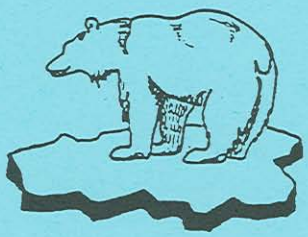
FS "Polarstern"
Expeditionsprogramm Nr. 38



German-Russian Expedition ARCTIC 95

- LADI -

RV "Polarstern"
ARK XI/1
Chief Scientist: E. Rachor

In cooperation with

TRANSDRIFT III
(RV "Kapitan Dranitsyn")

ALFRED-WEGENER-INSTITUT FÜR POLAR- UND MEERESFORSCHUNG
Bremerhaven, Juni 1995

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"Polarstern"-Expedition ARK XI/1:

Laptev Sea - Arctic Deep Basin Interrelations

1 Zusammenfassung

Der Fahrtabschnitt ARK XI/1 vom 7. Juli bis zum 20. September 1995 ist die zweite "Polarstern"-Expedition in sibirische Gewässer und zugleich ein weiterer Beitrag zur deutsch-russischen Kooperation in der Grundlagenforschung über das Geo-/Ökosystem Laptewmeer.

Das vorgesehene Programm hat sich aus dem sehr erfolgreichen Gemeinschaftsunternehmen von FS "Polarstern" und FS "Iwan Kirejev" im Sommer 1993 und den danach fortgeführten Forschungsarbeiten im Laptewmeer und den angrenzenden sibirischen Abflußgebieten (Taimyr-Halbinsel, Lena-Delta) entwickelt. Aber auch die guten Erfahrungen anderer "Polarstern"-Expeditionen ins Nordpolarmeer haben die Planungen für ARK XI/1 gefördert: "ARCTIC ´91", die die eurasischen Becken querte, und die "Arctic EPOS" von 1991, eine multidisziplinäre europäische Studie über das System des nördlichen Barentsmeeres.

Außer den Arbeiten im eigentlichen Laptewmeer soll die anstehende Expedition einen möglichst weit nach Norden reichenden Vorstoß in die packeisbedeckten Beckenbereiche des zentralen Arktischen Ozeans ermöglichen.

Das Hauptziel ist es, die Beziehungen der Schelfmeere (Laptew- und, sofern möglich, auch nordöstliches Karameer) mit den angrenzenden Tiefseebecken zu untersuchen; dabei steht der Kontinentalhang im Vordergrund, vor allem der Bereich, wo der Lomossov-Rücken auf den Hang trifft. Die Expedition soll auch einen ersten Beitrag zum europäischen 10-Jahresprogramm "Arctic Ocean Grand Challenge" ermöglichen (s. Johannessen et al., 1994).

Folgende Arbeitsrichtungen
werden zum wissenschaftlichen Programm beitragen:

Die physikalische Ozeanographie wird sich auf die verschiedenen Wassermassen, ihre Transformationen und die Zirkulation im Untersuchungsgebiet konzentrieren. Kombinationen verschiedener automatischer Meßgeräte sollen an drei Positionen am Kontinentalhang verankert werden, um die großräumige Zirkulation am Lomonossov-Rücken über ein Jahr zu studieren. Dabei sollen auch die Eisdrift und der Partikelfluß erfaßt werden (letzterer mit Sedimentfallen).
Chemiker werden natürliche und anthropogene Tracer der Wassermassen-Zirkulation, organische Substanzen und Pflanzen-Nährstoffe messend verfolgen.
Die Eisforscher planen die detaillierte physikalische Untersuchung von Eisstrukturen und zudem die Erfassung der Eisbewegungen, alles sowohl im mikro- als auch makroskaligen Bereich. Erkundungen und Messungen mit Hubschraubern sowie Satellitenbild-Auswertungen spielen dabei eine besondere Rolle.
Die Gruppe der Biologen interessiert sich vor allem für die Produktion, Umwandlung und Nutzung organischen Materials sowie für sein Schicksal am Meeresboden (Partikelflüsse, pelago-benthische Kopplungen). Sie wird sich dabei mit der großen Vielfalt der Ökosystem-Kompartimente befassen (Meereis-, Phyto- und Zooplankton-, mikrobielle und benthische Gemeinschaften).
Benthische Stofflüsse, besonders diejenigen, die mit dem Abbau organisch gebundenen Kohlenstoffs zusammenhängen, werden durch biogeochemische Messungen bestimmt; zusammen mit den Biologen soll eine Bilanzierung der Flüsse versucht werden.
Von den Geologen werden Boden-Morphologie sowie heutige und frühere Sedimentationsverhältnisse untersucht (als Anzeiger von Paläo-Umwelt- und Paläo-Klima-Verhältnissen). Darüber hinaus interessiert das Schicksal organischen Material aus verschiedenen Quellen (Land, Schelfmeer, ozeanischen Bereichen). Aerosole als atmosphärische Eintragskomponente landbürtiger Substanzen werden zusätzlich untersucht, ebenso wie die Sedimentfracht der Meereises, wovon ein großer Teil über die Transpolardrift zur Grönlandsee gelangt.

Andere deutsch-russische Aktivitäten im Laptewmeer-Bereich sind Expeditionen zur Taimyr-Halbinsel und zu den Deltas von Lena und Jana sowie die Herbst-Expedition mit dem Eisbrecher "Kapitan Dranitsyn".

Zur Durchführung ihres kooperativen multidisziplinären Programms wird "Polarstern" Bremerhaven am 7. Juli verlassen and nach Murmansk dampfen (unterwegs eine Arbeitsstation auf der Breite von Tromsø). In Murmansk werden am 13. Juli die russischen Fahrtteilnehmer mit ihren Arbeitsgeräten an Bord kommen; eine Gruppe von Gästen aus der Wissenschaftsverwaltung wird das Schiff verlassen.

Nach Murmansk wird "Polarstern" direkten Kurs zum östlichen Karameer nehmen und die Wilkitzki-Straße so früh wie möglich zu passieren versuchen (etwa 20. Juli). Im nördlichen Laptewmeer und der angrenzenden Tiefsee sind 5 Süd-Nord-Transekte vorgesehen sowie nach Möglichkeit einer quer dazu über den Lomonossov-Rücken (A - E, F in Abb. 2). Dabei haben die östlichen S-N-Transekte und der westlichste Vorrang, da sie die sich geographisch am stärksten unterscheidenden Meeresgebiete abdecken (Transekt A im Übergang zum Ostsibirischen Meer; Transekt E im Bereich der westlichen Eingänge zum Laptewmeer). Es wird von den Eisverhältnissen abhängen, ob auch am zusätzlich vorgesehenen Transekt im Nordosten des Karameeres (G) gearbeitet werden kann. Der Versuch dazu wird entweder zu Beginn oder am Ende der Arbeitsperiode in den sibirischen Gewässern unternommen.

Etwa am 12./13. September muß "Polarstern" das Arbeitsgebiet verlassen und zurück nach Murmansk dampfen. Dort gehen die russischen Partner von Bord; einige Arbeitsgeräte werden zum russischen Eisbrecher "Kapitan Dranitsyn" gegeben. Dieser wird bald danach zur dritten deutsch-russischen TRANSDRIFT-Expedition aufbrechen, um Forschungen über das Laptewmeer-System in der Haupt-Eisbildungsphase im Herbst durchzuführen.

Von Murmansk wird "Polarstern" nach Tromsø fahren (Ankunft am 20. September), um dort das wissenschaftliche Personal auszutauschen. Anschließend geht es zum zweiten Fahrtabschnitt von ARK XI in die herbstliche nördliche Grönlandsee.

Die generelle Fahrtroute ist in Abb. 1 dargestellt.

