природы континентальных сбросов из сибирских рек и их поведение в примыкающем арктическом бассейне".

Натурные исследования проведены в рамках совместной экспедиции с использованием НИС "Академик Борис Петров" Института геохимии и аналитической химии им.В.И.Вернадского (ГЕОХИ РАН). НИС "Академик Борис Петров" снабжён аппаратурой и приборами для изучения радиоактивности, химических примесей, выявления следов углеводородов и т.д., имеет опыт соответствующих исследований. Широкий набор методов и средств, размещённых на судне, позволяет проводить многопараметрические исследования Мирового океана, включающее изучение водной среды до глубин 5 000 - 6 000 м, отбор м анализ донных отложений и контроль приводного слоя атмосферы. Судно имеет вертолётную площадку и условия дл размещения погружаемого подводного аппарата до глубины 300 м.

Экспериментальные работы осуществлялись в эстуариях рек Обь и Енисей, южной части Карского моря и Гыданском заливе. Всего было проведено 59 станций.

Научная программа совместной экспедиции охватывала широкий круг вопросов, связанных с органической и газовой геохимией, окислительно-восстановительным состоянием и биогеохимической активностью в осадках, гидрохимией внутренних вод и поведением неорганических загрязнителей, с особым вниманием на радионуклиды, как маркеры происходящих геохимических процессов в воде и осадках.

В экспедиции с российской стороны принимали участие учёные из различных институтов Российской Академии наук - Института геохимии и аналитической химии им. В.И. Вернадского (ГЕОХИ - г.Москва), Института океанологии им. П.П. Ширшова (ИО - г.Москва), Института общей и неорганической химии им. Курнакова (ИОНХ - г.Москва), Института геологии рудных месторождений, петрографии, минералогии и геохимии (ИГЕМ - г.Москва), Мурманского морского биологического института (ММБИ - г.Мурманск), Института почвоведения и фотосинтеза (г.Пушкин, Московская обл.,), а также Института Арктики и Антарктики

(ААНИИ - г.Санкт-Петербург) и ВНИИОкеангеология (г.Санкт-Петербург).

С германской стороны - Институт Альфреда Вегенера полярных и морских исследований (г.Бремерхафен), Институт биохимии и морской химии (г.Гамбург), Научный центр морских геологических исследований (г.Киль).

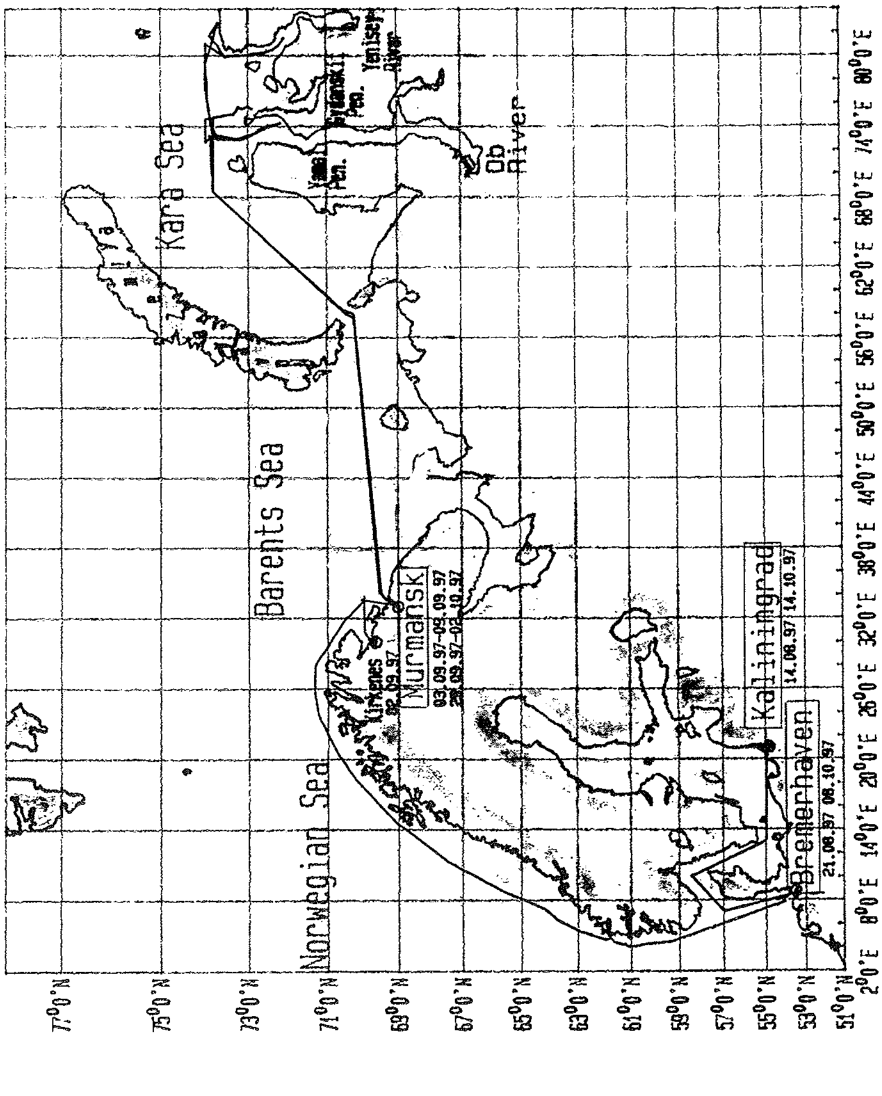


Fig 1-1: Cruise track of the 28th cruise of RV *Akademik Boris Petrov.*

Introduction (English Version)

O.V. Stepanets[1], J. Matthiessen[2]
1)Vernadsky Institute of Geochemistry and Analytical Chemistry, RAS, Moscow
2) Alfred Wegener Institute for Polar and Marine Research, Bremerhaven

In correspondence with the plan of the Russian Academy of Sciences for the Exploration of the World Ocean (Chairman: Vice President of the Russian Academy of Sciences Academician N.P. Laverov) and in the framework of the cooperation agreement between the V.I.Vernadsky Institute of Geochemistry and Analytical Chemistry of the Russian Academy of Sciences (GEOKHI RAS) (Coordinator Academician E. M. Galimov) and the Alfred Wegener Institute for Polar and Marine Research, Germany (AWI) (Coordinator Professor Dr. D. Fütterer), a joint international scientific expedition into the Russian Arctic basin Kara Sea has been carried out in August to October 1997 (Fig. 1-1). The scientific investigations should lead to a better understanding of the oceanographical, biological, biogeochemical, geochemical, and geological processes which influence and control the influx and dispersal of riverine water and its dissolved and suspended matter into the Kara Sea, and which are at relevance within the context of global environmental and climatic changes at present and in the past.

The Arctic basin plays a substantial role in the formation of the earth's climate. The balance of absorbed and reflected solar energy within the polar regions largely determines the thermal regime on the earth's surface. The global cycles of atmospheric water, CO_2, CH_4 close in the Arctic basin. The conditions of gas exchange between ocean and atmosphere influence directly the ozone layer of the earth. An enormous body of fresh water (ca. 3300 km^3/yr) is discharged into the Arctic Ocean by few large rivers. This fresh water input is essential for the maintainance of the low salinity surface water layer and for the formation of sea ice on the shelves. Intermediate and deep water masses are formed in the Arctic Ocean which finally feed the deep waters of the World Ocean. On the other hand, changes in climate and environmental parameters, caused by both natural reasons and anthropogenic impact, can drastically affect the fragile equilibrium existing in the Arctic ecosystems.

The great Siberian rivers jointly with the northern shelf seas compose a part of the global hydrosphere within which the processes of continental erosion, transport and accumulation of sediments take place, i.e. the process of geochemical interaction between the continent and ocean.

As it's known, the contact of fresh riverine water with marine water of high salinity results in the sharp change of all hydrological and hydrochemical parameters including redox state, pH and ion strength in the estuaries (mixing zone). This causes intensive processes of flocculation and coagulation of dissolved and suspended matter including fine particles and colloids with subsequent accumulation at the sea bottom, and formation by this way leads to enhanced concentration of some metals and radionuclides and especially artificial radioactive pollutants. The variations of the environmental parameters in the mixing zones which cause transformation and redistribution of organic and inorganic compounds in the river mouths are poorly understood and must be studied extensively in the future.

The 28th expedition of the research vessel *Akademik Boris Petrov* is the first step in the planning of long-term joint Russian-German investigations in the framework of the Project "The Nature of Continental Run-off from Ob and Yenisei Rivers and its Behavior in the adjacent Kara Sea".

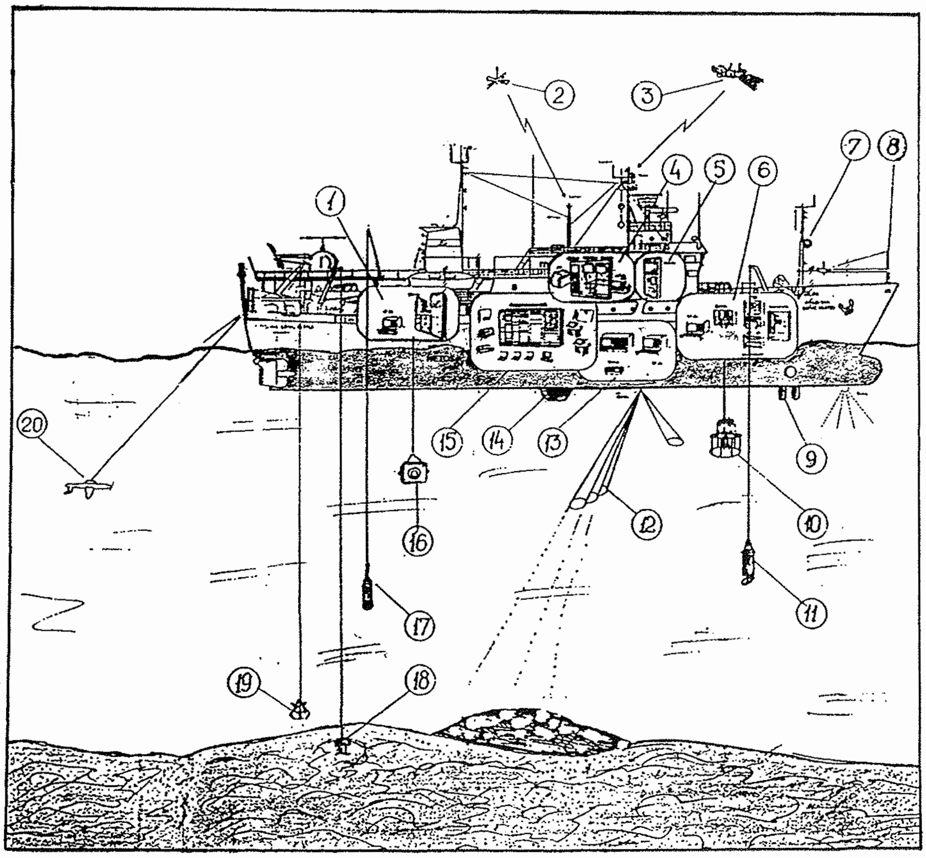
Natural investigations have been carried out during the joint multidisciplinary expedition aboard R/V *Akademik Boris Petrov* which belongs to the V.I. Vernadsky Institute. The research vessel is equipped with instruments and devices to study radioactive and chemical pollution including e.g. hydrocarbon traces in the marine environment. The large set of devices and appliances onboard enable to carry out multiparametric investigations in the World Ocean, including studies of water masses down to the depth of 5,000-6,000 m, to sample and analyze the bottom sediments and to control the near-water atmosphere layer. The vessel is equipped with a helicopter deck. It is possible to place a small submersible (down to max. 300 m water depth) on the deck (Fig. 1-2).

During the expedition research work has been carried out at 59 scientific stations in the estuaries of the rivers Ob and Yenisei, and the southern Kara Sea including Gydansky Bay (Fig. 1-3).

The scientific program of the joint expedition covered a wide range of objectives related to organic and gas geochemistry, redox state and biogeochemical activity of the sediments, geological and biological investigations (including the study of phytoplankton, zooplankton and benthic biota), hydrochemistry and inorganic pollution of the marine environment with special attention to radionuclides as markers in hydrology and geochemistry.

The scientists of many research institutes of the Russian Academy of Sciences participated in the expedition (Vernadsky Institute of Geochemistry and Analytical Chemistry, Shirshov Institute of Oceanology, Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Kurnakov Institute of General and Inorganic Chemistry, Institute of Soil Science and Photosynthesis, Murmansk Marine Biological Institute) along with scientists from the State Research Center - Arctic and Antarctic Research Institute, the All-Russian Research Institute for Geology and Mineral Resources, and German scientists from the Alfred Wegener Institute for Polar and Marine Research, the Institute for Biogeochemistry and Marine Chemistry, and the Research Center for Marine Geosciences.

The present report contains the scientific program and the initial results of the expedition which will be elaborated in the months to come, and which will form the basis for future joint investigations on the Kara Sea environment.



1. Seismoaccustical Laboratory
2. Satellite Navigation System
3. Satellite Meteodata
4. Echo-Sounding Laboratory
5. Computer based Navigationsystem
6. Hydrochemical Laboratory
7. "Air" Gamma-Ray Detector
8. Automated Meteostation
9. Water Samples
10. "Rosette" System (Temperature, Salinity, Sampling)
11. Bathometer (200l)
12. Multibeam Echo-Sounder
13. Nuclear Low-Background Instruments for Sample Analysis
14. Under-keel Gamma-Ray Detector
15. Central Computer
16. Deep-Sea Photocamera
17. Deep-Sea Gamma-Radiometer
18. Gravity Corer
19. Okean Grab
20. Tugged Gamma-Ray Detector

Fig. 1-2: Ship plan of RV *Akademik Boris Petrov.*

2 Itinerary

J. Matthiessen[1], O.V. Stepanets[2]
1) Alfred Wegener Institute for Polar and Marine Research, Bremerhaven
2)Vernadsky Institute of Geochemistry and Analytical Chemistry, RAS, Moscow

The expedition to the Kara Sea started in Kaliningrad on August 14, 1997, where the Russian cruise participants were boarded (Fig. 1-1). After sailing through the Baltic Sea, around Skagen and through the North Sea, the RV *Akademik Boris Petrov* entered Bremerhaven harbour on August 17. The following four days were filled with the final preparations for the cruise, in particular with the loading of the expedition equipment of the German scientists. The RV *Akademik Boris Petrov* left with 35 scientists and 35 crew members Bremerhaven on August 21, heading for the Russian port of Murmansk where one additional Russian scientist should join the crew. After a port call at Kirkeness on September 2 we arrived at Murmansk early next morning. The ship finally left Murmansk early in the afternoon of September 10, crossed the eastern Barents and western Kara seas, and reached the investigation area due to excellent weather conditions already three days later.

A first station was run at the northern end of the Ob transect on Saturday, 13th September (Fig. 1-3) where all scientific equipment was tested successfully. Station work was principally conducted after the ship cast anchor. In order to save ship time water column sampling was often conducted simultaneously on the forecastle and aft deck. Despite the limited space on the working deck, we were able to handle with the help of the A-frame even a gravity corer (penetration weight up to 1.5 t, core barrel length up to 5 m) to take sediment cores of up to 5 meters length. The success of our expedition is to no small extent the result of an experienced crew under the the command of Captain Lysak. This expedition showed that the RV *Akademik Boris Petrov* is well-suited for complex hydrographical and geological investigations in the Siberian shelf seas.

During the following 12 days excellent weather conditions allowed to conduct an extensive station program. Only one station was abandoned because of increasing wind force. On the main stations along the Ob and Yenisei transects and on several stations in the northern part of the investigation area sampling was carried out for all scientific programs to obtain comparable data sets both from the water column and sediments. Station work included sampling for hydrographical and hydrochemical measurements, radio- and organic geochemical, biological and geological studies using CTD, Rosette, plankton nets, Okean grab, large box corer, multi corer, gravity corers and benthos dredge. These stations were supplemented by smaller stations where samples were taken for some research programs.

After the first sediment trap was deployed at the end of the first day, RV *Akademik Boris Petrov* headed southward to the second sediment trap location which was deployed on station 13 in the outer estuary of the Ob river 38 hours later. Afterwards the water column and sediments were sampled on few stations in the outer estuary. When steaming to the north an extensive hydrographic survey was conducted on September 15 to collect samples from the water column across the salinity gradient. Continuous CTD-measurements however revealed a strong oceanographical front in the outer estuary of Ob River instead of an smooth salinity gradient from brackish to fresh water.

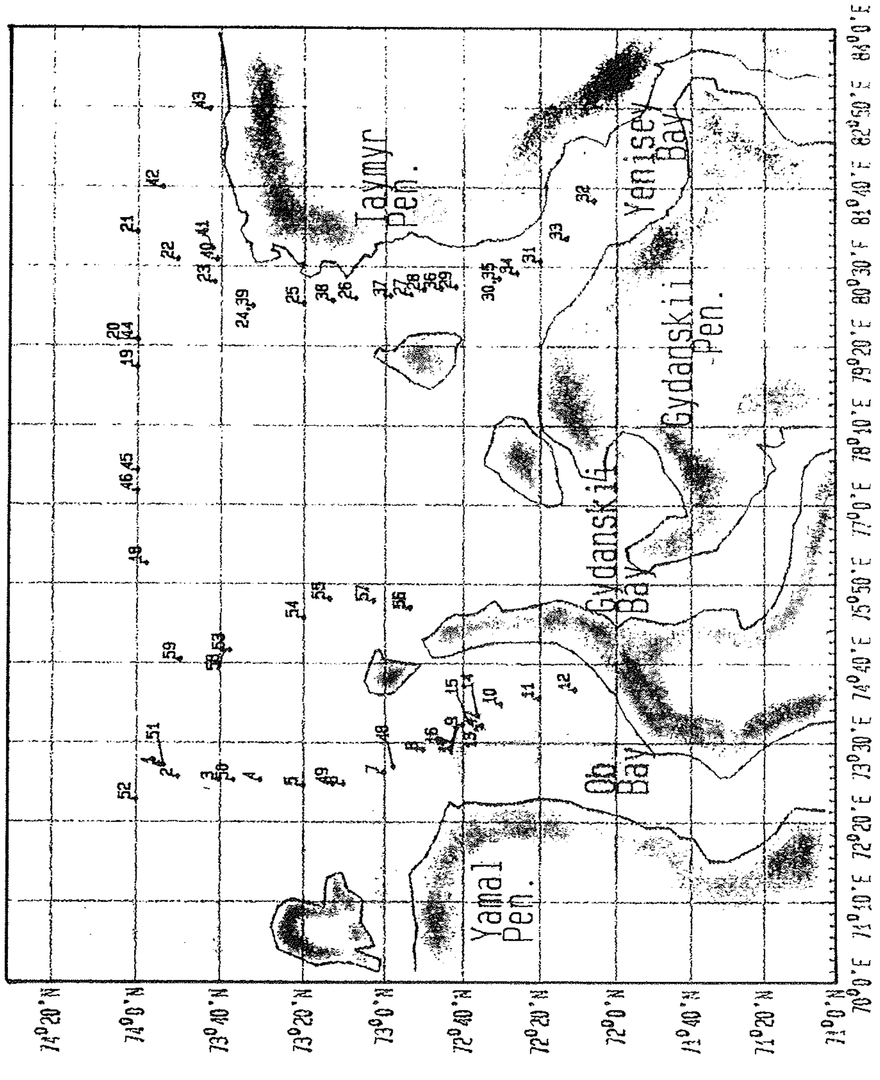


Fig. 1-3: Map of the inner Kara Sea showing the sampling stations of the 28th cruise of RV *Akademik Boris Petrov.*

On the transit to the Yenisei transect, where the other set of sediment traps should be deployed, biological, geochemical and geological sampling was conducted on stations on an west - east transect along latitude 74°. The third sediment trap was set at station 20 at the northernmost end of the Yenisei transect on September 16. Until the 20th September complex stations were worked up on this transect on the way to the south and when the ship returned northward. Inbetween the fourth sediment trap was deployed and recovered at station 28. After the third sediment trap was recovered on September 21, RV *Akademik Boris Petrov* occuppied again stations on the 74°N transect and steamed back into the outer Ob estuary to station 13. Unfortunately, the attempt failed to recover the sediment trap mooring. Heading northward, the Ob transect was completely sampled up to the location of station 1 where the last trap was recovered on September 23.

A last short transect was worked up in the Gydanskii Bay the following two days, and in the evening of September 25 we completed our working program and left the investigation area in the Kara Sea. After a port call of 5 days from September 28 to October 2 we left Murmansk and arrived at Bremerhaven in the evening of October 7. Until the 11th of October the ship was unloaded and returned with the Russian participants finally to Kaliningrad on October 14.

3 Meteorological Conditions

B. Ivanov, V. Churun
State Research Center - Arctic and Antarctic Research Institute, St. Petersburg

The synoptical processes and weather conditions during the joint Russian-German expedition to the southern Kara Sea and the Ob and Yenisei estuaries were determined by cyclonic activity developing over northern Europe and the western Arctic Ocean.

From September 13 to 19, the area of expedition was under the influence of deep depressions moving from the Scandinavian Peninsula to the north of Franz losef Land where they filled up. During this time south-western winds with speeds of 4 to 8 m/s prevailed. The wind speed increased up to 12-14 m/s when frontal systems crossed the area of investigation.

From September 20 to 21, the southern Kara Sea was under the influence of a cyclone which moved from the northern European part of Russia to the New Land Island where its activity was reinforced. Thereafter, this cyclone filled up progressively and was displaced to the north of Franz losef Land Archipelago. At this time strong south-eastern and southern winds with speed from 11 to 14 m/s were observed over the Ob and Yenisei estuaries.

The passage of a very active cyclone of small size across the southern Kara Sea area was observed on September 23. The cyclone moved from the south-west to the north-east. In isolated cases, the air pressure in the frontal part of this cyclone dropped by 12 gPa per 3 hour. The cyclone caused the initiation of storm winds with speeds of 21-24 m/s, first from the south-eastern direction and then from the north-western direction.

During the following days from September 24 to 26 the weather conditions in the study area were determined by a depression of limited activity over the Kara Sea. South-western winds with speeds of 3-7 m/s prevailed.

We would like to thank our colleague A. Korgikov from AARI who helped us to prepare this weather review. The review of weather conditions was written on the base of synoptical maps collected in the Murmansk Hydrometeorological Department.

4 Physical and Chemical Oceanography

(V. Churun, B. Finkenberger, B. Ivanov, R. Richter, L.K. Shpigun)

4.1 Water Column Sampling

A common scheme has been used to sample the water column with a rosette sampler equipped with 24 Niskin bottles (1.8 l). Sampling depths were chosen according to the salinity/ temperature profiles of the CTD probe which was deployed before the rosette sampler. On the rosette stations water samples were taken for all scientific programs from the following depth intervals:

- surface layer
- deep surface (depending on the thickness of the mixed layer)
- above the pycnocline
- below the pycnocline
- deep water

In total, rosettes were deployed at 21 stations. The basic hydrographical and hydrochemical data of the samples are presented in Annex 9.2.

4.2 Investigations of the Hydrophysical Structure in the Mixing Zone between Fresh and Saline Waters in the Ob and Yenisei estuaries

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Introduction and Scientific Goal

The remarkably shallow southern region of the Kara Sea is characterized by high amounts of river run-off from the large Siberian rivers Ob and Yenisei. Fresh water from the Ob and Yenisei rivers, due to the strong differences in the water density, is mixing with saline sea water very weakly and spreads on the Kara Sea surface layer over long distances. As the result of river discharge, the surface plume with low salinity forms annually in summer time in the southern Kara Sea. On the outer periphery of this plume is located the frontal zone with horizontal gradients of surface temperature and salinity above 1°C/ km and 1 ppt/km separating the transformed river waters from the saline sea waters. The plume of fresh water is a very dynamic formation moving on the southern Kara Sea area permanently in dependence of the prevailing winds.

On the other hand, saline sea water can penetrate far into the Ob and Yenisei estuaries. As a consequence, local frontal zones can form in the interior area of the Ob and Yenisei estuaries.

River waters transport a significant amount of dissolved and suspended organic and biogenic matter of terrestrial origin into the Kara Sea. One part of this matter is sinking to the river and sea bed, another part of the matter is transported and redistributed in the Kara Sea by currents and drifting sea ice as well as by convection and turbulence. The processes of matter exchange are more active in the contact zone between fresh and saline waters with its different physical and chemical parameters.

The main goal of the oceanographic measurements during the expedition to the southern Kara Sea and Ob and Yenisei estuaries was focused on the investigation of the hydrophysical structure in the mixing zone between fresh and saline waters.

Working Program

At every oceanographic station 1-2 soundings of the water column were made with the hydrophysical CTD set OTS-116 Probe Serie 3 produced by Meerestechnik Electronic GmbH, Germany. The CTD set OTS-116 Probe Serie 3 is equipped with sensors for recording the water pressure, the temperature, the conductivity and the dissolved oxygen content. The CTD set was carried out in combination with an Notebook IBM PC 486SX. Hydrophysical parameters were recorded with a depth resolution of 7-12 cm. The sensors of the CTD set were calibrated before the expedition. The system worked smoothly during the entire cruise.

Oceanographic measurements during the expedition were carried out in the southern Kara Sea area limited to the north by latitude 74°N as well as in the Ob and Yenisei estuaries. A total of 59 CTD stations were conducted during the cruise. Part of the CTD stations were carried out on the following transects:

- the first Ob estuary section from 73°54´ N, 73°10´ E to 72°10´ N, 74°17´ E with a total extension of 120 nm and a distance between stations of 10 nautical miles (nm) was carried out from September 13 to 15 (Fig. 4-1);
- the second Ob estuary section from 72°35´ N, 73°44´ E to 73°53´ N, 73°10´ E with a total extension of 90 nm and a distance between stations up to 24 nm was fulfilled from September 22 to 23 (Fig. 4-2);
- the first Yenisei estuary section from 73° 32´ N, 79°55´ E to 72°05´ N, 81°28´ E with a total extension of 100 nm and a distance between stations up to 18 nm was carried out from September 17 to 18 (Fig. 4-3); this section was carried out for a second time from September 19 to 20 (Fig. 4-4).

The conductivity-temperature-depth profiles were used to select the water depths to be sampled with Niskin bottles from the rosette system.

Preliminary Results

The following preliminary results of oceanographic recordings were obtained during the investigations in the Ob and Yenisei estuaries:

1. The position and hydrophysical parameters of the fresh water plume off the Ob and Yenisei estuaries could not be determined due to the limited area of investigation. Moreover, comparing the values of surface temperature and salinity recorded during the expedition with climatic data for this area of the Kara Sea (Burenkov and Vasilkov, 1994) we can conclude that the field investigations in summer 1997 were carried out within the fresh water plume.

2. On the first Ob estuary transect carried out from September 13 to 15 a narrow local frontal zone was observed, separating original river water with a salinity less than 3 ppt from more saline water with a salinity of 10-12 ppt

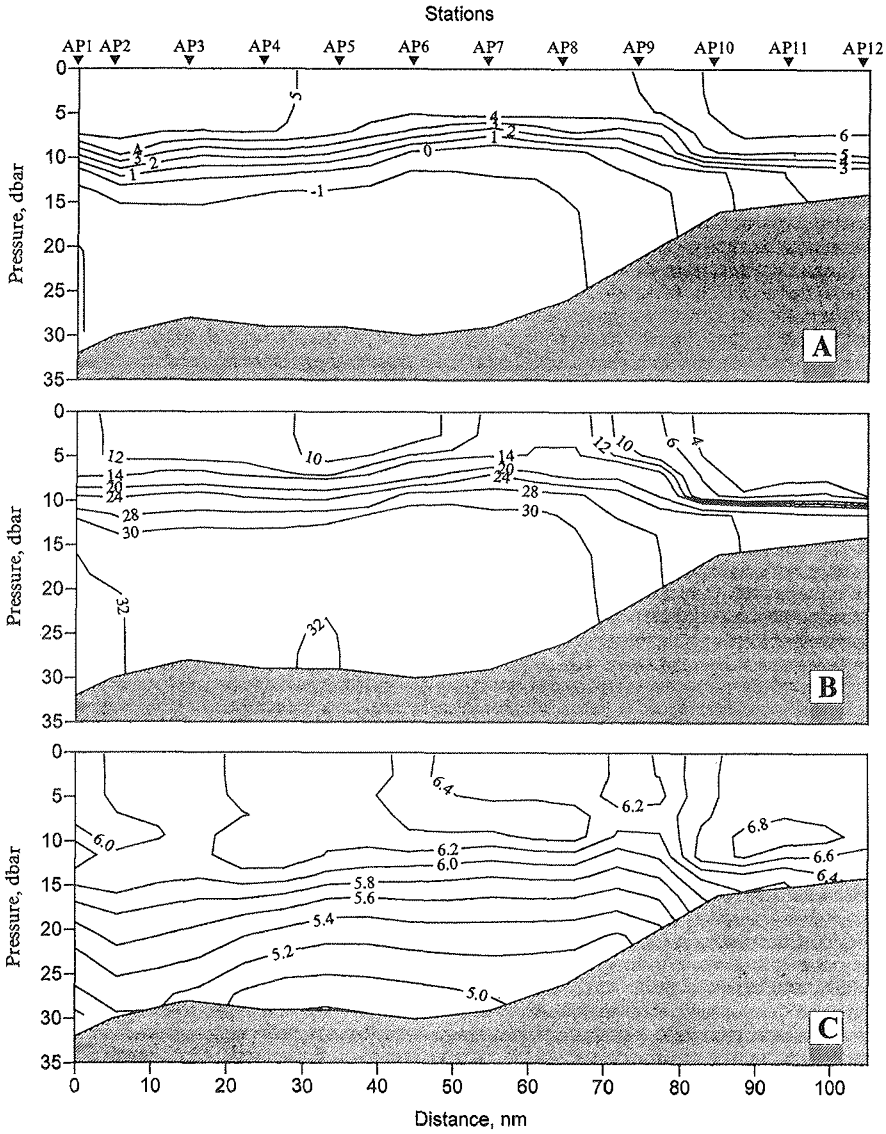

Fig. 4-1: Distribution of temperature, °C (A), salinity, ppt (B), and oxygen, ml/l (C) on the transect along the Ob Bay from 73°54'N, 73°54'E to 72°10'N, 74°17'E (September 13-15, 1997).

