Otto-Schmidt-Labor für Polar- und Meeresforschung

Schlussbericht 03PL037A

Bremerhaven, Kiel und St. Petersburg
Juli 2005

Schlussbericht

Zuwendungsempfänger:	Stiftung Alfred-Wegener-Institut für Polar- und Meeresforschung in der Helmholtz-Gemeinschaft (AWI) Am Handelshafen 12 27570 Bremerhaven
Projektleiter:	Prof. Dr. Jörn Thiede
Vorhabensbezeichnung:	Otto-Schmidt-Labor für Polar- und Meeresforschung FZK 03PL037A
Berichtszeitraum:	01.11.2002 bis 31.12.2004

Inhalt

I. SCHLUSSBERICHT - KURZE DARSTELLUNG

1. Aufgabenstellung des Vorhabens

Das Otto-Schmidt-Labor für Polar- und Meeresforschung (OSL) am Staatlichen Institut für Arktis und Antarktisforschung in St. Petersburg (AARI) ist seit 2000 eine ideelle und logistische Basis für Forschungsvorhaben, die im Rahmen der Fachvereinbarung zur Zusammenarbeit auf dem Gebiet der Meeres- und Polarforschung zwischen dem russischen Ministerium für Bildung und Wissenschaft (MON) und dem Bundesministerium für Bildung und Forschung (BMBF) durchgeführt werden. Es ist eine Plattform für die Koordination und Weiterentwicklung der bilateralen Forschungsvorhaben und fungiert als Schnittstelle im Netzwerk der beteiligten russischen und deutschen Forschungseinrichtungen und Universitäten. Vorrangig widmet es sich der wissenschaftlichen Qualifizierung und Förderung junger NachwuchswissenschaftlerInnen. Im Mittelpunkt des wissenschaftlichen Arbeitsprogramms steht die Erforschung des komplexen Umweltsystems der eurasischen Arktis. Hier sollen natürliche Hintergründe, Auswirkungen und Rückkoppelungsmechanismen von kurzfristigen Klimaveränderungen erfasst werden.

Mit dem Vorhaben sollen die Erfolge des im Jahr 2000 gegründeten Forschungslabors (FKZ 03PL026A) für den Antragszeitraum gesichert werden. Übergeordnet wurden folgende Ziele gesetzt:

- Aufrechterhaltung des Routinebetriebes und Optimierung der wissenschaftlich-technischen Nutzung des Labors,
- weiterführende fächer- und projektübergreifende Auswertung von bilateralen Vorhaben im Bereich der Polar- und Meeresforschung,
- Nachwuchsförderung,
- Förderung der Wissenschaftskooperation zwischen Russland und Deutschland.

2. Voraussetzungen des Vorhabens

Das wissenschaftliche Fundament für das OSL sind die in den neunziger Jahren durchgeführten bilateralen Forschungsvorhaben (insbesondere System Laptev-See: FZK 03G0517, 1.3.1994 bis 28.2.1997; Aufstockung 1.3.1997 bis 31.12.1997; System

Laptev-See 2000: FZK 03G0534, 1.1.1998 bis 30.6.2001). Die gut abgestimmte wissenschaftliche und technische Zusammenarbeit mit den russischen Partnern und die sich hier abzeichnenden Perspektiven für eine weitere Vertiefung der Zusammenarbeit waren gute Voraussetzungen zum Aufbau und Betrieb eines gemeinsamen Forschungslabors. Gewachsen ist daraus in der Zwischenzeit eine enge wissenschaftliche und menschliche Partnerschaft zwischen Polarforschern aus Deutschland und Russland.

3. Planung und Ablauf des Vorhabens

Das OSL in St. Petersburg wurde in der Pilot- und Ausbauphase (FKZ 03PL026A, 1999 bis 2002) mit einer wissenschaftlich-technischen Basisausstattung eingerichtet (Abb. 1), und seit Juli 2000 steht die Förderung des wissenschaftlichen Nachwuchses im Mittelpunkt des jährlich neu ausgeschriebenen Stipendienprogramms.

Die Projektaufgaben im Rahmen der zweiten Ausbauphase wurden, trotz des um drei Monate verspäteten Projektbeginns, erfolgreich durchgeführt. Allerdings musste der Beginn der Stipendienprogramme 2002/2003 und 2003/2004 zeitlich verschoben werden (1.1.2003 bis 31.12.2003 bzw. 1.2.2004 bis 31.12.2004). Um dennoch den erfolgreichen Abschluss des Stipendienprogramms 2003/2004 und den laufenden Betrieb des OSL zu gewährleisten, wurde das Projekt kostenneutral bis zum 31.12.2004 verlängert (ursprüngliches Abschlussdatum des Projektes war der 31.8.2004).

Weitere Einzelheiten sind dem Abschlussbericht für das Pilotvorhaben (FKZ 03PL026A) und dem Zwischenbericht 2003 für dieses Vorhaben zu entnehmen (Kopien der Berichte sind auf der anliegenden CD abgespeichert).

4. Wissenschaftlicher und technischer Stand bei Projektbeginn

In der Russischen Föderation gab es vor der Gründung des OSL keine vergleichbare Einrichtung. So wurden bereits vor Beginn der Pilotphase die Struktur und die Organisation des OSL gemeinsam von VertreterInnen des BMBF, MON, IFM-GEOMAR,

Abb. 1: Im OSL am AARI in St. Petersburg wurde ein modernes wissenschaftliches Labor für die Fachgebiete Ozeanographie, Meeres- und Geochemie, Biologie, Sedimentologie und Mikropaläontologie eingerichtet.

AARI und AWI entwickelt und im Oktober 1999 in einemVertrag über den Aufbau und den Betrieb des OSL festgelegt. Mit dem OSL wurde somit in beiden Ländern Neuland betreten. Besondere Meilensteine waren dabei:

- die Entwicklung eines effizienten Kooperationsmodels mit einem leistungsstarken Koordinationsbüro,
- die interdisziplinäre Vernetzung der Forschungsarbeiten im Rahmen der Fachvereinbarung zur Zusammenarbeit auf dem Gebiet der Meeres- und Polarforschung zwischen dem MON und dem BMBF,
- der Aufbau und die Einrichtung eines modernen wissenschaftlichen Labors für die Fachgebiete Ozeanographie, Meeres- und Geochemie, Biologie, Sedimentologie und Mikropaläontologie am AARI in St. Petersburg,
- die administrative Verwaltung des Projektes nach deutschem Vorbild,

- das jährlich öffentlich ausgeschriebene Stipendienprogramm zur Aus- und Weiterbildung von russischen NachwuchswissenschaftlerInnen im Bereich der Meeres- und Polarforschung,
- die wissenschaftliche Bewertung der Stipendienanträge (Punktesystem) durch den Wissenschaftlichen Beirat des OSL,
- die praxisbezogene Aus- und Weiterbildung von Studierenden durch den Masterstudiengang für angewandte Polar- und Meereswissenschaften POMOR.

5. Zusammenarbeit

Die Wissenschaftskooperation zwischen russischen und deutschen Universitäten und Forschungseinrichtungen auf dem Gebiet der Polar- und Meeresforschung konnte durch die Aktivitäten des OSL deutlich vertieft werden. Die Einbindung vieler russischer Forschungseinrichtungen und Universitäten wurde dadurch gewährleistet, dass die StipendiatInnen direkt in die gemeinsame Forschung eingebunden wurden. So haben sich 16 Forschungseinrichtungen aus St. Petersburg, Moskau, Kazan, Jakutsk und Tiksi an dem Stipendienprogramm beteiligt (vgl. Anhang). Diese institutionelle Einbindung wurde durch die Besetzung des Wissenschaftlichen Beirats des OSL verstärkt. Die Zusammenarbeit mit der Staatlichen Universität St. Petersburg und dem Verbund der Norddeutschen Universitäten wurde durch die enge Kooperation bei der Planung und Durchführung des Masterstudienganges für Angewandte Polar- und Meereswissenschaften (POMOR) deutlich intensiviert.

Darüber hinaus ist es gelungen, auf nationaler und internationaler Ebene neue Partnerschaften zu bilden (siehe auch Zwischenbericht 2003). So wurde im Juli 2003 in direkter Nachbarschaft zum OSL unter Federführung des Norwegischen Polar-Institutes in Tromsø das „Fram Arctic Laboratory“ eröffnet (Abb. 2). Außerdem haben die Chefs der Staats- und Senatskanzleien der norddeutschen Länder im Anschluss an den Besuch der Ministerpräsidentin des Landes Schleswig-Holstein Heide Simonis im OSL beschlossen, das OSL als gemeinsame Initiative der deutschen Küstenländer mit St. Petersburg auf politischer Ebene zu unterstützen (Abb. 2). Eine breite politische Unterstützung findet das OSL auch im Rahmen des Petersburger Dialogs. So wurde die Projektleitung eingeladen, das bilaterale Forschungsmodell OSL persönlich anhand einer aktuellen Farbbroschüre und eines Posters auf dem Petersburger Dialog zu präsentieren (am 10. bis 12.4.2003 in St. Petersburg und am 9.

bis 10.9.2004 in Hamburg). Das OSL unterstützte zudem die Durchführung des 9. Arbeitstreffens im Rahmen der Fachvereinbarung zur Zusammenarbeit auf dem Gebiet der Meeres- und Polarforschung zwischen dem MON und dem BMBF sowie diverse Rundtischgespräche zur Anbahnung weiterer Kooperationen.

Abb. 2: Eröffnung des „Fram Arctic Laboratory" im Juli 2003 durch den norwegischen Umweltminister Børge Brende (links). Die Ministerpräsidentin des Landes Schleswig-Holstein Heide Simonis informiert sich über das OSL und den Masterstudiengang POMOR.

II. SCHLUSSBERICHT - EINGEHENDE DARSTELLUNG

1. Eingehende Darstellung der erzielten Ergebnisse

Das OSL hat sich in der Pilotphase (1999 bis 2002) und in der Ausbauphase zu einem international anerkannten Forschungslabor entwickelt. Neunzehn Forschergruppen und fünf Graduierte wurden 2003 und 2004 im Rahmen des Stipendienprogramms unterstützt. Die Forschungsergebnisse wurden auf vielen nationalen und internationalen Tagungen präsentiert (146 Tagungsbeiträge) und in 99 Veröffentlichungen publiziert (vgl. Anhang). Hervorzuheben ist dabei ein Sonderband in der internationalen Fachzeitschrift „Global and Planetary Change". Darüber hinaus wurden fünf Dissertationen und drei Diplomarbeiten abgeschlossen (vgl. Anhang).

Der wissenschaftliche Austausch zwischen den Stipendiaten und mit den Partnerwissenschaftlern in Deutschland wurde im Berichtszeitraum durch zwei Arbeitstreffen in St. Petersburg (12. bis 13.5.2004) und Kiel (2. bis 4.12.2004) und 20 mehrwöchige Gastwissenschaftleraufenthalte an deutschen Forschungseinrichtungen und Universitäten gewährleistet (vgl. Anhang). An den Arbeitstreffen haben auch Vertreter des Wissenschaftlichen Beirats des OSL und des MON teilgenommen.

Darüber hinaus nutzt eine Reihe russischer Forschungseinrichtungen das analytische Labor, werden Tagungen und Arbeitstreffen durchgeführt, und sechs Expeditionen in die sibirische Arktis wurden logistisch unterstützt. Deutlich ausgebaut wurde der Schwerpunkt „Wissenschaftliche Qualifizierung und Förderung junger NachwuchswissenschaftlerInnen“. So wurde im OSL eine „Spring School for Analytical Methods in Marine and Polar Science“ mit 28 Teilnehmern von 10 russischen Forschungseinrichtungen durchgeführt (29.3. bis 2.4.2004). Mit Unterstützung des OSL wurden im Rahmen des Masterstudiengangs POMOR moderne und praxisorientierte Lehrveranstaltungen auf internationalem Niveau realisiert und unter der Leitung von OSL-MitarbeiterInnen haben 19 Studierende an internationalen Feldpraktika in die Arktis teilgenommen (Abb. 3). Fünf POMOR-Absolventen haben ihre wissenschaftlichen Tätigkeiten im Rahmen der laufenden bilateralen Projekte fortgesetzt und Ende 2004 mit ihren vom AARI finanzierten Doktorarbeiten in der Ozeanographie, Meteorologie, Eisphysik und Hydrologie am AARI/OSL begonnen.

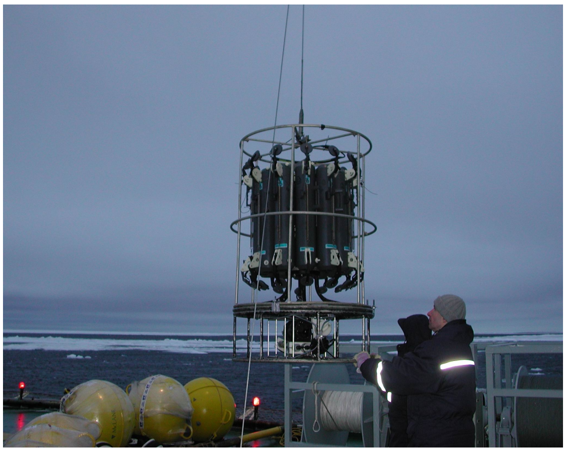

Abb. 3: Die wissenschaftliche Qualifizierung und Förderung von NachwuchswissenschaftlerInnen zählt zu den Hauptaufgaben des OSL. So wurden im Sommer 2003 zwei Feldpraktika mit Studierenden des Masterstudiengangs POMOR nach Spitzbergen (links) und in den zentralen Arktischen Ozean an Bord des Eisbrechers „Kapitan Dranitsyn“ (rechts) durchgeführt.

In den letzten fünf Jahren ist es dem OSL gelungen, als internationales Beispiel für ein bilaterales Forschungslabor zu fungieren. So wurde im Jahr 2003 in direkter Nachbarschaft zum OSL das „Fram Arctic Laboratory“ eröffnet, welches die OSL-Strukturen übernommen hat (vgl. I.5). Im Mittelpunkt des norwegisch-russischen Forschungslabors steht die Erforschung der Klima- und Umweltbedingungen in der Barents-See. Beide Labore haben ihre aufeinander abgestimmten Stipendienprogramme gemeinsam ausgeschrieben. So werden die Synergien der Förderung der russischen Arktisforschung beider Programme genutzt. Das große internationale Interesse spiegelt sich auch in den Besuchen vieler nationaler und internationaler Persönlichkeiten und Delegationen wider. Dazu zählen:

- Mikhail Efimovich Nikolaev, ehemaliger Präsident der Republik Sacha (2/03),
- Matvey Vasilyevich Muchin, Vize-Premierminister der Republik Sacha und Ständiger Vertreter der Republik Sacha in St. Petersburg (2/03),
- Børge Brende, norwegischer Umweltminister (3/03 und 7/03),
- Ivan Fedorovich Glumov, stellvertretender Minister für natürliche Rohstoffe der Russischen Föderation (7/03),
- Heide Simonis, ehemalige Ministerpräsidentin des Landes Schleswig-Holstein (9/03),
- Rinat Raupovich Murzin, Leiter der Abteilung für Ressourcen der Binnenmeere, der Territorialmeere, des Kontinentalschelfs und des Weltozeans im Ministerium für natürliche Rohstoffe der Russischen Föderation (6/04),
- Garrett Brass, Executive Director US Arctic Research Commission (6/04),
- Philip Alexander Symonds, Senior Adviser – Law of the Sea in the Petroleum and Marine Division of Geoscience Australia (6/04).

2. Voraussichtlicher Nutzen, Verwertbarkeit der Ergebnisse

Generell förderte das Vorhaben die Zusammenarbeit im Forschungs- und Bildungsbereich beider Länder und führte damit zur weiteren Vertiefung der guten Beziehungen. Durch den Aufbau der Beziehungen zu beiderseitigem Vorteil in einem Bereich vergleichbarer Potenziale ist es gelungen, in beiden Ländern gleichermaßen die Wettbewerbsfähigkeit der Wissenschaft zu fördern. Zu den zentralen Aufgaben des OSL zählt, Studierende und NachwuchswissenschaftlerInnen beider Länder gemeinsam auszubilden und ihre Zusammenarbeit mit europäischer Perspektive zu fördern. Durch die gemeinsame Förderung von NachwuchswissenschaftlerInnen wird eine wichtige Voraussetzung für die weitere Entwicklung produktiver, bilateraler Wissenschaftbeziehungen geschaffen.

3. Fortschritt auf dem Gebiet bei anderen Stellen

Das OSL-Konzept wird national und international als neues Forschungsmodell anerkannt. Ein gutes Beispiel dafür ist die Einrichtung des „Fram Arctic Laboratory“. Interesse zeigen nicht nur europäische Forschungseinrichtungen, sondern auch Institutionen aus den USA, China und Indien.

Ein großer Fortschritt war die Einrichtung des Masterstudienganges POMOR. In enger Zusammenarbeit mit der Staatlichen Universität St. Petersburg und dem Verbund der Norddeutschen Universitäten wird dieses Projekt von den MitarbeiterInnen des OSL koordiniert und durchgeführt. Das Projekt wird seit August 2001 maßgeblich vom DAAD im Rahmen des Programmes „Export deutscher Studienangebote“ gefördert (vgl. Zwischenbericht 2003).

Auch der Aufbau und die Einrichtung des Büros der Helmholtz-Gemeinschaft (HGF) in Moskau mit einer geplanten Nebenstelle am OSL in St. Petersburg zählt zu den Fortschritten des Vorhabens, denn diese Initiative ist auf Mitarbeiterinnen des OSL zurückzuführen. Das HGF-Büro in Moskau wurde im Februar 2005 offiziell eingeweiht.

4. Veröffentlichungen der Projektmitarbeiterinnen und -mitarbeiter

Eine Liste der Veröffentlichungen im Rahmen der Stipendienprogramme ist im Anhang aufgeführt.

III. ERFOLGSKONTROLLBERICHT

1. Beitrag der Ergebnisse zu den förderpolitischen Zielen des Förderprogramms

Das interdisziplinäre Vorhaben widmete sich bei der Durchführung von wissenschaftlichen Forschungsaufgaben im Bereich der Erdsystemforschung den zentralen Zielsetzungen der deutschen Forschungsprogramme „Polarforschung“ und „Geotechnologien“ (Forschungsschwerpunkte „Methan im Geosystem“ und „Globale Klimaänderungen: Ursachen und Auswirkungen“) sowie des russischen Forschungsprogrammes „Weltozean“ (Unterprogramm: Natur des Weltozeans; Abteilung: Interdisziplinäre Forschung und Monitoring der arktischen Meere Russlands). Durch die logistische und inhaltliche Unterstützung der bilateralen BMBF-Vorhaben auf dem Gebiet der Meeres- und Polarforschung wurde die wissenschaftlich-technische Zusammenarbeit auf eine breite Basis gestellt.

2. Wissenschaftlicher und technischer Erfolg des Vorhabens und wesentliche Erfahrungen

Das OSL bietet jungen russischen WissenschaftlerInnen hervorragende Forschungs- und Weiterbildungsmöglichkeiten in der Polar- und Meeresforschung in ihrem Heimatland. Ihnen wird dadurch der Anschluss an die internationale Forschergemeinde deutlich erleichtet. So werden den StipendiatInnen Perspektiven für weitergehende wissenschaftliche Karrieren sowohl im eigenen Land als auch auf internationaler Ebene eröffnet. Ein gutes Beispiel zur Nutzung dieses Potenzials sind die Tatsache, dass OSL-StipendiatInnen international erfolgreich abgeworben worden sind, sowie zahlreiche nationale Auszeichnungen für die StipendiatInnen in den Jahren 2003 und 2004 (Auszeichnungen, die im Rahmen der Pilotphase verliehen wurden, sind im Schlussbericht 03PL026A aufgeführt):

- Irina Akhmetshina (OSL-02-01): Für ihren Vortrag „Peculiarities of diel vertical migrations of Copepoda on the Laptev Sea shelf" auf der alljährlichen Konferenz „Students' Conference of the Kazan State University 2003" am 17. April 2003 erhielt I. Akhmetshina den mit ca. 1.000 Rubel dotierten Preis für den besten Vortrag.
- Dmitry Streletskiy (OSL-02-11): D. Streletskiy wurde als Gewinner des „Soros Student 2003"-Wettbewerbs von der Soros Foundation mit einem Stipendium in Höhe von 10.000 Rubel ausgezeichnet.
- Anna Stepanova (OSL-02-30): A. Stepanova erhielt 2003 eine Goldmedaille von der Moscow State University für ihre hervorragende Diplomarbeit. Sie wurde aufgefordert, diese Arbeit in erweiterter Form als Dissertation einzureichen. Ihr Diplom ist ein im Russischen so genanntes „rotes Diplom", d.h. ein Diplom mit vorwiegend ausgezeichneten Noten. Im Jahr 2004 wurde die Doktorarbeit erfolgreich verteidigt. Des Weiteren erhielt sie im Paleontological Institute RAS den Hans-Rausing-Preis für die beste Veröffentlichung unter Nachwuchspaläontologen für ihren Artikel: Stepanova, A., Taldenkova, E., and Bauch, H.A. (2003) Recent Ostracoda of the

Laptev Sea (Arctic Siberia): taxonomic composition and some environmental implications. Marine Micropaleontology, 48 (1-2), pp. 23-48.

- Sergey Dem'yankov (OSL-02-30): S. Dem'yankov wurde als Gewinner des „Soros Student 2003"-Wettbewerbs von der Soros Foundation mit einem Stipendium in Höhe von 10.000 Rubel ausgezeichnet.
- Mikhail Grigoriev (OSL-03-06): M. Grigoriev wurde von der populärwissenschaftlichen jakutischen Zeitschrift „Science and Engineering in Yakutia" für den besten Zeitschriftenartikel 2004 für seinen Beitrag: M.N. Grigoriev (2004), Destruction of ice-rich coasts of Yakutia (Science and Engineering in Yakutia, 1 (6), S. 29-35) ausgezeichnet.
- Miroslav Nitishinsky (OSL-03-17): M. Nitishinsky erhielt als Nachwuchswissenschaftler des Rosgidromet 2004 den A.Ya.-Kupfer-Preis für seine Dissertation: Nitishinsky, M. (2002) Seasonal variability of hydrochemical characteristics and nutrient fluxes in the Laptev Sea. State Research Center - Arctic and Antarctic Research Institute, 2002.
- Anna Stepanova (OSL-03-24): A. Stepanova erhielt 2004 zum zweiten Mal im Paleontological Institute RAS den Hans-Rausing-Preis für die beste Veröffentlichung unter Nachwuchspaläontologen für ihren Artikel: Stepanova, A., Taldenkova, E., and Bauch, H.A. (2004) Ostracod species of the genus *Cytheropteron* from late Pleistocene-Holocene and recent sediments of the Laptev Sea (Arctic Siberia). Revista Española de Micropaleontología, 36 (1), pp. 83-108.
- Irina Veshnyakova (OSL-03-01): I. Veshnyakova wurde für ihre Diplomarbeit (Titel: „The pelagic fauna of the different water pools in the Lena Delta") durch die Universität Kazan ausgezeichnet.
- Anna Bryantseva (OSL-03-12): Der Vortrag „Pleistocene diatoms from the New Siberian Islands and Lena Delta region", den A. Bryantseva auf der Tagung „First All-Russia Science School of Young Paleontologists" (Moskau, 20.-24. Oktober 2004) hielt, wurde als bester Vortrag der Tagung ausgezeichnet.

Insgesamt wurde mit dem OSL und vor allem mit dem Stipendienprogramm das bestehende deutsch-russische Netzwerk intensiviert. So konnten eine deutliche Erleichterung und Effizienzerhöhung der wissenschaftlichen Arbeiten für die Vorhaben der Fachvereinbarung erreicht werden.

3. Fortschreibung des Verwertungsplans

Das Konzept des OSL, die Förderung junger russischer WissenschaftlerInnen mit Arbeitsmöglichkeiten auf hohem internationalen Niveau im eigenen Land, hat sich bewährt und soll zu einem festen Bestandteil der Forschungslandschaft auf dem Gebiet der Polar- und Meeresforschung werden. Seit 2005 wird die Grundfinanzierung des OSL vom Alfred-Wegener-Institut für Polar- und Meeresforschung, vom Leibniz-Institut für Meereswissenschaften (IfM-GEOMAR) und vom Staatlichen Institut für Arktis- und Antarktisforschung getragen. Die Kernaufgabe des OSL, die Qualifizierung und Förderung von russischen NachwuchswissenschaftlerInnen, wird mit einem vom BMBF geförderten Stipendienprogramm „Umweltsysteme im Umbruch" unterstützt. Die wissenschaftliche Flankierung von laufenden Vorhaben im Rahmen der Vereinbarung zur Zusammenarbeit auf dem Gebiet der Meeres- und Polarforschung zwischen dem MON und dem BMBF steht dabei im Vordergrund.

4. Arbeiten, die zu keiner Lösung geführt haben

Insgesamt ist das Projekt sehr positiv verlaufen und die geplanten Arbeiten konnten erfolgreich durchgeführt werden. Zollprobleme gab es jedoch, wie bereits in der Pilotphase, bei der offiziellen Einfuhr von wissenschaftlichen Geräten und Ersatzteilen nach Russland. Dies führt – vor allem zu Lasten der StipendiatInnen - immer wieder zu Verzögerungen im Laborbetrieb (vgl. Zwischenbericht 2003).

5. Wissenstransfer auf weitere Nutzer

Das OSL ist ein wichtiger Baustein auf dem Weg der gemeinsamen Polar- und Meeresforschung beider Länder und dient als Modell für eine neue Form internationaler Kooperationsvorhaben. Mit dem OSL und vor allem mit dem Stipendienprogramm wurde das bestehende deutsch-russische Netzwerk deutlich intensiviert. Das OSL soll sich mittelfristig zur Koordinationsstelle für die deutsch-russische Zusammenarbeit auf dem Gebiet der Polar- und Meeresforschung entwickeln und langfristig internationale Vorhaben anderer Förderinstitutionen unterstützen. Es sollen komplexe und/oder langfristige Vorhaben initiiert und realisiert und die wissenschaftlichen und logistischen Synergieeffekte der laufenden bilateralen Projekte besser genutzt werden.

6. Einhaltung der Kosten- und Zeitplanung

Es ist gelungen die Kostenplanung einzuhalten. Einzelheiten sind den Verwendungsnachweisen des Vorhabens zu entnehmen. Die Zeitplanung hat sich verschoben (vgl. I.3).

Berichtsblatt

1. ISBN oder ISSN

2. Berichtsart
Schlussbericht

3a. Titel des Berichts
Abschlussbericht zu dem Vorhaben "Otto-Schmidt-Labor für Polar- und Meeresforschung"

3b. Titel der Publikation

4a. Autoren des Berichts (Name, Vorname(n))
Kassens, Heidemarie und die MitarbeiterInnen des Vorhabens

4b. Autoren der Publikation (Name, Vorname(n))
Vgl. Anhang des Abschlussberichtes

5. Abschlußdatum des Vorhabens
31.12.2004

6. Veröffentlichungsdatum

7. Form der Publikation

8. Durchführende Institution(en) (Name, Adresse)
Alfred-Wegener-Institut für Polar- und Meeresforschung (Am Handelshafen 12, 27570 Bremerhaven)
Staatliches Institut für Arktis- und Antarktisforschung (Bering St. 38, 199397 St. Petersburg, Russland)
Leibniz-Institut für Meereswissenschaften IFM-GEOMAR (Wischhofstr. 1-3, 24148 Kiel)

9. Ber.Nr. Durchführende Insitution

10. Förderkennzeichen *)
03PL037A

11a. Seitenzahl Bericht
15 + Anhang

11b. Seitenzahl Publikation

12. Literaturangaben
253

13. Fördernde Institution (Name, Adresse)
Bundesministerium für
Bildung und Forschung (BMBF)

53170 Bonn

14. Tabellen

15. Abbildungen
3

16. Zusätzliche Angaben

17. Vorgelegt bei (Titel, Ort, Datum)

18. Kurzfassung

Das Otto-Schmidt-Labor für Polar- und Meeresforschung (OSL) hat sich in der Pilot- und Ausbauphase zu einem international anerkannten Forschungslabor entwickelt. Es dient der Koordination und Weiterentwicklung von bilateralen Forschungsvorhaben im Bereich der Meeres- und Polarforschung und fungiert als Schnittstelle im Netzwerk der russischen und deutschen Institute. Vorrangig widmet es sich der Qualifizierung junger Nachwuchswissenschaftler mit einem Stipendienprogramm.
Das OSL soll sich mittelfristig zur Koordinationsstelle für die deutsch-russische Forschungszusammenarbeit auf dem Gebiet der Polar- und Meeresforschung entwickeln.
Die beantragte Aufgabenstellung wurde unter Einhaltung des Kosten- und Zeitplans erfolgreich durchgeführt.

19. Schlagwörter
Russisch-deutsche Zusammenarbeit im Bereich der Meeres- und Polarforschung, Klimaforschung in der sibirischen Arktis

20. Verlag

21. Preis

*) Auf das Förderkennzeichen des BMBF soll auch in der Veröffentlichung hingewiesen werden.

Document Control Sheet

1. ISBN or ISSN	2. Type of Report Final report
3a. Report Title Final report of the project "Otto Schmidt Laboratory for Polar and Marine Research"	
3b. Title of Publication	
4a. Author(s) of the Report (Family Name, First Name(s)) Kassens, Heidemarie and the colleagues of the project	5.End of Project 31.12.2004
	6. Publication Date
4b. Author(s) of the Publication (Family Name, First Name(s)) See Appendix to the final report	7. Form of Publication
8. Performing Organization(s) (Name, Address) Alfred-Wegener-Institut für Polar- und Meeresforschung (Am Handelshafen 12, 27570 Bremerhaven) State Research Center Arctic and Antarctic Research Institute (38, Bering St., 199397 St. Petersburg, Russia) Leibniz-Institut für Meereswissenschaften IFM-GEOMAR (Wischhofstr. 1-3, 24148 Kiel)	9. Originator's Report No.
	10. Reference No. 03PL037A
	11a. No. of Pages Report 15 + Appendix
	11b. No. of Pages Publication
13. Sponsoring Agency (Name, Address) Bundesministerium für Bildung und Forschung (BMBF) 53170 Bonn	12. No. of References 253
	14. No. of Tables
	15. No. of Figures 3
16. Supplementary Notes	
17. Presented at (Title, Place, Date)	

18. Abstract

During the pilot and extension phases the Otto Schmidt Laboratory for Polar and Marine Research (OSL) has developed into an internationally recognized research laboratory. Its purpose is to coordinate and further develop bilateral research projects in the field of marine and polar research. The OSL functions as an interface in the network of the Russian and German institutions. For the main part it is concerned with the qualification of young scientists by way of its fellowship program.

The OSL is planned to develop in the longer run into a coordination center for German-Russian cooperation in the field of polar and marine research.

The planned tasks were successfully carried out according to the project's financial and working schedule.

19.Keywords

Russian-German cooperation in the field of marine and polar research, climate research in the Siberian Arctic

20. Publisher	21. Price

V. ANHANG

Liste der Stipendienprogramme 2002/2003 und 2003/2004

OSL-	Titel	Stipendiaten	Institution	Publikationen als Erstautor	Tagungsbeiträge als Erstautor	Anzahl der Gastverträge
02-01	Historical-faunistic, ecological, population, and production analysis of zooplankton from lakes of different regions and geomorphological levels in the Lena Delta	E. Abramova (Leiterin) I. Akhmetshina (Studentin) E. Vinogradova (Studentin)	Lena Delta Nature Reserve, Tiksi Kazan University, Tatarstan	1	2	1
02-05	Hydrological response of the Lena river basin to climatic change	S. Berezovskaya (Doktorandin)	Russian State Hydrometeorological University, St. Petersburg		3	
02-08	Submarine and Terrestrial permafrost in the eastern Laptev Sea region: a comparative study	S. Drachev (Leiter) M. Kasymskaya (Diplomandin) V. Kaulio (Doktorand)	VNIIOkeangeologia, St. Petersburg Moscow State University, Moscow St. Petersburg State University, St. Petersburg	1	5	
02-09	Evolution of the lacustrine geosystems of the Taimyr Peninsula	G. Fedorov (Doktorand)	Arctic and Antarctic Research Institute, St. Petersburg			
02-11	The Laptev and East Siberian Seas coastal erosion database dynamics, classification, sedimentation, sediment and organic carbon content	M. Grigoriev (Leiter) I. Shapovalova (Diplomandin) D. Streletskiy (Diplomand)	Permafrost Institute RAS, Yakutsk Moscow State University, Moscow	6	5	1
02-13	Spatial variations in ice formation onset in the Laptev Sea: consequence of the vertical heat fluxes caused by internal waves overturning	S. Kirillov (Doktorand)	Arctic and Antarctic Research Institute, St. Petersburg	1	1	
02-16	Late Pleistocene and Holocene paleoenvironmental conditions, their changes and influence on the distribution of mammals in the Laptev Sea surroundings	T. Kuznetsova (Leiterin) N. Noskova (Doktorandin) A. Bryantseva (Studentin)	Moscow State University, Moscow	1	3	
02-22	High-resolution reconstruction of Lena river discharge patterns during the late Holocene	E. Polyakova (Leiterin) T. Klyuvitkina, geb. Novichkova (Doktorandin) E. Golovnina (Studentin)	Moscow State University, Moscow	1	9	4
02-27	Reconstruction of Late Pleistocene Seasonal Temperatures in the Siberian Arctic	A. Sher (Leiter) S. Kuzmina	Severtsov Institute of Ecology and Evolution RAS, Moscow Paleontological	7	7	2

OSL-	Titel	Stipendiaten	Institution	Publikationen als Erstautor	Tagungsbeiträge als Erstautor	Anzahl der Gastverträge
	Lowlands Based on Insect Fossils: the Mutual Climatic Range Method	(Postdoc) A. Sokolov (Doktorand)	Institute RAS, Moscow Severtsov Institute of Ecology and Evolution, RAS, Moscow			
02-30	Postglacial and Holocene environments of the western Laptev Sea and eastern Kara Sea as reflected in fossil assemblages	E. Taldenkova (Leiterin) A. Stepanova (Diplomandin) S. Dem'yankov (Diplomand)	Moscow State University, Moscow	1	9	2
03-01	The role of mesozooplankton in sedimentation of organic and inorganic matter on the Laptev Sea shelf	E. Abramova (Leiterin) S. Kirillov (Doktorand) I. Veshnyakova, geb. Akhmetshina (Studentin)	Lena-Delta Nature Reserve, Tiksi Arctic and Antarctic Research Institute, St. Petersburg Kazan University, Tatarstan	2	1	2
03-02	Varved lacustrine sediments as an indicator of the last millenium paleoenvironment of the Russian Arctic	D. Bolshiyanov (Leiter) M. Pavlov (Postdoc) A. Makarov (Student)	Arctic and Antarctic Research Institute, St. Petersburg St. Petersburg State University	2		
03-06	An assessment of the distribution and evolution of the sub-sea permafrost in the near-shore zone of the Laptev Sea	M .Grigoriev (Leiter) I. Shapovalova (Diplomandin) G. Kraev (Student)	Permafrost Institute SB RAS, Yakutsk Moscow State University, Moscow	6	7	
03-07	Comparison of Late Quaternary environments at the North Kara – North Laptev key sites	E. Gusev (Leiter) P. Rekant (Postdoc) K. Malinkin (Doktorand)	VNIIOkeangeologia St. Petersburg State Mining Institute		1	1
03-11	Assessment of contribution of zooplankton to vertical carbon fluxes in the Kara and White seas from experimental data and sediment trap collections	K. Kosobokova (Leiterin) D. Martynova (Doktorandin) A. Prudkovsky (Doktorand)	P.P. Shirshov Institute of Oceanology RAS, Moscow Zoological Institute RAS, Moscow Moscow State University, Moscow	1	3	
03-12	Unique (non-analogue) paleoenvironmental conditions of Late Pleistocene and Holocene terrestrial ecosystems of the Laptev Sea surroundings (detailed reconstruction)	T. Kuznetsova (Leiterin) N. Noskova (Doktorandin) A. Bryantseva (Studentin)	Moscow State University, Moscow	3	6	1

OSL-	Titel	Stipendiaten	Institution	Publikationen als Erstautor	Tagungsbeiträge als Erstautor	Anzahl der Gastverträge
03-14	Gas hydrate forming fluid vents in the Sea of Okhotsk: hydro-geochemical studies	T. Matveeva (Leiterin) L. Mazurenko (Doktorand) E. Logvina (Studentin)	VNIIOkeangeologia, St. Petersburg St. Petersburg State University	4	4	
03-17	Nutrient budgets in the coastal areas, estuaries, and estuarine zones in the Siberian arctic seas	S. Pivovarov (Leiter) M. Nitishinsky (Postdoc) A. Novikhin (Doktorand)	Arctic and Antarctic Research Institute, St. Petersburg	1	2	
03-18	Comparison of postglacial shelf evolution between the Kara and Laptev seas using fossil algae assemblages	E. Polyakova (Leiterin) T. Klyuvitkina (Doktorandin) E. Golovnina (Studentin)	Moscow State University, Moscow	8	8	1
03-20	Palynological study of the cores from the Laptev Sea shelf in order to investigate paleoclimate and paleovegetation evolution	V. Razina (Doktorandin)	St. Petersburg State University			
03-21	Evolution and modern condition of the permafrost and the gas hydrate stability zone on the arctic shelf of Eastern Siberia	N. Romanovskii (Leiter) A. Eliseeva (Doktorandin) A. Belan (Studentin)	Moscow State University, Moscow	2	4	
03-23	Pathways and fluxes of natural and anthropogeni tracers in the western Russian arctic seas	V. Shevchenko (Leiter) A. Novigatsky (Doktorand) A. Klyuvitkin (Doktorand)	P.P. Shirshov Institute of Oceanology RAS, Moscow	5	10	
03-24	Late Pleistocene-Holocene and recent ostracods of the Laptev Sea (Arctic Siberia): detailed taxonomic studies and applications to paleoenvironmental reconstructions	A. Stepanova (Doktorandin)	Paleontological Institute RAS	1	4	1
03-25	Postglacial environmental changes in the western Laptev Sea: evidence from fossil benthic assemblages, isotope composition of microfossils and geochemical data	E. Taldenkova (Leiterin) S. Dem'yankov (Diplomand) A. Strezh (Studentin)	Moscow State University	2	2	

Kurzfassungen des Stipendienprogramms 2002/2003

Historical-Faunistic, Ecological, Population, and Production Analysis of Zooplankton from Lakes of Different Regions and Geomorphological Levels in the Lena Delta

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[1]Lena Delta Nature Reserve, Tiksi, Russia
[2]Kazan University, Tatarstan, Russia

The project is aimed at investigating zooplankton in the lakes from different regions and geomorphological levels of the Lena Delta for understanding peculiar features of the modern pelagic fauna of this big region and the history of its formation. The main results are:

- in the lakes of the Lena Delta, 128 taxa of zooplankton belonging to 2 types (Rotatoria and Arthropoda) were determined.
- the species composition is very similar in polygonal ponds situated in different parts of the delta. A remarkable difference in the species composition is typical for large thermokarst lakes as well as for alas lakes.
- the highest abundance, biomass and production of zooplankton were observed in the polygonal and flood-plain lakes of the first terrace, which are regularly influenced by river water. The seasonal dynamics of quantitative characteristics shows a well-pronounced conformity connected with environment conditions and the life cycle of the common species.
- the pelagic fauna of the lakes is of heterogeneous origin and consists mainly of both recent and modern freshwater elements with amphibiotic brackish-waters organisms of neolimnic assemblage.

Hydrological Response of the Lena River Basin to Climatic Change

S.L. Berezovskaya
Russian State Hydrometeorological University, St. Petersburg, Russia

Our current knowledge on the Siberian Arctic is incomplete. Our understanding of the changes observed in Arctic hydrological system, therefore, are limited. This project was aimed at determining and quantifying the change in the hydrological regime of the second largest arctic river. The water balance of the Lena River was studied in order to assess the role of climatic and anthropogenic factors in runoff variations. Historical data analyses show that the Lena River and its major tributaries experienced an extended low-water period from 1936-1957 and high-water periods from 1974-1983 and 1988-2001. Since the late 1960s the increase in river discharge and annual precipitation has been particularly pronounced due to large-scale changes in atmospheric circulation patterns. Runoff in the Lena River basin increased by 10% from 1936 to 2001 due to extended wet periods during the second part of the past century. The trend is weaker for the Vilui River basin because it is subject to reservoir regulations that cause additional water losses through reservoir filling and increased evaporation. Runoff regulation strongly affects the winter runoff regime of both the Vilui River and the lower reaches of the Lena River causing an increased winter discharge at the Lena river outlet station of approximately 33%. The results of this project improve our understanding of current changes in the Siberian Arctic as they prove that increased precipitation produces additional runoff to the Laptev Sea. This also directs our attention to the importance of human impact within the Vilui sub-basin, which should not be neglected while analyzing the runoff changes on a regional scale.

Submarine and Terrestrial Permafrost in the Eastern Laptev Sea Region: a Comparative Study

S. Drachev[1], M. Kasymskaya[2], V. Kaulio[3]
[1]VNIIOkeangeologia, St. Petersburg, Russia
[2]Moscow State University, Moscow, Russia
[3]St. Petersburg State University, St. Petersburg, Russia

This project was funded in 2003 with the main goal of revealing the structure of the uppermost part of the permafrost developed on the eastern Laptev Sea shelf, on the New Siberian Islands and adjacent mainland, with particular emphasis on their comparative analysis. This study was based on numerous scientific data collected within the scope of the Russian-German program "Laptev Sea System 2000" as well as on PARASOUND data obtained during RV "Polarstern" 1998 cruise and drill cores recovered from several shallow wells in the course of RV "Kimberlit" 2000 cruise. PARASOUND transects obtained during 1993 and 1995 cruises of RV "Polarstern" were also used, as well as published results of upper sedimentary layer sampling with piston corers. The results previously obtained within the framework of the OSL project OSL-01-07 (Principal Investigator S.S. Drachev), in particular the Map of Submarine Permafrost Roof in the eastern Laptev Sea and its basis and the digital grid of depths, and of the OSL project OSL-01-19 (Principal investigator N.N. Romanovskii) were widely involved. The results of many years of permafrost research obtained by the scientific team led by N.N. Romanovskii (Geological Department of Moscow State University) were used as a basis when determining the major forms of permafrost-generated landscapes of the New Siberian Islands and Primorskaya Lowland.

Evolution of the Lacustrine Geosystems of the Taimyr Peninsula

G. Fedorov
State Research Center – Arctic and Antarctic Research Institute, St. Petersburg, Russia

Within the framework of this project it was intended to prepare and defend a PhD thesis, which is the outcome of 8 years of activity within the framework of the Russian-German research in the Laptev Sea region. An attempt was made to analyze all the obtained data and knowledge on lakes and their evolution gained throughout the years of research.

The aim of the project was to investigate the modern structure and evolution of the lacustrine geosystems of Taimyr Peninsula. To achieve this goal the following fundamental tasks were to be solved: 1. to reveal the main factors responsible for lacustrine geosystems formation on Taimyr Peninsula; 2. to reveal the primary stages of lacustrine geosystems evolution on Taimyr Peninsula; 3. to carry out palaeolimnological zoning and classification of lacustrine geosystems of Taimyr Peninsula.

In general the main factors influencing the formation and evolution of the lacustrine systems are climate (general moisture fluctuation), connected in the Arctic in the Late Pleistocene mainly with glacier formation and degradation, basic levels of erosion fluctuations, associated on Taimyr Peninsula with oscillations of the Kara and Laptev sea levels, and also tectonic movements resulting in the rearrangement of the hydrological system.

Other tasks were to investigate several important inferences concerning the evolution of sea-level oscillations, the development and main features of glaciers and the neotectonic structure on Taimyr Peninsula, to classify Taimyr lacustrine systems, and to describe in detail the evolution history of Taimyr Lake since its formation until the present day.

The Laptev and East Siberian Seas Coastal Erosion Database: Dynamics, Classification, Segmentation, Sediment and Organic Carbon Contribution

M.N. Grigoriev[1], I. Shapovalova[2], D. Streletskiy[2]
[1]Permafrost Institute RAS, Yakutsk, Russia
[2]Moscow State University, Moscow, Russia

Published data concerning the dynamics and composition of coasts, their lithology, morphology, hydrodynamic and geocryological conditions within a coastal zone were collected and along with our own data analyzed for a detailed assessment of basic parameters and the effect of coastal erosion. Based on current material a database was developed involving parameters of coastal erosion and assessment of sediments and organic carbon fluxes. Database development is based on detailed segmentation of coasts by the parameters indicated above as well as classification of erosional, stable and accumulative coast types of the Laptev and East-Siberian Seas. The basic results of works are reflected in a digital map. Our research made it possible to generalize all collected data on a set problem concerning the coast of these seas, where the influence of permafrost peculiarities on the character and intensity of relief-forming and sedimentological processes is extremely strong.

Spatial Variations in Ice Formation Onset in the Laptev Sea: Consequence of the Vertical Heat Fluxes Caused by Internal Waves Overturning

S. Kirillov
State Research Center - Arctic and Antarctic Research Institute, St. Petersburg, Russia

This project was aimed at studying the interior ocean dynamics in the eastern Laptev Sea shelf area. Short and long-term ADCP measurements were analyzed in order to recognize the spatial distribution of heat transport by internal-wave overturning in the Laptev Sea and its role in the formation of freeze-up pattern anomalies. It was found that the mixing intensity due to the breaking of internal waves varies from molecular up to $5\text{-}30 \cdot 10^{-5}$ m^2/s within the pycnocline layer. This could result in ice-formation onset being delayed by up to 5-6 days over the eastern part of the Laptev Sea during freeze-up period. It was also found that an energy increase by the factor of 2-3 is possible during strong atmospheric forcing. These forcings might significantly delay ice formation onset due to the fact that the heat exchange is increased by internal-wave action.

Late Pleistocene and Holocene Paleoenvironmental Conditions, their Changes and Influence on the Distribution of Mammals in the Laptev Sea Surroundings

T. Kuznetsova, N. Noskova, A. Bryantseva
Moscow State University, Moscow, Russia

The project is aimed at the reconstruction of the basic futures of the Laptev shelf environment during the Late Pleistocene and Holocene. The research was focused on the investigation and analysis of favourable and unfavourable periods of environmental conditions for different species of mammals and plants. We reconstruct the animal population and traced their change. All the data are new. Another focus is the study of oxygen isotope ratios in bone’s phosphate as indicator of climate variations.

A combination of paleozoological and paleobotanical (diatoms) data under strictly defined stratigraphic and chronological (^{14}C) control allows us to reconstruct the Late Pleistocene and Holocene paleoenvironmental history of the Laptev Sea surroundings.

High-Resolution Reconstruction of Lena River Discharge Patterns During the Late Holocene

Ye.I. Polyakova, T. Novichkova, E. Golovnina
Moscow State University, Moscow, Russia

The main goal of our study within the scope of this project was to reconstruct the short-term variability in the Lena River discharge onto the Laptev Sea shelf during the late Holocene. The study was based on detailed investigations of the downcore distribution of aquatic microalgae in the sediment cores obtained from the regions adjacent to the Lena Delta during the TRANSDRIFT expeditions. Using diatom and aquatic palynomorph assemblages as a proxy, the following major paleoenvironmental results were achieved: (i) spatial and temporal variations in the surface water salinity in the Laptev Sea shelf area adjacent to the Lena Delta were reconstructed for the last 6 cal. ka; (ii) the impact of the Atlantic waters on the inner Laptev Sea hydrology during the Holocene was revealed; (iii) the major stages of the changes in the direction of the Lena River discharge were revealed: generally eastward outflow via the Bykovskaya channel approximately between 6 and 4.2 cal. ka, and after 2.8 cal. ka, and increase in riverine outflow in the northward direction via the Trofimovskaya channel between 4.2 and 2.8 cal. ca.

Reconstruction of Late Pleistocene Seasonal Temperatures in the Siberian Arctic Lowlands Based on Insect Fossils: the Mutual Climatic Range Method

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[1]Severtsov Institute of Ecology and Evolution RAS, Moscow, Russia
[2]Paleontological Institute RAS, Moscow, Russia

The Mutual Climatic Range (MCR) method based on fossil insect assemblages is a powerful tool for reconstructing climatic conditions of the past. A very large volume of information on the distribution of many insect species and the climatic parameters of their ranges was collected in the course of this project. The usage of this information has already allowed us to build comparative climatic characteristics of certain periods in the Late Pleistocene and early Holocene.

Postglacial and Holocene Environments of the Western Laptev Sea and Eastern Kara Sea as Reflected in Fossil Assemblages

E.E. Taldenkova, A. Stepanova, S. Dem’yankov
Moscow State University, Moscow, Russia

The project is aimed at investigating recent and fossil benthic assemblages from the eastern Kara and western Laptev seas in order to reconstruct paleoenvironmental changes under postglacial sea-level rise with particular interest lying in the traces of Atlantic water influence on the studied regions. The main results are:

- first recent ostracods from the eastern Kara Sea were studied in detail (species identification, description, SEM photos);
- the recent distribution of ostracod and mollusc assemblages were established from coretop samples from the eastern Kara Sea in relation to salinity and water depth changes;
- the paleoenvironmental changes in the eastern Kara Sea mid-shelf since 8.1 cal.ka were reconstructed; a considerable influence of marine (Atlantic-derived?) waters from ca. 6-5 cal.ka was revealed;
- the continuous influence of Atlantic water on the western Laptev Sea continental slope is recorded in the species composition of microfossils since ca. 15.8 cal.ka with its maximum between ca. 11 and 4 cal.ka.

Kurzfassungen des Stipendienprogramms 2003/2004

The Role of Mesozooplankton in Sedimentation of Organic and Inorganic Matter on the Laptev Sea Shelf

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[2]State Research Center – Arctic and Antarctic Research Institute, St. Petersburg, Russia
[3]Kazan University, Tatarstan, Russia

The main idea of our project was to evaluate the role of Copepoda species, as a main component of the biological filter, in the sedimentation processes on the southeastern Laptev Sea shelf using data obtained in earlier studies on distribution, life cycles and seasonal dynamics of zooplankton. The main results are:

- the biological filter occupies the near-shore area in the western and the eastern parts of the Laptev Sea shelf, where small Copepoda are the most numerous organisms in the pelagic fauna;
- for all studied species the rate of filtration increases with body mass from naupliar stage to adult copepodid stages. The daily volume of water filtrated by all organisms occurring in 1 m^3 of surface water in August-September, when the highest abundance was observed, is comparable with that recorded in May due to the differences in the age structure of populations in these months;
- during the whole active period of life (about 8 months) the animals from 1 m^3 of surface layer filtrate approximately 13 liters of water (not taking into consideration the daily feeding rhythm);
- the seasonal vertical migrations of zooplankton in the Laptev Sea shelf might be considered as the main reason for seasonal variations in the daily volume of water filtrated by copepods.