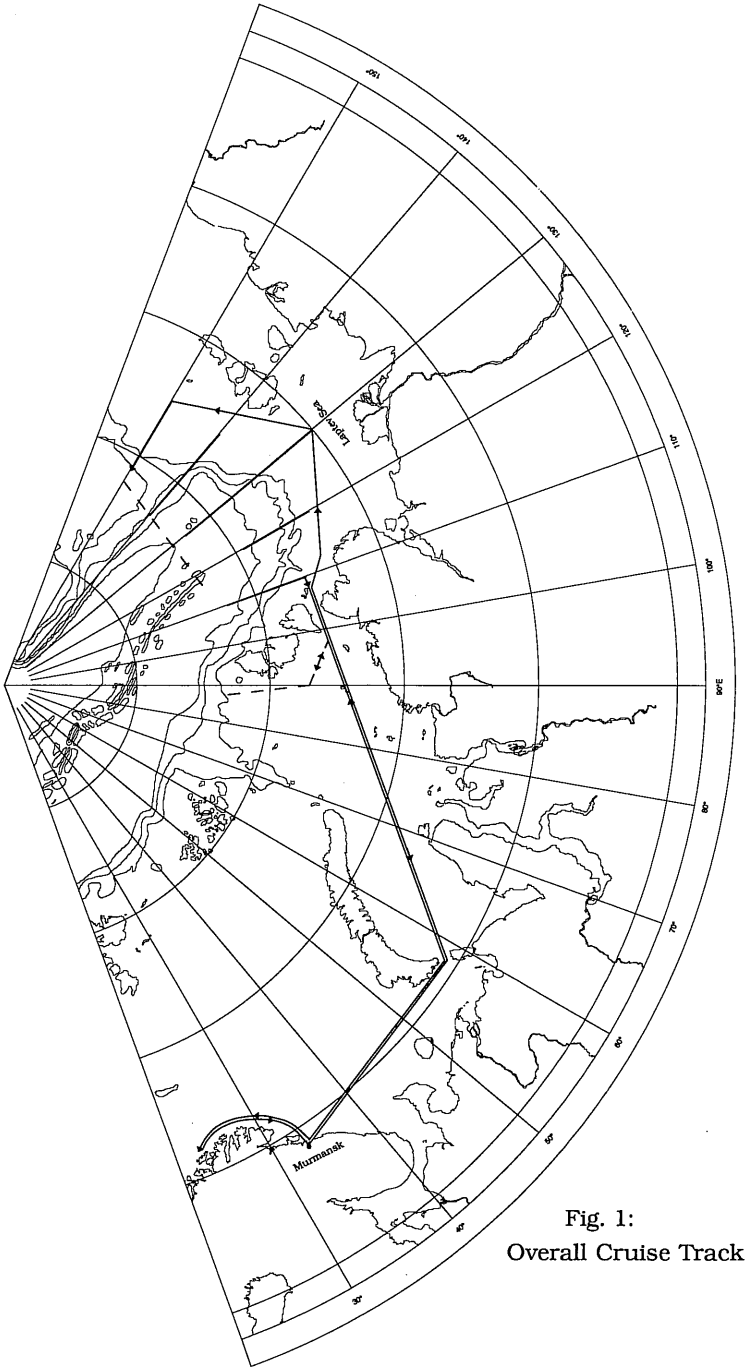

Fig. 1:
Overall Cruise Track

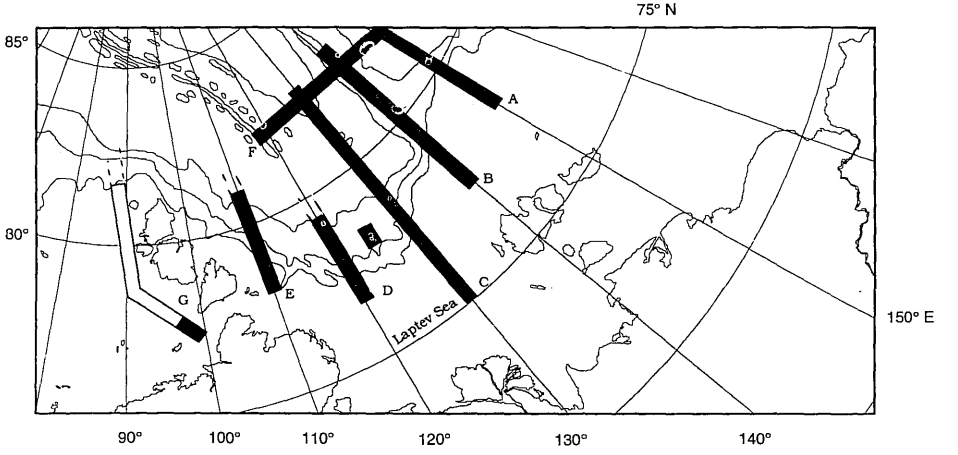

Fig. 2: Planned Transects in the Siberian Waters

1.2 "Поларштерн"-экспедиция ARK XI/1

Введение. Общая программа.

"Поларштерн" круиз продлится с 7 июля по 20 сентября 1995 года; это вторая экспедиция в Сибирских водах, которая включает Российско-Германское фундаментальное научное сотрудничество на море Лаптевых.
Предлагаемая программа была составлена на примере успешной совместной работы экспедиций "Поларштерн" и "Иван Киреев" в 1993 году в море Лаптевых и близлежащих Сибирских добычных районах (п-ов Таймыр, дельта р. Лена), а также других экспедиций в Арктическом океане (Арктика 90, проходившая в Евроазиатском бассейне; "Arctic EPOS 1991", проводившая многофункциональное изучение севера Баренцева моря).
Помимо работы в море Лаптевых, экспедиция старается попасть как можно севернее в глубоководную часть Центрального Арктического океана.
Главная задача заключается в исследовании отношений шельфовых морей (море Лаптевых и, если возможно также северо-восточной части Карского моря) к близлежащему глубоководному бассейну, особенно к континентальному склону, где хребет Ломоносова касается континентальной границы.
Экспедиция также представляет собой первый шаг в Европейской программе "Arctic Ocean Grand Challenge", которая была определена во время и после ECOPS Европейской научной конференции в Хельсинки (JOHANNESSEN, WADHAMS, LEMKE & SANDVEN, и др., 1994).

Физическая океанография будет фиксировать изменение концентрации водных масс, их перемещение и циркуляцию; несколько различных автоматически замеряющих инструментов будут пришвартованы в 3-х местах на континентальном склоне до хребта Ломоносова для изучения крупномасштабной циркуляции в течение одного года.
Природные и антропогенные следы циркуляции водных масс, органические вещества будут подвергнуты химическим исследованиям.
Исследователи льда собираются изучать физические черты и движение морского льда (от микро- до крупных размеров), включая съемку с вертолета и результаты космической съемки со спутника.
Биологи, главным образом, заинтересованы в продукции, трансформации и бентосной судьбе органики (осаждение частиц, пелаго-бентосное соотношение). Они будут анализировать большое разнообразие отдельных областей экосистем (морской лед, фито - и зоопланктон, микробиологические и бентосные сообщества).
Биогеохимия будет способствовать пониманию и оцениванию бентосных потоков, особенно имеющих отношение к минерализации органического углерода.

Геологическая группа будет изучать морфологию дна, современные и предшествующие режимы седиментации (как показатели состояния палеосреды/палеоклимата), а также судьбу органического вещества от различных источников (земля, шельф, океанические воды).
Аэрозоли, как атмосферные поставщики землеобразующих субстанций и седиментологической нагрузки на морской лед, большая часть которых переносится через Трансполярный Дрифт в Гренландское море, также будут изучаться.

Для этой объединенной программы, "Поларштерн" планирует отправиться из Бремерхафена 7 июля и пойдет в Мурманск для принятия на борт российских участников и их оборудования и также оставит делегацию научных менеджеров 13 июля; затем они отправятся в восточную часть Карского моря и попытаются пройти пролив Вилкитского как можно раньше (20 июля). В северной части моря Лаптевых и близлежащих глубоководных районах планируется провести 5 переходов север-юг и одно пересечение хребта Ломоносова (A, E, F, fig. 2). Восточная и западная части S-N переходов имеют особое значение, т.к. они охватывают наиболее различные географические части моря (переход A в области транзита Восточно-Сибирского моря; E-закрывает западный проход моря Лаптевых).

Учитывая ледовую обстановку, предполагается другой S-N маршрут в северо-восточную часть Карского моря. Этот маршрут окончательно будет определен в начале или конце рабочего периода в Сибирских водах.

Район будет покинут 12/13 сентября для возвращения в Мурманск. Российские партнеры будут высажены здесь, и некоторое оборудование будет передано на российский ледокол "Капитан Драницын", который выйдет для 3-ей Российско-Германской экспедиции "Transdrift" для исследования системы моря Лаптевых в период главного ледового формирования осенью.

После стоянки в Мурманске, "Поларштерн" направится в Тромсе для замены научного персонала; и затем стартует для второй части экспедиции ARK XI, которая пойдет в северные воды Гренландского моря.

Маршрут экспедиции ARK XI/1 представлен на рисунке 1.

1.3 Overview

The "Polarstern" cruise leg from July 7 till September 20, 1995, is the research icebreaker's second expedition to Siberian waters and will contribute to the Russian-German fundamental scientific cooperation on the Laptev Sea System.
The intended program has been developed from the very successful joint "Polarstern" and "Ivan Kireev" cruises in 1993 and the ongoing work in the Laptev Sea and adjacent Siberian catchment areas (Taimyr Peninsula and Lena Delta), as well as from other expeditions to the Arctic Ocean ("Arctic 91" across the Eurasian basins; "Arctic EPOS 1991", a multidisciplinary European study of the northern Barents Sea system).
Beyond the work in the Laptev Sea, the expedition is intended to proceed as far as possible to the north into the pack-ice covered deep central Arctic Ocean.
The main aim is to study the relations of the shelf seas (Laptev Sea and, if possible, also northeastern Kara Sea) with the adjacent deep basins, especially the continental slope areas with emphasis on that part, where the Lomonossov Ridge hits the continental margin. The expedition is also regarded a first step into the decadal European "Arctic Ocean Grand Challenge" program, as defined during and after the ECOPS Euroscience conference in Helsinki (JOHANNESSEN, WADHAMS, LEMKE & SANDVEN, eds., 1994).

Physical oceanography will focus on the varius water masses, their transformation and circulation; and arreys of various automatically measuring instruments will be moored at three locations on the continental slope close to the Lomonsossov Ridge to study the large-scale circulation for about one year. Natural and anthropogenic tracers of water mass circulation, organic substances and nutrients will be measured by the chemists. Ice researchers are going to investigate physical features and motion of sea ice from micro- to large-scale, including helicopter surveys and satellite image analyses.
The biologists are mainly interested in the production, transformation and benthic fate of organic matter (particle flux, pelago-benthic coupling). They will deal with the great variety of ecosystem compartments (sea ice, phyto- and zooplankton, microbial and benthos communities).