(Fig. 4-1). The presence of the frontal zone corresponds to the decrease of bottom depth from 30 to 18 m. The width of this frontal zone did not exceed 10 nm. The frontal zone was characterized by values of horizontal gradients of surface temperature and salinity equal to 0.07°C/km and 0.3 ppt/km, respectively.

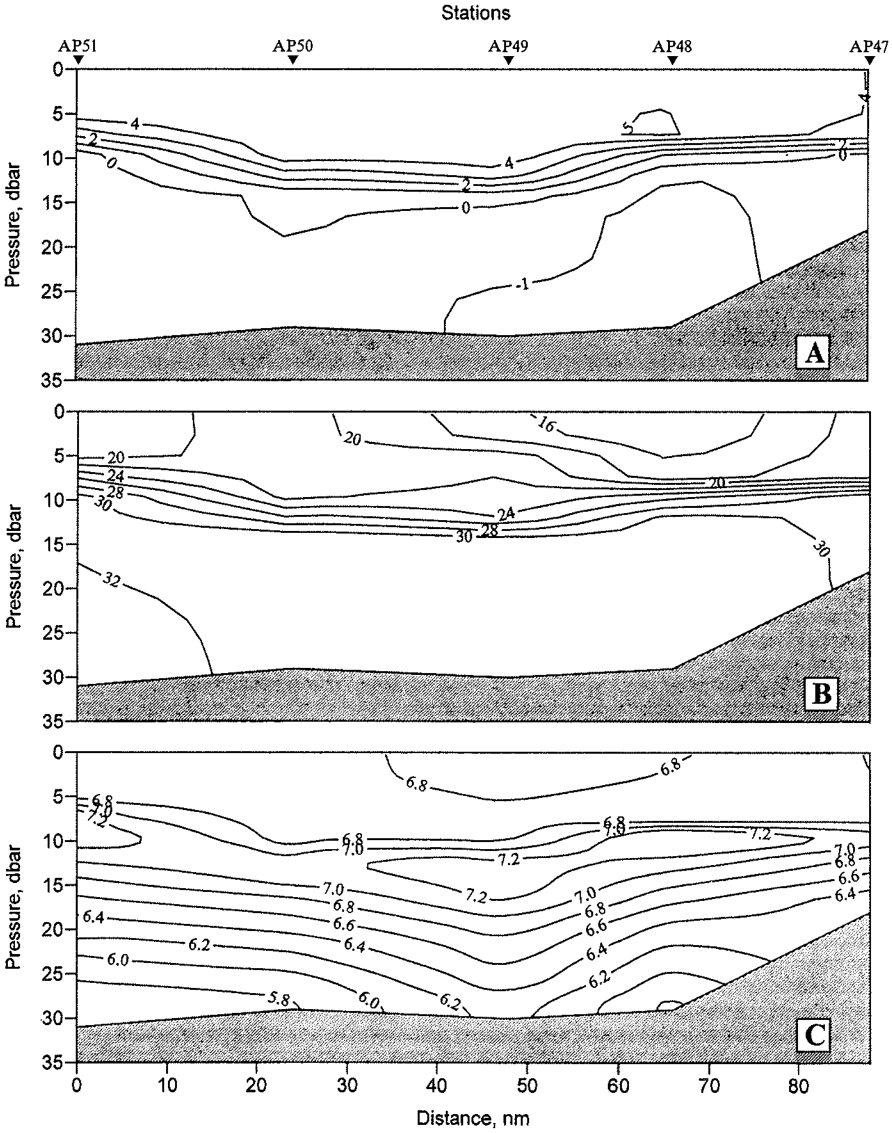

Fig. 4-2: Distribution of temperature, °C (A), salinity, ppt (B), and oxygen, ml/l (C) on the transect along the Ob Bay from 72°35′N, 73°44′E to 73°53′N, 73°10′E (September 22-23, 1997).

This local frontal zone is not only a boundary separating the fresh water from saline water, but also a natural interface between two different types of water stratification.

The water column north of the frontal zone consists of two layers. The surface layer is relatively warm with a temperature of 4-5.5°C and fresh with a salinity of 10-12 ppt, a combined effect of the mixture of meteoric water (fresh Ob River water plus precipitation; MW) and saline surface water of the Kara Sea. We can define this layer as the transformed meteoric water of the Ob estuary (TMW). The thickness of this layer is of 5-8 m. The second layer lies around 12-30 m and consists of sea saline water with a negative temperature up to -1.5°C and a salinity up to 32 ppt formed in the Kara Sea during winter time (polar winter water of the Kara Sea, PWKS). The strong pycnocline with a thickness of 7-8 m is located between these two layers.

Further to the south of the frontal zone the pycnocline sinks to the bottom. The water column to the south of the local frontal zone is almost under the prevailing influence of the meteoric water (MW). The whole water column is composed mainly of the relatively warm meteoric water with a temperature above 6°C and a salinity varying from 2.3 to 3.1 ppt. The thin layer with a salinity up to 21 ppt and a temperature up to 2.2°C is observed near the bottom only. The water in this layer was formed in spring time during the break-up of sea ice in the Ob estuary and represents the effect of mixing of meteoric water and saline polar winter water of the Kara Sea in the summer time (transformed polar winter water of the Kara Sea, TPWKS).

A local surface lens with a salinity of 8.3-8.6 ppt and a temperature of 4.7-4.9°C surrounded by waters with a higher surface salinity was observed on the first transect in the Ob estuary. The width of this lens did not exceed 6 nm. Probably, the formation of that fresh local lens is a result of the frontal divergence.

3. The presence of a frontal zone was not observed during the fulfillment of the second transect in the Ob estuary from September 22 to 23. Moreover, compared to the previous situation in this area the surface temperature decreased up to 3.9-5.0°C and the surface salinity increased up to 13.8-20.8 ppt (Fig. 4-2). The increase of the surface salinity in the Ob estuary appeared at regular intervals by strengthening of Yamal current. One more result of Yamal current strengthening is the displacement of the fresh plume to the east. Thus, the surface salinity was lowered at the average of 1.2 ppt during the fulfillment of the transects in the Yenisei estuary.

4. A local frontal interface between fresh and saline waters was not found in the Yenisei estuary. Up to 72°35'N the salinity decreased monotonously from 11.87 in the north to 2.21 ppt in the south of the section while the temperature increased (Fig. 4-3 and 4-4).

As well as in the Ob estuary, the water column in the Yenisei estuary consists of two layers. The upper layer around 6-8 m is composed mainly of transformed meteoric water (TMW) formed by a mixture MW and surface saline water of the Kara Sea. TMW in the Yenisei estuary has a salinity of 5.74-11.87 ppt and a temperature of up to 6.8°C. The bottom layer at around 19-40 m is occupied by sea saline water with a negative temperature and salinity up to 32 ppt of winter origin (polar winter water of the Kara Sea, PWKS). The resistant pycnocline with a thickness of 4-6 m is located between these two layers. Notice that PW of the Yenisei estuary has a slightly lower salinity than the same water in the Ob estuary.

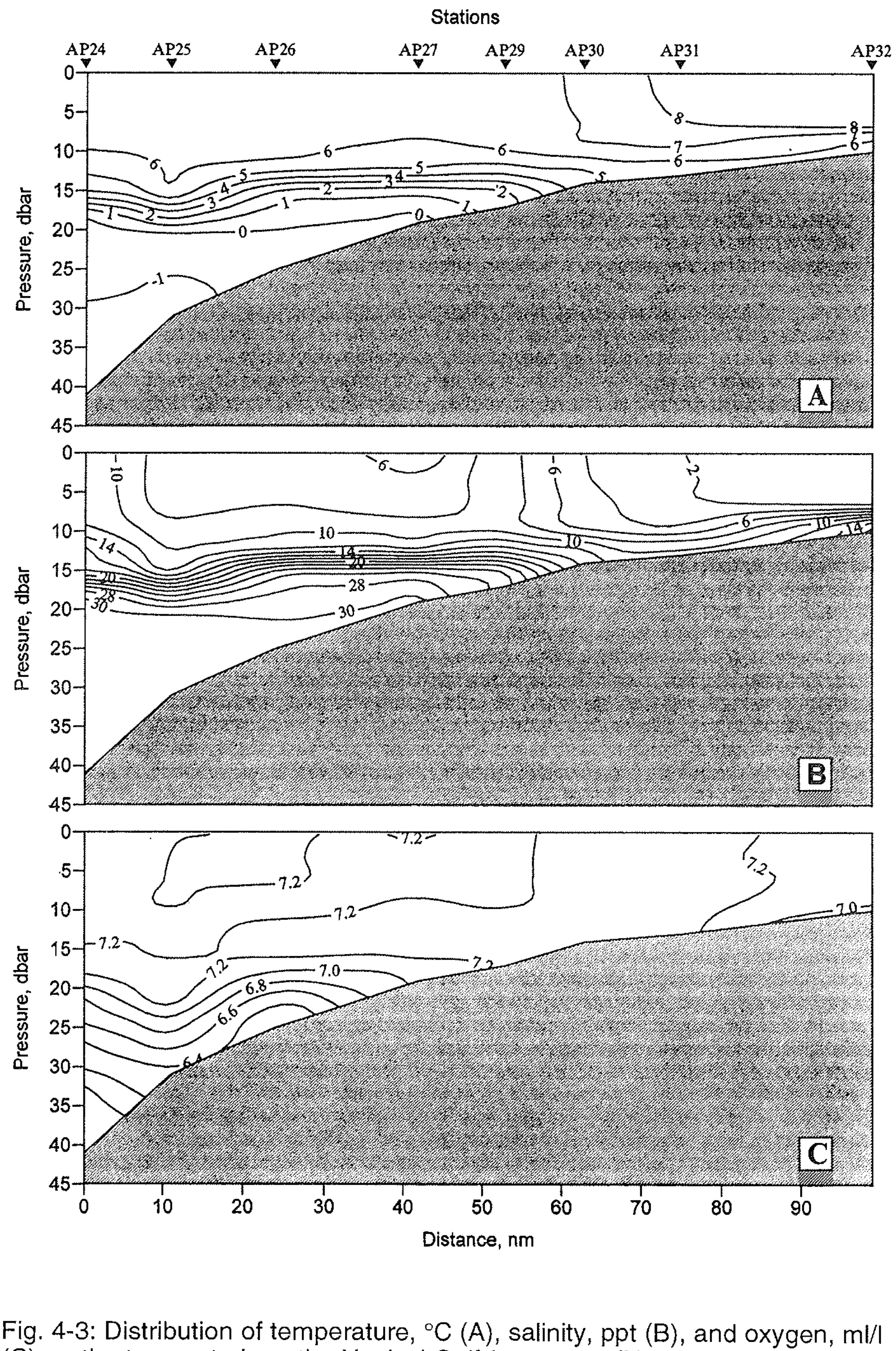

Fig. 4-3: Distribution of temperature, °C (A), salinity, ppt (B), and oxygen, ml/l (C) on the transect along the Yenisei Gulf from 73°32'N, 79°55'E to 72°05'N, 81°28'E (September 17-18, 1997).

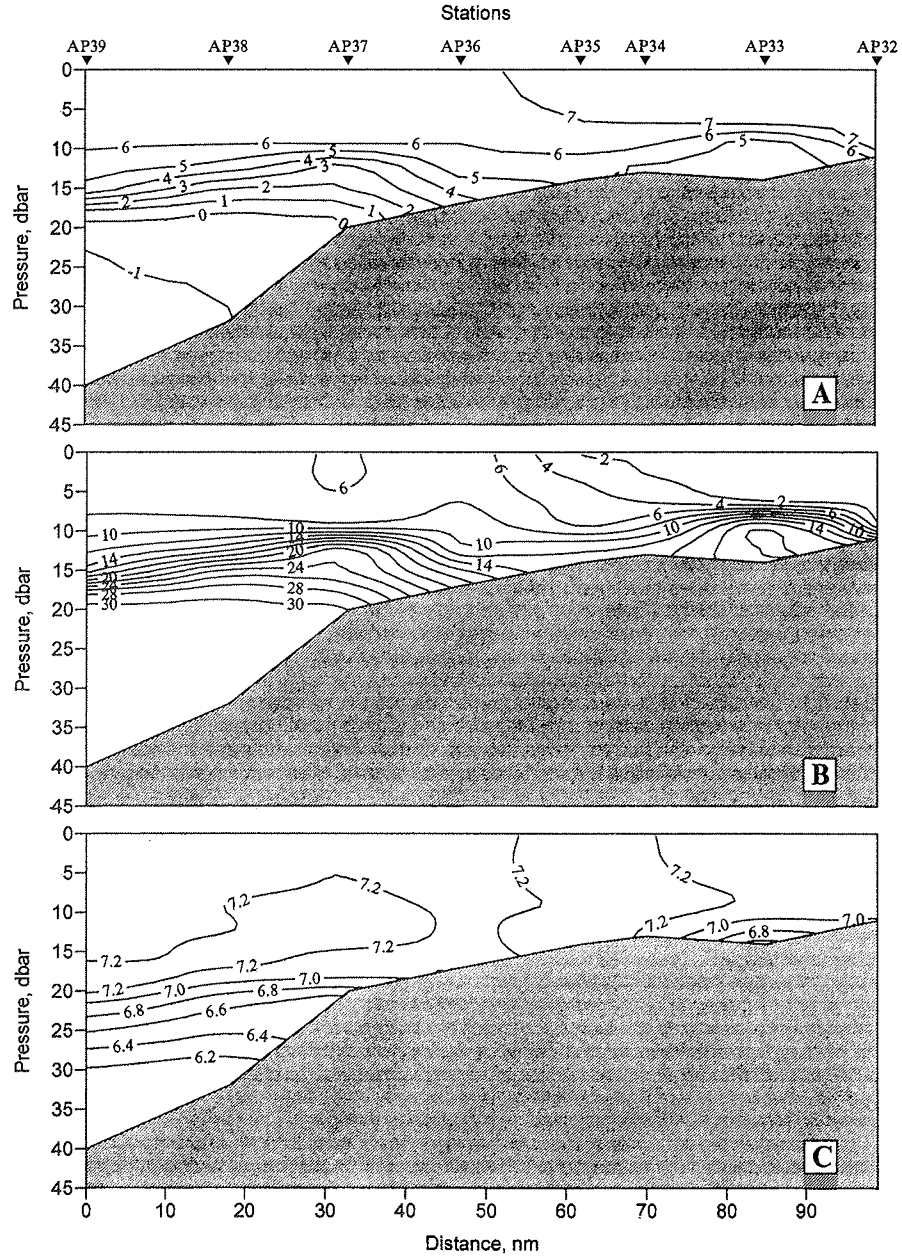

Fig. 4-4: Distribution of temperature, °C (A), salinity, ppt (B), and oxygen, ml/l (C) on the transect along the Yenisei Gulf from 72°05´N, 81°28´E to 73°32´N, 79°55´E (September 19-20, 1997).

Just south of 72°35'N the whole water column is composed mainly of meteoric water (MW) with a salinity less than 1.93 ppt and temperature up to 8.01°C. The brackish water with salinity up to 18 ppt and positive temperature was found close to the bottom only. This water formed by a mixture of meteoric water of the Yenisei river and polar winter water of the Kara Sea and presents the polar winter water of the Kara Sea (TPWKS) transformed in the summer time.

5. T,S-parameters of the main water types forming the water column structure of the Ob and Yenisei estuaries are identified based on the results of the CTD-measurements (Table 4-1).

Table 4-1: T,S-parameters of water types in the Ob and Yenisei estuaries.

Water type	Ob estuary		Yenisei estuary	
	T [°C]	S [ppt]	T [°C]	S [ppt]
MW	up to 6.3	<3.1	up to 8.0	< 1.9
TMW	4.4 - 5.4	7.6 - 13.1	6.1 - 6.8	5.7 - 11.8
PWKS	-0.1 - -1.5	30.7 - 32.3	-0.7 - -1.2	30.9 - 31.9
TPWKS	0.8 - 2.2	20.2 - 25.0	4.2 - 5.6	9.9. - 17.9

MW - meteoric water (Ob River or Yenisei River plus precipitation);
TMW - transformed meteoric water;
PWKS - polar water of the Kara Sea;
TPWKS - transformed polar water of the Kara Sea.

4.3 Hydrooptical Measurements in the Frontal Zone of the Ob and Yenisei Estuaries

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Redistribution of short-wave solar radiation incoming on the sea surface is governed by dispersion and absorption processes. The value of absorbed solar energy depends on the optical properties of fresh and sea water, dissolved substances and mineral and biological suspensions. Solar energy absorbed by sea water turns into chemical and heat energy. The dispersion of solar radiation in natural marine environments is governed by dispersion of sea water and suspended particles which as it was mentioned above may have an organic or non-organic origin. The processes of dispersion and absorption are acting in the natural marine environment simultaneously. Therefore, the relaxation of solar radiation during its penetration into the sea surface will take place at the expense of both processes.

The relaxation index of sea water in the visible part of the solar spectrum (380-770 nm) varies on the average from 0.02 (1/m) in clear sea water up to 1-10 (1/m) in coastal regions. Water layers with decreasing transparency are formed by accumulation of suspended particles, the increase of the concentration of dissolved substances as well as the increase of phyto- and zooplankton density.

Redistribution of solar radiation in sea water is related to the temperature and salinity structure (light refraction on the boundary between layers with different density) and the amount of short-wave radiation incoming on the sea water. The short-wave solar radiation depends on clouds and altitude of the sun. On the last parameter depends also the length of solar pathways when passing in the water column from the sea water surface to a particular level.

The goals of investigations were the following:
- the study of the influence of river water outflow peculiarities on the hydro-optical characteristics of sea water in the Ob and Yenisei estuaries;
- the investigation of relationships between hydrooptical, oceanographical, biological and hydrochemical characteristics in the outflow zone and adjacent area.

Working Program

The working program involved the following aims:
- the fulfillment of special underwater radiation measurements (parallel to the CTD-measurements) in the Ob and Yenisei estuaries and in the frontal zone between river and sea water masses and in the adjacent areas;
- the conduction of routine meteorological and actinometrical observations during hydrooptical measurements.

Observations and Equipment

The hydrooptical measurements were carried out at 15 CTD-stations (see Annex 9.1) in the Ob and Yenisei estuaries and to the north of the outflow zone at stations along 74° N.

The portable underwater pirronometer (UPW-1) designed by the Electro-technical University of St. Petersburg was used for recording the penetrating solar radiation into sea water. The UPW-1 has the following technical characteristics:

spectrum range	- 300 - 2800 nm;
sensitivity	- 0.062 mV/W/m^2;
time constant	- 15 s.

Incoming short-wave solar radiation on the sea surface was measured with the standard air pirranometer CM-10 with a sensitivity 0.00514 mV/W/m^2. The air standard pirranometer CM-10 was placed at the bow of the ship in a special kardanic construction. These measurements are used as reference to correct and control for changing atmospheric conditions at the surface during the measurements in the water. For each sounding the irradiance for different depths are corrected for variations in atmospherical radiation. All sensors were checked in June 1997.

Preliminary Results

The index of underwater illumination was calculated for CTD stations where hydrooptical measurements were made. On the basis of the calculations two main regions with a different type of vertical distribution of penetrating solar radiation in the water column were revealed in the southern Kara Sea (Table 4-2). It was determined that 95% of the solar radiation accumulates in the upper meter in the Ob and Yenisei estuaries. The 95% level of absorption in the marine water was fixed at 2 m of water depth.

Table 4-2: Index of underwater illumination, percentages for two regions in the southern Kara Sea.

Depth [m]	Index of underwater illumination [%]	
	Ob and Yenisei estuaries	74° N
1	94 - 96	92
2	98 - 99	95
3	99 - 100	97
4	100	100

The relative increase of the relaxation index was observed in the lower part of the mixing layer at a depth of 3-6 m at stations located along 74° N. Probably this phenomena is connected with an increase of the phytoplankton concentration over the seasonal pycnocline.

Comparison of hydrooptical and oceanographical data revealed that there is no significant influx of short-wave solar radiation below the seasonal pycnocline located in the area of investigations at the depth of 8-12 m.

4.4 Hydrochemical Characteristics of the Kara Sea - Ob and Yenisei Facing Zones

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The content and distribution of trace chemical components in the marine environment is of interest from many points of view. In particular, concentration profiles of some elements in the sea water and in the pore water of bottom sediments are caused by various hydrochemical processes.

River run-off significantly influences the water balance of the Kara Sea as well as the water exchange between its zones and determines the chemical composition of water and bottom sediments. This influence is especially strong in the outflow zones of the Yenisei and Ob rivers. Thus, systematical observations and knowledge of nutrient cycling and primary productivity in the mixing zone of the river water with Kara Sea water are very important.

The hydrochemical studies during the expedition included the following main aspects:

- the composition of the carbonate system in the water along the Ob - and Yenisei - transects;
- vertical and horizontal concentration profiles of inorganic nutrients, trace metals and other chemical compounds in the water;
- chemical features of the "biologically active" upper water layer and the water-sediment interface;
- distribution of river water in the Ob and Yenisei - Kara Sea facing zones;
- comparison with the hydrochemical results of expeditions to the Kara Sea in 1993 and 1995.

Our interest focused on the investigation of the chemical composition of the water column in relation to hydrographical, biological and other environmental conditions. The determination of the elements of the carbonate system such as pH values, total alkalinity (Alk_t) and total inorganic carbonate (TCO_2) allow to calculate carbon dioxide exchange processes. The pH values, dissolved oxygen and nutrient data are necessary to estimate the primary productivity rates in the upper water layers. The alkalinity/salinity ratio as well as the dissolved silica concentration will enable to trace the river water in the Kara Sea.

Methods and Instruments

- pH - potentiometric method based on using a pH-electrode connected to the digital pH-meter/millivoltmeter 701A (Orion Research) (precision of about 0,005 pH units);
- Total alkalinity, total dissolved carbonates, phosphates, silicates, sulphates, inorganic nutrients and trace metals (Fe and Mn) - spectrophotometric flow-injection methods available for shipboard use owing to speed of analysis, *on-line* sample pretreatment and reliable analytical characteristics (Shpigun et al., 1992; Zolotov et al., 1997). All measurements were made by using a FIAstar 5010 Analyzer which was connected to a computer working with Super Flow Software.

Samples

For the investigation of the chemical composition of water and distribution of chemical species in the water column, 170 water samples were collected from the Niskin bottles at the 21 hydrochemical stations. Additionally, bottom water samples were taken by a multi corer at 23 stations. Furthermore, some pore water samples were also obtained. The total number of all samples was 350.

Total alkalinity, total dissolved carbonates and pH values were determined immediately after sampling. A number of samples were filtered through Satorius filters (45 µm pore diameter) and then they were frozen or were fixed with acid (pH 1.5) and stored in plastic bottles.

First Results

A large amount of hydrochemical measurements was made. Some analytical data obtained for selected hydrochemical parameters from the standard water depths are summarized in Annex 9.2. The analysis of these experimental results in combination with data on the temperature, salinity and dissolved oxygen (Winkler titration) will allow to estimate the distribution of the Ob and Yenisei river water run-off and to describe schemes of surface and bottom currents in the mixing zone of sea and fresh water.

The distribution of the main elements of the carbonate system (pH-values, total alkalinity Alk_t and total dissolved inorganic carbonate TCO_2) were obtained. According to the preliminary experimental results, a positive correlation between Alk_t and salinity values in the surface water layers was observed. The results indicate the continuous increase of the alkalinity/salinity ratio from 0.089 - 0.116 to 0.320 - 0.528 along both the Ob and Yenisei transects. In contrast, the values of TCO_2 and pH for surface water decreased strongly in this direction. The lowest values of these parameters were obtained at station 97-32 of the Yenisei transect (pH = 7.625, TCO_2 = 0,6 mM) and at station 97-10 of the Ob transect (pH = 7.634, TCO_2 = 0,75 mM).

Future detailed studies of the vertical and horizontal distribution of the nutrients and some other important microelements in the water column will give the opportunity to characterize the transport processes of organic matter as well as pollution from the rivers to the Kara Sea. The preliminary results of the complicated study of the chemical composition of the sediment pore waters are discussed in Kodina et al. (chapter 7.2.2).

4.5 Inorganic Nutrients

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The inorganic nutrients belong to the main hydrochemical parameters to characterize water masses, and measurements are needed to support biological and physical investigations. Alkalinity and silicate contents have been successfully used to distinguish between different water masses, e.g. Ob and Yenisei water masses in the Kara Sea (Stunzhas, 1995). These data are not only important to understand hydrochemical processes in the Kara Sea, but also to understand the interaction with the Central Arctic Ocean. Together with dissolved oxygen, DOM and pH values nutrient data are also necessary to investigate primary production in the surface layer.

During the expedition to the Kara Sea the major goal was to characterize the concentration and composition of the inorganic nutrients along the surface salinity gradient. During the cruise 25 surface water samples were taken for further laboratory analyses. All samples were poisoned with mercuric chloride. At the AWI the concentration of nitrate, nitrite, ammonium, phosphate and silicate will be determined.

4.6 Stable Oxygen Isotope Analysis of Sea Water

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The oxygen isotope ratio ($^{18}O/^{16}O = \delta^{18}O$) of river water is very low compared to normal ocean water because of isotope fractionation during evaporation and atmospheric transport from the oceans to the continents. Also, the carbon isotope ratio ($^{13}C/^{12}C = \delta^{13}C$) of the dissolved inorganic carbon (DIC) in river water is low because of low ^{13}C values in continental soils. Thus, it is possible to trace the river water outflow in adjacent ocean areas by the isotope composition of sea water. In contrast to other major Arctic rivers, the isotopic signature of the rivers Ob and Yenisei is largely unknown. Therefore, the water column was sampled on all rosette stations along the salinity gradient to obtain samples from the riverine surface water as well as from deeper, marine influenced waters.

The samples were taken as soon as possible after the rosette sampler returned to the ship's deck to avoid the loss of CO_2 and the exchange with atmospheric CO_2. At each station, water was slowly filled into 100 ml glass bottles. 0,2 ml $HgCl_2$ were added to stop biological activity. Bottles were closed tightly with a glass cork and stored under cool conditions. The stable isotope analyses will be carried out at the Leibniz Laboratory of Kiel University, Kiel.

5 Marine Biology

(M. Poltermann, H. Deubel, C. Halsband, S. Korsun, R. Richter)

Strong seasonality in the light regime and the sea ice cover are special characteristics of polar oceans. Together with these factors the strong signal of fresh water, heat and matter supply originating from the large Siberian rivers Ob and Yenisei during spring and summer are dominating factors which influence the marine biosphere in terms of productivity, consumption and transformation processes in the Arctic Kara Sea. Biological communities living under such severe conditions are often characterized by only few species occurring in high abundances; therefore they play an important role in the transformation of organic matter.

The main objectives of the biological working groups on board RV *Akademik Boris Petrov* in 1997 were to study structures of different biocoenoses in the estuaries of Ob and Yenisei, to identify key species and to assess their role in transformation processes of inorganic and organic matter. Furthermore, doing a first step in the description of diversity patterns along the gradients from the rivers up to the deep Arctic Ocean as well as the sensitivity of the benthos to the annual disturbances by ice and river outflow.

5.1 Phytoplankton

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Phytoplankton investigations were one topic of the biological program during the cruise of RV *Akademik Boris Petrov* to the Kara Sea in September 1997. The main interest was to investigate the horizontal and vertical distribution of phytoplankton species composition and biomass with regard to the different hydrographical, chemical and other environmental conditions.

Water samples to analyze species composition and biomass were collected with a Niskin rosette sampling system at 21 stations. On every station sub-samples were taken from 3 to 4 different water depths according to different water masses determined by the CTD profiles. In most cases, samples were taken at the surface, just above and below the pycnocline and, close to the bottom.