Varved Lacustrine Sediments as an Indicator of the Last Millennium Paleoenvironment of the Russian Arctic

D. Bolshiyanov[1], M. Pavlov[1], A. Makarov[2]

[1]State Research Center – Arctic and Antarctic Research Institute, St. Petersburg, Russia
[2]St. Petersburg State University, St. Petersburg, Russia

The main aim of our project is a complex investigation of arctic lake sediments in order to reconstruct the paleoenvironment during the last millennium. The obtained data are an important link for studying the climate of the past and makes forecasting future climatic changes possible.

In the course of the project, sediments of such arctic lakes as Izmenchivoye (Severnaya Zemlya Archipelago), Astronomicheskoye, Levinson-Lessing, Schel’, Taimyr (Taimyr Peninsula), Lama, Kapchuk, Talikit, Tonel’ (Putorana Plateau), Nikolay-Kyuele and Mentikilir (Lena Delta area) were investigated. In addition to the lakes stated in the project, three further lakes were surveyed. These are two lakes in the Arkhangelsk area: Zabugornoye and Kamennoye; and the lake in the Lena Delta on Buor-Khaya-Sise Island.

One of the important results of the project is the reconstruction of the Little Ice Age (LIA) phases. Almost all investigated sediments have thin annually deposited lamination (varves). The calculation of these layers in connections with the analysis of spore-pollen, geochemical and other data allowed establishing sufficiently precise time frameworks of climatic fluctuations. The events of the LIA started and ended asynchronously in different parts of the Russian Arctic. The cooling of the LIA took place in 2 phases.

An Assessment of the Distribution and Evolution of Sub-Sea Permafrost in the Near-Shore Zone of the Laptev Sea

M.N. Grigoriev[1], I. Shapovalova[2], G. Kraev[2]
[1]Permafrost Institute SB RAS, Yakutsk, Russia
[2]Moscow State University, Moscow, Russia

Within the scope of this study, the main parameters of sub-sea permafrost evolution and distribution within the shallow shelf zone of the Laptev Sea were evaluated. Newly obtained data as well as other published and unpublished information concerning shoreface composition, permafrost features, lithology, morphology and hydrodynamics were reviewed and analyzed. Based on the available data sub-sea permafrost evolution was described and its distribution in the near-shore zone was estimated. The main objects of the investigations are: sub-sea permafrost table position, shoreface morphology, coastal dynamics, temperature and salinity regimes, bottom deposits and seabed sediment structures.

Comparison of Late Quaternary Environments at the North Kara – North Laptev Key Sites

E. Gusev[1], P. Rekant[1], K. Malinkin[2]
[1]VNIIOkeangeologia, St. Petersburg, Russia
[2]St. Petersburg State Mining Institute, St. Petersburg, Russia

The aim of this project was to study the Kara and Laptev shelves’ paleogeographic conditions in the Late Pleistocene and to compare these conditions. The basic data for studying were seismoacoustic profiles and data from bottom mooring stations. We analyzed samples of the Kara Sea Quaternary deposits by means of the modern equipment of the Otto Schmidt Laboratory. While during the Holocene the conditions of the Kara and Laptev seas were comparable, it is possible to speak about different paleogeographical conditions in the Late Pleistocene. We investigated the paleogeographical conditions at two key sites in the central and northern parts of the Kara Sea and at one site in the central part of the Laptev Sea.

Assessment of Contribution of Zooplankton to Vertical Carbon Fluxes in the Kara and White Seas from Experimental Data and Sediment Trap Collections

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[1]P.P. Shirshov Institute of Oceanology RAS, Moscow, Russia
[2]Zoological Institute RAS, Moscow, Russia
[3]Moscow State University, Moscow, Russia

The project was aimed at improving our understanding of the interdependency of biological and geochemical processes in the Kara and White seas. The role of zooplankton in the transformation of particulate organic matter in the water column was investigated on the basis of zooplankton populations in the White Sea. Faecal pellets of the dominant plankton organisms were obtained during feeding experiments and examined morphologically. Dry weight, organic carbon and nitrogen content, and C/N ratio of pellets of different types were measured. Faecal-pellet production rates were assessed under natural conditions. The structure of the zooplankton communities was studied both in the Kara and White seas in order to use the abundance and distribution data for assessing the potential zooplankton faecal-pellet production. Based on these data, the contribution of the pellet material to the vertical carbon flux was assessed for the different regions of the White and Kara seas. The regional and seasonal variations of the pellet carbon input observed during this study in both seas were strongly related to the structure of the zooplankton communities and distribution of populations of the dominant "pellet producers".

Unique (Non-Analogue) Paleoenvironmental Conditions of Late Pleistocene and Holocene Terrestrial Ecosystems of the Laptev Sea Surroundings (Detailed Reconstruction)

T. Kuznetsova, N. Noskova, A. Bryantseva
Moscow State University, Moscow, Russia

The main goal of the project is to elaborate and verify the reconstructed basic environmental features of the Laptev Sea shelf area and coastal lowlands during the Late Pleistocene and Holocene. The project is based on complex analyses of paleozoological and paleobotanical remains combined with geochronological and stable-isotope data. Special attention was given to the interpretation of isotope data on fossil mammal bones in comparison and correlation with the data obtained from the analysis of stable isotope ratios in forage plants. Modern analytic methods of stable isotope ratios for fossil mammal remains allow reconstructing the environmental conditions in detail. All the collected data and expected results of the project are new.

Gas Hydrate Forming Fluid Vents in the Sea of Okhotsk: Hydrogeochemical Studies

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[1]VNIIOkeangeologia, St. Petersburg, Russia
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The study allowed revealing hydro-geochemical peculiarities of the hydrate formation process and revealed the origin and composition of water and gas involved in the accumulation of gas hydrates associated with venting structures in the Sea of Okhotsk. Hydrogeochemical data suggest that not only free gas expulsion but also discharge of relatively mineralized water takes place. The two types of water differ in isotopic composition from each other and seawater and play a role in the formation of carbonates and gas hydrates. The source of uprising fluids varies with time. Biogenic methane generated in situ in the upper sediment strata and methane uprising from hydrocarbon reservoirs (also biogenic in origin) are two main sources of gas hydrates. Precipitation of gas hydrates under decreasing methane solubility during gas-saturated water input and segregation of water by free gas are two main mechanisms in the developed model of gas hydrate formation.

Nutrient Budgets in the Coastal Areas, Estuaries, and Estuarine Zones in the Siberian Arctic Seas

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State Research Center – Arctic and Antarctic Research Institute, St. Petersburg, Russia

New data of nutrient distributions were obtained. Silicate, phosphate, nitrate and nitrite concentrations were measured in 758 water samples. The young scientists of the team became familiar with new methods of chemical analyses.

For the first time we obtained such data which allowed us to assess nutrient fluxes into the arctic marine systems as a result of coastal erosion. The contribution of coastal erosion to the total nutrient budget is far smaller than that of river input.

Our studies on nutrient budgets show that almost all systems in the Kara and Laptev seas are net autotrophic systems despite their hydrography and independent of whether they are large or small-scale systems. The only exeption is the northern part of the Ob Gulf; here we find a heterotrophic system. The bottom layer in many systems is heterotrophic, especially in winter, when the destruction of organic matter exceeds its production.

The contribution of different sources to the nutrient budgets depends on system dimension, and hydrological and ice conditions. River run-off dominates in the bays, which are directly subject to discharge of the great Siberian rivers. Coastal erosion dominates in the 500 m coastal belt. For large-scale systems, the main fluxes come from the bottom layer and from the Arctic Basin.

Comparison of Postglacial Shelf Evolution Between the Kara and Laptev Seas Using Fossil Algae Assemblages

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The main goal of our study was to reveal temporal and regional peculiarities of hydrological and sedimentation processes in the western Laptev Sea and the neighboring regions of the southeastern Kara Sea. These regions are influenced by extensive riverine discharge. The study was based on the investigation of fossil algae assemblages in sediment cores as well as on detailed radiocarbon age control. Using diatom and aquatic palynomorph assemblages as a proxy the following major results were achieved: (i) the extent of the influence the Atlantic waters had on the northwestern Laptev Sea and southeastern Kara Sea during the postglacial time was revealed; (ii) variations of the surface water paleosalinities in the southeastern Kara Sea during the Holocene were reconstructed; (iii) changes in riverine discharge to the northwestern Laptev Sea and southeastern Kara Sea and the overwhelming influence of the postglacial transgression on the evolution of the Siberian arctic shelf water masses were revealed.

Palynological Study of the Cores from the Laptev Sea Shelf in Order to Investigate Paleoclimate and Paleovegetation Evolution

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Pollen analysis of the two cores PS-51-159-10 and PS-51-154-11 and borehole KI001 from the outer and inner Laptev Sea shelf showed that interpretation of pollen results, pollen distribution in the spectra and its concentration have several similarities in the analyzed spectra.
According to the obtained pollen results we assume that the sediments started to form under severe environmental conditions coinciding with the Late Pleistocene/Early Holocene environmental conditions as the bottom spectra is extremely poor in terms of pollen and spores content or other microfossils. All the pollen data is supported with radiocarbon data.

The pollen spectra trend shows a clear transition from periglacial conditions with the dominance of transported coniferous pollen in the spectra and surroundings, represented by shrubby vegetation with xerophytes and steppe sedge, to Holocene period. The percentage spectra register rather unchangeable conditions throughout the core according to the percentage pollen diagram. Nevertheless, according to the concentration variability, which is more representative in our case it is clear that pollen production for the Holocene period varied greatly. It is likely to be explained by the ecological and environmental changes that might have occurred throughout this time span.

Evolution and Modern Condition of the Permafrost and the Gas Hydrate Stability Zone on the Arctic Shelf of Eastern Siberia

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Two main objectives were studied in the research project:

- to jointly study the evolution and present condition of the ice-bearing permafrost and gas hydrate stability zone (GHSZ) on the Laptev Sea shelf and the western part of the East-Siberian Sea shelf; dynamics of the ice-bearing permafrost and GHSZ in rift structures of the arctic shelf. The first problem was investigated by means of modeling using the well-known model by Tipenko, Romanovskii and Kholodov (1999) and the published paleogeographical scenario by Romanovskii and Hubberten (2001). The paleogeographical scenario covers approximately 400 ky. Maps of the thickness of the offshore relict permafrost and GHSZ for the recent time were drawn up on the basis of the received data.
- to determine the dynamics of the ice-bearing permafrost and GHSZ in rift structures of different sizes and the location on different parts of the East Siberian arctic shelf of the during the mentioned period. The results were the first estimation for the East Siberian arctic shelf because of a continuity of coexistence of the ice-bearing permafrost and GHSZ and also because of the possibility and occurrence conditions of the open taliks and "faults" in GHSZ through which emission of greenhouse gases can occur in sub-permafrost layers.

Pathways and Fluxes of Natural and Anthropogenic Tracers in the Western Russian Arctic Seas

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Within the framework of our project we studied the role of atmospherically derived elements and compounds, suspended matter, ice-rafted sediments, and vertical particle fluxes in the processes taking place in the shelf seas of the western Russian Arctic (the Laptev, Kara, Barents, Pechora and White seas) on the basis of concepts and principles of the Russian-German Program “Laptev Sea System“. In 2004 the participants of this project were responsible for studying aerosols, suspended matter and particle flux in the White Sea within the scope of the “White Sea System” Program under the leadership of Academician A.P. Lisitzin. This grant, therefore, studied the composition of aerosols, suspended particulate matter (SPM), sedimentary matter from sediment traps and bottom sediments collected during the expeditions to the White Sea. A strong seasonality of aerosol and suspended matter distribution and composition in the White Sea was revealed. We could show that the composition of White Sea aerosols is similar to the composition of aerosols of the arctic seas. Wit hrespect to some chemical elements (Pb, V, Cd) aeolian input into the White Sea is of great importance. The highest concentrations of SPM are registered during the spring flood; terrigenous material dominates in the composition of SPM at this time. In summer a less prominent peak in SPM concentration is observed, This is the result of phytoplankton bloom. The lowest concentrations of both terrigenous and biogenic SPM are registered in winter. The seasonality of SPM concentrations is reflected in the seasonality of vertical particle fluxes. The character of geochemical processes in the Northern Dvina, Onega and Kem’ estuaries is similar to that in the large arctic estuaries.

Late Pleistocene-Holocene and Recent Ostracods of the Laptev Sea (Arctic Siberia): Detailed Taxonomic Studies and Applications to Paleoenvironmental Reconstructions

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In 2004 the author completed her PhD thesis entitled “Pleistocene-Holocene and recent Ostracoda of the Laptev Sea and their importance for paleoenvironmental reconstructions.” This work is the first detailed investigation of the Late Pleistocene-Holocene and recent ostracods of the studied area. In total 45 species belonging to 22 genera and 13 families were identified; one species was described as new. For the first time three ecologically different assemblages linked to three areas of the sea (western-central, eastern and southern) were distinguished among recent Ostracoda. Fossil Ostracoda from AMS^{14}C-dated sediment cores from the eastern shelf area (with lower datings 11.3-11.1 kyr) and the western continental slope (with lower dating 15.8 kyr) were also studied for the first time. The analysis of fossil ostracod assemblages allowed the author to supplement previously obtained data on the chronology of the postglacial transgression.

Postglacial Environmental Changes in the Western Laptev Sea: Evidence from Fossil Benthic Assemblages, Isotope Composition of Microfossils and Geochemical Data

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The project is aimed at reconstructing the postglacial paleoenvironmental history of the western Laptev Sea outer shelf and continental slope on the basis of a multiproxy approach (high-resolution benthic assemblage studies, oxygen isotope composition of microfossils, bulk geochemical parameters). The succession of benthic assemblages in core PS51/154-11 from the upper continental slope reveals the major features of the last postglacial environmental evolution in the area. Prior to 15.8 cal.ka the absence of calcareous biogenic remains probably results from oxygen deficiency in the bottom water layer due to perennial sea-ice cover. During the period from 15.8 to 13.8 the proximity of the paleocoast to the shelf break resulted in no or little fast-ice formation and in the existence of a nearshore polynya. The latter fact is shown by the high percentage of planktic foraminifers and ostracod assemblages from the debris flow deposits containing freshwater and brackish-water species. The presence of *Cassidulina teretis* indicates the first Atlantic-derived water inflow to the site already at 15.8 cal.ka, which is about 0.8 kyr earlier than in the Barents and Kara seas. Between 13.8 and 11.6 cal.ka species composition and the highest total abundance of benthic microfossils indicate a seasonally changeable environment and an increasing organic matter supply due to maximum freshwater outflow (with its peak at about 13.0 cal.ka) and shelf flooding (starting at 12.7 cal.ka). The sharp reduction in sedimentation rates after 11.1 cal.ka resulted in poor preservation of calcareous remains and low total abundances of microfossils although their taxonomic composition gives evidence for the maximum influence of Atlantic water inflow on the western Laptev Sea continental slope between 11.6 and 6.5 cal.ka. Modern-like environments were established since 6.5 cal.ka, which was generally correlative with sea-level stabilization. After 2.5 cal.ka high IRD content indicates active iceberg-rafting, which was not recorded previously.

Veröffentlichungen im Rahmen der Stipendienprogramme

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Diplom- und Doktorarbeiten

Long-term variability of the Lena River runoff and propagation of river waters over the Laptev Sea shelf

PhD thesis

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The thesis deals with the main reasons of the Lena River discharge in winter and its influence upon the thermohaline structure of the Laptev Sea water column. A concept of the interaction between multiannual variations in river discharge and thermohaline structure of the shelf water column during the summer under different atmospheric circulation regimes is formulated.

The main scientific results are the following:

- The empirical data give evidence for a considerable increase in the average annual air temperature in the studied area since 1976. In the multiannual variations of the total annual precipitation a period of enhanced precipitation has been depicted from the mid-sixties to the present. It results from the change of circulation epochs according to the typization of Vangenheim-Girs, namely, the period of enhancement in the macroprocess E form.
- Based on the analysis of the water balance elements and the statistical analysis of the series structure, it is shown that the air temperature rise has not affected the process of the annual water discharge formation in big catchment basins, at least until the 1990s.
- Variations in the total water storage of the big river basins (Alsan, Vilyui, upper Lena down to Solyanka station) exhibit similar tendencies in these three regions. The period of decreasing water storage of the river basins until the mid-sixties and the subsequent period of increasing water accumulation until recent times are conditioned by the peculiarities of the multiannual precipitation dynamics. The polyzonality of this process gives evidence on the large-scale variations in the system of atmospheric processes and corresponds to the change in atmospheric circulation epochs.
- The salinity and thermal regimes of seawater in the estuarine area of the Lena River during winter depend only slightly on the dynamics of winter river discharge even though the latter has increased by 30%.
- The influence of the multiannual variations in the Lena River runoff on the estuarine seawater during summer is ambiguous and depends on the atmospheric circulation regime over the Arctic Basin according to the classification of Protushinsky and Johnson.
- Under the cyclonic circulation regime (1964-1971, 1980-1983, 1989-1993), river discharge causes a freshening of the surface water layer in proportion to its volume. Onshore winds prevent the riverine water plume from propagation to the north (downwelling of surface water), and interaction with the underlying saline water is weak because the freshwater lens is stable. Under these conditions, the bottom water thermal regime is independent of the river discharge dynamics.
- Under the anticyclonic circulation regime (1972-1979, 1984-1988), river discharge favors the integral salinization of the surface water layer due to involvement of the underlying saline water because of the dynamic effect of the riverine water plume spreading and the upwelling of seawater under the influence of offshore winds. The compensatory current produced by the riverine water movement and enhanced by reversal currents results in the salinization of the bottom water layer and an increase in its heat content.

Evolution of the lacustrine geosystems of the Taimyr Peninsula

PhD thesis

G. Fedorov (OSL-02-09)

St. Petersburg State Unviversity, St. Petersburg, Russia

This thesis was aimed at investigating the lacustrine complexes of Taimyr Peninsula, including questions of water body, catchment area, and sediments. The Taimyr lacustrine geosystems were investigated with respect to their modern structure and their development.

Within the framework of this thesis, questions concerning sea-level fluctuations on Taimyr in the Late Neopleistocene were tackled. This was done by applying geologic-geomorphological methods, i.e. analyzing the paleocoast complexes. Thus, 92 dated coastal complexes of the Late Neopleistocene were subjected to several methods. The results are the following:

1. In the Late Neopleistocene the region of the modern Taimyr Peninsula was dominated by marine sedimentation during oxygen-isotope stages 5e, 5d, and 5b, 5a. During stages 5c and 4 a, Taimyr was subject to glaciation coupled with a slight regression of the sea. A sea level considerably lower than that of today was observed only for stage 2.
2. During the so-called Karginian (corresponds to oxygen-isotope stage 3) Taimyr was not subject to transgression, but at the reference marks the sea level stabilized at approximately 10-15 m higher than today's marks while the Arctic Ocean in general was subject to regression.

For the investigation of the lacustrine geosystems the method called in Russian scientific literature „geographical approach" was applied to Taimyr Peninsula for the first time. This method determines the peculiarities of physical-geographical zonation, contemporary processes and the paleogeographical history of lacustrine geosystems. This method allowed drawing the following conclusions:

1. The physical-geographical zonation of Taimyr Peninsula revealed 4 main hierarchic levels linked to the impact which the development of the modern tectonic structures of east-northeastern strike and of north-northwestern strike has, as well as to the influence of the processes of Quaternary sedimentation depending in the first place on sea-level fluctuations and on the development of Quaternary glaciations. All these impacts continually govern the processes of topographic formation and are responsible for the formation of the smallest components of the topographic structure (permafrost, slope, erosional, and coastal components etc.).
2. The formation of the lacustrine geosystems of Taimyr Peninsula took place in 4 main stages. These are connected to the tectonic activation of the beginning Late Pleistocene, to the stabilization of the sea level during the Karginian at the same time as a general regression took place, to the deglaciation of Sartanian glaciers and to the processes of formation of the smaller components in the topographical structure during the Holocene.
3. The lacustrine geosystems of Taimyr Peninsula can be divided into 4 main types, which correspond to the four main hierarchic levels of physical-geographical zonation on the one hand and to the four main development stages of the lacustrine geosystems on the other hand.

Calcareous nanoplankton of Campanian age from the Desna River basin

Diploma thesis

S.S. Dem'yankov (OSL-03-25)
Moscow State University, Moscow, Russia

The investigation is devoted to the species composition and stratigraphic distribution of calcareous nanoplankton in the Campanian deposits of the northern Dnieper-Don depression within the Desna River basin. Based on the data on nanoplankton distribution, stratigraphic intervals were established, which were correlated with the general stratigraphic scheme. Species composition of nanofossils from the studied sections consists of 39 species, which belong to 23 genera. Detailed taxonomic descriptions are given for 14 species belonging to 13 genera. Zonal subdivision based on two zonal scales of the Upper Cretaceous is represented by 3 zones with 6 subzones.

Feeding of the dominant copepod species (superfamily Centropagoidea) in the White Sea

PhD thesis

D.M. Martynova (OSL-03-11)
Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russia

The diet of the three boreal copepod species *Acartia bifilosa* (Giesorecht, 1882), *Centropages hamatus* (Lilljeborg, 1853) and *Temora longicornis* (O.F.Müller, 1792) in the White Sea was investigated. The analysis of copepod gut content showed that the animals consumed diatoms (*Chaetoceros* spp., *Coscinodiscus* spp. (Centricae), *Navicula* spp., *Thalassionema* sp. (Pennatae)) and some other groups of phytoplankton: Pyrrophyta *(Peridinium* spp.) and Dinoflagellatae (*Dinophysis* spp.). Also zooplankton remains were detected. Contents of various fatty acids differed in the copepods of each species but were similar in parts. Dominant fatty acids (FA) for all copepods were C14:0, C16:0, C16:1(n-7), C20:5(n-3), C22:5(n-3) (from diatoms) and C18:0, C18:1(n-9), C18:4(n-3), C22:6(n-3) (from dinoflagellates). Also C15:0 FA (from heterotrophic bacteria) was detected. The Cryptophytes (C18:3(n-6), C18:3(n-3), C20:1(n-9), C20:1(n-7)) FA content was minor for all the species. The selectivity of different food was different for each stage and species. The mouthpart structure proved the omnivorous type of feeding of the investigated animals. The electivity differed for the different species and varied with growth and development.

The main quantitative parameters of copepod feeding rates in the White Sea were investigated under laboratory conditions. Ingestion rate of organic carbon varied from $4.58 \cdot 10^{-3}$ µg C/ind h (CII-CIIIs of *T. longicornis*) to $62.08 \cdot 10^{-3}$ µg C/ind h (females). Ingestion rate depended on the species, stages and light in daily experiments. The daily ratio varied from 6.9% of body carbon for *C. hamatus* CIV-CV copepodids to 59.4% for *A. bifilosa* CII-CIIIs. Filtration rate increased with growth and development and varied from 0.25±*0.07* ml/ind h (CI-CIIIs of *A. bifilosa*) to 2.03±*1.13* ml/ind h (females *C. hamatus*). Filtration rate in all three species correlated with development stages. Assimilation efficiency in the copepodids varied from 1.4 to 77.4%. In *A. bifilosa* it averaged to 27.0±*23.3*%, in *C. hamatus* to 27.7±*17.8*%, and in *T. longicornis* to 46.0±*23.9*%. Assimilation efficiency did not depend on species and light conditions, but correlated with developmental stage factor and temperature in the interval from +5 to 16ºC.

Maximum total population density of boreal zooplankton species in summer was ca. 17.000 ind/m^3 (17.566 ind/m^3 in the small inlets and 16.930 ind/m^3 near the Cape Kartesh). Grazing rates of the population of *Acartia bifilosa* on organic carbon varied from 0.01 to 8.45 mg C/m^2 day, with an average of 2.92±*2.82* mg C/m^2 day. The same parameter for *Centropages hamatus* varied from 0.03 to 37.58 mg C/m^2 day, with an average of 10.03±*11.27* mg C/m^2 day. For *Temora longicornis* it ranged from 0.20 to 18.94 mg C/m^2 day, with an average of 4.59±*6.71* mg C/m^2 day. Grazing rate of populations of boreal species was from 0.003 to 2.43 mg C/m^2 day near Cape Kartesh and from 0.002 to 5.55 mg C/m^2 day in the small inlets. Grazing rate of total zooplankton stock calculated from our experimental data ranged from 9.18 to 70.33 mg C/m^3 day, with an average of 18.00±*15.51* mg C/m^3 day. Grazing rate depended on the organic carbon content of zooplankton (regression analysis; $F=237.26$; $p<0.0001$) and carbon content in seston (regression analysis; $F=2.90$; $p=0.09$).

Faecal pellet production rates, sinking velocity, pellet size and dry weight were measured under laboratory conditions. A low content of phytopigments was typical for all pellets and varied from 0.9% to 19.1% of its initial concentration in seston. The phaeophytine content in pellets was by 1.2 to 12.5 times higher than in seston. The organic carbon content of pellets varied from 2.8 to 18.3% of pellet dry weight, being 9.7% on average. Pellet length and width varied from 97 to 168 µm, and from 13 to 23 µm respectively. Sinking velocities of pellets measured experimentally averaged 2.5 ± 0.4 m $hour^{-1}$, whereas those rates calculated with Stoke's equation were ca. 5.1 m $hour^{-1}$. The highest sinking velocity was observed for *Temora* pellets, the lowest for *Centropages*. Pellet length differed for different producers; the shortest pellets were produced by *Acartia*, the longest by *Centropages*. Pellet production rate (FP) varied from 0.017 to 0.050 min^{-1} or 0.13 to 0.65 µg C per day per copepod and depended on copepod species. FP increased with growth in all species observed. Organic carbon flux via faecal pellets of the studied copepod species varied from $16.7 \cdot 10^{-3}$ to 13.7 mg C_{org} m^{-2} day^{-1} in the 0-10 m water layer.

Gas hydrates formation in the fluid venting areas

PhD thesis

L.L. Mazurenko (OSL-03-14)
VNIIOkeangeologia, St. Petersburg, Russia

Geological-geophysical studies carried out in the ocean during recent decades have revealed widespread indications of fluid venting from the seafloor. In physical form, seafloor features associated with these discharges can be characterized as pockmarks, mud volcanoes, clay diapirs, chemosynthetic communities, particular affiliations of authigenic mineralization, sea-bottom accumulation of gas hydrate, and also low-temperature hydrothermal vents and some geophysical features (VAMP's and "Pagoda" structures). Over 70 locations with gas hydrate samples and indirect indications of hydrate were identified in the seafloor by the beginning of 2002. All submarine gas hydrates are related to infiltration of gas-containing fluids in and through the temperature-pressure field of the gas hydrate stability zone. They are distributed mainly as accumulations and can be subdivided into two groups: accumulations at or just below the sea floor and accumulations situated from tens to hundreds of meters below the seafloor. Most accumulations of the first group are related to focused fluid discharge at the seafloor. For gas hydrate accumulation in the fluid venting areas, two basic mechanisms are known. First, hydrate can form from precipitation of water where a saturated solution moves to a zone of lower temperature. Second, hydrate can form in static pore water in the hydrate formation zone by reaction with percolating free gas that has migrated from hydraulically subjacent zones. In the case of a biphasic infiltration (both water and gas), which is commonly found at fluid discharge locations in the mud volcanoes, both mechanisms can be active. Restricted vents of gas-bearing fluids are a widespread phenomenon both at continental margins and in internal and border seas. These fluid discharges from the seafloor are unique natural foci for the formation of gas hydrates.

Late Pleistocene and Holocene ostracods of the Laptev Sea

Diploma thesis

A. Stepanova (OSL-02-30)
Moscow State University, Moscow, Russia

In this work we present the results of investigating late Pleistocene-Holocene ostracods of the Laptev Sea and the geological review of the region. A total of 45 species were identified, which belong to 21 genera and 13 families. 15 species of the genus *Cytheropteron* Sars, 1866, were monographically described, one species is described as a new one. We present the results of our research concerning the distribution of recent ostracods in surface samples; three assemblages were established, which correspond to three areas of the sea: western-central, eastern and southern. Our study of fossil ostracods from marine core sections from the eastern Laptev Sea mid-shelf, dating back to 11.3-11.1 cal ka, resulted in establishing three assemblages, which correspond to certain stages of the Holocene transgression. In a marine core section from the inner shelf region, dating back to 6.4 cal ka, two ostracod assemblages were established. It was supposed that river runoff had been stronger from 6.4-2.7 cal ka, and after that the present environmental conditions started to develop. In a marine core section from the western upper continental slope, dating back to 16 cal ka, three ostracod assemblages were established: (1) upper Pleistocene, the taxonomy of which points to a temporal increase in river runoff; (2) in the sediments dating back to 11-4 cal ka, only marine ostracods were found, mainly of Atlantic origin, which is evidence for the fact that the advection of the North Atlantic waters increased during that period; (3) after 4 cal ka the development of present environmental conditions in this region started.

Pleistocene-Holocene and recent ostracods of the Laptev Sea and their importance for paleoecological reconstructions

PhD thesis

A.Yu. Stepanova (OSL-03-24)
Paleontological Institute RAS

This work is the first detailed investigation of the Late Pleistocene-Holocene and recent ostracods of the studied area. In total 45 species belonging to 22 genera and 13 families were identified; one species was described as new. For the first time three ecologically different assemblages linked to three areas of the sea (western-central, eastern and southern) were distinguished among recent Ostracoda. Fossil Ostracoda from AMS^{14}C-dated sediment cores from the eastern shelf area (with lower datings 11.3-11.1 kyr) and the western continental slope (with lower dating 15.8 kyr) were also studied for the first time. The analysis of fossil ostracod assemblages allowed the author to supplement previously obtained data on the chronology of the postglacial transgression.

Pelagic fauna of different water pools in the Lena Delta

Diploma thesis

I. Veshnyakova (OSL-03-01)
Kazan University, Kazan, Tartastan, Russia

This thesis is devoted to the study of pelagic fauna from different water pools in the Lena Delta. We investigated (1) species composition of zooplankton; (2) its spatial distribution; (3) seasonal dynamics in total abundance, biomass, and production; (4) biology and life cycles of several common crustacean species. We used the data collected in the southern part of the delta during the joint Russian-German expeditions LENA 2002 and Lena-Anabar 2003. Sampling was carried out in water pools of different origins: river channels, flood-plain lakes and thermokarst lakes of different sizes located at three distinct geomorphological levels.

The main results of our investigations could be summarized in the following way:

- zooplankton of the studied area is represented by 107 species belonging to two types (Rotatoria and Arthropoda). 52 species were described as new for this region. High species diversity of pelagic fauna is characteristic of the flood-plain lakes which are river-affected during the spring flood. Zooplankton of alases and big thermokarst lakes is taxonomically poor, probably due to the lakes' oligotrophic character and isolation;
- the average abundance of planktic organisms in water pools of different origins can vary considerably. Small thermokarst lakes (polygons) are the most common and productive water pools of the delta showing the highest values of the total abundance and biomass. Zooplankton is also abundant in the flood-plain lakes. In big thermokarst lakes and alases the total abundance is considerably lower;
- during the ice-free period, three peaks of zooplankton abundance are observed in polygonal lakes. These are related to the reproduction of the most common species (Cyclopoida, Calanoida, and Cladocera). The amplitude of seasonal and interannual variations in the total abundance and biomass largely depends on the specific life cycles of the common crustacean species and the duration of favorable temperature conditions during a certain year;
- Calanoida species from the studied area are characterized by one generation per year. Wintering occurs at the stage of latent eggs. Their reproduction period usually corresponds to mid-summer. Cyclopoida species spend their winter diapause in the form of elder copepodite stages frozen into ice. Their reproduction coincides with ice melting. Cladocera produce 2-3 partenogenetic generations during summer. Prior to the onset of unfavorable conditions females produce wintering stages (ephipies);
- the total absolute zooplankton production in small thermokarst lakes with a water volume of 82 km^2 equals up to 121 g per day. The mean seasonal production of a polygon makes

up about 6-7 kg. Given the absence of any predator stress on the zooplankton of these lakes, the total organic matter production in polygons over the whole polygonal tundra of the Lena Delta can reach several tons.

Gastwissenschaftleraufenthalte in Deutschland

Nr.	Name	Zeitraum/Ort	Aufgabe
1	Abramova, E. Lena Delta Reserve, Tiksi	01.12.-26.12.2002 GEOMAR, Kiel	Erstellung eines Berichts über die Vertikalwanderungen der Zooplankter in der Laptev-See (OSL-02-01)
2	Abramova, E. Lena Delta Nature Reserve, Tiksi	02.02.-28.02.2004 IFM-GEOMAR, Kiel	Erstellung eines Berichts über die Zusammensetzung und Verbreitung von Zooplankton auf dem Laptev-See-Schelf (OSL-03-01)
3	Abramova, E. Lena Delta Nature Reserve, Tiksi	28.11.-27.12.2004 IFM-GEOMAR, Kiel	Erstellung eines Berichts über die Verteilung von Zooplankton in der Laptev-See anhand der ersten Ergebnisse der TRANSDRIFT-X-Expedition (OSL-03-01)
4	Are, F.E. Petersburg State University of Means of Communication, St. Petersburg	08.06.-10.07.2003 GEOMAR, Kiel	Erstellung eines Berichts über den Beitrag der Küstenerosion zur Sedimentation in der Laptev-See
5	Grigoriev, M. Permafrost Institute, Yakutsk	17.11.-12.12.2003 AWI-Potsdam	Erste Auswertung und Interpretation von Ergebnissen der "Lena-Anabar 2003"-Expedition im Rahmen seines OSL-Stipendiums Nr. OSL-02-11
6	Gukov, A. Hydrometeorological Department, Tiksi	15.03.-30.04.2003 GEOMAR, Kiel	Erstellung eines Berichts über die Rolle von Polynjas im marinen arktischen Ökosystem
7	Gukov, A. Lena Delta Nature Reserve, Tiksi	18.11.-17.12.2004 IFM-GEOMAR, Kiel	Erstellung eines Berichts über die Benthosverteilung in der Laptev-See anhand der ersten Ergebnisse der TRANSDRIFT-X-Expedition
8	Klyuvitkina, T. Moscow State University	05.03.-13.04.2004 IFM-GEOMAR, Kiel AWI-Potsdam	Beprobung und Aufbereitung von Palynomorphen in den Sedimentkernen PS51/154-11, PS51/159-10 und PS51/92-12 (OSL-03-18)
9	Kuzmina, S. Severtsov Institute for Ecology and Evolution, Moscow	03.08.-31.08.2003 GEOMAR, Kiel	Erstellung eines Berichts über die Taxonomie fossiler und moderner Insektenarten in der sibirischen Arktis zusammen mit A. Sher (OSL-02-27)
10	Kuznetsova, T. Moscow State University	05.10.-04.11.2004 AWI-Potsdam	Auswertung der paläontologischen Interpretationen der Fossilkollektionen (Säugetierknochen) von den Neusibirischen Inseln; Vorbereitung einer Publikation zu quartären Umweltveränderungen im Gebiet der Neusibirischen Inseln (OSL-03-12)
11	Lisitzin, A.P. P.P. Shirshov Institute for Oceanology RAS, Moscow	08.04.-07.05.2003 GEOMAR, Kiel	Erstellung eines Berichts über den Transport und die Verbreitung von Aerosolen in der Arktis
12	Novichkova, T. Moscow State University	17.02.-19.03.2003 GEOMAR, Kiel/ AWI-Potsdam	Aufbereitung von Palynomorphen in den Sedimentkernen PM 9482 und PS51/80 (OSL-02-22)
13	Polyakova, Ye. Moscow State University	03.11.-01.12.2002 GEOMAR, Kiel	Beprobung der Sedimentkerne PM 9482, PS 51/92 und PS 51/80 und Erstellung eines Manuskriptes über den Vergleich holozäner Diatomeenvergesellschaftungen in der Laptev-See und Kara-See (OSL-02-22)
14	Polyakova, Ye. Moscow State University	01.03.-31.03.2003 GEOMAR, Kiel	Mikropaläontologische Bearbeitung der Sedimentkerne PS51/80 und PS51/92 (OSL-02-22)

15	Polyakova, Ye. Moscow State University	26.10.-23.11.2003 GEOMAR, Kiel	Überarbeitung und Fertigstellung eines Manuskripts über "Past Changes in Laptev Sea Water Masses Deduced from Diatom and Aquatic Palynomorph Assemblages" für die Veröffentlichung in der Zeitschrift "Global and Planetary Change" (OSL-02-22)
16	Rekant, P. VNIIOkeangologia, St. Petersburg	15.12.-26.12.2004 IFM-GEOMAR, Kiel	Erstellung eines Berichts über die Ergebnisse der TRANSDRIFT-X-Expedition (OSL-03-07)
17	Sher, A. Severtsov Institute for Ecology and Evolution, Moscow	03.08.-31.08.2003 GEOMAR, Kiel	Erstellung eines Berichts über die paläoklimatische Rekonstruktion in der sibirischen Arktis anhand von Makrofossilien zusammen mit S. Kuzmina (OSL-02-27)
18	Stepanova, A. Paleontological Institute RAS, Moscow	01.12.-29.12.2004 IFM-GEOMAR, Kiel	Erstellung eines Berichts über die Verteilung von Ostrakoden in der Laptev-See anhand der ersten Ergebnisse der TRANSDRIFT-X-Expedition (OSL-03-24)
19	Taldenkova, E. Moscow State University	01.12.-26.12.2002 GEOMAR, Kiel	Fertigstellung eines Berichts über Ostrakoden- und Foraminiferenvergesellschaftungen in der Laptev-See (OSL-02-30)
20	Taldenkova, E. Moscow State University	27.11.-26.12.2003 GEOMAR, Kiel	Erstellung eines Berichts über die postglaziale Entwicklung des Laptev-See-Schelfs mit Hilfe von Mollusken, Ostrakoden und Foraminiferen (OSL-02-30)

7th Meeting of the OSL, 2.-4. Dezember 2004, Kiel

7th Meeting of the Otto Schmidt Laboratory for Polar and Marine Research

• Sessions and events at a glance •

Wednesday, December 1, 2004

Arrival at Hamburg airport and transfer by KIELIUS and taxi (Kombicard) to the hotel „Am Segelhafen“ (Schoenberger Str. 32-34, phone +49 431 729900)

Thursday, December 2, 2004

10:00	Guided tour of IFM-GEOMAR (start lobby of building 8)
12:30	Lunch
13:30	OSL Workshop: 2004 Fellowship Program (Chairperson: H. Kassens) Oral reports of the OSL fellows
16:00	Coffee and poster session
17:00	OSL Workshop: 2004 Fellowship Program (Chairperson: J. Hoelemann) Oral reports of the OSL fellows
19:00	Discussion

Friday, December 3, 2004

09:00	Oral session: Development and stability of permafrost (Chairperson: J. Hoelemann)
	Wegner, C., Hölemann, J.A., Churun, V., Haas, C., Kirillov, S., Kassens, H., Timokhov, L.: Seasonal variability in near-bottom temperature in the Laptev Sea – preliminary results
	Junker, R.: Thermal stability of sub-sea permafrost on the Laptev Sea shelf
	Hubberten, H.: The dynamics of permafrost during the last climatic cycle in the Laptev Sea region, Russia
	Eliseeva, A., Romanovskii, N.N., Belan, A.: Permafrost and gas hydrate stability zone dynamics in rift structures on the east-Arctic shelf
	Grigoriev, M.N., Shapovalova, I., Kraev, G.: Sub-sea permafrost table dynamics at the near-shore zone of the Laptev Sea
10:30	Coffee

10:50 Oral session and discussion: Short and long-term environmental changes in the central Siberian Arctic (Chairperson: T. Mueller-Lupp)

Kosobokova, K., Martynova, D., Prudkovsky, A.: Contribution of zooplankton to vertical carbon fluxes in the Kara and White seas – assessment from experimental data and sediment trap collections

Golovnina, E.: Aquatic palynomorphs as indicators of postglacial environments in the Laptev and Kara seas

Stepanova, A., Taldenkova, E., Bauch, H.A.: Late Pleistocene-Holocene and recent ostracods of the Laptev Sea (Arctic Siberia): detailed taxonomic studies and applications to paleoenvironmental reconstructions.

Kuznetsova, T.: Alteration of Late Quaternary paleoenvironmental conditions in the Laptev Sea region (paleontological data)

Schirrmeister L., Meyer, H., Grosse, G., Kunitsky, V., Derevyagin, A., Kuznetsova, T., Grigoriev, M.: Studies of terrestrial permafrost - first results of the Mamontovy Klyk site

Müller-Lupp, T., Bauch, H.A., Erlenkeuser, H., Kassens, H.A.: Short and long-term environmental changes in the Laptev Sea

Bauch, H.: Thermohaline circulation and the high latitudes

13:00 Lunch

14:00 Oral session: High-resolution seismic characterization of submarine permafrost (Chairperson: T. Schwenk)

Gusev, E., Rekant, P., Malinkin, K.: Comparison of Late Quaternary paleoenvironments of the North Kara-North Laptev seas

Schwenk, T., Spiess, V., Kassens, H., Zühlsdorff, L., Voigt, T., Belan, A., Gusev, Ye., Rekant, P., Hoelemann, J.: Imaging of the Laptev Sea with high-resolution multichannel seismic data. First results from the Expedition TRANSDRIFT X

16:00 Coffee

16:30 Oral session: Microbial-driven processes in permafrost (Chairperson: D. Wagner)

Spieck, E., Alawi, M., Fiencke, C., Lebedeva, E.: Detection of nitrifying bacteria in Siberian permafrost

Alawi, M., Spieck, E.: Molecular biological characterization of nitrifying bacteria from Laptev and Lena sediments, tundra and permafrost

Zimmermann, U.: Studies on microbial methane oxidation in different permafrost habitats

Wagner, D.: Characterization of methanogenic communities from marine and terrestrial habitats in the Laptev Sea region

19:00 Banquet at the IFM-GEOMAR (building 12, 2nd floor)

Saturday, December 4, 2004

08:30 Internal workshops

- Seismic (Chairpersons: Ye. Gusev, V. Spiess)
- Oceanography (Chairpersons: S. Kirillov, J. Hoelemann)
- Permafrost and Microbiology (Chairpersons: E.-M. Pfeiffer, N. Romanovskii)
- Expeditions in 2005 (Chairpersons: H. Kassens, H.-W. Hubberten)

12:00 Social event

Sunday, December 5, 2004

Transfer to the airport and departure

Liste der Teilnehmer

Nr.	Name	Institut
1	Abramova, Ekaterina	Lena Delta Nature Reserve, Tiksi
2	Alawi, Mashal	Biozentrum Klein-Flottbek, Universität Hamburg
3	Bauch, Dorothea	IFM-GEOMAR, Kiel
4	Bauch, Henning	Akademie der Wissenschaften und der Literatur, Mainz
5	Belan, Anna	Moscow State University
6	Bryantseva, Anna	Moscow State University
7	Dem’yankov, Sergey	Moscow State University
8	Eliseeva, Anastasiya	Moscow State University
9	Grigoriev, Mikhail	Permafrost Institute Yakutsk
10	Gukov, Aleksandr	Lena Delta Nature Reserve, Tiksi
11	Gusev, Evgeny	VNIIOkeangeologia, St. Petersburg
12	Hölemann, Jens	Alfred-Wegener-Institut, Bremerhaven
13	Hubberten, Hans-W.	Alfred-Wegener-Institut, Postdam
14	Junker, Ralf	Universität Bremen
15	Kassens, Heidemarie	IFM-GEOMAR, Kiel
16	Kirillov, Sergey	Arctic and Antarctic Research Institute, St. Petersburg
17	Klagge, Torben	IFM-GEOMAR, Kiel
18	Korolyeva, Lyudmila	Otto-Schmidt-Labor, St. Petersburg
19	Kosobokova, Ksenia	P.P. Shirshov Institute for Oceanology, Moskau
20	Kraev, Gleb	Moscow State University
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Stipendienprogramm 2002/2003: Abschlussberichte

Contents:

HISTORICAL-FAUNISTIC, ECOLOGICAL, POPULATION, AND PRODUCTION ANALYSIS OF ZOOPLANKTON FROM LAKES OF DIFFERENT REGIONS AND GEOMORPHOLOGICAL LEVELS IN THE LENA DELTA

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Introduction

Investigations of zooplankton in the Lena Delta started at the beginning of the 20th century, during the Russian Polar Expedition 1901-1903. Our knowledge about the structure and functioning of zooplankton community in this big region, however, is still insufficient. This is demonstrated by the small number of articles on this topic offering only certain information about species composition and abundance of zooplankton (Rylov, 1928; Bening, 1942; Urban, 1949; Pirozhnikov and Shulga, 1957; Pirozhnikov, 1958; Botvinnik and Vershinin, 1958; Ammosov, 1961; Kerer, 1968; Serkina, 1969; Sokolova, 1984). Since 1987, the Lena Delta State Nature Reserve launched regular monitoring investigations of the pelagic fauna in the Lena Delta. The results of these investigations for the period from 1987 to 2001 are presented in “Letopis’ Prirody”, a yearly report by the Lena Delta Nature Reserve (Abramova, unpublished data). Aconcise interpretation of the obtained data, however, has not yet been provided.

The area of the Lena Delta, one of the world’s biggest deltas, comprises about 28,000-32,000 km^2. About 58,700 lakes are found in the Lena Delta, on average every 1,000 km^2 incorporate 2,120 small and big lakes (Mostakhov, 1973). The lakes occupy various geomorphological levels depending on their age and altitude in the Lena Delta: a modern low and a high Late Holocene flood plain, the first accumulative terrace of the early Middle Holocene age, the second terrace of the Early Holocene age, and the third terrace of the Late Pleistocene age (Schwamborn et al., 2002; Pavlova et al., 2000). Undoubtedly, the numerous lakes play a significant role in the delta ecosystem. our detailed taxonomic, historical-faunistic and ecological analyses of zooplankton will help to understand peculiar features of the modern pelagic fauna of the delta and the history of its formation. On the other hand, estimation of the seasonal zooplankton production allows evaluating its role in the accumulation of organic sediment components in different lake types. The obtained data can be used for estimating organic matter fluxes in the delta ecosystems.

Scientific background

The proposed research project is a continuation of the zooplankton investigations in the Laptev Sea region. Previous results indicate the close interaction of the coupled Laptev Sea/ Lena Delta system. Freshwater organisms washed into the sea by river runoff constitute about 50% of the total summer zooplankton abundance in the shallow brackish-water bays of the Laptev Sea (Abramova, 2000). The taxonomic composition of zooplankton of the Lena River itself and its channels is poor and its abundance is low. Considerable stream velocity and high concentration of suspended particulate matter hamper the formation of stable zooplankton assemblages. Lake species transported into the channels of the Lena Delta and the Laptev Sea bays during flood play an important role in the composition of the zooplankton associations in these waters(Gukov, 2001).

In the different water pools of the Lena Delta, 142 zooplankton taxa belonging to 2 types (Rotatoria and Arthropoda) were determined. 90% of these species are found in the zooplankton assemblages of the lakes. Small thermokarst lakes are the most abundant type of water bodies in the Lena Delta. Polygonal tundra occupies about one third (9,600 km^2) of the total delta area (Grigoriev, unpublished data). The annual primary production in these lakes is known to be low, but this is largely due to the short ice-free season. However, our preliminary data suggest that, compared to other tundra water basins, zooplankton abundance, biomass and production in the small thermokarst lakes are rather high. For example, the daily production of only one dominant species *Daphnia pulex* varied from 4.3 mg/l to 5.3 mg/l during summer 2001 (Akhmetshina and Abramova, 2002).

A preliminary historical-faunistic analysis of Copepoda from different lakes of the Lena Delta has allowed distinguishing a paleolimnic assemblage (family Diaptomidae) that does not have any direct ancestors in the sea, a mesolimnic assemblage with not clearly defined ancestors (some representatives of the families Temoridae, Cyclopoidae, Canthocamptidae), and a neolimnic assemblage composed of amphibiontic species (families Centropagidae, Tachidiidae and some representatives of the families Temoridae and Cyclopidae). The high number of specific freshwater species from the mesolimnic complex (family Cyclopoidae) gives evidence for the introduction of amphibiontic taxa (Abramova, 1996; Stepanova and Abramova, 1997).

<u>Goals and objectives</u>

The goals of the project were to investigate and compare the biodiversity, ecology, population structure and production of zooplankton in the lakes from different regions and geomorphological levels of the Lena Delta and to estimate the influence of riverine or seawater upon pelagic fauna formation in different regions of the Lena Delta. Our objectives were:

- to study species composition and distribution of zooplankton of the Lena Delta lakes;
- to compare species composition of the different lakes with the help of species similarity indices (Jaccard, 1901; Simpson, 1949);
- based on detailed taxonomical analyses of Copepoda species, to determine paleo, meso and neolimnic complexes;
- to investigate ecological affinity of certain species, primarily their temperature limits;
- to study the development of the mass Copepoda species (number of generations per season, age structure, diapausal stages, etc.);
- to analyze seasonal dynamics of zooplankton abundance and biomass in polygon lakes, big thermokarst lakes and terrace lakes from the different regions of the Lena Delta;
- to reveal temperature - abundance/biomass dependences;
- to determine the daily and seasonal production of zooplankton in the different lakes of the Lena Delta;
- to compare quantitative parameters characterizing the plankton assemblages of the different lakes.

Research activities

Approach

In the present study we examined zooplankton assemblages from the different regions and types of lakes in the Lena Delta: flood-plain lakes, big thermokarst lakes, alases, and polygon lakes of two types, young shallow polygons with Carex and deep polygons without any plants (stable stages).