Biogeochemistry will contribute to the understanding and budgetting of benthic fluxes, especially of processes related to the mineralisation of organic carbon. The geological group will study bottom morphology, modern and past sediment regimes (as indicators of paleoenvironmental/ paleoclimatological conditions), as well as the fate of organic matter from different sources (land, shelf, oceanic waters). Aerosols as atmospheric inputs of land-derived substances and the sediment load of sea ice, a great part of which is transported via the Transpolar Drift to the Greenland Sea, will also be studied.

For this cooperative multidisciplinary program, "Polarstern" will leave Bremerhaven on July 7 and sail to Murmansk to embark the Russian participants and their equipment as well as to disembark a group of science administrators on the 13th of July. Thereafter she will directly proceed to the easternmost Kara Sea and try to pass Vilkitski Strait as early as possible (ca. July 20). In the northern Laptev and adjacent deep sea five south-to-north transects and one across the Lomonossov Ridge (A - E, F, Fig. 2) are planned. The eastern- and westernmost S-N-transects are regarded of priority, as they will cover the most different geographical parts of the sea (transect A in the transition area to the East Siberian Sea; E close to the western entrance of the Laptev Sea).

Depending on the ice conditions, another south-to-north transect in the northeastern Kara Sea is intended. This transect will be performed in the beginning or in the end of the working period in the Siberian waters.

The area will be left on September 12./13. to sail back to Murmansk. The Russian partners will be disembarked there; and some equipment will be transferred to the Russian ice-breaker "Kapitan Dranitsyn", which is to depart for the third Russian-German "Transdrift" expedition to investigate the Laptev Sea system during the main ice formation period in autumn.
After her stay in Murmansk, "Polarstern" will sail to Tromsø for the exchange of scientific personnel (September 20); and then to start for the second ARK- XI-leg, which will go to northern Greenland Sea waters.

The overall cruise track of ARK XI/1 is indicated in Fig. 1.

2 Research Program of RV "Polarstern" (ARK XI/1):

2.1 Physical Oceanography

(AARI, APL, AWI, SAIC, ZMK)

Background:

The modification of water masses and the related thermohaline circulation in the central Arctic Ocean are to a large extend controlled by processes on the Eurasian shelves and slopes. Shelf waters contribute to the deep basins in all depth levels depending on their density which is determined by the addition of river and melt water and by salinisation during freezing. A feature formed by these processes is the cold Arctic halocline. Its strong density stratification prevents the upward heat flux from deeper waters towards the ice cover and the atmosphere. Turbulent fluxes through the halocline (100 to 200 m) are probably mainly related to the shear exerted by internal waves.

In addition, the circulation of intermediate and deep waters is steered by the bottom topography of the different basins. The exposure of water masses to the influences of the particular shelf areas will depend upon the recirculation within and of the exchange between the different basins. Therefore this exchange influences greatly the characteristics of the water masses of the Arctic Ocean. The overflow occurs mainly at the intersections of the ridges with the continental slope, and these are key areas of the circulation pattern.

The Eurasion part of the Arctic Ocean is, in the intermediate layers, characterized by warm, saline Atlantic Water. It enters the Ocean through Fram Strait as a subsurface flow, and via the Barents Sea, where it is considerably modified. Both branches converge in the eastern Nansen Basin. The modification during their different pathways is of great importance for the downstream thermohaline dynamics. Parts of the intermediate water are deflected from the basin slope and return towards Fram Strait in the Nansen and Amundsen Basin, while the rest enters the

Canadian Basin. Rate and characteristics of this return flow as well as of intermediate water crossing the Lomonossov Ridge are largely unknown.

Objectives and program:
It is planned to study the confluence of the Atlantic branches, to describe the evolution of the boundary current along the continental slope north of the Laptev and East Siberian Seas and to investigate its splitting into the different basins at the Lomonossov Ridge. The mesoscale structure and motion of the upper water layers down to below the halocline will be studied.

This will be done by ship-borne observations along a series of transects with a dense station grid across the continental slope and the Lomonossov Ridge and - for the first time in this area - by long-term moorings. Temperature and salinity profiles will be measured by a CTD. Continuous velocity measurements will be done along the whole cruise track with an Acoustic Doppler Sonar Profiler. The strength and the time variability of the boundary flow along the continental slope and at the Lomonossow Ridge will be measured by moored instruments. The moorings are equipped with current meters and temperature/salinity recorders and Upward Looking Sonars (ULS). The ULS will provide information about the time variability of the ice thickness. The moorings will be deployed for one year; one of them will be equipped with sediment traps for ecological and geological studies.

2.2 Chemical Oceanography

2.2.1 Natural and anthropogenic tracers in the water column
(IUH, L-DEO, AWI)

Tritium; Helium, Oxygen-18; Chlorofluorocarbons; Krypton-85:
The extensive continental shelves around the Arctic Ocean play an important role in the formation of sub-surface water masses in the central ocean. Extensive sea ice formation occurs over the shelves, and
brine enriched waters formed by salt exclusion during the freezing process can accumulate in depressions on the shelves and then flow into

the Arctic Basin. Since these brine enriched waters originate from surface water, they are tagged with anthropogenic tracers that have been proven to be very useful for the investigation of ocean water mass formation, mixing and circulation. These tracers include tritium, the helium isotopes helium-3 and helium-4, oxygen-18 and the chloro-fluorocarbons (CFCs) F-11, F-12 and F-113.

During the past decade, with ships such as the "Polarstern", high quality hydrographic/tracer surveys were made in the Arctic Ocean. Most of the tracers listed above were measured on these surveys. They have been used to investigate the ventilation of the Arctic halocline and inter-mediate and deep waters. These investigations have revealed that the most recently ventilated deep water is found in boundary currents along the continental slopes of the Eurasian shelves and along subsurface ridges.
The overall objectives of our tracer program are to investigate the input of shelf water from the Eurasian shelves into the subsurface water masses of the Arctic Ocean and to study the circulation of these subsurface water masses.
Specific objectives are: to investigate
1. locations of shelf water input,
2. the circulation of the shelf derived waters along the continental slopes and their spreading into the Arctic Ocean interior,
3. mixing between shelf waters and the ambient water into which they flow to form the subsurface water masses, and
4. to estimate time scales of water mass formation and assess mean residence times by determining tracer ages for the various water types and mixtures.

Tracer sampling is planned at nearly all the stations along transects extending from the shallow Laptev and adjacent East Siberian Seas across the continental slopes into the deep Amundsen and Makarov Basins. Furthermore, a tracer section crossing the Lomonosov Ridge is planned. Thus, shelf water masses and halocline water, Atlantic water, inter-mediate, deep and bottom waters will be sampled. We anticipate 1000 - 1200 CFC analyses during the cruise; and a total of about 500 samples each for measurement of tritium, helium and oxygen-18 will be taken. A few samples (up to 24) will also be collected for krypton-85

measurements, which will be carried out at L-DEO. The krypton-85 data will be used to determine if there is any evidence of large-scale radioactive contamination from former Soviet Union nuclear waste disposal sites in the Kara Sea entering the central Arctic Ocean with the inflowing shelf water masses.

Radionuclides:

Naturally occurring radionuclides are other powerful tools for studying oceanic processes, such as particle dynamics and water mass circulation. Thus, highly particle-reactive radionuclides, such as thorium, produced in the water column by decay of their relatively soluble uranium and radium parents, are suitable tracers for studying particle fluxes in the surface waters and transport and resuspension of particles in the bottom nepheloid layer. To this purpose, during ARK XI/1, we shall measure two thorium isotopes of different half-lives, 234-Th (half-life = 24.1 d) and 228-Th (half-life = 1.9 y), in both the dissolved and particulate phases. The evaluation of the extent of the disequilibrium between parent and daughter nuclides are expected to provide us detailed informations about particle flux rates and residence times of particles in bottom waters.

Apart from thorium isotopes, we shall also measure radium isotopes: 226-Ra (half-life = 1602 y) and 228-Ra (half-life = 5,75 y). Both radium isotopes are supplied to the ocean from deep-sea and continental shelf sediments. From 228-Ra/226-Ra activity ratio distributions in surface and deep waters, we hope to contribute to specify the origin and transport rates of shelf waters in the Arctic Basin.

Water samples for thorium and radium measurements will be collected in surface and bottom waters with the CTD-Rosette. Samples of approximately 35 litres for the thorium and 50 litres for the radium will be combined and filtered. Because of its very short half-life, 234-Th activities in dissolved and particulate phases will be determined on board using a beta-counter.

2.2.2 Dissolved organic matter
(AWI)

Characterisation of dissolved organic matter
under consideration of the terrigenic contribution:

The role of dissolved organic matter (DOM) in marine systems is critical for the understanding of the global carbon and nitrogen cycles. DOM in the ocean contains approximatly the same amount of carbon as the atmosphere. Also, the greatest part of nitrogen of the suface water in the oceans is bound as DOM.
It is a very interesting fact that the structure of some organic substances can change to very stable humic substances, so that these compounds can abandon the active cycles for long periods of time. The humic substances are quite resistant to microbiological attack, so that they can represent a sink for atmospheric CO_2. A significant portion of the DOM in the Arctic Ocean has its origin in the high loads of the Siberian rivers. A part of this terrigenic DOM is transported with the transpolar drift through the Arctic Ocean towards the Fram Strait and North Atlantic. Organic substance is transported in form of particulate or dissolved matter in the water column or included in ice matrices.