Species composition: Samples of about 200 ml were stored in brown glass bottles and fixed with hexamine-buffered formalin (final concentration about 0,5 %). The species composition of plankton will be analyzed at AWI with an inverted microscope.

Chlorophyll-a: 250 - 500 ml of water were filtered on Whatman GF/F glasfibre filter and stored at -18° C and will be analyzed at AWI.

5.2 Zooplankton

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5.2.1 Introduction

The aim of the investigations is to describe the distribution of oceanic zooplankton species, i.e. *Calanus* spp., and the composition of communities along the salinity gradient caused by the strong fresh water input from the Siberian rivers Ob and Yenisei.

Moreover, we wanted to study the role of these zooplankters for the transformation of organic matter, brought into the Kara Sea by the rivers mostly as detritus. With the help of laboratory experiments with freshly captured animals some aspects of the feeding and life strategies were investigated:

First, the in-situ faecal pellet production which gives information about the current feeding situation. Preserved material can be analyzed later for gut contents, faecal pellet composition, energy exploitation and transformation processes during digestion.

The second topic was the study of in-situ egg production which mirrors at the same time the efficiency of feeding and the current reproductive state of the females. Fixed material can serve for analysis of gonad development.

A third aspect was the salinity tolerance of oceanic species towards low salinities. The fresh water signal of the estuaries extends many hundred miles northwards and influences the vertical and horizontal zooplankton distribution. The question in how far oceanic species are able to persist low salinities in order to feed on detritus in the oligohaline, detritus-rich surface layers was elucidated.

5.2.2 Material and Methods

5.2.2.1 Sampling

At 20 stations zooplankton samples were taken with a Nansen closing net of 150μm mesh size, which was towed vertically with less than 0.5 ms^{-1}. According to the respective salinity regime 4 nets were deployed at each station: One net haul from below and above the pycnocline, respectively, were preserved in 4% buffered formaline. From the other two net hauls from the deep layers living animals were sorted out for experiments (Table 5-1).

5.2.2.2 Experiments

I. In-Situ Faecal Pellet Production

48 *Calanus* CV (if available) and as many females as possible were kept individually in cell wells® filled with filtered sea water, which was sampled in a large volume bathomat and filtered with cellulose-nitrate filters (0.45 μm). After 24 h incubation in a refrigerator at about 20°C pellet production was controlled and pellets were fixed in formaline for each stage (CV, females) separately.

Table 5-1: Zooplankton sampling stations.

Station	Date	Latitude	Longitude	Depth [m]	Salinity [ppt] (surface)	Salinity [ppt] (bottom)	Pycnocline [m]	Nets	Sample depth [m]	Experiment*
BP97-01	13.09.1997	73°54′38″	73°10′59″	28	13	32	7	2	25-12; 12-0	
BP97-10	14.09.1997	72°30′01″	74°04′51″	19	1	25	11	4	12-9; 9-0	
BP97-18	16.09.1997	73°57′42″	76°08′20″	31	11	32	10	4	28-10; 10-0	FP, D
BP97-21	17.09.1997	74°00′28″	81°00′02″	40	15	32	12	4	37-12; 12-0	FP
BP97-24	17.09.1997	73°32′04″	79°55′16″	39	11	31	15	4	36-15; 15-0	FP
BP97-27	18.09.1997	72°53′21″	80°05′33″	19	4	31	14	4	16-12; 12-0	FP, D
BP97-30	18.09.1997	72°30′30″	80°20′11″	13	4	13	12	2	12-0	
BP97-32	19.09.1997	72°05′35″	81°28′52″	10	1	15	8.5	2	6-0	
BP97-38	20.09.1997	73°12′51″	80°00′19″	31	7	31	14	4	28-10; 10-0	FP
BP97-42	20.09.1997	73°53′57″	81°40′12″	30	15	32	15	4	27-15; 15-0	FP, D
BP97-43	20.09.1997	73°42′55″	82°48′80″	31	11	32	20	4	27-20; 20-0	FP
BP97-46	21.09.1997	73°59′96″	77°12′24″	27	12	32	10	4	24-10; 10-0	FP
BP97-47	22.09.1997	72°35′06″	73°44′54″	18	19	29	8	2	15-8; 8-0	
BP97-48	22.09.1997	72°57′68″	73°00′08″	28	14	31	10	4	25-10; 10-0	FP
BP97-49	23.09.1997	73°12′57″	72°53′06″	29	16	32	12	4	26-12; 12-0	FP
BP97-50	23.09.1997	73°36′66″	72°57′00″	29	21	32	12	4	26-12; 12-0	FP, D, S
BP97-52	24.09.1997	74°00′03″	72°39′72″	29	18	32	8	4	26-8; 8-0	FP, S
BP97-55	24.09.1997	73°13′48″	75°37′12″	14	10	18	12	1	11-0	
BP97-56	25.09.1997	72°53′39″	75°28′95″	14	9	16	12	1	11-0	
BP97-58	25.09.1997	73°39′02″	74°50′32″	21	9	31	13	2	17-12; 12-0	

* FP = In-situ faecel pellet production
D = Detritus feeding experiment
S = Salinity tolerance experiment

II. In-Situ Egg Production
For egg production experiments, individual females were incubated in cell walls for at least 24 hours at ambient temperatures. The wells were checked every half day for eggs.

III. Feeding Experiments
At four stations (No. 18, 27, 42, 50) all animals from the experiment I were fed several times a day with detritus-rich surface waters which was salted up to about 30‰ with marine salt (except station No. 18: 15‰). After 36-48 h incubation faecal pellet production was controlled.

IV. Salinity Tolerance
At stations No. 50 and 52, 30 CV and 20 females captured at 30‰ were incubated in 2 l beakers with artificially salted water and exposed to a dilution series from 22.5‰ down to 8‰. Every 24 h dead animals were removed and salinity was lowered at 2.5‰ intervals by dilution with fresh water. At the end of the experiment all remaining animals were fixed in formaline for further species determination.

5.2.3 Preliminary Results

Species Distribution
The occurrence of *Calanus* was restricted to the deep water layers with salinities >30‰. The three North Atlantic species of the genus *Calanus* were observed, *C. finmarchicus, C. glacialis* and *C. hyperboreus*. In the upper water layers mainly species typical for fresh or brackish water were observed, e.g. *Oithona* spp.

In Situ Faecal Pellet Production of Calanus Species
At all stations only CV produced faecel pellets and only very few pellets were produced per animal in 24 h. Maximum individual production rate was 8 pellets per day by a CV from station No. 49. It was quite obvious that more faecal pellets were produced in the open sea than in the river estuaries, where sometimes none of the specimens produced any pellets.

In-Situ Egg Production
At all stations none of the collected females produced any eggs.

Feeding Experiments with Calanus Species
In neither of the feeding experiments with surface waters faecel pellets were produced, neither by CV nor by females.

Salinity Tolerance
CV as well as females showed a rather high tolerance towards low salinities. From CV some *C. glacialis* died first at 12‰, three more at 10‰ and all others at 7.9‰. The first female *C. glacialis* died at 17.4‰, four more at 15‰ and another two at 12.4‰ (all *C. glacialis*). At 10‰ only three were still alive but nearly inactive.

5.3 Benthos Ecology

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Introduction

The aim of the benthos working group was to analyze the structure (species composition, abundance and biomass) of benthic macrofauna (> 0,5 cm) communities with special emphasis on the relevance of biotic and abiotic gradients in the estuaries of Ob and Yenisei. Although the benthic macrofauna of the Kara Sea was studied by Russian scientists during past expeditions, there is little knowledge about the ecology and life strategies of most species. The outcoming results of our expedition will be used to elucidate the importance of benthic communities for matter transformation originating from the discharge of Ob and Yenisei into the Kara Sea.

Table 5-2: Zoobenthos sampling stations.

Station-No.	Date	Depth	Okean-Grab	Dredge
001	13.09.1997	28 m	**2**	**1**
008	14.09.1997	25 m	**2**	0
010	14.09.1997	15 m	**2**	**1**
012	15.09.1997	13 m	**2**	0
017	15.09.1997	20 m	**2**	**1**
018	16.09.1997	31 m	**2**	**1**
019	16.09.1997	30 m	**2**	**1**
021	17.09.1997	40 m	**2**	**1**
024	17.09.1997	40 m	**2**	**1**
027	18.09.1997	19 m	**2**	**1**
030	18.09.1997	14 m	**2**	**1**
032	19.09.1997	10 m	**2**	**1**
034	19.09.1997	12 m	**2**	**1**
036	19.09.1997	18 m	**2**	0
038	19.09.1997	30 m	**2**	0
042	20.09.1997	30 m	**2**	0
043	20.09.1997	32 m	**2**	**1**
046	21.09.1997	27 m	**2**	**1**
047	22.09.1997	18 m	**2**	**1**
048	22.09.1997	30 m	**2**	0
049	23.09.1997	30 m	**2**	**1**
050	23.09.1997	30 m	**2**	**1**
052	23.09.1997	29 m	**2**	**1**
055	24.09.1997	15 m	**2**	**1**
056	25.09.1997	14 m	**2**	**1**
058	25.09.1997	22 m	**2**	**1**
			52	**20**

Field Sampling

During the 1997 expedition of RV *Akademik Boris Petrov* macrozoobenthos organisms were sampled quantitatively and qualitatively along different transects in the area of the Ob and Yenisei estuaries (Kara Sea). On these transects sampling was performed along the increasing influence of river water from north to south.

At 26 stations a total of 52 Okean grabs, each covering an area of 0,25 m^2, were taken in water depths between 10 to 40 m. Additional material for quantitative studies were taken by dredge samples at 20 stations. The dredge (Kieler Kinderwagen) with an opening of 100 by 30 cm and a meshsize of 0.5 cm was used to get information about the larger epi- and endofauna within an area of several hundred meters. The grab contents were washed with the help of a sediment-washing-machine and passed through a sieve with 500 µm mesh size, whereas the dredge material was sieved with a 1000 µm screen. The remaining animals and sediments of both samples (grab and dredge) were preserved with Natriumtetraborat buffered 7% formaldehyde and will later be transferred into 70% ethanol.

Species specifications, biomass measurements and population studies will be done later in the laboratories at the Alfred Wegener Institute in Bremerhaven. For further details of sampling, see Table 5-2.

5.4 Benthic foraminifera in the Ob and Yenisei estuaries

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Background and Objectives

Two Great Siberian rivers, Ob and Yenisei, discharge into the Kara Sea delivering annually 1300 km^3 of fresh water which accounts for 55% of the continental run-off of Arctic Eurasia. This tremendous fresh-water inflow, contacting sea water, forms a vast mixing zone that occupies the Ob and Yenisei estuaries and the adjacent Kara Sea (Burenkov and Vasilkov, 1994). This mixing zone is a perfect model area to study biotic shifts along the transition from fresh via brackish to saline waters.

The first insight into the distribution of foraminiferal assemblages in the mixing zone has been provided by an analysis of a few surface sediment samples collected during the R/V *Dmitry Mendeleev* 1994 cruise (Khusid and Korsun, 1996). The goal of the present research was to study the distribution of modern benthic foraminifera in the salinity gradient that would improve our understanding of Arctic foraminiferal ecology.

Material and Methods

Samples for the foraminiferal analysis were collected at all the 21 stations where a full procedure of sediment sampling was fulfilled (stations no. 1, 10, 12, 17, 19, 21, 24, 27, 30, 32, 42, 43, 46, 47, 48, 49, 50, 52, 55, 56, 58). The samples were obtained from the upper 1-cm layer of sediment retrieved by a multicorer (the standard 12-tubes version, 6-cm inner tube diameter). Two samples per station, ca. 60 cm^3 each, were preserved in 96% alcohol stained with Bengal Rose (1 g/l). The final concentration of alcohol in the preserved samples is assumed ca. 75% due to diluting with pore water. These samples are stored for future laboratory processing.

Two additional samples, 30 cm^3 each, were taken for preliminary onboard studying: one at station 27 in the Yenisei estuary and another at station 52 in the open sea (Table 5-3). These two samples were kept for three days in Bengal Rose stained alcohol and then washed on a 0.125 mm screen. Foraminifera were examined in water under a dissecting microscope with incident light, magnification x50.

Table 5-3: Foraminiferal samples chosen for preliminary microscoping. See chapter 4.2 of this volume for water mass description and hydrographic data.

St no	Location	Water depth [m]	surface S [‰]	bottom S [‰]
27	Yenisei estuary	19	6.4	31.4
52	open sea	31	19.5	31.8

Preliminary Results

In sample 27 from Yenisei estuary, only scarce soft-shelled foraminifera belonging to one unidentified allogromiid species occurred. In the open-sea sample (St. 52), there was an assemblage consisting of both calcareous and arenaceous forms. The registered taxa in the descending order of abundance were: Allogromiina gen. sp., *Protelphidium orbiculare, Ammotium cassis, Quinqueloculina seminula, Reophax curtus,* and *Lagena gracillima* (a total of 32 specimens counted). Most of the specimens were alive (Bengal Rose stained).

Brief Discussion

The most remarkable feature of the pilot data set is the dominance of soft-shelled foraminifera in the proximal location (St. 27). Soft-shelled foraminifera (allogromiids), as supposedly primitive and opportunistic forms, are generally expected to dominate foraminiferal assemblages of disturbed habitats. There is, however, little literature to support that understanding. The problem is that conventional methods of sampling and handling (drying, floating on a heavy liquid) destroy the allogromiids; only time-consuming wet samples allow to study the soft-shelled fauna (Gooday, 1988). Arnold and Lee (1982) provide evidence that allogromiids are opportunistic, which is based on laboratory cultures of salt marsh material. The dominance of allogromiids has been revealed in glaciomarine settings affected by extensive glacial meltwater discharge (Korsun et al., 1995). Further investigations may prove the dominance of allogromiids to be characteristic of disturbed habitats including brackish ones.

Foraminiferal diversity increases seawards in the study area. *Protelphidium orbiculare* is a marker species of brackish environments. *Ammotium cassis* and *Reophax curtus* are characteristic of coastal waters. Thus, the distal assemblage (St. 52), which includes the above taxa, seems to be typical of the Arctic shelf with low bottom salinities.

6 Marine Geology

(J. Matthiessen, L. A. Kodina, B. Boucsein, B. Braun,
B. Finkenberger, S. Korsun, A. D., Krasnyuk, V. N. Lukashin,
A. Y. Miroshnikov, C. Müller, C. Neumann, L.N. Petrunin,
V.A. Samarkin, F. Schoster, M. Siebold, O.V. Stepanets)

The influx of fresh water has a profound influence on the modern and past environments of the inner Kara Sea. The large Siberian rivers Ob and Yenisei discharge more than 1100 km^3 freshwater per year, amounting to ca. 30% of the total annual fresh water influx into the Arctic Ocean (Aagard & Carmack, 1989). The huge sediment load carried by these rivers (Pocklington, 1997) is of comparable importance for the specific environmental conditions in the Kara Sea causing low light penetration depths in the investigation area (Burenko et al., 1995).

The Kara Sea has been visited during several major expeditions in the past few years, e.g. the cruise of RV *Dmitriy Mendeleev* in 1994 (Lisitsyn and Vinogradov, 1995) and the cruise of RV *Akademik Boris Petrov* in 1995 (Galimov et al., 1996). An extensive sampling program has been conducted in the whole Kara Sea, and detailed geochemical, sedimentological, biological, hydrochemical and oceanographical data sets are available about the modern environment and their underlying surface sediments from this region (e.g. Lisitsyn and Vinogradov, 1995; Stein et al., 1996). However, few stations were sampled in the inner Kara Sea, where the riverine waters mix with marine waters at the mouth of the rivers Ob and Yenisei, and relatively few investigations were conducted on Holocene and late Weichselian sediments.

Therefore, the joint Russian-German expedition with RV *Akademik Boris Petrov* conducted an extensive geological sampling programme
- to study the modern environment in order to characterize the river supply of the rivers Ob and Yenisei in particular with respect to their geochemical parameters,
- to identify processes modifying the river supply in the estuaries and the inner shelf sea,
- to analyze the dispersal and deposition of the river supply in the Kara Sea,
- and finally to study paleoenvironmental changes in the Kara Sea during the late Weichselian and Holocene.

The results of these investigations may lead additionally to a better understanding of transport pathways of dissolved and suspended matter from the Kara Sea across the shelf edge into the Arctic Ocean.

6.1 Geological Sampling Program

The water column and the sediments were generally 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. The major goal of the investigations was to characterize changes in the water column and sediments along the salinity gradient in the modern river systems by means of various sedimentological, micropaleontological and geochemical methods. The sampling program concentrated on the two major rivers Ob and Yenisei, and transects along the salinity gradient were sampled.

Geological stations were usually started after the ship cast anchor. Single Okean grabs were also deployed while the ship was drifting. The sedimentary sequences were cored with a set of different corers. The geological sampling always started with grab samplers and large box corers to get an overview of the composition of the near-surface sediments. This was important for the decision which core barrel and penetration weight should be used for the gravity corer. Sub-bottom profiling of the upper sediment layers could not be conducted during the expedition.

Surface and near-surface sediments were immediately sampled after core recovery. The individual samples taken on each station from Okean grabs, box corers and multicorers are listed in Annex 9.3.

Sampling of Near-Surface Sediments

Okean Grab Sampler
This grab sampler (weight of ca. 100 kg) samples usually an area of ca. 0.25 m^2 up to a depth of ca. 30 cm. It was used to obtain samples for benthos, geochemical and radio-geochemical analyses. The Okean grab has been used 90 times on 39 stations. Samples were taken for the following investigations:

- radio-geochemistry (Stepanets)
- radio-geochemistry (Miroshnikov)
- organic geochemistry (Kodina)
- sedimentology and fluxes (Lukashin)
- inorganic geochemistry (Krasnyk)

Giant Box Corer
The giant box corer (weight of ca. 500 kg; volume of sample 50 x 50 x 60 cm; manufactured by Fa. Wuttke, Henstedt-Ulzburg, Germany) was successfully used 29 times on 21 geological stations. Only two box core casts failed because of technical problems. The recovery ranged from ca. 30 to 60 cm. The box cores were sampled for the following investigations:

a. surface sediments
- stable isotope analysis of benthic calcareous organisms (Finkenberger)
  surface sediment 10 x 10 from the upper 2 cm fixed with bengal-rose-methanol-solution, ca. 100 cm^3,
  surface sediment 10 x 10 from the upper 5 mm, ca. 100 cm^3
- biomarker and organic geochemical analysis (C/N ratio, Rock Eval pyrolysis, TOC, $CaCO_3$) (Siebold)
  surface sediment 10 x 10 cm (ca. 50 cm^3), stored frozen at -20°C
- organic geochemical analysis (Corg/N, carbonate, biogenic silica (Opal), carbohydrates, amino acids) (Neumann)
  surface sediment 10 x 10 cm (ca. 50 cm^3), stored frozen at -20°C
- bulk surface samples and core profiles for archive purposes (AWI)
- bulk surface samples (Korsun)

b. profiles
- organic geochemistry (Kodina)
- sedimentology and fluxes (Lukashin)
- methane analysis (Samarkin)
- pore water analysis (Damm)
- radio-geochemistry (Stepanets)
- radio-geochemistry (Miroshnikov)
- inorganic geochemistry (Krasnyk)

Multicorer

The standard 12-tubes-version multicorer (weight of 495 kg; manufactured by Fa. Wuttke, Henstedt-Ulzburg, Germany) with an inner tube diameter of 6 cm was used. The penetration weight was always 250 kg. The multi corer was successfully used 46 times on 23 stations, and usually recovered undisturbed surface sediments.

The sediment column of one tube was visually described from most stations (Annex 9.3) while the core was cut into 1 cm slices. Sediment colours were identified according to the "Munsell Soil Color Chart" (Kollmorgen Instruments Corp., Newburgh, USA). Smear slides of surface sediments from selected stations were analyzed under the light microscope. The tubes were sampled according to the following scheme depending on the number of cores filled with sediments:

a. surface sediments
- bottom water (Shpigun)
- bottom water (Petrunin)
- maceral analysis and palynology (Boucsein & Matthiessen)
  1-3 tubes, ca. 30-90 cm^3, stored frozen
- inorganic geochemistry (Schoster), 1 tube, ca. 10 cm^3
- grain size analysis and clay mineralogy (Müller), 1 tube, ca. 10-30 cm^3
- diatoms (Polyakova), 1 tube, ca. 10-30 cm^3
-TOC (AWI), 1 tube ca. 10-30 cm^3
- stable isotope analysis of benthic calcareous organisms (Finkenberger)
  2-3 tubes (60-90 cm^2) from the upper 2 cm fixed with bengal-rose-methanol-solution to stain living organisms,
  2-3 tubes (60-90 cm^2) from the upper 5mm
- bentic foraminifera (Korsun)
  4 tubes (ca. 120 cm^3) from the upper cm fixed with bengale-rose-methanol-solution to stain living organism

b. profiles
- biomarker and organic geochemical analysis (C/N ratio, Rock Eval pyrolysis, TOC, $CaCO_3$) (Siebold)
  1-2 tubes (30-60 cm^2) from the upper cm, stored frozen at -20°C,
  1 tube sampled at 5 cm intervals, and additionally at lithological changes, stored frozen at -20°C
- organic geochemical analysis (Corg/N, carbonate, biogenic silica (Opal), carbohydrates, amino acids) (Neumann)
  1-2 tubes (30-60 cm^2) from the upper cm, stored frozen at -20°C,
  1 tube sampled at 5 cm intervals, and additionally at lithological changes, stored frozen at -20°C
- archive AWI: 1 tube cut into cm slices, stored cool

- methane analysis (Samarkin), 1 tube
- organic geochemistry (Kodina), 1 - 2 tubes
- radio-geochemistry (Miroshnikov), 1 tube
- inorganic geochemistry (Krasnyk), 1 tube

Coring of Long Sediment Cores

Gravity Corer

The gravity corer has a penetration weight of up to 1.5 t and core barrel segments of 500 cm and 300 cm length and 120 mm diameter. The gravity corer was used on 17 stations and sediment cores of variable length were recovered during the cruise, ranging from 50 cm to 480 cm (Table 6-1). Three core barrels were destroyed during coring, and two cores were empty due to stiff or hard sediment layers close to the sediment surface. After recovery the sediment cores were cut into 100 cm sections, and were stored under cool conditions or were frozen at -9°C. Additionally, core catchers were sampled.

Table 6-1: Gravity corer statistics.

station	GC 500	GC 300	stored frozen	Corer Weight (t)	Pene-tration (cm)	Reco-very (cm)	Core Loss (cm)	Remarks
BP97-01	x			1.5	200	179		core barrel destroyed
BP97-10	x		x	1.5	700	480	±20-30	overpenetration
BP97-19	x			1.5	600	130		core catcher did not close
BP97-21	x		x	1.5	350	289	±20	
BP97-27	x			1.5	670	479	±200	overpenetration
BP97-30	x			1.2	700	489	±30	
BP97-32	x		x	1.2	520	434		
BP97-39	x			1.2	100	-		empty, sand layer?
BP97-42	x			1.5	100	-		empty, sand layer?
BP97-43	x			1.5	>700	480	200-300	overpenetration
BP97-46	x			1.5	100	50		
BP97-48	x			1.5	270	79		core barrel destroyed
BP97-49	x		x	1.5	300	263		
BP97-50	x			1.5	250	129		core barrel destroyed
BP97-52		x	x	1.5	300	260		
BP97-56	x		x	1.25	600	478	20-30	
BP97-58	x			1.25	300	100		

Small Gravity Corer

A small gravity corer with a fixed barrel length of 400 cm (diameter 75 mm) was occassionally used by scientists from Vernadsky Institute to obtain samples for geochemical analyses.

6.1.1 Sampling of Aerosols, Suspended Matter, Settled Material and Bottom Sediments

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The scientific goal is the study of matter fluxes from the atmosphere to the sea surface, from the rivers to the sea and through the water column to the seafloor in order to create a sedimentation model for the Kara Sea. The main task during the cruise was to collect new material for scientific investigations in the laboratories at the Shirshov Institute.

The program aboard RV *Akademik Boris Petrov* included three objectives:

1. The atmospheric program focused on sampling of aerosols using the mesh method for estimation of the aerosol concentrations above the Norwegian, Barents and Kara seas, aerosol fluxes to the sea surface, and determination of the mineral and chemical composition of eolian matter including contaminants (ashes, heavy metals, etc.).

2. The water program focused on: (i) sampling of the suspended matter by filtration of the water from the Niskin bottles of the rosette sampler for determination of particle concentrations and chemical composition of the particulate matter (POC, PON, trace elements including heavy metals); (ii) sampling of the sinking material using the sediment traps for estimation of the vertical particle fluxes and determination of matter, mineral and chemical (including POC, PON, POP) composition of the caught material.

3. The sediment program focused on sampling of bottom sediments (the upper layer) for determination of mineral and chemical composition, measuring of age and rates of sediment accumulation by Pb-210, and comparing these data with those on vertical fluxes of the settled material.

Methods

Collection of Aerosols
Aerosols were collected using neylon meshes. The size of each mesh is 1 m^2, pore diameter - 0,61 μm^2. Five such meshes were exposed in front of the first mast on a special frame each time when the wind direction was favourable (less than 60° right or left from the ship´s course) to prevent contamination from the ship. Meshes were usually exposed between 10 to 24 hours. During exposure wind speed and direction were constantly registrated by the meteorological station Midas-320. After exposure the meshes were washed in distilled water twice into different buckets, then water was poured into one bucket and was filtrated through pre weighted Russian nuclear pore filters with diameter 100 mm and pore size 0,45 μm. After filtration the filters were dried at a temperature of 60°C, afterwards packed in Petry cups and then sealed in plastic envelopes for sending to the home laboratory.

Collection of Suspended Matter

The sea water samples for filtration were taken from 1.8 l Niskin bottles after the rosette sampler returned onboard. Water was collected in special pre-pared clean bottles (ca. 2, 5 or 10 litres) and filtrated through pre weighted Russian nuclear pore filters with a diameter of 47 mm and a pore size of 0.45 µm on Millipore filterholders using vacuum. Each sample was filtrated through three filters: two - nuclear pore filters (ca. 0.5-1.5 l) for determination of the concentration of the suspended matter, for investigation of the particle composition using electronic microscope, and for determination of the chemical composition using atomic-absorption analysis; one - precombusted Whatman GF/F glass-fiber filter for determination of POC and PON (ca. 2-5 l). After filtration filters were washed with distilled water, dried at 60°C, packed in Petry cups and then sealed in plastic envelopes for later analyses in the home laboratory.

Collection of Settled Matter using Moorings of Sediment Traps

Four mooring stations with sediment traps were deployed during the expedition for the determination of short-term vertical fluxes of the settled matter. We used small cylindric sediment traps (Lisitzin et al., 1994). First the sites of mooring deployments were chosen and stations were prepared in correspondance to depths. Stations consisted of anchor (about 100 kg), buoy-rope and undersurface buoy.

Sediment traps were attached to the buoyrope on different depths. The small bright painted buoy was attached to the undersurface buoy by a rope, swimming on the sea surface and serving as a marker to find the stations easily. Three stations were deployed with this scheme; another station had an acustic release and did not have a marker buoy (it was lost). Positions, dates, exposure times and depths are presented in the Table 6-2. Before deploying the samplers were filled with fixing solution (4% formalin in sea water from Norwegian Sea) for preventing any microbial activity. After sediment trap recovery the samples were fixed with formalin and stored in a refrigerator until transport to Moscow.

Collection of Bottom Sediments

Bottom sediments were collected from grab or box corers using a plastic sampler (tube with diameter 100 mm and length 300 mm). The upper liquid layer was collected in a vertical position of the sampler, then the core was laid on the table, cut and described. Sampling was carried out in accordance to lithological types of sediments. Samples were packed and deep-frozen at temperatures less than -10°C.

List of Received Samples

1. Aerosols	- 8
2. Water filtration:	
a) nuclear pore	- 147
b) whatman glass-fiber GF/F	- 74
3. Samples from sediment traps	- 12
4. Bottom sediments:	
a) from grab	- 35
b) from box corer	- 51

Investigation of Received Material

Investigation of samples is as follows:

1. Aerosol samples will be weighted for determination of dust concentrations in the atmosphere and calculation of aerosol fluxes to the sea surface. Then analytical studies will be carried out including electronic microscopy, X-ray diffractometry and different chemical methods: CHN, wet chemistry (Si, Al, P), atomic absorption, instrumental neutron activation.
2. Samples of suspended matter will be weighted for determination of the concentration in the sea water. Analytical investigations include electron microscopy, atomic absorption, instrumental neutron activation and CHN.
3. Studies of settled material from sediment traps include microscopical identification of particles by biologists; then filtration and estimation of fluxes; then the same analytical studies as with aerosol samples.
4. Investigations of sediment samples include smear-slide analyses, analyses of size fractions, determination of mineral composition by microscope and X-ray diffractometry, inorganic geochemical studies using different analytical methods, determination of C_{org} and carbonates, measuring the rates of sediment accumulation with the Pb-210 method.