The following data were used for solving the stated problems:

- 530 quantitative and qualitative zooplankton samples collected during the period 1987-2000 from different kinds of lakes in various parts of the Lena Delta;
- 40 quantitative zooplankton samples collected during the Russian-German expedition LENA 2001 from lakes on five islands in summer 2001 (June-August);
- 65 quantitative zooplankton samples collected during the Russian-German expedition LENA 2002 from the same lakes in summer 2002 (June-beginning of September);
- temperature records (carried out simultaneously with zooplankton sampling).

The whole sample or a part of it was studied in the Bogorov's camera under a microscope Olympus SZX9 or Wessex WSP2, and the abundance of organisms was calculated. We determined species, sex and moulting stages. The data were recalculated to 1 m^3 of water. The microscope Olympus BX60 was used for detailed taxonomic analyzes of the pelagic organisms.

To identify the individual weight of the organisms, we used the formula:

$W=ql^b$

where W is body weight, l – body length (mm), q – weight at 1 mm body length, b – index.

The production of the populations was estimated through the daily biomass growth. The relative duration of the different age stages development was either estimated experimentally or taken from relevant publications. The daily production of each growth stage of the most common species was calculated separately. The total daily production of a population was calculated as the sum of the values of the different age groups.

Pelagic assemblages were compared with the help of Jaccard and Simpson indices (Jaccard, 1901; Simpson, 1949).

Based on the taxonomic analyses, and using the number of asymmetric body parts of Copepoda species as an indirect criterion of specialization (Brodskii et al., 1983), we carried out a historical-faunistic analysis of the modern freshwater fauna in the Lena Delta.

Accomplishments

In this year 65 quantitative zooplankton samples collected during summer 2002 and all old material from the different regions of the Lena Delta intended for study have been analyzed. The abundance and biomass of zooplankton in the different types of lakes were calculated and peculiarities of their seasonal dynamics were discussed.

The production of zooplankton populations in the small polygon lakes was estimated. The pelagic fauna of the different lakes was compared with the help of species similarity indices and paleo, meso and neolimnic zooplankton complexes were determined.

The preliminary results of our investigations have been published (Abramova, 2002, 2003; Akhmetshina and Abramova, 2002) and the final results will be included into a concise international paper about zooplankton of the Lena Delta in the near future.

Results

Species composition, distribution and structure of zooplankton assemblages

In the lakes of the Lena Delta, 128 taxa of zooplankton belonging to 2 types (Rotatoria and Arthropoda) were determined during the whole period of investigations (1995-2002), among them Rotatoria with 65 taxa, Arthropoda, class Crustacea with 63 species including Copepoda with 44 species (Cyclopoida with 20, Calanoida with 16, Harpacticoida with 8), Cladocera with 17, and Anostraca with 2. There are well-manifested differences in species composition in water basins of different types (Fig. 1). The highest species diversity was recorded in the terrace lakes (50-58 taxa), and the lowest species diversity was determined in the alas (11 taxa) and in the big thermokarst lakes (20 species) occupying the first and second terraces in the Lena Delta. On average 30 zooplankton species occur in the small polygons. In the different lake types species composition was clearly dominated by Rotatoria. The latter reached maximum diversity in the terrace lakes, big thermokarst lakes and alases, where they sometimes constituted more than 60% of the total species richness. Copepoda (about 45% of the total species number), Cladocera and two species of Anostraca were the main components of zooplankton in the polygon lakes. Cladocera was widely distributed in all types of water pools, but species diversity of this group was comparatively low.

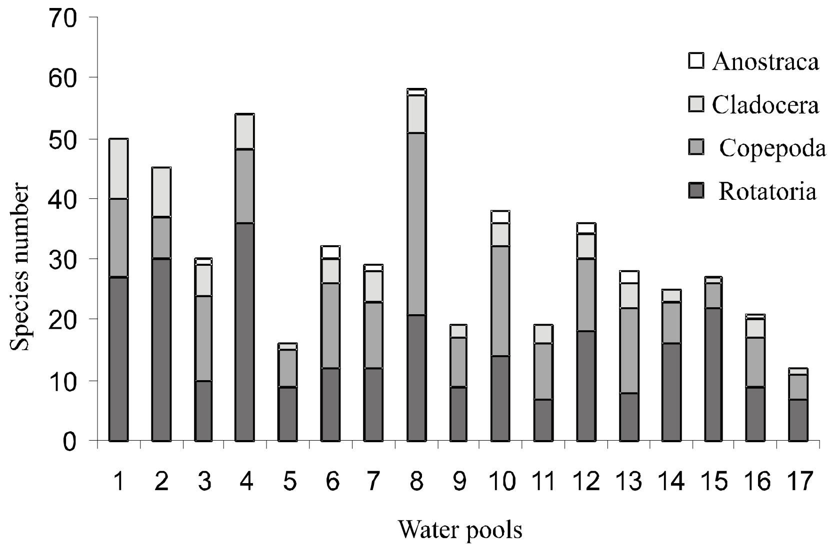

Fig. 1: Distribution and variation of the zooplankton species diversity in the different regions and water pools of the Lena Delta (1995-2002): Tit-Ary Island: 1 – flood-plain lake, 2 – big thermokarst lake, 3 – polygons; Samoylov Island: 4 – terrace lake, 5 – big thermokarst lake, 6 – polygons , 7 – crack between polygons; Sagastyr Island: 8 – flood-plain lake, 9 – big thermokarst lake, 10 – polygons; Dunay Island: 11 – lake-lagoons; Arga-Muora-Sise Island: 12 – big thermokarst lake, 13 – polygons; Sardakh: 14 – big thermokarst lakes; Buor-Khaya Island: 15 – alas, 16 – polygons; America-Khaya Island: 17 – alas.

Comparison of pelagic fauna of various lake types

The indices of Jaccard (K_j) and Simpson (K_s) show a high degree of similarity in the zooplankton of polygonal ponds situated in different parts and on different geomorphological levels of the delta (Jaccard, 1912; Simpson, 1949). The index of the species similarity (K_j) varied between 35% and 51% while the index of degree of inclusion of the poorest community into the richest one (K_s) varied between 56% and 86 %. Zooplankton of flood-plain lakes is less homogenous. Here K_j ranged from 30% to 37% and K_s from 48% to 56%. A remarkable difference in the species composition is typical for large thermokarst lakes of the first and second terrace above the flood-plain as well as in alas lakes of the third terrace. In the former case K_j does not exceed 17% with K_s reaching 50%. In the latter case the indices make up 14% and 41% respectively. When comparing the pelagic fauna of the different lake types on three terraces, we can see that the highest degree of specific similarity (K_j about 25%) occurs in polygonal and flood-plain lakes of the first terrace (Tit-Ary, Samoylov, and Sagastyr islands). For the other lake types on the first terrace, the degree of specific similarity does not exceed 16%. The differences in species composition of zooplankton communities are more pronounced between polygonal ponds and large thermokarst lakes situated on the second terrace (Arga-Moora-Sise Island) and between polygonal ponds and alas lakes situated on the third terrace (Buor-Khaya Island), for which the index of similarity was less than 14%.

Abundance, biomass and production of zooplankton

The highest quantitative characteristics of zooplankton were observed in the polygonal and flood-plain lakes of the first terrace, which are regularly influenced by river waters in the period of spring runoff of the Lena River. The abundance of zooplankton organisms can reach 40,000-50,000 ind./m^3 in these lake types. The biomass of zooplankton in the flood-plain lakes, however, is one to two times lower than in the polygons. In the latter biomass can reach 2-3 g/m^3, due to the large Copepoda and Cladocera species being abundant. The abundance and biomass of pelagic organisms in the big thermokarst lakes of the second and third terrace and alas are on average 10-20 times lower than they are in the polygons.

Zooplankton abundance, biomass and production are characterized by their own peculiar seasonal dynamics in the different lake types. Their maxima usually depend on the periods of reproduction of the mass zooplankton species. Normally, one or two maxima of abundance are well pronounced in the flood-plain lakes during summer (Fig. 2A). The first one usually coincides with the intensive reproduction of Rotatoria species and the second with the reproduction period of Copepoda. In the polygon lakes two-three peaks of quantitative characteristics of zooplankton may be recorded in summer (Fig. 2B). The first maximum of abundance, biomass and zooplankton production is usually connected with Cyclopoida, which start to reproduce at the beginning of the ice-free period. The second peak of the quantitative characteristics of zooplankton observed in mid-summer is linked to the reproduction of Calanoida and Cladocera species and the third one with the repeated partenogenetic reproduction of Cladocera. Some Cladocera are able to form two-three generations during summer depending on the duration of the favorable conditions.

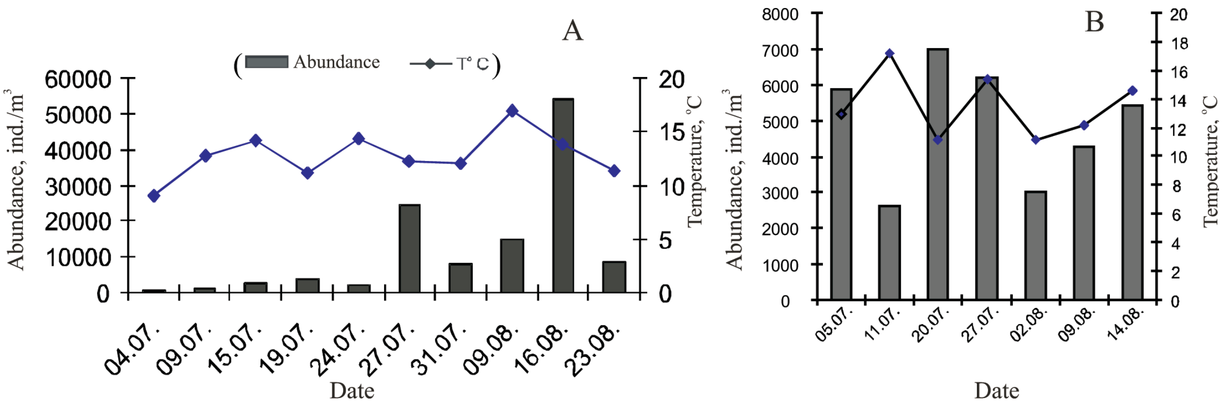

Fig. 2: Seasonal dynamics of total zooplankton abundance and water temperature; A – in the flood-plain lake and B – in the polygons on Samoylov Island in summer 2002.

The average daily production for different polygons varied from 0.01 to 1.5 g/m^3 in our material. The total absolute daily production of medium-size ponds with a water volume of about 82 m^3 varies from 11 g to 121g per day and reaches its maximum in the periods of the most intensive reproduction of the dominant species. The average seasonal production for average-size polygons can reach 6-7 kg. For the whole polygonal tundra of the Lena Delta this amounts to several tons of organic material.

Historical-faunistic analyses

Little is known about freshwater fauna in terms of evolutionary paleontology. It is difficult to separate ancient freshwater elements from recent ones. According to the existing concept about paleo, meso and neolimnic freshwater fauna and considering the number of asymmetric body parts of Copepoda as a criteria of specialization we investigated the pelagic fauna of the Lena Delta for the presence/absence of any direct ancestors in the sea. The paleolimnic complex includes 8 species of Diaptomidae. It seemingly does not have any direct marine ancestors. The mesolimnic complex with non-evident ancestors includes 12 species of Copepoda from 3 families (Temoridae, Cyclopidae, Canthocamptidae). The youngest neolimnic complex, which is represented by amphibiotic taxa, includes 24 species from four families (Centropagidae: 2 species, Temoridae: 5, Cyclopidae: 15, Tachidiidae: 2).

Conclusion

We obtained the first detailed data about species composition and distribution of pelagic fauna in the lakes of the Lena Delta. 128 taxa of zooplankton were identified. The highest species diversity was recorded in the terrace lakes influenced by river waters in the period of spring runoff. Riverine waters wash nutrients, organic matter and zooplankton species into these lakes. The big thermokarst lakes of the second and third terrace are oligotrophic and have been isolated from river-water influence for a long time. Zooplankton of these lakes is poor qualitatively as well as quantitatively.

Often, polygonal ponds are the most productive ecosystems as compared with other lake types. The species composition is very similar in polygonal ponds situated in different parts of the delta. The homogeny in distribution of the pelagic fauna is seemingly related to wind-induced dispersion of inactive stages of the pelagic organisms after drying of polygonal ponds. A remarkable difference in species composition is typical for large thermokarst lakes as well as for alas lakes.

The seasonal dynamics of zooplankton abundance, biomass and production are very similar, which is connected with the environmental conditions and the life cycle of the common zooplankton species. In different years, however, they can vary strongly.

An analysis of relative numbers of amphibiotic taxa in the lakes of the Lena Delta shows that the increase in taxa level leads to an increase in the number of specimens. This indicates that the disconnection of marine and freshwater fauna has been shifted from family to genus. The relatively high abundance of specific freshwater Cyclops of the neolimnic complex gives evidence of the replenishment of freshwater fauna of this region from mainly amphibiotic taxa. Therefore, the pelagic fauna of the lakes of the Lena-Delta is of heterogeneous origin and consists mainly of both recent and modern freshwater elements with amphibiotic brackish-waters organisms of neolimnic assemblage.

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HYDROLOGICAL RESPONSE OF THE LENA RIVER BASIN TO CLIMATIC CHANGE

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Introduction

Paleoclimatic studies provide evidence of the enormous changes experienced by the Laptev Sea region since the last glacial maximum (Polyakova et al., 2000; Bauch et al., 2001; Mueller-Lupp et al., 2003). Nevertheless the rate of changes for many environmental characteristics observed during the last century is quite likely unprecedented (Vorosmarty et al., 2000). Overpeck et al. (1997) reported that in the last four centuries temperature increase in the Arctic was most pronounced between 1840 and the mid 20th century. The arctic hydrological system is particularly sensitive to the temperature rise since it is strongly affected by both the meteorological factors (evaporation, ablation, transpiration) and processes affecting runoff (development and propagation of taliks, active layer dynamics). Sazonova et al. (in press) examined the impact of various scenarios of climatic warming on the depth of active layer thawing over the East-Siberian transect, which covers the central part of the Lena River basin from the head waters to the delta. Their results indicate that an air temperature rise of 3-7 ^{0}C will lead to additional thawing of the active layer by 0.5-2.0 m everywhere within the transect. Savelieva et al. (2000) reported soil warming to at least 2 m downwards from analyses of soil temperature observations within the Lena River watershed. Taken together, these changes affect the hydrological regime of the arctic rivers, especially during the winter season, through their influence on subsurface flow and the storage volume of talik zones. Under these conditions the low-flow season is considered to be the most sensitive period in the annual cycle because river discharge is completely controlled by ground water supply. Savelieva et al. (2000) and Yang et al. (2002) recorded a significant increase in winter discharge of the major rivers of the Russian Arctic. A recent analysis of discharge records from the six largest Eurasian rivers including the Lena River indicates that annual runoff increased by 7% from 1936 to 1999 (Peterson et al., 2002). Lately, the potential factors causing the trend in runoff records have been much discussed. Although precipitation over the basin is the primary source of river discharge, year-to-year variations in runoff are caused not only by the quantity of precipitation, but also by the way precipitation is transformed within the basin. Investigations of the water balance, which seem to be the most appropriate approach to solving the question, is limited by the availability of climatic data and by their accuracy. Data coverage and quality vary significantly from basin to basin: Western Siberia is provided with a station network of higher density as Eastern Siberia. Besides, the three largest basins spread in different geographical zones of the Arctic, and the magnitude of changes vary significantly between them. The focus on understanding runoff changes and their control at the watershed scale seems to be beneficial in terms of both data availability and methodology.

The primarily goal of this project was to analyze the Lena River water balance to assess the role of natural and anthropogenic impact in the basin.

Research activities

<u>Approach</u>

The hydrometeorological data have been analyzed to determine the temporal homogeneity using tests of mean and variance. The Kolmogorov-Smirnov, Student and Fisher tests were used to quantify the degree to which the observed distribution, mean and variance before 1970 differed from time series after 1970 as a statistical significance level. A statistical analysis was provided for separate regions with similar runoff variability within the Lena River basin. Based on this, three subbasins were determined: the Upper Lena, Aldan and Vilui subbasins (Fig. 1).

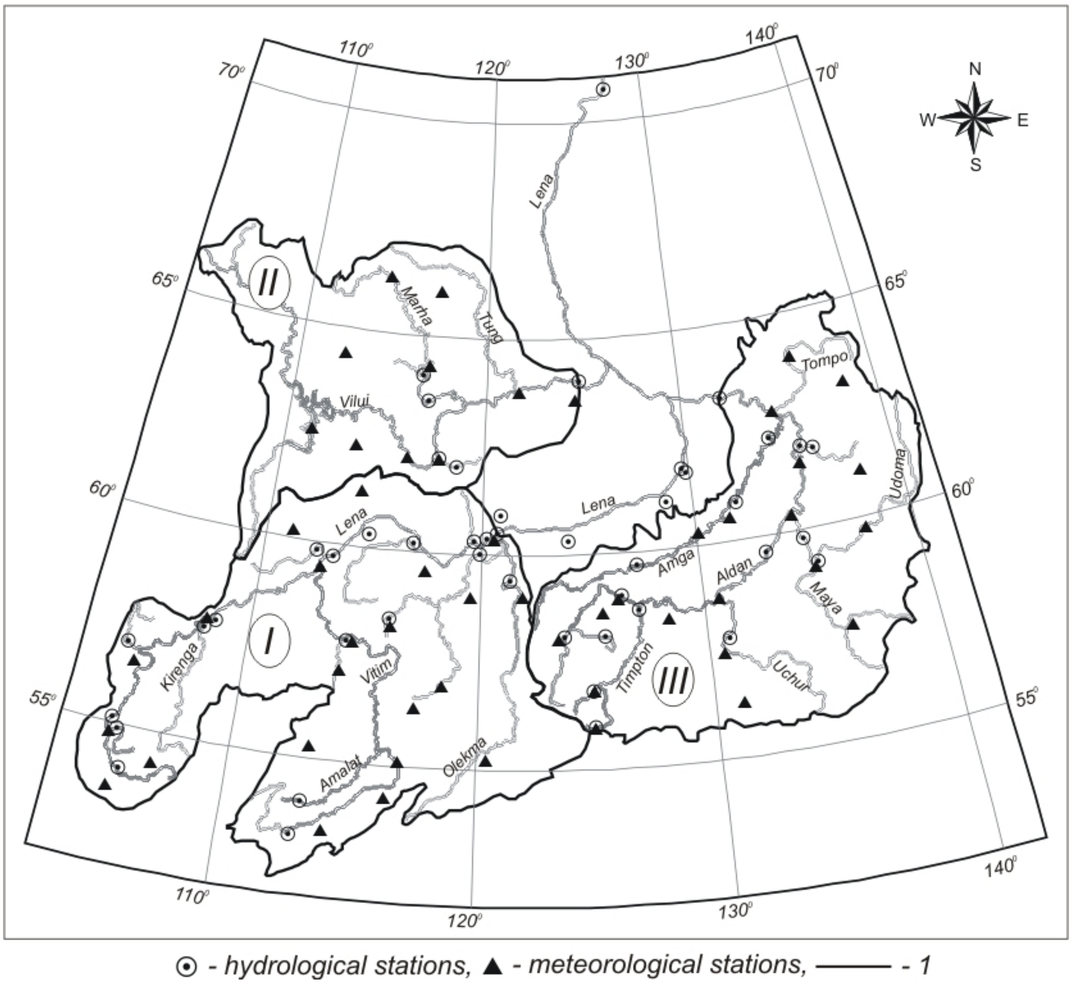

Fig. 1: Location of hydrological and meteorological stations and regions with synchronous fluctuations of river runoff (1): I - the upper Lena basin, II – the Vilui basin, III – the Aldan basin.

For each of the subbasins, the annual water balance was calculated to determine runoff response to long-term alteration in climatic factors. The water-balance equation for a hydrological year is applied in the following form: $\pm U = P$(precipitation)–R(runoff)-E(Evapotranspiration). Water storage in the basin (U) is actually the sum of two factors: the change in the ground water storage and changes in the volume of depressions or other surface-land storage. The third possible component, change in the volume of water stored in snow cover and ice, was eliminated because this frozen water is transformed into surface runoff in each hydrological year. The change in water storage $\pm U$ is an indicator of changes within the particular watershed. It should be noted that only approximate values of $\pm U$ are obtained due to uncertainties in measuring and calculating meteorological parameters (*P*, *E*).

P and *E* components were estimated from the data of individual locations and were improved by applying the empirical functions of elevation developed specifically for the mountainous region of the Lena River watershed (Vuglinsky, 1972). The annual precipitation (*P*) over a defined watershed was calculated based on the corrected values of observed precipitation using the Thiessen polygon method. Precipitation patterns vary significantly within the Lena River watershed with maximum values in the southern mountainous part of the basin. Vuglinsky (1972) derived three annual precipitation functions of elevation *(H)* from detailed data analyses of 48 meteorological stations in the Vitim basin and part of the Aldan basin (the Aldan highlands) over a 20-year period. These inter-relationships vary with distance from the northwestern margins, yielding minimum precipitation in the western part and maximum values in the northwestern region. Elevation adjustments in mountainous region (the upper Lena River, part of the Aldan River basin) have been accounted for using $P_i=f(H_i)$ functions in Vuglinsky (1972) with an average elevation of each Thiessen polygon (H_i). Elevation adjustments result in an average increase by 10% of the annual precipitation within the mountainous margins.

The annual depth of evapotranspiration (*E*) was calculated using Konstantinov's (1968) method separately for the snow-covered period (October-April) and the snow-free period (May-September). Konstantinov's scheme is based on the method of turbulent diffusion and the relationship between evapotranspiration and the vertical gradients of air temperature and relative humidity. *E* values were estimated for each meteorological station and total evapotranspiration was then computed from the weighted contribution. All spatial calculations required for water balance and statistical studies were carried out with GIS using ESRI software.

Accomplishments

The key tasks and output of the project with their dates of accomplishment are presented in Table 1.

Table 1: Key tasks and output

Key tasks and output	**Target date**
Data analysis: annual water balance calculations for the three major watersheds within the Lena River basin (Aldan River, Vilui River, and Upper Lena River basins down to Solyanka station); statistical analysis of seasonal flow within the Lena River watershed (60 stations)	Oct. 2002
Defence of PhD thesis entitled "Long-term variability of the Lena River Runoff and propagation of river waters over the Laptev Sea shelf"	Dec. 19, 2002
PhD certificate (Decision of State Attestation Committee in Moscow to certify PhD thesis)	March 14, 2003
Analysis of winter runoff increase in terms of human impact versus natural variations and of the impact of a 30% winter runoff increase on the estuarine region (thermohaline characteristics)	May 2003
IUGG International Conference, Sapporo, Japan; oral presentation: "Searching for evidence of climatic change in the Lena River basin toward feedback to the Laptev Sea hydrography"	June 30 – July 11, 2003
Analysis of low runoff response to the permafrost dynamics	Aug. 2003
Article "Long-term Annual Water Balance Analysis of the Lena River" submitted to a comprehensive volume about the Arctic ("Global and Planetary Change")	Sept. 2003
AGU Fall Meeting, San-Francisco, USA; poster presentation: "Low runoff response to permafrost dynamic within the Lena River watershed"	Dec. 8-12, 2003
Report submitted to OSL	Dec. 2003

Results

Annual water balance

An analysis of long-term discharge data (Lammers et al., 2001) indicates that the annual runoff of the southeast Lena basin increased by more than 10% during the 1980s relative to the period of 1960-1979. Considering the results of water balance analyses, this increase is likely associated with precipitation variability.

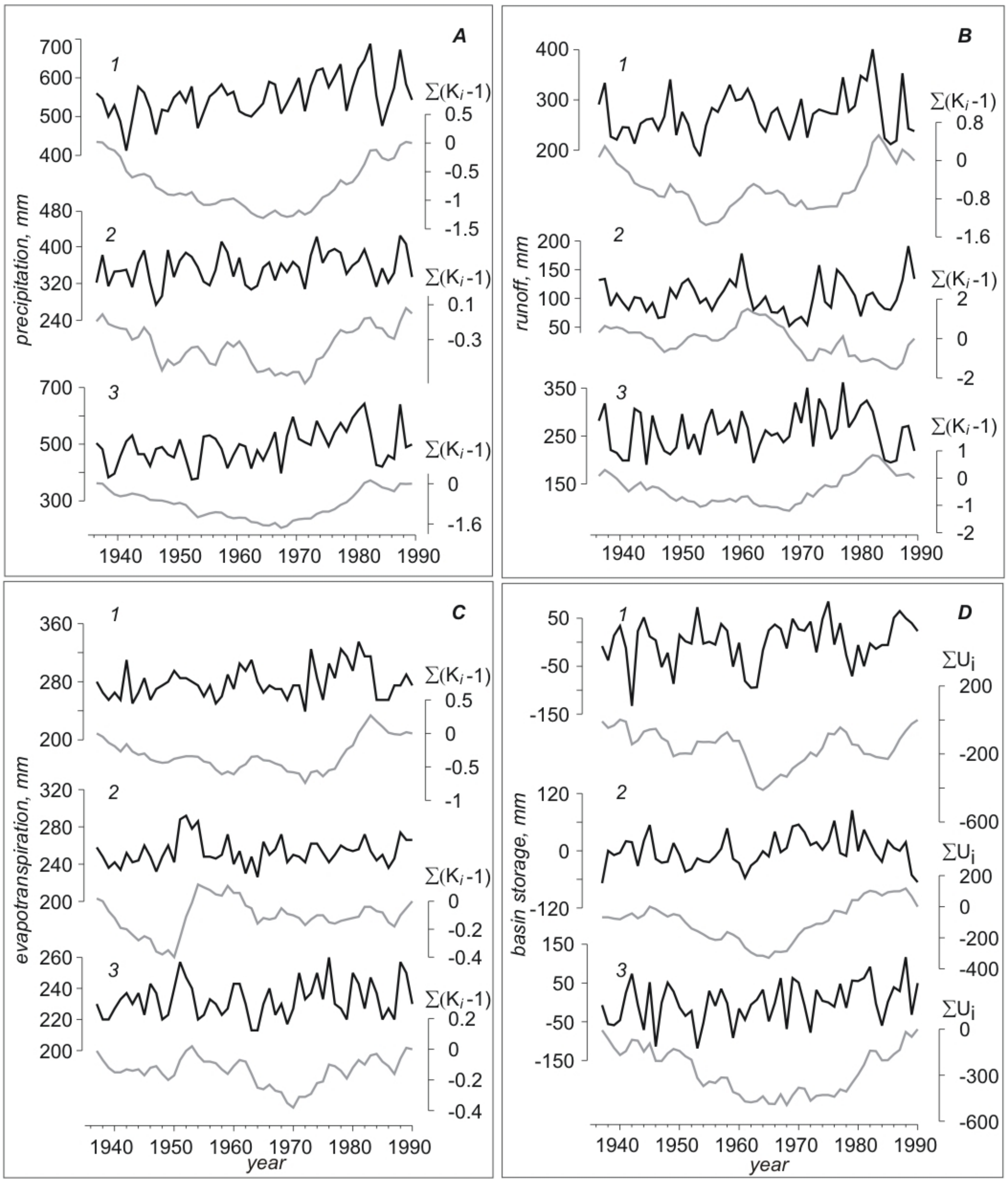

Fig. 2. Long-term fluctuations of water balance components: A - precipitation, B - river runoff, C - evapotranspiration, D - value of accumulated or dissipated moisture within the region: 1 - the upper Lena basin, 2 - the Vilui watershed, 3 - the Aldan watershed. K is normalized value.

The long-term annual precipitation fluctuations for the three regions show similar patterns, slightly decreasing until the late 1960s and then increasing until the mid 1980s (Fig. 2A). In the late 1980s a wet period prevailed. Wet and dry periods in runoff depth generally follow this pattern with the exception of the Vilui basin. This exception is primarily related to hydropower reservoirs operating within the Vilui watershed, which contributes significantly to additional water losses such as reservoir filling and enhanced evaporation from the reservoir surface. We consider the Upper Lena and Aldan River regions as negligibly disturbed by human activity. A period of enhanced evapotranspiration in the Aldan and Upper Lena basin corresponds well to the air temperature rise since the mid 1970s (Fig. 2C-1). However, it does not contribute much to the river runoff fluctuations. In fact, a wet period that prevailed in the basins at that time.

The residual term of the water balance over a hydrological year (U) is considered to be a quantity of accumulated or dissipated water within the drainage basin, which could characterize the basin feedback to the changes in factors affecting runoff (meteorological and land-surface factors). Prior to 1965 a decreasing tendency in the water storage (±U) is observed, which has been recorded in all regions (Fig. 2D). This period is followed by a number of years during which water accumulated within each watershed.

Analyzing the atmospheric circulation pattern, it was found that there has been a general increase in annual precipitation, river runoff and water storage (±U) in recent decades associated with the shift in atmospheric circulation patterns. Girs (1971) suggested three major atmospheric patterns over Eurasia: the western type (W), eastern type (E) and meridional type (C). The W pattern is characterized by waves of small amplitude that rapidly move from the west driving all near-surface atmospheric formation eastward. The E and C patterns are characterized by waves of bigger amplitude moving eastward and in meridian direction, respectively. The basic distinction between the W and E patterns is that an eastward transfer of pressure systems and isallobaric fields is significantly intensive during the E pattern (Girs, 1956). The W pattern experienced a recession in the mid 1930s, which extended to the 1990s. The E pattern started intensifying in the mid 1960s and is still underway. According to Girs (1971), the E pattern established the negative anomaly of land atmospheric pressure, creating a surplus of precipitation over the Lena River basin, which caused recent natural changes in the Lena River basin.

Anthropogenic impact

Water withdrawal from the Lena River basin is much less than that from the other large Siberian rivers (Yenisei or Ob). With respect to the mean annual runoff of the Lena River (527 km^3) water consumption comprises less than 0.5%. Water consumption due to barrage construction is significantly higher. For instance, during the period of 1967-1971 water losses induced by the Vilui reservoir filling (mostly dead storage) comprised 4-9 km^3/year, whereas the mean annual runoff volume of the Vilui River comprises 46 km^3. The period of reservoir filling is clearly apparent in the annual hydrography in Figure 2B. The impact of the Vilui reservoir on the water regime of the Vilui and Lena rivers is especially pronounced during the winter period (November-April). Since 1970 winter discharge at the outlet station of the Vilui River has increased by 800 m^3/s, i.e. by almost a factor of 10. The same amount of discharge increase has been observed at the Lena River outlet station of Kyusyur, where the discharge increased by 33% compared with the average value for the period prior to 1970. In order to determine whether there is any impact in winter runoff increase from the middle and upper Lena River basin, the temporal homogeneity of winter discharge data (41 stations) has been analyzed. Only two stations at the Vilui River and Lena River outlet station of Kyusyur are characterized by a non-homogeneous mean, which is caused by a pronounced increase of winter runoff since 1970 due to reservoir operation. The winter runoff into the Laptev Sea has, therefore, increased by one third due to the influence of one tributary, the Vilui River.

Conclusion

An increasing trend in annual runoff has been observed along the Lena River basin in recent decades. Many previous evaluations of the water balance in the Lena River watershed have been conducted. These studies were utilized to verify these assessments of changes in the thermal and hydrological dynamics of the Lena River. The purpose of this project was not to reassess the water resources of the Lena River watershed, but to focus on the long-term changes in water balance components and consistency of their fluctuations to understand the mechanisms driving this runoff increase.

The Lena River experienced an extended low water period in the early part of the century (1936-1957), which was followed by relatively wet periods (1974-1983 and 1988-2001). Similar combinations of dry and wet periods in river runoff were observed for the upper Lena basin and the Aldan River. The last period of increased runoff beginning in the 1970s reflects a positive trend in discharge records, at many stations up to 12% above the average annual value. Water balance analyses of three regions suggest that the runoff increase is mainly associated with precipitation variability. The large area over which these changes have occurred suggests a link to large-scale variability of atmospheric processes and corresponds to a change in atmospheric circulation patterns. According to Girs (1971), an intensifying eastward transfer of pressure systems and isallobaric fields since the mid 1960s has resulted in a surplus of precipitation over the Lena River basin. High and low periods in runoff generally follow this cycle with the exception of the Vilui River basin. The construction of hydropower reservoirs within the Vilui watershed caused additional water losses due to reservoir filling and enhanced evaporation from the water surface leading to changes in the hydrological and thermal regime that would overwhelm changes in response to atmospheric dynamics.

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SUBMARINE AND TERRESTRIAL PERMAFROST IN THE EASTERN LAPTEV SEA REGION: A COMPARATIVE STUDY

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Introduction

Scientific background

The natural system of the shallow epicontinental Laptev Sea in northeastern Russian evolves under the strong influence of permafrost-driven processes both in terrestrial (surrounding land and islands) and submarine conditions. This region has attracted increasing attention from many scientists from different fields of geosciences. Fundamental studies have been undertaken during the last 15 years by several Russian and German institutions, and the present-day data set consists of ca. 30,000 km of multichannel seismic reflection and acoustic PARASOUND echosounder lines, and a considerable amount of environmental data collected within the framework of the Russian-German program "Laptev Sea System 2000" (see, for instance, Kassens et al., 1999; Kassens et al., 2002). As one of the major results of precursory studies it was established as a fact that at the end of the last glacial maximum about 15 ka BP, large parts of the present-day shelf were situated above sea level, therefore being exposed to the very cold atmosphere and thus being deeply frozen (Romanovskii, 1993; Romanovskii et al., 1997; Alekseev, 1997; Bauch et al., 1999). This pre-Holocene eroded aerial topography controlled marine sedimentation, and the permafrost, whose top has mainly inherited the topography of the land surface, was preserved underwater.

The top of the submarine permafrost (SMP) was one of the main subjects of this project. This interface was mapped using PARASOUND acoustic data, and some physical properties of the frozen sediments from the drill cores were analyzed. It was found that the SMP roof is located 0-25 m below the seafloor, and is strongly modified in situ both by tectonics and by erosion.

As it is commonly known, the Laptev Sea natural system is evolving under the strong influence of active extensional tectonics along the boundary between the North American and Eurasian lithospheric plates. Recent and present-day tectonic movements represent a very important factor of development for the Laptev Sea environment (Drachev, 2000). The rifting-related fault displacements affect the seafloor morphology, which, in turn, causes a particular pattern of near-bottom currents and of the distribution of sediment transport pathways. The main structural elements of the Cenozoic rift system control sea-bottom relief and, consequently, distribution of different types of seafloor landscapes (Drachev et al., 1998; Gukov, 1999). These latter are an important factor shaping the roof of the SMP after its submergence during the Holocene. As another important factor cryogenic processes influenced the topography of the top of the SMP during the pre-Holocene aerial stage of shelf development and during the Holocene transgression causing marine abrasion.

Goals and objectives

The recent progress in studying both submarine and terrestrial permafrost in the eastern Laptev region has made it necessary to conduct a comparative study of these phenomena. So the main scientific task of this project was to provide a better understanding of the natural environment of the Laptev Sea in a recent past and the tendency of the SMP evolution during last 10-8 Ka with its transition from a terrestrial to a marine environment. This goal involved two aspects: (1) the identification of permafrost-generated landscapes in the SMP roof; and (2) the study of physical and chemical properties of drill cores recovered from the eastern Laptev Sea in 2000.

Research activities

The major research was focused on:

- interpretation and digitizing of 1993 and 1995 PARASOUND profiles to reveal seismoacoustic properties of the upper SMP and the zone of its transition to unfrozen marine sediments;
- determination of the major physical properties of both frozen and unfrozen sediments from the drill cores collected from the upper SMP, such as moisture, porosity, chemical composition of pore water, i.e., the properties which are significant to define the formation and evolution conditions of SMP. These investigations were carried out at the OSL with the use of the available devices (i.e. ionic chromatograph METROHM);
- definition of the facial types of SMP using their acoustic image and, where available, physical state;
- definition of major permafrost-generated landscapes in the topography of the New Siberian Islands and the coastal land;
- identification and mapping of different types of the SMP paleo-landscapes;
- comparison of the physical properties of the upper relic permafrost on both shelf and land areas to identify SMP paleo-landscapes on the eastern Laptev Sea shelf.

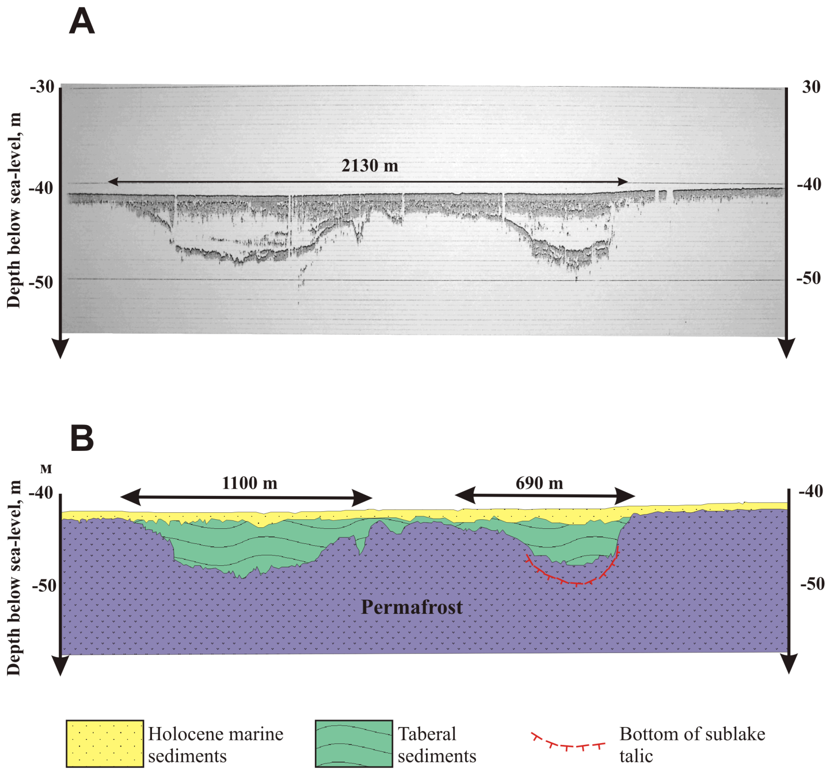

Fig. 1: Fragment of seismoacoustic PARASOUND record (A) and its interpretation (B) showing the typical relief of the top of submarine permafrost caused by Pleistocene thermokarst.

Results

<u>Study and identification of permafrost-generated landscapes in the SMP roof</u>

The conducted studies have resulted in developing a method for distinguishing permafrost-generated landscapes in the SMP roof on the shelf, based on geometric interpretation of seismoacoustic records. The following landscapes have been identified:

- variously shaped depressions filled with well-stratified deposits and interpreted as buried thermokarst and alases (Fig. 1);
- negative landscapes having a distinct base and gentle slopes, which can possibly be interpreted as sub-lake taliks;
- well-pronounced elevations averaging 2 m in height and 600 m in length, located between depressions. Elevations are apt to be relics of ice complex, while depressions are most likely of thermokarst origin.

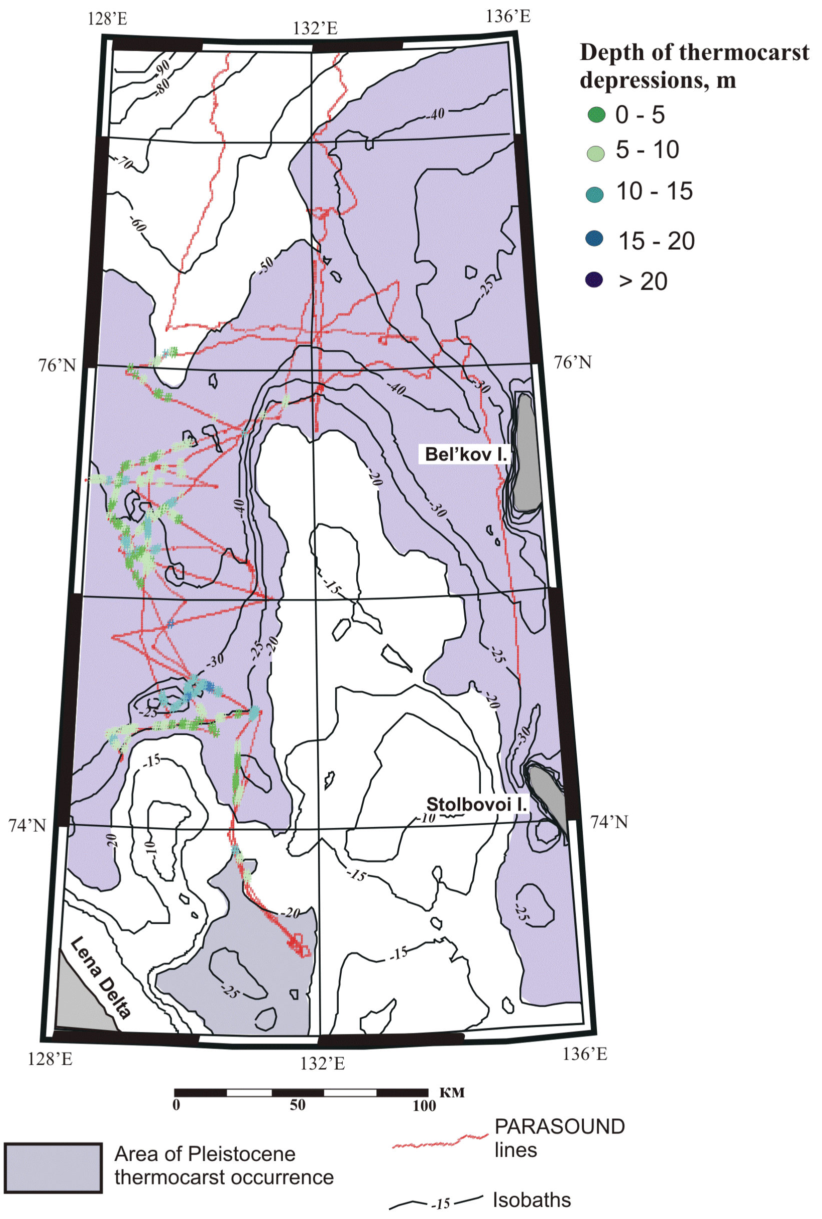

Fig. 2: Distribution of the Pleistocene thermokarst depressions on the eastern Laptev Sea shelf.

Alas and thermokarst depressions were mapped along PARASOUND profiles and classified according to the depth of the SMP roof. Their distribution is defined as regular: the deeper ones (10-20 m) are located at the elevated zones of the seafloor whereas the depressions with SMP roof depth less than 10 m occur in the lower zones. As suggested by Tumskoy (2002), the area of spread of distinguished depressions was in a subaerial position for at least 55 Ka. In accordance with the sea-level variation curve for the Late Pleistocene and Holocene (Fairbanks, 1989), the depressions were submerged at 7.5-10 Ka. All these facts served as the basis for compiling the map of thermokarst distribution (Fig. 2).

Studies of physical and chemical properties of drill cores in the Laptev Sea

Porosity, gravimetric moisture and specific gravity were measured at the OSL using the available devices (electronic balance, sublimator). To prevent organic matter from destruction, samples were dried using the sublimation method (the samples were dry-freezed in a vacuum). Density of solid particles was determined by the bottle method in the GEOMAR laboratory.

Our investigations revealed a high variability along the sections of KI001 and KI005 drill cores. Porosity values range from 0.65 in the upper section to 0.37-0.50 at the depths of 1400-1600 cm, i.e. within the intervals where frozen sediments were recovered. As the density of solid particles remains virtually invariable with 2.60-2.68 g/cm^3, specific gravity of sediments directly depends on porosity with correlation factor R=-0.996. Gravimetric moisture is also highly variable along the section varying from 0.42 in the upper intervals to 0.17-0.27 in the frozen ones.

Heat conductivity of the drill cores was measured at the OSL using the measuring device LITHOS, which belongs to VNIIOkeangeologia. The finctioning of the device is based on the use of a method of cylindrical probe with a linear heat source of permanent power. Measurements were implemented without breaking the cores at the temperature of 20°C. Margin of error is 5%.

Heat conductivity is well correlated with gravimetric moisture, porosity and specific gravity of the sediments. The minimum heat conductivity value was recorded in the upper intervals with 1.4 Wt/mK, the maximum value of 3.3 Wt/mK was reached at 1140 cm.

Measurements of specific electric conductivity were conducted with an 8-contact specific electric conductivity measuring device, available at VNIIOkeangeologia, at the temperature of 20°C. Total error is 10%.

The specific electric conductivity values are significant in determining total salinity of the sediments. Our investigations demonstrated that the specific electric conductivity is well correlated with gravimetric moisture precluding determination of the frozen-sediment distribution in the core. Correlation factor accounts for - 0.88.

Measurements of magnetic susceptibility were conducted with a magnetic susceptibility measuring device, produced by Bartington Instruments, at room temperature, continuously along the cores. Receptiveness of the device is $1*10^{-6}$ units CGS.

Distribution of magnetic susceptibility is virtually homogeneous, varying within the range of $20\text{-}40*10^{-6}$ units CGS. A significant increase in magnetic susceptibility within the 1000-1400 cm interval gives evidence for either dense-sediment inclusions or an increased content of ferromagnetic particles.

For the measurement of anion composition of porous waters the ionic chromotograph METROHM available at the OSL was used. Measurements were conducted at room temperature. Unfortunately, application tuning of the device allowed determination of only anion composition of the porous waters. Margin of error is 1%. Porous waters were separated by a centrifuge with rotation frequency of separator bowl of 3000 revo. The volume of the analyzed water samples accounted for 20 microliters, resulting in using a minimum amount of samples.

The studies of anion composition of porous waters included determination of chlorides, sulfides and phosphates. The obtained anion composition testifies to the marine origin of porous waters. Significant deviations of salinity from the composition of porous waters characteristic for normal marine sediments were not observed.

Furthermore, the major results of the project are the following:

- interpreted PARASOUND acoustic records illustrating buried permafrost-generated landscapes;
- map of upper SMP acoustic facies distribution and paleo-landscapes in the eastern Laptev Sea shelf (Scale 1:1,000,000);
- results of studying SMP physical properties;
- model of formation and evolution of permafrost-generated landscapes of the eastern Laptev Sea.

Conclusion

The interrelation of the recent tectonic processes and cryogenic processes is one of the main factors shaping the Laptev seabed morphology and depositional environment. Scouring by icebergs from Severnaya Zemlya and an extensional sea-ice regime account for unique conditions on the arctic shelves. Seismicity reveals active normal faulting. Near-bottom sediments are affected by extensional dislocations, detected by high-resolution seismic data. The faulted seafloor relief influences near-bottom currents, distribution and redistribution of sediment transport pathways, and, consequently, the submarine landscapes. The latter are important factors shaping the roof of the submarine permafrost after its submergence during the Holocene.

The SMP roof is well pronounced in the physical properties of the sediments, as gravimetric moisture, porosity and specific gravity. As permafrost formed at terrestrial conditions, the moisture of sediments is essentially lower than that of the overlying sediments: moisture of the samples collected from the core intervals above the permafrost accounts for 0.45-0.3, which is typical for marine sediments, whereas moisture in the frozen part of the core is 0.15-0.25.

The data of the magnetic susceptibility measurements have revealed deviations in values in the zone of SMP roof occurrence suggesting either decreased moisture of the sediments or inclusions of dense sediments, or increased content of ferromagnetic particles that can be evidence of subaerial conditions during sediment formation. Unfortunately, the data on total salinity and anion composition of the sediments do not reveal any pronounced changeability in the properties of marine and frozen deposits. A more distinct picture can be obtained by studying the cation composition of porous waters.

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EVOLUTION OF THE LACUSTRINE GEOSYSTEMS OF THE TAIMYR PENINSULA

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Introduction

During the last decade of the 20th century Russian and foreign scientific organizations, within the framework of both international and national programs, carried out research dealing with the paleogeography, paleoclimatology, paleolimnology of the arctic region. The present work was accomplished within the framework of the joint Russian-German project “Laptev Sea System”, the international project QUEEN (Quaternary Environment of the Eurasian North), and the scientific program of the Arctic and Antarctic Research Institute (AARI) “Arctic Climate System Response to Global Climate Fluctuations.”

This project was focused upon the lacustrine complexes of Taimyr Peninsula, including the water area, the basin and the bottom sediments. Their modern structure was characterized and the evolution of the lacustrine geosystems of Taimyr Peninsula was investigated. The main tasks of the project were to reveal the major factors of the lacustrine geosystem formation on Taimyr Peninsula, to trace the main stages of development of lacustrine geosystems on Taimyr Peninsula, and to carry out limnological zoning and classification of the lacustrine geosystems of Taimyr Peninsula.

Research activities

This project is based on data obtained during the expeditions (1994-2002) to Taimyr Peninsula within the framework of the international projects “Laptev Sea System” and QUEEN, in which the author took part. In addition, the author took part in hydrological and sediment-balance investigations, geomorphological mapping, examination of the geological structure of Quaternary sediments, sampling and seismoacoustic sounding of the bottom lacustrine sediments. All data from these investigations were used to achieve the goals of this work. Also photos of the scales 1:1,000,000-1:50,000 were used as well as maps of the scales 1:1,000,000 up to 1:100,000. Besides, all published material was analyzed in detail.

For the first time this project provides a general overview of the ample modern data on the marine Pleistocene sediments on Taimyr. A new concept of the character and interrelations of the Late Neopleistocene marine and glacial events in northern Central Siberia was created and proved by data. For the first time the Taimyr lacustrine geosystems were classified. This classification is used for developing recommendations for the use of water bodies, which are of vital importance for the ecosystem of Taimyr Peninsula. Paleogeographical reconstructions were carried out to evaluate and forecast the development of the environment in the future. The results of the investigations were used for the AARI research entitled “Arctic Climate System Response to Global Climate Fluctuations”.

In order to reveal the major factors of the formation of the lacustrine geosystems on Taimyr Peninsula and to trace their main development stages, the following paleogeographical methods were applied: analysis of the correlated form of relief and sediments, morphostructural analysis, lithological and structural-facial analysis of Quaternary sediments, interpretation of the results of the paleobotanical studies and dating methods, seismographical methods, and the method of evaluating the amplitudes and velocities for the modern tectonic movements based on the differences in height between dated terraces.

The limnological zoning and classification of the lacustrine ecosystems was carried out using the method presented by Kalesnik (1965). During this stage of work it was necessary to use the OSL computer laboratory.

Results

We investigated the development of the limnosystem of Taimyr Peninsula and its main development stages. Sea level oscillations and modern tectonic movements on the peninsula in the Late Neopleistocene were analyzed as they are the most important factors responsible for lacustrine geosystem formation.