The proposed work aims to investigate the character and the quantity of DOM in the Arctic Ocean with chemical, physical and biological methods, focussing on the contribution of terrigenic components. This includes the structural changes in DOM in its way from the source to the sinks. Lignin, a phenolic biopolymer, can be used as a tracer of terrigenic material.
During this expedition we plan to obtain samples by a CTD water sampler at four depths (two in the euphotic zone, one at ca. 300 m and another near the bottom). The filtered water samples will be kept frozen (-30°C) until analysis on land. DON, DOC, amino acids, nutrients and lignin derivates will be determined in aqueous samples and DOM extracts. Amino acids, lignin derivates and stable carbon and nitrogen isotopes will be determined in particulate material.
Furthermore, we are specially interested in the distribution of lignin monomers, because they can provide valuable information about the origin and age of DOM. Tangential ultrafiltration will be used for the determination of the molecular weight distribution of DOM. Later (on

land), the different fractions will be analyzed with regard to DON, DOC and amino acids. The bioavailability and the structural changes in DOM extracts, including the lignin derivates, will be studied by means of microbiological tests.
At selected stations we intend to process big water volumes (40 litres per depth) with different XAD resin columns to extract humic substances and other DOM fractions, which will be analysed in the home laboratory.
With the Seastar system a continuous extraction of DOM in the surface water will be performed, simultaneously collecting particulate matter. On board we shall measure three-dimensional fluorescence spectra on untreated and fractionated water samples to attempt an optical characterisation of DOM, which will be correlated with chemical determinations.
In addition, and in cooperation with other research groups, it is planned to investigate the content and distribution of humic substances and associated compounds in sea ice and sediment samples.

2.2.3 Plant Nutrients

(IO Moscow)

To understand and estimate the biological production, the main inorganic plant nutrients (Si, P, N) in their relevant compounds will be quantitatively analysed on board from samples taken by Rosette water bottles. In addition, the nutrients may be used as tracers of water masses, such as of Atlantic, Pacific and riverine sources.
Measurements of nutrients in the ice and in the sediment pore water will be supported.

2.3 Sea Ice Physics

(AARI, AWI, GEOMAR and HSVA)

Studies of the sea-ice regime in the source region of the Transpolar Drift: Radiation balance over different surfaces; thickness and properties of the ice cover; distribution of sea-ice sediments; microwave remote sensing

Thickness, structure and properties of the Arctic sea-ice cover constitute an important variable in the global climate system. Numerical model experiments and previous expeditions demonstrate that the thickness distribution, the properties and the surface characteristics of the Arctic ice cover are very sensitive to processes occurring during the melt season. As of yet, these processes are poorly understood, with a distinct lack of field data to assess the validity of the conceptual framework and numerical modelling approaches. Growth, ageing and melting of ice over the broad Eurasian shelves are of particular interest in this context.
The Transpolar Drift transports ice from the shelves across the Basins into the Greenland Sea and may be regarded as the most important sea-ice circulation system in the world. The ice transports significant amounts of dissolved and particulate matter entrained over the shallow, river-dominated Eurasian shelves.

The expedition ARK XI/1 provides the unique opportunity to study the transitional ice regime between the shelf areas dominated by first-year ice and the multi-year pack north of the shelf break.

Radiation balance studies comprise measurements of the spectral composition of incoming, penetrating and outgoing shortwave solar radiation over different surfaces (bare ice, melt ponds and leads), determined with a underwater pyranometer (6 spectral bands). Furthermore, measurements with respect to the long-wave radiation balance will be carried out over melt ponds.

Detailed studies on the distribution of ice sediments and dissolved substances in surface melt puddles and the interior of the ice will be carried out jointly with extensive ice thickness measurements and studies of ice microstructure and properties. Small-scale field experiments are aimed at quantifying dispersal of sediments and tracers in the ice.

The large-scale distribution of sediments and variability of surface albedo will be assessed through helicopter line-scan and video flights,

in conjunction with the radiation-balance work (see above). This work is part of a larger research initiative funded by the German Research Ministry, involving collaboration with sedimentologists and other researchers as well as a continuation of studies into the freeze-up season 1995 on board the Russian research vessel "Kapitan Dranitsyn".
Information about the ice-thickness distribution will be obtained through indirect electromagnetic measurements carried out continuously from the ship, by helicopter or on the ice. The latter will be carried out in the vicinity of the ship (distances of 5-10 km) by an amphibic sled. In combination with helicopter laser-altimeter flights, these measurements will provide valuable information on the ice thickness distribution along the cruise track.
Ice dynamics will be deduced from remote-sensing comprising satellite data from NOAA AVHRR, ERS-1/2 SAR, and airborne measurements (available from INTAARI, St. Petersburg), aimed at putting the local measurements into a regional perspective.
Remote sensing work furthermore comprises ground-truth measurements of microwave backscatter coefficients (X-band) as well as emissivity measurements at a frequency of 37 GHz over different ice surfaces. These coefficients are necessary for the correct interpretation of SAR images from ERS-1/2, radar and microwave images from "Okean". They are also of importance with respect to the AARI side-looking airborne radar (SLAR) system, which will be flown by helicopter (in conjunction with laser altimeter and video flights).

Measurements during ship's stations of (at least) several hours duration comprise the following activities:
(1) ice-core drilling in different ice types,
(2) hydrographic and morphological studies of melt puddles,
(3) radiation balance measurements in melt puddle and lead areas,
(4) measurements of spectral albedo of the ice surface along with studies of the small- and large scale distribution of ice sediments along transects of a few kilometers length in the ship's vicinity,
(5) direct and indirect measurements of ice thickness along transects (same as (4)),

(6) helicopter overflights of transects (4) and (5) with video/line-scan camera, laser altimeter. and side-looking airborne radar (SLAR) operated by AARI,
(7) ground-truth measurements of the radar backscatter coefficients and emissivities of different ice surfaces.
During one or more longer-term (>20 hours duration) stations it is planned to carry out an extensive program providing a two-dimensional array of the respective sea-ice data and conduct a series of field tracer experiments aimed at quantifying transport of solutes and particulates within the ice cover.
By revisiting a site prepared at the beginning of the Laptev Sea work, longer-term changes in ice characteristics and distribution of ice sediments are to be assessed. This work is closely coordinated with the studies of the ice biology group.
Further work carried out on board include (1) indirect ice thickness measurements in combination with laser altimetry from the bow crane, with the ship travelling along linear transects (independent of ice conditions) of several kilometers length, (2) measurements of surface temperature (with PRT-5 radiometer) and microwave emissivity by sensors mounted on bow crane (as described before), (3) observations and documentation of ice conditions encountered along the cruise track and (4) receival of AVHRR (and possibly "Okean") satellite data with the HRPT receiving station on board the ship.

2.4 Biology / Ecology:

Arctic marine communities and the functioning of the Arctic Ocean ecosystem are insufficiently investigated and understood so far. Crucial open questions are:
- How intensive is the coupling between the main sub-systems (ice - pelagial - benthal); and
- To what extent is life in the ice-covered deep basins dependent on the importation (advection) of organic matter from the shelves, among which the Laptev Sea shelf is most important.

The Arctic Ocean is regarded a system of high climatic sensitivity. Greenhouse warming will reduce the pack ice substantially, by which the present coupling of production and sedimentation areas of organic matter will be drastically changed. Altogether, the biota of the Arctic will presumably experience dramatic alterations. Scenaria about the expected ecosystem changes can only be set up, when today´s distribution and energy flux patterns are sufficiently described. The biological work during ARK XI/1 is intended to contribute to these scientific challenges.

2.4.1 Sea Ice Ecology

(IPÖ, AWI)

- s. also under plankton ecology/particle flux -

Arctic sea ice is a unique habitat for a specialized, diverse sympagic community. Organisms found inside the Arctic sea ice cover a wide range of sizes (0.2 to more than 1000 µm). Processes in the ice and at the ice-water interface influence the pattern of colonization, the food web structure and the degree of export of organic material to deep water strata.

The distribution and the abundance of sympagic organisms are strongly affected by physical and chemical properties of the ice and by the hydrodynamic situation at the ice-water interface leading to patchi-ness on scales from millimeters to kilometers. The sea ice food web structure is influenced by the spatial distribution of single organisms and consequently dependent on the three-dimensional structure of inhabited space and the prevailing physico-chemical conditions. Especially the brine channels in the ice constitute a complex habitat for organisms.

The biological studies on Arctic sea ice will focus
on the following topics:

- the general characterization of properties of sea ice and the upper meters of the underlying water column (ice coverage; ice thickness; snow cover; temperature; salinity; brine channel structure; water exchange rates between ice and water, current velocity profiles, ice-water interface morphology);

- the spatial distribution of the sympagic community within the brine channel system, including bacteria, algae, protozoa and metazoa;
- abundance, distribution and behavior (feeding) of organisms directly at the ice-water interface and within the first ten meters below the ice.

In situ incubation experiments of the ice with dye tracers will aid in quantifying fluid motion within and across the ice-water interface. Newly constructed instruments, which will be deployed through core holes, will allow to simultaneously determine vertical and horizontal exchange processes together with hydrodynamic features below the ice.

The structure of the brine channel system will be determined by a cast technique using ice core material. A recently developed substitution technique is used to resolve nannoscale (µm to mm) distributions of organisms within the brine channel structures. The in-situ small scale distribution will be compared with results from a simulated brine channel system to reveal the influence of the structural component of the brine channel system on the food web structure. Furthermore, ice cores will be taken for the analysis of abundance, biomass and diversity of the sympagic flora and fauna.