Expected Results

1. Geochemical description of aerosols and calculation of their input to the sea surface with determination of heavy metal fluxes.
2. Geochemical description of processes of suspended matter transformation on transects in the mouths of Ob and Yenisei rivers, especially in the mixing zones; estimation of matter input to the Kara Sea and determination of anthropogenic components.
3. Estimation of vertical fluxes of sedimentary material and its components from sediment trap data and geochemical description of settled matter.
4. Lithological and geochemical description of the bottom sediments.
5. Our data together with data of other investigators will permit to create a geochemical model of sedimentation in the Kara Sea.

Table 6-2: Information about sediment trap stations.

Station no.	Time (GMT) date of deployment	Position Latitude (N) Longtitude (E) Depth (m)	Depth of sediment traps (m)	Sediment trap-no.	Time (GMT) date of uplift	Exposure (days)
1	1759 13.09.97	73° 53.30' 73° 10.52'32"	20 24	14 18	1505 23.09.97	9.88
13	0718 15.09.97	72° 34.94' 73° 44.64'18"	8 10 14	5 15 22	Station was lost	
20	1704 16.09.97	73° 59.80'0 79° 25.16'30"	16 18	17 20	0305 21.09.97	4.45
28	0656 18.09.97	72° 49.80' 80° 10.11'18"	11 14	23 24	1440 19.09.97	1.32

6.1.2 Clay Mineralogy of Suspended Matter and Surface Sediments

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The sedimentation in the eastern Kara Sea is mainly controlled by the terrigenous input of clastic sediments transported from the hinterland by the large rivers to the shelf. In order to get information about the mineralogical composition of the suspended matter of river water, samples were taken on 5 stations along 2 short transects (N-S) in the Ob and Yenisei rivers. The surface-water layer was sampled with buckets and a large volume sampler (LVS), respectively (Table 6-3).

Table 6-3: Water column samples for clay mineral analysis.

Station	Latitude	Longitude	Gear	Request
BP97-01	73°54'38.0"	73°10'59.0"	bucket	30 L
BP97-10	72°30'10.0"	74°04'51.0"	bucket	30 L
BP97-17	72°41'19.2"	73°43'50.4"	LVS (200 L)	40 L
BP97-30	72°30'30.6"	80°20'10.8"	LVS (200 L)	40 L
BP97-32	72°05'35.4"	81°28'52.2"	LVS (200 L)	40 L

To separate the suspended matter the surface water was centrifugated (about 10.000 turns/min) onbord in a Labofuge 15000 (Fa. Heraeus, Germany). The obtained sediment except from the first station (the amount was too low) was filled into 20 ml plastic jars for further investigations which will be carried out in the Alfred Wegener Institute.

Surface sediments (10-30 cm^3) were taken at 20 stations by multi corer. The suspended matter as well as the surface sediments will be analyzed for grain-size distribution and clay minerals.

For mineralogical investigations the organic matter will be removed from the sediment by using hydrogen peroxide. The sand fraction (>63 µm) will be separated from the carbonate-free samples by wet sieving. After separating the grain sizes >2 µm by means of the Atterberg settling method, the samples will be prepared for X-ray diffraction analysis to calculate the clay mineral composition and the ratios of feldspar/quartz and potash feldspar/plagioclase. The results will be compared with other mineralogical investigations of surface sediments from the Kara Sea (Gorbunova, 1997; Wahsner et al., subm.). Additionally, it will be considered whether selective sedimentation of clay minerals occur along the salinity gradient influencing the composition of clay minerals in the surface sediments.

6.2. Sedimentological Investigations in the Outer Estuaries of the Rivers Ob and Yenisei

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6.2.1 Composition of Surface Sediments

The visual description of multi corer profiles showed that surface and near-surface sediments only differ slightly in grain size, colour and composition in the investigation area (Annex 9.3). Sediment surfaces were always even and consist of dark brown clays to silty clays with rare to abundant polychaete tubes. Molluscs were not found on sediment surfaces. Benthic organisms other than polychaetes were usually absent except for rare occurrences of small brittle stars and isopods. Brownish sediment colours are usually restricted to the upper 1 to 3 cm of the sediment column.

Smear slide analyses revealed that the surface sediments contain abundant diatoms. Calcareous and agglutinated benthic foraminifers are also occasionally present (see Korsun, chapter 5.4). The composition of surface sediments gradually changes along the transects from the Ob Bay to the inner Kara Sea (stations 12, 47, 17, 48, 49, 50, 52), and the Yenisei Bay to the inner Kara Sea (stations 32, 35, 27, 39, 21, 42, 43). The amount of diatoms is estimated to be high in the bays (stations 12, 47, 17; 32, 35, 27 respectively) decreasing to the north. Coarser clastic particles are more abundant in sediments from the inner Kara Sea than from the river mouths.

The same holds true for near surface sediments which differed slightly in grain size and more strongly in density ranging from soft to relatively stiff sediments along the transects from the estuaries to the inner Kara Sea. All sediment columns recovered from MUC tubes were to a variable degree bioturbated (see Annex 9.3). Lamination or other sediment structures were not observed. Additionally, shells and living specimens of bivalves and gastropods were occasionally found in profiles. Pieces of wood (st. 21, 32), macroscopic plant fragments (st. 42) and sand layers (st. 18, 59) were present in some profiles.

6.2.2 Sediment Cores

Sediment coring during the expedition was of variable success. In the mouth of the rivers Ob and Yenisei the gravity corer usually penetrated 5 to 7 meters into the sediment and recovered soft and fine grained sediments up to a length of 480 cm. North of 72°40´ to 73°20´N, the recovery was usually less than 300 cm, due to very stiff, compacted sediments. At two locations from the northeastern part of the Yenisei transect, even the core catchers were empty, because the gravity corer could not penetrate sandy layers despite a maximum penetration weigth of 1.5 t. We could not observe any distinct lithological changes at the bases of each 100 cm section, except in some core catchers, which were filled with black sandy silty clays on two stations (50, 52) at the northern end of the Ob transect. There was no evidence of permafrost or glacial marine sediments at the core bases.

6.2.3 The Depositional Environment

The upper Quaternary deposits of the Kara Sea were previously divided into two main facies zones (Levitan et al., 1995, 1996). The western Kara Sea province can be distinguished by differences in sedimentary matter sources, the distance from the source areas, the hydrodynamic regime and the bottom topography from the Ob /Yenisei province. Furthermore, the provinces were divided into different sequence types. The investigation area is located in the subzone B of the Ob/ Yenisei province (Levitan et al., 1995, 1996), which is characterized by a high accumulation of clay and a bad sorting of sediments. This subzone contains the "marginal filter" (Lisitsyn, 1995) located at the mouth of the rivers Ob and Yenisei, where due to the mixing of riverine and sea water ranging in salinity from 1 to 15 ‰ complex geochemical processes cause enhanced fluxes of dissolved and suspended matter to the sea floor.

The definition of subzone B was however just based on a few coring stations partly located within the investigation area between 72° and 74°N, while we recovered there surface samples and sediment cores from more than 20 geological stations. Our preliminary results suggest that the depositional environments in the inner Kara Sea might further be subdivided into two sedimentary provinces: the mixing zones in the Ob and Yenisei Bay and the inner Kara Sea.

Based on the shipboard investigations, the surface sediments do not differ much in the mineralogical composition (cf. Gorbunova, 1997), but micro-paleontological data indicate some variability along the transects. Diatoms appear to be more abundant in the estuaries than in the open sea. Korsun (chapter 5.4) also noted major differences in the benthic foraminiferal faunas between the Yenisei Bay and the open sea.

The decrease in diatom abundances may be related to the gradient in opal contents in surface sediments. Nürnberg (1996) observed that opal concentrations generally decrease with increasing distance from the estuaries to the inner Kara Sea. Detailed information on diatom assemblages is not available from the Kara Sea, but Polyakova (1994: 411; 1996: 322) found only fresh water diatoms in the Ob Bay. If this holds true for the whole investigation area, then the elevated opal contents in surface sediments must primarily be attributed to the influx of allochthonous diatom assemblages from the rivers. The bay areas are characterized by strongly changing salinity conditions from almost fresh to brackish waters, and autochthonous assemblages should consist of a mixture of brackish and freshwater species. The higher abundances in the sediments underlying the mixing zone, estimated from smear slides may be caused by higher sedimentation rates of fine material and associated higher fluxes of allochthonous diatoms to the sediment.

Total organic carbon values range from 0.7 to 2.2% in the inner Kara Sea, and Ob and Yenisei estuaries, detailed organic geochemical analysis point to a terrestrial source of the organic matter (Stein, 1996). Investigations on lipid biomarkers showed that terrestrial compounds principally dominate in surface sediments located along a transect from the inner Ob estuary to the Kara Sea (Belyaeva and Eglington, 1997). Thus, these observations suggest that relatively low amounts of autochthonous marine organic matter are recorded in surface sediments. Additionally, low carbonate values (less than 1%) indicate that even the production of calcareous shells and tests is low (Stein, 1996; see also Levitan et al., 1996). However, dissolution may have also overprinted the primary signal (Khusid and Korsun, 1996). Therefore, a low amount of fossilizable biogenic hard parts is preserved in the sediments from the investigation area, and relatively high amounts of biogenic opal may be attributed to an allochthonous source.

Low sediment core recovery in the inner Kara Sea, the changes in diatom abundance and assemblage composition of benthic foraminifera in surface sediments suggest that a pronounced change in the sedimentation regime must occur around 73°N. It can be assumed that in the river mouths south of this latitude accumulation rates are high and mostly fine grained sediments are deposited. These high accumulation rate areas are probably associated with the mixing zone of marine and riverine water where large amounts of dissolved and particulate matter sink to the bottom due to flocculation and coagulation. North of 73°N accumulation rates probably decrease strongly, and coarser grained sediments may be eroded from shoals, the Yamal Peninsula or the small island between Ob and Yenisei, and are finally deposited in deeper parts of the Kara Sea and the channels of Ob and Yenisei. However, these interpretations must be considered preliminary, and shorebased geochemical, sedimentological and stratigraphical analyses are required to provide detailed information on the late Quaternary paleoenvironmental evolution in this area.

7 Geochemistry

(O.V.Stepanets, L.A. Kodina, A.P. Borisov, B. Boucsein, A. Henne, A.D. Krasnyuk, A.Y. Miroshnikov, K. Neumann, L.N. Petrunin, T.N. Pribylova, R. Richter, V.A. Samarkin, F. Schoster, M. Siebold, L.K. Shpigun, G.Yu. Solov'eva, S. Steffen, V.G. Tokarev, L.N. Vlasova)

7.1 Radio-Geochemistry

7.1.1 Geochemical Study of Distribution and Migration Pathway of Artificial Radionuclides in the Water Medium of the Arctic Basin

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The present radioecological state of the sea medium of the Arctic basin, exposed to considerable radioactivity contamination, generated a great deal of public and scientific interest, since the ocean water is characterized by great mobility and carry this contamination over long distances through various migration pathways. Radionuclides in marine water may have many sources, including naturally ones from cosmic radiation and rocks, and atmospheric and oceanic transport from accidents, weapon testing and nuclear waste disposal in the ocean and on land. It is well known that unauthorized wastes from nuclear sources have entered the sea. The investigation of the distribution and migration pathways of artificial radionuclides is one of the important problems of the modern sea medium geochemistry, the solution of that should be based on a wide experimental data base.

The behavior of radionuclides in the marine environment depends on both their chemical nature and the physicochemical situation in the basin. The alkaline element cesium (Cs) and alkaline-earth strontium (Sr) are mobile in water. The residence time in dissolved form in oceanic water is estimated at $6*10^5$ years for cesium and $4*10^6$ for strontium (Förster and Wittman, 1981). In contrast, plutonium is fixed easily by colloids of ferrous hydroxide, manganese, and dissolved organic substances (Turekian and Rona, 1997; Orlandini et al., 1990). Plutonium radionuclides are rapidly concentrated in sediments and retained there, while 90% of the cesium remains in the water (Alberts et al., 1981; Santschi et al., 1983). The most active selective sorbents of cesium are micaceous clay minerals, especially illite (Francis and Brinkley, 1976; Gerling and Turner, 1982; Sawhney, 1972). The clay fraction plays an important role in the river mouth areas - the "marginal filters" - where about 90% of the suspended matter supplied by rivers settles together with the elements absorbed from sea water (Dai and Martin, 1995). It is important that the absorption of cesium radionuclides on clay particles is reversible. Under certain conditions, precipitated cesium can be recycled into the sea water. Only when entering deeper, into intracrystalline layers, cesium does become strongly bonded (Comans et al., 1991).

Of the cations capable of exchange with cesium, potassium and ammonium are common in water basin environments. The appearance of high concentrations of ammonium and other biogenic substances in pore waters, resulting from microbial destruction of organic matter, is evidence of the development of reducing conditions in sediments. In such a situation, from 20 to 80% of the cesium can be mobilized from the sediments (Evans et al., 1983). The direct correlation of K_d with the ammonia concentration in pore waters (with a correlation coefficient of 0.94) was demonstrated by the example of a fresh water lake with buried radioactive wastes (Comans et al., 1989). The appearence of an ammonia concentration gradient between pore and near bottom waters created conditions for a flux of radioactive isotopes from sediments into the water.

Therefore, the distribution and behavior of radionuclides in water basins is determined by the location of their sources and aggregate of geochemical factors such as the composition of particulate matter in water, conditions of reworking of organic matter, and resulting redox conditions in the sediments.

Working Program

The main tasks of our investigation were:
- multiscale study of artificial radionuclide distribution in water medium of the Arctic basin with different geochemical characteristics;
- assessment of radiocesium (and radiostrontium) sorption by various kind of bottom sediments on board by using the tracer method;
- determination of the degree of radionuclide preconcentration by particles in laboratory experiments with radioactive tracers, as well as by direct detection of radionuclides in particulate matter and filtered water;
- study the time history of radionuclides input in the area by determination of ^{137}Cs distribution through the vertical section of the core samples and measurement of the natural isotope ^{210}Pb;
- assessment of the effect and contribution of the main pollution sources in the study area related to the total radioactivity of water medium using radionucli of similar ($^{137}Cs/^{134}Cs$) or close ($^{137}Cs/^{90}Sr$) geochemical behaviour in the marine medium.

Sampling and Analytical Methods

<u>Sediment Sampling</u>

Sediment was sampled by means of a box corer having an inner area of 50x50 cm and an Okean grab with subsequent subsampling by use of a plastic tube having an inner diameter of 10 cm. The core was cut in 1-2 cm sections. Radioactivity in the surface layer of sediments was measured in a low-background ship laboratory. The remaining part of the core and the surface layer of the sample were stored after slight drying for g-spectrometric analysis of ^{137}Cs and radiochemical analysis of ^{90}Sr and $^{239,240}Pu$ at GEOKHI. We made the sediment sampling at 35 stations.

<u>Handling of the water</u>

Water from the different depths was poured into two tanks of 100 l each (the first for ^{137}Cs and the second for ^{90}Sr or $^{239,240}Pu$ concentration). We sampled water at 26 station, at 6 stations surface and deep-water samples were taken.

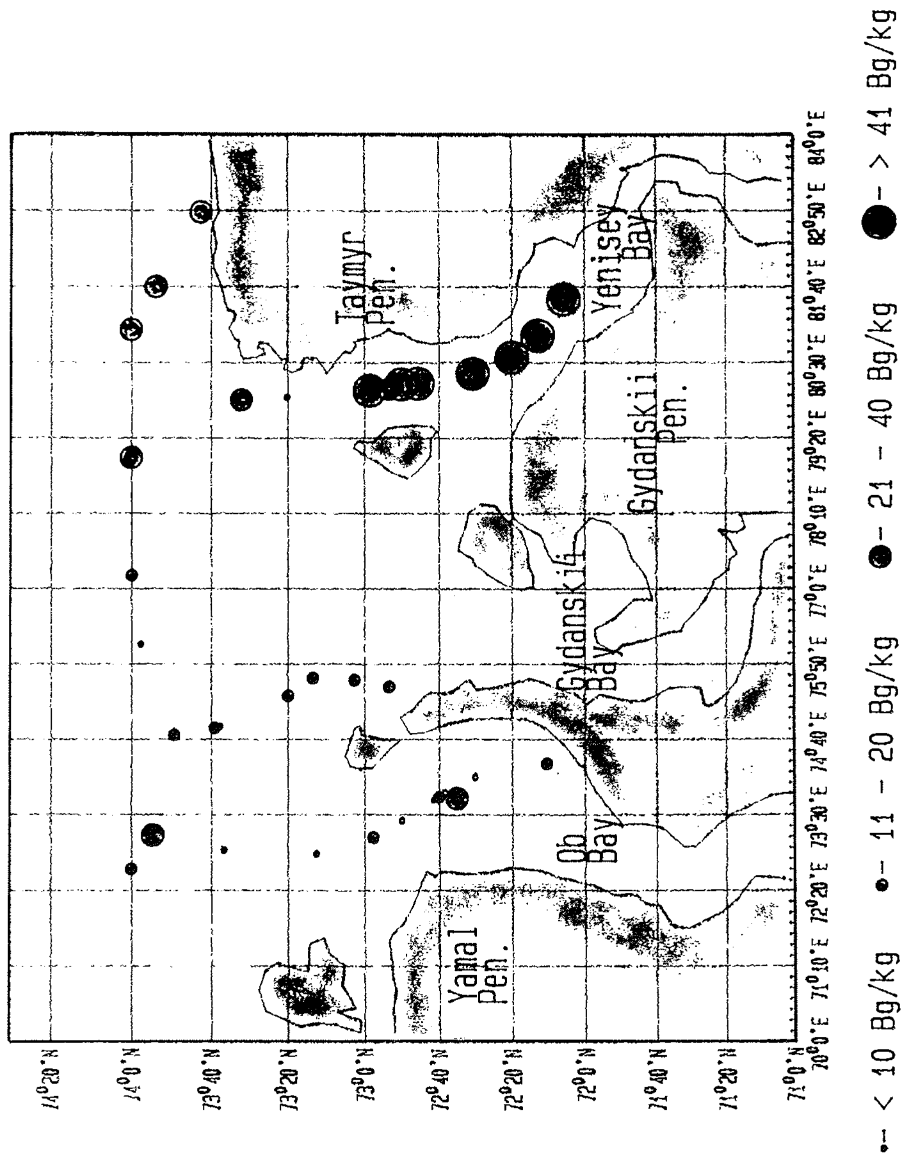


Fig. 7-1: Distribution of ^{137}Cs in the sediment surfaces (0-2 cm) in 1997, measured on the 28th cruise of RV *Akademik Boris Petrov.*

Determination of ^{137}Cs was carried out in sea water samples of 100 l, using the sorption method under dynamic conditions with measurement of the concentrate on low-level g-ray spectrometer. Cobalt hexacyanoferrate (II) fixed on an organic matrix was used for concentration of Cs from sea water. The ion-exchange fibre Mtilon-T, which is a grafted sopolymer of cellulose and polyacrylonitril containing thiamide functional groups was used as a matrix. The availability of ionogenic groups allows sorbents to be obtained in which the hexacyanoferrate (II) group is firmly attached to the matrix and is not removed during a prolonged contact with a large volume of water. The low-level g-ray spectrometer is equipped with Ge-Li detector (80 cm^3 well) with a multichannel analyzer and an IBM personal computer.

Determination of Sr in water samples (50 l) involved precipitation of Sr as carbonate, following isolation of the Sr radionuclide by extraction with dicyclohexil-18 crown-6 in chloroform, re-extraction and then finally isolation of the carbonate. The measurement of ^{90}Y is carried out on a low-level b-apparatus with a background equal to 1 counts min^{-1}. During the expedition we stored the samples after precipitation of the Sr as carbonate for analysis at GEOKHI.

At each station one hundred litres of water was collected in large precipitation tanks for Pu-analysis. The water was adjusted to pH=2 by adding HNO_3 conc., and then adding 8 g $FeSO_4*7H_2O$ ($FeCl_3*6H_2O$). After 1 hour stirring the water was adjusted to pH=9.5 by addition of NaOH solution and was left for at least 8 hours, thereafter the supernatant was siphoned off and the precipitated slurry (transuranic elements co-precipitated with $Fe(OH)_3$ was transfered to a 1 l polyethylene container for further radiochemical separation in the laboratory prior to alpha counting.

Zoobenthos sampling was carried out on all transects (at 3 stations) using a benthos dredge. These samples have been sieved on board and preserved in formalin with CH_3OH for further measurement of total radioactivity in GEOKHI.

Preliminary and Expected Results

The data on ^{137}Cs distribution in the top layer of the bottom sediments on the all transects are presented in Figure 7-1. The data demonstrate that the distribution of ^{137}Cs in the upper (0-2 cm) layer is irregular. In the Yenisei Bay, localities with very high concentrations of this radionuclide are observed. The next highest values of ^{137}Cs cluster are in the southeastern part of our working area, and at some localities of the Ob Bay.

Considering the data on ^{137}Cs radioactivity which we obtained in this expedition with the ones of the expedition 1995 (Figs. 7-2), in combination with the lithology and geochemical activity of the sediments, we can estimate the peculiarities in the distribution of this radionuclide in the Arctic basin including the Kara Sea, and the estuaries of rivers Ob and Yenisei. Thus, in the studied part of the Ob Bay, the reduced sediments are represented by sandy mud that does not absorb cesium, consequently, the ^{137}Cs concentration is very low.

On the contrary, in the Yenisei Bay, the bottom sediments are characterized by a high fraction of partially oxidized clays, with high capabilities of absorbing ^{37}Cs, which resulted in the higher specific activity of ^{137}Cs in the bottom sediments. Preliminary data on the geochemistry of sediments were received from the geochemical group (leader - Dr. L. Kodina).

For the investigation of regularities of artificial radionuclide distribution in bottom sediments of the Arctic basin we carried out shipboard experiments (by

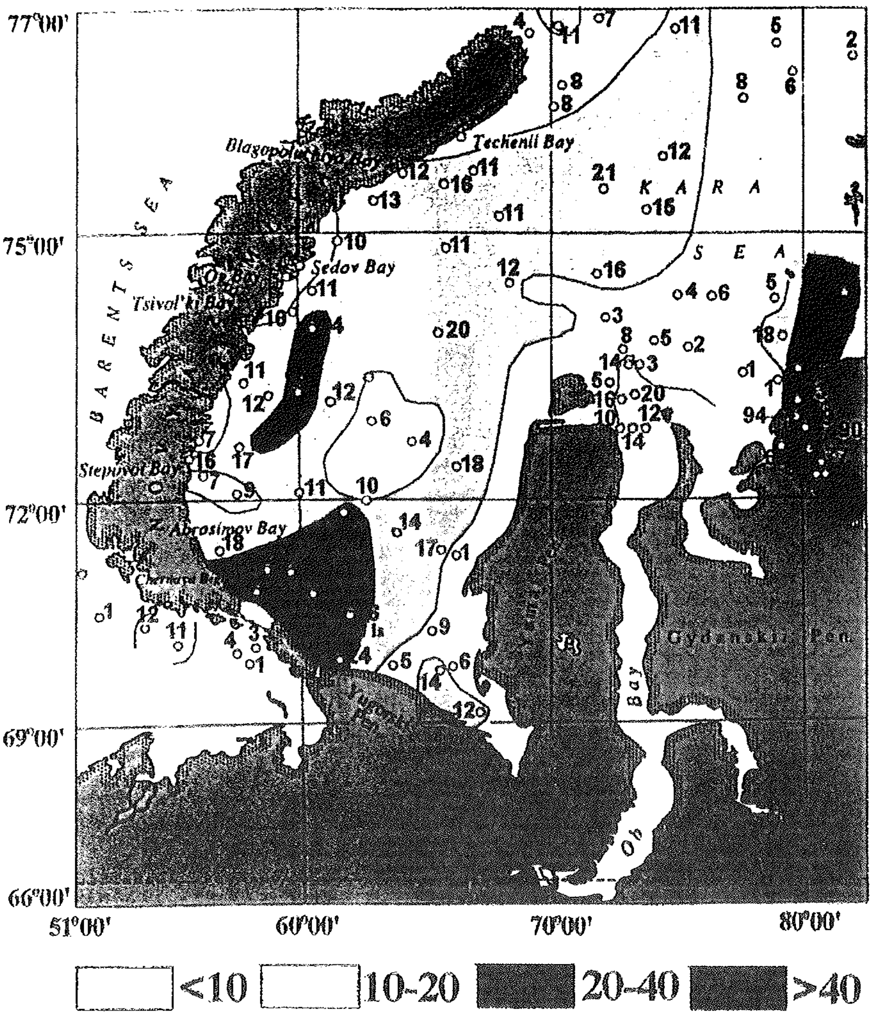
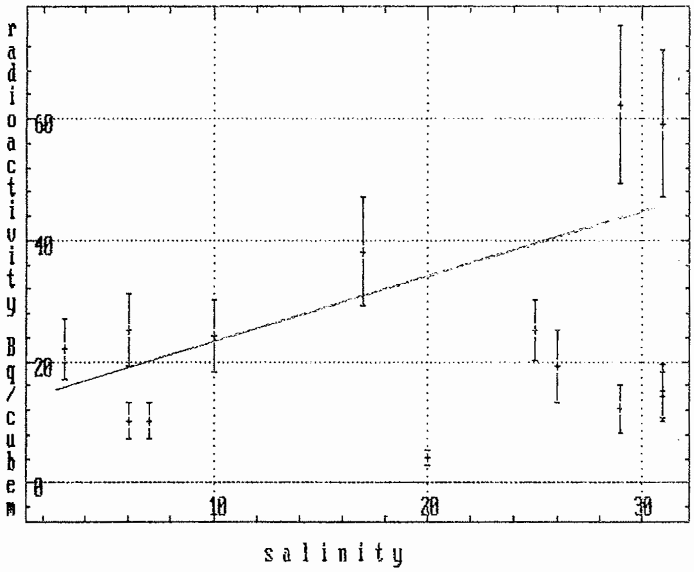


Fig. 7-2: ^{137}Cs content in the bottom sediments of the Kara Sea (Bq/kg) in 1995, measured on the 22th cruise of RV *Akademik Boris Petrov.*

the tracer method) on the determination of preconcentration coefficients of ^{137}Cs in different sediment types taken in the southern part of the Kara Sea, and the estuaries Ob and Yenisei. The experiments were conducted as follows: a definite quantity of sediment is added to water samples, containing radioactive tracer (^{137}Cs). The samples were stored at natural temperatures and then the partition coefficient was determined in different time intervals. It was found that all sediments can be divided into several groups based on their sorption ability. This fact is well explained by lithological composition of sediments. This work will be continued in our institute.



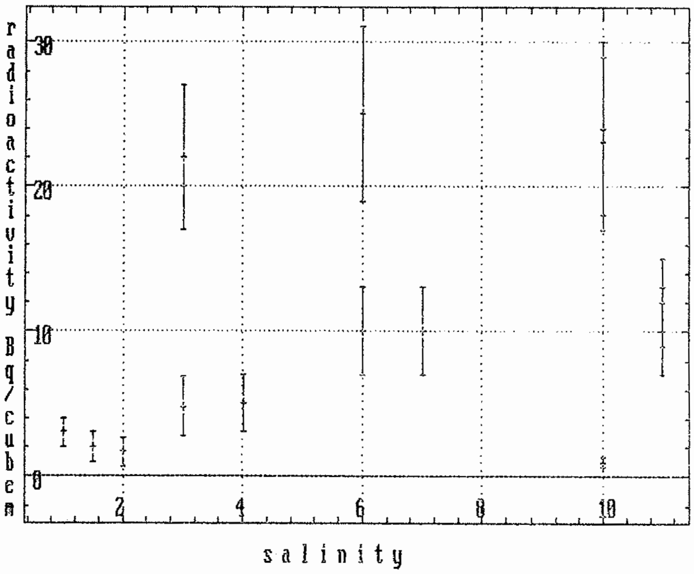


Fig. 7-3: ^{137}Cs concentration (dissolved) in sea water samples, collected in the open sea (A) and the mixing zone (B) as a function of salinity.

The core profiles of layers 20 (10) mm each were dried (~100°C) and packed in plastic containers for subsequently measuring the level of ^{137}Cs and ^{210}Pb-radioactivity. We hope, that the time history of the input of radionuclides from the Ob Bay and Ob River can be assessed taking into account the radionuclide distribution in the area of high accumulation rate, and non-bioturbated sediment records in the river estuary.

In contrast to the sea-floor sediments the distribution of ^{137}Cs in the water is rather uniform. It is shown, that the distribution of ^{137}Cs demonstrates a concentration gradient with highest values in high saline waters in the open Kara Sea, whereas they are low in the mixing zone (Fig. 7-3).

We are planning to carry out at GEOKHI the long-time measurement of some concentrated samples (volume ~1000 l) taking from different areas (Norwegian Sea, North Sea, Baltic Sea) for determination of two radionuclides (^{137}Cs, ^{134}Cs) and their ratio. It enables us to assess the contribution of the concrete radioactivity source to the total radioactivity of the water area under study. The part of the main water samples from each research area (Kara Sea, Ob Bay, Yenisei Bay) was initially filtered through the 0.45 µm filter for removing suspended matter. The main task of these experiments is to determine the level of ^{137}Cs in the dissolved and particle fractions of samples, taken in sea and river areas.