The existing approaches to classification of lake geosystems can be divided into three main groups based on 1. structure, 2. function and 3. development history. It was shown that the classifications of both the second and third systems cannot be considered as satisfactory at the modern state of knowledge. The classification proposed in this work is constructed on the basis of landscape structure (Table 1).

Table 1: Classification of the limnosystems of Taimyr Peninsula.

Type	Sub-type	Landscape unit	Forming factors	Development scenario	Age
1		**Byrranga mountains**	1+2	1	Beginning of Late Neo-Pleistocene/ Holocene
	1.1	Central mountainous Taimyr			
	1.2	Western mountainous Taimyr			
2		**Taimyr Lowland**	2+3	2	Middle of Late Neo-Pleistocene
	2.1	Northeastern region			
	2.2	Southeastern region			
	2.3	Southwestern region			
3		**Accumulative Uplands**	3	2	Early Holocene
	3.1	Taimyr Lowland			
	3.2	Northern Taimyr			
4		**Lowest ranks of landscape structure**	4	3	Holocene
	4.1	Inter-mountainous lakes			
	4.2	Corrie lakes			
	4.3	Oxbow lakes			
	4.4	Thermokarst lakes			
	4.5	Lagoon lakes			

Several paleo-limnological scenarios were studied. According to these scenarios, the three main processes of lacustrine-system formation are the following (Table 1):

1. formation of lacustrine systems is still active, which not only causes a constant further development of the already existing lakes of this type, but also the formation of new lakes (which, therefore, can be of very different ages);
2. formation of lacustrine systems took place in a relatively short time period, (after the impact of this formation process subsides, new lakes do not form any more, while the

already existing lakes slowly degrade; note that all the lakes of this type are of almost the same age);

3. formation of lacustrine systems is active for a long period of time, but the individual lakes are not preserved for a long time, due to the influence of other factors (the lakes are of different ages, but exist only for a relatively short time).

The main factors of the formation of the Late Pleistocene geosystem of Taimyr Peninsula were determined and are listed below in order of significance:

- development of the latest tectonic structures of east-northeastern strike;
- development of the latest tectonic structures of north-northwestern strike;
- processes of Quaternary sedimentation, which primarily depend on sea-level oscillations and development of Quaternary glaciations;
- everlasting landscape-forming processes responsible for the formation of landscape features of lower ranks (cryogenic, slope, erosion, coastal processes, etc.).

According to this classification, we divided the Taimyr Peninsula limnosystems into zones.

The main stages of the lake geosystem development were analyzed. For each of the determined types, lake morphometry, geological-geomorphological characteristics of the depressions and basins, and sediment types were analyzed.

Lake Taimyr is a unique environmental system and does not belong to any of the above-mentioned landscape units since it lies at the boundary of the different geographical, botanical, geomorphological and tectonic regions of the peninsula. The lake is situated between the Byrranga mountains and the Taimyr Lowland, at the boundary of Eastern and Central Taimyr. It is also unique due to the fact that the conditions of its formation could be met only in this area. The main formation factors of Lake Taimyr are: 1. development of the latest tectonic structures of east-northeastern strike; 2. development of the latest tectonic structures of north-northwestern strike; 3. influence of the processes of Quaternary sedimentation during the period of sea-level stabilization as a result of the regression in the Karginian.

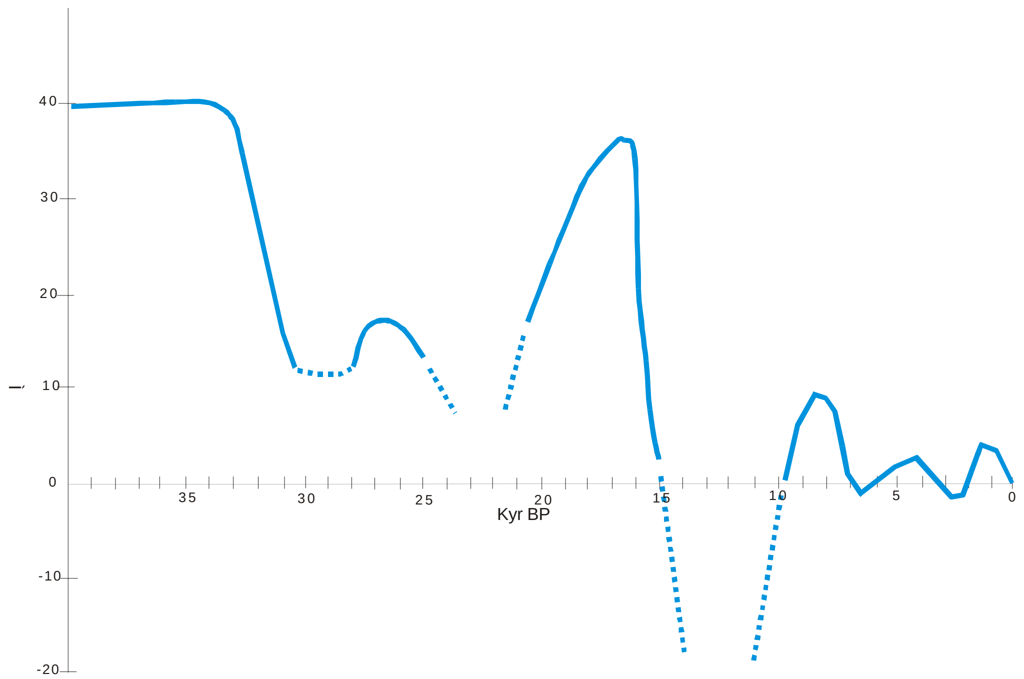

Fig. 1: Lake Taimyr level oscillations in the Late Neopleistocene and Holocene.

We described the sediment sections of Lake Taimyr terraces, the fragments of echo-sounding profiles of the lake sediments of Taimyr and other lakes of the Taimyr basin as well as Holocene climate change curves of Central Taimyr and the Taimyr Lowland constructed on the base of spore-pollen analyses of the samples from lacustrine and alluvial sediments. The reconstructed level oscillations of Lake Taimyr in the Late Neopleistocene and Holocene are presented in Figure 1.

Conclusion

The main results of this project can be summarized in the following way:

- Four hierarchic ranks of landscape zones were identified for Taimyr Peninsula. They are related to the development of the latest tectonic structures of east-northeastern and north-northwestern strikes and the processes of Quaternary sedimentation. The latter primarily depends on sea-level oscillations, development of Quaternary glaciation, and also on ever-lasting landscape processes responsible for the formation of the lowest landscape ranks (cryogenic, slope, erosion, coastal processes, etc.).
- Four main stages of the formation of the Taimyr lake geosystems were identified. They are related to 1. tectonic activity at the beginning of the Late Neopleistocene, 2. stabilization of the sea level in the Karginian as a result of regression, 3. deglaciation of the Sartanian glaciers, and 4. processes forming the lowest landscape ranks during the Holocene.
- The lacustrine geosystems of Taimyr Peninsula were divided into 4 main types corresponding to the 4 main landscape ranks on the one hand, and to the 4 main stages of the peninsula lake geosystems on the other hand.

As a result of this study, a PhD thesis was prepared and defended.

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THE LAPTEV AND EAST SIBERIAN SEAS COASTAL EROSION DATABASE: DYNAMICS, CLASSIFICATION, SEGMENTATION, SEDIMENT AND ORGANIC CARBON CONTRIBUTION

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Introduction

Scientific background

Coastal erosion plays a significant role in the sediment and organic carbon balance of the Arctic Ocean. The coast of the Laptev and East Siberian seas is composed of different types of rock and sediment including permafrost characterized by high ice content, fast coastal retreat rates and high content of organic material. There is a great number of published data which describe coastal processes in the studied area. However, the volume of sediment input to the shelf of the Laptev and East Siberian seas as a result of coastal erosion has so far been incompletely studied. There are less data on the contribution of coastal erosion to the organic carbon balance on shelves. Numerous publications about coastal characteristics of that area are available (Toll, 1897; Gakkel 1957, 1958; Zenkovich, 1962; Grigoriev, 1966; Kluyev 1970; Kaplin et al., 1971; Holmes and Creager, 1974; Are, 1980, 1985, 1987; Archikov et al. 1982; Korotaev, 1984; Budyko and Izrael, 1987; Pavlidis et al., 1988; Lisitzin, 1990; Grigoriev, 1993, 1996; Reimnitz et al. 1994; Kuptsov and Lisitzin, 1996; Alabyan et al., 1995; Kaplin and Selivanov, 1999; Lopatin, 1999; Semiletov, 1999, 2000, and others). However, the portion of sediment that is supplied to the shelf from each type of erosive coastal section of the Laptev Sea is known insufficiently. Moreover, most of these papers are dealing with coastal retreat rates and sediment input only and publications considering the organic carbon flux are very limited (Semiletov, 1999, 2000; Lisitzin, 1990; Ronov, 1993; Romankevich and Vetrov. 2001).

During the expeditions within the framework of the Laptev Sea System project (1998-2003), eroded coastal sectors, especially ice-rich areas, were studied in detail (50 key sites in the western, eastern and central parts of the Laptev Sea, and in the western part of the East Siberian Sea). Research on the dynamics of ice-rich coasts shows that the predominant rate of coastal erosion within the Ice Complex coast is 1-4 m per year. Research results confirm our suggestion that the greatest contribution of sediments and organic carbon from erosional coasts into the sea is due to a very fast destruction of the Ice Complex.

Goals and objectives

The goals of the project were:

- to classify all typical sections at the coasts of the Laptev and East Siberian seas with regard to geomorphology and coastal processes;
- to conduct a detailed segmentation of the coastal study areas based on the following parameters: dynamics and composition of coasts, lithology, morphology, hydrodynamics and geocryological conditions;
- to assess sediment and organic carbon fluxes from each segmented coastal section of the Laptev and East Siberian seas;
- to create a database of erosional coasts of these seas with a GIS-based digital map.

Research activities

Approach

The basic work of this project is a summary of our own and published materials including the results of the Russian-German expeditions (1998-2003) in the coastal zone of the Laptev and East Siberian seas. It was planned to process data on more than 100 research sites at the coast, 50 boreholes, geomorphologic, geologic, geocryologic, bathymetric and other thematic maps, satellite images and aerial photographs. For a more precise segmentation of coastal sections we used internet data on the coastline (World Vector Shoreline) and coastal bathymetry (IBCAO and GEBCO). The Ice Complex which occupies about one third of the whole coastline was investigated in greater detail. Database development was based on the most detailed (for a chosen scale of digital maps) division of the coast into typical segments. There are 73 segments within the Laptev Sea and 50 segments within the East Siberian Sea, the latter being much more simple in coast structure and configuration. All coastal parameters were determined by average characteristics specified for each separate coastal section.

Accomplishments

Our investigations of coastal dynamics are based on a comparative analysis of our own and previously published data, up-to-date material of theodolite surveys of coastlines and remote sensing material, such as large-scale maps, satellite images and aerial photographs obtained between 1951 and 2001. To assess the coastal rock and sediment composition, we used all material about the geological structure of coasts in the study sections, investigated outcrops and boreholes as well as detailed maps on Quaternary geology and cryolithology. GIS-based technologies (ArcInfo/ArcView version 8.1, and ENVI version 3.4) were used for creating a database and processing remote-sensing material. The methods for estimating eroded coastal sediments and organic carbon input into the sea include the following procedures:

- assessment of average rates of coastal retreat at representative sites based on field observations and measurements and on comparison with remote sensing material (in different periods);
- determination of coast morphology, mostly elevations of cliffs and slopes, for estimating the volume of sediment input onto the shelf (considering data of item 1);
- analysis of coastal geological and geocryological composition including average values of volumetric ice content and special density of sediments, which allow estimating the weight of sediment input into the sea as a result of coastal erosion;
- evaluation of total organic carbon content in coastal sediments for each basic sediment type to assess the weight of organic carbon transport from the coastal zone onto the shelf;
- segmentation of coasts and correlation of results obtained from each coastal section for estimating the general contribution of coastal erosion with regard to sediment and organic carbon in the Laptev and East Siberian seas.

Results

The following goals were achieved:

- coastal classification of the Laptev and East Siberian seas based on a digital map;

- segmentation of study coasts based on the following parameters: coastal dynamics, coastal composition, lithology, morphology, hydrodynamics, coastal bathymetry and geocryological conditions (Fig. 1);
- assessment of the contribution of coastal erosion to the budget of continental sediments and total organic carbon of these two seas;
- creation of a database on the coastal zone of the Laptev and East Siberian seas.

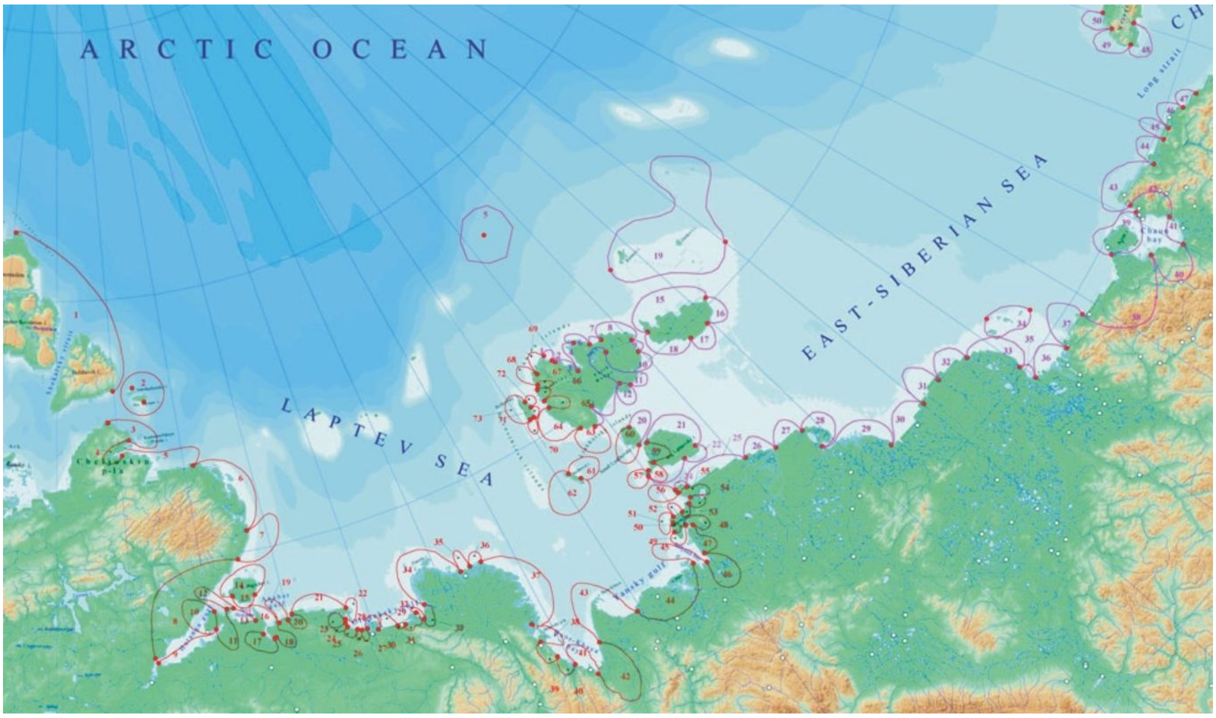

Fig. 1: Coastal segmentation of the Laptev and East Siberian seas depending on coastal dynamics, morphology, lithology, geocryological conditions, near-shore hydrodynamics and bathymetry.

The structure of the database (with average parameters for each section) comprises the following items: 1. section number; 2. name, initial and final point of the section (from west to east); 3. section coordinates; 4. main coastal forms; 5. dominating types of coastal dynamics; 6. dominating types of rock/sediments; 7. total length of coastal section (km); 8. average height of coastal cliff/slopes (m); 9. average rate of erosion retreat or coast accretion (m/yr); 10. average distance from coastline to the 2, 5, 10 and 100 m isobaths; 11. average volumetric ice content in the rock (%); 12. average specific density (t/m^3); 13. average value of eroded coastal sediments transported into the sea (t/yr); 14. Average weight (%) of organic carbon; 15. average value of total organic carbon transported into the sea through coastal erosion (t/yr); 16. main features of coastal section; 17. summary on coastal section; 18. generalized parameters of the sea; 19. illustrations.

Conclusion

Based on previous estimations, the values of coastal input to the Laptev and East Siberian seas for sediment amounted to 58.4 million tons per year for the Laptev Sea and 66.5 million tons per year for the East Siberian Sea. For organic carbon they made up 1.8 million tons per year and 2.2 million tons per year, respectively. Now the interpretation of data on all selected and characterized segments in the database allows obtaining more precise values of total sediment (Laptev Sea: 62.6 million tons per year; East Siberian Sea: 68 million tons per year) and total organic carbon input (Laptev Sea: 1.63 million tons per year; East Siberian Sea: 1.9 million tons per year) onto the shelf.

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SPATIAL VARIATIONS IN ICE FORMATION ONSET IN THE LAPTEV SEA: CONSEQUENCE OF THE VERTICAL HEAT FLUXES CAUSED BY INTERNAL WAVES OVERTURNING

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Introduction

In the Laptev Sea pronounced non-uniform physical properties of the water column are the result of vertical and horizontal density stratifications that are caused by the huge freshwater input. In this respect a most important role is played by the dynamical processes that occur at the pycnocline and have a distinct effect on the hydrological regime of this arctic shelf sea (Kirillov et al., 2001; Dmitrenko et al., 2001). A striking example for these effects is the delay of the onset of the ice formation onset in fall. Until recently it was hypothesized that the onset of ice formation in the Laptev Sea occurs simultaneously in all areas. This hypothesis was not supported by satellite observations during the freeze-up period. As soon as oceanographic and remote sensing information concerning the ice formation onset were collected on a regular basis, our view on these processes changed dramatically. It was observed that the freeze-up in the Laptev Sea showed a spatial pattern that consists of distinct zones with different times of freeze-up onset (Kirillov et al., 2002). The dimensions of these zones exceed tenths of kilometres and the onset of the freeze-up differed by weeks. A possible reason for this observed difference is a variable heat exchange through the pycnocline. In this study we tried to evaluate the effect of internal waves (IW) on the vertical exchange of heat, and the importance of this process during the freeze-up.

In 1972 Garrett and Munk (GM) presented an overview of the historical data on internal waves in the ocean. They assumed that internal waves occupy the frequency-band from local inertial to buoyancy frequencies. As a result of this work they formulated a model (GM72) with an internal wave background which is steady in time and space regardless of the vertical and horizontal boundaries of the ocean basin. This model was modified by different authors (Garrett and Munk, 1975; Cairns and Williams, 1976; Munk, 1981), who revised some details of the frequency spectrum, but did not challenge the general assumptions of the model. The universal GM spectrum is in good agreement with observations and within the framework of the GM model several models of dissipation rate were formulated (McComas and Bretherton, 1977; McComas and Müller 1981; Henyey et al., 1986; Gregg, 1989). Despite the universal character of the GM model, the shape of the horizontal kinetic energy (HKE) spectrum is consistent with observations of internal wave dynamics in different areas of the World Ocean although the spectral energy level may vary in space. In particular, the Arctic Ocean is a region with a HKE that is one order of magnitude below the predicted HKE for mid-latitude level (Levine et al., 1985; Padman and Dilon, 1989). On the other hand there is evidence that the GM model is also working within shallow-water conditions near the shore (Pringle, 1999; D'Asaro and Lien, 2000; Levine, 2002). In this respect the velocity measurements carried out in the shallow Laptev Sea are of special interest. The extremely shallow water makes these measurements a unique data set for estimating the vertical heat exchange due to internal wave breaking according to the GM model.

The aims of this project were:

- to describe the distinctive features of internal waves background on the Laptev Sea shelf;
- to verify the results of the GM model with data from short-term ADCP current records;

- to check if the variability of the ice formation onset is caused by the action of internal waves at the pycnocline.

Research activities

In general the investigation closely matched the initial aims. According to our plan we studied the mechanism of internal wave breaking and its relation to the vertixal heat fluxes through the pycnocline. Additionally we tried to understand the relation between atmospheric forcing and the energy of internal waves. It was found that the energy enhances by the factor of 2-3 during strong atmospheric forcing. This forcing might significantly postpone the ice formation onset due to increasing heat exchange in the water interior.

Results

Time series of the horizontal velocities in a Siberian Arctic shelf sea were analyzed to compare the HKE spectrum with the GM79 model of the internal-wave spectrum. As already stated in previous publications, it was found that the energy level of the spectrum is two orders of magnitude lower than that predicted by the GM model. Despite this the spectral shape of energy is mostly in good agreement with theory and the internal waves continuum shows a -2 slope (predicted by GM) with high probability.

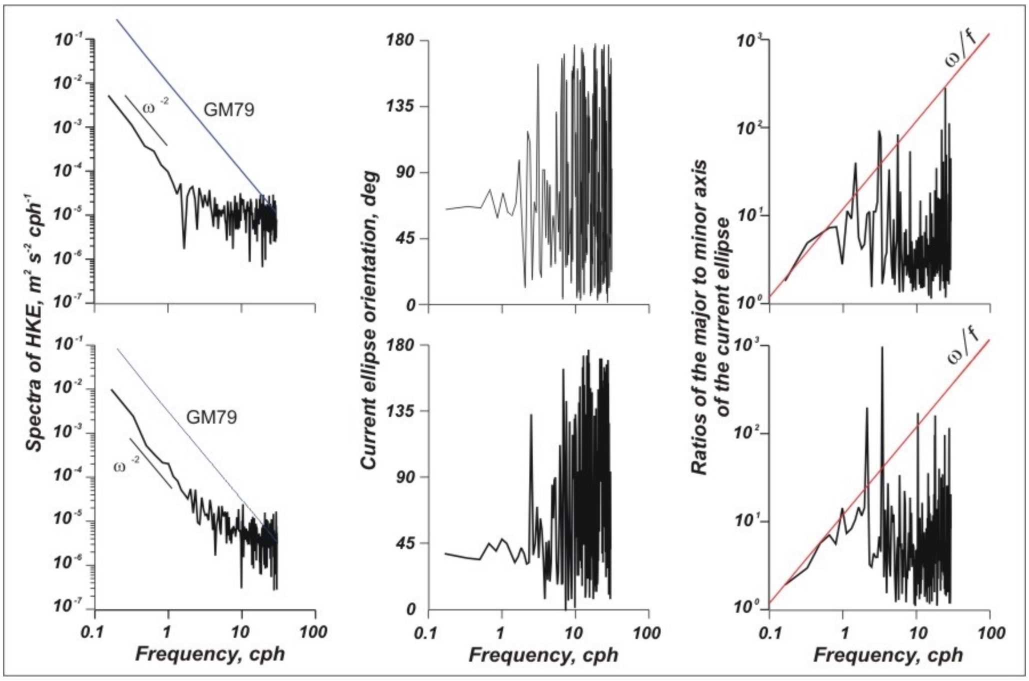

Fig.1: The frequency dependence of the current ellipse characteristics at 17 m depth (top panel) and 38 m depth (bottom) at the mooring station 24.

The traditional exceptions in the shape of the spectra are the maximum at the near-inertial frequency (approximately 12.4 hours) and the spectral “shoulder” at the high frequency (Fig. 1). These discrepancies were noted by different authors in observations of the internal-wave pattern throughout the world (Levine et al., 1999), but our results are especially interesting because the “shoulders” start far away from the local buoyancy level (more than 50 cph anywhere). Analysis of the possible errors revealed the only beam separation is able to considerably change the spectra. But it affects the spectra level at the highest vertical modes supplying only a very small part of the total energy.

The GM spectrum was evaluated initially as isotropic in different directions, but near the shore this assumption is rather disputable. Sufficient polarization of horizontal velocity found in numerous regions far away from the open ocean tends to focus the wave energy toward the coast (McKee, 1973). ADCP observations were analyzed in the light of this issue to find out the wave orientation and ellipticity of the current ellipse. But like the GM model our spectrum was considered as a isotropic one with the only exception of the frequency band from local inertial frequency to the “shoulder” at station 24 where strong polarization is obvious (Fig. 1). Wave-ellipse orientation varies a little within the 40°-65° range in the counterclockwise direction from the east. In terms of topography it means that the energy of the waves, vectored across topography irregularities, predominates the other directions. The specific topography at station 24 allows us to assume reflection to lie at the basis of the energy focusing.

Following Osborn (1980), Henyey et al. (1986) and Gregg (1989), we define mixing diffusivity intensity through the relation of observed shear variance of the horizontal velocity (S^2) and the expected shear variance according to the GM79 model (S^2_{GM}). The GM spectrum deals with the 0.1cpm vertical wave-number cutoff as a critical value for shear (Ri=1/4). Nevertheless, in a non-GM internal wave model this parameter can be much higher, especially if the HKE level is less than the of GM. We chose an arbitrary vertical cutoff value as the start of the white slope in the vertical wave-number spectrum (not presented here). It is approximately 0.7 cpm instead of GM's 0.1cpm. In addition we used 1.39 as a multiplier for S^2 to make it comparable to S^2_{GM} as a correction for the attenuation of the first-difference filter (Gregg and Sanford, 1988) and 0.6 multiplier for ADCP-beam separation correction (Alford and Pinkel, 2000).

The vertical mixing diffusivities were defined by using Gregg’s (1989) approach with modification in the critical wave-number cutoff value. To estimate the shear we used the frequencies below the “shoulder” for a better comparison with the GM as this was evaluated without taking into consideration such irregularities as “shoulders.” The background level of mixing intensity is calm enough: the averaged values of mixing coefficients vary from molecular up to $5\text{-}30\cdot10^{-5}$ m^2/s within the pycnocline at YS0024. These estimations are in good agreement with the $4\cdot10^{-4}$ maximum value of vertical diffusivity in the Laptev Sea pycnocline (Kirillov et al., 2002). It might result in a delay of ice formation onset by up to 5-6 days over the eastern part of the Laptev Sea (Kirillov et al., 2002).

These results do not correspond to the two-three week delay in ice formation onset according to the SSM/I images analysis. The values mentioned above are based on the short time-series observed during a relatively calm (not windy) period. But the shallow-water dynamics is very sensitive to atmospheric forcing and the energy level can dramatically change under these conditions (Levine et al., 1985). We consulted Henyey (1986) to estimate dissipation rate increase (and mixing efficiency as a result). The dissipation rate is proportional to the squared total internal-wave energy per unit area. In the terms of Henyey the relation $\sim E^2_S$ is appropriate if the shape of the spectra corresponds to that of the GM model.

Despite some discrepancies with the latter assumption (spectral shape quite different during pre-storm and storm period) we analyzed long-term series of the horizontal velocity measurements to find out the order of the HKE increase at YANA station. Under strong atmospheric forcing we considered the enhancement of the energy as matching the factor of 2-3 (Fig. 2). We arbitrarily chose three events when strong atmospheric forcing was observed between calm periods. For these events the total energy increase (within the frequency band

0.09-1 cph) is by 2.87, 1.88 and 3.09 times higher than the prestorm HKE level. After having eliminated wind forcing, the HKE spectra level sinks rapidly to its level in calm conditions.

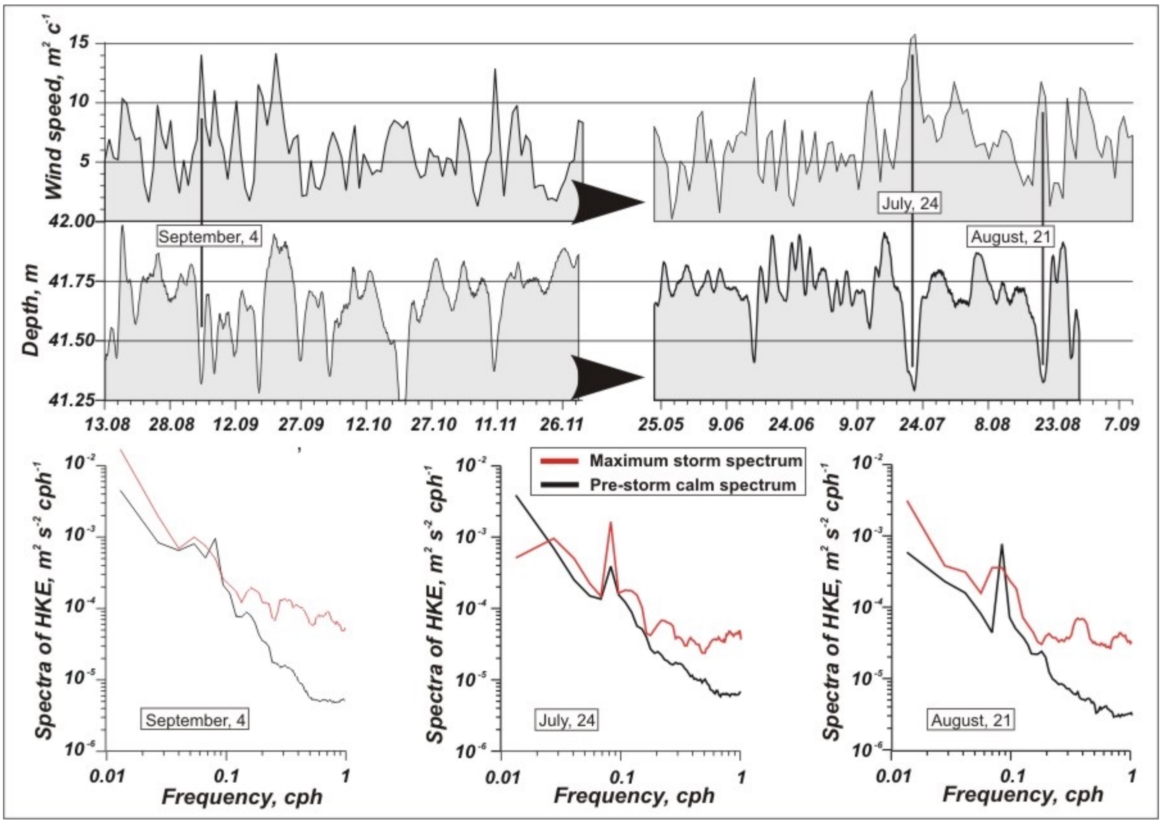

Fig. 2: HKE spectral level evolution during several events of strong atmospheric forcing at YANA mooring station evaluated from NCEP Reanalyse Data and pressure records.

Conclusion

Through their instability and breaking internal waves seem to play a significant role in generating dissipation energy. Under the strong density interface due to the huge amount of river runoff in the Laptev Sea, the water interior is a favourable environment for the occurrence of internal waves. This research was aimed at answering the question whether the internal wave breaking results in delay of ice formation onset and at evaluating the time scale of the delay. We have found that this process could result in ice formation delay by up to 5-6 days over the eastern part of the Laptev Sea. This, however, does not correspond to the two-week delays in ice forming observed in the Laptev Sea region.

Another possible mechanism was analyzed in order to answer this discrepancy. Storm events during fall are thought to be responsible for the further delay of ice formation.

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LATE PLEISTOCENE AND HOLOCENE PALEOENVIRONMENTAL CONDITIONS, THEIR CHANGES AND INFLUENCE ON THE DISTRIBUTION OF MAMMALS IN THE LAPTEV SEA SURROUNDINGS

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Introduction

Our knowledge of the Arctic climate system has been significantly improved through multi-disciplinary investigations carried out in the Siberian Arctic during the Russian-German project "Laptev Sea System 2000" (Rachold and Grigoriev, 1999, 2000, 2001; Pfeiffer and Grigoriev 2002; Kassens et al., 1999). Important information concerning the complex modern system and detailed climatic reconstructions of the Late Quaternary were obtained and provide important data for the prediction of future climate changes. The investigations document the closely coupled land-ocean system of the Laptev Sea with the East Siberian hinterland and its complex connections, in which the Lena Delta represents a key region for the understanding of environmental changes.

The role played by the Laptev Sea system in the modern arctic climate and environment is extremely important, and is therefore subject to extensive current studies. Due to a much lower sea level until 15,000-12,000 years ago, this epicontinental shelf sea did not exist and flat lowlands spread very far to the north (Sher, 1997). The understanding of this environment is only possible by interdisciplinary studies of corresponding terrestrial deposits of the shelf.

One of the main types of continental deposits in the Laptev Sea region is the Ice Complex formation, extreme ice-rich, syngenetically frozen permafrost sequences of silty and sandy deposits with peaty paleo-soils and large ice wedges. This formation is widely distributed along the southern and eastern coasts of the Laptev Sea, including the New Siberian Islands and was continuously accumulated over a vast territory during the Late Pleistocene. Multidisciplinary studies of Ice Complex deposits are very important because of the numerous paleoecological, geochemical, sedimentological and stable isotopic data stored in these permafrost deposits (Schirrmeister et al., 2002 and others).

The terrestrial Pleistocene deposits of the former shelf contain various bioindicators of the past environment like mammal bones, insects, mollusk shells, diatoms, pollen, ostracods etc. The study of this evidence, supplemented with dating methods, provides an incomparable archive of the past life and the Pleistocene paleoenvironmental conditions.

Scientific background

Within the framework of the Russian-German "Lena Delta Expeditions" (1998-2002), carried out under the umbrella of the "Laptev Sea System 2000" project, we investigated Late Pleistocene and Holocene deposits on the southern and southeastern coasts of the Laptev Sea and New Siberian Islands (Rachold and Grigoriev, 1999, 2000, 2001). More than 3000 fossil mammal bones have been collected in the Lena Delta region, on the New Siberian Islands, Oyogos Lowland and Muostakh Island (Kuznetsova et al., 1999a, 1999b, 2000, 2001; Kuzmina et al., 1999; Sher et al., 1999; Kuznetsova and Kuzmina, 2000, 2001, 2002; Schirrmeister et al., 2002) (Fig. 1). In contrast to former collections, our collection is unique because of the 100% registration of all bone findings. Such an approach provides the opportunity to understand the composition, fluctuation and migration of mammal populations that existed in these areas during the Late Pleistocene and Holocene.

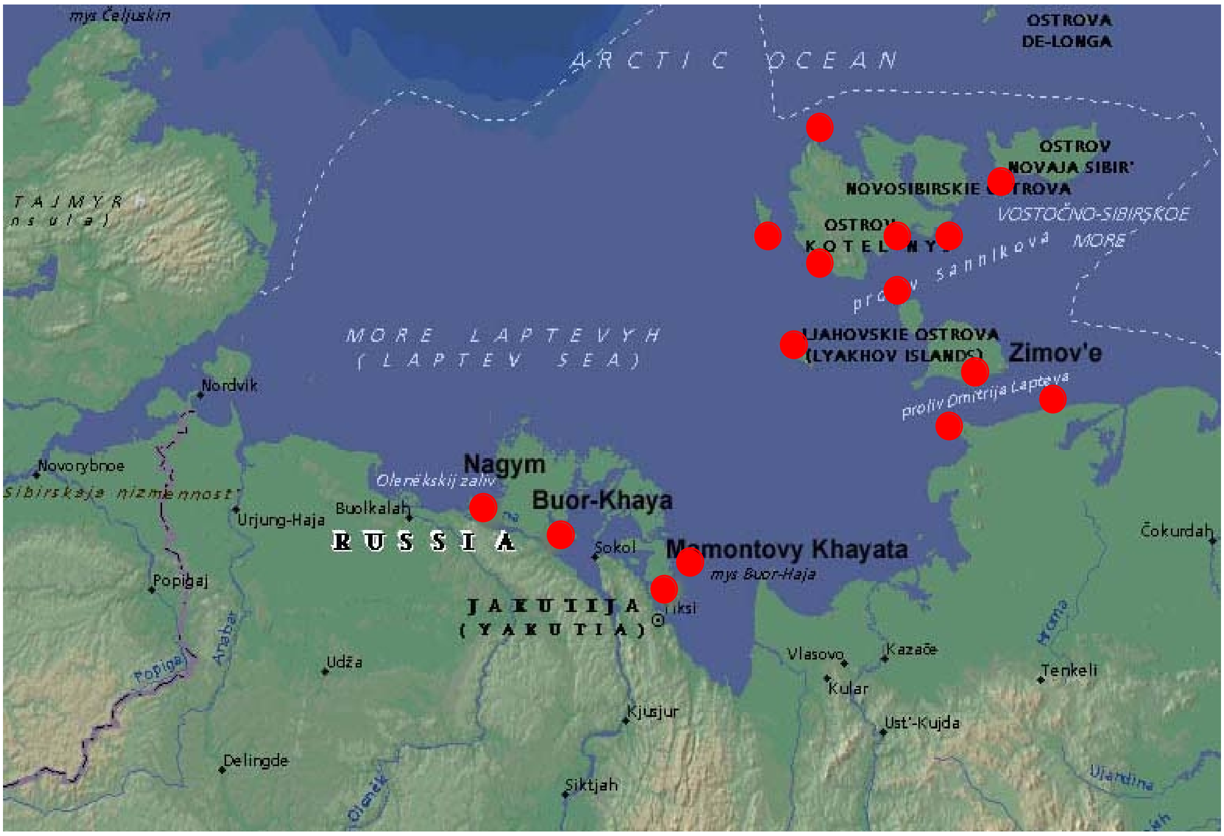

Fig. 1: Location map of the working area.

The principal investigator T. Kuznetsova participated in two projects within the framework of the OSL Fellowship Programs 2000 and 2001 and closely cooperated with colleagues from others OSL projects. Two databases (LAPPAL) were created with the applicant's participation, the database of fossil mammals from the Laptev Sea area and the database of radiocarbon dating of mammals from the Laptev Sea area (Sher et al., 2000). In addition, a revision of fossil animals from previous collections (more than 30 collections) from the Laptev Sea Region was started.

The investigations in the scope of the "Lena Delta Expedition" and the OSL Fellowship Programs were focused on the study of members of the "Mammoth fauna" (woolly mammoths, horses, bisons, woolly rhinoceros, muskox, pleistocene lion, hares and different groups of rodents). The results indicate that the study of fossil mammals is very important for the understanding and reconstruction of paleoenvironmental conditions.

The determined composition of large mammals in the "Mammoth fauna" of the Laptev Sea region was different to the results during the 100 years after Cherskiy (1891). Woolly mammoth, horse, bison and reindeer bones dominate in our collection and these mammals dominated in "Mammoth fauna" too. That is a result of the entire registration of all bone findings (Kuznetsova et al., 2001).

A new approach to the registration of bones and an extensive program of bone collagen radiocarbon dating (^{14}C) makes it possible to reconstruct the composition of animal populations during the Late Quaternary. For the first time we indicated the period between 20 and 15 ka BP with only a few findings of woolly mammoth bones. Such a decrease of mammoth fossil bones and their subsequent increase indicate less favourable environmental conditions for woolly mammoths during the first period and better conditions during the second period and therefore fluctuations or migrations of the mammoth populations.

Age dating by bones of muskox and horse proves that these large grazing mammals lived in the territory of the East Siberian Arctic during the Late Holocene. Two very young muskox dates from Bykovsky Peninsula (3,200±40 and 3,180±100 yr BP) show for the first time a wide muskox distribution on the southern coastal land of the Laptev Sea in the late Holocene. Besides there are two very important dates for Holocene horses from this region (4,610±40 yr BP from Bykovsky Peninsula and 2,200±50 yr BP from Bol'shoy Lyakhovsky Island). They refute that wild horses did not live in the Siberian Arctic during the Holocene (Kuznetsova et al., 2001, 2002).

Last year we included the data on terrestrial diatoms for higher accuracy and control of the obtained results by changing environmental conditions. Anna Bryantseva started to analyse recent and fossil diatom assemblages of the Laptev Sea region (Bol'shoy Lyakhovsky Island).

Goals and objectives

The main goals of the project were the recognition and reconstruction of the basic features of the environment and climate of the Laptev Sea shelf area and coastal lowlands during the Late Pleistocene and Holocene on the basis of paleontological and geochronological evidences. The main objectives were:

- taxonomical and morphological studies of new paleontological material that was collected during the expedition "Lena Delta and New Siberian Islands 2002" in the Lena Delta, on the New Siberian Islands and Oyogos Yar coast. A revision of fossil mammals from the previous collections in the Laptev Sea area;
- the reconstruction of composition of the animal populations and their changes on the Laptev Sea shelf during the Late Pleistocene and Holocene. Analysis and explanation of inhomogeneous distribution of populations;
- identification of favorable and unfavorable periods of environmental conditions for different species of mammals on the New Siberian Islands and in the eastern part of the Laptev Sea coastal lowland during the Late Pleistocene and the Holocene. Analysis and comparison of environmental factors which influence the distribution of different animal species;
- detailed micro-paleontological and paleo-environmental studies of the most interesting periods. Study of diatom assemblages of terrestrial deposits that were formed in these periods;
- reconstruction of temperature variations during the Late Pleistocene and Holocene.

Research activities

Approach

The study of fossil remains of mammals provides information about past life and important proxy evidence for the reconstruction of past climate conditions. Combined with the traditional paleobotanical analysis and with a complex of sedimentological research, it forms the basis for the most complete reconstruction of the past environment. Our fundamental methodological approach consists in the postulate that there are no complete analogues of the Pleistocene terrestrial communities in modern biota.

This research project was carried out applying the following methods:

- morphological study and taxonomical determination of each sample of fossil animals (approximately 15 taxa of mammals);
- radiocarbon dating of bone collagen (^{14}C);
- analysis of distribution and migration of Late Pleistocene and Holocene animals (woolly mammoths, horses, bisons, muskox, rodents, etc.);
- taxonomical determination and analysis of fossil diatom assemblages from the Late Pleistocene terrestrial deposits;
- interpretation of data on oxygen isotope ratios in fossil mammal bones.

The main method was the multidisciplinary paleoecological analysis, in which various kinds of paleoecological information have to be summarized by a strictly defined stratigraphic and chronological control.

The above outlined tasks were carried out in close cooperation with German (e.g. H.-W. Hubberten, C. Siegert, L Schirrmeister) and Russian colleagues (e.g. N. Romanovsky, V. Tumskoy, S. Kuzmina, E. Taldenkova, S. Drachev), who are involved in the joint Russian-German project “Laptev Sea System” and various OSL projects. The main part of the material was collected during the Russian-German expedition LENA DELTA (1998-2002) with active help of all the team members. Taxonomy and morphology of the large mammal were studied with the help of A. Sher. Radiocarbon dating of bone collagen was carried out by L. Sulerzhitsky in the Geological Institute RAS (Moscow).

For carrying-out the above outlined objectives we used the following material:

- Unique new collections of more than 3,000 mammal bones from the Lena Delta region (Bykovsky Peninsula, Olenyek Channel), New Siberian Islands (Bol’shoy Lyakhovsky, Maly Lyakhovsky, Kotel’ny, Stolbovoy, Bel’kovsky, New Siberia), Oyogos Lowland and Muostakh Island (Fig. 1), including the material (600 samples) was collected by T. Kuznetsova during the expedition “Lena Delta and New Siberian Islands 2002”; collections of recent and fossil hears and rodents from the southern coast of the Laptev Sea. The collecting was rather concise as all identifiable fragments were registered in order to obtain complete statistics of the species composition.
- We planned to work on paleontological material that had been collected in the Laptev Sea region from 1886 (collection of A. Bunge and E. Toll) to 1995 (collection L. Sulerzhitsky). These collections are kept in the Zoological Institute RAS (St. Petersburg), the Paleontological Institute RAS and Geological Institute RAS (Moscow). They needed a revision according to modern paleontological knowledge.
- We used and expanded the databases on fossils mammals by more than 5,000 bones and nearly 600 chronological data (LAPPAL), which were established during a previous OSL project.
- For palynological and diatom analyses we used published data (Andreev et al., 2002a,b) and own material (nearly 60 samples) from the Laptev Sea and other regions (White Sea and Barents Sea).

<u>Accomplishments</u>

More than 600 samples of bones and bone fragments were collected on the New Siberian Islands and Oyogos Yar as well as in the Lena Delta during the joint Russian-German expedition “Lena Delta and New Siberian Islands 2002.” A comparative documentation was elaborated using the facilities of the computer centre of OSL. The most interesting bones were radiocarbon-dated. The dating was conducted in cooperation with L. Sulerzhitsky in laboratory of Geological Institute RAS (Moscow).

Reconstruction of the composition of animal populations and their changes on the dry Laptev shelf during the Late Pleistocene and Holocene was based on the obtained morphological, taxonomical and radiocarbon data. For analysis and explanation of inhomogeneous distribution of populations we used the data on the geological compositions of outcrops and taphonomic conditions (cooperation with German and Russian project partner).

Favorable and unfavorable periods of environmental conditions on New Siberian Islands and the eastern part of Laptev Sea coastal land for different species of mammals were determined. The environmental factors influencing the spreading of different animal species were analyzed and compared in close cooperation with the project partners A. Andreev (palynological analysis), L. Schirrmeister (sedimentology analysis) and others. At this stage we planned joint work with German colleagues in AWI (Potsdam). We expected to receive data on summer and winter temperature, thickness of snow cover, hardness of soil, humidity and continentality of climatic conditions.

Another task were detailed paleontological and paleoenvironmental studies of the most interesting time periods. Diatom analysis provides detailed information about local climatic conditions. Diatoms are very sensitive plants and they rapidly react on changing life conditions, such as type of water body, depth, salinity, temperature, ice cover, etc. The study of diatom assemblages from terrestrial deposits that formed in the appointed time periods broadens and deepens our knowledge on climate conditions. We planned to analyse three profiles (near 60 samples). There is little information about diatoms from the terrestrial deposits of the Laptev Sea area. We planned to prepare a special publication dealing with their description, photos and occurrence in various locations.

Analysis of oxygen isotopes in fossil mammal bone phosphate is a modern trend in science. Isotope ratios as an indicator for climate variations have just begun to be studied. Now we have obtained first data on oxygen isotopes in 82 samples, bones of woolly mammoth, wild horse, muskox, bison, and woolly rhinoceros (33 samples from Bykovsky Peninsula and 49 samples from Bol’shoy Lyakhovsky Island). They were received as a result of our collaboration with Dr. Kharhu (Helsinki University) and T. Tuetken (Tubingen University). This was our first step on the study of bone isotopes. We tried to check the seasonal temperature variations that are preserved in the mammoth and horse teeth. We think this a very promising approach to the reconstruction of average annual temperature in the Laptev Sea region during the Late Pleistocene and Holocene. Our large collection of fossil mammal bones with a lot of dating materials provides the unique possibility to develop this way of paleoenvironmental reconstruction. First results of our research will be presented at the workshops and conferences.

Results

The investigations within the framework of the OSL Fellowship Programs were focused on the study of members of the “Mammoth fauna” and terrestrial diatom assemblages as providing higher accuracy of marks of the changing terrestrial environmental conditions.

All fossil mammal bones and fragments (more than 1000 bones) were studied. They were collected on the New Siberian Islands, Oyogos Lowland, Muostakh Island and in the Olenek-Anabar region during the joint Russian-German expeditions “Lena Delta and New Siberian Islands 2002” and “Lena Delta and Olenek-Anabar Region 2003” (Fig. 1). Their number is twice more than we supposed. The study of the morphology of different skeleton parts made it possible to reconstruct the exterior of animals. The reconstruction of an animal population is possible by taxonomical analysis of all the fossil material.

During this year N. Noskova revised the biggest mammal collection from the Laptev Sea region – the collection of A. Bunge and E. Toll (1886) – at the Zoological Institute RAS (St. Petersburg) and the Paleontological Institute RAS (Moscow). She expanded the database of fossil mammals from the Laptev Sea hinterland. Comparative documentation was elaborated using the facilities of the OSL computer laboratory. Digital photos of the bones were processed there as well.

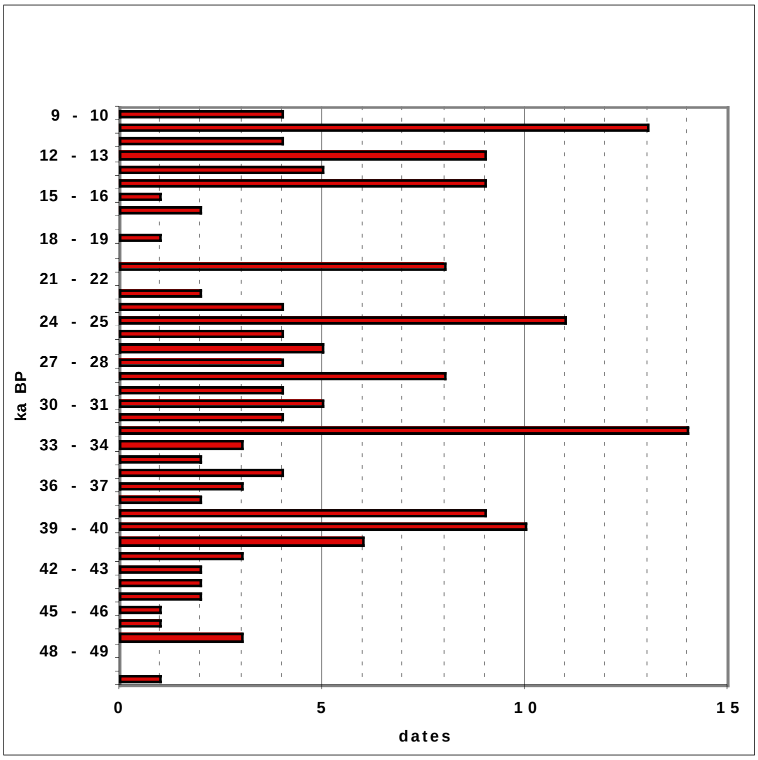

Fig. 2: Age data distribution of woolly mammoth.

A large part of the collection consists of *Mammuthus primigenius* bones (nearly 38%), and mammoth dates in our database are predominant (about 200 dates) (Fig. 2). Increases in mammoth fossil bone numbers and their subsequent decreases indicate favorable and less favorable environmental conditions for woolly mammoths during periods of amelioration and deterioration of climate, fluctuations in the population size and/or migrations of the mammoth herds (Schirrmeister et al., 2002). We indicated four “mammoth” periods: 1. ca 50 ka BP to 35-34 ka BP; 2. 33 ka BP to 23-22 ka BP; 3. 22 to 15 ka BP and 4. 15 to 9 ka BP.