Specialized sympagic algae and amphipods together with vertically migrating pelagic species inhabit the underside of the ice floes and can thereby mediate between the ice and the pelagic system. Attached or pelagic organisms find shelter in crevices during phases of their live cycles. High concentrations of algae and variable physico-chemical factors presumably control the distribution of organisms into zones along gradients of their acceptable tolerance.

The distribution and abundance of under-ice organisms will be investigated with an under-ice video- and a pump system, respectively. They will be deployed during ice stations through ice core holes. Current velocity, temperature and salinity profiles will be determined to about 10 m water depth to describe the expected strong gradients at the ice water interface.

Feeding experiments of maintained amphipods and copepods with cultured ice algae and freshly collected organic material from the ice will clarify dietary demands and faecal pellet production rates of these organisms. The data obtained will provide insights into the cryopelagic coupling processes taking place directly at the ice-water interface.

2.4.2 Plankton Ecology and Vertical Partical Flux
(AWI, IO, MMBI)

Latest investigations on the ecology of plankton over deep polar seas have shown a dominance of small autotrophic and heterotrophic flagellates in the pelagic system throughout the year. Diatom blooms seem to be rather the exception. Phytoplankton biomass in the investigation area is assumed generally to be low. Higher concentrations of algae occur only in small areas for a short time period. Such higher biomass is assumed to be related to sea ice melting and fresh water input, as was found during our first expedition to the Laptev Sea in 1993. Accordingly, the distribution pattern of plankton biomass in space and time is fairly heterogeneous.
These findings will have consequences for the composition and the amount of sedimenting organic matter. In addition, it is known from some other polar areas that zooplankton may have a great influence in modifying the organic matter, the remainders of which finally reach the sea floor.
Studies on the vertical flux of organic matter have almost not been carried out in the Laptev Sea region so far. First results from 1993 indicate a strong correlation of flux with the sea ice cover and the freshwater input of the river Lena in specific areas.

In order to get a complete picture of the pelagic regime of the Laptev Sea and to understand the flux of organic matter, the deeper, northern waters as well as the distribution of organisms in and under the sea ice must be taken into consideration.
We assume a considerable influence of the sea ice and sea ice related biological processes in the deeper part of the Laptev Sea. Biological processes mediated by autotrophic and heterotrophic sea ice organisms are major determinants of turnover and fluxes of organic material within

the ice environment and between ice and underlying water column. For the various sea ice habitats typically encountered in the Arctic Ocean (surface ponds, multi-year ice floes, sub-ice mats and strings of *Melosira arctica)*, little information is currently existing to what extent organic matter produced by ice algal assemblages is channelled through ice-associated microbial food webs (i.e. protozoa and bacteria); and what is finally available for the pelagic food web.

In general the following questions are to be answered:

- Are there regional differences in the seasonal distribution patterns of sea ice organisms and plankton?
- Which are the most remarkable features of the pelagic food web?
- What is the influence of the respective abiotic factors?
- How important are the sea ice production and biological processes within the ice for the pelagic food web; how much is produced in open waters?
- How is the relationship between algal growth and grazing pressure?
- What is the role of zooplankton in deeper water layers?
- What is sedimenting out of the water column and available for the benthos?
- What is the answer of the bacteria in the sediment to the respective input of fresh organic material?

To understand phytoplankton ecology, species composition, primary productivity, biomass and particulate organic carbon as well as nitrogen and biogenic silica within ice-associated habitats (surface ponds, multi-year ice floes, sub-ice mats and strings of *Melosira arctica)* will be investigated; and the results will be compared to those of phytoplankton assemblages in the water column beneath the sea ice cover down to 300m.

Ice samples will be obtained by coring (see: Sea Ice Research).
Water samples will be taken from Rosette bottles to measure chlorophyll-a, particulate organic carbon and nitrogen, biogenic silica, and to study species composition and biomass of phyto- and protozooplankton and bacteria. Primary production will be measured at selected stations by

radiotracer technique (C-14 uptake). In additon, ammonia will be analyzed to measure heterotrophic activity of small heterotrophic organisms (see: Nutrient Chemistry).

Particulate organic carbon and nitrogen, biogenic silica, species composition and biomass of phyto- and protozooplankton and bacteria in samples taken from the ice and the water will be analysed at home. The C-14 incubation ("in situ simulated") will be carried out with the aid of an incubator (5 -10 h incubation time). Ammonia will be analyzed on board.

Microbiological investigations are designed to study bacterial processes in sea ice, in the water column (and in the sediment, see below). Biomass and productivity of bacteria living within ice-associated habitats (surface ponds, multi-year ice floes, sub-ice mats and strings of *Melosira arctica)* will be compared to those of bacterial assemblages in the water column beneath the sea ice cover and/or within aggregates. Bacterial production will be measured by radiotracer technique (incorporation of tritiated thymidine into DNA). Conversion factors for estimation of bacterial carbon production from thymidine incorporation rates will be determined separately for the different ice and water habitats investigated.

Measurements of bacterial productivity will be carried out parallel to those of phytoplankton and of ice algae in order to trace the connection between primary production and bacterial consumption of organic matter. In order to achieve information about the fate of bacteria, grazing experiments are also planned. Comparisons of algal primary production, bacterial secondary production, and protozoan grazing pressure on the bacteria within ice-associated habitats and in underlying water bodies will provide information about fluxes of energy and organic matter (carbon) within and/or among microbial food webs of these compartments, and will give indications on ecological couplings between sea ice and the pelagic environment.

The material to estimate vertical particle flux will be collected in a few locations by short term deployments of sediment traps (attached to ice floes). In addition, two sediment traps will be deployed for about one year in one of the oceanographic moorings at ca. 100 m water depth and above

the sediment. In the collected material chlorophyll-a, particulate organic carbon and nitrogen, biogenic silica, species composition and biomass of phyto- and protozooplankton and faecal pellets will be analysed.

In addition, to understand potential factors modifying vertical flux via faeces, like distribution and abundance of cyclopoid copepods, the vertical distribution of small zooplankton and faecal pellet stocks will be analysed from 5 strata collected with the multinet (63 µm) at selected stations.

Meso-zooplankton will be collected by a multiple closing net (multinet) with 150 µm meshes to provide stratified samples down to 3000 m. Species composition, abundances and biomass, and vertical distribution patterns will be analysed from these. Catches of bongo nets (with 300 and 500 µm meshes) from the upper hundred meter will be used for dry weight, protein, lipid and carbon content measurements, for laboratory experiments on grazing rates, egg production and defecation. Larger zooplankton will also be analysed from these bongo net hauls.

The planned investigations on the sedimentation of organic matter to the sea floor and its microbial degradation in the sediment will be a continuation of the work of 1993 in the deeper parts of the Laptev Sea (see next part chapter).

2.4.3 Benthos Ecology and Zoogeography
(AWI, MMBI, ZISP)

Zoogeography and benthic-pelagic coupling

After the "Polarstern" and "Kireev" cruises in 1993, a first scheme of the zonation of macrozoobenthos communities in the whole Laptev Sea has been developed (Sirenko et al., 1995). Zoogeographical analyses indicate a predominance of Atlantic elements in the western and central Laptev Sea; however, it is still unknown, how distinct the transition is between the Atlantic and Pacific Siberian subregions near the continental slope, and whether and where a border can be delineated. Warming of the Arctic

Ocean will dramatically shift the distribution of species, consequently zoogeographical boundaries.
Densities and species numbers at the continental margin were found to be relatively high, especially in the northeastern (ice-free) part of the sea, which indicates a considerable input of organic matter. The microbial decomposing activities measured by A. Boetius (1995) substantiated these findings.
Another interesting finding in the 1993 zoobenthos samples was the existence of a subfossil hydrothermal vent fauna at about 2000 m depth on the slope near the origin of the mid-oceanic Gakkel Ridge. We do not know whether there are still habitats supporting a living vent fauna.

The benthos program during ARK XI/1 is intended to complete the 1993 findings and clarify the open questions indicated above. Together with the other disciplines, benthos studies in the deeper, ice-covered central Arctic Ocean basins will contribute to the understanding of the fluxes, sedimentation and transformation of organic matter. The budgetting of aerobic remineralisation of organic matter, as intended by the biogeochemistry group, will be supported by densitiy estimates of benthic animals and bacteria.
Our main hypothesis anticipates an important advection route of organic matter from the eastern Laptev Sea shelf into the central ocean via the boundary current of water of Atlantic origin along the Lomonossov Ridge. The zoobenthos density and biomass distribution is regarded as an integrating indicator of the larger scale (more or less regular) sedimentation regime.

Working program:
Benthic macrofauna will be collected qualitatively by Agassiz trawl (AGT) hauls in all accessible depths. Additional material from the near-bottom water will be obtained by a small epibenthic net combined with the AGT. Quantitative endofauna samples will by taken from large ("giant") box corers and/or van Veen grabs, and from multiple corers.
The material will be pre-sorted and preserved on board; identification of species and quantitative analyses will be done in the home laboratories (St. Petersburg, Murmansk, Bremerhaven and Oldenburg).

A collection of animals from the waters of the easternmost Laptev Sea will be deep-frozen for $\partial^{13}C$-measurements, to try and trace back to the sources of food supply (i.e. Lena River, shelf waters).