Thus, the data obtained on the 28th cruise of R/V *Akademik Boris Petrov* in addition to our results obtained in 1995 show, that a comprehensive and objective understanding of the radioecological situation can only be achieved by the combination of radioactive pollution studies and the knowledge of the basin geochemistry with respect to sediment and sea water.

7.1.2 Tracking and Distribution of Radioactive Contamination from the PA "Mayak" Site in the Bottom Sediments of the Ob River and the Kara Sea Basin

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Different types of industrial contamination, including radioactive products of the PA "Mayak" activity, migrate in the waters of the river system Mishelyak River -Techa River - Iset River - Tobol River - Irtysh River - Ob River to the Kara Sea. However, unambiguous data are absent to the point whether or not there is an impact of industrial activity of the PA "Mayak" on the ecology of the Arctic Ocean. The radionuclide contamination composition and dispersal, and in this connection the possible alteration of the radiation situation in this region are obscure. The reason for such alterations may be the unloading of contaminated underground waters from the Karachay Lake into the Mishelyak River bed and the tracking of radioactive contamination in the river net. Nowadays another probable possibility of Ob basin contamination is determined: that is the unsatisfactory conditions of industrial buildings (dams) of the Techa cascade of the low-active water reservoir-accumulators, from which straight penetration of radioactivity into the Techa river was established not long ago.

Sampling and Methods

Twenty seven sediment cores were taken during the 28-th cruise of RV *Akademik Boris Petrov*. Sediment samples were obtained by box corer and Okean grab and then were subsampled with subcores with a diameter of 105 mm. These cores were sectioning into layers of 10 (20) mm each and packed in plastic jars. Thus, I obtained 294 samples (Table 7-1).

Table 7-1: List of samples taken for radionuclid measurements.

	Station	Number of Layers	Thickness of Layers (mm)	Height (mm)	Equipment
1	BP 97-01	18	20	360	GKG
2	BP 97-08	8	20	160	Okean
3	BP 97-09	10	20	200	Okean
4	BP 97-10	36	10	360	GKG
5	BP 97-12	40	10	400	GKG
6	BP 97-17	17	10	170	Okean
7	BP 97-18	12	10	120	Okean
8	BP 97-21	3	20	60	Okean
9	BP 97-23	3	20	60	Okean
10	BP 97-25	1	20	20	Okean
11	BP 97-27	9	20	180	Okean
12	BP 97-29	16	10	160	Okean
13	BP 97-30	30	10	300	GKG/MUC
14	BP 97-31	14	10	140	Okean
15	BP 97-32	28	10	280	GKG/MUC
16	BP 97-42	2	10	20	Okean
17	BP 97-43	2	10	20	Okean
18	BP 97-48	2	10	20	Okean
19	BP 97-49	3	10	30	Okean
20	BP 97-50	3	10	30	Okean
21	BP 97-51	3	10	30	Okean
22	BP 97-52	3	10	30	Okean
23	BP 97-53	3	10	30	Okean
24	BP 97-55	10	10	100	Okean
25	BP 97-56	10	10	100	Okean
26	BP 97-57	4	10	40	Okean
27	BP 97-58	4	10	40	Okean

Analytical Programme

All samples will be analyzed for ^{137}Cs, ^{90}Sr, $^{239,240}Pu$, ^{238}Pu by radiochemistry/ alpha spectrometry and mass spectrometry and with the employment of new sorbents (natural alginates) and unique techniques developed at Moscow State University (Dr.Y. Sapozhnikov, Radiochemical Division). The measurement of ^{210}Pb by the alpha spectrometry/radiochemistry method is also planned to determine absolute ages of sediment layers and of the sediment accumulation rates. Research will be carried out on the microstructure and physical structure of various types of sediments, the geochemical study of sorption media with the employment of the method of instrumental neutron-activation analysis (INAA), as well as mineralogical studies of the clay and aleurite fractions. We are planning a series of experiments with different types of sediments identified aiming at the assessment of their sorption properties.

Expected Results

This work will result in the identification of grain-size and mineral contents, the structure of vertical profiles of bottom sediments and their geochemical characteristics. The radionuclide distribution in vertical profiles of bottom sediments will be related to various mineral layers of known ages. The distribution of various types of bottom sediments will be described, reflecting the distribution of radioactive contamination. On the basis of the data obtained, a forecast model of the transport and distribution of radioactive contamination in sediment types in the Ob River-Kara Sea system will be simulated. A risk assessment will be made of the past, present and future contamination scenarios from the Mayak facilities with their spatial and time distribution evolution. This forecast is particularly important for the development of scenarios of unexpected changes in the situation with respect to radioactivity contamination.

7.2 Organic Geochemistry

7.2.1 Dissolved Organic Matter (DOM)

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2) Alfred Wegener Institute for Polar and Marine Research, Bremerhaven

One of the topics during the research cruise onboard the R/V *Akademik Boris Petrov* was to characterize the influx and fate of terrigenous dissolved organic matter from the rivers Ob and Yenisei into the Kara Sea.

The oceanic DOM-pool is one of the main active carbon reservoirs of the world (Farrington 1992) and has attracted significant research in the recent past. Although the world's rivers contribute large quantities of DOM to the ocean, potentially filling the oceanic pool of DOM in less than 2000 years (Deuser 1988), we can identify only a small amount (about 1-2%) of terrigenous DOM in the ocean. Therefore, either our estimates are flawed, or effective transformation mechanisms for terrigenous DOM have to exist within the ocean.

The fact that the Arctic has high concentration of terrestrial-derived DOC makes it a perfect place to study the fate and transformation processes of that material. With a suite of bulk and molecular level analysis we will identify the origin and diagenetic transformations of terrestrial-derived organic matter in the Arctic and hope to determine the role of Arctic rivers as source of terrestrial DOM for the global ocean.

Key issues during this cruise were to determine quantity and quality of DOM entering the Kara Sea, as well as to investigate the distribution and behavior of DOM during estuarine mixing.

One of the main challenges of recent DOM research is it's extraction from the salt water matrix. Therefore, we used two different methods to concentrate the DOM fraction: the ultrafiltration and the XAD-extraction methods (humic and fulvic acids). For further characterization of the different DOM fractions, samples were taken to analyze the changes in the ratio of DOC to DON. Also samples were taken to detect the characteristics of amino acids and carbohydrates. In addition, samples were taken to measure the fluorescence of yellow substances to identify the proportions of dissolved marine and terrigenous fluorescent material, and to study their behavior during the estuarine mixing processes.

During the expedition there was a clear salinity gradient in the surface waters of the river Yenisei, whereas in the river Ob we found different water masses without a real gradient.

Sampling Program
A. Henne, S. Steffen

DOC Sampling
Water samples from Niskin bottles were taken with 1.8 l go-flo bottles and filtered immediately after sampling under a slight vacuum through pre combusted

Whatman GF/F filters. After filtration the samples were preserved with 50 % phosphoric acid to reach pH 2 and stored in pre combusted 10 ml glass ampoules at +50°C and at -18°C to compare the durability.

XAD-Extraction for DOM Analysis

Surface water was taken with a large volume sampler (200 l) at 12 stations and filtered immediately after sampling through a large volume filtration, first through 3 µm filter, followed by a 0.2 µm filter. After filtration 37 % hydrochloric acid was added to reach pH 2. 70 l from each sample were pumped into a XAD-8 filled column with a flow rate of 10 l/h. Afterwards filtration was conducted with 0.1 M NaOH solvent at a flow rate of 1 l/h, leading to 2.5 l extract of humic and fulvic acids. The extract was filled into glass bottles and for storing 37% hydrochloric acid was added to reach pH 2 and $HgCl_2$ to fix the sample.

Fluorescence of Yellow Substance

Vertical CTD hydrocast samples were taken with 1.8 l go-flo bottles and not filtered. Three different emission scans with a Shimadzu RF 551 spectrofluorometer were performed: two with the excitation wave length 308 nm and one with 270 nm. Three emission scan ranges were used: the first between 320 nm - 450 nm, the second between 400 nm - 720 nm, and the third from 280 nm - 500 nm.

The samples will be analyzed at the laboratories of the Institute of Biogeochemistry and Marine Chemistry, Hamburg.

Sampling Program

R. Richter

DOC/DON

At 25 stations surface water samples were taken from the Niskin rosette and filtered under a slight vacuum through pre combusted Whatman GF/F filters. After filtration three subsamples of each station were stored in pre combusted 15 ml glass ampoules at -18°C.

Ultrafiltration Samples

Surface waters were sampled with a large volume sampler (200 l) at 9 stations to extract the DOM fraction. They were pre filtered immediately after sampling through a large volume filtration unit consisting of two consecutive PC membrane filters (Nuclepore), 3 and 0.2 µm pore size, respectively. These water samples were stored under cold and dark conditions in 30-60 l HDPE containers for further processing at the AWI.

Amino Acids and Carbohydrates

In addition to the large volume samples, 100 ml of surface water were filtered through a pre combusted Whatman GF/F filters and stored in Teflon bottles at -18°C. The samples will be analyzed at the AWI, Bremerhaven.

Sampling Program

K. Neumann

A total of 79 water samples at 21 stations have been taken from a 24-bottles Niskin rosette sampling system at water depths between the surface and 35 m. The samples were filtered through preweighted polycarbonate membrane filters (Schleicher & Schuell) with a pore size of 0,4 µm and a diameter of 47 mm. Depending on the concentration of the suspended particles, usually 3-5 l were filtered. The filters were dried at 40°C for 24 hours.

In addition, subsamples of surface and near-surface sediments were collected from giant box corer (GKG) and the multi corer (MUC). For details of sampling see chapter 6.1.

The following analysis will be performed on the suspended particulate matter and the sediment samples:

- Corg, N
- carbonate
- biogenic silica (opal)
- carbo hydrates
- amino acids

The analyses will be conducted at the laboratory of the Institute of Biogeochemistry and Marine Chemistry, Hamburg.

7.2.2 Geochemistry of Organic Matter and Other Elements of the Carbon Cycle in the Southern Kara Sea and the Estuarine Zone (Ob, Yenisey Rivers)

L.A. Kodina[1], V.G. Tokarev[1], L.N. Vlasova[1], T.N. Pribylova[1], L.K. Shpigun[2]

1)Vernadsky Institute of Geochemistry and Analytical Chemistry, RAS, Moscow
2)Kurnakov Institute of General and Inorganic Chemistry, RAS, Moscow

Introduction and Goals

There are special features in the geochemistry of the carbon cycle in the Arctic Basin related to the severe climate conditions, the large fluvial impact on the shelf area, the massive sea-ice cover during most time of the year, the high hydrodynamic activity etc. However, only a limited number of studies concerned with the geochemistry of the most important elements of the carbon cycle, namely organic matter, carbon dioxide and hydrocarbon gases have been carried out in the shelf sea area so far.

The amount of terrestrial organic matter in the ocean is one of the most poorly known factors in the global carbon balance. The data on the subject are scarce and contradictory. The problem is of special importance for Russian polar shelf sea areas, where the great rivers Ob, Yenisei and Lena discharge. They carry a lot of clastic, suspended and dissolved organic material collected from the huge Siberian territory including forests, mountains and swampy lowlands. Estuaries modify the amount and composition of organic matter being delivered by rivers: most part (more than 90% after Lisitzin, 1995) of this material is buried in the mixing zone sediments due to the processes of flocculation and precipitation of dissolved organic matter (DOM) and gravity differentiation of the clastic and particulate material. The quantification of the genetic types of organic matter (OM) in the oligotrophic Arctic shelf seas (terrigenous supply vs. marine productivity) is of major significance for the understanding of the carbon cycle activity in the polar area.

The second problem relates to the biogeochemical activity of suspended and buried OM and is connected tightly with carbon dioxide and methane fluxes in the marine environment. The most early degradation of OM takes place in the water column and in the surface sediment layer. Although oxic decomposition of OM dominates in the marine systems, anoxic conditions prevail in coastal (estuarine) regions where the majority of carbon preservation occurs. The most important process of anaerobic destruction of OM in sediments is bacterial reduction of sulfates (Henrichs and Reeburgh, 1987). The process depends strongly on the nature of OM (marine-derived is preferable) and temperature. The last factor is of special significance in the study area because temperature has a great effect on the sulfate reduction rate when the organic substrate is refractory what might be in the case with fluvial impact. Decomposition of organic matter in the water masses and sediments appears, by this way, to be an important process controlling the chemical composition of sea water (O_2, nutrients, CO_2 supply) and sediments as well as the geochemical behaviour of heavy metals and radioactive pollutants in the marine system.

The first step in the study of the problems being indicated above has been done in the 22nd cruise of R/V *Akademik Boris Petrov* in 1995 (Galimov et al., 1996). The inner Kara Sea area had been mapped with respect to the data obtained on redox-state and organic carbon distribution in the bottom sediments, methane concentration and sedimentary organic carbon isotope composition. The first isotope data had been obtained for C_{org} and for dissolved inorganic carbon in sea and pore waters (Kodina et al., manuscript in preparation).

The present work aimed at continuing the study in these directions in the very important geochemical zone of the great Siberian rivers' estuaries. Geochemistry of organic matter in the polar shelf mixing zone is now at the very beginning of its investigation. The central point of our experimental approach is the carbon isotope analysis which enables us to conduct complex investigations of the environment and by this way to make progress towards a better understanding of carbon dynamics in the study area.

Working Program and Methods

In order to get reliable natural material for more detailed studies of organic matter as a key compound of carbon cycle operation in the estuarine zone, it has been conducted an extensive investigation of the water column and bottom sediment at the 59 stations located along 4 transects.

The work on board has been carried out on the following directions:

Sampling of Sediments
for organic geochemistry study by using stable carbon isotope analysis, Rock-Eval II pyrolysis, and GL-chromatography etc. Wet sediments were dried at 105°C, and packed in foil or glass flasks for transportation;

Sampling of Sea Water
for hydrochemistry (on board) and determination of dissolved organic carbon (DOC) by chromium-H_2SO_4 wet oxidation with subsequent potentiometry of CO_2 (on shore laboratory);

Core Study:
Σ visual description (colour, lithology, texture, inclusions);
Σ measurement of redox-potential, layer by layer along the core depth by using the "Orion-Research" apparatus;
Σ determination of water content and bulk density in wet cores, layer by layer by using medical balances and plastic syringes for sampling of 10 cc sediment;
Σ separation of pore water from several sections per core along the core depth by using a steel screw press with plastic package inside, pressure varied from 1 to 10 Pa, temperature was kept close to natural. The procedure started immediately after box-core recovery.

Pore Water Hydrochemistry:
Σ determination of pH values with combined pH-electrode 98-78 "Orion Research";
Σ determination of TAlk, $Alk_{HCO_3^-}$, SO_4^{2-}, Cl^-, PO_4^{3-} etc. by using flow-injection analyzer FIAStar 5020 with spectrophotometric detector 5023 (Tecator, Sweden);
Σ preparation of dissolved inorganic carbon from sea water (as $BaCO_3$) for isotope analysis.

Methane Geochemistry:
Σ separation of small volume gas samples for determination of methane and its higher homologues concentration in sediments and sea water (surface and near-bottom) over the study area by "head space" technique. Sediments samples of 100 g, or water sample of 500 ml were degassed in concentrated NaCl solution at T = 75-80° C by shaking flasks until the gas reached equilibrium state;
Σ preparation of large volume gas samples for methane carbon isotope analysis, the volume of wet sediment samples were about 2 l.

Biogeochemistry of Sediments and Sea Water:
Σ determination of the rate (intensity) of bacterial processes of sulfate reduction in sediments with radioisotope ($^{35}SO_4^{2-}$) technique. Incubation of sediment samples with inoculated sulfur radioisotope was done during 10 hours at the temperature close to *in situ* conditions, afterwards the reaction was stopped by injection of concentrated cadmium acetate and alkali solutions into sample. Further treatment of the samples and determination of the reduced S-compounds will be performed in the shore laboratory;
Σ conservation of pore water samples with $HgCl_2$ and NaOH for isotopic analysis of inorganic carbon;

Σ determination of the rate of the total CO_2 bioassimilation in the photic layer with radioisotope ($^{14}HCO^-_3$) technique. Incubation of sea water samples (0.5 l) with inoculated nanomolar amounts of carbon radioisotope under *in situ* conditions. Afterwards water samples were filtered off through nuclepore filter (0.47 μm). Particulate organic matter on the filter was washed carefully with acidified water and dried to be analyzed in the shore laboratory for ^{14}C - uptake as an indicator of the intensity of the total CO_2 bioassimilation processes in the photic layer.

Σ determination of the rate of heterotrophic microbial CO_2 bioassimilation in sediments by using the radioisotope ($^{14}HCO_3^-$) technique.

Particulate Organic Matter in Sea Water and Sediments:

Σ samples of particulate matter were obtained from 3-5 horizons of the water column at each rosette station by pump filtration of sea water samples through the glass fiber GF/F (Whatman) filter which had been kept beforehand in a furnice at 450°C. Samples will be used for determination of POC concentration in sea water and organic carbon isotope composition in the shore laboratory;

Σ samples of the fine and coarse fractions were obtained from the box-corer near-bottom water and/or top sediment layer from the multi corer. Suspended sample (sediment or near-bottom water) was shaken in chemical glass and left on the table. Coarse (sand or aleurite) fraction settled first, finest one - in several days. Subfractions will be used for carbon isotope analysis and pyrolysis to reveal the phemomenon of gravity fractionation of the organic material in the marine environment and the nature of settled organic material.

Preliminary Results

The work during the expedition included the following procedures: sampling, preparative work with wet samples, and measurement of some geochemical parameters of the wet samples. Core samples were collected at 35 stations, water samples at 20 stations.

Preparative and Analytical Work on board:

Σ	Separation of pore water from sediments	- 115 samples
Σ	Preparation of dissolved inorganic carbon samples ($BaCO_3$) from sea water for isotope analysis	- 70
Σ	Preparation of gas samples for isotope analysis of methane carbon	- 15
Σ	Preparation of gas samples for methane and its homologues quantification	- 95
Σ	Preparation of sediment samples for determination of microbiological activity	- 100
Σ	Preparation of particulate matter from water and sediments samples	- 100
Σ	Determination of water content in sediment	- 180
Σ	Determination of bulk density in sediment	- 180
Σ	Measurement of Eh-values in sediment	- 500
Σ	Measurement of pH-values in pore water	- 130
Σ	Measurement of TAlk-values in pore water	- 130
Σ	Measurement of TCO_2 in pore water	- 130

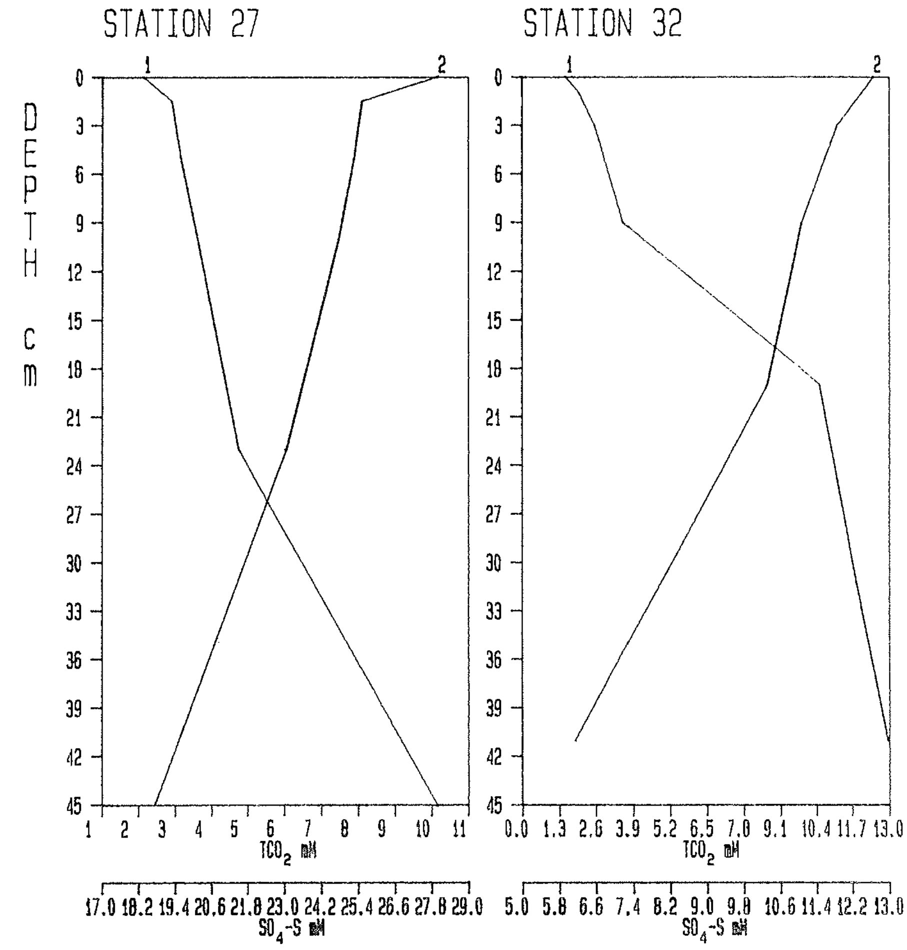

Fig. 7-4: Sediment column profiles of the pore water transformation at two stations of the Yenisei transect (1 - TCO_2, 2 - SO_4-S).

The natural observations, few experimental data obtained aboard together with the experience from the Kara Sea geochemistry study in the cruise 1995 enabled us to give some preliminary considerations on organic and gas geochemistry.

Organic Matter and Biogeochemical Processes in Sediments

Assessment of terrigenous input in marine settings and geochemistry of terrestrial organic matter in the sea environment is considered to be one of the intriguing problems of marine organic geochemistry. The biomarker study seems to be rather informative in this field, nevertheless there are definite limitations because biomarker represent extremely small portions of organic

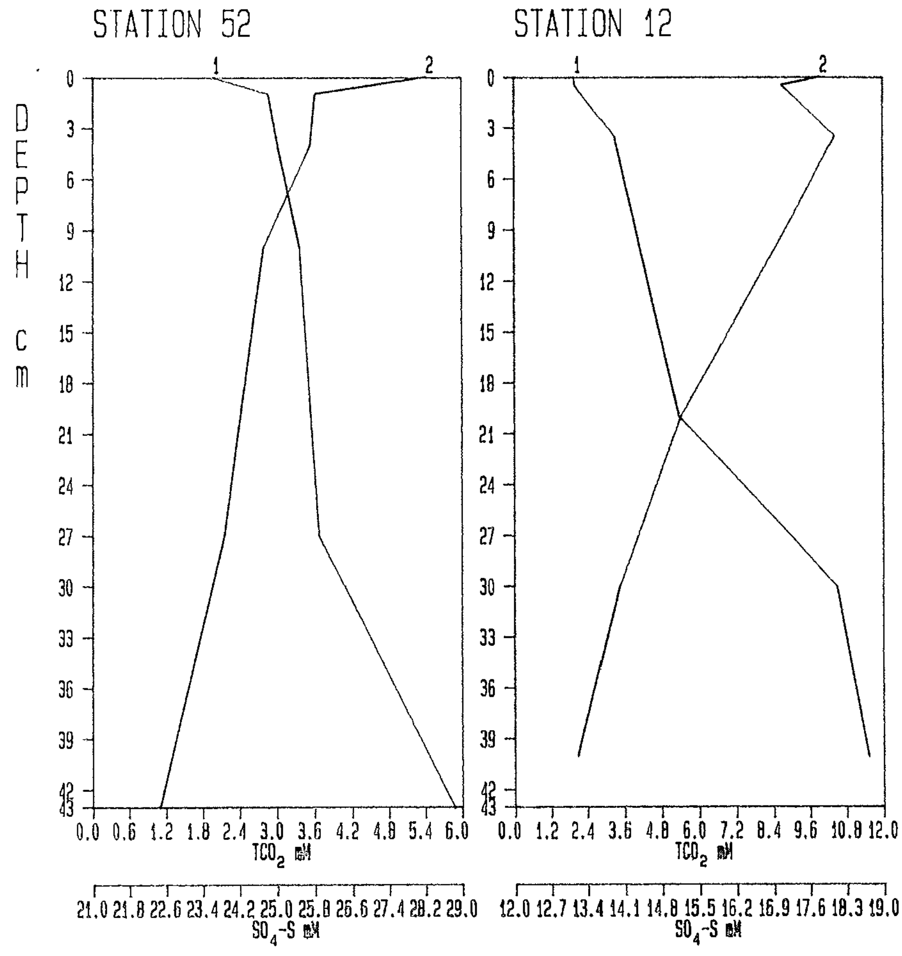

Fig. 7-5: Sediment column profiles of the pore water transformation at two stations of the Ob transect (1 - TCO_2, 2 - SO_4-S).

material and the geochemical behaviour of some of them might differ highly from the bulk organic matter (Jasper & Gagosian, 1993).

The stable carbon isotope composition reflects the source of organic matter and the $^{13}C/^{12}C$-ratio of the bulk organic carbon has been routinely used to infer the relative proportions of marine and terrestrial carbon in marine settings.

Our results on the organic carbon isotope composition in the top layer (0 - 2 cm) of recent sediments over the inner Kara Sea area (the $\delta^{13}C$- values range between -22.5 ‰ and -28.2 ‰ vs. PDB) provide reason enough to revise the traditional view on the negligible role of autochtonous marine production vs.

terrigenous supply in the Kara Sea sediments. The high HI-values (up to 400 mg HC/gC_{org} obtained for some sediment samples from the 22nd cruise R/V *Akademik Boris Petrov* as well as organic carbon isotope composition correspond well with an autochtonous nature of organic matter. A relative enrichment of marine-derived material in sediments as has been indicated by the fatty acid investigation was found in the northern part of the transect from the Ob River mouth to the north of the Kara Sea (Belyaeva et al., 1996). Zegouagh et al. (1996) determined a dominant contribution of marine-derived production into the surface sediments of the Laptev Sea not far from Lena delta, with a low contribution of higher plant material. In these and other cases (Fahl and Stein, 1997) as well as in the present study area the high primary productivity in some localities of the open sea might be induced by nutrient influx from the river water.

In the present work we got some indirect proof of the presence and geochemical activity of the labile, "fresh" organic matter in the river estuary area sediments.

According to our preliminary observations made on the expedition the estuary zone in total contains rather highly reduced sediments with a clearly seen oxidized layer of 1 - 2 cm thickness, brown in colour, liquid or jelly-like, with water contents ranging from 64.3 to 79.2%. Reductive processes start in the horizon of enhanced density at the depth of 4 - 7 cm indicated by Eh-values (0 - - 50 mV), dark coloration (hydrotroillite) and increase in TCO_2 concentrations in pore water.

In the "river" part of the zone (at the first contact of the fresh and saline waters) and in the lowermost places of bottom relief in the Ob and Yenisei transects occur sediments with enhanced water content in which the diagenetic transformation can be clearly seen in the upper horizon (0 - 20 cm) of sediments according to the Eh-values and dark-grey coloration (reduced sulfur compounds are present) as well as in the metamorphism of pore waters. It should be noted that alkalinity values in the top oxidized layer increase in the transects from "riverine", relatively warm stations to "marine", cold ones. At a depth of about 40 cm the degree of reductivity was nearly similar over the entire study area according to the mentioned parameters.

At the higher points of the bottom relief and in the erosion zones the sediments have much lower water contents (18,7%) due to higher proportion of mineral material (aleurite, small-sized sand grains) and the diagenetic transformation of the sediments is not so evident.

At Station 24 (Yenisei mouth) brownish-yellow crystals were found in the reduced dark grey sandy clay at a depth of 5- 20 cm underlain by sandy horizons. They were twin crystal aggregates of different size (ranging from 10 to 50 mm), and lost water easily at room temperature. According to the preliminary investigations, the crystals have a density of about 1.8 g/cm^3, contain 52% of water, calcium carbonate and trace amounts of ferrous irons responsible for coloration. The mineral is supposed to be identical with ikaite $CaCO_3*6H_2O$ (Feklichev, 1977). $\delta^{13}C$ values (-28.8, -29.2 and -30.0 ‰ vs. PDB) for three different specimens are compatible with a substantial contribution of organic-derived CO_2.