These periods were compared with climatic periods by analysis of pollen remains (Kuznetsova et al., 2003; Andreev et al., 2002a,b). The period ca. 50 ka BP to 35-34 ka BP corresponds to the Middle Weichselian (Early Karginsky) Interstadial. It was the beginning of climatic warming, drainage of lakes and active development of ice complex formation on Taimyr Peninsula. Pollen data from the southern Taimyr indicate the presence of open *Larix* forest with *Betula nana* and *Alnus fruticosa.* Pollen-based climate reconstruction shows that it was a rather warm and wet period with temperatures by 0.5-1.5°C warmer and precipitation by 25-75 mm higher than today. On the contrary, pollen data from the Laptev Sea coast (Bykovsky Peninsula and Bol’shoy Lyakhovsky Island) indicate treeless vegetation and a rather cold and dry climate.

The second “mammoth” period (33 ka BP - 23-22 ka BP) is correlated with the Late Karginsky interval reflected in pollen records from the northern Taimyr Peninsula and Laptev Sea coast. According to pollen spectra, open steppe-like herb communities dominated vegetation. Environmental conditions were rather severe (with temperatures by 2-5°C colder and precipitation by 50-100 mm lower than today).

The period of the most unfavorable environmental conditions was probably between 22 ka BP and 15 ka BP, as only a few dates from woolly mammoth bones (fig. 2) were obtained for this time (Kuznetsova et al., 2001, 2003). It is interpreted as an extremely cold and dry period during the Late Pleistocene. The lack of mammoth dates for this period does not indicate the total absence of mammoths in the Laptev Sea region but rather reflects a relative decrease in their numbers.

The last “mammoth” period was from 15 ka BP to 9 ka BP with a maximum number of dates around 11-10 ka BP (fig. 2). The 11.5-10 ka BP interval is characterized by a rapid increase of warm and wet elements in pollen spectra. It can be interpreted as amelioration of climatic conditions. The reconstructed temperatures were by 1.5° warmer and precipitation was by ca. 25 mm higher than today. It is also the period with the largest number of woolly mammoth dates during the Late Pleistocene. This may indicate that it was the period with the most favorable environmental conditions for the mammoths (Kuznetsova and Kuzmina, 2002; Kuznetsova et al., 2003).

A. Bryantseva has started to analyze the fossil diatom assemblages from the Bol’shoy Lyakhovsky Island and Lena Delta region. However, the concentration of diatom shells in samples is very low, their preservation is unsatisfactory, therefore, the study is very time-consuming. Also, she has to combine her research with her studies at the university. All forms (12 species) from 63 terrestrial samples have been described and photographed. A. Bryantseva has started creating a database of the terrestrial diatom assemblages from the Laptev Sea region.

For the first time, stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) of mammoth hair were studied. 244 isotope samples were analyzed. Carbon and nitrogen isotope ratios in consumers are mainly determined by stable isotope composition of forage plants. The reconstructed average carbon isotope composition of plants from Bol’shoy Lyakhovsky Island (New Siberian Islands) about 28,000 years ago is quite similar to that of recent plants from the East Siberian Arctic (Nikolaev et al., 2003).

The final part of our project was devoted to combine all received paleo-ecological information and its interpretation. We plan a publication on the results of radiocarbon dating of fossil mammal bones, explanation of inhomogeneous distribution in populations of large mammals and description of paleoenvironmental conditions in favorable and unfavorable periods. This part was carried out in close cooperation with all Russian and German colleagues from Moscow State University, the Alfred Wegener Institute for Polar and Marine Research and the members of the Otto Schmidt Laboratory.

Conclusion

Palaeoecological records from the New Siberian Islands and Lena Delta region document environmental history. During the works under this project we studied fossil mammal bones and their fragments (more than 1000 bones) from the New Siberian Islands, Oyogos Lowland, Muostakh Island and Olenek-Anabar Region. A large part of the collection consists of *Mammuthus primigenius* bones (nearly 38%). We indicated four “mammoth” periods: 1. ca. 50 ka BP to 35-34 ka BP; 2. 33 ka BP to 23-22 ka BP; 3. 22 to 15 ka BP and 4. 15 to 9 ka BP.

Increases in mammoth fossil bone numbers and their subsequent decreases indicate favorable and less favorable environmental conditions for woolly mammoths during periods of amelioration and deterioration of climate, fluctuations in the population size and/or migrations of the mammoth herds.

These periods were compared with climatic periods by analysis of pollen remains. The period of ca. 50 ka BP to 35-34 ka BP corresponds to the Middle Weichselian (Early Karginsky) Interstadial. Pollen-based climate reconstruction shows that it was a rather warm and wet period with temperatures by 0.5-1.5°C warmer and precipitation by 25-75 mm higher than today. On the contrary, pollen data from the Laptev Sea coast (Bykovsky Peninsula and Bol'shoy Lyakhovsky Island) indicate a treeless vegetation and a rather cold and dry climate. The second "mammoth" period (33 ka BP to 23-22 ka BP) is correlated with the Late Karginsky interval reflected in pollen records from the northern Taimyr Peninsula and Laptev Sea coast. Environmental conditions were rather severe (with temperatures by 2-5°C colder and precipitation by 50-100 mm lower than today). The period of the most unfavorable environmental conditions was probably between 22 ka BP and 15 ka BP, as only a few dates from woolly mammoth bones were obtained. It is interpreted as an extremely cold and dry period. The last "mammoth" period was from 15 ka BP to 9 ka BP with a maximum number of dates around 11-10 ka BP. The reconstructed temperatures were by 1.5° warmer and precipitation was by ca. 25 mm higher than today.

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HIGH-RESOLUTION RECONSTRUCTION OF LENA RIVER DISCHARGE PATTERNS DURING THE LATE HOLOCENE

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Introduction

Due to its unique geographical position the Laptev Sea, constituting the central part of the wide Eurasian Arctic shelf, is a key area for studying the influence of river systems on the Arctic Ocean (Kassens et al., 1998). The many rivers draining onto the Laptev Sea shelf comprise about 25% of the total annual riverine input into the Arctic Ocean (Aagaard and Carmack, 1989). The main portions of freshwater are transported annually in the Arctic Ocean through the Lena River, the second largest river in the Northern Eurasia in terms of water discharge (Gordeev, 2000). Moreover, the Laptev Sea flaw polynya is an important production area of arctic sea ice, which, together with fluvial runoff, has a profound influence on the upper hydrography and the sea-ice regime in the Arctic Ocean (Zakharov, 1996; Kassens et al., 1998). From this point of view, understanding the history of Lena River discharge is a critical but insufficiently understood component of the Arctic Ocean paleohydrology and sea-ice regime.

Scientific background

Due to shallow sediment coring carried out in recent years on the Laptev Sea shelf, the Holocene development of paleoenvironments in this region under postglacial sea-level rise is quite well understood (e.g., Bauch et al., 1999, 2001; Mueller-Lupp et al., 2000). The paleohydrology of the shallow Laptev Sea shelf and riverine outflow through time, however, have not yet been completely reconstructed. Micropaleontological studies now indicate that groups such as diatoms and aquatic palynomorphs offer the opportunity to investigate past water salinities, sea-ice conditions and riverine discharge (Bauch and Polyakova, 2000, 2003; Kunz-Pirrung, 2001; Polyakova, 2003). But reconstructions of the Lena River discharge as the major source of freshwater input into the Laptev Sea are still incomplete, in particular with regard to the late Holocene.

Goals and objectives

Our research focused on the Lena River/Laptev Sea shelf system using high-resolution sediment cores obtained from the region near the largest freshwater source in the Laptev Sea. The main goal of our study was to reconstruct the short-term variability of freshwater discharge to the Eurasian Siberian shelf via this system during the Late Holocene. To accomplish our goal we selected sediment cores (PS 51/092-11, PS 51/92-12, PS 51/080-11, PS 51/080-13, PM 9482-2) from the shallow inner Laptev Sea shelf adjacent to the Lena Delta, which were obtained during the TRANSDRIFT expeditions to the Eastern Laptev Sea. High-resolution seismic data and radiocarbon control of recovered sediments from this region indicate that the thickness of the Holocene section varies from 1 to 7 m (Kleiber and Niessen, 1999, 2000; Bauch et al., 1999; 2001). Thus, these sediments provide the basis for obtaining high-resolution data for the reconstruction of Lena River discharge during the late Holocene. Our project contributed to the multidisciplinary Russian-German ”Laptev Sea System” project and was carried out in collaboration with German and Russian participants from this project from GEOMAR, the Arctic and Antarctic Research Institute (AARI) and the Otto Schmidt Laboratory for Polar and Marine Research (OSL).

Research activities

Approach

Our research activities were focused on the following:

- detailed (1-2 cm sampling intervals) investigations of downcore distribution of microfossils: diatoms and aquatic palynomorphs (dinoflagellate cysts, chlorococcalean algae, and other organic-walled remains) in the upper Holocene sediments from the southeastern Laptev Sea as indicators of marine conditions and riverine discharge;
- establishment of possible temporal and regional peculiarities in hydrological parameters (surface water salinity, sea-ice conditions) on the inner Laptev Sea shelf;
- reconstruction of short-term variabilities of the Lena River discharge during the late Holocene and theirs relationship to climate fluctuations in the Arctic.

Accomplishments

According to our working program sampling of core sediments was carried out by T. Klyuvitkina at GEOMAR (Kiel, Germany). The subsequent freeze-drying of samples was carried out at GEOMAR and the OSL (St. Petersburg). Treatment of samples for the purposes of palynomorph study was carried out by T. Klyuvitkina at the Alfred Wegener Insitute (Potsdam), and for diatom analyses at the Laboratory of Pleistocene Paleogeoraphy (Moscow State University) by T. Klyuvitkina and E. Golovnina. All in all 173 samples were prepared for studying fossil algae assemblages. The morphological study of dinocysts and freshwater algae under a microscope Olympus BX-60 was carried out by T. Klyuvitkina and E. Golovnina at the OSL. The fossil algae records and geochronological model (represented by H. Bauch) were combined, and reconstructed paleoenvironmental events within the southeastern Laptev Sea were correlated.

Using diatom and aquatic palynomorph assemblages as a proxy, the following major paleoenvironmental results were achieved:

- temporal variations in the surface water salinity on the inner Laptev Sea shelf adjacent to the Lena Delta were reconstructed for the last 6 cal. ka;
- changes in directions of the Lena River outflow through the major Lena Delta channels were established for the late Holocene;
- significance of the Atlantic water entering the Laptev Sea shelf from the continental slope due to reversal upwelling currents for the Holocene inner Laptev Sea hydrology were revealed.

Results

Selected cores were obtained from the inner Laptev Sea shelf from water depths between 21 m and 34 m. Kasten core PS51/80-13 and box-core PS51/80-11 (21 m water depth) are located just east of the Lena Delta. This southeastern region of the Laptev Sea is influenced by the Lena River outflow via the Bykovskaya Channel, which currently receives ~30% of the Lena River waters (Mikhailov, 1997). According to radiocarbon dating, the cores encompass the last approximately 6.0 and 1.5 cal. ka correspondingly (Fig. 1).

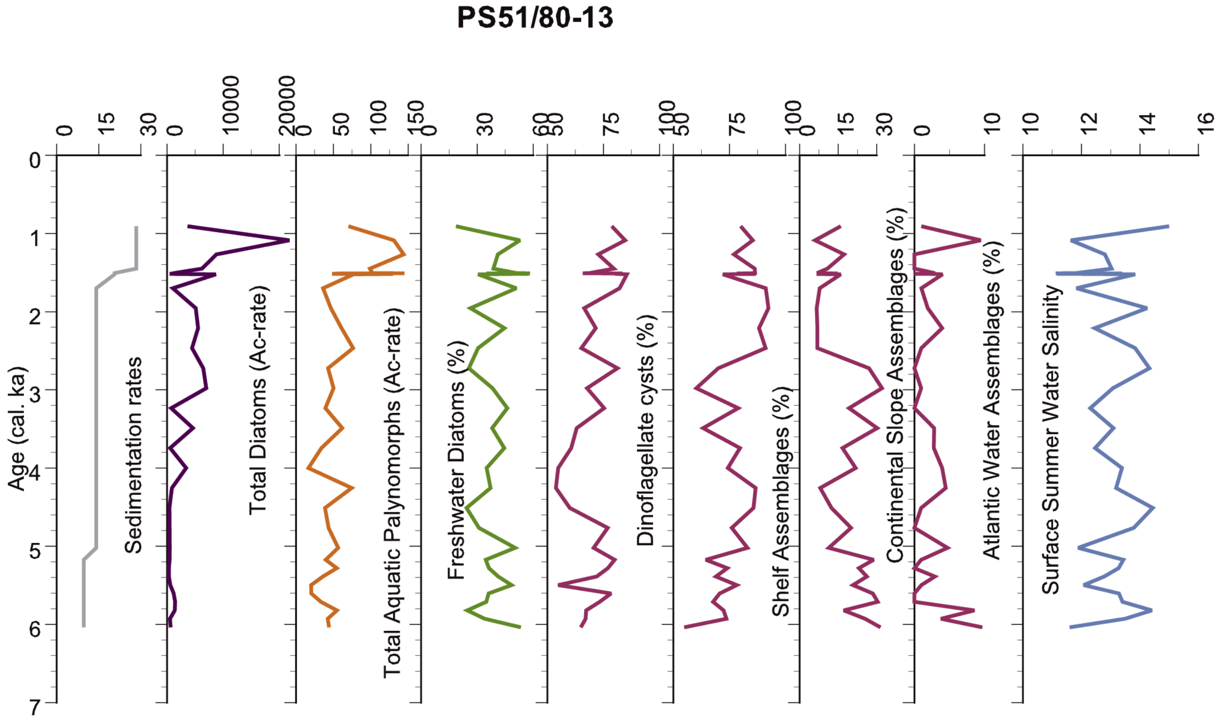

Fig.1: Accumulation rates of total diatom valves (mln valves/cm^2/1000 yr) and aquatic palynomorphs (1,000 specimens/cm^2/1000 yr), downcore distribution of the main ecological groups of algae, and reconstructed summer surface water salinity from core PS51/80-13, Laptev Sea.

The total concentration of diatom valves in core PS51/80-13 in general increases upcore (up to 770,000 valves/g), and maximum accumulation rates of diatom valves (average ~20 mln valves/cm^2/1000 yrs) corresponding to the sharp increase in sedimentation rates were observed between approximately 1.5 and 0.9 cal. ka BP (Fig. 1). The lowest accumulation rates of diatom valves were marked for the time interval 6.0 - 4.2 cal. ka BP. The freshwater diatoms group is represented by riverine and boggy taxa transported by rivers to the shelf zone. Their total relative abundances vary around 40% indicating a constant riverine discharge to the study area. Reconstructed surface water salinities using freshwater diatoms as a proxy (Polyakova, 2003) provide evidence for a salinity range between 11 and 15 during the last 6 cal. ka, which reflects temporal changes in the Lena River outflow. These changes may be interpreted as a result of variations in the Lena River runoff connected with climate fluctuations or as a result of channel migration within the delta.

It was revealed that between 6 and 4.2 cal. ka BP surface water salinities on the southeastern inner Laptev Sea shelf (coring site PS51/80) varied between 12 and 14 (average value ~13). A marked decrease in water salinities (<12) between 4.2 and 2.8 cal. ka BP was possibly caused by an increase in the Lena River outflow to the southeastern Laptev Sea region. It is interesting to note that at the site (core PM94-82) located just north of the Trofimovskaya Channel, currently contributing about 60% of the annual Lena River runoff, the maximum salinities were observed for the time >2.7 cal. ka BP (Bauch and Polyakova, 2003). This discrepancy in the tendency of salinity fluctuations between the eastern and northern Laptev Sea shelf regions adjacent to the Lena Delta allows us to assume an increase in the Lena River outflow eastward via the Bykovskaya Channel during the time between 4.2 and 2.8 cal. ka BP. Although the period after 2.8 cal. ka BP was characterized by high variability in sea water salinity ranging between 11 and 15 in the coring site PS51/80, reconstructed salinities generally were higher than 13 indicating reduction of the Lena River outflow eastward. At the same time, the decrease in water salinities (down to 9) observed northward of the Lena Delta (site PM94-82) before 2.7 cal. ka provides evidence for an increase in Lena River outflow in the northward direction via the Trofimovskaya Channel and its reduction eastward via the Bykovskaya Channel during this time.

The group of marine and brackish-marine diatoms in cores PS51/80-13 and PS51/80-11 largely consists (up to 50%) of euryhaline species (*Thalassiosira baltica, T. hyperborea*) typical of freshened areas of the arctic shelf (Polyakova, 1997, 2003). The marine-diatom group also includes a specific of sea-ice species (*Fossula arctica, Fragilariopsis oceanica*, and *F. cylindrus*), which is regarded as indicator of the sea-ice regime in the arctic seas and the winter polynya location (Bauch and Polyakova, 2000; Polyakova, 2003; Polyakova et al., 2000). Although the relative abundances of sea-ice species vary between 0% and 16% in the sediments of core PS51/80, they mainly remain <10%, thus indicating a generally more distal and seaward location of the Laptev Sea polynya in the southeastern region during the last 6 cal. ka.

Aquatic palynomorph records extracted from the cores PS51/80-13, PS51/80-11 and PM 94/82-2 are in good accordance with diatom-assemblage data. Maximum accumulation rates of aquatic palynomorphs, revealed in the core PS51/80-13 between approximately 1.5 and 0.9 cal. ka BP, correspond to the sharp increase in sedimentation and accumulation rates of diatom valves. Aquatic palynomorph assemblages from this core, dominated by marine dinocysts, are also largely comprised of freshwater chlorococcalean algae indicating river-proximal environments (Kunz-Pirrung, 2001). The increase in the relative proportions of freshwater algae corresponds to the low salinity interval between 4.2 and 2.8 cal. ka BP in core PS51/80-13. In general, the dinocyst assemblages in these cores are largely comprised (average ~80%) of the cold and shallow-water species (*Islandinium minutum, Echinidinium karaense*) which are typical for the freshened waters on the Laptev Sea inner shelf (Kunz-Pirrung, 2001). Relatively warm water dinocyst species (*Operculodinium centrocarpum, Selenopemphis quanta)* were of low abundance in most of the studied sediment assemblages (below 5%), thus providing evidence for the Atlantic water inflow to the southeastern inner Laptev Sea shelf during the last 6 cal. ka.

In addition to previously obtained diatom records from core PS 51/092-12 (Bauch and Polyakova, 2003), diatom assemblages were studied in box-core PS 51/092-11, and aquatic palynomorphs were studied in cores PS 51/092-12, PS 51/092-11. These cores were recovered from the Lena River paleovalley (32 m water depth) currently influenced by the Lena River outflow via the Timokovskaya Channel. According to radiocarbon dating, the cores encompass the last approximately 9 cal. ka. The general trend of increasing surface water salinity in this inner Laptev Sea region during the last 9 cal. ka (Bauch and Polyakova, 2003) is in good accordance with the increase in concentrations and relative abundances of marine dinoflagellate cysts (2000-3500 cysts/g, up to 80%). A sharp decrease in relative abundances of freshwater algae, was observed approximately 7.4 cal. ka BP (Fig. 2).

For the purposes of paleoenvironmental reconstructions marine the dinocyst species were combined into three main ecological groups on the basis of ecological preferences of species and of dinoflagellate cyst occurrence in the surface sediments of the Laptev Sea shelf and the adjacent continental slope (Kunz-Pirrung, 2001). The distribution patterns of these ecological groups are characterized by a high variability throughout the core sections, reflecting changes in hydrological conditions on the Laptev Sea shelf under postglacial sea-level rise and fluctuations of the Lena River discharge. The group of “shelf assemblages” consist of cold-adapted species (*Islandinium minutum, Islandinium cesare, Echinidinium karaense),* which dominate shelf assemblages and cover the entire sea-surface temperature and salinity range in the Laptev Sea (Kunz-Pirrung, 2001). Relative abundances of this species group vary between

13.3 and 100%, in general increasing upcore with the sharp increase in abundances observed approximately 7.4 cal. ka BP. The group of "continental slope assemblages", currently restricted to the continental margin, consists of both cold polar-water species (e.g., *Brigantedinium* spp. group) and cosmopolitan ones (*Operculodinium centrocarpum, Selenopemphis quanta).* Total percentages of the "continental slope assemblages" stepwise decrease upcore with the maximum abundances (up to 90%) observed between 8 and 9 cal. ka BP, when sea-level was lower than nowadays (Bauch et al., 2001). Therefore, we assume that the preliminary predominance of "continental slope dinocyst assemblages" was caused by the fact that the coastline was closer to the continental slope, where reversal upwelling currents are most active in particular during the ice-free time (Dmitrenko et al., 2001). To assess the influence of Atlantic water masses on the Laptev Sea shelf hydrology, the group of "Atlantic water assemblages" was extracted. This group is represented by relatively warm-water-indicating species (*Operculodinium centrocarpum, Selenopemphis quanta)* and suggests a relation to the inflow of Atlantic waters into the Laptev Sea due to reversal upwelling currents (Dmitrenko et al., 2001). It is noticeable that the maximum abundances of this group (up to 63.6%) occur in the lowermost part of the core assemblages (time interval 9-8.4 cal. ka BP) when the sea-level was lower than nowadays (Bauch et al., 2001).

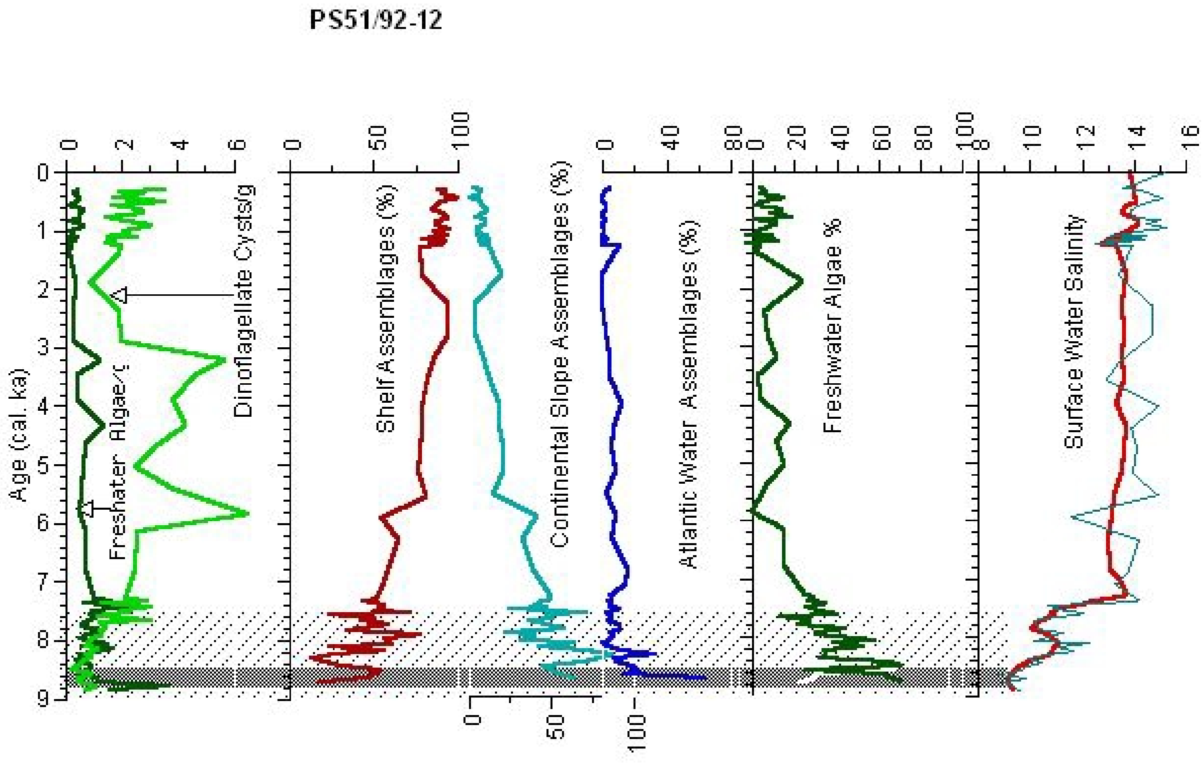

Fig. 2: Downcore distribution of total dinoflagellate cysts and freshwater chlorococcalean algae (in 1,000 specimens/g dry sediment), relative abundances of the main ecological groups of dinoflagellate cysts, and reconstructed summer surface water salinity from core PS51/92-12, Laptev Sea.

Conclusion

Thus, on the basis of the fossil microalgae records and detailed radiocarbon chronology of sediment cores obtained from the southeastern inner Laptev Sea shelf adjacent to the Lena

Delta the following peculiarities of the Laptev Sea paleohydrology and Lena River discharge could be emphasized:

- since approximately 9 cal. ka the inner Laptev Sea hydrology was under the influence of the Atlantic waters entering the shelf due to reversal upwelling currents;
- Holocene variations in surface water salinities in the area adjacent to the Lena Delta were mainly caused by the changes in the volume of Lena River runoff through the major riverine channels;
- the following stages of the changes in the direction of the Lena River discharge were revealed: (i) generally eastward outflow via the Bykovskaya Channel approximately 6-4.2, and after 2.8 cal. ka, and increase in riverine outflow in the northward direction via the Trofimovskaya Channel between 4.2 and 2.8 cal. ca.

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RECONSTRUCTION OF LATE PLEISTOCENE SEASONAL TEMPERATURES IN THE SIBERIAN ARCTIC LOWLANDS BASED ON INSECT FOSSILS: THE MUTUAL CLIMATIC RANGE METHOD

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Introduction

Scientific background

Understanding the Pleistocene climate and reconstructing its quantitative parameters is a very important task by itself. It can help us not only to reconstruct the past biota and its environmental conditions, but also to forecast future climatic and environmental changes. It is, however, of special significance in the Laptev Sea and the East Siberian Sea areas, which, according to many lines of evidence, played a very peculiar role in the history of the whole Eurasian (and, to some extent, the North American) biota. The existing reconstructions are based mostly on pollen analysis data (e.g., Klimanov, 1984), which have many limitations, such as operating with high-level taxa that potentially include plants with very different ecological requirements and different distributions. Insects, however, are known to be more sensitive indicators of the past climate; moreover, most of the insect fossils are resolved to species or even subspecies level. That makes the analysis of fossil insect assemblages a very appropriate tool for climatic reconstructions. Such a kind of analysis – the Mutual Climatic Range (MCR) Method based on fossil insect assemblages – has been used for about 20 years in Europe and recently in North America. MCR is considered one of the most reliable methods to reconstruct past temperature in the terrestrial environments. Our project is only the second attempt to apply this method to the Siberian environments (the first wasby Alfimov et al., 2001, for the Kolyma River lower course).

Goals and objectives

The main aim of the project was the quantitative estimation of summer and winter temperature in the Arctic Lowlands of Eastern Siberia during the time periods corresponding to MIS 3 and MIS 4 (Marine Isotope Stages). That was supposed to be done with the Mutual Climatic Range (MCR) Method based on fossil insect assemblages. The proposed attempt to apply this method to the unique sequence of fossil insect faunas in the Laptev Sea region would certainly improve our understanding of the peculiar climate system of the Siberian Arctic in the Pleistocene.

As the main object of research, we intended to analyze the most complete and well-dated succession of insect faunas from the Ice Complex on Bykovsky Peninsula (Mamontovy Khayata section), covering the time range in question. The total number of the insect species found in this section was about 100, which seemed too much for one year of work. That is why we originally restricted the project by selecting samples to characterize the most important stages of environmental evolution in the area recognized through ecological analysis of insect assemblages (Sher et al., 2005). Such stages are the "warm Karginian" (50-35 ka), "cold Karginian" (35-24 ka), "cold" Sartanian (LGM, 24-15 ka) and "warm" Sartanian (15-12,5 ka) periods. The planned total number of fossil assemblages to be analyzed was about 12-15.

The first research task was to collect data on modern occurrences of all insect species in the selected assemblages, and their number was 30-50. That implied careful work in the entomological collections, and consultation with entomologists who work with the relevant taxonomic groups. The second task was to collect climatic data for all modern locations of those species from meteorological records. By combining the collected data on the species distribution and climate in the joint database, we were going to determine the "climate envelopes" for the species selected for our analysis (the range of climatic parameters of their modern distribution). Superimposing the obtained "climate envelopes" for each fossil assemblage, we were to obtain the desired range of possible summer and winter temperature of the environment. The last step in the MCR analysis should have been the calibration of results with specially developed equations.

The conclusive task would have been to compare the results of the MCR reconstructions with the changes in ecological composition of the insect faunas, as well as with other proxy evidence (plant macrofossils, ground ice isotopes) and to develop the resulting climatic and environmental models for the studied time period.

Research activities

Approach

As soon as we started to work on the project, we realized a few methodological problems. Although the MCR method has a rather long history of application in Europe and North America (Atkinson et al., 1987; Elias, 2001), our first attempt to use it in Russia (Alfimov et al., 2003) proved that some modifications of the method are necessary for the Siberian material. First of all, it became clear that plant-eating insect species (usually ignored by traditional MCR analysis) here give better paleoclimatic information than the commonly used carnivorous and scavenging species. Second, we realized that it was impossible to use the same calibration equations in Siberia as suggested for Europe or Alaska, and we had to develop new equations for our region. Accepting both facts would require information on the modern distribution of much more numerous species than we originally selected.

Since this project was thought to be an initial part of future more extensive work (more samples, other localities), we anticipated the need to work in the collections again and again, every time for a new list of species. From the technical point, however, it turned out that it was not easy to organize that work (the necessity to examine both taxonomic and regional collections, hard access to some of them, very limited time of curators and experts, etc.). For that reason, and to meet the requirements of calibration formulas, we decided to enlarge the list of species under study – from those 30-50 from the selected samples in one section up to an almost complete species list from a much larger set of important samples from the Laptev Sea area (80-100 species).

A similar situation arose with the meteorological data. As we were unable to get a ready set of a sufficient amount of data (free databases on the Internet contain too few stations and few climate parameters, and the access to others costs more than our whole project), we had to build the necessary database ourselves from open library sources. As soon as we started that work, it became evident, that if we had to process 68 volumes of the FSU Climate Reference, it would be more rational to get not only temperature, but a few other parameters for each station so that we potentially could use them in the future. But of course, this was a more time-consuming task.

Accomplishments

We have collected data on modern locations for 85 insect species that we found in the Laptev Sea area as fossils. For 37 of them, the data were first collected in St. Petersburg by A. Alfimov in 2002, and complemented by us in Moscow in 2003. Our work in Moscow, St. Petersburg and other insect collections allowed us to get a maximum number of modern locations where each species is currently found. For some species, there were less than 10 sites, but hundreds for many others. Table 1 (see Appendix) gives the list of these species, with their position in our ecological classification (Eco Codes) and generalized description of their modern distribution and ecology.

We completed the database on selected climatic parameters for the whole territory of the Former Soviet Union and Mongolia (as some of our fossil beetles occur there now). Those parameters are:

(1) mean monthly and annual air temperature (T°);

(2) mean of absolute minima of air T°

(3) sums of mean daily air T° above 0°, 5°, 10°, and 15°;

(4) the same for air T° below 0°, -5°, and -10°;

(5) mean, minimum and maximum T° of soil surface;

(6) the same for the upper layers of soil (at the depth of 5, 10, 15 and 20 cm);

(7) mean monthly and annual precipitation;

(8) average, minimum and maximum thickness of snow cover.

Parameters (1) and (7) provide the most generalized characteristics of climate. Parameters (3), (5) and (6) allow estimating the amount of heat, required for the summer development of insects. Parameters (2), (4), (6), and (8) help to estimate the boundary conditions of winter survival of insect species.

There were about 5,000 meteorological stations in the FSU that could provide long-term records of air T° [(1)-(4)]; some of them regularly measured soil T° [(5),(6)]. Practically all of those 5,000 have precipitation records (7), but these records are available also for 7,000 other stations of lower class; only part of those 12,000 measured the snow cover depth.

All the listed records for the multiyear periods of various durations are included in the database.

During the visit to Germany in August 2003, in cooperation with German colleagues we compared insect and plant records from the key sections on Bykovsky Peninsula (Sher, Kuzmina) and Bolshoy Lyakhovsky Island (Kuzmina) in detail.

Although the accomplished amount of our work was several times more than had been planned (cf. the previous section), we were able to announce only preliminary results of it. That means that we have prepared the working variant of both databases (on the modern distribution of characteristic insect species and on climate parameters), but we were not able to complete them to the condition when they could be deposited in the OSL archive or website and become available for other scientists. The main reason for this is that we faced the problem of defining the precise geographic coordinates of many occurrences of modern insects. The locations are very often described as small rivers or villages that could not be found on the available topographic maps. Searching for their coordinates required more detailed maps than we had and much longer time than we could expect. We hoped to continue this work in 2004, and submitted a new project to the OSL competition, which included both the continuation of our 2003 work, and incorporated a vast amount of new material on the subject, obtained by us during the last expeditions to the Lena Delta and Alaska. Unfortunately, that proposal was not granted. The team member responsible for that database completion (A. Sokolov) was not able to continue his work on it without further support from the OSL, and found another job. Thus, the database has not been completed. Nevertheless, we were able to use some of the data collected for our research work on the past environment in the Laptev Sea area (Hubberten et al., 2004; Sher et al., 2005; Kuzmina & Sher, in press). Below are some important conclusions that we were able to make as the result of the project.

Results

At present we can make some important conclusions, mostly about summer temperature of different stages, although they require further refinement and verification (Figs. 1,2).

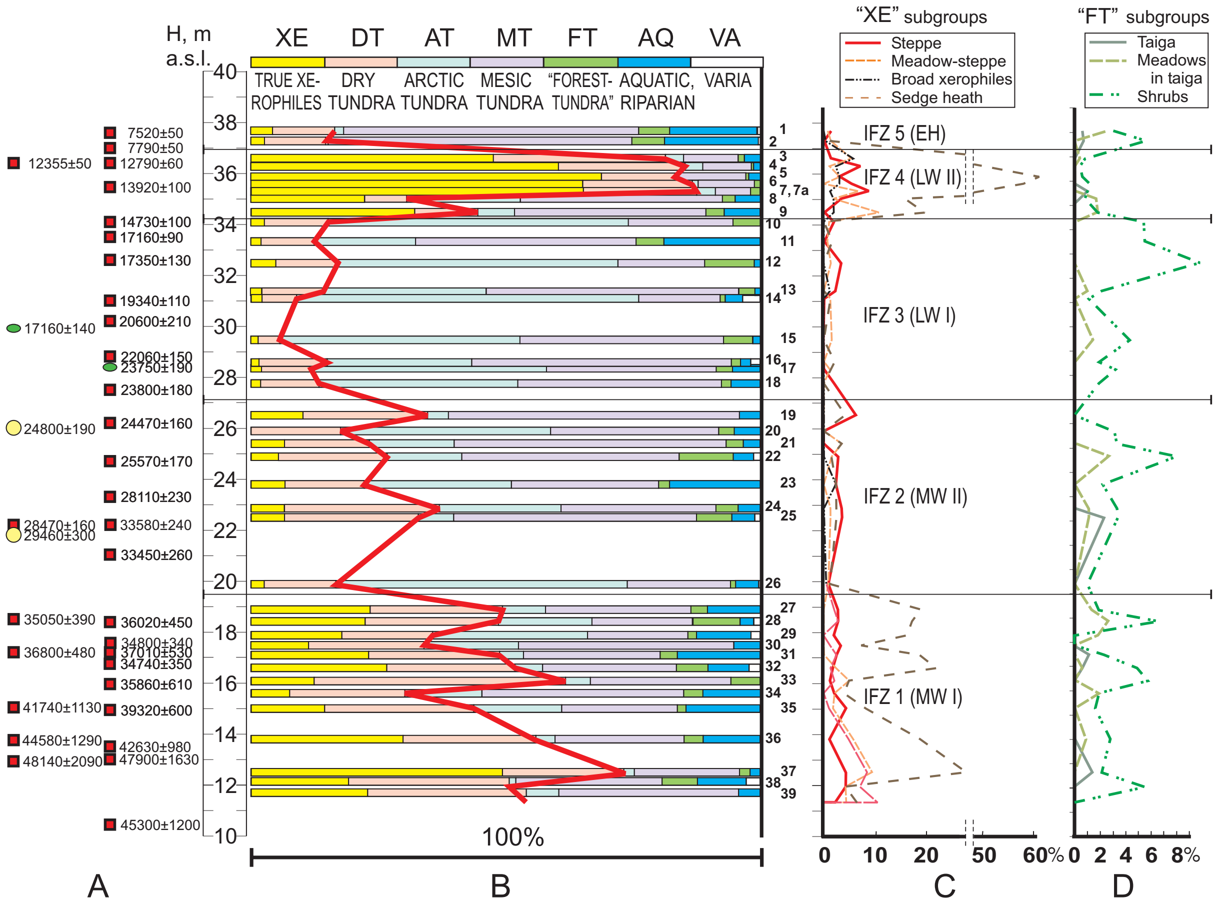

Fig. 1: Ecological structure of fossil insect assemblages, the distribution of radiocarbon dates and the Insect Faunal Zones in the Mamontovy Khayata main section. A - radiocarbon dates: right column: exactly or closely corresponding to the insect samples (same profiles); left column – taken in other profiles and correlated with the insect samples by altitudinal position. AMS dates: on plant remains (red squares) and on insect fossils (green ovals); conventional dates on mammal bones (yellow circles). B – percentage of main ecological groups of insects in each sample represented by a single bar; minimum number of individuals in the sample equals 100%. Main ecological groups: XE - true ("southern") xerophiles, DT - dry tundra inhabitants “northern” xerophiles), AT - arctic tundra insects, MT – inhabitants of mesic sites in tundra, FT – “forest-tundra” species, AQ – aquatic and riparian insects, VA – species with uncertain ecology (see more details in text). Sample numbers to the right correspond to those in Figs. 2B and 2C. The thick red curve shows the total percentage of all xerophilic species ("southern" and tundra, XE plus DT). C – subgroups of true xerophiles; D - subgroups of “forest-tundra” species; (note a different horizontal scale in B, C and D, and the break of the axis in C).

There are several groups of beetle species whose presence in the assemblage imposes certain lower limits on the reconstructed July T°:

(a) the presence of weevils *Stephanocleonus* does not allow expecting July T° below 10.5 or even below 12°C;

(b) the second group includes some pill beetles and ground beetles, that currently do not live in the areas with July below 9°C;

(c) the third group indicates a July T° not lower than 8°C.

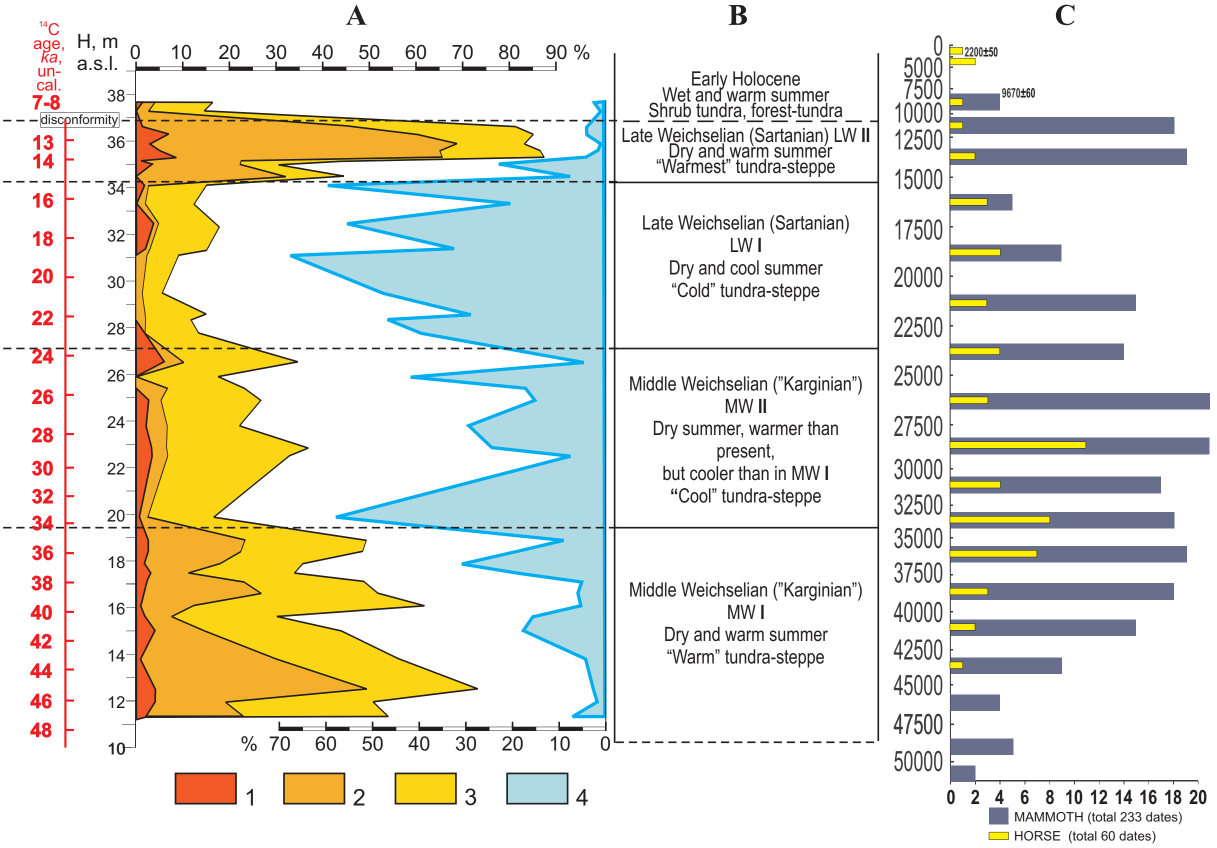

Fig. 2: Inferred summer climate changes and dated record of mammals in the Laptev Sea area. Uncalibrated ^{14}C ages in the left column are calculated from two separate regression equations after about 40 AMS dates. A - Fossil insect record in the Mamontovy Khayata section, Bykovsky Peninsula. Percentage of selected ecological groups of insects: True, or "southern", xerophiles (XE on Fig. 1): 1 - steppe species; 2 – other xerophilous insects (except tundra ones); Insects, currently common in tundra: 3 – dry tundra inhabitants, DT (prefer warmer sites); 4 – Arctic tundra insects, AT (plotted from the right axis). B - Climatic and environmental interpretation of the insect assemblages from the Mamontovy Khayata section. C - Radiocarbon dates of mammal bones from the Laptev Sea area (number of dates in 2,500-year intervals). The latest available dates for mammoth and horse are indicated at the top.

There are some insect species in fossil assemblages that cannot be directly used for the MCR analysis because of their peculiar modern distribution. Those are either the species that have survived only in narrow relic habitats (their modern T° range is very restricted, so its usage in the analysis leads to overestimation or underestimation of summer T° in the past), or haveevidently changed their distribution since the Pleistocene, e.g. are now located in coastal, but not inland habitats (like in the past). Each of these species requires a special additional investigation.

The fossil assemblages that include the species of the group “a)” characterize a warm or reasonably “warm” variant of tundra-steppe environment (early Karginian and late Sartanian). Those not including the group “a)” species, but groups “b)” or “c)”, give us approximate T° parameters of “cool” or even “cold” tundra-steppe (late Karginian and early Sartanian). For comparison, we should note that at present mean July air T° at the site in question (Bykovsky Peninsula) is not higher than 7°C (Tiksi), or even as low as 4.3°C (Muostakh Island in 30 km SE of the Mamontovy Khayata cliff). That means that summer in the times of “warm” tundra-steppe was at least 3-5°C warmer than today, and in the times of “cool” or “cold” tundra-steppe at least 1-2° warmer. The summer T° during the “coldest” times (LGM) is still to be verified, but preliminary estimation suggests it was still not lower than today (Sher et al., 2002a).

These results confirm and refine our earlier hypothesis that continentality was one of the most powerful climate drivers on the Laptev shelf in the Late Pleistocene (Sher et al., 2002b). Even during the Last Glacial Maximum the effect of continentality overrode that of the general climate cooling. As a result, the summer T° (but not humidity) varied during the MIS 3 and 2, but due to the retained continentality remained high enough to allow the survival of large grazing mammals. The suggested model of environment and climate evolution in the Lena Delta in the Late Pleistocene was presented at several international meetings in 2003 and contributed to the summary of the QUEEN program (Hubberten et al., 2004). The paper describing the evidence for this model in detail has been recently published (Sher et al., 2005).

We were also able to use the results of this OSL project in our research on the Holocene insects and environment in the Laptev Sea area (Kuzmina and Sher, in press). In this work we described the Holocene insect assemblages from the central Lena Delta, Bykovsky Peninsula, and Bolshoy Lyakhovsky Island. The early Holocene assemblages turn out to be very different from the Pleistocene ones, as they were dominated by mesophilic tundra species. On the other hand, they included some more thermophilic insects which are currently not known in the corresponding research sites, and even some relic tundra-steppe species, common in the Pleistocene. Such a complex character of the early Holocene assemblages (corresponding to the time of the Holocene Thermal Maximum and northern advance of trees and tall shrubs) is interpreted by putting together our paleontological data, paleobotanical evidence and the recent model of the Holocene transgression on the Laptev Sea Shelf (Bauch et al., 2001). We have concluded that until about 7000-8000 years BP (uncalibrated ^{14}C age) the vegetation and insect fauna were still influenced by a higher than present continentality of climate (since the sea level was still about 30 m lower than present), and at the same time affected by the increasing precipitation and the snow cover especially. Active thermokarst over the Ice Complex sediments gave rise to millions of lakes that further increased local humidity. Such a combination of summer temperature higher than nowadays and relatively high humidity resulted in a tremendous outburst of plant biomass and non-analogue insect faunas.

Conclusion

The Mutual Climatic Range (MCR) method based on fossil insect assemblages is a powerful tool in reconstructing climatic conditions of the past. Widely accepted in Europe and North America, the MCR method is, however, in the initial stage of development in Russia. We have modified some methodological aspects of this method for better correspondance with the Siberian conditions. A very large volume of information on distribution of many insect species and the climatic parameters of their ranges was collected in the course of this project. The usage of this information has already allowed us to build comparative climatic characteristics of certain periods in the Late Pleistocene and early Holocene. The main conclusion is that the climate continentality was the most important driver of the environment in the Laptev Sea area during this time. The changes in insect distribution and mammal population numbers have been explained by variations in summer temperature. The MIS 3 conditions on the Laptev shelf remained relatively warm, but dry. During most of the MIS 2 (LGM) summers were colder, but aridity was retained. The Late Glacial Event (ca. 15-12.5 ^{14}C yr BP) was marked by a sharp rise in summer temperature and a peak of steppe species abundance. Unusual combination of relatively high summer temperature and increased humidity at the initial stages of the marine transgression resulted in a very fast demise of the tundra-steppe ecosystem and in the early Holocene peak of plant biomass productivity in the high latitudes.

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Appendix

Table 1: The list of the beetle species for which we have collected detailed data on their modern distribution during our work on the OSL project in 2003. All listed species are known as fossils from the Laptev Sea coastal areas.

Species ecological codes: st - steppe ms - meadow-steppe, ss - cold sedge steppe, ks - broad xerophil, dt - dry habitats in tundra, mt - wet habitats in tundra, at - arctic tundra, sh - related to shrubs, ta - taiga, me - meadows in taiga, aq - aquatic, na - near-aquatic (riparian), oth – others.

Taxa	Eco Code	Modern distribution	Ecology
Family Carabidae - ground beetles			
Carabus (Morphocarabus) shilenkovi O.Berlov	dt	Magadan Region, Chukotka.	In the mountains above the treeline.
Carabus (Morphocarabus) odoratus Motsch.	dt	Polar Urals, Yakutia, Magadan Region, South Siberia (Irkutsk, Kemerovo, Krasnoyarsk regions), Northern Mongolia.	Widespread species in taiga, forest-tundra, less common in tundra. Inhabits various biotopes, including mesic.
Carabus (Aulonocarabus) truncaticollis Esch.	mt	North of Europe and Siberia, Chukotka, Magadan region, Koryak Mts, Alaska, Canada.	Tundra species, most common in southern tundra, sometimes can be found in northern taiga, almost absent in northern tundra.
Pelophila borealis Payk.	na	Circumboreal species, from Northern Europe to Chukotka and Kamchatka, to Khabarovsk Region in the south. In Siberia does not spread further north than the southern subzone of typical tundra.	Boggy habitats, common along the river banks.
Nebria frigida Sahlb.	na	Siberia east of the Ob River, Chukotka, Magadan, Khabarovsk, and Amur regions; Alaska, northwestern Canada. In the south of its range is restricted to the mountains.	Tundra riparian species.
Notiophilus aquaticus L.	ks	Widespread species - from Europe to Chukotka and Sakhalin Is., Khabarovsk and Amur regions.	Most common in tundra and taiga zones. Prefers dry habitats, but can be found on wet meadows, tundra meadows. In Europe is common on glacial till terrain.
Blethisa catenaria Brown	mt	Northern Siberia, Magadan region, Alaska, Canada.	Bogs in taiga and forest-tundra.
Diacheila polita Fald.	mt	Northern Europe, Siberia, Magadan region, Kamchatka, Sakhalin Island, Khabarovsk and Amur regions, Alaska, Canada.	Southern (shrub) tundra and forest-tundra, in mountain areas in taiga. Not common in typical tundra.
Elaphrus riparius L.	na	Widespread species: Europe, Siberia, Primorye, Korea, Japan, North America	Along the river banks in taiga, but can be found in forest-tundra and typical tundra subzone.
Dyschirius nigricornis Motsch.	na	Northern Europe, Siberia, Magadan region, Alaska, Canada.	Mostly in taiga, along the banks of water bodies, but can occur in forest-tundra and southern (shrub) tundra.