For microbiological work and collection of meiofauna, bottom sediments will be obtained by multiple corer (in cooperation with other groups). Bacterial biomass will be determined, phyto-pigments analysed, and bacterial enzyme activities measured.

1.5 Benthic Biogeochemistry

(AMCG, AWI)

Scientific background:
Marine particulate organic matter will either be preserved in the sedimentary record or mineralized to CO_2 and other metabolites and returned to the ocean water. By this way fluxes at the sediment-water interface participate in the global biogeochemical cycles in the ocean.
The main topic of the program will be the quantification of benthic fluxes of recycled organic carbon. The investigations will include the estimation of respiration rates by sediment oxygen uptake and, especially on the shelf, with further electron acceptors. Combined with the results of benthic biology, especially density estimates combined with specific respiration rates of various benthic organisms, biogeochemical budgets of carbon mineralisation and other fluxes on the sea floor will be produced. In combination with parallel studies in the water column, the quantification of benthic carbon fluxes will help to quantify the lateral advection of organic carbon from the shelf and slope into the deep basins. Complementary efforts will be put on the concentration and composition of carbohydrates in the sediments, their fraction of the DOC pool, their role in benthic carbon cycling and how all this is dependent on the depositional environment - shelf, slope, deep basins (cooperation with geologists).
To understand the interaction with other processes of early diagenesis, a series of additional physico-chemical analyses of pore water and sediments will be performed. These studies will help us to find out to what extent paleosignals on organic matter are preserved in the

sedimentary record. As an example, we attempt to predict the respective proportions of organic material buried and recycled with the aim to reconstruct paleofluxes from observed carbon burial rates.

Working program:
Sediment samples will be obtained by a multiple corer (MUC) at several locations on the transects going from the shelf over the slope into the deep basins. Benthic fluxes of O_2, total "CO_2", alkalinity, nutrients, dissolved organic carbon and nitrogen, and saccharides will be directly measured by incubations of virtually undisturbed sediment cores together with overlying ambient bottom water at in-situ temperature on board.
In addition, measurements of oxygen gradients across the sediment-water interface will be carried out with microelecrodes. Pore water will be analysed for total "CO_2", alkalinity, nutrients, dissolved organic carbon and nitrogen, saccharides, dissolved mangenese and iron, and sediment samples for nitrogen as well as organic and inorganic carbon and total carbohydrates in the home laboratories.

1.6 Marine Geology

(AWI, GEOMAR, MMBI, IO, GUT, VNIIO)

Sediment facies, fluxes, and paleoenvironment at the Eurasian continental margin and in the adjacent Arctic Ocean basins

The Arctic Ocean and its marginal seas are key areas for understanding the global climate system and its changes through time. The deep-water exchange between the Arctic and Atlantic Oceans, for example, is a major driver of the world ocean thermohaline circulation controlling heat transfer and climate. The permanent Arctic sea-ice cover with its strong seasonal variations in the marginal areas has strong influences on earth's albedo, the marine ecosystem, and the water circulation, which are also major mechanisms effecting the global climate. Despite the importance of the Arctic Ocean for the global climate system, its exploration remained relatively poor in comparison to the other oceans.

The overall goals
of the marine-geological research program can be summarized as
(1) high-resolution studies of changes in paleoclimate, paleoceanic circulation, paleoproductivity, and sea-ice distribution in the central Arctic Ocean and the adjacent continental margin during Late Quaternary times, and
(2) the long-term history of the Mesozoic and Cenozoic Arctic Ocean and its environmental evolution from a warm to an ice-covered polar ocean.

Of major interest are the significance of the Arctic Ocean for the global climate system, the correlation of paleoenvironmental data from the different depositional environments (i.e., shelf - slope - deep sea), and the correlation of marine and terrestrial climatic records. To reach these objectives, detailed sedimentological, geochemical, mineralo-gical, and paleontological as well as biological investigations (s. chapter 2.4) will be performed on sediments from the Laptev Sea continental margin and the adjacent deep sea.
The research program will include studies of aerosols, particles sampled within the water column using sediment traps and in-situ pumps, surface sediments, and sediment cores. Coring positions have to be selected carefully using detailed bathymetric mapping and sub-bottom profiling systems (i.e., Hydrosweep and Parasound, respectively) to avoid areas of sediment redeposition (turbidites and slumps) and erosion. In areas such as the Lomonosov Ridge pre-Quaternary sediments are cropping out, which may even be taken with coring gears routinely used aboard *Polarstern* and which would allow to study the Tertiary/Cretaceous history of the (preglacial) Arctic Ocean.

Research objectives:

2.6.1 Stratigraphical investigations
As basis for all further reconstructions of paleoenvironmental changes, a high-resolution stratigraphic framework has to be established for the deep sea and Eurasian continental margin areas. This work will include absolute AMS ^{14}C age dating, oxygen and carbon stable isotopes, natural radionuclides, amino acids, microfossils, paleomagnetic investigations,

magnetic susceptibility, and the correlation to other existing (dated) Arctic Ocean records.

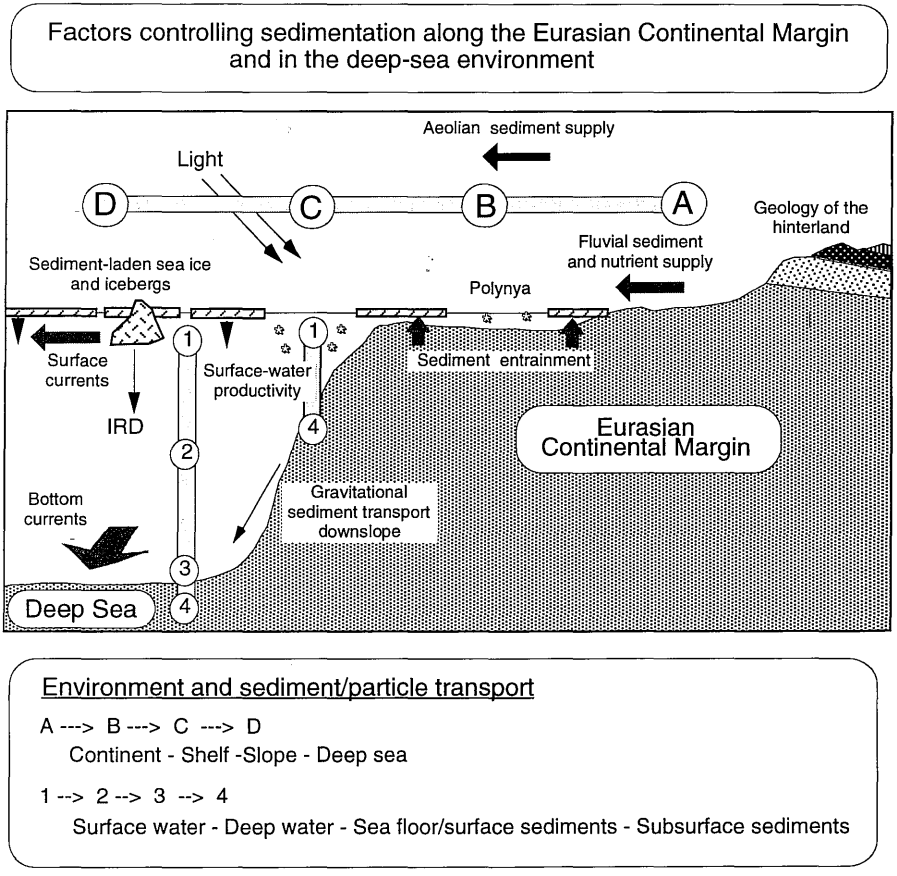

Fig. 3: Sedimentation Scheme

2.6.2 Sedimentological investigations

The terrigenous sediment supply from the Eurasian continent to the marine realm, its transfer from the shelf via slope to the deep sea, and its variation between glacial and interglacial times is main topic of the sedimentological working-group. The Laptev Sea is believed to be the source area for the main portion of sediments entrained into sea ice and transported via the Transpolar Drift across the Arctic Ocean. The river Lena is one of the most important contributors for the siliciclastic sediment budget in the entire eastern Arctic Ocean. The distinct glacial/interglacial changes in siliciclastic/fluvial sediment supply have to be quantified (flux rates), qualified, and correlated with the deep-sea records. The correlation between data derived from shelf/upper slope areas close to the river mouth with data from the Central Arctic Ocean may provide information about the evolution of paleoceanographic circulation patterns, extent of sea ice (and ice-bergs), and the paleoclimate of Eurasia.

Sedimentological investigations will include analyses of sedimentary structures (X-ray radiographs), grain size distribution, qualitative and quantitative sediment composition (e.g., X-ray diffractometry, light microscopy, coarse fraction analysis). Systematic studies on the mineralogical composition (e.g., heavy minerals, clay minerals) of shelf, slope, deep sea and sea ice sediments may provide evidence for active entrainment of terrigenous material into the Arctic sea ice cover, its transport (by currents, gravity flow, sea ice drift), and release. In addition, aerosol particles will be investigated for its mineralogical, organogenic, and geochemical composition. The river run-off from the Asian continent and corresponding surface-water salinity changes in space and time will be reconstructed from stable oxygen and carbon isotope records.