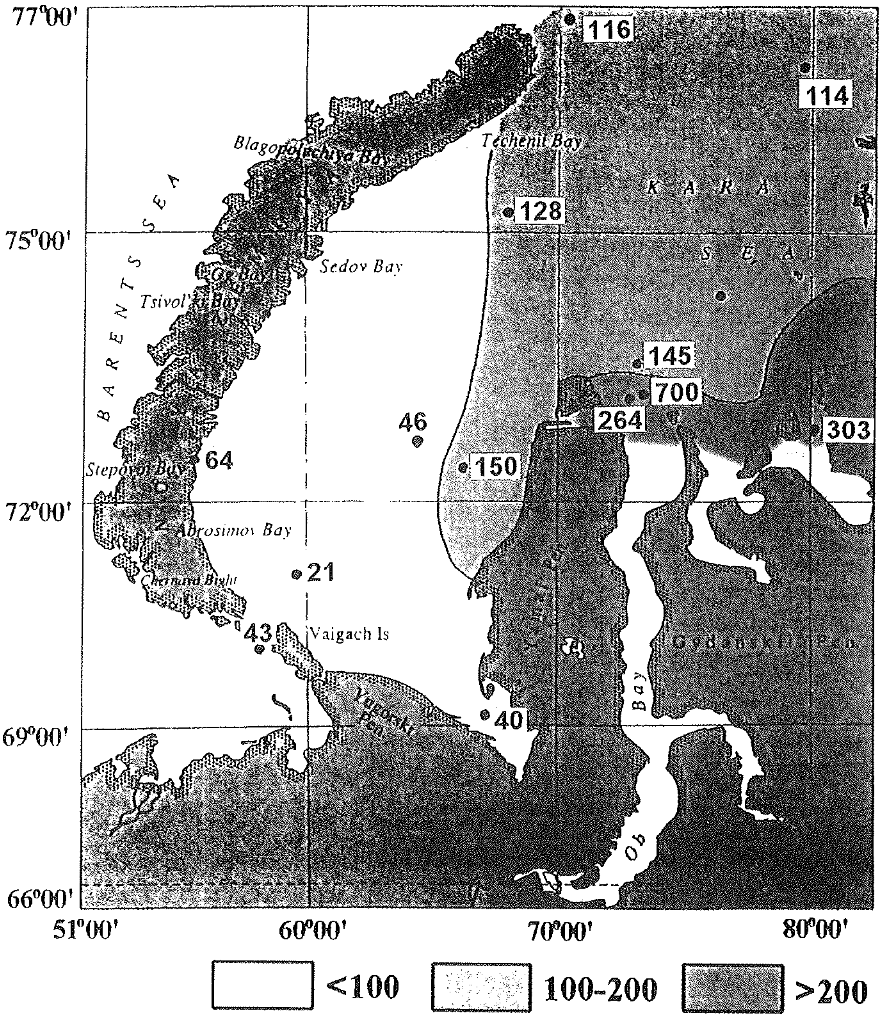

Fig. 7-6: CH_4 content in the subsurface layers (10-20 cm) in the Kara Sea. in 1995, measured on the 22th cruise of RV *Akademik Boris Petrov.*

Figures 7-4 and 7-5 present the data on the variations of key parameters of pore water with core depth for two stations from the Ob and two stations from the Yenisei transects. It's clearly seen that the early transformation of sediments due to destruction of organic matter produced increasing yield of carbon dioxide (the origin of the carbon dioxide will be revealed when the data on its $\delta^{13}C$-value is available). The process is especially distinct at the stations with positive temperatures: station 12 in the Ob transect with the bottom temperature of +2°C and station 32 in the Yenisei transect with a higher temperature of +5.5°C, whereby Yenisei's sediments are more highly reduced than Ob' ones.

Some differences in the diagenetic transformation observed over the study area seem to be caused by the river morphometry, variations of bottom relief, water dynamics, temperature etc.

The reliable data on the geochemistry of organic matter (genesis and transformations in sediment and water mass) in the estuary zone will be obtained in the framework of complex investigations of different elements of the carbon cycle with the stable isotope and biomarker techniques alongside with other traditional methods of organic geochemistry.

Methane Geochemistry

The problem of methane genesis in the estuarine zone of two great Siberian rivers deserves a special attention if taken into account that there exist large gas fields on the land area (Yamal peninsula) close to the investigation area.

In the present work we continued investigations on methane distribution over the inner Kara Sea and made efforts to study in more detail the estuarine zone of Ob and Yenisei. We hope to get new information on the methane genesis and oxidation in water and/or top layer of sediment by getting methane carbon isotope composition and more detailed study of regularities of methane homologues distribution in close correlation with organic matter geochemistry. The data on the stable carbon isotope composition of dissolved inorganic carbon of pore water could be a very effective tool in the study methane geochemistry.

The preliminary few measurements of methane concentration in the Ob estuary are very close to the data of Bol'shakov and Egorov (1995), and to our data obtained on the 22nd cruise R/V *Akademik Boris Petrov* in 1995. Therefore we found it appropriate to present here the data of that cruise (Fig. 7-6) which demonstrate the geochemical zonality in methane distribution in the subsurface (10 - 20 cm) sediments of the Kara Sea area.

7.2.3 Fluxes and Composition of Organic Matter in the Southern Kara Sea

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Introduction

The distribution and origin of organic matter in the Kara Sea is poorly known in comparison to other ocean areas. First rough information about the content and composition of organic matter in the Kara Sea is given by organic-geochemical bulk parameters (TOC-content, hydrogen index values, organic carbon/nitrogen (C/N-ratios)), indicating the importance of terrigenous (fluvial) input of organic matter (Stein, 1996). Biomarkers such as fatty acids, alkanes, alkenones, pigments, and sterols are valuable tools to characterize the origin and source of the organic fraction of the sediments in more detail because they are specific for different biological groups. Therefore, they may be used as indicators of surface-water productivity and terrigenous organic carbon input in marine sediments (e.g. Fahl and Stein, 1997). Studies of lipid biomarkers in surface sediments of the Kara Sea and in the Ob estuary show a pre-dominance of terrestrial constituents and an increase in planktonogenic and bacterial lipids further offshore (Belyaeva and Eglinton, 1997). Further detailed information about the quality and quantity of organic matter can be obtained by light microscopy, i.e., maceral analysis and palynological methods.

Biomarker in the Water Column and Sediments

Samples for biomarker analyses were taken both from the water column and the sediments at the same stations along the salinity gradient. Comparison of data obtained from water samples and surface sediments will show whether the variability in the modern environment is adequately reflected in the bottom sediments.

Water sampling was carried out with a Niskin rosette water sampler. Samples were taken at 21 stations. Depths of subsamples were selected according to the CTD profile. 79 subsamples of about 3-5 l depending on the concentration of suspended matter were collected. The water samples were filtered through GF/C Whatman filters (glass fibre, diameter 47 mm). The filters were stored under light protection in 10 ml methanol : dichlormethane (1:2) at -20°C.

Surface sediments and near-surface sediments were sampled for the same analyses (see chapter 6.1). Additionally, TOC, $CaCO_3$, Rock Eval pyrolysis, and C/N analyses will be conducted on the sediment samples. All sediment samples were frozen in amber glass bottles at -20°C. Selected sediment cores were stored frozen at -9°C.

Further preparation of samples and gas chromatographic (GC) and gaschromatographic/massspectrometric (GC/MS) analyses of specific biomarkers (n-alkanes, sterols, fatty acids, alkenones) will be carried out at the Alfred Wegener Institute in Bremerhaven.

Particulate Organic Matter in Surface Waters and Sediments

For microscopical studies of the particular organic matter the surface water layer and sediment surfaces were sampled. Water samples were taken with a phytoplankton net (>10 µm) by hand. Respectively, 3 water samples were taken in the river Ob at stations 48, 17, 10 where salinities of the surface layer vary between 2.4 to 14 ‰ and in the river Yenissei at stations 27, 35, 32 with salinities between 1.2 to 7 ‰. In the offshore W-E transect 5 water samples were taken at stations 1, 18, 21, 42, 43 where salinities reach values around 13 ‰. After sampling the organic matter was fixed in formaline (4%). Surface sediments were taken by a multi corer (see chapter 6.1).

Primarily we are interested in the composition of the aquatic algae in the particulate organic matter, e.g. fresh water algae such as *Botryoccocus* and *Pediastrum* or marine algae. In Arctic coastal marine environments, these fresh water algae may contribute significantly to the aquatic portion of the total organic matter (Kunz-Pirrung, in press), making the interpretation of geochemical parameters difficult. Additionally, the source of organic matter can be characterized by determination of the maceral groups. Furthermore, palynological analysis will give valuable information about source and age of organic matter.

The investigations will be carried out in oil-immersion under incident light and under fluorescent light by using blue light exication according to palynological methods and maceral analysis.

7.2.4 Methane Biogeochemistry in the Ob and Yenisei Estuaries and the Kara Sea

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Methane plays an important role in atmospheric chemistry and global climate warming. It accounts for about 15% of the anthropogenic greenhouse effect and its tropospheric concentrations continue to increase at an annual rate of approximately 0.7-1% (Khalil and Rasmussen, 1990). Quantitative estimation of the CH_4 emissions are required to predict the trend of its atmospheric concentrations and its future impact on climate. The Arctic shelf seas and the large rivers are very vulnerable and sensitive to the climate warming. The study of methane biogeochemistry in these ecosystems is of particular importance.

Methane release from water ecosystems is controlled by the microbial processes of CH_4 formation in sediments and its oxidation in sediments and waters. To quantify the CH_4 emission from the Kara Sea, the Ob and Yenisei estuaries, it is essential to measure the activity and to estimate the balance of these two processes. The goals of the study of methane biogeochemistry on this cruise were:

∑ to measure methane content and distribution in waters and sediments,
∑ to evaluate methane generation and oxidation rates,
∑ to estimate the methane flux to the atmosphere and its transport by the rivers Ob and Yenisei to the Kara Sea.

Working Programme and Research Methods

During this cruise 48 water samples and 100 sediment samples were taken from 14 stations grouped in 4 transects: the Ob Estuary, the Yenisei Estuary, Gydansky Bay and "Ost " transect.

Methane Concentration Measurements

Methane concentrations were determined by the multiple phase equilibration method and gas chromatography (GC) with flame ionisation detection (FID). (McAuliffe, 1971). Fifty milliliter samples were drawn into a 60 ml syringe equipped with a steel needle closed by a rubber stopper. The samples were equilibrated at room temperature within 8-12 hours without any headspace. After the equlibration 5 ml of pure N_2 was drawn into each syringe which were then vigorously shaken for 3 minutes. The gas phase from the syringe was transfered into a 12 ml glass vial closed with a rubber stopper replacing saturated NaCl alkali solution in it. The procedure of equilibration with N_2 was repeated twice to calculate Henry's constant. The samples were then stored for further GC analysis.

Sediment samples were taken from multi corer cores usually at 0-2 cm, 2-5 cm and further at 5 cm intervals to the bottom of the core using 10 ml plastic syringes with cut off ends. The sample was immediately transfered into a 58 ml glass vial containing 20 ml of saturated NaCl alkali solution. The vial was closed with a screw cup with rubber septa, vigorously shaken for 3 minutes to homogenize sediment and solution and stored at room temperature for GC analysis (Bol'shakov and Egorov, 1988).

Methane concentrations were measured on board using a portable GC XPM-4 ("Chromatograph" Co., Russia) equipped with FID. To calibrate the GC, standard gas mixtures (10, 100, 1000 and 10000 ppm CH_4) were prepared from pure (99,99%) methane by injection of the appropriate CH_4 amount into a glass bottle of known volume filled before with pure N_2 and closed with a rubber septa and screw cup.

Determination of Methane Generation and Oxidation Rates

Water samples for the determination of methane oxidation rates were drawn from the Niskin bottles of the rosette sampler. Sterile 20 ml glass vials were filled with water without any headspace and were closed with rubber septae and aluminium cups. An aliquot (0,1 ml) of degassed water with $^{14}CH_4$ dissolved in it (0,04 MBq) was injected into vials through the septa with a gastight syringe. Samples were incubated for 12-24 hours close to "in situ" temperatures and then were terminated by the addition of 0,25 ml 6N NaOH. In control vials 6N NaOH was added immediately after the injection of $^{14}CH_4$.

A separate core was taken from the larger box corer for tracer experiments with sediments. Undisturbed sediment samples (5 ml) were drawn from the central part of the core at predeterminated intervals into glass test tubes with a cut off tip. Tubes were closed with a rubber plunger from the one side and with a rubber stopper from the opposite side without any headspace.

The samples were line-injected through the stopper with 0,1 ml of ^{14}C-sodium bicarbonate or 2-^{14}C-sodium acetate solution (0,4 MBq) for the determination of methane generation rate, or with 0,1 ml of water with dissolved $^{14}CH_4$ (0,04 MBq) for the methane oxidation rate measurements. Samples were incubated for 24-48 hours close to "in situ" temperatures and then were terminated by the injection of 5 ml 1N NaOH in each tube.

Further radiotracer experiments will be conducted in the Institute of Soil Science and Photosynthesis, RAS (ISSP, RAS, Pushchino).

Pore Water Analysis

Sediment pore waters were obtained to determine concentration of substrates (dissolved inorganic carbon and acetate) which are necessary to calculate the rate of methane generation.

Pore waters were squeesed by Res. Sci. V. Tokarev using the "Pneumopress" and were analyzed by Dr. L. Shpigun on DIC concentrations with the FI spectrophotometry (see chapter 7.2.2). Additional pore water samples were squeesed at a pressure of up to 5 atm. with a mechanical press designed in ISSP. 40 ml pore water samples were fixed by the addition of 0,25 ml 6N NaOH for acetate determination using a "Biotronic" ion chromatograph in ISSP RAS.

Preliminary Results

The first data on methane content in the surface sediments of the transect from the Kara Sea to the Ob estuary are presented in Figure 7.-7. The methane content increases from the open sea (St. 1) to the Ob Estuary by two (St. 10) to twenty times (St. 12). These results are in a good agreement with earlier data from this region (Bol'shakov and Egorov, 1995).

The detailed interpretation of the CH_4 distribution with depth in sediment cores will be possible after the determination of the rates of methane generation and oxidation.

Methane concentrations in the surface waters increase in the same direction from about 0.15 (St. 1) to 0.5 (St. 12) microliters per liter of water. The preliminary results suggest that surface waters of the Kara Sea and the Ob estuary are supersaturated with CH_4 relative to its equilibrium concentrations and that this area can serve as a source of atmospheric methane.

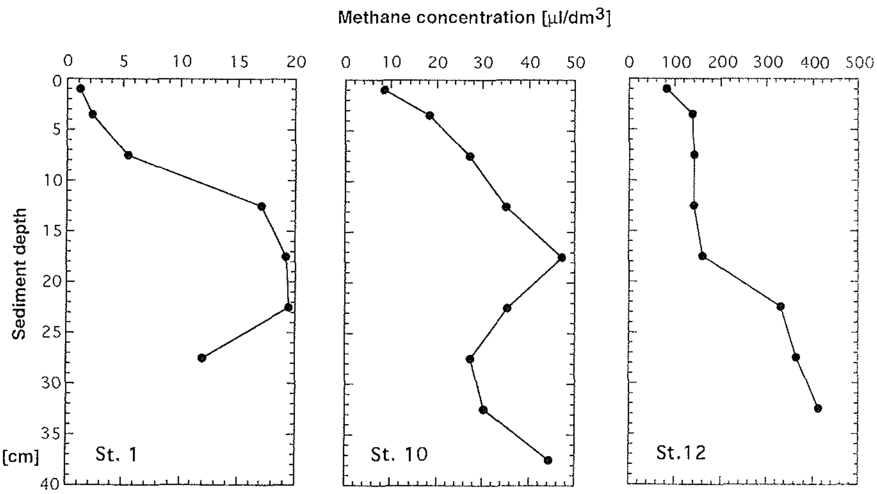

Fig. 7-7: Methane content in surface sediments in the Kara Sea (ST.1) and in the Ob estuary (St. 10, 12).

Acknowledgements
I sincerely thank Prof. Dr. D. Fütterer, Head of the Geological Department of AWI and Academician Prof. Dr. E.M. Galimov, Director of GEOKHI, RAS for the kind invitation to participate on the expedition. I very much appreciate Res. Sci. V. Tokarev for the assistance in GC analysis of methane. The research work on this project was partly funded by the Russian Foundation for the Basic Researches (Grant 95-04-12526a).

7.3 Inorganic Geochemistry

7.3.1 Determination of Heavy Metals in Bottom Sediments

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The distribution of microelements in the bottom sediments and the water column were studied in the framework of the scientific program which deals with the dynamics and consequences of dissolved and suspended material supplied by rivers to the Arctic Ocean basin under conditions of increasing technogenic impact.

The investigations aimed at studying the distribution of Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Br, Rb, Sr, Ba and Pb in the upper two centimeters of the bottom sediments in the area of the Ob and Yenisei river estuaries. The analysis of the elemental composition of the sediments was carried out on dried samples, collected by box corer, okean grab and multi corer, using the x-ray fluorescent method with the scanning spectrometer SPARK-1.

Equipment and Method

The scanning spectrometer SPARK-1 conducts x-ray spectral analysis of chemical elements from Ti to Sr in the K-series and from Ba to U in the L-series of the fluorescent radiation. The fluorescent radiation is resolved into a spectrum with the focussing crystal-analyzer LiF (200), bended according to the Joganson method. The energy resolution in the central part of the scanning scale (about 30 eV) provides highly precise analytical parameters (about 0.000n%). The lines of spectra are registered with a X-ray detector.

The specific element lines indicate the presence of the elements in the studied sample. The intensity of the lines correlates with the concentration of the element. The concentration is calculated by comparing with the results of analysis of standard samples. The time necessary to measure samples is 30 - 100 seconds.

The bottom sediment samples were dried at 150°C. Then they were rubbed to get a thickness of 50-100 mm and were analyzed in bathes of 0,25 cm^3 volume. The counts were conducted with the method of external standards. Standards used were the standards of bottom sediments: SBS-1 (terrigenous clay), SBS-2 (volcanic- terrigenous silt), SBS-8 (siliceous silt) and SBS-9 (red deep-water clay). During the cruise 1260 determinations of elements were conducted.

Results

The analyses were carried out on samples from 36 stations. During the cruise the elemental composition of 1260 samples were analyzed. The following samples were taken:

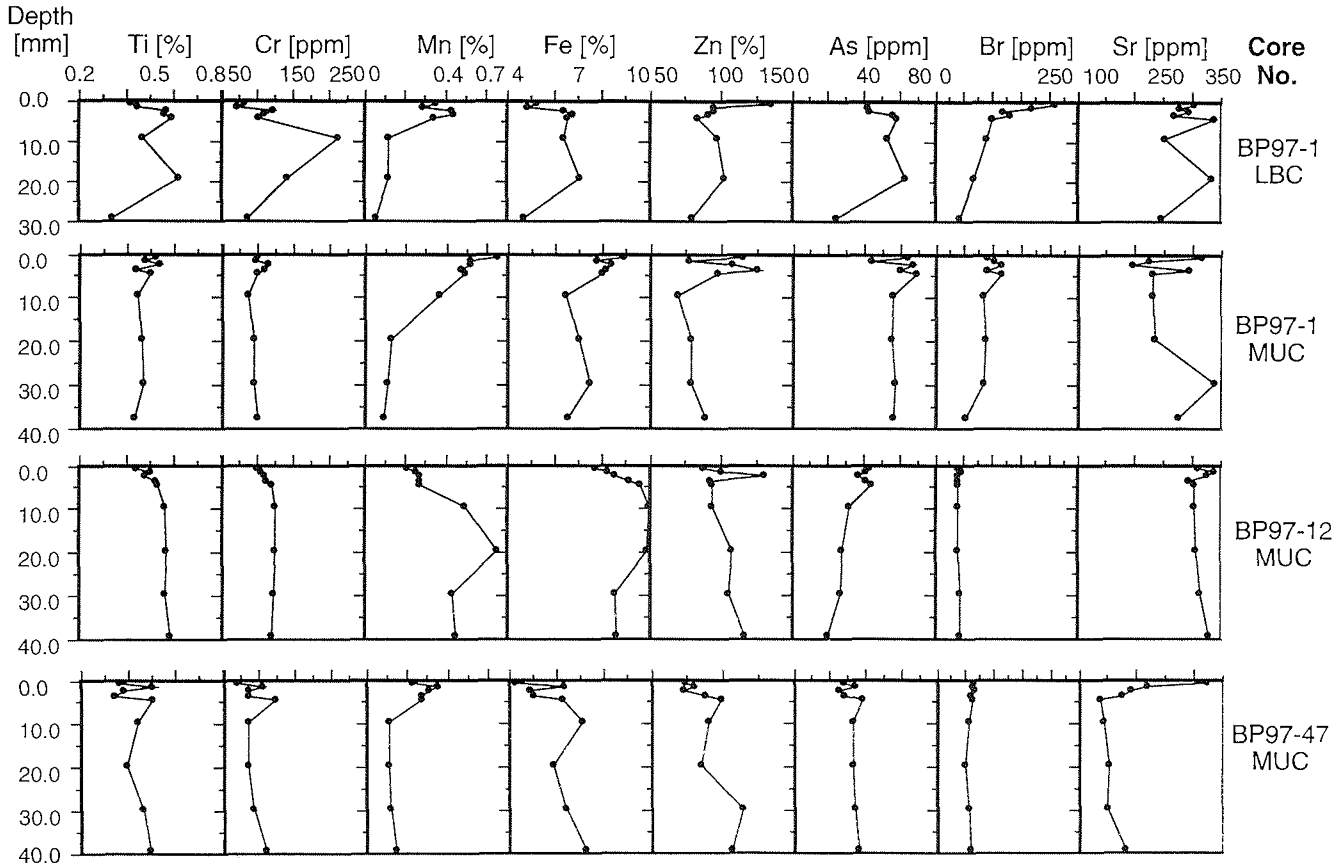

Fig. 7-8: Element concentration in sediment cores from the Kara Sea (LBC- large box corer, MC - multi corer).

1) The sample intervals 0-3 cm, 3-6 cm, 6-10 cm, 10-20 cm, 20-30 cm, 30-40 cm were collected at 10 stations from multicorer cores (21, 24, 27, 30, 32, 42, 43, 46, 47, 48).
2) Sediment columns were sampled from 0 to 40 mm at 22 stations: multicorer: 1, 10, 12), box corer: 1, Okean grab: 17, 18.
3) Samples of up to 1.5 kg weight for the analysis of ^{37}Cs activity were selected from the upper 10 cm of Okean grabs (18, 21, 24, 32, 48, 50).
4) Samples from the upper 0-2 cm were analyzed onboard from all Okean grabs (provided by Dr. Stepanets).
5) bottom water samples of 0.5 l volume were collected from the multicorer.

The results show the presence of anomalous concentrations of heavy metals in sediment cores (Figs. 7-8). On station 47 the additional measurements of the distribution of listed elements along the core were conducted at steps of 2 centimeters. The surface layer was measured every 1 mm at stations 1 and 47, selected from the box corer and the multi corer. With such resolution, the behaviour of Mn and Br in the oxidation zone is better resolved. These elements can vary by a factor of 3-6 down to a depth of 10-15 mm, whereas the variability of other elements is weak.

Such close sampling illustrates that this tool is well-suited to study the nature and interaction of local processes, leading to the formation of the surface sediment layers. The further analysis of samples in stationary conditions can provide more accurate information about the dominant processes of accumulation of sediments under certain conditions in a specific region.

7.3.2 The Application of SPRUT-M System in Combination with Ion-Selective Electrodes for River and Sea Water Analysis

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The investigations were carried out in the framework of the general research programme, studying the source of matter, the dynamics of its transfer by the Siberian rivers and the associated processes taking place in the Arctic basin under the increasing technogenic stress. The goals of the research work during this cruise were:

- the study of the characteristics of ion-selective electrodes (ISEs) as detectors for the SPRUT-M system;
- the test of such system for the determination of the chemical composition of river and sea waters;
- the improvement under working conditions of the measuring block of the ISE SPRUT-M system in order to reveal local pollution of waters and to search for flooded technical objects.

Samples

The study of the ISE characteristics were carried out on board using samples which were taken from the Niskin bottles of the rosette system and from the multicorer cores. The water samples were collected from the layers above and below the thermo- and halocline and the sediment-water interface.

Instruments

The ion-selective solid-state membrane electrodes were designed at the St. Petersburg University. A saturated calomel electrode was used as reference. The potentiometric signal was registrated by the measuring block of the SPRUT-M system constructed in VNIIOKEANGEOLOGIA, St. Petersburg. The range of the inlet signal varied from -2 V to +2 V with a sensitivity of the detector of ±1 mV and from -200 to + 200 mV with a sensitivity of ±0,1 mV.

Internal software of the SPRUT-M station allows to control the measurement process, to filter signals and to record data on magnetic tapes for their further processing. The program of data processing permits to separate efficient signals from the comparable instrument electronic noise, to present results on the display and to print them in tabular and graphic forms.

Methods

The calibration of the ISEs was performed with the standard procedure using solutions with different known concentrations of the elements being measured. The control test with "Standard Sea Water" was made before each sample measurement continuously during the cruise. The number of the determined elements (ionic species) was limited by the available ISEs, namely Cl, CN, Pb, Ag, Cd, Cu and Hg. The measurements were performed at a temperature of 18°C. The precision of the detection potential was up to 0,1 mV.

Preliminary Results

97 samples from vertical water sections of 21 stations were analyzed. 679 determinations of element concentrations were made in total. The results obtained will be presented in absolute concentrations of the elements, in tabular graphic and kartographic forms after further processing with the software of the SPRUT-M system in the Institute laboratory.

Water samples filtered over 0,45 μm cellulose-acetate filters and non-filtered water were analyzed in the process of the on board testing of the measuring system. The obtained information will make it possible to estimate the influence of particulate matter (suspension effect) on the ISE and to compare the results with earlier data received by using the ISE SPRUT-M system for direct sounding of the water in the Barents and the Baltic seas.

7.3.3 Major and Minor Elements in Surface Sediments of the Southern Kara Sea

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In the framework of paleoenvironmental studies in the Arctic Ocean, geochemical investigations are used to determine the source area of sediments. Furthermore, the pathways of particular matter transported from the source areas to the Arctic Ocean are reconstructed. The Ob and Yenisei rivers are two of the largest rivers draining into the Arctic Ocean. They are transporting big quantities of fresh water and suspended matter. The latter is sedimented in the Kara Sea and the Arctic Ocean. Therefore, it is important to know the elemental composition of the sediments in the Ob and Yenisei rivers, and the distribution of major and minor elements in the sediments of the Kara Sea.

During the cruise of RV *Akademik Boris Petrov* surface sediment samples were taken at 20 stations with a multi corer (MUC). The first centimeter of the core top was collected. In the home laboratory, the samples will be dried, grounded and molten with Lithium-tetraborate to a glass pellet, and afterwards analyzed by XRF (PW 2400, Fa. Philips) with a Rh-tube. The major elements like Si, Al, Ti, Fe, Mn, Na, K, Ca, Mg and P will be measured and the concentrations of the minor and trace elements As, Ba, Ce, Co, Cr, Ni, Pb, Rb, Sr, V, Y, Zn, and Zr determined. International reference standards will be used to check the analysis.

The composition of suspended matter transported by rivers depends on the geology of the catchment area. The Yenisei river transports weathered basaltic material from the Putoran Mountains with its flood basalts, while the catchment area of the Ob river is dominated by archaean and metamorphic rocks (Dolginow and Kropatschjow, 1994). First results of XRF-analyses of surface samples collected during the 49th cruise of the RV *Dmitriy Mendeleev* in 1993 show that the composition of surface sediments of Ob and Yenisei rivers differ in their elemental composition, e. g. when normalized on Al, there are differences in Ni/Al-, Ti/Al- and Rb/Al-ratios.

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Table of Content

9.1 Station List

Abbreviations of Activities

BD	-	Benthos Dredge
CTD	-	Conductivity-Temperature-Depth probe for oceanography
GC 500	-	Gravity Corer with 500 cm core barrel (penetration/core recovery)
GC 300	-	Gravity Corer with 300 cm core barrel (penetration/core recovery)
LBC	-	Large Box Corer (GKG)
LVS	-	Large Volumer Sampler (Batomat 200l)
MUC	-	Multiple Corer
OG	-	Okean Grab
PHN	-	Plankton Hand Net (10 µm)
PN	-	Plankton Net (zooplankton 150 µm)
RS	-	Rosette Sampler
SGC	-	Small Gravity Corer
ST	-	Sediment Trap
UWR	-	Under Water Pirranometer

The latitude and longitude of each station represents the geographic position of the ship´s anchorage. The number following the type of gear indicates the number of deployments.