Taxa	Eco Code	Modern distribution	Ecology
Bembidion (Peryphus) dauricum Motsch.	dt	Northern Sweden, Northern Norway, East Siberia, Chukotka, Magadan Region, Northern Mongolia, northwestern North America.	In Sweden lives in dry sandy and glacial till habitats in birch forest-tundra. In Siberia - northern taiga, forest-tundra and shrub tundra, in dry habitats.
Bembidion (Peryphus) umiatense Lindrt.	na	Yakutia, Magadan region.	Mostly near water in taiga, can occur in southern (shrub) tundra.
Poecilus (Derus) nearcticus Lth.	dt	A few isolated modern occurrences in Arctic Canada (Andersen River delta, NWT) and Northeast Siberia (Ayon Island near Chukotka coast, middle part of the Keremesit River in the Lower Indigirka basin).	On Ayon Island two specimens were collected on the wind-blown sand with scattered grasses and sedges. On the Keremesit River about 50 specimens were found on a dry slope with Artemisia and ground squirrel burrows in typical tundra.
Pterostichus (Cryobius) ventricosus Esch.	mt	Siberia, tundra and forest-tundra.	In arctic tundra the species occupies various habitats and is one of the dominant beetle species.
Pterostichus (Cryobius) pinguedineus Esch.	mt	Siberia, tundra.	In arctic tundra the species occupies various habitats and is one of the dominant beetle species.
Pterostichus (Cryobius) brevicornis (Kirby)	mt	Circumpolar species, tundra.	In arctic tundra the species occupies various habitats and is one of the dominant beetle species.
Pterostichus (Stereocerus) haematopus Dej.	dt	Polar Urals, Gydan Peninsula, Lower Yenissey, Taimyr, Chukotka, Wrangel Island, Magadan region to the Okhotsk coast, upper Indigirka R., upper Aldan R., Upper Angara R., Sayany, north of Sakhalin (?), (? Labrador).	Common in tundra on dry, usually sandy soil with crowberry (Empetrum).
Pterostichus (Steroperis) vermiculosus Men.	mt	North of European Russia, northern Siberia, Canada, Alaska.	Tundra, sometimes in forest-tundra, polytopic, but mostly on reasonably moist grass-herb meadows.
Pterostichus (Steroperis) costatus Men.	mt	Northern Siberia from Yamal Peninsula (Lower Ob) to Chukotka, North America.	Typical subarctic species, only in tundra zone, on bumpy and polygonal bogs.
Pterostichus (Steroperis) agonus Horn.	mt	Siberia, North America.	Typical subarctic species, tundra zone only, mostly in boggy tundra.
Pterostichus (Petrophilus) magus Man.	ta	East of European Russia, Siberia.	Mostly in taiga.
Pterostichus (Petrophilus) abnormis Sahlb.	dt	Siberia.	More common in taiga, than in tundra.
Pterostichus (Petrophilus) tundrae Tschitsch.	dt	Eastern Palearctic.	Southern tundra.

Taxa	Eco Code	Modern distribution	Ecology
Pterostichus (Petrophilus) montanus (Motsch.)	dt	East of European Russia, Siberia.	Mostly in taiga, rarely in tundra on dry open places.
Pterostichus (Petrophilus) eximus Mor.	dt	Siberia, Mongolia.	Mostly in taiga and mountain tundra.
Pterostichus (Lyperopherus) sublaevis Sahlb.	dt	Holarctic tundra species. Sometimes extends to northern taiga along large river valleys (Yenissey R. up to Dudinka, Lena R. up to Zhigansk).	Mostly on dry south-facing slopes, prefers sandy soil.
Agonum impressum Panz.	na	Europe, Siberia, East Asia from Magadan region to northeastern China.	River valleys, near water, mostly wet meadows.
Curtonotus alpinus Payk.	dt	Circumpolar species, common in north Siberia, in North America was found in Rocky Mountains and New England at high altitude.	One of the most abundant tundra species, not found in arctic tundra. Prefers open dry habitats and sandy and gravely soils; common on herb-rich meadows. Feeds on flowering shoots and young grass seeds, particularly, Poa and Alopecurus.
Amara glacialis Mnnh.	dt	Siberia east of Yenissey, Chukotka, Alaska, Canada.	Open sandy habitats, often on river banks; a large series was collected in the Lena Delta area, on sandy flood-plain under driftwood and in dry tundra with wind-blown sand.
Amara interstitialis Dej.	dt	Siberia, north taiga and forest-tundra, rarely tundra.	Northern taiga and forest-tundra, rarely in shrub tundra. According to Kiselev (1981), occupies open dry habitats with sparse vegetation, and the well-heated grass-herb meadows in tundra.
Harpalus vittatus vittatus Gebl.	ms	South Siberia from Altai to Eastern Transbaikalia, Mongolia, Khabarovsk region.	Mostly steppe habitats, sometimes on dry meadows and forest edges.
Harpalus vittatus kiselevi Kat. et Shil.	ms	Northern Yakutia (Verkhoyansk, Zhigansk, Tomtor).	Mostly steppe habitats, sometimes on dry meadows and forest edges.
Trichocellus mannerheimi Sahlb.	dt	Northern Europe, Siberia, Chukotka Peninsula, Magadan region, Mongolia, North America.	Boreal species, but also lives in southern (shrub) tundra on dry slopes.
Cymindis arctica Kryzh. et Em.	st	Now only in the Middle Indigirka River basin, but was much more widespread in the Pleistocene.	Found in relic steppe areas; as fossil is associated with "steppe" complexes.
Family Dytiscidae			
Hydroporus lapponum (Gyll.)	aq	Arctic part of Holarctic.	Aquatic
Hydroporus acutangulus ? Thoms.	aq	Arctic part of Holarctic.	Aquatic

Taxa	Eco Code	Modern distribution	Ecology
Agabus moestus (Curt.)	aq	Circumpolar arctic species, north of taiga, on the lowlands and arctic islands.	Small ponds and lakes, among the plants, protruding over the water surface; winters in soil. The northernmost species in the genus.
Agabus thomsoni (J.Sach.)	aq	Boreal and arctic species, except the high Arctic.	Small ditch-waters and peat ponds.
Colymbetes dolabratus (Payk.)	aq	Circumpolar species, north boreal and arctic (in Greenland up to 75°N).	In shallow waters, good flyers, for wintering can move to deeper water bodies.
Family Gyrinidae			
Gyrinus opacus Sahlb.	aq	Northern Europe, Chukotka, Kamchatka, Northern Kurile Islands.	Aquatic.
Family Hydrophilidae			
Helophorus (Helophorus) splendidus Sahlb.	aq	Polar Urals, northern Siberia (from Gydan Peninsula to the Chaun Bay in Chukotka (not in the high Arctic), Okhotsk Coast of the Magadan region, Northern Canada.	In small ditch-waters, with abundant plants.
Hydrobius fuscipes F.	aq	Holarctic widespread species, except tundra.	In various ditch-waters, sometimes polluted. Often flies from one water body to another.
Family Leiodidae			
Cholevinus sibiricus (Jean.)	mt	Northern Siberia from Taimyr to Western Chukotka. Tundra zone only, mostly typical and arctic tundra.	Probably scavenger or detritophage, on tundra meadows. Common on inactive grass-covered baidzerakhs, usually among moist soil clods.
Family Silphidae A71			
Thanatophilus lapponicus F.	oth	Chukotka and Kamchatka peninsulas, Magadan, Khabarovsk, and Amur regions, Primorye, in tundra and forest-tundra in the north, in the mountains in the south.	On carrion, can feed on dry meat, dry fish and fur.
Blitophaga opaca L.	ta	Holarctic boreal species; not known in tundra.	Phytophage beetle, feeds on young leaves and sprouts.
Family Staphylinidae			
Olophrum consimile Gyll.	mt	Widespread Holarctic species, in Siberia up to 50° N, in America to Northern Alaska.	On stream and lake banks, in decaying leaf litter (particularly of alder and willow), in moss, in sedge tussocks, under fallen trees, mostly in taiga and mountains, sometimes in shrub tundra.
Tachinus arcticus Motsch.	mt	Holarctic species, mostly arctic and typical tundra.	Common mesic species, was observed on Bolshoy Lyakhovsky Island under dried scum crust in depressions among baidzerakhs.
Family Byrrhidae - pill beetles			
Simplocaria arctica Popp.	mt	Northern Eurasia, in tundra and taiga.	Under moss, stones, and plant detritus.

Taxa	Eco Code	Modern distribution	Ecology
Simplocaria semistriata F.	mt	Northern Eurasia, in tundra and taiga.	Under moss, stones, and plant detritus.
Curimopsis cyclopedia Muenst.	mt	Northern Eurasia, in tundra and taiga.	Meadows-like habitats.
Morychus viridis Kuzm. et Kor.	ss	Upper Kolyma, Chukotka: Middle Amguema, Chaun Lowland, Aion Island, Anadyr Lowland (Utesiki), Lena Delta (Belaya Skala).	On very dry places with xerophilic sedge Carex argunensis and fine cover of moss Polytrichum piliferum (larvae feeding plant) (see Berman).
Family Melyridae			
Troglocollops arcticus L.Medv.	ms	Chukotka (Chaun Bay), Wrangel Island.	Only in steppe-like warm and dry habitats
Family Chrysomelidae - leaf beetles			
Bromius obscurus L.	me	Europe, Siberia, Kazakhstan, Far East, Mongolia, from tundra (Kola Peninsula) to the south of steppe zone.	On sorrel and fire-wood.
Chrysolina perforata Gebl.	st	Altai, Tuva, Sayany, Baikal region, Transbaikalia; in Yakutia on steppe patches.	Steppe patches in the forest zone, steppe, on Artemisia and Thymus.
Chrysolina arctica Medv.	ms	Wrangel Island only.	Steppe-like patches on Wrangel Island.
Chrysolina brunnicornis bermani Medv.	st	Yakutia (Upper Indigirka, Balagannakh).	Relic steppe patches, on Artemisia.
Chrysolina tolli Jac.	at	Typical and arctic tundra from Yenissey (Taimyr) to Kolyma, Wrangel Island	On cruciferous plants. More common in typical tundra. On Taimyr the highest densities in the south of arctic tundra.
Chrysolina subsulcata Mnnh.	at	Severnaya Zemlya (October Revolution Island), Novosibirsk Islands (Faddeyevsky, Kotelny, Lyakhovsky), arctic coast from Taimyr to Chukotka, Alaska.	Abundant in arctic tundra, less common in typical tundra and polar desert; polyphagous, often on sedges.
Chrysolina purpurata Fald.	st	Mongolia, Baikal region.	Steppe.
Chrysolina septentrionalis Men.	mt	Mostly in the Arctic - Novaya Zemlya, Severnaya Zemlya, Wrangel Island, arctic coast from Polar Urals to Chukotka. Isolated occurences in the south (Lipetsk Region, Perm, Krasnoyarsk, Nizhneilimsk).	Abundant in arctic and typical tundra, occurs in southern tundra and polar desert; polyphagous, commonly on Ranunculaceae.
Chrysolina bungei Jac.	at	Novosibirsk Islands, Yana River mouth.	Arctic tundra.
Chrysolina wollosowiczi Jac.	at	Novosibirsk Islands, Wrangel Island.	Arctic tundra.
Chrysomela blaisdelli Van Dyke	sh	Taimyr, Chukotka Peninsula, Alaska.	On well-heated slopes with forbs and climps of Salix arctica.

Taxa	Eco Code	Modern distribution	Ecology
Phratora polaris Schn.	sh	Northern Europe, Siberia, Irkutsk region, Mongolia.	On willows, mountain tundra, common in forest-tundra and shrub tundra; occurs as far north as typical tundra (in willow clumps along the river banks and lows).
Hydrothassa hannoverana F.	na	Europe, Siberia, Sayan, Irkutsk region, Kazakhstan.	On Ranunculaceae. In taiga zone is common near water, in tundra in various habitats, as far north as typical tundra.
Hydrothassa glabra Hbst.	na	Europe south of Karelia, Western Siberia.	On Ranunculaceae.
Phaedon concinnus Steph.	me	Europe, Siberia, Far East, Baikal region, Tuva, Mongolia.	On Ranunculaceae and crucifers, moist meadows in taiga, as far north as typical tundra.
Phaedon armoraciae L.	me	Europe south of Murmansk region, Siberia, Altay, Baikal region, Transbaikalia, Kazakhstan, Mongolia.	Wet medows in taiga. On crucifers, Veronica, Caltha.
Galeruca interrupta circumdata Duft.	st	Europe (except north), Caucasus, Siberia, Mongolia, Tibet.	On Artemisia.
Family Apionidae			
Mesotrichapion wrangelianum Kor.	dt	Wrangel Island only.	On legumes.
Hemitrichapion tschernovi T.-M.	dt	Polar Urals, Dikson, Tareya (Taimyr).	On legumes. Tundra species.
Family Curculionidae - weevils			
Sitona borealis Kor.	dt	Taimyr, northern Yakutia, Magadan region, Wrangel Island, Chukotka Peninsula. Tundra.	Tundra meadows and mountain slopes, on legumes (Hedusarum).
Sitona lineellus Bonsd.	me	Widespread Holarctic species. Europe, Siberia (as far north as southern Chukotka), Mongolia, North Anerica.	On legumes.
Coniocleonus ferrugineus Fahr.	ms	Southern Urals, Novosibirsk region, Yenissey from Krasnoyarsk to Taimyr, Altai, Sayan, Tuva, Baikal and Transbaikalia, Yana, Indigirka and Kolyma upstreams, Amur, Primorye, Mongolia, northern China.	Mountain steppe.
Stephanocleonus eruditus Faust	st	Altay, Khakasia, Tuva, Irkutsk Region, Buryatia, Transbaikalia, Central Yakutia, northeastern Yakutia (Yana, Adycha and Indigirka upstreams), Mongolia.	Mountain steppe. Relic steppe patches in Yakutia.
Stephanocleonus fossulatus F.-W.	st	Altay, Khakasia, Tuva, Irkutsk region, Buryatia, Mongolia, Transbaikalia, Central Yakutia, Yana, Indigirka and Kolyma upstreams, Priamurye.	Mountain steppe. Relic steppe patches in Yakutia. Feeds on Artemisia santolinifolia.
Stephanocleonus paradoxus Fahr.	st	Transbaikalia, Mongolia.	Most common in desert steppe and mountain steppe, feeds on Artemisia, Allium, some grasses.

Taxa	Eco Code	Modern distribution	Ecology
Lepyrus nordenskjoeldi Faust	sh	In the Arctic from Polar Ural to North America, Khabarovsk and Amur regions, Primorye, Japan, Korea, northeastern China.	On willows, rarely on birch and alder, in tundra on dry slopes under willows. Larvae feed on willow roots; in the southern part of the range live on flood-plains and mountain tundra.
Hypera ornata Cap.	dt	Northern Europe, Khibiny, Kara Tundra, Taimyr, Central and northeastern Yakutia (as far north as Kharaulakh), Chukotka, Wrangel Island, Tien-Shan, Altai, Sayan, Tuva, Transbaikalia, Primorye, Mongolia.	On legumes, in tundra in the driest and warmest habitats.
Hypera diversipunctata Schrank.	dt	Extremely widespread species - from Central Europe and Baltic to Kamchatka and from the Arctic (Novaya Zemlya, Wrangel Island) to Azerbaidzhan, Kazakhstan, and Altai.	On Caryophyllaceae. In tundra in various habitats except wet, in taiga in dry biotopes.
Dorytomus imbecillus Fst.	sh	Siberia, Chukotka, Primorye, northern North America, Canada.	On willows, in Chukotka on prostrate species in rocky tundra.
Notaris aethiops F.	na	Europe, Siberia, Khabarovsk, Amur and Magadan regions, Primorye, Kamchatka Peninsula.	Sedge meadows in stream valleys.
Tournotaris ochoticus Kor.	na	Yakutia, Magadan, Amur and Khabarovsk regions, Primorye, Transbaikalia, Mongolia.	On monocotyledons, in river and stream valleys.
Isochnus arcticus Kor.	at	Wrangel Island, Chukotka Peninsula, Taimyr, Alaska, Arctic Canada.	Arctic willows, sometimes prostrate. On Wrangel Island mostly in river valleys and dry places in the northern part of the island, larvae mine willow leaves (Salix arctica), imago were found under willows in litter.
Isochnus flagellum Erics.	sh	Europe, Siberia, Khabarovsk, Amur and Irkutsk regions, Transbaikalia, Primorye.	On poplar and willow.

POSTGLACIAL AND HOLOCENE ENVIRONMENTS OF THE WESTERN LAPTEV SEA AND EASTERN KARA SEA AS REFLECTED IN FOSSIL ASSEMBLAGES

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Introduction

Scientific background

Since the last glaciation the Eurasian Arctic continental margin underwent drastic changes related to the northern hemisphere climate warming and eustatic sea-level rise as indicated by complex investigations of sediment cores from the shelf and continental slope (e.g., Bauch et al., 1999, 2001; Stein et al., 1999, 2001, 2003; Boucsein et al., 2000; Mueller-Lupp et al., 2000; Polyakova et al., in press). In the course of previous OSL projects our group carried out investigations of the previously non-studied recent and fossil benthic assemblages from the eastern Laptev Sea shelf and gained new interesting results about paleoenvironmental changes in this part of the sea under the Holocene transgression (Stepanova et al., 2003; Taldenkova et al., in press). Interestingly, the shallow nearshore assemblages of the initial stages of inundation from the middle and outer shelf contain abundant planktic foraminifers which presently occur in the relatively deep-water regions of the upper continental slope affected by Atlantic waters and have not been found in the samples from the coastal regions. The current project is aimed at reconstructing the paleoenvironmental conditions in the western Laptev Sea and eastern Kara Sea based on the study of recent and fossil assemblages of mollusks, ostracods, and foraminifers. Special attention is paid to signs of Atlantic water inflow reflected in the composition of benthic assemblages.

Goals and objectives

The goals of this project were:

- to analyze the temporal changes in composition of fossil assemblages of mollusks, ostracods and foraminifers in the western Laptev Sea during post-glacial sea-level rise;
- to study recent and fossil ostracodal and molluskan assemblages from the eastern Kara Sea;
- to reconstruct postglacial and Holocene environments of the western Laptev and eastern Kara seas on the basis of fossil assemblage data, to relate paleoenvironmental changes in these areas to the previously obtained data on the eastern Laptev Sea shelf, and to trace the signs of enhanced Atlantic water inflow reflected in the composition of benthic assemblages.

Research activities

Approach

Following the proposed objectives we investigated various recent and fossil benthic assemblages:

- In the western Laptev Sea, we started detailed investigations of fossil mollusks, ostracods, and foraminifers in core PS51-154, upper continental slope (water depth 270 m). Core length is 674 cm (708 cm with core catcher), the whole core was sampled in 2 cm thick slices. The lower sediment interval (below 570 cm) is barren of fossils; the total number of samples for assemblage study is 285.

- In the Kara Sea we investigated: a) the composition of modern mollusks and ostracods from coretop sediment samples collected in the eastern Kara Sea in 1999-2001 (63 samples in total); b) fossil assemblages of mollusks and ostracods from sediment core BP00-07, central eastern Kara Sea shelf, water depth 43 m. Core length is 632 cm; in total, 88 samples were studied.

All samples for benthic assemblage studies were freeze-dried, weighed, and subsequently washed over a 63µm meshsize sieve. Valves and tests were picked, counted, described, identified, and photographed (SEM). The total abundance of microfossils is expressed as specimens per 100 g of the dry bulk sediment. In core PS51-154, simultaneously with taxonomic studies, tests of planktic foraminifers and those of the benthic species *Cassidulina teretis* were picked for future isotope measurements.

Accomplishments

We investigated fossil assemblages from core PS51-154, but by now about 150 samples have been analyzed (Task 1), these investigations are going to be continued in the future.

All samples planned for recent (Task 2) and fossil (Task 3) assemblage studies in the Kara Sea were analyzed. The obtained results will be discussed in two papers that are currently under preparation. The first one is provisionally entitled «Holocene environmental changes on the eastern Kara Sea shelf: combined evidence from recent and fossil assemblages and stable isotope composition of microfossils» (Taldenkova, Stepanova, Simstich) and is devoted to the paleoenvironmental reconstructions based on core BP00-07. The second one, „Modern ostracods from the eastern Kara Sea: taxonomic composition, assemblage studies and comparison with the eastern Laptev Sea» (Stepanova, Taldenkova, Simstich, Bauch), deals with description of the so far non-studied modern ostracods from the Kara Sea and comparison of ostracod assemblages from the river-affected eastern Kara and Laptev Sea shelves.

Results

The results of assemblage studies are discussed separately for the different study regions.

The western Laptev Sea (Task 1)

Since only part of the samples from core PS51-154 has been analyzed by now, and most of those coming from the upper half of the core sediment sequence, we can draw only some preliminary conclusions.

A total of 9 datings ensure good chronological framework for paleoreconstructions in the core (Bauch et al., 2001). Sedimentation rates were relatively high until 11.1 cal.ka, but later, after the outer shelf had been flooded, they sharply decreased by nearly an order of magnitude. The lower core unit is barren of any fossils, but enriched in small-size plant debris, vivianite and mica, thus evidencing proximity of the paleocoast to the slope break prior to 15.8 cal.ka. There are evident variations in the taxonomic composition of fossils in the upper 5.7-m thick fossil-bearing part of the core, which reflect certain paleoenvironmental changes. Until ca. 13.5 cal.ka fossil assemblages are poor in terms of both abundance and taxonomic diversity. *Portlandia arctica* is dominant among mollusks. This species is able to survive in harsh arctic environments with considerable sedimentation rates and high input of plant debris (Syvitski et al., 1989; Aitken and Gilbert, 1996; Taldenkova et al., in press). Few relatively deep-water ostracod species predominate. High abundance of *Krithe* is indicative of cold habitats with low nutrient content (Cronin et al., 1995). Among foraminifers, the presence of *C. teretis* is remarkable since its occurrence in the Arctic Ocean is clearly associated with Atlantic waters (Lubinski et al., 2001 and references therein). Thus, already at 15.8 cal.ka Atlantic waters reached the western Laptev Sea continental slope, where bottom environment was characterized by cold, waters of low nutrient content, high sedimentation rates, input of plant debris, and, probably, existence of a perennial ice cover. *C. teretis* is present throughout the core sequence indicating that the core site has remained affected by Atlantic waters since 15.8 cal.ka until present. The period between ca. 13.5 and 11.5 cal.ka is characterized by increasing abundance and diversity in all three groups. The presence of numerous shallow-water euryhaline and brackish-water ostracods could be indicative of an especially high freshwater discharge and active sea-ice transportation of these species to the continental slope. The subsequent period, between ca. 11.5 and 11.1 cal.ka is distinguished by the highest sedimentation rates and low abundance of fossils. After 11.1 cal.ka the benthic assemblages of the continental slope are dominated by relatively deep-living marine species. Especially the period between 11.1 and ca. 4 cal.ka is characterized by only deep-living ostracods with clear North Atlantic affinities, thus probably reflecting the strongest inflow of the Atlantic waters.

The eastern Kara Sea shelf (Tasks 2 and 3)

The distribution of modern mollusks and ostracods in the eastern Kara Sea demonstrates their close relation to salinity variations dependent on river runoff influence and distance from the shore (Fig. 1). In the innermost parts of the estuaries, southward from approximately 72°N in Yenisei Bay, and 70°N in Ob Bay, mollusks are absent, and ostracods consist of the freshwater species *Cytherissa lacustris* and *Candona candida* with an admixture of the euryhaline species *Heterocyprideis sorbyana* (in Yenisei Bay). In the middle part of the estuaries, between 72-72.5°N in Yenisei Bay, and 70-72°N in Ob Bay, mollusks are also absent while ostracods are represented by the single brackish-water species *Cytheromorpha macchesneyi*. Mollusks appear only in the outer estuarine zone. In Ob Bay there is found brackish-water species *Portlandia aestuariorum*, and in Yenisei Bay numerous *Portlandia arctica*. The latter species remains dominant in the inner shelf zone down to water depths of 15-20 m (~73-73.5°N). The ostracod assemblage in the outer estuarine/inner shelf zone represents a mixture of brackish-water, euryhaline, and shallow marine species. The euryhaline species *Heterocyprideis sorbyana* and *Paracyprideis pseudopunctillata* predominate. In the coastal zone along western Taimyr, *P. arctica* is the most abundant among mollusks although some other species are also present. Ostracods in the samples from this zone consist of euryhaline and shallow marine species; the relatively high percentage of euryhaline species is characteristic for the fast-ice zone. In the remaining part of the shelf marine species are dominant among both mollusks (*Yoldiella lenticula, Y. fraterna, Leionucula bellotii, Thyasira sp., Dacrydium vitreum*) and ostracods *(Rabilimis mirabilis, Semicytherura complanata, Cluthia cluthae, Sarsicytheridea punctillata, Argilloecia conoidea, Cytheropteron tumefactum, Polycope sp.).* The share of relatively deep-living species gradually increases offshore in this part of the shelf.

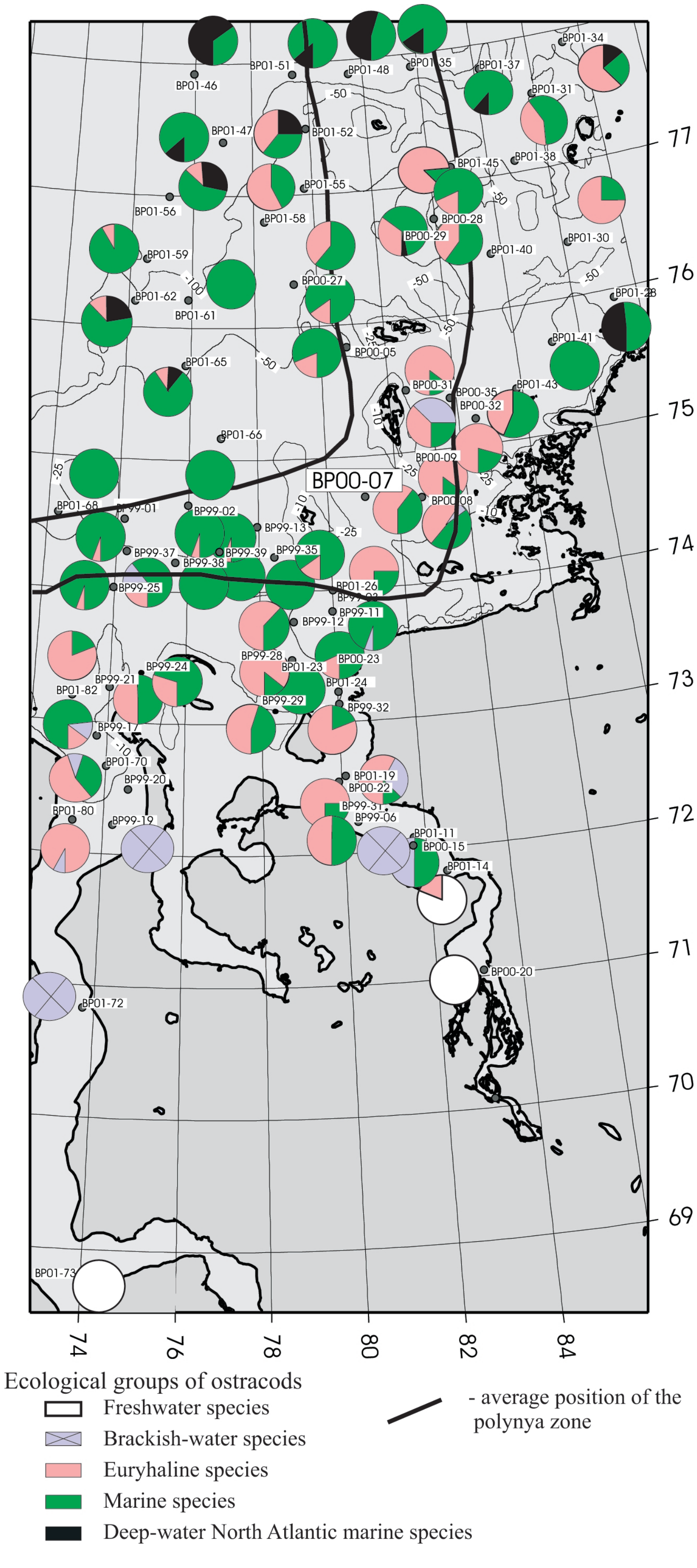

Fig. 1: Site locations of coretop samples and distribution of recent ostracods in the eastern Kara Sea.

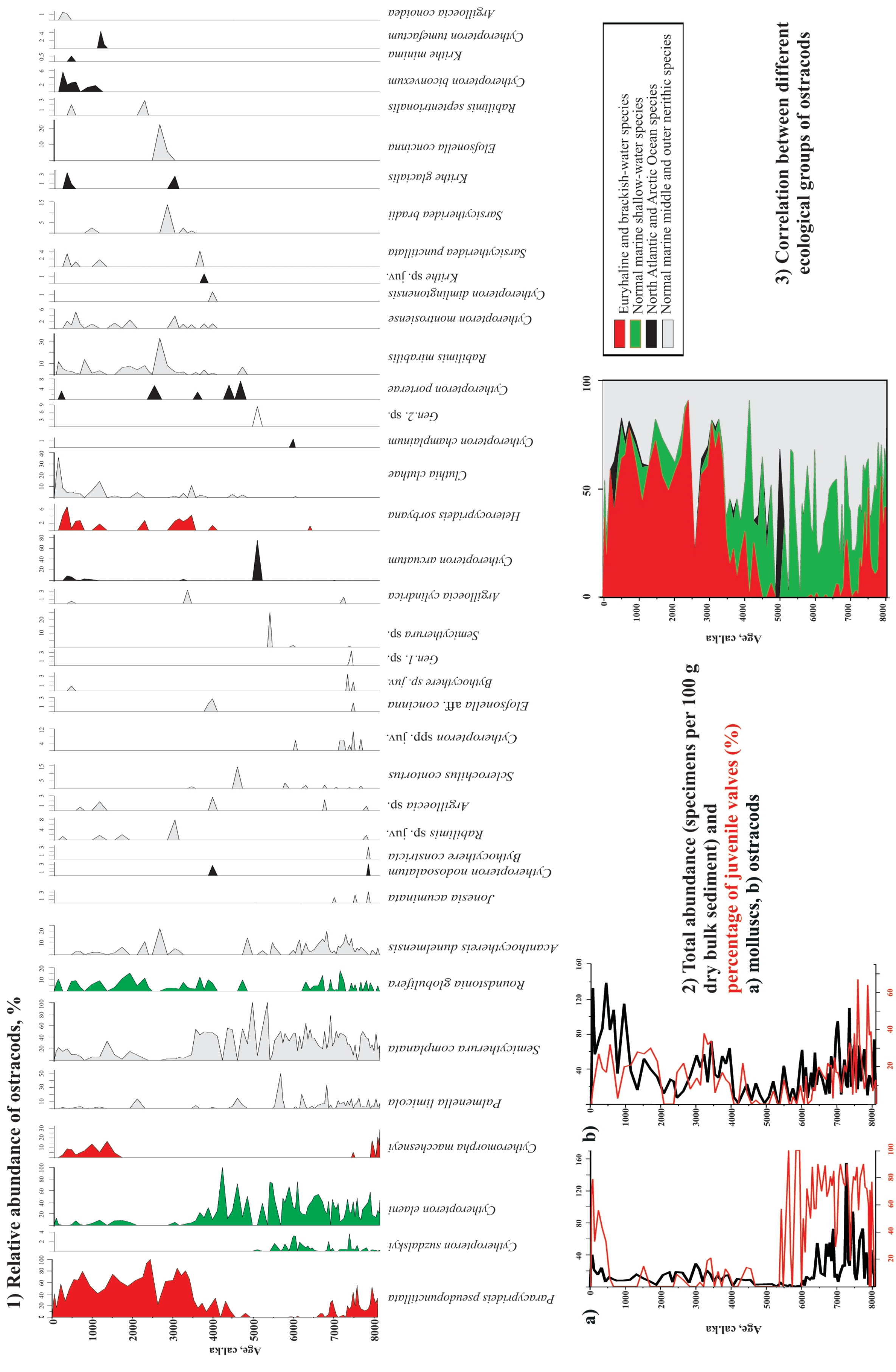

Fig. 2: Downcore data on distribution of fossil ostracods and mollusks in core BP00-07/5, eastern Kara Sea.

Several stages of paleoenvironmental changes were recognized in core BP00-07 according to our investigation of fossil benthic assemblages (Fig. 2). Between 8.1 and 6 cal.ka, the total abundance of mollusks and ostracods is highest, as is the share of juvenile forms. *P. arctica* predominates among mollusks, and shallow marine and euryhaline species among ostracods. During this time the core site was located in a narrow estuary with high TOC input (Stein et al., 2003). Sedimentation rates reached 124 cm/kyr. The species composition of the fossils suggests a considerable influence of river runoff on the site, which might have been located within the zone of riverine and seawater mixing where considerable amounts of terrestrial plant debris were accumulated. Significant changes in species composition occurred between 6 and 5 cal.ka when all euryhaline and brackish-water ostracods suddenly disappeared, as well as juvenile forms among mollusks (*P. arctica*). Also the total abundance of both groups decreased considerably. By this time the sea level reached its modern position (Bauch et al., 2001). Therefore, this territory was no longer located within an estuary but in a small meridional seafloor depression of the mid-shelf with a water depth of about 40 m. At present similar parts of submarine valleys on the mid-shelf, for instance, within the zones of polynyas, are subject to strong wind-induced reversal currents (Dmitrenko et al., 2001; Wegner, 2002). The sharp decrease in the total abundance of valves and disappearance of juveniles might be the result of active hydrodynamic conditions due to initiation of such currents. Besides, another major change in the pathways of terrigenous input by rivers and coastal erosion to the more eastward direction occurred about 6 cal.ka as indicated by increasing TOC accumulation rates in core BP01-42 at the Taimyr coast (Stein et al., 2003). Therefore, bottom current activity and decreasing food supply might have caused the observed decrease in the total abundance of benthic organisms. The sharp increase in percentage of marine species also results from this change in the direction of freshwater outflow towards the Taimyr coast and possible intense advection of more saline Atlantic-derived (?) water with reversal currents. After 5 cal.ka the total abundance and species diversity in both groups increased again, and relatively deep-living species appeared for the first time. This provides evidence for the establishment of rather stable near-bottom conditions with a water salinity around 32-33 similar to the modern environment of the studied area. At the same time, the simultaneous increase in the relative abundance of euryhaline and brackish-water ostracods, especially between 3.5 and 0.5 cal.ka, allows assuming an increase in river runoff and, probably, more active ice-rafting of these species from the inner shelf region to the core site. We recorded a similar increase in the share of euryhaline and brackish-water ostracods combined with the increase in taxonomic diversity on the inner Laptev Sea shelf after 2.7 cal.ka (Taldenkova et al., 2003).

Conclusion

The intention of the current project was to study recent and fossil benthic assemblages from the eastern Kara and western Laptev seas in order to reconstruct paleoenvironmental changes in the course of postglacial transgression with particular interest lying on the traces of Atlantic-water influence on the studied regions. The main results and conclusions achieved so far are listed below.

The analysis of the composition of recent ostracods and mollusks from 63 coretop samples obtained in different parts of the eastern Kara Sea revealed distinct changes in species composition clearly related to salinity and water depth variations. Four benthic assemblages replacing each other in offshore direction following salinity and water depth increase were established: the inner estuarine assemblage represented by freshwater species solely; the outer estuarine assemblage dominated by brackish-water species; the inner shelf assemblage dominated by euryhaline and marine species; and the outer shelf assemblage dominated by marine species with a considerable share of deep-living North Atlantic and arctic species. It should be noted that prior to our investigations, only 5 publications mentioning ostracods of the Kara Sea were available (and the species described in these publications were mainly obtained from water depths exceeding 200 m; see Cronin et al., 1991). We identified 16 species that have not been previously reported from the Kara Sea. Our paper in preparation on recent ostracods from the Kara Sea will contain the first illustrations and descriptions of ostracods from this area.

Based on downcore data on fossil ostracods and mollusks, paleoenvironmental changes in the eastern Kara Sea mid-shelf during the past 8.1 kyr were reconstructed: i) 8.1-6 cal.ka: predominance of euryhaline and brackish-water species and high total abundance of fossils indicate extremely high riverine influence on the site located in an estuarine-like environment; ii) 6-5 cal.ka: sharp decrease in the total abundance of both groups, disappearance of euryhaline elements, maximum abundance of marine species including some deep-living ones indicate considerable influence of marine waters, probably, in the form of active reversal bottom currents advecting Atlantic-derived (?) waters (cf. Dmitrenko et al., 2001); iii) 5-0 cal.ka: increasing taxonomic diversity and total abundance, predominance of marine species provide evidence for a modern-like marine environment; higher freshwater influence was recorded at ca. 3.5-0.5 cal.ka.

While on the eastern Kara Sea mid-shelf some indirect traces of Atlantic-derived waters correspond to the period of 6-5 cal.ka, continuous influence of Atlantic waters since ca. 15.8 cal.ka is recorded in the species composition of microfossils from the sediment sequence of the upper continental slope in the western Laptev Sea.

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Stipendienprogramm 2003/2004: Abschlussberichte

Contents:

THE ROLE OF MESOZOOPLANKTON IN SEDIMENTATION OF ORGANIC AND INORGANIC MATTER ON THE LAPTEV SEA SHELF

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Introduction

About ninety percent of riverine suspended matter and about 40% of dissolved elements are deposited in the zone of the marginal filter. The mechanism of a marginal filter located at the land-sea boundary depends on the combination of several systems, i.e., gravitational deposition of suspensions, colloidal system and biological pump. Biological processes are most effective in those places where a sufficient amount of light is combined with a high concentration of nutrients. These conditions are sufficient for high phytoplankton production. The phytoplankton bloom is followed by zooplankton (above all copepod) development. Copepods feed on phytoplankton (grazer control), thus combining separate cells into large pellets. The pellets precipitate to the seafloor at a high rate (Lisitzin, 2002). Vertically migrating zooplankton also play an important role in transport by consuming organic particles in the surface water layer at night and metabolizing the ingested food below the mixed water layer during the day.

Numerous zooplankton investigations were carried out in the southeastern Laptev Sea in different seasons of the year during the period of 1989-2003. The studies carried out in this region were also focused on different aspects of chemistry (Pivovarov et al., 1999; Gukov, 2001), oceanography (Dmitrenko et al., 1999, 2001), geochemistry (Rachold et al., 2000; Hölemann et al., 1999; Wegner, 2002), and investigations of phytoplankton and bacteria-plankton (Sorokin and Sorokin, 1996; Tuschling, 2000; Gukov, 2001). Abundant data on composition, quantity, distribution, and seasonal dynamics of different biotic and abiotic components and processes in this region were collected.

Scientific background

The proposed research project is a continuation of the previous projects “Pelagic invertebrate fauna of the Laptev Sea shelf waters” and “Diel vertical migrations of zooplankton in the Laptev Sea shelf waters.” These projects summarized the results of taxonomical diversity, abundance, distribution, seasonal and interannual dynamics, vertical migration, life cycles and ecology (temperature-salinity limits) of zooplankton species on the Laptev Sea shelf (Abramova, 2000; Abramova et al., 2002). Copepods have always been identified as the major component of zooplankton assemblages on the Laptev Sea shelf. The copepod community is clearly dominated by small calanoid copepods (Kosobokova et al., 1998; Abramova, 2000; Lischka et al., 2001).

There are only few reports on feeding ecology, composition of food, quantitative food consumption and feeding rates of marine small copepods. Filtration feeding is characterized mainly by water filtration rates, feeding rates (ration), composition and concentration of food, daily nutrition rhythm (Daro, 1980; Landry, 1981; Vinogradov et al., 1996) and a number of other factors characteristic for copepods. It is especially worth paying attention to the biology of development (age structure, number of generations, duration of diapause) and seasonal abundance dynamics of the species themselves as well as their nutrients and their general characteristics (Gutelmakher et al., 1988).

Goals and objectives

To evaluate the role of Copepoda, as a main component of the biological filter, in the sedimentation processes on the Laptev Sea shelf during different seasons of the year, we planned to use the available data on phytoplankton and salinity distributions, mineral and biogenic components, feeding strategy of Copepoda species and our own long-term data on different aspects of zooplankton existence. The objectives of the project were:

- to designate the territorial borders of the biological area of the marginal filter in the eastern part of the Laptev Sea in different seasons throughout one year according to salinity distribution;
- to evaluate the daily filtration activity for the common Copepoda species (separately for naupliar and copepodid stages) without determinating the daily feeding rhythm;
- to trace the vertical distribution of Chlorophyll *a*, suspended particulate matter and the daily dynamics in vertical distribution of different stages of Calanoida, and the time of their presence in the nutrient-rich layers in order to investigate the daily feeding rhythm of filter species, especially well-marked during daily vertical migrations;
- to define the daily capacity of the biological filter during the ice-covered (April-May) and ice-free periods (August-September);
- to estimate the annual volume of the filtered biotic and abiotic matter in the southeastern part of the Laptev Sea according to the data on seasonal abundance dynamics, taking into account the life cycles (duration of active and passive periods), and the annual dynamics of the age structure of the Calanoida population.

Research activities

The following material was used for this project:

- published data on salinity distribution, phytoplankton, and biotic and abiotic components of suspended matter in the eastern part of the Laptev Sea;
- data on species composition, distribution of abundance and biomass, seasonal dynamics, vertical migration and life cycles of zooplankton collected during our investigations (1987-2003) on the Laptev Sea shelf. Our own data on abundance and age structure of Copepoda in the different seasons of the year were used for estimating the seasonal variations in filtration activity of the biological filter;
- zooplankton samples collected on the Laptev shelf in 2003 (TRANSDRIFT IX) were used for analyzing the contents of the peptic organs of the copepods and measurements of their body length; the total body length of 30-45 organisms of older copepodid stages (V-VI) of every mass Copepoda species (*D. bungei, A. longiremis* and *Pseudocalanus* spp.) were measured using the microscope Olympus SZX9;
- published data on feeding ecology, composition of food, quantitative food consumption and feeding rates of small marine copepods dominated in the eastern Laptev Sea.

We analyzed the contents of the peptic organs of fixed and crushed copepods (20-30 specimens of each dominant species) with a microscope Olympus BX60. The results of visual estimations of bowel contents allow obtaining some information about the character and the size of food.

Based on the data about the average filtration rate for Copepoda (Gutelmakher et al., 1988), we calculated the rate of filtration and the daily/monthly volume of filtrated water for four age groups (Nauplii, CI-II, CIII-IV and CV-VI) of each dominant species. In order to evaluate the rate of filtration for different Copepoda stages, we used published data on their dry individual weights (Coyle et al., 1990; Hanssen, 1997).

Results

The essential part of the biological filter is located between the 5-20‰ isohalines (Lisitzin, 2002) and occupies the near-shore area in the western and the eastern parts of the Laptev Sea shelf in summer. In winter, this zone is located in the southeastern part of the sea bounded by 74^{o}N (Dmitrenko et al., 2001) (Fig. 1A).

Peculiarities of zooplankton existence on the southeastern Laptev Sea shelf

Several small brackish-water and neritic Calanoida (*Drepanopus bungei*, *Pseudocalanus* spp., *Acartia longiremis*) and one Cyclopoida species (*Oithona similis*) are the most numerous organisms in the pelagic fauna of the southeastern Laptev Sea shelf over the year (Fig. 1B). The highest zooplankton concentration is usually observed in the zone of river water influence. The amplitude of seasonal and interannual variations of the total average zooplankton abundance mainly depends on the state of populations of the above-mentioned key Copepoda species. Two maxima in the total zooplankton abundance per year occur on the southeastern Laptev Sea shelf, one at the end of winter (March-May) and another one in summer (July-September). They coincide with the most intensive reproduction periods of the common Copepoda species. It was observed that the reproduction of these Copepoda on the Laptev Sea shelf is prolonged and the active life period of the populations lasts for 6-8 months. During this time the organisms are actively feeding and growing.

The vertical distribution of different age stages of Copepoda dominating the pelagic fauna shows a permanently high abundance of different age stages, especially young stages, in the surface water layer. During the complete annual cycle, two periods with normal daily vertical migrations of adult stages of Copepoda (February-May and August-November) have been recorded. In these periods their abundance in the upper layers increases at night and decreases during daytime.

Size-mass characteristics of common Copepoda species

The main part of sediment flux (89%) in seas and oceans is constituted by faecal pellets of animals with body size exceeding 1 mm. Pellets of the smallest zooplankton organisms do not sink to the seafloor by themselves (Tseitlin, 2000). Measurements of the total body length of 30-45 organisms of older copepodid stages (V-VI) of every mass Copepoda species (*D. bungei, A. longiremis* and *Pseudocalanus* spp.) showed that they range between 1.22 and 2.40 mm. Naupliar and early copepodid stages (I-III) of these species are less than 1 mm in size. In the investigated area, these latter copepodid stages constitute the major part of zooplankton abundance in the surface water layer (0-10 m) during different seasons of the year. Their pellets are probably incorporated into “marine snow” aggregates and sink to the seafloor. Some of the pellets are probably utilized by bacterioplankton or zooplankton already in the surface water layer.

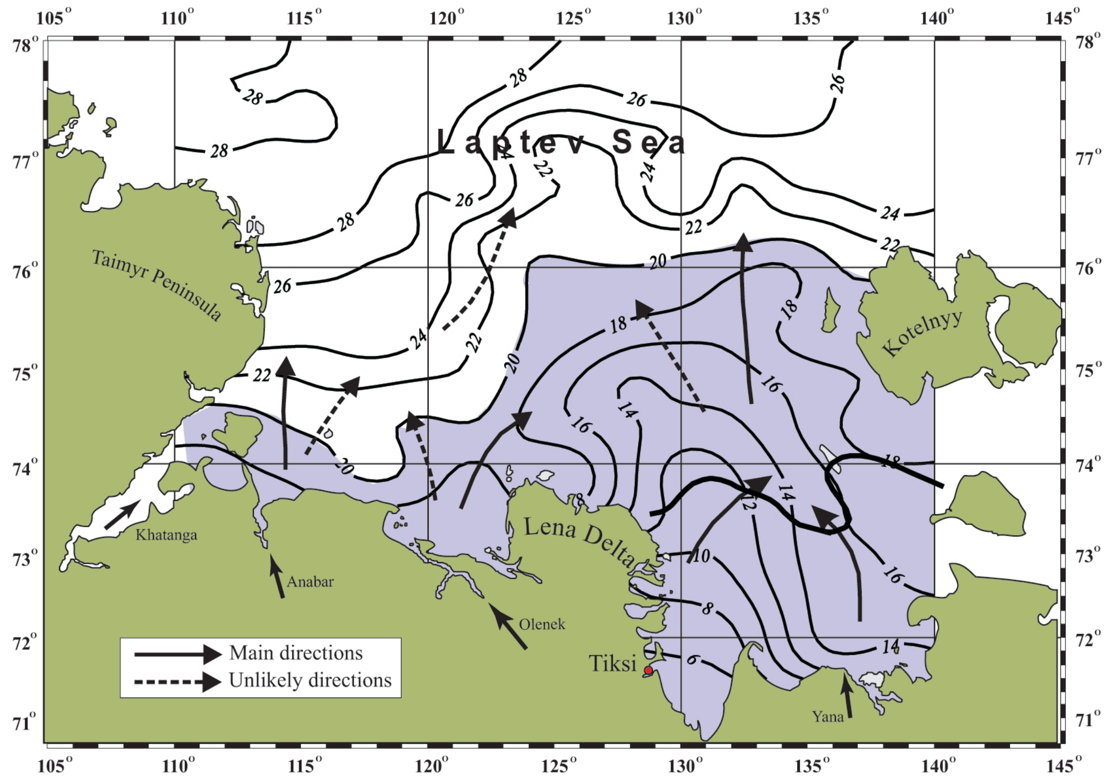

Fig.1A

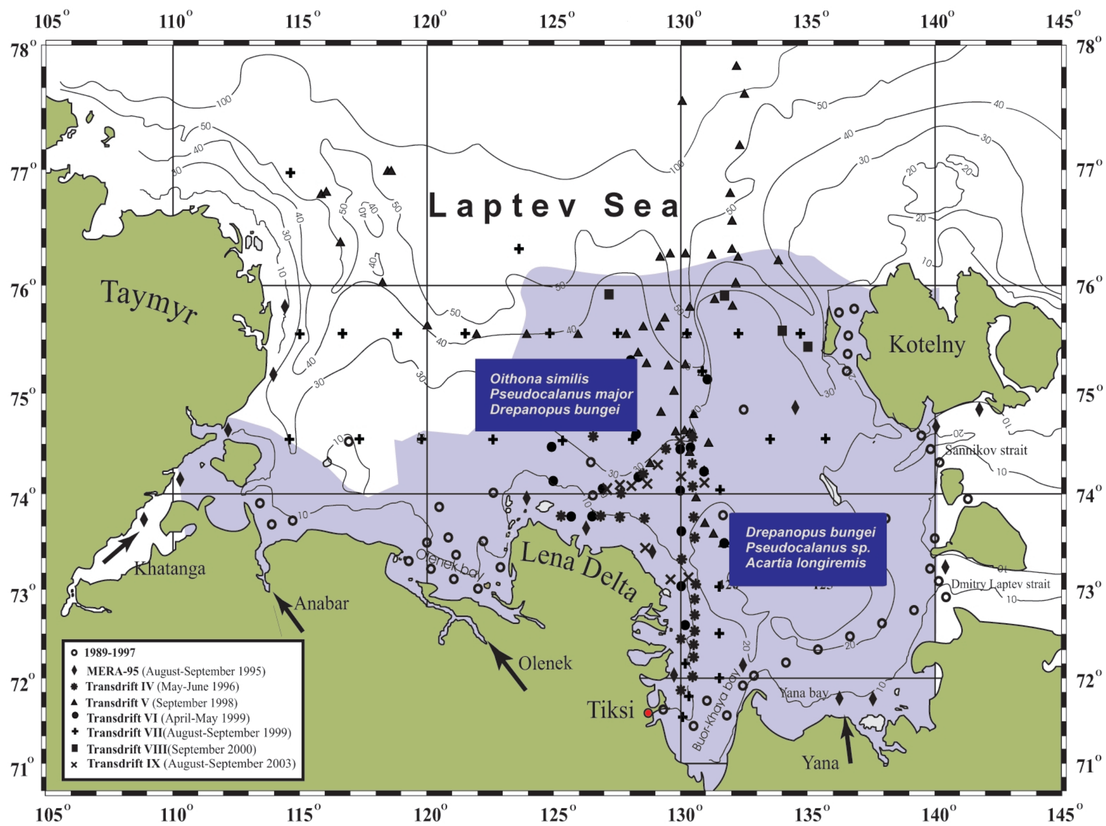

Fig .1B

Fig. 1: A – Summer surface salinity distribution (Dmitrenko et al., 2001) and location of the biological filter on the Laptev Sea shelf in summer ( ) and in winter ( ). B – Location of zooplankton stations (1989-2003) and dominant zooplankton assemblages in the southeastern Laptev Sea in summer and winter.