2.6.3 Micropaleontological investigations

The modern distribution of foraminifers, dinoflagellates, diatoms, calcareous nannoplankton, and palynomorphs (pollen, spores) in relation to the actual Arctic environment (bathymetry, water mass properties, sea-ice distribution and transport, availability of nutrients, biological activities, terrigenous input, etc.) will be described. Based on these results, an actualistic model can be derived which will subsequently be applied to the

fossil record and allow to reconstruct environmental changes during late Cenozoic glacial/interglacial cycles.

The micropaleontological studies will include investigations of material from plankton net hauls, sediment traps, and in-situ pumps, as well as from sea-ice sediments, surface sediments, and sediment cores. Furthermore, the micropaleontological records will be correlated to specific biomarker (alkenones, dinosterols etc.) as well as other geochemical parameters ($\partial^{18}O$, $\partial^{13}C$; barium).

2.6.4 Organic and inorganic geochemical investigations

Organic carbon flux:
Surface-water productivity vs. terrigenous supply

Mechanisms controlling the organic carbon budget such as surface water productivity may affect the concentration of atmospheric CO_2 (i.e., during times of increased phytoplankton productivity the ocean may act as a sink for CO_2, "biological pump") and, thus, may serve as important controlling factors for the climate. Though the importance for organic carbon storage in these areas is apparent, data on spatial and temporal changes in Arctic Ocean and Eurasian marine shelf productivity are rare. Thus, one of the major goals is to quantify the fluxes of organic carbon on the shelf as well as the slope and in the deep sea together with the biologists and to characterize the mechanisms controlling organic carbon deposition (i.e., surface-water productivity vs. terrigenous input; biotransformation). Corresponding results are requisite for detailed modelling climate variations.

Main emphasis will be laid on the quantification of the marine and terrigenous organic carbon accumulation rates in the Eurasian shelf, slope and deep-sea environments. Its spatial and temporal change and its relationship to changes in sea ice distribution, river run-off and paleoclimate is of fundamental importance for paleoenvironmental reconstructions. The amount, composition, and maturity of the organic carbon fraction (i.e. (sub-) recent marine and terrigenous organic carbon, reworked fossil material like coal) will be determined.

Furtheron, a major attempt will be made to distinguish between the different factors controlling organic carbon deposition (high productivity caused by fluvial nutrient supply; ice-edge blooms; fluvial supply of terrigenous material), using specific biomarkers. Biomarkers such as long-chain n-alkanes and lignin are important indicators for terrigenous input. Phytoplankton-specific substances (such as alkenones, dino-sterol, etc.), on the other hand, will be used to obtain more detailed informations on surface-water productivity and its importance for the carbon budget.

To estimate the importance of the "biological pump" for the global climate system as well as to reconstruct surface-water paleo-productivity from sediment core data, it is important to understand the processes controlling the pathway of organic and inorganic particles through the water column and at the sea floor. In the line of this process, CO_2 is rejected from the ocean/atmosphere system and subsequently stored in the marine deposits. For the quantification of the "export production" (organic-carbon flux) and the decomposition rate of organic carbon during its fall through the water column, studies of material from in-situ pumps and sediment traps as well as sea-ice and surface sediments will be performed in close cooperation with the planktologists, microbiologists and geochemists.
In addition, inorganic-geochemical tracers (e.g., barium), biogenic opal, and other microfossil groups as well as $\partial^{13}C$-measurements within the organic material as well as in benthic foraminifers will support the attempt to reconstruct paleo-productivity.

Terrigenous input, oceanic circulation, and diagenesis

Main, minor and trace element analyses of bulk sediments focus on the characterization of different sediment facies. The comparison of geochemical data sets from shelf and slope sediments with similar sets from deep sea deposits will be used to understand transport mechanisms and source areas of pelagic sediments.

Heavy metal distribution patterns in sediments will indicate recent environmental contamination and oceanic circulation patterns. In this line, solid phases and pore waters will be investigated as described in

chapter 2.5 to study early diagenetic processes within the sediments and to quantify a number of early diagenetical fluxes.

Methods to be applied are elemental (C-H-N-)analyses, Rock Eval pyrolysis, carbon stable isotopes of organic matter, kerogen/coal petrography, gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS). For barium, X-ray fluorescence analysis and atomic absorption analysis (AAS, ICP) is planned.

2.6.5 Physical properties

Physical properties in Arctic Ocean sediments (e.g., wet/dry bulk density, water content, porosity) are basic parameters, which will be performed routinely aboard. These parameters can be significantly influenced by oceanographic changes, as could be shown for Arctic Ocean deep sea sediments. Here, drastic and abrupt climatic changes (e.g., deglaciations) are reflected in pronounced variations of physical properties. Furthermore, they are basic parameters to calculate sediment accumulation rates. Measurements will be directly performed on single samples as well as on whole cores.

Physical properties of whole cores (core logging)

Continuous down-core logs in 1-cm steps of magnetic susceptibility, gamma-ray absorbtion and p-wave velocity of whole gravity cores as well as box-subsamples from the Kastenlot are to be measured routinely on board. The above properties can be determined simultaneously using a "Multi-Sensor Core Logger".

Magnetic susceptibility is a measure of the amount of magnetizable compounds in the sediments. Generally, the downcore variation of amplitudes is used as an indicator for shifts of biogenic versus terrigenic compounds. Logs from sediment cores taken in Arctic marine environments have shown that the magnetic susceptibility provides an excellent tool for lateral core correlation and can also be used for stratigraphic interpretations.

The attenuation of gamma rays is a measure of the bulk wet density of the sedimentary core material. This, in turn, is generally a function of porosity. Bulk wet density is an important parameter for assing a possible

over-consolidation of a given sediment body due to past glacier or ice-cap load. Moreover, density and porosity are basic parameters necessary for the quantification of past sediment accumulation rates.

The results from p-wave velocity and density measurements can be used to calculate the downcore variation of acoustic impedancies. This can then be converted to synthetic seismograms. The latter provide tools to link the down-core variation of physical properties with reflection patterns obtained by the high-resolution seismic system PARASOUND. As a result, paleoenvironmental information from parameters determined in sediment cores can be extrapolated from a sampling spot to area and space.

2.6.6 PARASOUND-Sedimentechography

The ship-mounted PARASOUND sediment echosounder will be in operation along all working cruise tracks. The system creates a secondary parametric frequency between 2.5 and 5.5 kHz. This is suitable for subbottom profiling of the upper tens of metres of the sediment column with a vertical resolution of ca. 10-20 cm. The PARASOUND records are simultanously digitized and stored on tape for post-processing.

The aim of the PARASOUND survey during ARK XI/1 is three-fold:
- to give information from sub-bottom reflectors for the selection of sediment sampling sites,
- to provide a two- or even three-dimensional stratigraphic framework for lateral linking of sediment cores based on sub-bottom refection pattern, and,
- to detect changes in sediment facies in space and time by means of interpretion of the sub-bottom reflection configuration (reflector geometry and sound penetration).

With respect to the results of the 1993 "Polarstern" expedition to the Laptev-Sea, there are three main goals which are to be addressed during this cruise:

(1) further mapping of erosional features on the continental shelf which are related to grounding of sea ice and/or ice-bergs, (2) detection of the regional extent of sub-glacial and proglacial facies with respect to the glacier/ice-cap history of the Eurasian shelf, and, (3), characterization of continental slope and deep-sea facies with respect to fluvial sediment input (e.g. within the sub-marine fan of the River Lena) and their changes between glacial and interglacial stages.

Geological sampling procedures:

Undisturbed sediment surface and subsurface samples as well as long, undisturbed sediment cores will be obtained along the transects perpendicular to the continental margin from the shelf edge/upper slope down to the deep sea. Coring positions have to be selected by detailed bathymetric and shallow sub-bottom profiling systems. For sampling, multicorer, giant box corer, Kastenlot corer, gravity corer and/or piston corer will be applied.

Sediment particles from the water column will be obtained by in-situ pumps and sediment traps. Particles transported by wind will by collected on top of the "Polarstern" bridge, using a specific aerosol sampling device.

For sampling of "dirty" sea ice, ice coring and surface sampling of floes is planned at all ice stations (s. sea ice research program, 2.3). Observations on the distribution of "dirty" ice patches will be conducted along route. Helicopter support is necessary to cover broad areas of the pack ice.
Ice cores and snow samples will be melted on board "Polarstern" in order to obtain sediment concentrates by vacuum filtration.

3 Participants/Teilnehmer/ Участники ARK XI/1

Name	Discipline	Institution
Natalya A. Anisimova	Biology, Zoobenthos	MMBI
Anja Bartel	Biology , Phytoplankton	AWI
Marion Behrends	Geology, Sedimentology	AWI
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Steffen Burkhardt	Biology, Microbiology	AWI
Ellen Damm	GeoChemistry , Sediments	AWI
Clark Darnall	Ozeanography, phys.	APL
Andrey Darovskikh	Ice Remote Sensing	AARI
Technician N.N.	Ice Remote Sensing	INTAARI /AARI
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Karl-Ulrich Evers	Ice Physics	HSVA
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John Gunn	Oceanography, phys.	SAIC
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Till Scherzinger	Biology, Zooplankton	AWI
Helmut Schottmüller	Ice Remote Sensing	AWI
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Vladimir Shevshenko	Geology/Aerosols	IO
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Robert Spielhagen	Geology, Sediment. & Forams	GEOMAR
Ruediger Stein	Geology, Sedimentology	AWI
Wilhelm Stein	Oceanography, Tracers	IUH
Kjell Svindland	Geology , Sedimentology	AWI/GUT
Sergey Timofeev	Biology , Zooplankton	MMBI
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Iris Werner	Ice Biology	IPÖ Kiel
Hannelore Witte	Oceanography , phys.	AWI
Russian "Advisor" N.N.		