Station	Date	Time (GMT)	Latitude °N	Longitude °E	Depth (m)	Activity
BP97-01	13.09	09:08	73°54'38.0"	73°10'59.0"	31	CTD-1, PN-4, PHN-1, RS-3, LVS-3, OG-3, LBC-3, MUC-1, GC 500-1 (200/179), BD-1, UWR-1, ST
BP97-02	13.09	20:56	73°49'56.0"	73°00'06.0"	30	CTD-1
BP97-03	13.09	22:23	73°40'04.0"	72°57'03.0"	28	CTD-1
BP97-04	13.09	23:51	73°30'02.0"	72°57'00.0"	29	CTD-1
BP97-05	14.09	01:17	73°19'58.0"	72°52'32.0"	29	CTD-1
BP97-06	14.09	02:43	73°10'01.0"	72°53'39.0"	29	CTD-1
BP97-07	14.09	04:07	73°00'01.0"	73°03'55.0"	29	CTD-1
BP97-08	14.09	05:35	72°50'03.0"	73°24'13.0"	26	CTD-1, OG-3, UWR-1
BP97-09	14.09	07:56	72°39'55.0"	73°46'19.0"	21	CTD-1, UWR-1, OG-1,
BP97-10	14.09	09:59	72°30'10.0"	74°04'51.0"	15	CTD-1, PN-4, PHN-1, RS-3, LVS-3, OG-3, LBS-3, MUC-2, GC 500-1 (700/480), BD-1
BP97-11	14.09	19:17	72°20'07.0"	74°09'42.0"	13	CTD-1
BP97-12	15.09	01:06	72°10'13.0"	74°17'37.0"	13	CTD-1, RS-3, LVS-3, OG-3, LBC-1, MUC-2
BP97-13	15.09	08:23	72°35'01.8"	73°45'13.2"	18	CTD-1, UWR-1, ST
BP97-14	15.09	09:02	72°35'54.6"	73°54'34.8"	18	CTD-1
BP97-15	15.09	09:54	72°38'20.4"	73°49'56.4"	19	CTD-1, LVS-1, OG-1
BP97-16	15.09	11:29	72°45'04.8"	73°29'36.6"	24	CTD-1
BP97-17	15.09	18:01	72°41'19.2"	73°43'50.4"	20	CTD-1, PHN-1, RS-3, LVS-3, OG-3, MUC-2, BD-2
BP97-18	16.09	04:08	73°57'42.0"	76°08'19.8"	25	CTD-1, PN-4, PHN-1, RS-3, LVS-3, OG-3, LBC-1, BD-1, UWR-1
BP97-19	16.09	12:53	74°00'02.4"	79°01'28.4"	30	CTD-1, LVS-1, OG-3, LBC-1, MUC-1, BD-2, GC 500-1 (600/130),
BP97-20	16.09	17:10	73°59'48.0"	79°25'34.8"	30	CTD-1, ST
BP97-21	17.09	01:11	74°00'02.4"	81°00'27.6"	41	CTD-1, PN-4, PHN-1, RS-3, LVS-2, OG-3 LBC-2, MUC-2, GC 500-1 (350/289), SGC-1, BD-1
BP97-22	17.09	08:20	73°50'10.8"	80°36'46.8"	37	CTD-1
BP97-23	17.09	09:43	73°41'22.8"	80°16'23.4"	38	CTD-1, OG-1
BP97-24	17.09	11:16	73°32'04.2"	79°55'16.2"	40	CTD-1, PN-4, RS-3, LVS-2, OG-2, LBC-1, MUC-2, BD-1
BP97-25	17.09	16:51	73°20'00.0"	79°57'44.4"	31	CTD-1, OG-1
BP97-26	17.09	18:51	73°07'06.0"	80°02'19.2"	25	CTD-1

Station	Date	Time (GMT)	Latitude °N	Longitude °E	Depth (m)	Activity
BP97-27	17.09	23:40	72°53'21.0"	80°05'33.0"	19	CTD-1, PN-4, PHN-1, RS-3, LVS-3, OG-3, LBC-2, MUC-3, BD-2 GC 500-1 (670/479),
BP97-28	18.09	07:01	72°49'56.4"	80°09'59.4"	19	CTD-1, OG-1, ST
BP97-29	18.09	08:13	72°41'43.8"	80°12'00.6"	16	CTD-1, OG-1,UWR-1
BP97-30	18.09	10:26	72°30'30.6"	80°20'10.8"	14	CTD-1, PN-2, RS-3, LVS-3, OG-3, LBC-2, MUC-2, UWR-1, BD-1 GC 500-1 (700/489),
BP97-31	18.09	15:24	72°19'48.6"	80°35'04.8"	13	CTD-1, OG-1
BP97-32	18.09	23:37	72°05'35.4"	81°28'52.2"	10	CTD-1, PN-2, PHN-1, RS-2, LVS-3, OG-3, LBC-2, MUC-2, GC 500-1 (520/434), BD-1, UWR-1
BP97-33	19.09	07:19	72°12'43.2"	80°55'06.6"	14	CTD-1, OG-1
BP97-34	19:09	09:01	72°25'50.4"	80°24'25.8"	12	CTD-1, LVS-1, OG-3, UWR-1
BP97-35	19.09	10:19	72°30'31.2"	80°19'43.2"	14	CTD-1, PHN-1,LVS-2 MUC-1, UWR-1
BP97-36	19.09	12:51	72°45'39.6"	80°10'37.8"	17	CTD-1, OG-3
BP97-37	19.09	15:46	72°58'33.6"	80°04'09.6"	20	CTD-1, OG-1
BP97-38	19.09	17:23	73°12'51.0"	80°00'19.2"	31	CTD-1, PN-4, OG-2
BP97-39	20.09	00:56	73°32'09.6"	79°55'03.0"	40	CTD-1, LVS-1, LBC-1 MUC-1, GC 500-1 (100/ -)
BP97-40	20.09	05:09	73°40'51.0"	80°36'39.0"	37	CTD-1, LVS-3
BP97-41	20.09	07:00	73°41'53.4"	80°46'22.2"	39	CTD-1, LVS-2
BP97-42	20.09	09:11	73°53'57.6"	81°40'01.2"	32	CTD-1, PN-4, PHN-1, RS-3, LVS-1, OG-3, LBC-1, MUC-2, GC 500-1 (100/ -), BD-1, UWR-1
BP97-43	20.09	15:26	73°42'33.0"	82°48'48.0"	31	CTD-1, PN-4, PHN-1, RS-3, LVS-1, OG-3, LBC-1, MUC-2, GC 500-1 (>700/480), SGC-1, BD-1
BP97-44	21.09	04:05	74°00'00.0"	79°25'49.2"	30	CTD-1
BP97-45	21.09	07:46	73°59'55.8"	77°30'14.4"	24	CTD-1
BP97-46	21.09	08:55	73°59'57.6"	77°12'14.4"	27	CTD-1, PN-4, RS-3, LVS-2, OG-3, LBC-1, MUC-2, GC 500-1 (100/50), BD-1, UWR-1

Station	Date	Time (GMT)	Latitude °N	Longitude °E	Depth (m)	Activity
BP97-47	22.09	07:50	72°35'00.6"	73°44'54.6"	18	CTD-1, PN-2, RS-3, LVS-1, OG-3, MUC-3, UWR-1
BP97-48	22.09	12:44	72°57'40.8"	73°08'51.6"	29	CTD-1, PN-4, PHN-1, RS-3, LVS-1, OG-3, LBC-1, MUC-2, GC 500-1 (270/79), BD-1
BP97-49	23.09	02:17	73°12'34.2"	72°53'40.8"	29	CTD-1, PN-4, RS-3, LVS-1, OG-3, LBC-1, MUC-2, GC 500-1 (300/263), BD-1,
BP97-50	23.09	08:50	73°36'39.6"	72°57'04.8"	28	CTD-1, PN-4, RS-3,
						LVS-1, OG-3, LBC-1, MUC-2, GC 500-1 (250/129), SGC-1, BD-1, UWR- 1
BP97-51	23.09	15:05	73°53'17.4"	73°10'19.8"	30	CTD-1, OG- 1
BP97-52	24.09	01:55	74°00'01.2"	72°39'43.2"	30	CTD-1, PN-4, RS-3, LVS-1,OG-3, LBC-1, MUC-2, GC 300-1 (300/260) SGC-1, BD-1, UWR-1
BP97-53	24.09	11:10	73°37'35.4"	74°51'49.2"	21	CTD-1, OG-1
BP97-54	24.09	13:05	73°19'51.0"	75°20'36.6"	15	CTD-1, OG-1
BP97-55	24.09	14:48	73°13'27.9"	75°37'08.4"	14	CTD-1, PN-1, RS-2, LVS-1, OG-3, LBC-1, MUC-2, SGC-1, BD-1
BP97-56	25.09	01:47	72°53'23.4"	75°28'57.0"	14	CTD-1, PN-1, RS-2, LVS-1, OG-3, LBC-1, MUC-3, BD-1, GC 500-1 (600/478),
BP97-57	25.09	07:07	73°02'39.6"	75°35'15.6"	14	CTD-1, OG-1
BP97-58	25.09	11:18	73°39'01,2"	74°50'19.2"	23	CTD-1, PN-2, RS-3, OG-3, LBC-1, MUC-2 GC 500-1 (300/100), BD-1
BP97-59	25.09	16:23	73°49'23.4"	74°43'45.6"	18	CTD-1, RS-1, OG-1

9.2. Hydrochemical Data
(selected according to standardized water depths)
L.K. Shpigun

Station	Depth (m)	Temp. (° C)	Salinity (‰)	[O2] dis (ppm)	pH (NBS)	AlkT (meq./L)
BP97-01	0.5	5.412	12.682	5.9	7.880	1625
	7.4	5.363	13.032	5.9	7.911	1640
	9.9	1.599	25.720	6.2	7.794	2070
	17.1	-1.460	32.011	5.8	7.700	2200
	27.5	-1.513	32.219	5.1	7.624	2200
BP97-10	0.0	6.266	2.440	6.6	7.635	780
	10.0	5.388	3.291	6.8	7.633	800
	11.5	0.783	25.140	6.9	7.618	1050
	13.0	0.765	25.017	4.2	7.574	1770
BP97-12	0.0	6.081	3.133	6.6	7.634	800
	8.0	5.836	3.792	6.7	7.642	1060
	11.1	2.233	20.140	4.5	7.516	1720
BP97-17	0.0	5.410	6.975	6.1	7.674	1100
	5.1	4.176	14.030	6.0	7.686	1140
	9.0	-0.620	29.323	5.8	7.635	1690
	16.0	-0.688	29.789	5.1	7.560	1810
BP97-18	0.0	5.424	10.963	7.1	7.810	1300
	8.7	4.986	13.000	7.2	7.825	1370
	12.9	-0.223	29.095	5.3	7.640	1930
	22.3	-1.300	31.705	4.2	7.574	2200
BP97-21	0.0	5.656	15.316	6.8	7.875	1420
	9.8	3.726	14.126	7.1	7.860	1550
	15.0	-0.031	29.920	6.0	7.780	2060
	34.9	-1.390	32.595	5.2	7.660	2250
BP97-24	0.0	6.092	11.868	6.5	7.870	1380
	12.1	5.179	16.014	6.3	7.858	1540
	19.9	-0.310	30.322	5.4	7.729	1940
	32.0	-1.179	31.757	4.8	7.670	2280
BP97-27	0.0	6.577	4.196	6.4	7.702	1040
	8.0	6.104	7.991	6.2	7.696	1140
	13.9	2.417	23.093	6.5	7.607	1690
	18.1	-0.268	30.631	5.2	7.600	2140
BP97-30	0.0	7.280	3.971	7.3	7.672	990
	5.1	7.080	4.704	7.2	7.630	1060
	10.0	6.745	5.768	7.0	7.620	1100
	13.0	4.944	12.194	6.5	7.562	1280
BP97-32	0.0	7.798	1.211	6.4	7.625	700
	5.0	7.802	1.211	6.4	7.594	750
	8.0	7.794	1.268	6.1	7.580	1000

Station	Depth (m)	Temp. (°,C)	Salinity (%o)	[O2] dis (ppm)	pH (NBS)	AlkT (meq.L-1)
BP97-42	0.0	5.857	14.877	7.1	7.837	1430
	11.0	5.667	15.300	7.1	7.842	1520
	20.1	-0.790	30.816	5.7	7.655	2070
	27.9	-1.177	31.921	5.0	7.612	2200
BP97-43	0.0	6.174	10.556	6.8	7.800	1360
	20.0	5.035	18.217	6.4	7.680	1550
	28.1	-1.113	32.133	4.7	7.600	2180
BP97-46	0.0	5.595	11.765	6.2	7.830	1470
	10.1	2.575	24.059	6.5	7.685	1580
	22.3	-1.270	31.574	4.4	7.610	2190
BP97-47	0.0	3.978	18.941	6.6	7.756	1700
	6.0	3.953	19.049	6.6	7.632	1880
	10.1	-0.331	29.357	5.4	7.587	2170
	16.0	-0.466	29.653	5.1	7.576	2150
BP97-48	0.0	4.790	13.464	6.8	7.825	1500
	7.0	5.122	16.459	6.7	7.810	1650
	10.9	-0.855	30.270	7.3	7.620	2100
	23.9	-1.373	31.415	4.7	7.590	2310
BP97-49	0.0	4.755	16.387	7.0	7.830	1700
	11.1	4.800	22.603	6.7	7.783	2100
	15.9	-0.437	30.514	7.3	7.664	2270
	27.0	-1.347	31.615	5.2	7.640	2350
BP97-50	0.0	4.996	20.767	6.6	7.850	1840
	9.4	4.992	20.781	6.6	7.796	2010
	14.2	0.183	31.550	5.6	7.648	2320
	26.0	-0.067	31.808	5.0	7.635	2300
BP97-52	0.0	4.385	18.243	7.1	7.841	1800
	7.0	4.181	22.123	6.8	7.669	2180
	10.0	-0.962	31.011	5.3	7.630	2300
	27.0	-1.348	31.795	5.1	7.642	2310
BP97-55	0.0	5.162	9.550	7.3	7.714	1380
	6.0	5.163	9.547	7.2	7.707	1410
	11.0	5.196	9.716	7.2	7.684	1450
BP97-56	0.4	4.996	9.220	7.4	7.700	1330
	6.1	5.002	9.268	7.2	7.680	1400
	12.1	3.492	15.465	5.6	7.513	1820
BP97-58	0.4	4.775	9.392	7.0	7.741	170
	9.1	4.783	17.936	6.7	7.700	1950
	15.1	-0.114	28.965	7.1	7.568	2180
	20.2	-1.028	30.839	4.4	7.561	2260

9.3 Geological Core Descriptions

Legend:

Lithology

clay

silty clay

sandy silty clay

Structure

bioturbation

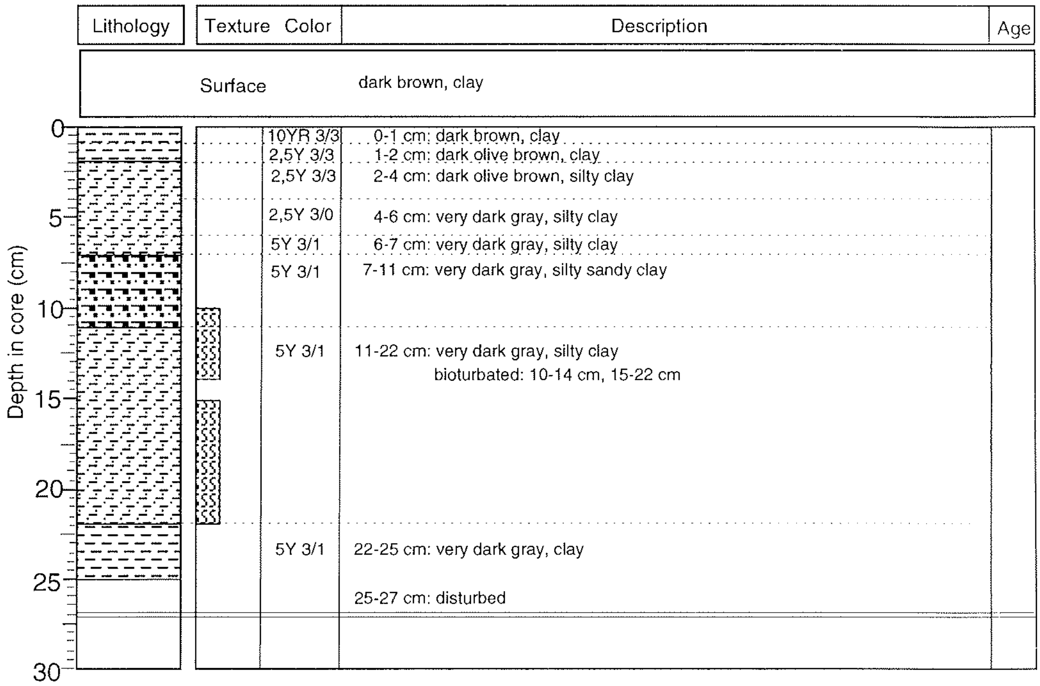
sharp boundary

gradational boundary

transition zone

BP97-10 (MUC) Ob Bay **Boris Petrov `97**

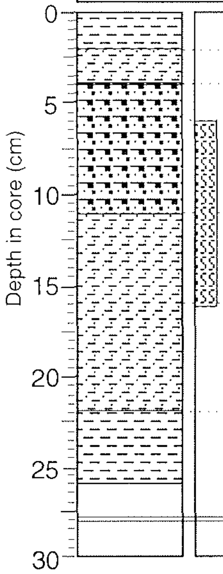
Recovery: 0.27 m 72°30` N 74°0.4` E Water depth: 15 m



BP97-12 (MUC) | Ob Bay | **Boris Petrov `97**

Recovery: 0.28 m | 72°10` N 74°17` E | Water depth: 13 m

Lithology	Texture Color	Description	Age
	Surface	dark olive brown, clay, 2 bivalves (alive), soft	



Color	Description
2,5Y 3/3	0-1 cm: dark olive brown, clay, 2 bivalves (alive), soft 1-2 cm: dark olive brown, clay, shell fragments, soft
2,5Y 3/3	2-4 cm: dark olive brown, silty clay, shell fragments, soft
2,5Y 3/3	4-6 cm: dark olive brown, sandy silty clay, soft
5Y 3/2	6-7 cm: gradational colour change to dark olive gray 7-11 cm: dark olive gray, sandy silty clay, bioturbated, plastic
5Y 3/2	11-16 cm: dark olive gray, silty clay, bioturbated, plastic Polychaete tubes: 11-12 cm, 13-16 cm
2,5Y N2	16-22 cm: black, silty clay, stiff
5Y 3/1	22-26 cm: very dark gray, clay, stiff 26-28 cm: disturbed

BP97-17 (MUC) Ob Bay **Boris Petrov `97**

Recovery: 0.30 m 72°41` N 73°50` E Water depth: 19 m

Lithology	Texture	Color	Description	Age
Surface			dark olive brown, silty clay, polychaete tube, strongly bioturbated, shell fragments	
		7.5YR 3/3	0-1 cm: dark olive brown, silty clay, polychaete tube, strongly bioturbated, shell fragments	
		2.5YR 3/3	1-3 cm: dark olive brown, silty clay, strongly bioturbated, soft	
		2.5YR 3/0	3-5 cm: very dark gray, silty clay, strongly bioturbated, soft	
		5Y 2/3	5-6 cm: dark olive gray, silty clay, plastic	
		5Y 3/1	6-11 cm: very dark gray, silty clay, plastic	
		5Y 2.5/1	11-13 cm: black, silty clay, plastic	
		5Y 2.5/1	13-17 cm: black, clay, plastic	
		5Y 2.5/1	17-18 cm: black, silty clay, bioturbated, plastic, shell fragments	
		5Y 3/1	18-19 cm: very dark gray, silty clay, bioturbated, plastic, polychaete tubes	
		5Y 2.5/1	19-20 cm: black, clay, bioturbated, plastic, polychaete tubes	
		5Y 2.5/1	20-22 cm: black, clay, bioturbated, plastic	
		5Y 2.5/1	22-24 cm: black, silty clay, bioturbated, plastic	
		5Y 3/1	24-26 cm: very dark gray, clay, bioturbated, plastic	
		5Y 2.5/1	26-27 cm: black, clay, bioturbated, plastic	
		5Y 2.5/1	27-28 cm: black, silty clay, bioturbated, plastic	
			28-30 cm: disturbed	

Depth in core (cm): 0, 5, 10, 15, 20, 25, 30

BP97-19 (MUC) 74° N Transect **Boris Petrov `97**

Recovery: 0.24 m 74°00` N 79°01`E Water depth: 30 m

Lithology	Texture	Color	Description	Age
Surface			very dark grayish brown, clay	
		10YR 3/2	0-1 cm: very dark grayish brown, clay	
		2.5Y 4/2	1-3 cm: dark grayish brown, slightly silty clay	
		5Y 2/3	3-6 cm: dark olive gray, silty clay	
		5Y 2/3	6-8 cm: dark olive gray, slightly silty clay 8-14 cm: dark olive gray, slightly silty clay, black dots worm (alive): 9-10 cm shill: 11-12 cm shell, bivalve: 13-14 cm	
		5Y 2.5/2	14-23 cm: black, slightly silty clay, black dots shill and polychaete tubes: 22-23 cm	
			23-24 cm: disturbed	

Depth in core (cm): 0, 5, 10, 15, 20, 25

BP97-21 (MUC) | 74° N Transect | **Boris Petrov `97**

Recovery: 0.19 m | 74°00` N 81°00`E | Water depth: 41 m

Lithology	Texture	Color	Description	Age
Surface			dark brown, silty clay	
		10YR 3/3	0-1 cm: dark brown, silty clay	
		2.5 Y 3/3	1-2 cm: dark olive brown, silty clay, black dots	
		5Y 3/2	2-3 cm: dark olive gray, silty clay, black dots	
		2.5 Y 3/2	3-5 cm: very dark grayish brown, silty clay, black dots worm (alive): 4-5 cm	
		5Y 3/1	5-6 cm: very dark gray, silty clay, black dots 6-8 cm: very dark gray, silty clay, black dots, bioturbated polychaete tubes: 6-9 cm	
		5Y 3/2	8-12 cm: Dark olive gray, silty clay, black dots, bioturbated	
		5Y 3/1	12-19 cm: very dark gray, silty clay, black dots polychaete tubes: 12-13 cm bioturbated: 12-14 cm (wood) branch: 17-19 cm	

Depth in core (cm): 0, 5, 10, 15, 20

BP97-27 (MUC) | Yenisei Bay | **Boris Petrov `97**

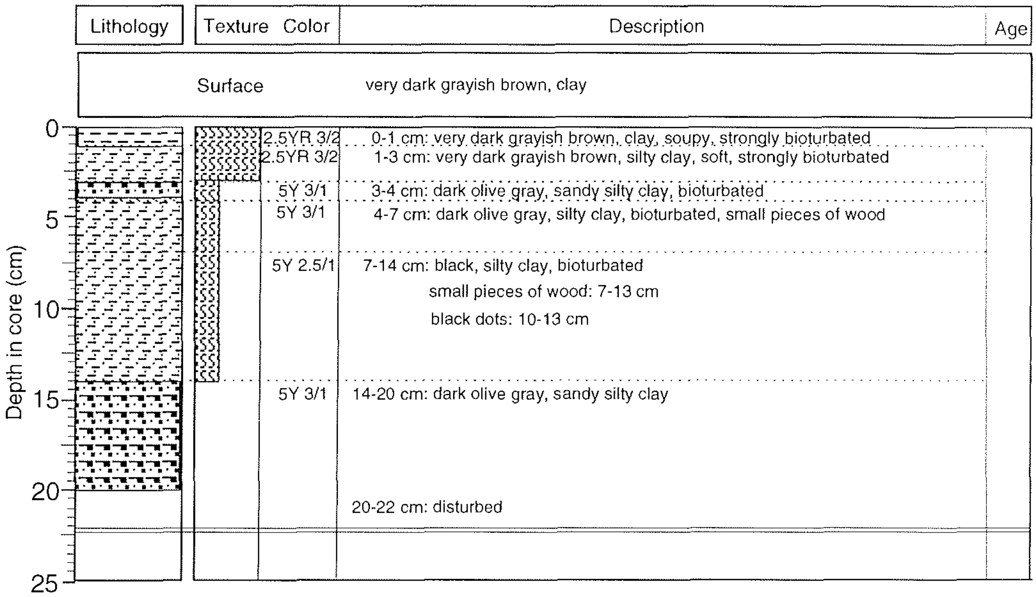
Recovery: 0.34 m | 72°53` N 80°05`E | Water depth: 14 m

Lithology	Texture	Color	Description	Age
Surface			dark brown, clay, bioturbated, soupy	
		10YR 3/3	0-3 cm: dark brown, clay, bioturbated, soupy	
		2.5Y 3/2	3-4 cm: very dark grayish brown, clay, bioturbated, soupy	
		5Y 4/2	4-5 cm: olive gray, clay, soupy 5-7 cm: olive gray, clay, bioturbated, soft 7-9 cm: olive gray, clay, soft	
		5Y 4/2	9-13 cm: olive gray, silty clay, bioturbated, soft	
		5Y 4/2	13-17 cm: olive gray, clay, bioturbated, soft 17-19 cm: olive gray, clay, bioturbated, plastic fibres: 16-17 cm, 20-25 cm:	
		5Y 4/2	19-20 cm: olive gray, silty clay, bioturbated, plastic 20-23 cm: olive gray, silty clay, bioturbated, plastic, black dots	
		5Y 4/2	23-24 cm: olive gray, clay, bioturbated, plastic, black dots	
		5Y 4/2	24-25 cm: olive gray, silty clay, bioturbated, plastic, black dots	
		5Y 3/2	25-28 cm: dark olive gray, silty clay, bioturbated, black dots, fibres	
			28-34 cm: disturbed	

Depth in core (cm): 0, 5, 10, 15, 20, 25, 30, 35

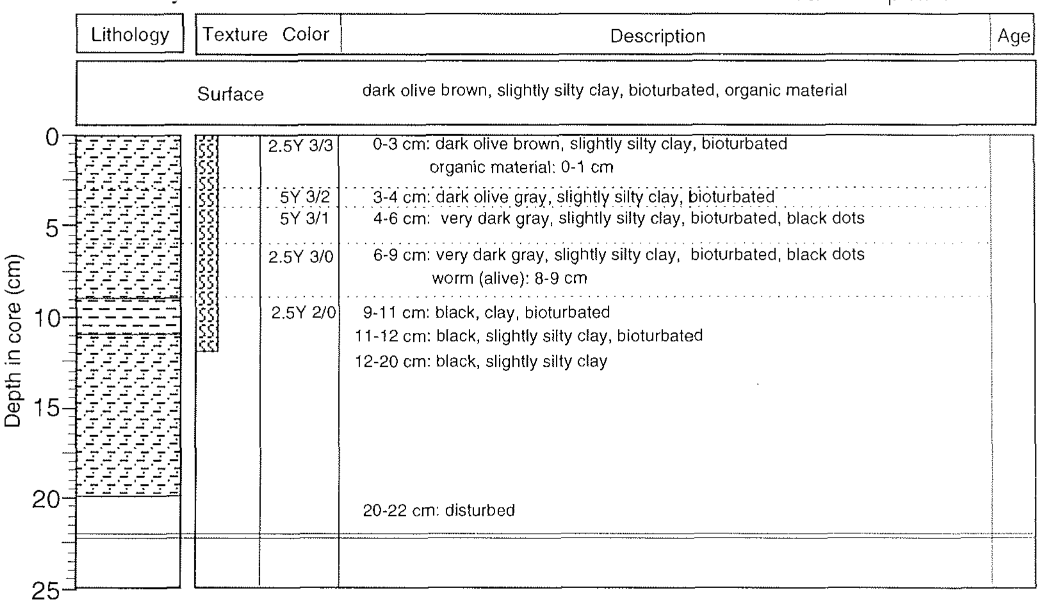
BP97-32 (MUC) Yenisei Bay **Boris Petrov `97**

Recovery: 0.22 m 72°05` N 81°29`E Water depth: 10 m



BP97-35 (MUC) Yenisei Bay **Boris Petrov `97**

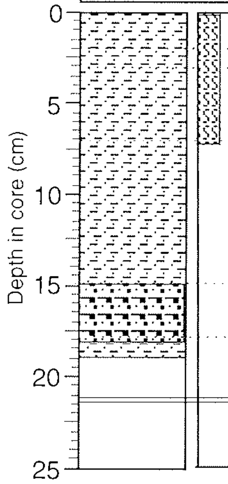
Recovery: 0.22 m 72°30` N 80°20`E Water depth: 14 m



BP97-39 (MUC) Yenisei Bay **Boris Petrov `97**

Recovery: 0.21 m 73°32` N 79°55`E Water depth: 40 m

Lithology	Texture	Color	Description	Age
Surface			dark yellowish brown, silty clay, bioturbated, black dots	

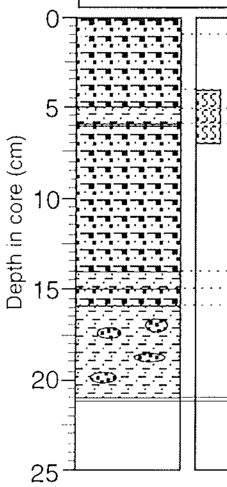


Color	Description
10YR 3/4	0-2 cm: dark yellowish brown, silty clay, bioturbated, black dots
2.5Y 3/3	2-3 cm: dark olive brown, silty clay, bioturbated, black dots
2.5Y 3/2	3-7 cm: very dark grayish brown, silty clay, bioturbated, black dots worm (alive), gastropod: 6-7 cm
2.5Y 3/1	7-15 cm: very dark gray, silty clay, black dots shill: 8-11 cm, 15-17 cm polychaete tubes: 11-15 cm
2.5Y 3/1	15-16 cm: very dark gray, clayey sand, black dots 16-18 cm: very dark gray, sandy clay, black dots
2.5Y 3/1	18-19 cm: very dark gray, silty clay, black dots 19-21 cm: disturbed