Food spectra of copepods

Analyzing the composition of intestines of 20-30 crushed adult specimens of each species under binocular did not enable us to reveal the food spectra of copepods. In most cases the food clot was represented by an unshaped mass including walls of diatom tests which can not be identified to species or genus level. This fact probably indicates that copepods primarily feed on protozoans, algae and flagellates, which do not have dense crusts on their bodies. A review of publications on food composition showed that flagellates, Cyanobacteria and phytoplankton are the main feeding objects for the species of Pseudocalanus genus while *Acartia longiremis* exclusively feeds on phytoplankton and *Oithona similis* prefers organic particles (Gardner and Szabo, 1982).

Food stock

The maximum silicon and oxygen concentrations as well as high concentrations of Chlorophyll *a*, Phaeopigment *a* and particulate suspended matter are usually observed in the upper layer on the Laptev Sea shelf (Pivovarov et al., 1999; Wegner et al., 2003). Diatoms, dinoflagellates, chrysophytes and chlorophytes were identified as dominant taxa in the southeastern region. Diatoms comprised the largest part of all taxonomic groups in 65% of the surface samples and 95% of the samples in 10 m depth (Tuschling, 2000). Phytoplankton biomass ranges from 70 to 140 mg/m^3 in the surface layer in the southeastern Laptev Sea (Sorokin and Sorokin, 1996).

Several studies have revealed that ciliates and also heterotrophic dinoflagellates constitute a substantial proportion of copepod diet (Levinsen et al., 2000). The symbiotic ciliate *Mesodinium rubrum* inhabits the surface low-salinity water layer above the halocline. It is dominant among the phototrophic microplankton with a biomass reaching 565 mg/m^3 in the southeastern region. Besides this species, the planktic protozoa are represented by zooflagellates (biomass 70-100 mg/m^3) and heterotrophic ciliates (biomass 10-70 mg/m^3). The bulk of surface primary production was contributed by the ciliate *M. rubrum* and by algae with 37-98 mg/m^3 day^{-1} (Sorokin and Sorokin, 1996).

Rate or intensity of filtration

According to 550 experimental measurement the average rate of filtration for Copepoda is about 0.35 ml/µg dry mass per day (Gutelmakher et al., 1988). Based on this value and dry individual weights of the different age stages, we calculated the rate of filtration and the daily volume of filtrated water for four age groups (Nauplii, CI-II, CIII-IV and CV-VI) of each dominant species from the studied area. Since the body size and mass of *D. bungei* and *Pseudocalanus* spp. differ insignificantly, for further calculations we used the average rate of filtration for these two species (Fig. 2). The rate of filtration of *A. longiremis* is about 40 times lower than that for the other two species.

Seasonal variations in the daily and monthly volume of filtrated water

At the end of winter (March-April), when the population of copepods is primarily represented by overwintering adult (mainly CIV-VI) and naupliar stages, zooplankton abundance is usually low. Therefore, plankton-filtration activity also remains low. All age stages occurring in 1 m^3 of the surface layer in March-April (we used data on average abundance for the region) filtrate two times less water per day than in May-August (Fig. 2). The increase of the filtration volume observed in May results from both the increasing abundance of adult copepods (CVI) and increasing food supply at the beginning of the spring flood. In August-September, average zooplankton abundance in the studied area is always the highest, but copepodids of the early stages (III-IV) predominate during this period. The daily volume of water filtrated by all organisms occurring in 1 m^3 of surface water is comparable with that recorded in May (Fig. 2).

Fig. 2A

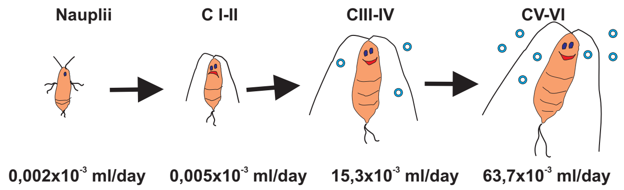

Fig. 2B

April	0,0024	0,00025	3,06	23,3	25,4
May	0,0036	0,025	2,14	52,9	55,1
Aug	0,003	0,0075	22,95	31,5	54,5

Fig. 2: A – The evolution of water filtration rates among different stages of Clausocalanidae species (for 1 ind.); B – The water volume (ml/day) filtrated of different age stages of the common Copepoda per day depending on abundance (ind./m^3) in different months of the year.

Calculated for one month the different age stages of the common Copepoda species from 1 m^3 of surface water (without determinating the daily feeding rhythm) are theoretically capable of filtrating about 1 liter of water in April and about 2 liters in May and August. At the beginning of September this amount increases up to 2.5 liters and then it decreases to 1-0.5 liters of water at the beginning of November, the time for transition to the winter diapause. The average volume of the filtrated water for five months is about 1,6 liters. During the whole active period of life (about 8 months) the animals from 1 m^3 of surface layer filtrate approximately 13 liters of water.

Vertical migrations and the daily nutrition rhythm

In the Norwegian Sea *Calanus finmarchicus* spends about 3-4 hours in the surface layers during the night, but the period of intensive feeding among copepodids V-VI of this species may continue for about 7-8 hours (Vinogradov et al., 1996). According to our data, in the surface layers on the Laptev Sea shelf the maximum abundance of copepodids V-VI of *D. bungei* and *Pseudocalanus* spp. was recorded at 21.00 h. After only three hours a decreasing abundance of adult stages was observed in the upper layers. Probably, like *C. finmarchicus*, the small Copepoda, dominating in the region of our investigation, stay in the surface layers for 3-4 hours. Intensified food consumption starts already at the time of their rising to the upper layers and, probably, continues during sinking down. This means that the duration of the active feeding time of our species also makes up more than 3-4 hours and consists of 5-8 hours for different stages. This shows that the daily volume of filtrated water will be at least by four times lower than it was calculated without determinating the daily feeding rhythm.

Conclusion

Because the formation of the vertical organic-carbon flux due to Copepoda pellets is a very complex process in the Arctic seas, it is of great importance to study in detail its various components (structure of populations and its seasonal dynamics, life cycle of the common species, vertical migration, food spectra of the endemic arctic species, temperature dependences of their rates of filtration, absolute and relative rations, food selectivity of different age stages, the rates at which pellets sink to the seafloor under negative temperatures, etc.). Based on our material, we can only establish these facts: 1. the total volume of water filtrated by Copepoda is primarily dependent on the total zooplankton abundance and abundance of certain age stages; 2. body mass is an important factor in estimating filtration rates; 3. the dominance of naupliar stages or copepodids of late and early stages in the different seasons of the year depends on the life cycle of crustaceans (number of generations per year, duration of diapause and active period of life, etc.); and 4. the seasonal variations in copepod filtration activity are also connected with seasonal vertical migrations of zooplankton on the Laptev Sea shelf.

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VARVED LACUSTRINE SEDIMENTS AS AN INDICATOR OF THE LAST MILLENNIUM PALEOENVIRONMENT OF THE RUSSIAN ARCTIC

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Inroduction

Scientific background

Knowledge on the climate changes of the last millennium presents a necessary key for understanding current climatic processes and predicting the climate of the future. One of the methods for increasing the length of the series of climatic parameters is to investigate bottom sediments of the arctic lakes storing rich information on environmental changes in the past. The available data on sedimentation in the sub-glacial arctic lakes suggest that varved sediments of sub-glacial and deep tectonic lakes are deposited in direct correspondence with the climate changes occurring in the basins of lakes and primarily in accordance with the summer air temperature. Thus, for example, it was possible to reconstruct fluctuations of mean July air temperature for the period of the last 1200 years for Lake Izmenchivoye (Severnaya Zemlya Archipelago) based on calculation of the sediment layer deposited annually and on substantiation of the relation of annual sediment thickness to the water body regime and summer air temperature (Bolshiyanov, 1985; Bolshiyanov and Makeev, 1995).

The time of the Little Ice Age (LIA) is determined ambiguously at the current stage of scientific knowledge, particularly for the Russian Arctic. According to data from a recently published monograph, obtained from decoding space images, the glaciers of Novaya Zemlya retreated from 1952 to 1993 by more than 800 m, which is attributed by the author to the warming event after the Little Ice Age. Datings of the shells of marine mollusks from glacial deposits (diamictons from marine sediments) show an age of 660±45 years BP, i.e., the time of advance of glaciers during the cooling event of the Little Ice Age (Zeeberg, 2003).

The joint Russian-German environmental studies carried out in the Laptev Sea and other regions of the Arctic (the Polar Urals and Chukotka) for several years, and also our own studies (Arkhangelsk oblast') allowed us to gather a collection of cores (more than 15) of bottom lacustrine sediments (up to 1 m in length), where varves are pronounced and can serve as an indicator of climate changes during the last millennium.

Goals and objectives of the project

The main aim of the project was to reveal the climatic fluctuations of the last millennium, changes of the hydrological regime, the area of the drift of detritus, the composition of vegetation and other parameters depending on climate changes. The following objectives were addressed:

- sampling of bottom sediments;
- study of stratigraphy and lithology of surface lacustrine sediments for identification of the layers deposited annually and determination of the sedimentation rate and age of sediments;
- study of spore-pollen and diatom spectra contained in bottom sediments to determine the environmental state at the time of their accumulation;

- study of the following parameters of bottom sediments, which also depend on environmental changes in the basins of the lakes: granulometric composition, magnetic susceptibility, content of organic carbon and nitrogen;
- revealing the climatic signals on the basis of the obtained data on bottom-sediment structure.

Research activities

Approach

Our experience in coring bottom sediments (Bolshiyanov and Pavlov, 2004) showed the most informative data on climatic fluctuations to be contained in sediments of deep lakes of the Arctic and Sub-Arctic. In the deep-water parts of such lakes as Lake Lama (250 m), the wave factors do practically not have any influence on the sedimentation regime, which results in a "quiet" sedimentation. Only a change of the hydrological lake regime disturbs the usual variations of the sedimentation process. Due to an extremely non-uniform hydrological regime, deep tectonic and sub-ice lakes of the Arctic experience pronounced seasonal changes of sedimentation throughout the year, which determines the deposition of varved sediments in the lake valleys. Shallower glacial-karst lakes are subject to a more complicated sedimentation regime due to the influence of wave and ice factors. In addition to accumulation of varved silty-clayey sediments, sandy interlayers of a thickness of up to 1.5 cm are observed in the cores. As a rule, lamination in such interlayers is not pronounced, and gravel grains and organic remains are observed in the form of poorly decomposed leaves and shoots of plants.

Calculation of the number of pairs of the annual layers allowed us to obtain the curves of sedimentation rates and its age. The sedimentation rates obtained for different lakes were comparable with the current rates calculated for Lake Levinson-Lessing from data of three years of observations using sedimentation traps (Ebel et al., 1999). For the segments where varves were absent, the average sedimentation rate for the entire core was assumed. The thickness of such interlayers is small leading to an average error of the age calculations not exceeding 20-30 years. As it is impossible to determine the duration of accumulation of sandy layers, for convenience of calculating the sedimentation rates, the time for the formation of such layers is assumed to be one year, which obviously also influences the accuracy of calculations.

For determining short climate fluctuations (up to 50-100 years), sampling was made continuously throughout the entire core, with the thickness of the collected specimen depending on lithological indicators and not exceeding 1 cm and rarely 2 cm. Sandy interlayers with a thickness of 0.2 cm are often observed in the bottom sediment cores. Such layers were sampled and investigated separately wherever possible.

The collected specimens were examined by means of a spore-pollen and diatom methods. The content of organic and inorganic carbon, and calcium carbonate and nitrogen were revealed.

A spore-pollen method similar to the diatom method made it possible to reveal changes in the composition of vegetation in the areas surrounding the lakes. A comparison of spore-pollen spectra of deeper horizons with surface samples (upper 1-2 cm) allows us to reveal the qualitative changes of vegetation in the basins of the investigated lakes in different periods of the last millennium. As the composition of vegetation reflects the temperature conditions of the vegetation period of plants, the derived ratios directly indicate changes of the summer air temperature in the lake basins. Only for Lake Izmenchivoye was a relation of the summer air temperature to the thickness of the annually deposited sediment found (Bolshiyanov, 1985;

Bolshiyanov and Makeev, 1995). It is, however, difficult to obtain the absolute air temperatures by the used methods. Our methodology allows us to reveal the relative temperature changes (warmer or colder).

Organic carbon is the most reliable indicator of the total content of organic substances in natural water and sediments. The composition and concentration of organic substances in natural waters is determined by a set of many processes differing by their nature and rate: life activity of aquatic fauna and flora; ingress of substances with atmospheric precipitation and surface runoff; ingress of substances as a result of atmospheric waters interacting with soils and the vegetation cover at the watershed surface; ingress of substances from other water bodies, from bogs, peat-bogs; ingress of substances with household and industrial effluents. The organic carbon concentration is subject to seasonal oscillations, their character being determined by the hydrological regime of the water bodies and related seasonal variations of chemical composition and temporal changes in the intensity of the biological processes.

Modern methods allow us to determine the content of both organic and inorganic carbon in the sample. The main content of inorganic carbon is determined by the drift of carbon-containing substances to the lake. Its appearance, however, can be caused by the chemical processes in the water body connected with formation of calcium carbonate. According to Siegenthaler and Eicher (1986), occurrence of calcium carbonate in bottom sediments can result from the life activity of aquatic plants and algae. With absorption by plants of CO_2 dissolved in water, favorable conditions are created for reaction (Ca^{+2} + $2HCO_3^-$ – CO_2 + $CaCO_3$ + H_2O) of calcium ions and dihydro-carbonates, after which calcium carbonate, poorly soluble in water, precipitates.

Ingress of a significant portion of nitrogen-containing organic compounds to natural waters is the result of the death of organisms, predominantly of phytoplankton and the decay of their cells. The concentration of these compounds is determined by the biomass and the rate of the indicated processes. Another important source of nitrogen-containing organic substances is their secretion by aquatic organisms during their life time. Significant sources of nitrogen-containing compounds also include atmospheric precipitation, where the concentration of nitrogen-containing organic substances is close to the concentration observed in surface waters. A significant increase in the concentration of these compounds is often connected with the discharge of industrial, agricultural and household effluents to the water bodies.

It is important to determine the concentrations of magnetic susceptible substances in the samples in order to be able to explain the occurrence of sandy interlayers in clayey sediments of the water bodies. In the sediments of Lake Bolshoye Shchuchye, the increased magnetic susceptibility correlates with such layers and correspondingly with the increased drift of detritus to the lake.

Accomplishments

As a result of the applied methods we created graphics and diagrams of the main indicators of climate fluctuations (spore-pollen, diatoms, organic carbon, nitrogen and others).

Results

To achieve the project objectives, 15 cores of bottom sediments from Russian arctic lakes were investigated (Fig. 1). Data on the structure of bottom sediments, diatom and pollen spectra, geochemistry, magnetic susceptibility, etc. were obtained.

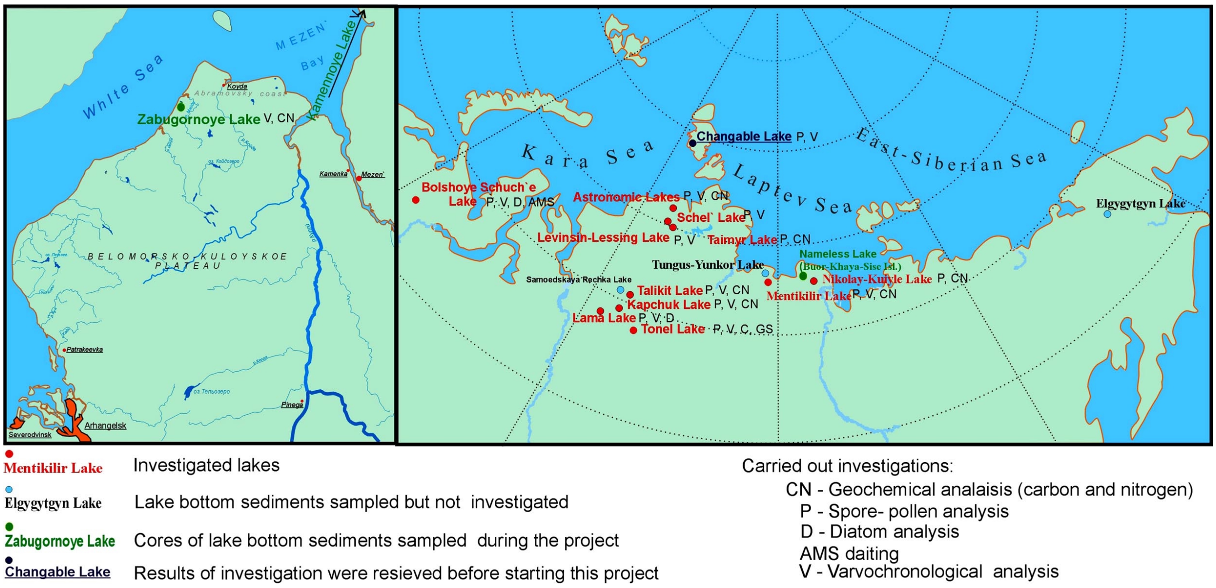

Fig. 1: Studied lakes and methods of investigation of their bottom sediments.

Continuous sampling from the cores of lacustrine sediments made it possible to analyze changes in climatic conditions with an accuracy of up to 20-30 years. The varvo-chronological (visual) method allowed calculating the age and rate of sedimentation in the lakes, which comprises 0.7 mm a year. The obtained rates were compared with data of multiyear measurements of modern sedimentation rates using sedimentation traps (Ebel et al., 1999) and with the results of studies of long cores of lacustrine sediments (Hagedorn et al., 1999).

Sandy interlayers that are encountered among silty-clayey varved lacustrine sediments are interpreted as related to the periods of the maximum drift of coarse detritus to the water body, which could be caused either by abundant precipitation or by melting of snow fields and glaciers within the watershed basin. Studies of similar interlayers in other lakes, e.g., Lake Ritterbush Pond in Vermont (USA), showed them to be a reflection of extreme hydrological and climatic events in the basis of the lake with an area of only 2 km^2 (Brown et al., 2000). The AMS date obtained from a sample of the bottom sediment core of Lake Bolshoye Shchuchye can provide evidence of sand occurrence at the background of silt-clayey varved material. At a depth of 10 cm, dated by the varv-chronological method as 90±20 years, the age determined by the AMS method (by a shoot) was 500±60 years. This discrepancy can be attributed to intense washout of material in the lake basin and its redeposition as bottom sediments.

Changes in the vegetation spectra are connected with lithological characteristics of bottom sediments. In sandy interlayers pointing to a change of the quiet hydrological regime to a catastrophic drift, a much greater content of pollen grains was revealed than in the silty-clayey varved material as for example, in Lake E. Mentikilir. In addition, in such samples, many identified pollen grains are poorly preserved in spite of relatively good conditions of pollen burial and a young age of the containing deposits (depths of 0.08-0.010 m, 0.12-0.14 m, 0.16-0.18 m, 0.20-0.22 m). The pollen grains are frequently torn or have surface afflictions.

A relation between the obtained spore-pollen, geochemical data and sedimentation rates was established. The increased sedimentation rates confined to the increased runoff periods correspond to the peaks of the quantity of pollen grains, with grains in the spectra being re-deposited and having deformation traces. Simultaneously, the content of inorganic carbon increases in these sediments. For Lake E. Mentikilir, the inorganic carbon concentration is connected with the content of calcium carbonate coming to the basin from eroded rocks of the Pronchishchev Ridge.

Organic carbon in deposits is mainly connected with the most favorable periods of vegetation development in the region. Its fluctuations correspond to variations of the curves of development of the main local types of vegetation. They are also connected to the increased sedimentation rates, when the runoff increased with melting of snow-fields and glaciers at the LIA. Sharp increases of organic carbon concentrations suggest a drift of material to the lake from the watershed basin limits as for example in Lake Bolshoye Shchuchye. Data on nitrogen indicate a changed biomass in the water body. No significant nitrogen fluctuations were revealed in sediments of the surveyed lakes. Insignificant climate deteriorations did practically not influence the life activity of the organisms. Based on geochemical data, it is established that there were no external anthropogenic impacts on the water bodies. Otherwise, significant increases of nitrogen and carbon concentrations would have been recorded.

Conclusion

As a result of the studies of bottom lacustrine sediments accumulated during the last millennium, general climatic signals for different regions of the Arctic and the Sub-Arctic were revealed (Fig. 2).

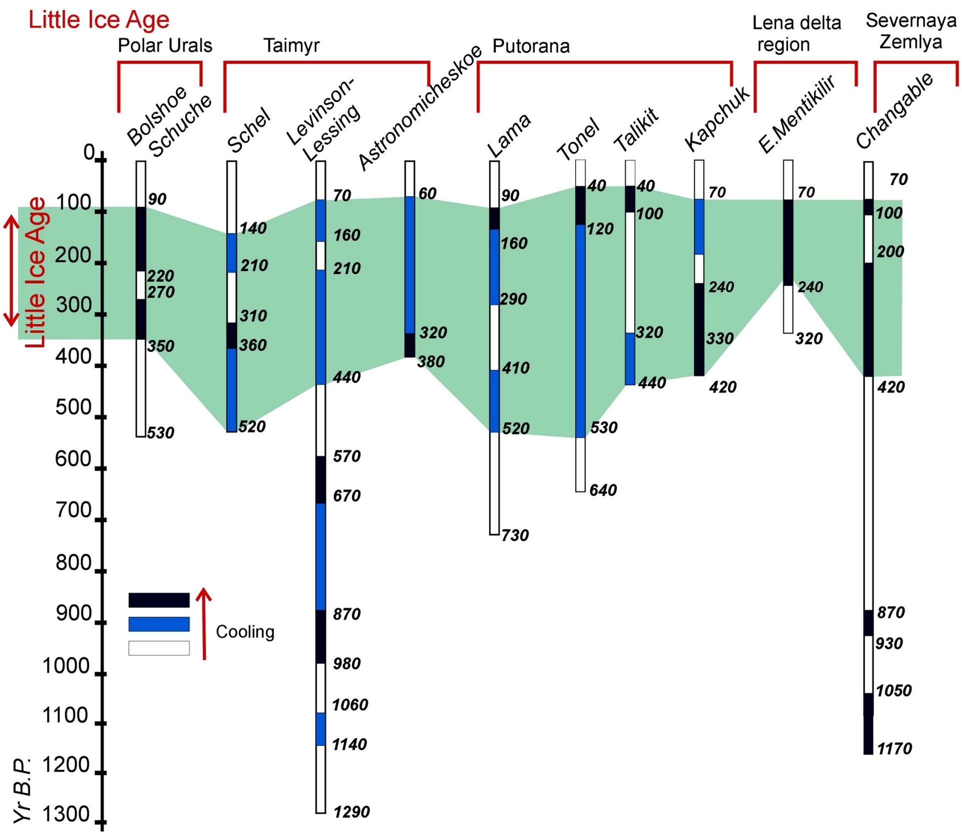

Fig. 2: Diagram of the Little Ice Age development in the regions investigated.

The white color in Fig. 2 denotes the most favorable climatic conditions for the vegetation development, i.e., the warmest conditions with moderate moistening. The blue color corresponds to cooler conditions and the black color to the coldest ones in each of the cores examined. The boundaries of cooling in the last millennium, the Little Ice Age, were determined. From 1480 onwards the LIA started to prevail in the study areas, and it terminated between 1860 and the 1930s. The time of the beginning and end of the Little Ice Age differ significantly in different arctic regions. In addition, at the time of the LIA, a warming phase is identified with a duration of 20 to 100 years. Longer cores of bottom sediments indicate that the periods of warming in the past also alternated with the periods of cooling. In the last 140-70 years, data of all cores examined indicate a warming event. Due to its manifestation before the technogenic era and the presence of cyclic cooling and warming events in the earlier time intervals of the last millennium, it can be concluded that the current warming event is of natural origin and will again be replaced by cooling in the near future. The obtained results allowed us to reveal the time frames of the LIA in the central Russian Arctic. These data are necessary for investigations related to predicting future climate conditions. As can be seen from the results, any forecast should be linked to the specific region of the Arctic, the environmental change of which is stronger, as was supposed before these studies were carried out.

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AN ASSESSMENT OF THE DISTRIBUTION AND EVOLUTION OF SUB-SEA PERMAFROST IN THE NEAR-SHORE ZONE OF THE LAPTEV SEA

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Introduction

Scientific background

The extremely dynamic transformation of ice-rich permafrost coastal systems is one of the main environmental characteristics of the Laptev Sea region. Environmental changes of the arctic coastal-shelf zone, including transformations of coasts, and onshore and offshore permafrost, are very rapid and widespread natural processes. So far there are more questions than answers concerning the problem of the existence and distribution of submarine permafrost. In fact only several relatively deep (30-80 m) boreholes have disclosed permafrost below the Laptev seabed. Most of the marine drilling profiles are located in the near-shore zone. In a number of cases there has been discovered relict continental permafrost submerged under the sea as a result of coastal retreat and sub-sea thawing. During the last transgression (17,000-6,000 yBP) the rates of eustatic sea level rise were, on average, 9 m per millennium (Kaplin, 1973). According to Are (1980) the southward movement of the shoreline covered 35-90 m/yr in the late Pleistocene/early Holocene. Besides, it is thought that thermal abrasion was intense during the Holocene climatic optimum, which lasted for 3,000 years at the final stage of the transgression, and sea level stabilized approximately 5,000 years ago. This was followed by the destruction of a 10 to 40 km wide land stripe due to coastal erosion. The relics of Pleistocene continental permafrost, submerged beneath the seabed, were frequently reached even in shallow boreholes. Submarine permafrost within the shoreface traced up to 10-15 m water depth is the most promising object of study. In this region, the dynamics of the submarine permafrost table and the parameters of major environmental factors have been studied in greater detail by drilling profiles at a number of key sites.

The dynamics of onshore permafrost and the evolution of offshore permafrost in the near-shore zone are closely connected. On the thermal abrasion coast on the shallow Laptev shelf, the submarine permafrost table is found by drilling at 5-60 m depth. Sometimes sub-sea permafrost formation was recorded on the shallows within accumulative bottom deposits. Our previous studies on coastal permafrost degradation at the Ice Complex coast showed that the sub-sea permafrost table slowly submerges from the shoreline to the deeper parts.

Goals and objectives

The main goals of the current project were:

- to collect and analyze all existing field data concerning submarine permafrost in the near-shore zone of the Laptev Sea;
- to review all data obtained from seabed drilling;
- to determine the main features and regularities of the distribution of submarine permafrost and to classify all main types of submarine permafrost within the study area;
- to characterize the basic parameters related to permafrost evolution;
- to estimate the rates of degradation of the upper layers of the near-shore permafrost in relation to the main environmental conditions.

Research activities

Approach

Our studies were focused on ice-rich s submarine permafrost, which was investigated in detail because more than 30% of the studied eroded coasts consists of the Ice Complex. According to published and to our own data, the foot of the Ice Complex very often lies below sea level (up to minus 10-20 m). When onshore ice-rich permafrost is transformed into a submarine state, its table changes very rapidly, at least initially. Therefore the studies of ice-rich permafrost are of highest priority. There are even more problems concerning submarine permafrost near the rocky, accumulative or delta coasts. It is not yet definitely known whether distinct correlations exist between permafrost table inclination and type of the coast. Based on coastal retreat rates, the timeat which a specific location was submerged can be dated. If, for example, the depth of the permafrost table at a 2-km-distance from the shoreline is determined at 15 m below sea level and the long-term coastal erosion rates are about 4 m/year, it is possible to conclude that 500 years ago this specific location was situated at the coast and that the mean trend of degradation of the sub-sea permafrost table is approximately 4 cm/year. However, it has to be noted that during the first stage of submergence the degradation of the permafrost table can be 10 times faster.

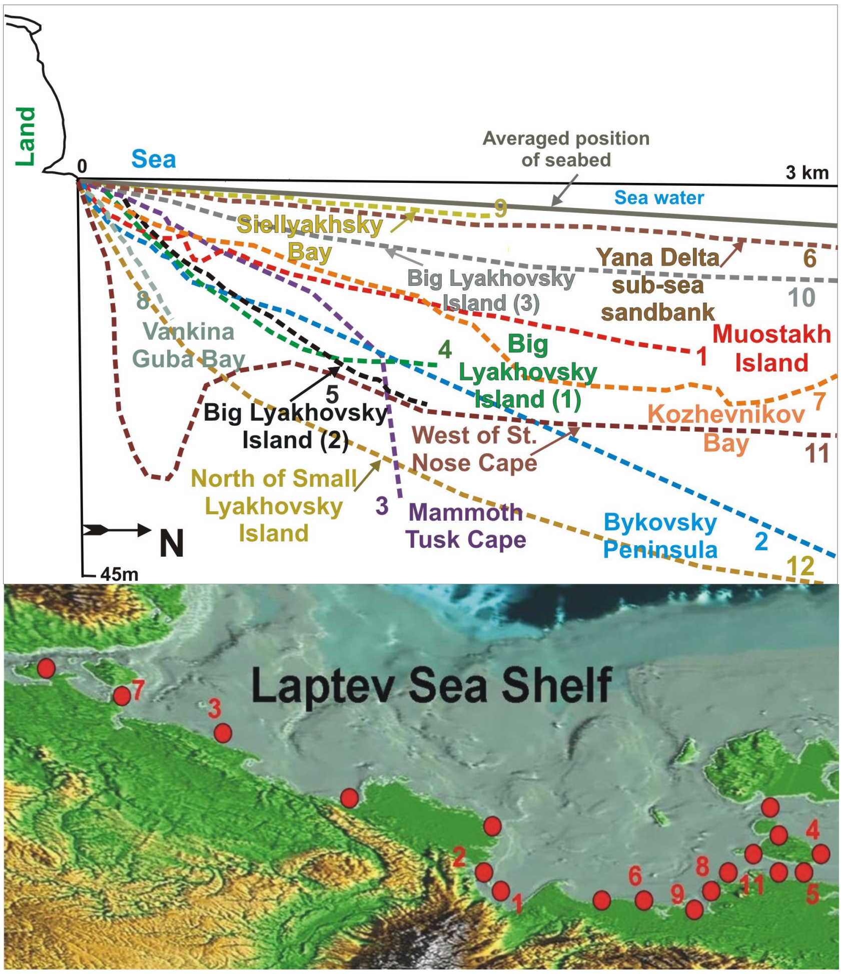

Fig. 1: Sub-sea permafrost table position at the key sites (near-shore zone of the Laptev Sea, including Dmitry Laptev Strait).

Accomplishments

Preliminary studies show that depending on the average coastal retreat rate and other environmental conditions, including sediment features, water temperature, salinity regime etc., the dominant rates of degradation of the sub-sea permafrost table during the first stage of submergence vary from 1 to 10-15 cm/year when permafrost table inclination is 0.002-0.35 (from the shore to the sea). An analysis of the sub-sea permafrost table position at the key sites of the Laptev Sea near-shore zone allows us to reveal the regularities and peculiarities in permafrost evolution. The most pronounced inclination (0.035) of the permafrost table was found in Vankina Guba Bay (profile 8) (Fig. 1). It is probably related to the slowed coastal erosion and environmental specificity in this area. The minimal permafrost table inclination (0,002-0.003) was recorded at those sites where accumulative sedimentation prevails (Yana Delta sub-sea sandbank, profile 6; Siellyakhsky Bay; profile 9). In this case submarine permafrost formation is generated within the very sallow shoreface profile. It is supposed that permafrost formation is active at the same time as the relict permafrost exists. Normally, the near-shore sites located under more or less open sea conditions are characterized by steeper permafrost table inclination (northwest of Big Lykhovsky Island, profiles 5, 7; Mammoth Tusk Cape, profile 3; Bykovsky Peninsula, profile 2). The sub-sea permafrost table located north of Maly Lyakhovsky Island (Sannikov Strait) is very steep (inclination 0.015) because the coastal retreat rate in that area is rather moderate (profile 12). It is quite difficult to explain the very complicated sub-sea permafrost table profile west of St. Nose Cape (profile 10).

Results

Our previous and present studies on coastal permafrost degradation at the coastal Ice Complex zone showed that the sub-sea permafrost table slowly submerges from the shoreline to the deeper parts. The inclination of the table depends on many factors, the main ones being coastal erosion retreat rate, water temperature and salinity. During our studies the drilling transects from Muostakh Island and Bykovsky Peninsula (Central Laptev Sea coast) providedpreliminary information about permafrost degradation at the rapidly retreating coasts. Average sub-sea permafrost table inclination at these sites is 0.007 and 0.013 (average coastal erosion rate 13 and 3 m/year), respectively (Grigoriev and Kunitsky, 2000). Some parameters of the Mammoth Tusk Cape area (Western Laptev Sea coast) are considerably different from the Central and Eastern Laptev Sea off-shore parameters. For example, water salinity at the Mammoth Tusk Cape is 3-7 times higher than that at the Central Laptev Sea coast. This fact is the reason for the peculiarity and rates of sub-sea permafrost degradation. The latitudinal drilling profile was started from the shoreline at the base of the snow-covered Ice Complex cliff. The profile consisted of 11 boreholes (depth from 1 to 32.5 m). Average erosion rate of the ice-rich coast at the selected site (the initial portion of drilling profile) is 5.8 m/year, while the general average erosion rate for the whole adjoining coastal segment is about 3-4.5 m/year. Within the initial part of the drilling profile the base of the Ice Complex was fixed at a depth of 3 m below sea level. Sand deposits encountered under the Ice Complex are traced at least up to a depth of 30 m. Drilling to 32.5 m yielded unexpected results. Despite the high erosion rate and the very low water temperature (-1.3 to -2.1°C) the inclination of the permafrost table was very steep (0.015) at the distance of 1.3 km from the shore and extremely steep (more than 0.3) between 1.3 and 1.4 km from the shore. This anomaly could be due to ancient thermokarst processes occurring under subaerial conditions. An estimation shows that the average rate of permafrost table degradation at the studied transect is about 8 cm/year or slightly more.

Conclusion

The results of the project can be summarized in the following way:

- sub-sea relict permafrost is distributed in most parts of the Laptev Sea shoreface where coastal erosion is active;
- new formation of submarine permafrost is active in the shallows surrounding the delta areas and the shallow accumulative bays, on condition that water depth is less than 2.5 m;
- average sub-sea permafrost table inclination in the near-shore zone at the key sites of the Laptev Sea is about 0.011 (0.002-0.038);
- the trend of sub-sea permafrost table degradation at the near-shore zone (for the different types of the shoreface) is about 1-20 cm/year, depending on sea water depth and the period of flooding;
- one of the main index of sub-sea permafrost table inclination for the eroded coast is the coastal retreat rate;
- evolution of the upper layers of submarine permafrost depends on a number of permanent factors: near-bottom water temperature, water salinity, coastal erosion rates (or rate of accumulation/accretion), shoreface inclination, general coastal morphology and shoreline configuration, coastal and shoreface sediment composition, ice content of deposits submerged bellow sea level, hydro-lithologic near-shore dynamics, etc.

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COMPARISON OF LATE QUATERNARY ENVIRONMENTS AT THE NORTH KARA – NORTH LAPTEV KEY SITES

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Introduction

In recent years the Laptev and Kara shelves have become the focus of intense scientific investigations, in particular of the two joint Russian-German research programs “Laptev Sea System” and “Siberian River Runoff.” The purpose of our project was to provide a correlation of paleoenvironmental features for the Kara and Laptev seas on the basis of lithological, seismic and microfauna/microflora analyses of data and cores obtained within the framework of these two bilateral programs. In order to be able to compare the conditions in the Kara and Laptev seas during the Pleistocene, we focused our research upon three well-documented key sites on the Yamal shoal, in the northern Kara Sea, and in the central Laptev Sea.

Research activities

Our overall goal was to study the paleogeographic conditions on the Kara and Laptev shelves during the Late Pleistocene and to compare these conditions. Our investigation was based on seismoacoustic profiles and data from the bottom stations. We analyzed samples from the Kara Sea Quaternary deposits by means of the modern equipment of the Otto Schmidt Laboratory as well as data on the microfauna and microflora of the Laptev Sea deposits.

For our project we used original seismic data obtained by the research group “Sonic” from VNIIOkeangeologia in the Kara Sea (2000) and in the Laptev Sea (2004). In addition we analyzed seismic data on the Kara Sea from the Marine Arctic Geological Expedition (MAGE, Murmansk) and PARASOUND data from the 1995 and 1998 “Polarstern” expeditions to the Laptev Sea. We carried out microfaunistic and spore and pollen analyses of the Quaternary deposits of cores recovered from the Laptev and Kara seas. These cores contained Late Pleistocene-Holocene marine, alluvial-marine and continental clays, aleurite clay, aleurites, aleurite pelites and sands of different grading and degree of lithification.

Echosounding records were provided as a result of the “Polarstern” expedition ARK-XI/1. As recorded in the PARASOUND profiles, well-stratified sediments were commonly cut by strong post-sedimentary reflectors at sediment depth of about 10 to 20 m (Rachor, 1997). These were interpreted as having been caused by the permafrost table and/or gas inclusions in the sediments.

Digitalized data on the facies recorded in PARASOUND profiles were collected and gridded using the Golden Software Surfer v.8.0 with the following specific parameters: 1. gridding method: Kriging; 2. node spacing: 500 m; 3. search radius parameter: 3.0 km. The kriging gridding method is described in detail and discussed by Cressie (1991) and Journel and Huijbregts (1978). Further processing of the data allowed constructing a 3D model of the distribution of the permafrost table.

For authentication of the age of the studied deposits from the Kara Sea, mollusk shells of the species *Hiatella arctica*, *Mya truncata*, *Serripes groenlandicus*, *Macoma calcarea*, *Clinocardium ciliatum*, and *Astarte elliptica* from the Holocene deposits were ^{14}C-dated in the

Laboratory of the St. Petersburg State University. Paleogeographical conditions were investigated for two key sites in the central and northern parts of the Kara Sea and for one site in the central part of the Laptev Sea.

Results

In the southern and central parts of the Kara Sea, in modern washout zones, there are exposed Late Pleistocene blue-gray clays (lm Q_{III}^4) with peat lamellas of a few tens of centimeters of thickness. This sediment was deposited in conditions of coastal swamps and marshes. The deposits are characterized by cross lamination. They contain shrub twigs and leaves. In situ marine fauna was not found in those deposits. Clays are often overconsolidated. This is due to the fact that during the Late Pleistocene the shelf was exposed as a result of regression and under the cold and dry climatic conditions the deposits were subject to dehydration and consolidation and as a result became overconsolidated to hard (Bondarev et al., 1995). Often extremely liquid aleurite pelites and pelites with numerous prolayers, pockets and lenses of sandy silts lie below the overconsolidated clays of small thickness. This fact provides evidence of a zone of degraded permafrost. This zone formed during the subsequent transgression. Such inversion sections are widespread in the southern parts of the Kara Sea (Mel'nikhov and Spesivtsev, 1995). At one of the stations in the area of overconsolidated clay ikaite was found. Ikaite is characteristic for cold-water marine basins. It can be found in the Laptev, Pechora and Kara seas. Ikaite provides a hint for the existence of free gases in the sediment. In general, the Late Pleistocene deposits of the Kara Sea are characterized by hydrosulphite inclusions. Gas-contained deposits are recorded in the seismoacoustic profiles as "bright stain" structures or zones where correlation of the seismic record is lost. These zones cross all lamellar structures and have an irregular top like the surfaces of erosional unconformities. The acoustic reflections which characterize permafrost and which can be recorded in the shallow waters of the Kara Sea are extremely similar to reflections from the gas-contained deposits. Therefore, it is very complicated to define the genetic types of the acoustic reflections. As a rule, in the seismic sections the Late Pleistocene-Holocene deposits have a thinly laminated wave structure.

The seismoacoustic profiles in the Kara Sea clearly record the end moraines of the Novaya Zemlya Archipelago glaciers that border the archipelago in a chain of submarine rises at the depth of 20-40 m. Probably, those ridges formed at the time of the last glacier maximum. The fact that the end moraines of the Late Pleistocene glaciers of Novaya Zemlya are located near the modern shoreline disputes the existent models of a large glacier sheet on Novaya Zemlya, which is said to have filled the Eastern Novaya Zemlya Trough and have reached the Saint Anna Trough (Svendsen et al., 1999).

The relict cryogenic submarine structures in the shallow-water areas at the western coast of Yamal Peninsula (Fig. 1) were found during the onshore and offshore expedition of VNIIOkeangeologia and the Moscow State University in 2001. The onshore work shows two different types of coast destruction. At the Marresale site there is a "linear" coastline recession with a rate of ~1.9 m/year whereas at the Spindler site the present "volumetric" type of destruction with a rate of ~3 m/year was determined (Leibman, 2001).

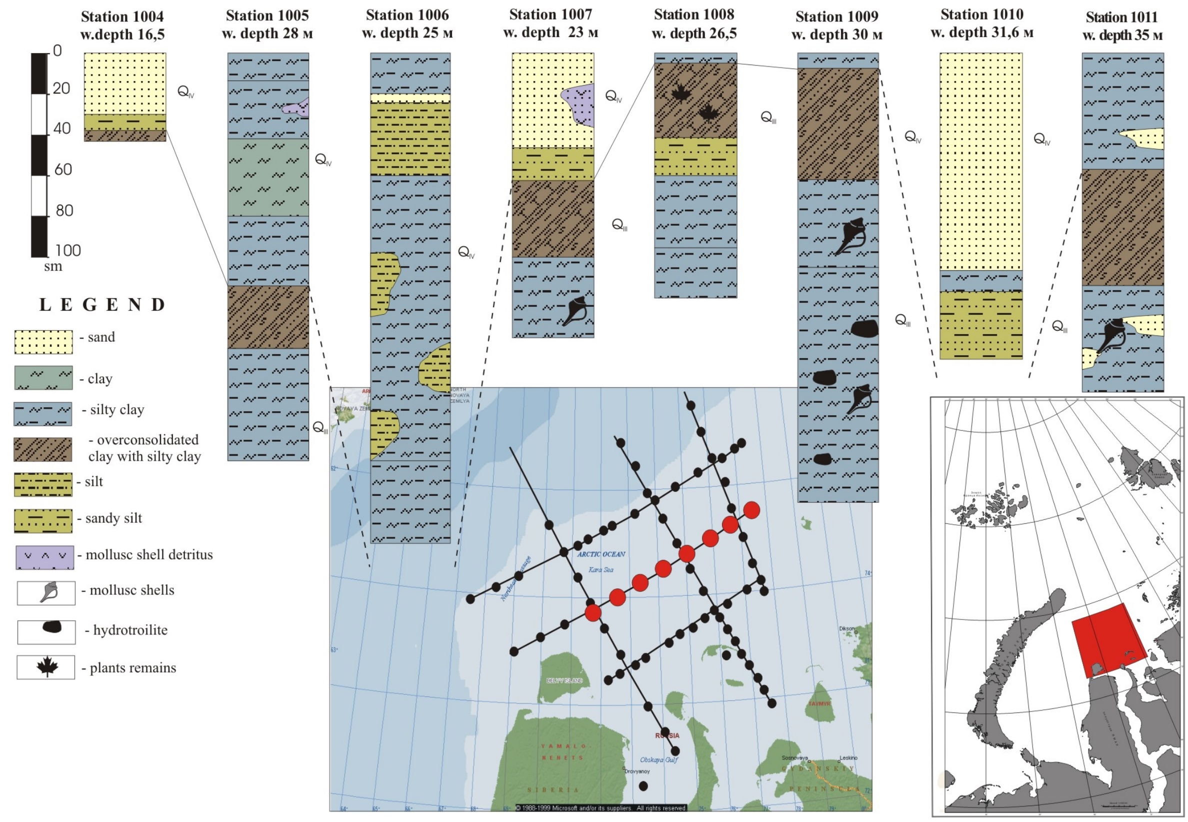

Fig. 1: Correlation scheme of geological stations from the Yamal shallow.

As a result of the high-resolution seismic profiling, two seismic units were defined. The upper unit is interpreted as melted permafrost and unfrozen Holocene sediments whereas the lower one is associated with the permafrost complex of the Late Pleistocene-Holocene. The strong reflector dividing the two units is interpreted as the permafrost table (Fig. 2).

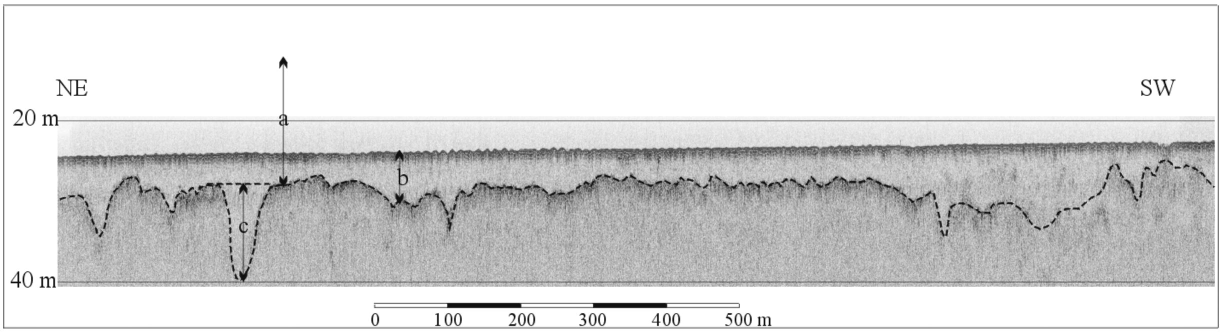

Fig. 2: Example of acoustic representation of the permafrost table at the western coast of Yamal Peninsula.

Our analysis of Kara Sea seismoacoustic data suggests that there is no permafrost here. Usually the seismoacoustic sequence reflected stratified sediments with gas inclusions.

The Laptev Sea shallow water area is one of the marine key sites for which submarine permafrost was predicted and subsequently found by both seismic investigations and drilling. There is evidence that during the times of the Pleistocene sea-level lowstand, water drainage via the rivers heading north toward the Arctic Ocean continued across the exposed Laptev shelf (Kleiber and Niessen, 1999). This may have prevented permafrost formation under the river beds. This area is a key location for understanding permafrost evolution and its rate and variability under different climatic conditions. The main parameters of submarine permafrost, however, are still known insufficiently.

Based on the internal reflection pattern, continuity and geometry three main seismic facies were identified within the sediment cover from the PARASOUND profile of August 14, 1998 (7:50-8:40 UTM) recorded during the TRANSDRIFT V expedition (Fig. 3). Facies 1 (F1, upper) is characterized by a flat sediment surface and by weakly to randomly stratified sediments of thicknesses of up to 15 m. The most prevalent thickness of F1 is 2-8 m. Within this facies several consecutive lithological and/or stratigraphical sequences can be determined. The upper part of the sediment sequence shows a weakly stratified to random reflection pattern. The lower stratum is more strongly stratified. There are lens-shaped and wedge-shaped sediment bodies. F1 dominates in a large area relatively close to the present Lena Delta. Generally, it does not exist on the slopes of the topographic elevations. F1 is based on two seismic boundaries, which show specific seismic patterns. The first pattern is represented by a strong seismic reflector with a frequently hummocky relief. The second pattern is represented by specific fuzzy seismic reflection showing a tooth-shaped pattern or small-scale spikes protruding into the overlying unit.

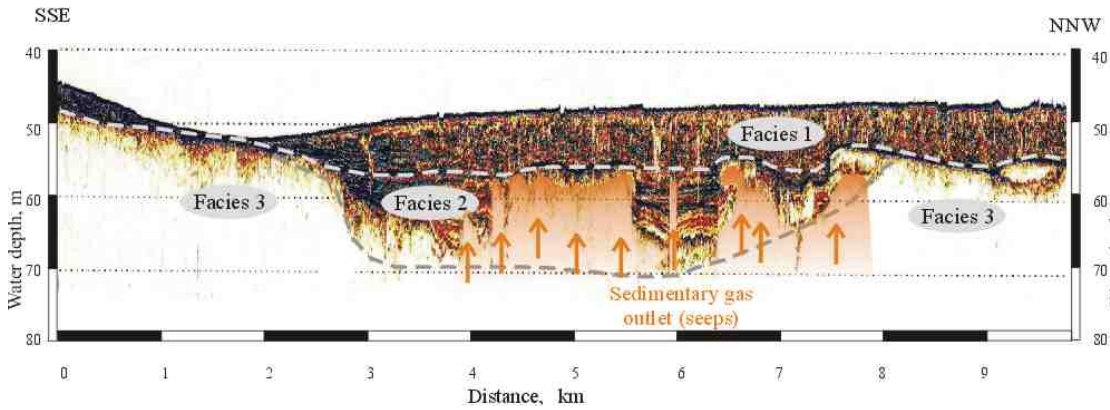

Fig. 3: Fragment of PARASOUND profile of August 14, 1998 (7:50-8:40 UTM).

Facies 2 (F2) is acoustically dominated by well-stratified sediments distributed within sharp U and V-shaped pockets alternating with hummocks. At some places the pocket shape has been modified by the influence of sedimentary gas seeps. The pockets are usually ca. 1 km wide and 10-20 m deep. The lateral transition between pockets and hummocks is very sharp. Some similar reflectors are traced within the nearby pockets at the same sediment depth. Moreover very often some nearby pockets have a rather similar reflector pattern and similar signal amplitudes. This can be explained as being the result of sediment accumulation within isolated basins with similar hydrological conditions.

Facies 3 (F3) is represented by acoustic transparent sediments. Its upper boundary is characterized by a reflector of extremely high amplitude and of distinct hummocky relief. This reflector prevents the seismic signal from penetrating the sediment strata. Very often the hummocks alternate with pockets filled with stratified F2 sediments. F3 is characterized by the presence of a widely distributed acoustic void beneath the upper reflector and the lack of any reflectors there. It dominates in most of the area, but not in such areas where penetration is up to 20 m and more. This facies was correlated with the permafrost table.

The fact that the seismic data on the permafrost table at the western coast of Yamal Peninsula (see Fig. 2) reflect two separable seismic units as well as processing the data of the PARASOUND profiles allowed us to create a 3D model of the modern position of the permafrost table (Fig. 4). It shows several depressions in the relief of the permafrost table up to 2 km in width. The edges of these depressions are very steep with a relative height of up to 10-15 m. The greater part of these structures is covered by modern sediments and does not show in the modern relief.