Participants ARK XI/1 ctd.

Uwe Bergholter	Meteorology	DWD
Herbert Köhler	Meteorology	DWD
Jürgen Büchner	Helicopter-Service	HSW
Dirk Brinkmann	Helicopter-Service	HSW
Volker Lundström	Helicopter-Service	HSW
Wolfgang Dinkeldein	Helicopter-Service	HSW
RESERVE:		
V.V. Potin, Research Scientist	Biology , Benthos	ZISP

Leg Bremerhaven-Murmansk (Chief Scientist: Prof. Dr. Max Tilzer):

Dr. Christine Bassarab	AOSB Secretary
Dr. Jean Boissonnas	EU Commission Brussels
Dr. Laurent D´Ozouville	ESF Strasbourg
Dr. Dietmar Gerstein	KOWI (AGF) Brussels
Dr. Paul Gray	EU Commission Brussels
Prof. Dr. Heinrich Miller	AWI Geophysics Bremerh.
Prof. Dr. Hans-Otto Pörtner	AWI Biology Bremerh.
Dr. Ulrich Schlüter	BMBF Bonn
Prof. Dr. Max Tilzer	AWI Director Bremerh.

4 INSTITUTIONS

AARI	Arctic and Antarctic Research Institute, St. Petersburg, Russia
AMCG	Dept. of Analytical and Marine Chemistry, Univ. Göteborg, Sweden
AOSB	Arctic Ocean Sciences Board
APL	Applied Physics Laboratory, Univ. Washington, Seattle, UAS
AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany
BMBF	Bundesministerium für Bildung und Forschung, Bonn, Germany
DWD	Deutscher Wetterdienst, Seewetteramt Hamburg, Germany
ESF	European Science Foundation, Strasbourg, France
EU	European Union, Commision in Brussels, Belgium
GEOMAR	GEOMAR Kiel, Germany
GUT	Geological Dept., Univ. Tromsø, Norway
HSVA	Hamburgische Schiffbau-Versuchsanstalt, Germany
HSW	Helicopter Service Wasserthal, Hamburg, Germany
IUH	Institut für Umweltphysik, Univ. Heidelberg, Germany
IO	P.P. Shirshov Institute of Oceanology, Moscow, Russia
IPÖ	Institut für Polarökologie, Kiel, Germany
KOWI	Koordinierungsstelle EU der Wissenschaftsorganisationen; Bonn & Brussels
L-DEO	Lamont-Doherty Observatory, Columbia Univ., Palisades , N.Y, USA
MMBI	Murmansk Marine Biological Institute RAS, Russia
SAIC	Science Applications International Corp., Seattle, W.A., USA
VNIIO	All-Russian Research Institute for Geology and Mineral Resources of the World Ocean, VNIIOkeangeologia, St. Petersburg, Russia
ZISP	Zoological Institute RAS, St. Petersburg, Russia
ZMK	Zentrum für Meeres- und Klimaforschung, Univ. Hamburg, Germany

5 Schiffsbesatzung / Ship's crew

Function	Name
Kapitän	H. Jonas
1. Offizier	I. Varding
Naut. Offizier	M. Block
Naut. Offizier	St. Schwarze
Naut. Offizier	N.N.
Arzt	U. Kapieske
Ltd. Ingenieur	K. Müller
1. Ingenieur	W. Delff
2. Ingenieur	H. Folta
2. Ingenieur	W. Simon
Elektriker	R. Erdmann
Elektroniker	K. Hoops
Elektroniker	A. Piskorzynski
Elektroniker	H. Pabst
Elektroniker	M. Froeb
Funkoffizier	Butz
Funkoffizier	W. Thonhauser
Koch	H.J. Schaefer
Kochsmaat	T. Voelske
Kochsmaat	M. Vavuz
1. Steward	A. Hopp
Stewardess	C. Lehmbecker
Stewardess	R. Klemet
Stewardess	B. Hildebrandt
Steward	B. Amran
2. Steward	C.L. Yu
2. Steward	C.L. Wu
Wäscher	C.C. Chang
Bootsmann	R. Loidl
Zimmermann	P. Kassubeck
Matrosen:	S. Moser
	H. Avcilar
	H. Thillmann
	J. Suarez Paisal
	J. Novo Loveira
	E. Dominguez
	N.N.
	N.N.
Lagerhalter	E. Barth
Maschinen-Warte	E. U. Hartmann
	H. Bloedorn
	J. Schade
	T. Rosenthal
	G. Fritz

6 The TRANSDRIFT III Expedition to the Laptev Sea on board the Russian Icebreaker 'KAPITAN DRANITSYN' (1.10.- 29.10.1995)

Heidemarie Kassens, GEOMAR Kiel

The impact of the polar regions on global climate development has been established some time ago. Modern climate models as well as paleoclimatic reconstructions have shown that the waxing and waning of the continental ice caps and changes in sea-ice distribution influence the renewal of deep and intermediate water masses and, therefore, thermohaline ocean circulation as well. However, our knowledge of the climate impact in the Arctic Ocean, e.g. of the influence of climate changes on sea-ice formation, is very limited, thus making it difficult to predict possible future global climate changes. This holds true in particular for the Siberian shelf seas, which, for logistical and political reasons, have long been inaccessible to the international scientific community.

Large amounts of Arctic sea ice are formed on these shelves, thus underscoring the central importance of these processes for the climate system. In its role as source area for the Transpolar Drift and of sediment loaded sea ice, the Laptev Sea is of particular interest. In this region it might be possible to demonstrate the extent to which global ocean circulation and, as a result, climate development are also influenced by extremely large amounts of freshwater transported into the Arctic Ocean through the Siberian river systems. Current oceanographic models have not yet taken such a direct terrestrial impact on the global climate into consideration.

The Russian scientific community has a long tradition in working on the Siberian Shelf Seas because of oil, gas and mineral resources found there and the economic advantages of the Northern Sea Route. Many data and numerous papers have been published, but only a small number of Russian scientific reports have been translated into a western language. Apart from data from American research programs in the 1960's and

some recent results from the Arctic Ocean which clearly point to the Siberian Shelf Seas in their central importance for the Arctic, little is known about the complex geosystem of the Laptev Sea.

However, in 1994 a major multidisciplinary research program 'Laptev Sea System' was designed between Russia and Germany to understand the Arctic environment and its significance for the global climate. Ongoing bilateral research activities in the scope of the 'Laptev Sea System' are including land and marine expeditions to the Laptev Sea area during different seasons of the year, workshops as well as the exchange of scientists. The GEOMAR Research Center for Marine Geosciences in Kiel, Germany, and the State Research Center for Arctic and Antarctic Research in St. Petersburg, Russia, are jointly responsible for organizing and coordinating the multidisciplinary project, which is funded by the Russian and German Ministries of Science and Technology.

The success of the pilot phase (AMEIS'91 to Kotelnyy, ESARE'92 to the Lena Delta and the New Siberian Islands, and TRANSDRIFT I on board RV IVAN KIREEV to the Laptev Sea in 1993) as well as the LENA'94 expedition to the River Lena and the TRANSDRIFT II expedition to the Laptev Sea on board RV PROFESSOR MULTANOVSKY in 1994 was very encouraging. That is why we decided to perform the next expedition TRANSDRIFT III during autum in order to study freeze-up processes in the Laptev Sea. It will be the first time that an expedition will be carried out during this season of the year. Consequently the expedition logistics is extremely difficult. The expedition on board the Russian icebreaker KAPITAN DRANITSYN, in which 50 scientists from Russia and Germany will take part, will start in Murmansk on the 1st of October. Its end is scheduled for the 30th of October in the port of Murmansk.

The main target area of the TRANSDRIFT III expedition will be the eastern Laptev Sea, e.g. the Lena Delta and the region of the Laptev Sea polynya. Scientific goals are:

- The influence of freeze-up on the environment and on depositional/erosional processes in the Laptev Sea,
- the processes of ice formation in open, turbulent water and associated entrainment of foreign substances,
- the influence of river discharge on new-ice formation,

- attempts to study sediment entrainment and subsequent dispersal by remote sensing techniques,
- the influence of sediment load in new ice on its spectral albedo,
- the influence of frazil ice in the water column and the new ice cover on biological productivity,
- and the influence of new-ice growth on water mass characteristics.

Working procedure:

- make ice observations combined with remote sensing by satellites,
- collect ice-, water-, and bottom samples (box corer, vibro corer),
- observe the formation of anchor ice in relationship to environmental parameters by use of dredging and other techniques,
- study the physical properties of ice.
- make measurements of CTD-, current-, and suspended matter,
- conduct chemical and biological studies of ice-, water-, and sediment samples,
- experiment with the entrainment of particulate and dissolved substances into new ice,
- and to make measurements on the relationship of depth of the thermocline and depth of suspension freezing.

Participating Institutions:

Arctic and Antarctic Research Institute, St. Petersburg
A.N. Krylov Central Research Institute, St. Petersburg
Lena Delta Reserve, Tiksi, Yakutia
Mitas & Redax Informatic, St. Petersburg
Regional Center for Monitoring of the Arctic, St. Petersburg
North-West Politechnition Institute, St. Petersburg
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Zoological Institute, RAS, St. Petersburg
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