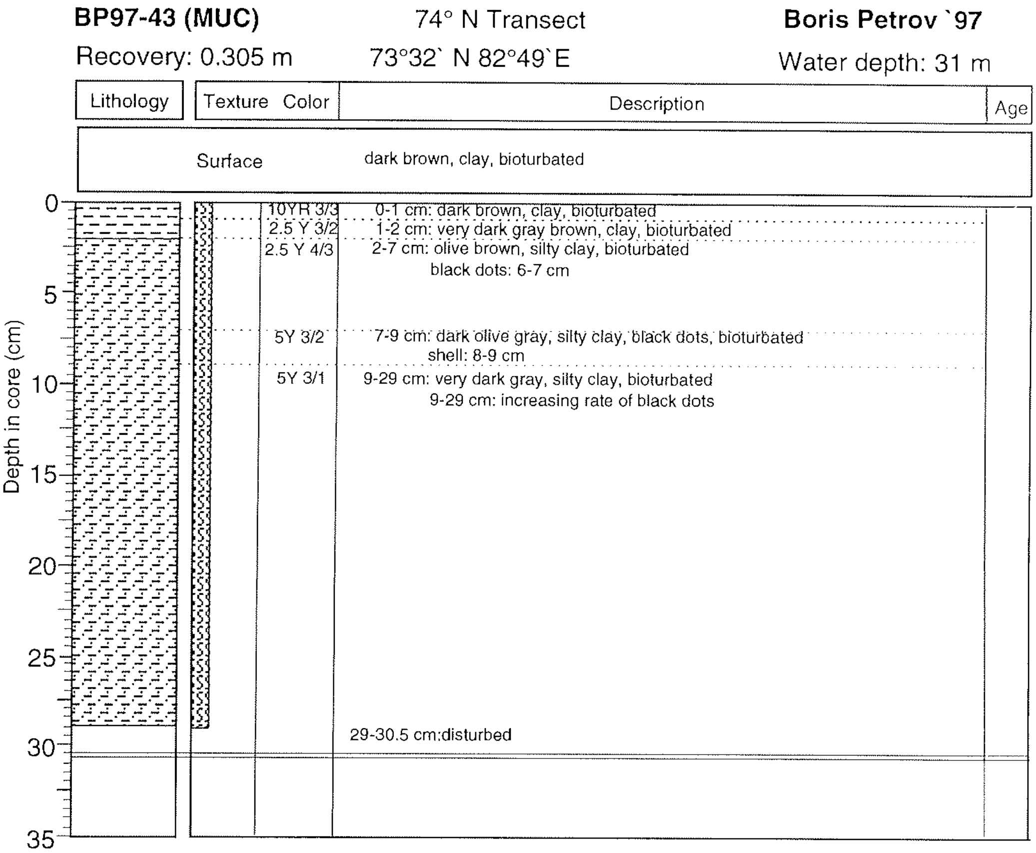
BP97-42 (MUC) 74° N Transect **Boris Petrov `97**

Recovery: 0.21 m 73°54` N 81°40`E Water depth: 32 m

Lithology	Texture	Color	Description	Age
Surface			dark olive brown, sandy silty clay, black dots	

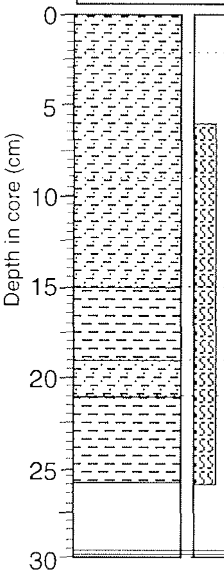


Color	Description
2.5Y 3/3	0-1 cm: dark olive brown, sandy silty clay, black dots
5Y 3/2	1-4 cm: dark olive gray, sandy-silty clay, black dots shell: 1-2 cm polychaete tubes: 3-4 cm
5Y 3/1	4-5 cm: very dark gray, sandy silty clay, bioturbated, black dots, worm (alive)
5Y 3/1	5-6 cm: very dark gray, silty clay, bioturbated, black dots
5Y 3/1	6-7 cm: very dark gray, sandy silty clay, bioturbated, black dots 7-14 cm: very dark gray, sandy silty clay, black dots pieces of plants (roots): 7-8 cm shill: 8-14 cm peat: 13-14 cm
5Y 2.5/1	14-15 cm: black, silty clay, black dots, shill, peat
5Y 2.5/1	15-16 cm: black, sandy silty clay, black dots, shill
5Y 2.5/1	16-21 cm: black, silty clay with sandy lenses, black dots, shill


BP97-43 (MUC)
74° N Transect
Boris Petrov `97
Recovery: 0.305 m
73°32` N 82°49`E
Water depth: 31 m
Lithology
Texture Color
Description
Age
Surface
dark brown, clay, bioturbated
10YR 3/3
0-1 cm: dark brown, clay, bioturbated
2.5 Y 3/2
1-2 cm: very dark gray brown, clay, bioturbated
2.5 Y 4/3
2-7 cm: olive brown, silty clay, bioturbated
black dots: 6-7 cm
5Y 3/2
7-9 cm: dark olive gray, silty clay, black dots, bioturbated
shell: 8-9 cm
5Y 3/1
9-29 cm: very dark gray, silty clay, bioturbated
9-29 cm: increasing rate of black dots
29-30.5 cm:disturbed
Depth in core (cm)
0
5
10
15
20
25
30
35

BP97-46 (MUC) | 74° N Transect | **Boris Petrov `97**

Recovery: 0.30 m | 74°00` N 77°12`E | Water depth: 27 m

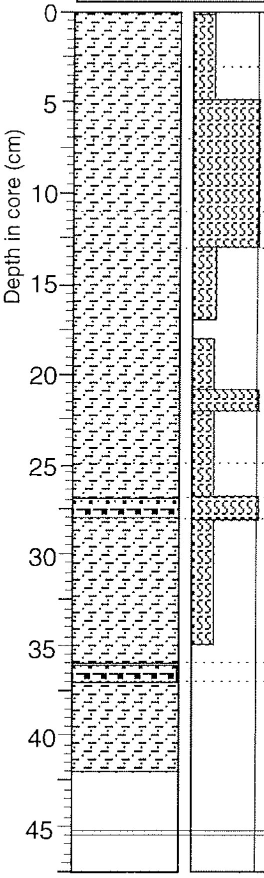


Lithology	Texture	Color	Description	Age
	Surface		dark oliv brown, silty clay	
		2.5Y 3/3	0-2 cm: dark olive brown, silty clay	
		5 Y 3/2	2-6 cm: dark olive gray, silty clay	
			6-9 cm: dark olive gray, silty clay, bioturbated, black dots	
		5 Y 3/1	9-15 cm: very dark gray, silty clay, bioturbated, big black dots	
		5 Y 3/1	15-19 cm: very dark gray, clay, bioturbated, big black dots	
		5 Y 3/1	19-21 cm: very dark gray, silty clay, bioturbated, big black dots	
		5 Y 3/1	21-26 cm: very dark gray, clay, bioturbated, big black dots	
			26-29.5 cm: disturbed	

BP97-47 (MUC) Ob Bay **Boris Petrov `97**

Recovery: 0.455 m 72°35` N 73°45`E Water depth: 18 m

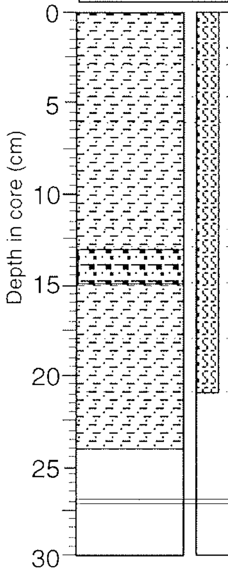
Lithology	Texture	Color	Description	Age
	Surface		dark olive brown, silty clay, bioturbated, soft	



Color	Description
2.5Y 3/3	0-3 cm: dark olive brown, silty clay, bioturbated, soft bivalve (alive, closed): 2-3 cm
2.5Y 3/2	3-7 cm: very dark grayish brown, silty clay, bioturbated, from 5-7 cm: strong bioturbated bivalve (alive, closed): 4-5 cm
5Y 3/2	7-11 cm: dark olive gray, silty clay, strong bioturbated
5Y 3/1	11-13 cm: very dark gray, silty clay, strong bioturbated worm (alive): 12-13 cm
5Y 3/2	13-25 cm: dark olive gray, silty clay, from 13-17, 18-21and 22-25 cm: bioturbated, from 21-22 cm: strong bioturbated worm (alive): 18-19 cm lense of clay, shill, polychaete: 21-22 cm
5Y 3/1	25-27 cm: very dark gray, silty clay, bioturbated
5Y 3/1	27-28 cm: very dark gray, silty sandy clay, strong bioturbated
5Y 3/1	28-35 cm: very dark gray, silty clay, bioturbated bivalve fragments: 30-31 cm peat:28-29 cm 35-36 cm: very dark gray, silty clay
5Y 3/1	36-37 cm: very dark gray, silty sandy clay, bivalve fragments, peat
5Y 3/1	37-42 cm: very dark gray, silty clay peat: 41-42 cm
	42-45.5 cm:disturbed

BP97-48 (MUC) Ob Bay **Boris Petrov `97**

Recovery: 0.27 m 72°58` N 73°09`E Water depth: 29 m



Lithology	Texture	Color	Description	Age
Surface			dark yellowish brown, silty clay, soft, bioturbated	
		10YR 3/4	0-2 cm: dark yellowish brown, silty clay, soft, bioturbated, polychaete	
		2.5Y 3/2	2-3 cm: very dark grayish brown, silty clay, bioturbated	
		5Y 3/2	3-5 cm: dark olive gray, silty clay, bioturbated	
		5Y 3/1	5-6 cm: very dark gray, silty clay, bioturbated	
		5Y 2.5/1	6-9 cm: black, silty clay, bioturbated, black dots 9-12 cm: black, silty clay, bioturbated bivalve: 11-12 cm	
		5Y 3/2	12-13 cm: dark olive gray, silty clay, bioturbated, black dots, bivalve	
		5Y 3/1	13-15 cm: very dark gray, sandy silty clay, bioturbated, shell fragments	
		5Y 2.5/1	15-18 cm: black, silty clay, bioturbated, black dots	
		2.5Y 3/0	18-21 cm: very dark gray, silty clay, bioturbated, black dots	
		2.5Y 2/0	21-24 cm: black, silty clay, shill	
			24-27 cm: disturbed	

BP97-49 (MUC) Ob Bay **Boris Petrov `97**

Recovery: 0.35 m 73°12` N 72°54`E Water depth: 29 m

Color	Description	Age
Surface	brown, clay	
10YR 4/3	0-2 cm: brown, clay	
5G 4/1	2-4 cm: dark greenish gray, silty clay, bioturbated	
5G 4/1	4-9 cm: dark greenish gray, clay, bioturbated worm (alive): 3-5 cm, 4-6 cm black dots: 5-13 cm shill: 8-9 cm	
5G 4/1	9-13 cm: dark greenish gray, silty clay, bioturbated	
5GY 4/1	13-15 cm: dark greenish gray, silty clay, bioturbated, many black dots	
5Y 3/1	15-20 cm: very dark gray, silty clay, slightly bioturbated, many black dots brown mud lenses: 18-20 cm	
5Y 3/1	20-23 cm: very dark gray, clay, slightly bioturbated, many black dots	
5Y 2.5/1	23-31 cm: black, clay, slightly bioturbated, many black dots	
5Y 2.5/1	31-33 cm: black, silty clay, slightly bioturbated, many black dots 33-35 cm: disturbed	

Depth in core (cm): 0, 5, 10, 15, 20, 25, 30, 35

BP97-50 (MUC) Ob Bay **Boris Petrov `97**

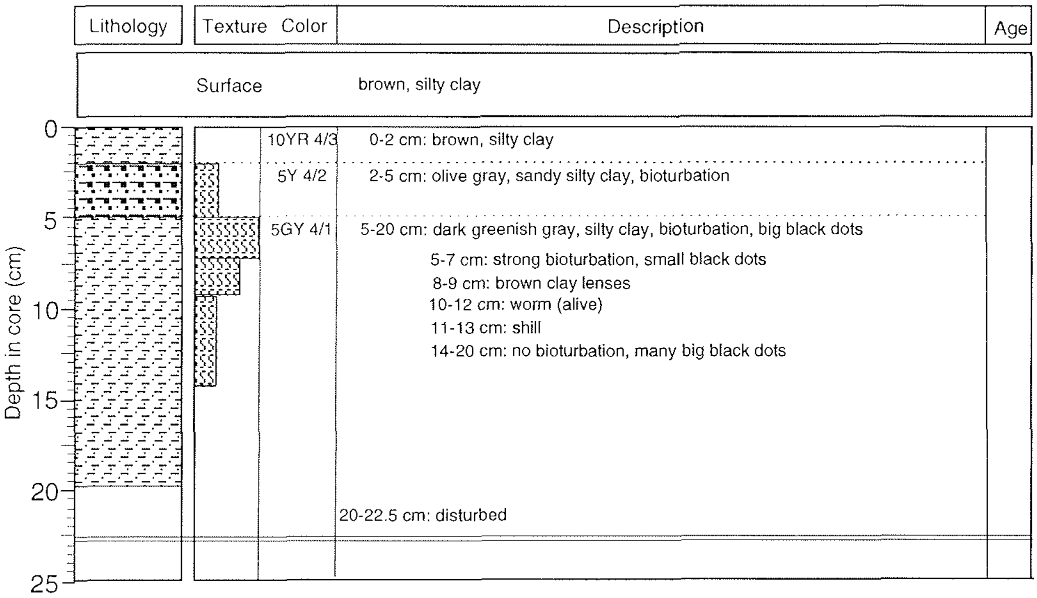
Recovery: 0.22 m 73°37` N 72°57`E Water depth: 28 m

Color	Description	Age
Surface	Dark olive brown, silty clay, bioturbated	
2.5Y 3/3	0-1 cm: dark olive brown, silty clay, bioturbated	
2.5Y 3/2	1-2 cm: very dark grayish brown, silty clay, bioturbated	
5Y 4/2	2-3 cm: olive gray, silty clay, bioturbated	
5Y 3/2	3-4 cm: dark olive gray, sandy silty clay, bioturbated, worm (alive)	
5Y 3/1	4-6 cm: very dark gray, silty clay, bioturbated, from 5-6 cm: black dots	
2.5Y 2/0	6-10 cm: black, silty clay, bioturbated, olive gray dots shill: 6-7cm, 8-10 cm	
5Y 3/1	10-11 cm: very dark gray, silty clay, bioturbated, black dots	
2.5Y 2/0	11-14 cm: black, silty clay, bioturbated, olive gray dots gastropods: 11-12 cm shill: 12-14 cm	
5Y 3/1	14-16 cm: very dark gray, sandy silty clay, black dots	
5Y 3/1	16-19 cm: very dark gray, silty clay, black dots bioturbated: 17-18 cm bivalves (fragment): 15-16 cm	
5Y 3/1	19-20 cm: very dark gray, sandy silty clay, black dots shill: 15-20 cm	

Depth in core (cm): 0, 5, 10, 15, 20

BP97-52 (MUC) 74° N Transect **Boris Petrov `97**

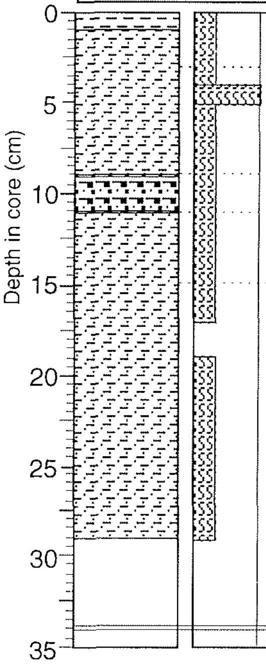
Recovery: 0.23 m 74°00` N 72°40`E Water depth: 30 m



BP97-55 (MUC) Gydanski Bay **Boris Petrov `97**

Recovery: 0.34 m 73°13` N 75°37`E Water depth: 14 m

Lithology	Texture	Color	Description	Age
Surface			very dark grayish brown, clay, bioturbated	
		10YR 4/2	0-3 cm: very dark grayish brown, clay, bioturbated bivalve (alive): 1-3 cm	
		5Y 4/2	3-9 cm: olive gray, silty clay, bioturbated, from 4-5 cm: strong bioturbated polychaete tubes: 3-4 cm, 5-7 cm worm (alive): 8-9 cm black dots: 7-9 cm	
		5Y 3/2	9-11 cm: dark olive gray, sandy silty clay, bioturbated, black dots	
		5Y 3/1	11-15 cm: very dark gray, silty clay, bioturbated, black dots polychaete tube: 12-13 cm	
		5Y 2.5/1	15-29 cm: black, silty clay, from 15-17 and 19-28 cm: bioturbated black dots: 15-16 cm, 18-28 cm shill: 15-16 cm polychaete tube: 28-29 cm	
			29-34 cm: disturbed	



BP97-56 (MUC) Gydanski Bay **Boris Petrov `97**

Recovery: 0.25 m 72°53` N 75°29`E Water depth: 14 m

Lithology	Texture	Color	Description	Age
Surface			dark olive brown, silty clay, bioturbated, amphipode	
		2.5Y 3/3	0-1 cm: dark olive brown, silty clay, bioturbated, amphipode	
		5Y 3/2	1-2 cm: dark olive gray, sandy silty clay, bioturbated	
		2.5Y 3/2	2-3 cm: very dark grayish brown, silty clay, bioturbated, mollusces	
		5Y 3/2	3-5 cm: dark olive gray, silty clay, bioturbated, polychaete worm (alive): 5-6 cm	
		5Y 2.5/2	6-8 cm: black, silty clay, strong bioturbated	
		5Y 2.5/1	8-11 cm: black, silty clay, strong bioturbated, clay lenses polychaete, worm (alive): 10-11 cm	
		5Y 3/2	11-12 cm: dark olive gray, sandy silty clay, strong bioturbated, worm (alive)	
		5Y 3/2	12-13 cm: dark olive gray, silty clay, strong bioturbated, polychaete tube	
		5Y 2.5/1	13-15 cm: black, silty clay, bioturbated, polychaete: 14-15 cm	
		5Y 3/1	15-18 cm: very dark gray, silty clay, bioturbated, black dots, polychaete: 15-16 cm	
		5Y 2.5/1	18-19 cm: black, silty clay	
		5Y 3/1	19-23 cm: very dark gray, silty clay, black dots bivalve (fragment): 19-20 cm polychaete tube: 21-23 cm	
			23-25 cm: disturbed	

Depth in core (cm): 0, 5, 10, 15, 20, 25

BP97-58 (MUC) Gydanski Bay **Boris Petrov `97**

Recovery: 0.25 m 73°39` N 74°50`E Water depth: 23 m

Lithology	Texture	Color	Description	Age
Surface			dark grayish brown, clay, strong bioturbation	
		10YR 3/2	0-1 cm: dark grayish brown, clay, strong bioturbation worm (alive): 0-3 cm	
		10YR 3/2	1-2 cm: dark grayish brown, silty clay, strong bioturbation	
		2.5Y 4/3	2-5 cm: olive brown, silty sandy clay, strong bioturbation shill, polychaete tubes: 2-3 cm, 3-5 cm bivalve, 2 valves closed: 3-4 cm	
		2.5Y 4/3	5-6 cm: olive brown, silty sandy clay, bioturbated, black dots	
		5Y 4/1	6-9 cm: dark gray, silty sandy clay, bioturbated, black dots shill: 5-7 cm 9-16 cm: dark gray, silty sandy clay, black dots shill: 11-12 cm, 13-15 cm	
		5Y 2.5/1	16-18 cm: black, silty sandy clay, black dots	
		5Y 4/1	18-21 cm: dark gray, silty sandy clay, black dots	
			21-25 cm: disturbed	

Depth in core (cm): 0, 5, 10, 15, 20, 25

Geological Sampling of Okean Grabs

Station	Kodina	Krasnyk	Lukashin	Miroshnikov	Stepanets
BP97-08		x		x	x
BP97-09	x	x	x	x	x
BP97-15	x	x			x
BP97-17	x	x	x	x	x
BP97-18		x	x	x	x
BP97-19		x			x
BP97-21		x	x	x	x
BP97-23				x	
BP97-24		x	x		x
BP97-25		x		x	x
BP97-27			x	x	
BP97-28		x			x
BP97-29	x			x	
BP97-30		x			
BP97-31	x	x		x	x
BP97-32		x			x
BP97-33		x			x
BP97-34	x	x			x
BP97-36	x	x	x		x
BP97-37	x	x			x
BP97-38					
BP97-42		x		x	x
BP97-43		x		x	x
BP97-46		x	x		x
BP97-47	x	x	x		x
BP97-48				x	
BP97-49		x		x	x
BP97-50		x		x	x
BP97-51		x		x	x
BP97-52		x		x	x
BP97-53	x	x	x	x	x
BP97-54	x	x			x
BP97-55				x	
BP97-56				x	
BP97-57	x	x		x	x
BP97-58		x		x	x
BP97-59	x	x			x

Geological Sampling of Box Cores

station	Damm	Finkenberger	Finkenberger	Krasnyuk	Kodina	Lukashin	Miroshnikov	Neumann	Samarkin	Siebold	Stepanets	Archive
	PW	0-2 cm	0-0.5 cm	P	P	P	P	S	P	S	P	P
BP97-01	x			x	x		x		x		x	x
BP97-10	x				x	x	x		x		x	x
BP97-12	x				x	x	x		x		x	x
BP97-18	x				x				x			x
BP97-19												x
BP97-21	x	x			x			x	x	x		x
BP97-24					x							x
BP97-27	x				x			x	x	x	x	x
BP97-30		x			x	x	x		x		x	x
BP97-32	x	x	x		x	x	x	x	x	x		x
BP97-39	x				x	x			x			x
BP97-42	x	x			x	x		x	x	x		x
BP97-43					x	x		x	x	x		x
BP97-46					x			x		x		x
BP97-48					x	x		x		x	x	x
BP97-49					x	x		x		x		x
BP97-50					x	x		x		x		x
BP97-52					x	x		x		x		x
BP97-55	x				x	x		x	x	x	x	x
BP97-56	x				x	x			x		x	x
BP97-58					x	x		x		x		x

PW: Pore Water
S: Surface Sample
P: Profile

Geological Sampling of Multicorers

Station	Boucsein	Finkenberger	Korsun	Kodina	Krasnyk	Matthiessen	Miroshnikov	Müller	Neumann	Petrunin	Polyakova	Samarkin	Schoster	Shpigun	Siebold	Archive
	S	S	S	S,P	S,P	S	S,P	S	S,P	BW	S	S,P	S	BW	S,P	S,P
BP97-01		x	x		x				x	x		x		x	x	
BP97-10	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x
BP97-12	x	x	x	x	x	x			x	x	x	x		x	x	x
BP97-17	x		x	x		x		x	x	x	x		x	x	x	x
BP97-19	x		x	x		x		x	x		x		x	x	x	x
BP97-21	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x
BP97-24		x	x	x	x				x	x				x	x	
BP97-27	x	x	x	x	x	x		x	x	x	x	x	x	x	x	
BP97-30		x	x	x	x		x		x	x		x		x	x	x
BP97-32	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
BP97-35	x					x		x			x		x	x		x
BP97-39	x			x		x		x			x	x	x	x		x
BP97-42	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x
BP97-43	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x
BP97-46	x	x	x	x	x	x		x	x	x	x		x	x	x	x
BP97-47	x	x	x	x	x	x		x	x	x	x		x	x	x	x
BP97-48	x	x	x	x	x	x		x	x	x	x		x	x	x	x
BP97-49	x	x	x	x		x		x	x	x	x		x	x	x	x
BP97-50	x	x	x	x		x		x	x	x	x		x	x	x	x
BP97-52	x	x	x	x		x		x	x	x	x		x	x	x	x
BP97-55	x	x	x	x		x		x	x		x	x	x	x	x	x
BP97-56	x	x	x	x		x		x	x	x	x	x	x	x	x	x
BP97-58	x	x	x	x		x		x	x	x	x		x	x	x	x

BW: Bottom Water
S: Surface Sediment
P: Sediment Profile

9.4 Participants

Country and Institutions		No. of Participants
Germany		
AWI	Alfred Wegener Institute for Polar and Marine Research Columbusstrasse 27568 Bremerhaven	10
GEOMAR	Research Center for Marine Geosciences University of Kiel Wischhofstr. 1-3 24148 Kiel	1
IFBM	Institute for Biogeochemistry and Marine Chemistry University of Hamburg Grabenstr. 27 20357 Hamburg	3
Russia		
AARI	The State Research Center - Arctic and Antarctic Research Institute 38 Bering Street St. Petersburg, 199397	2
GEOKHI	Vernadsky Institute of Geochemistry and Analytical Chemistry Russian Academy of Sciences 19 Kosygin Street Moscow, 117975	12
IGEM	Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry Russian Academy of Sciences Staromonetnyi per, 35 Moscow, 109017	1
IGIC	Kuznakov Institute of General and Inorganic Chemistry Russian Academy of Sciences 31 Leninsky Prospect Moscow, 117907	1
IORAS	Shirshov Institute of Oceanology Russian Academy of Sciences 23, Krasikova Street Moscow, 117218	2

Country and Institutions		No. of Participants
ISSP	Institute of Soil Science and Photosynthesis Russian Academy of Sciences Pushchino, 142292	1
MMBI	Murmansk Marine Biological Institute Russian Academy of Sciences 17, Vladimirskaya Street Murmansk, 183019	1
VNIIOkeanologia	All-Russian Research Institute for Geology and Mineral Resources 1, Maklina Prospect St. Petersburg, 190121	2

Research Participants

Name		Discipline	Institution
Stepanets	Oleg	Chief of Expedition	GEOKHI
Matthiessen	Jens	Co-chief Scientist, Geology	AWI
Borisov	Alexandr	Radio-Geochemistry	GEOKHI
Boucsein	Bettina	Geology	AWI
Braun	Barbara	Geology	AWI
Churun	Vladimir	Oceanography	AARI
Deubel	Hendrik	Biology	AWI
Dyadyk	Alexandr	Chemistry	GEOKHI
Finkenberger	Bettina	Geology	GEOMAR
Halsband	Claudia	Biology	AWI
Henne	Andreas	Marine Chemistry	IFBM
Ivanov	Boris	Oceanography	AARI
Khorshev	Victor	Engineer	GEOKHI
Kodina	Lyudmila	Organic Geochemistry	GEOKHI
Korsun	Sergey	Biology	MMBI
Krasnyuk	Alexander	Geochemistry	VNIIO
Lukashin	Vyacheslav	Geology	IORAS
Miroshnikov	Alexey	Geology	IGEM
Müller	Claudia	Geology	AWI
Neumann	Kirsten	Marine Chemistry	IFBM
Osadchiy	Nikoley	Engineer	GEOKHI
Petrunin	Leonid	Hydro-Geochemistry	VNIIO
Poltermann	Michael	Biology	AWI
Pribylova	Tatyana	Organic Geochemistry	GEOKHI
Prusakov	Boris	Computer Center Engineer	GEOKHI
Richter	Rainer	Marine Chemistry	AWI
Rusakov	Valeriy	Geology	IORAS
Samarkin	Vladimir	Geochemistry	ISSP
Schoster	Frank	Geochemistry	AWI
Shmelkov	Boris	Computer Center Engineer	GEOKHI
Shpigun	Liliya	Marine Chemistry	IGIC
Siebold	Martina	Organic Geochemistry	AWI
Solovyova	Galina	Radiochemistry	GEOKHI
Steffen	Sönke	Marine Chemistry	IFBM
Tokarev	Victor	Organic Geochemistry	GEOKHI
Vlasova	Lyudmila	Organic Geochemistry	GEOKHI

Ships Crew

Captain	Lysak	Viktor
Chief Mate	Stepura	Vladimir
2nd Mate	Vaulin	Alexandr
2nd Mate	Akinin	Leonid
Radio Officer	Krytin	Alexey
Physician	Puzanov	Alexandr
Scientific Engineer	Latko	Alexandr
Engineer	Poberezhny	Orkady
Chief Engineer	Bondarev	Vladimir
2nd Engineer	Vlasichev	Ruslan
3rd Engineer	Yatsenko	Sergey
4th Engineer	Osminin	Anatoliy
Electric Engineer	Drozdov	Fedor
Boatswain	Yankovskiy	Pyotr
Seaman	Saulin	Oleg
Seaman	Markovskiy	Vladimir
Seaman	Orlov	Sergey
Seaman	Petrov	Oleg
Seaman	Vitko	Ivan
Seaman	Domrachev	Aleksey
Seaman	Levkin	Vladimir
Repair Engineer	Golikov	Yuriy
Chief Motorman	Slepchenko	Vladimir
Motorman	Lyatovitskiy	Oleg
Motorman	Klimenko	Vyacheslav
Motorman	Zaytsev	Anatoliy
Motorman	Subbotin	Vladimir
Electroman	Drozdov	Ruslan
Stewardess	Dolmatova	Irina
Stewardess	Shorova	Natalya
Stewardess	Demyanovich	Galina
Steward	Yatsyshyn	Serhiy
Cook	Titova	Angelina
Cook	Kiselyov	Viktor
Cook	Klimenko	Oleg