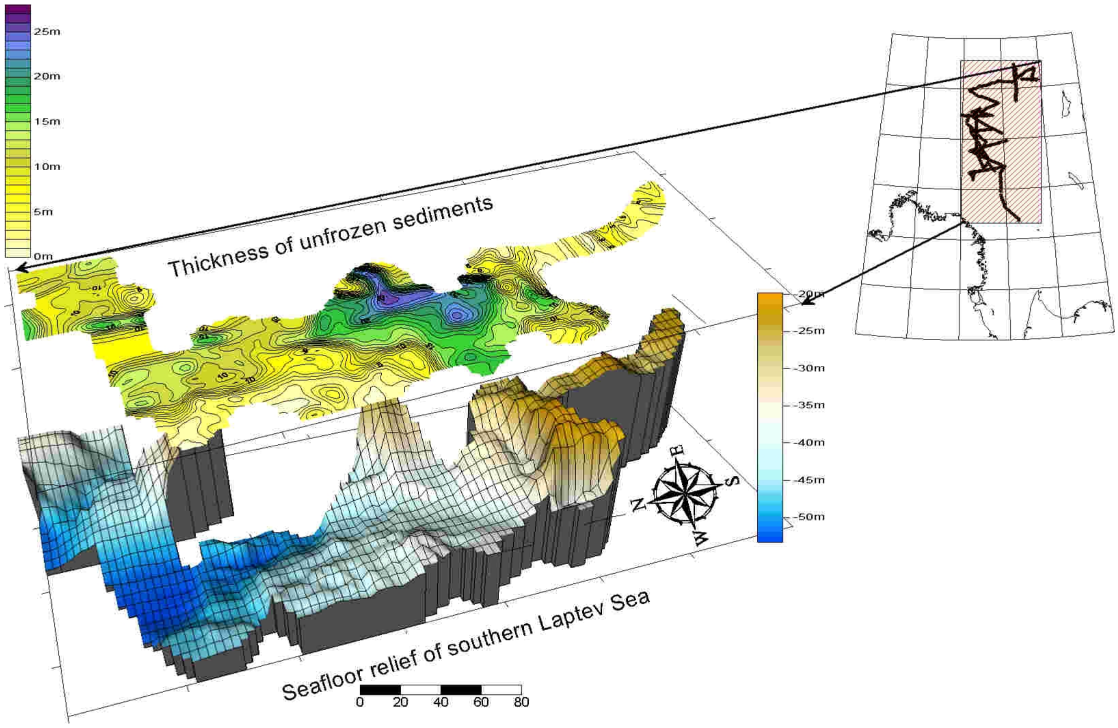

Fig. 4: The distribution of the permafrost table in the southern Laptev Sea.

The analysis of seismoacoustic profiles from the Kara and Laptev shelves has shown the similarity of the seismic facies of the top complexes. On both shelves nonlaminar or not clearly layered seismofacies are found, which characterizes the Holocene deposits of the Arctic seas. At water depths from 0 up to 50 m, furrows caused by icebergs and pack ice cover the seafloor. This structure is found practically everywhere. Usually it occurs on a rough surface of the underlying complex characterized by structures usually interpreted as being the result of permafrost processes. This complex bears traces of various scale deformations, and has a strongly marked layered structure. The structure of this complex in the Kara Sea differs from the structure in the Laptev Sea. In the Kara Sea acoustically transparent facies, corresponding to permafrost, are not particularly common. In the Laptev Sea those seismofacies are more widespread and occur closer to the seafloor. In the coastal areas of the Laptev Sea as, for example, the Lena Delta, the permafrost top has a complex outline and repeats the pattern of the modern drainage system of the coast with its rivers and numerous lakes. On the Kara shelf the acoustically transparent facies are only widespread along the Yamal Peninsula coast. 20 km from the coast they are replaced by a mostly layered sequence.

For the Laptev shelf, the upper 10-12 m of the Quaternary sequence were studied. This part is characterized by mainly clay components and marine sedimentation conditions. Deposits contain mollusk shells, foraminifers, spores and pollen, which are characteristic for the Late Pleistocene time. Within the framework of this project, the sediment, microflora and microfauna from samples recovered from the Kara Sea were studied. The Kara sequence can be subdivided into marine Holocene deposits and Late Pleistocene overconsolidated clay of continental origin. Analyses have shown that the Holocene period of the Kara Sea does practically not differ from that of the Laptev Sea. Holocene deposits of the Kara and Laptev seas are of similar lithology and microfauna and microflora complexes. With respect to the Late Pleistocene deposits, the situation is a completely different one. On the Laptev shelf these sediments are characterized by transitional facies between marine and continental conditions. On the Kara shelf the continental origin of these sediments is clearly shown. They are represented by blue-gray clay with interlayers of peat. These sediments were deposited in conditions of coastal swamps and marshes, and are characterized by cross lamination, presence of shrub twigs and leaves, and also absence of in situ marine fauna. Foraminifers are completely absent but a rich spore-pollen spectrum is found.

Therefore, in spite of the similarity of the Holocene conditions in the Kara and Laptev areas, it is possible to speak about the paleogeographical distinctions during the Late Pleistocene.

Conclusion

By the end of the Sartanian regression in the first key area (the central part of the Kara Sea) the polygenetic cryolithic zone had formed. The thickness of this zone can reach 400 m. With the beginning of the Holocene transgression the permafrost started to degradate and, most likely, was covered by marine deposits. Such deposits contain salty water and, therefore, their freezing point is lower. Thus, the existing cold sediment temperatures were insufficient for re-freezing the marine deposits from below.

The second key area (the northern part of the Kara Sea) is nowadays characterized by the fact that frozen deposits do practically not exist within the sequence covered by the seismoacoustic profile. The sediments prone to being frozen here do not exceed 5-8 meters and lie directly on the bedrock. Thus, the Sartanian regression here led to the re-freezing of the lithified and already dehydrated ancient sediments, but did not penetrate deeper into the deposits. Partially permafrost was eroded in zones of elevations. The remaining part of slightly re-frozen deposits was warmed soon after the onset of the Holocene transgression.

In the third key area (the central part of Laptev Sea) degradation of the cryolithic zone took place under different conditions. Until the beginning of the transgression this area was characterized by widespread development of thermokarst pits and lakes. By the time the area became submerged, the lake basins most likely had been completely filled with sediment. Thus, freshwater lake deposits were formed on the permafrost surface in the thermoabrasion basins. During the sea-level rise these, in turn, were covered by marine deposits and, therefore, were isolated from the thermal impact of the sea. After that, inside the mass of lake sediments the freshwater deposits were probably repeatedly re-frozen from below. The acoustically transparent zones at the slopes of the thermokarst pits are likely to testify to these processes.

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ASSESSMENT OF CONTRIBUTION OF ZOOPLANKTON TO VERTICAL CARBON FLUXES IN THE KARA AND WHITE SEAS FROM EXPERIMENTAL DATA AND SEDIMENT TRAP COLLECTIONS

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Introduction

<u>Scientific background</u>

Zooplankton organisms are active agents, consuming organic matter produced in the pelagic zone through photosynthetic activity by phytoplankton. Therefore, zooplankton strongly modifies the vertical carbon flux in the sea. On the one hand, zooplankton significantly reduces the amount of settling organic matter by grazing on phytoplankton. On the other hand, it contributes to the flux by the faecal pellet material.

The faecal pellets of zooplankton are important components of settling matter and principal conveyors in the vertical flux of particulate and dissolved material (Fowler and Knauer, 1986). Settling of fecal pellets is followed by multiple processes, such as re-ingestion or break-down by producers (Lampitt et al., 1990), microbial degradation and release of particulate and dissolved matter into the water column. As life at the seafloor mainly depends on the input of organic material from the euphotic zone (Grahl et al., 1999), vertical transport of pellets and processes of transformation of their organic content are of great importance for the bottom inhabitants.

In the polar seas, pellet production is largely restricted to the summer season when phytoplankton is available and zooplankton organisms are feeding actively. In other words, contribution of zooplankton to vertical flux has a pronounced seasonal pattern (Hargrave et al., 1994; Gaye-Haake et al., 2002). Unfortunately, seasonal variations of this contribution remain poorly studied due to the restricted accessibility of the Arctic seas during most of the year and especially in winter. Consequently, the linkage between biological and biogeochemical processes and contribution of the pelagic inhabitants to the sedimentation also remains largely unknown.

<u>Goals and objectives</u>

The major goal of our project was to improve our understanding of the role of zooplankton in transforming particulate organic matter in the water column and to assess the contribution of the zooplankton pellet material to the vertical carbon fluxes in the Kara and White seas. The study concentrated on investigating qualitative and quantitative parameters of zooplankton feeding and faecal pellet production, examining and enumerating pellets in the seston samples, and assessing pellet contribution from the available data on zooplankton distribution. Special attention was paid to investigating seasonal and regional variations of the contribution of the pellet material to carbon fluxes in the pelagic ecosystems of the Arctic seas.

Research activities

Scientific approach

The Kara and White seas are inhabited by zooplankton fauna of low diversity. In both seas, a few zooplankton species contribute up to 95% of the zooplankton biomass and abundance and, therefore, hold a key position in the pelagic food web (Pertzova, 1980; Pertzova and Prygunkova, 1995; Pertsova and Kosobokova, 2003; Vinogradov et al., 1994; Fetzer et al., 2002). As the composition of the key species in the both seas is quite similar, our major approach was to use results of the experimental studies conducted in the White Sea for assessing the pellet contribution in the Kara Sea, where it was hard to carry out experimental studies. To obtain the parameters required for this assessment, rates of pellet production and pellet sinking rates were measured in field experiments in the White Sea. Additionally, distribution of pellet material within the water column was studied. The grazing impact of carnivorous zooplankton on copepods and other plankters was assessed from experimental observations on feeding of the zooplankton predators. The structure of zooplankton communities was studied in the Kara and White seas in order to use abundance and distribution data for assessing the potential pellet production. Finally, the White Sea pelagic ecosystem was used as a model "Arctic Sea" to assess the possible range and pattern of seasonal variations of the zooplankton faecal pellet production.

Accomplishments

Within the framework of the project we carried out experimental studies on feeding and faecal pellet production of the "key" zooplankton organisms in the White Sea. We described the morphology of their faecal pellets (size, shape, and color) in order to be able to identify pellets in the water column and in the sediment trap collections. We established relationships between pellet length/volume and body length (BL) of the organisms. We obtained data on pellet dry weight (DW), organic carbon (C_{org}) and nitrogen (N) content, C/N ration, and established relationships between DW, pellet volume (PV) and pellet carbon content. The pellet production time (gut evacuation rate, GER) was measured for the most abundant zooplankton organisms in the coastal waters of the White Sea. Pellets of 70-80 μm length were used to measure pellet sinking rates. The predators' grazing impact on the zooplankton community was assessed from daily ratios of carnivorous zooplankton. Carbon content of carnivorous zooplanters (hydromedusas) was measured with the C/N analyzer VARIO EL III in the analytical laboratory of the Otto Schmidt Laboratory. Zooplankton community structure was studied in terms of species diversity, abundance, and biomass from data collected in the White and Kara seas during several expeditions between 1998 and 2003.

Based on the zooplankton community structure data, pellet production rates, and pellet carbon content, we calculated potential pellet carbon input into the coastal waters and open deep areas of the White Sea during different seasons. We showed that it varies seasonally within two orders of magnitude and depends strongly on the zooplankton composition. Similar calculations were made for the different areas of the Kara Sea for the summer period.

The research was in good accordance with the working program and it was possible to fulfill almost all tasks of the project. Initially, in addition to the work described above we intended to compare our assessments with the data on pellet content in the sediment traps. Sorting of the sediment trap samples had been started, but due to just a partial (50%) financial support of our project, we were forced to restrict our initial tasks and to postpone the comparison of the experimental and field data to the next stage of work on the project.

Results

Our results indicate that the faecal pellets of different zooplankton organisms differ in size and shape and even their color depends strongly on the food consumed by zooplankters. The pellet size correlates positively with the individual plankter's body size. Together with pellet shape their size may be used to attribute pellets to a particular producer. However, small organisms of the same taxonomic group with the same body size (e.g. copepods) produce quite similar types and size classes of pellets. When different organisms of similar size dominate, the pellet size seems to be hardly a useful parameter for identification of the pellet origin. The pellet sinking rates of 2.5 m/hour or 60 m/day measured during this study showed that the pellet material could reach the bottom within one day in well mixed areas of the White and Kara seas with 50-80 m depth. The microbial destruction seems to hardly take place during such a short sinking time due to the low temperature in both these seas. In the stratified areas, however, sinking rates could be somewhat different. Consequently, the pellet destruction and degradation in such areas requires further investigation.

Herbivorous and omnivorous zooplankters experience grazing pressure from the plankton predators (chaetognaths, medusas and ctenophores), which reduce their abundance and their potential pellet production. During spring season the hydromedusas' impact on other zooplankton organisms was at maximum and reached 8 to 10% of the total prey abundance per month.

Based on community structure data, experimentally obtained pellet production rates, and pellet carbon content, we calculated potential pellet carbon fluxes for the different regions and seasons in the White Sea. In the shallow coastal zone, where small boreal copepods dominated, the pellet flux varied within a wide range (Fig. 1). It was lowest at the beginning of June when abundance of boreal copepods was low, and reached its maximum of 13.7 mg C_{org}/m^2day by the end of August when their abundance was highest (Fig. 1).

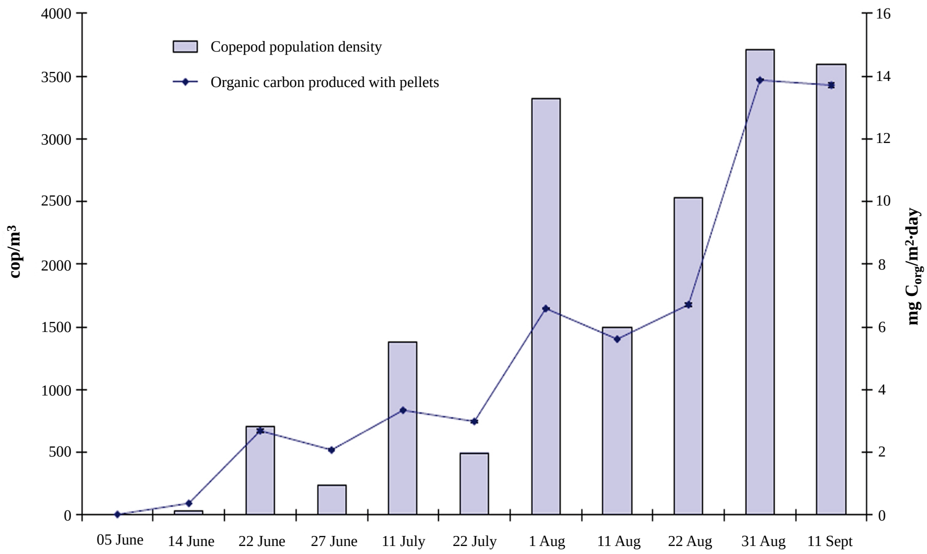

Fig. 1: Seasonal variations of daily pellet carbon flux (C_{org}/m^2 24h) and abundance of boreal copepod species (cop/m^3) in the coastal zone of the White Sea (0-10 m water layer).

In the open deep sea regions where the large herbivorous copepods *Calanus glacialis* and *Pseudocalanus minutus* and the omnivore *Metridia longa* dominate, the seasonal variations of pellet carbon flux were even more pronounced.

We made assessments for early spring, summer and late fall for the upper 0-50 m water layer taking into consideration the grazing impact of predators and assuming that food was not a limiting factor. In the spring, when the population of predominantly herbivorous *Calanus glacialis* was especially abundant near the surface and fed there on phytoplankton, the estimated daily pellet flux reached 98 mg C_{org}/m^2 (Fig. 2). At the sinking rates reported by Arashkevich and Sergeeva (1991) this material could reach the bottom within two days.

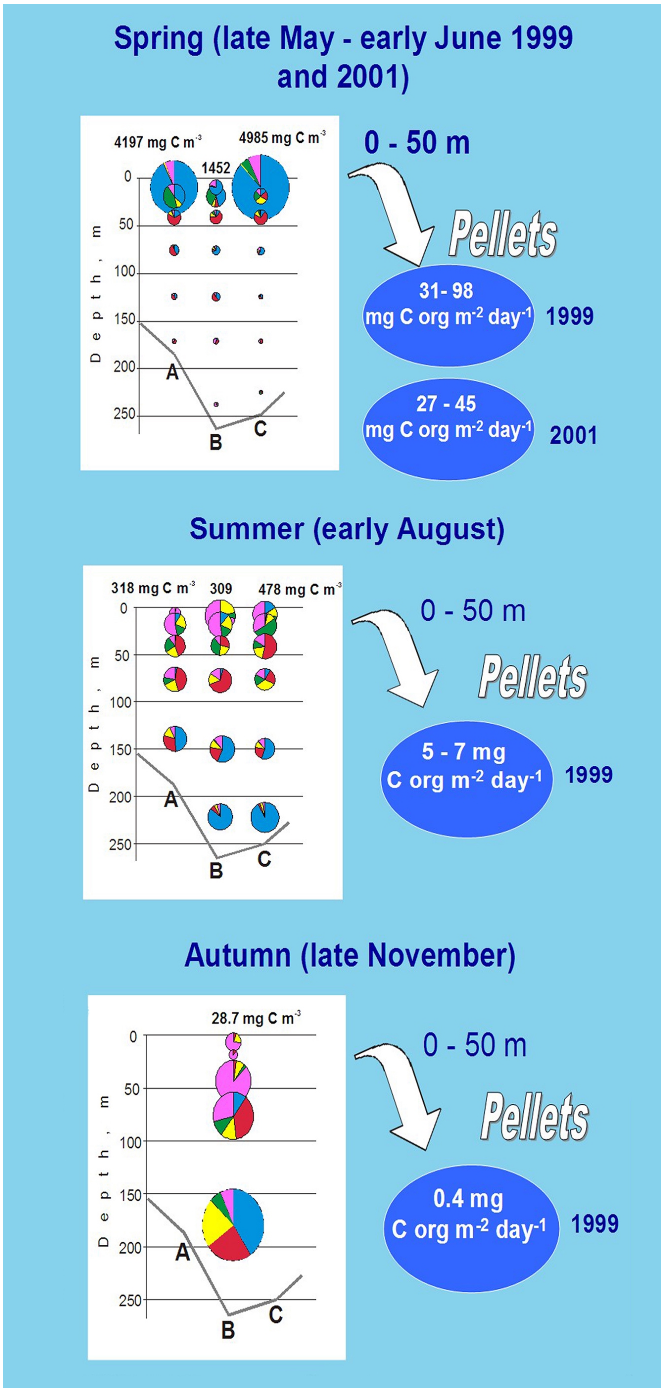

Fig. 2: Deep stations A, B, C in the Kandalaksha Bay of the White Sea. Vertical distribution of zooplankton biomass (left) and daily pellet carbon flux (C_{org}/m^2 day) from the 0-50 m water layer in spring, summer, and fall. Blue: *Calanus glacialis*, yellow: *Pseudocalanus minutus*, red: *Metridia longa*. Broken line: bottom profile.

In mid-summer, when the large *Calanus glacialis* descended from the upper layers (Fig. 2) and was replaced by smaller copepods *P. minutus* and *M. longa*, the flux decreased by one order of magnitude to 5-7 C_{org}/m^2 day (Fig. 2).

In fall, the feeding activity of planktic herbivores decreased significantly, they descended into the deep water layers (Fig. 2c) and, therefore, the pellet flux in the upper 50-m-layer hardly reached 0.4 mg C_{org}/m^2 day (Fig. 2).

Table 1. Daily faecal pellet production (mg C_{org}/m^2 day) and relative abundance (% of total abundance, in brackets) of zooplankton in different Kara Sea areas.

Region	Southern Sea		Central Sea
	Freshwater influenced area, including river mouths, 7-40 m depth		East of Yamal Peninsula, 60-80 m depth
Expedition, year	BP-1997	BP 1999	MMBI- 2000
Calanus glacialis	9.6 (1.4)	3.5 (2.3)	112.1 (5.1)
Drepanopus bungei	24.1 (58.7)	8.7 (44.7)	9.7 (2.6)
Limnocalanus macrurus	< 0.1	83.0 (10.6)	< 0.1
Metridia longa	< 0.1	< 0.1	< 0.1 (0.3)
Pseudocalanus acuspes/minutus	0.34 (7.1)	0.03 (3.5)	3.0 (11.4)
P. major	0.2 (3.5)	0.17 (12.6)	< 0.1 (0.5)
Total fecal pellet carbon, mg C_{org}/m^2 day	34.9	95.6	124.8

Similar calculations were carried out for the summer period for several regions of the Kara Sea with different hydrolophysical regime. In the estuarine zone, faecal pellet flux varied from 35 to 96 mg C_{org}/m^2 day (Table). It was mostly formed by pellets of brackish-water omnivorous copepods. In the central sea with the typical marine community, the flux value reached 125 mg C_{org}/m^2 day. As in the open White Sea, the major pellet producers were the herbivorous copepods *C. glacialis* and *P. minutus*.

Conclusion

Our results indicate that zooplankton organisms significantly modify particulate matter settling within the water column. They assimilate just a part of the organic matter obtained with food and, therefore, their faecal pellets contain less organic carbon and nitrogen than the consumed food or pure phytoplankton. According to our measurements, pellets of omnivorous copepods contained only 50% of the organic carbon compared to the carbon content of seston, and only 10% of Chlorophyll *a*, compared to its content in phytoplankton. The low nitrogen content of pellets resulted in a 20% higher C:N ratio of pellets compared to natural seston.

Our results clearly show that pellet production has a pronounced seasonal pattern. In the open and deep regions of the White Sea with predominance of large arctic herbivorous copepods, maximum pellet carbon flux was observed in spring when these copepods fed near the surface and consumed the spring phytoplankton bloom. In summer and fall the pellet carbon flux decreased dramatically (by 1-2 orders of magnitude) due to vertical migration of large copepods to the overwintering depths. In contrast to this, in the shallow coastal regions the pellet production reached its maximum in late summer and fall when the major producers of pellets, small boreal copepods, reached their highest abundance in the water column.

Our assessment of the potential zooplankton pellet carbon showed that zooplankton may contribute up to 30% to the total carbon flux during particular seasons in the White and Kara seas. These results are in good agreement with other studies in this region based on investigations of sediment trap collections (Gaye-Haake et al., 2002). The results of our assessment show that it is essential to have detailed information on the plankton community structure and the zooplankton pellet production in order to obtain reasonable estimates of the zooplankton contribution to the carbon fluxes in the sea.

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UNIQUE (NON-ANALOGUE) PALEOENVIRONMENTAL CONDITIONS OF LATE PLEISTOCENE AND HOLOCENE TERRESTRIAL ECOSYSTEMS OF THE LAPTEV SEA SURROUNDINGS (DETAILED RECONSTRUCTION)

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Introduction

Recent multidisciplinary studies of the permafrost deposits in Northern Yakutia have greatly improved our knowledge about the Late Pleistocene environmental history of this region (Kassens et al., 1999; Schirrmeister et al., 2002; Kuznetsova et al., 2003 and others). These studies were carried out within the framework of the Russian-German project “Laptev Sea System” (Kassens et al., 1999; Rachold and Grigoriev, 1999, 2000, 2001; Pfeiffer and Grigoriev 2002). The shallow shelf seas in the East Siberian Arctic are of very recent origin. They have existed for only a few thousand years, since the early Holocene, when the dramatic rise of global sea level resulted in the fast inundation of the flat shelf. Thus in the Late Pleistocene the East Siberian Arctic shelf extended 400-700 km north, up to about 78°N, and incorporated all the present-day islands (Sher et al., 2003).

The role of the Laptev Sea system in the modern Arctic climate and environment is extremely important, and is therefore the subject of extensive current studies. Understanding this environment is only possible through interdisciplinary studies of corresponding terrestrial deposits of the shelf.

The terrestrial Pleistocene deposits of the shelf contain various fossils as indicators of the past environment (Schirrmeister et al., 2002; Andreev et al., 2004). The study of these evidences, supplemented with dating methods, provides an incomparable archive of the past life and the Pleistocene environmental conditions. Modern methods of analysis of stable isotope ratios of collagen for fossil mammal bones and hair allow reconstructing the environmental conditions in detail (Karhu et al., 2000 and others).

Scientific background

Within the framework of the Russian-German LENA expeditions (1998-2003), carried out under the umbrella of the “System Laptev Sea” project, we investigated Late Pleistocene and Holocene deposits of the continental coasts of the Laptev Sea and New Siberian Islands (Rachold and Grigoriev, 1999, 2000, 2001). One of the interesting facts about the past life on the Laptev Sea shelf is the abundance of fossil mammal bones, found on the coastal lowlands and the shelf. More than 4000 fossil mammal bones have been collected in the Lena Delta region, on the New Siberian Islands, Oyogos Lowland, Muostakh Island and in the Anabar-Olenek region (Kuznetsova et al., 1999a, 1999b, 2000; Kuznetsova and Kuzmina, 2000, 2001, 2002; Kuzmina et al., 1999, Sher et al., 1999, Schirrmeister et al., 2002).

The principal investigator of this project participated in the Otto Schmidt Laboratory (OSL) Fellowship Programs 2000 and 2001 and closely cooperated with colleagues from other OSL projects. Two databases (LAPPAL) were created through this cooperation, the database of fossil mammals from the Laptev Sea area and the database of radiocarbon dating of mammals from the Laptev Sea area (Sher et al., 2000).

As a results of these studies it was possible to determine four “mammoth” periods (Kuznetsova et al., 2003). The first period (ca. 50 ka BP to 35-34 ka BP) corresponds to the

Middle Weichselian (Early Karginian) Interstadial. It was the beginning of climatic warming, drainage of lakes and active development of ice complex formation on Taimyr Peninsula. Pollen data from southern Taimyr indicate the presence of open *Larix* forest with *Betula nana* and *Alnus fruticosa.* Pollen-based climate reconstruction shows that it was a rather warm and wet period with temperatures by 0.5-1.5°C warmer and precipitation by 25-75 mm higher than today. In contrast to this, pollen data from the Laptev Sea coast (Bykovsky Peninsula and Bol'shoy Lyakhovsky Island) indicate treeless vegetation and a rather cold and dry climate (Andreev et al., 2002a, 2002b).

The second "mammoth" period (33 ka BP to 23-22 ka BP) is correlated with the Late Karginian interval reflected in pollen records from northern Taimyr and the Laptev Sea coast. According to pollen spectra, open steppe-like herb communities dominated the vegetation. Environmental conditions were rather severe (with temperatures by 2-5°C colder and precipitation by 50-100 mm lower than today) (Andreev et al., 2002a).

The period of the most unfavourable environmental conditions was probably between 22 ka BP and 15 ka BP, as for this time only a few dates from woolly mammoth bones were obtained (Kuznetsova et al., 2001, 2003). It is interpreted as an extremely cold and dry period during the Late Pleistocene. The lack of mammoth dates for this period does not indicate the total absence of mammoths in the Laptev Sea region but rather reflects a relative decrease in their numbers.

The last "mammoth" period was from 15 ka BP to 9 ka BP with a maximum number of dates around 11-10 ka BP. The 11.5-10 ka BP interval is characterized by a rapid increase of warm and wet elements in pollen spectra. This can be interpreted as reflecting an amelioration of climatic conditions (Andreev et al., 2002a, 2002b). The reconstructed temperatures were by 1.5° warmer and precipitation was by ca. 25 mm higher than today. It is also the period with the largest number of woolly mammoth dates during the Late Pleistocene. This may indicate that it was the period with the most favorable environmental conditions for the mammoths (Kuznetsova and Kuzmina, 2002; Kuznetsova et al., 2003).

Goals and objectives

The main goals of the project are detailed elaboration and verification of the reconstructed basic features of the environment and climate of the Laptev Sea shelf area and coastal lowlands during the Late Pleistocene and Holocene. It is based on complex analyses of mammal distribution and diatom assemblages combined with geochronological and stable isotopic data. Our main objectives were:

- taxonomical and morphological studies of new paleontological material that was collected during the expedition "Lena-Anabar 2003." All bones were found *in situ,* and the most interesting bones were radiocarbon-dated;
- analysis of the spatial changes in composition of mammal assemblages during the "mammoth" periods. Study of diatom assemblages in terrestrial deposits, that were formed during these periods;
- analysis of the carbon and nitrogen isotope rations ($\delta^{13}C$ and $\delta^{15}N$) of the recent and Late Pleistocene forage plants from the Lena Delta region and Bol'shoy Lyakhovsky Island (New Siberian Islands). Interpretation of oxygen isotope data on collagen of fossil bones of grazing mammals using the data on the carbon isotope ratio in forage plants;
- reconstruction of vegetation and composition of the grazing animal populations and their changes on the Laptev Sea shelf during the Late Pleistocene and Holocene. Analysis and comparison of the factors which influence the distribution of different animal species;

- compilation and synthesis of all received paleoecological information. Reconstruction of temperature variations during the Late Pleistocene and Holocene. Detailed micro-paleontological and paleoenvironmental study of the most interesting periods.

Research activities

Approach

The main part of the material was collected during the Russian-German LENA expeditions (1998-2003) with the help of all team members. For achieving our objectives we used the following material:

- unique collections of about 4,000 mammal bones from the Lena Delta region (Bykovsky Peninsula, Olenyek Channel), the New Siberian Islands (Bol’shoy Lyakhovsky, Maly Lyakhovsky, Kotel’ny, Stolbovoy, Bel’kovsky, New Siberia), Oyogos Lowland, Muostakh Island and the Olenek-Anabar region, including the material (about 400 samples) collected by T. Kuznetsova during the expedition “Lena-Anabar 2003.” The collecting was carried out rather thoroughly: all of the found identifiable fragments were registered in order to obtain complete statistics of the species composition;
- previous paleontological collections from the Laptev Sea region from 1886 (collection of A. Bunge and E. Toll) to 1995 (collection of L. Sulerzhitsky). We revised all samples according to modern paleontological knowledge;
- for diatom analyses we be used our own materials (more than 70 samples) from the Lena Delta region, Bol’shoy Lyakhovsky Island, the Yana Delta region and published data;
- we also used all material and results which were established of previous OSL projects.

Our tasks were carried out in close cooperation with the participants of the Russian-German project “Laptev Sea System” and various OSL projects (e.g., H.-W. Hubberten, C. Siegert, L Schirrmeister, A. Andreev, Th. Tuetken from Germany; N. Romanovsky, L. Sulerzhitsky, V. Tumskoy, S. Kuzmina, E. Taldenkova, V. Nikolaev from Russia).

Our fundamental methodological approach consisted in the postulate that there are no complete analogues of the Pleistocene terrestrial communities of the Siberian Arctic in modern biota. The abundance of grazing herbivores in high latitudes invites the assumption of some pasture ecosystems, essentially different from modern tundra, in fact, a non-analogue environment. The study of fossil remains of mammals provides information about the past life and important proxy evidence for the reconstruction of past climate conditions. Combined with the traditional paleobotanical analysis and with a complex of sedimentological research, it forms the basis for the most complete reconstruction of the past environment.

The project was carried out applying the following methods:

- morphological study and taxonomical determination of each sample of fossil animals (approximately 15 taxa of mammals);
- radiocarbon dating of bone collagen (^{14}C);
- determination of stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) of plants and fossil bone collagen;
- analysis and comparison of the factors which influence the distribution of different animal species in the Late Pleistocene and Holocene;
- taxonomical determination and analysis of fossil diatom assemblages from the Late Pleistocene and Holocene terrestrial deposits;
- detailed micro-paleontological study of sediments of two periods: 22 ka BP to 15 ka BP and 15 ka BP to 9 ka BP from different regions of the Laptev Sea surroundings.

Our main method was the multidisciplinary paleoecological analysis, in which various kinds of paleoecological information are to be summarized by a strictly defined stratigraphic and chronological control.

<u>Accomplishments</u>

During the joint Russian-German expedition “Lena-Anabar 2003“ almost 500 samples of bones and their fragments have been collected. These samples are the first paleontological material from this region which has been professionally collected. All of the found identifiable fragments were registered, in order to obtain statistics as complete as possible of the species composition. The study of the morphology of different skeleton parts provides us with the possibility to reconstruct the exterior of animals. The study of each species has its own traditional methods. The reconstruction of an animal population is possible by taxonomical analysis of all the fossil material. The facilities of the OSL computer laboratory were used for creating a collection database and digital photos of bones. It will be published in a volume on the “Lena-Anabar 2003” expedition in Reports on Polar and Marine Research.

All bones were found *in situ* and the most interesting bones were radiocarbon-dated. Radiocarbon dating of bones found *in situ* yields the time of deposition and sometimes allows us to correct the AMS-dating of plants. In other cases, where bones had been found on the shore, we determinated only the age of the bones. Radiocarbon dating of these bones makes it possible to trace changes in the composition of the animal populations of the study area during the Late Pleistocene and Holocene. The dating was done in cooperation with L. Sulerzhitsky in the laboratory of the Geological Institute RAS (Moscow).

We studied the paleontological collections of “Mammoth” fauna from the Laptev Sea region which are preserved in the museums and institutes of Yakutsk (Geological Institutes SB RAS, Mammoth Museum and Yakutian Museum of Regional Ethnography). More than 500 separate horse and mammoth bones, skeletons and soft tissues were studied (Fig. 1). 100 samples of cranial material were described, measured and photographed. All fragments of mammoth and horse carcasses were photographed.

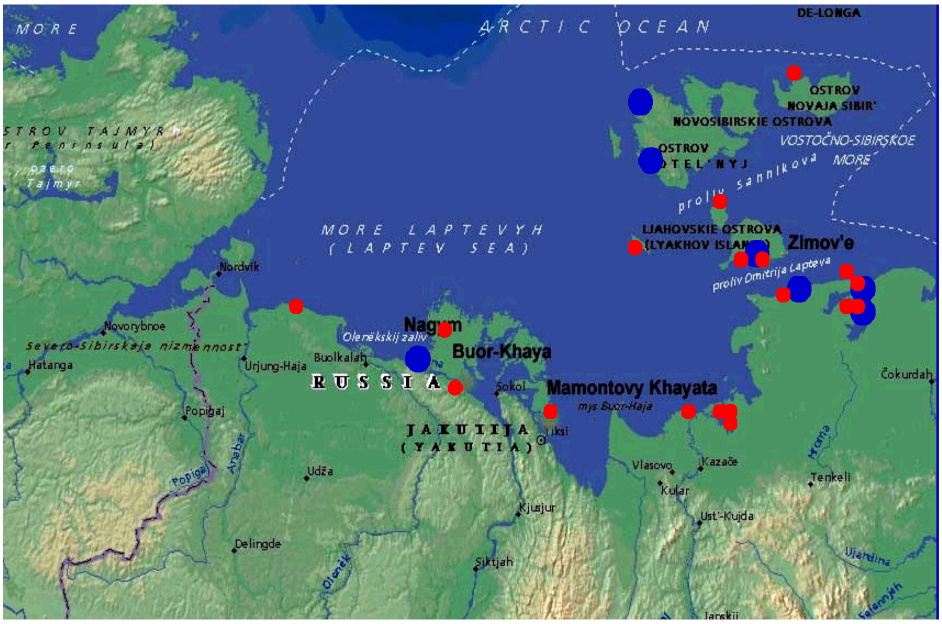


Fig. 1: Locations of the collections and separated finds of hair, soft tissues, hoofs from the Laptev Sea Region.

T. Kuznetsova and N. Noskova created the morphometrical database on Pleistocene horses of Northern Yakutia. It includes all measurements of the cranial material which was collected during the Russian-German expeditions from 1998 to 2003 and of the material from diverse museum collections (Zoological and Paleontological museums RAS, Geological Institutes SB RAS, Mammoth Museum and Yakutian Museum of Regional Ethnography). N. Noskova completed the database "Finds of "Mammoth fauna" from the Laptev Sea Region" (Kuznetsova et al., 2004). We also created the electronic version of "The determinant of the large mammals of the "Mammoth" fauna by postcranial bones". For this part of our work we used the facilities of the OSL computer laboratory. Part of the database "Collection of the Late Pleistocene and Holocene of mammalian bones from the Olenek-Anabar region" and the data of our paleontological study around Cape Mamontov Klyk have been published (Kuznetsova, 2004; Kuznetsova et al., 2004).

Findings of Pleistocene small mammals from Bol'shoy Lyakhovsky Island and Bykovsky Peninsula were also described and analyzed (Kuznetsova and Tesakov, 2004).

We inserted the radiocarbon data on fossil mammals into the database which was created by the OSL project "LAPPAL – the database on the Pleistocene environment of the East Siberian Arctic shelf (Laptev land paleoecology)" (OSL-00-05) in 2000. We added 100 new dates of mammal bones from the Laptev Sea region to this database. Another 50 bones were sent to the Laboratory of Isotope Geochemistry and Geochronology of the Geological Institute RAS (Moscow) for the purpose of radiocarbon-dating.

We analyzed the spatial changes of mammal assemblages during our distinguished four "mammoth" periods based on the geological composition of different outcrops (Lena Delta region, Bol'shoy and Maliy Lyakhovsky islands, Kotelny Island, Oyogos Yar and Olenek-Anabar region), taphonomic conditions, palynological and paleoentomological data. We achieved this in close cooperation with German (L. Schirrmeister, H. Meyer, A. Andreev) and Russian (S. Kuzmina, A. Derevyagin V. Tumskoy, A. Bobrov) project partners. The final stage was to prepare an article on the paleoenvironment on Bol'shoy Lyakhovsky Island (New Siberian Islands) during the Late Quaternary.

A. Bryantseva prepared and processed 148 diatom samples from the Lena Delta region, Bol'shoy Lyakhovsky Island and the Yana Delta region. More than 400 samples were determined and photographed. Diatom samples were studied at the Moscow State University and the OSL (microscope and digital camera). A. Bryantseva to a great extent increased the database on terrestrial diatoms from the Laptev Sea region. She prepared a presentation on "Pleistocene diatoms from the New Siberian Islands and Lena Delta region" for the First All-Russia Science School of Young Paleontologists (Moscow, October 2004) (Bryantseva, 2004). Her presentation was declared the best presentation of the conference.

Another task was to analyze the carbon and nitrogen isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) of the recent and Late Pleistocene forage plants (for example, *Larix* sp., *Betula nana, Alnus fruticosa, Carex argunensis, Artemisia* sp. and others) from the Lena Delta region and Bol'shoy Lyakhovsky Island (New Siberian Islands). We interpreted isotope data on collagen of fossil bones of grazing mammals using the data on analysis of the isotope ration in forage plants. Isotopic study and interpretation were carried out in close cooperation with our project partners and other colleagues (V. Nikolaev, Th. Tuetken). First results of our research will be presented at workshops and conferences.

We reconstructed the vegetation and composition of the grazing animal populations and their changes on the Laptev Sea shelf during the Late Pleistocene and Holocene. In doing so we analyzed and compared the factors that influence the distribution of different animal species. A publication about the paleoenvironment on Bol'shoy Lyakhovsky Island (New Siberian Islands) during the Late Quaternary is being prepared. In June 2004 T. Kuznetsova presented our “Reconstruction of the Late Pleistocene-Holocene paleoenvironment of the East-Siberian Arctic (Laptev Sea Region)” during the workshop “Surviving the Ice Age” within the framework of the Russian-Dutch research cooperation “The evolution of the mammalian fauna and flora in Western, Central and Eastern Europe during the Pleistocene-Holocene transition (25-10 ky BP)” in Leiden.

The final part of our project (compilation and synthesis of all received paleoecological information, reconstruction of temperature variations during the Late Pleistocene and Holocene) was carried out in close cooperation with all Russian and German colleagues from the Moscow State University and the Alfred Wegener Institute for Polar and Marine Research, and with the members of the Otto Schmidt Laboratory.

Results

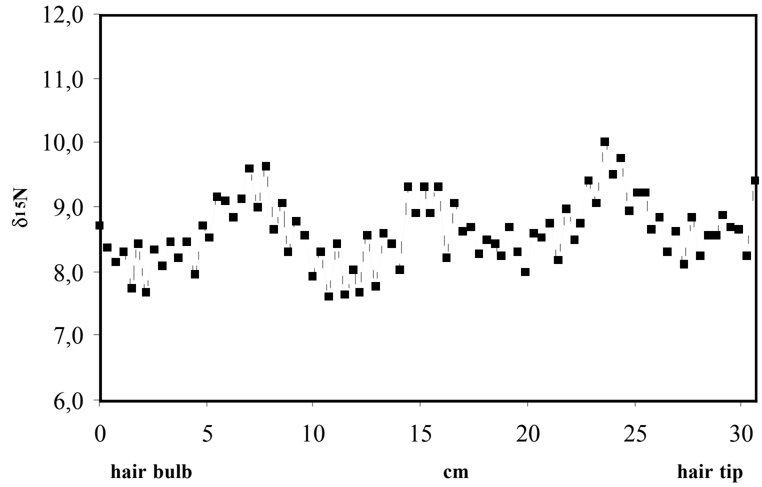
In general the taxonomic composition of the collection of fossil mammal bones from the Olenek-Anabar region is quite similar to that of the Late Pleistocene “Mammoth” fauna from other regions of Arctic Siberia. Reindeer (38.6%), horse (29.8%) and woolly mammoth (9.4%) fossils dominate, followed by bison (4.6%). Muskox and wolf make up about 1% each of the whole collection. More interesting is the predominance of horse remains over mammoth remains. Possibly this depends on taphonomic factors and does not correspond to the composition of the Late Pleistocene animal population in this region. Preservation of bones is typical for the Ice Complex sites.

The paleontological significance of various groups of animals and plants is different. Ice-rich permafrost deposits, called “Ice Complex”, and associated formations are the most important archives of the Quaternary climatic and environmental history in the nonglaciated areas of Northern Siberia. Large parts of Bol’shoy Lyakhovsky Island are covered by such permafrost deposits. Russian and German colleagues together have analyzed and united all the collected paleontological, geological, taphonomic, palynological and paleoentomological data on the Bol’shoy Lyakhovasky Island (Zimov’e River region). The article “Late Saalian and Eemian paleoenvironmental history of the Bol’shoy Lyakhovsky Island (Laptev Sea region, Arctic Siberia)” (Andreev et al., 2004) is the result of science collaboration.

Special attention was given to the study of diatom assemblages of terrestrial deposits. Diatom analysis provides detailed information about local climate conditions. Diatoms are very sensitive plants and they rapidly response to changing environmental conditions, such as type of water body, depth, salinity, temperature, ice cover, etc. The study of diatom assemblages from terrestrial deposits formed in the appointed time periods broadens and deepens our knowledge on climate conditions. We described and photographed 12 species from 63 samples. She determined a several species belong to 16 genuses. We are planning to analyze a further 70 samples from the different regions of the Laptev Sea surroundings (Lena Delta region, Bol’shoy Lyakhovsky Island, Yana Delta region). This will provide us with the possibility to create a representative diatom database on the Laptev Sea region. For this study the analytical laboratory of the OSL (microscope and digital camera) is needed and the investigations were carried out in the OSL.

Five large mammals dominate the Late Pleistocene community: mammoth, horse, bison, reindeer and muskox. Mammoth, horse and bison were almost exclusively grazers, but had different strategies for foraging and processing grasses, while muskox and reindeer are mixed grazers and browsers adapted mostly to foraging tundra plants. Differences in diet, habitat selection, climate and physiology of these herbivores were manifested in stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) of collagen of fossil bones. The carbon and nitrogen isotope ratios in consumers are mainly determined by the stable isotope composition of forage plants. Variation in isotopic signature within taxa was interpreted as due to either change in diet or environmentally-driven changes in the isotopic composition of forage plants (Matheus et al., 2003).

The fossil mammal bone collagen is a new source of paleobiological information. We continued analyzing the carbon and nitrogen isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) in fossil mammal bone phosphate and other remains. We studied the isotope ratios in mammoth hair for the first time (Fig. 2). The obtained results reflect the seasonal variations of isotope ratios of food. They depend on the composition of forage vegetation and different strategies for foraging and processing grasses. The reconstructed average composition of the carbon in mammoth hair is quite similar to recent carbon compositions of comsumers from Eastern Siberia. Consequently we suppose that the paleoenvironmental conditions were close to the modern ones (Nikolaev et al., 2004; Yakumin et al., 2004).



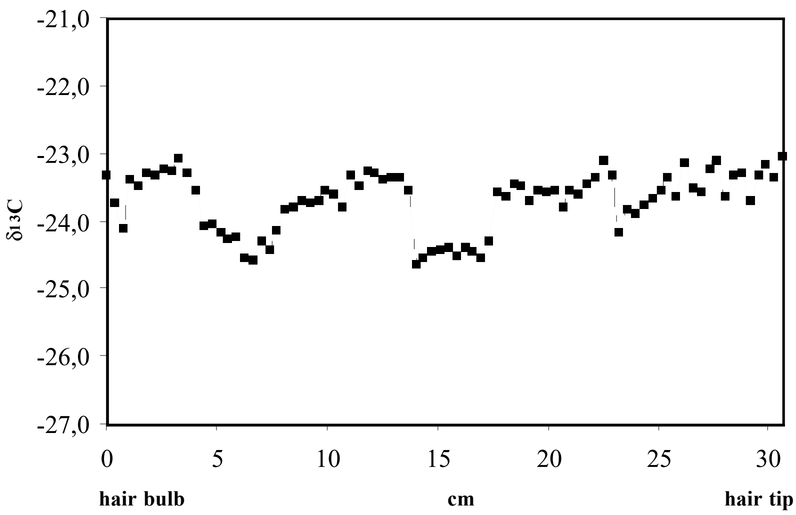


Fig. 2: Isotope composition nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) of *Mammuthus primigenius* hair from the Bol'shoy Lyakhovsky Island.

On the basis of our vast paleontological, geological, taphonomic, paleobotanical, palynological and paleoentomological data on the eastern part of the Laptev Sea region, we reconstructed the vegetation and composition of the grazing animal populations and their changes on the Laptev Sea shelf during the Pleistocene. Paleoenvironmental records from permafrost sequences document the environmental history in the region for at least the past 200 ka. Pollen spectra and insect fauna indicate that relatively wet grass-sedge tundra habitats dominated during an interstadial ca. 200-170 ka BP. Summers were rather warm and wet while stable isotopes reflect severe winter conditions. The pollen spectra reflect sparser grass-sedge vegetation during Late Saalian stage (ca. 170-130 ka BP) with environmental conditions much more sever compared with the previous interstadial. Open *Poaceae* and *Artemisia* plant associations dominated in the vegetation at the beginning of the Kazantsevo (Eemian) ca. 130 ka BP. Some shrubs grew in more protected and wetter places as well. The climate was relatively warm during this time, resulting in the melting of Saalian ice wedges. Later, during the interglacial optimum shrub tundra dominated in the vegetation. Climate was relatively wet and warm. Quantitative pollen-based climate reconstruction suggests that mean July temperatures were by 4-5°C higher during the optimum of the Eemian than at present while late Eemian records indicate a significant climate deterioration (Andreev et al., 2004).

The final part of our project was devoted to the compilation and synthesis of all received paleoecological information and the reconstruction of temperature variations during the Late Pleistocene and Holocene. Multidisciplinary study of different sections on the Laptev Sea coast provides the most complete record of Middle and Late Weichselian environment in the East Siberian Arctic. The large number of radiocarbon dates from the Mamontovy Khayata cliff (Bykovsky Peninsula) together with an extensive ^{14}C database on mammal bones, a great number of pollen and plant macrofossil and insects samples allowed us to interpret the environment and climate of the shelf between 50,000 and 14,000 years ago. During the Karginian Interstadial and the Sartanian Glacial the vegetation remained a mosaic arctic grassland with a relatively high diversity of grasses and herbs and dominance of xeric habitats: the tundra-steppe type. This biome was supported by a constant and very continental climate, which was caused by the fact that the shelf had become a terrestrial environment due to the low sea level.

Variations within the broad pattern were caused mainly by fluctuations in summer temperatures These were related to the global trend but even more strongly influenced by the effect of continentality. No major changes in humidity were observed nor were advances of the modern type of forest or forest-tundra recorded. The changing subtypes of the tundra-steppe environment were persistently favorable for mammalian grazers, which inhabited the shelf lowlands throughout the studied period. Mammal population number decreased during the Last Glacial Maximum, especially toward its end, and then flourished in a short but impressive peak in the latest Weichselian, just before the collapse of the tundra-steppe biome (Sher et al., 2005).

Conclusion

Multidisciplinary study of different sections on the Laptev Sea coast provides paleoenvironmental records of the region for at least the past 200 ka. During an interstadial ca. 200-170 ka BP summers were rather warm and wet while stable isotopes reflect severe winter conditions. The Late Saalian stage (ca. 170-130 ka BP) was characterized by environmental conditions much more severe compared with those of the previous interstadial. Open *Poaceae* and *Artemisia* plant associations dominated in the vegetation at the beginning of the Kazantsevo (Eemian) ca. 130 ka BP. The climate was relatively warm during this time, resulting in the melting of Saalian ice wedges. Later, during the interglacial optimum climate was relatively wet and warm. Quantitative pollen-based climate reconstruction suggests that mean July temperatures were by 4-5°C higher during the optimum of the Eemian than at present, while late Eemian records indicate a significant climate deterioration.

The paleontological significance of various groups of animals and plants is different. "Ice Complex" and associated formations are the most important archives of the Quaternary climatic and environmental history in the nonglaciated areas of North Siberia. The records from Bykovsky Peninsula show how climate change, and the Last Glacial Maximum in particular, affected terrestrial organisms such as insects and large grazing mammals. During both the Karginian Interstadial and the Sartanian Glacial the vegetation type was that of a tundra-steppe due to the very continental climate.

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GAS HYDRATE FORMING FLUID VENTS IN THE SEA OF OKHOTSK: HYDROGEOCHEMICAL STUDIES

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Introduction

Scientific background

Methane hydrate occurrences related to active gas vents in the Sea of Okhotsk are known from off Paramushir Island and off northeast Sakhalin Island (Zonenshayn et al., 1987; Ginsburg et al., 1993; Soloviev et al., 1994). During the expedition of VNIIOkeangeologia and DALMORGEOLOGIA onboard RV "Geolog Piotr Antropov" in 1991, ten gas vents were found off Sakhalin Island on the western slope of the Deryugin Depression at a water depth of 620-1040 m (Ginsburg et al., 1993). The location of the gas seepage sites was detected with echosounding and through high methane concentrations in the water column (Obzhirov, 1992). The fact that the gas seepage sites occur on the continental slope northeast off Sakhalin Island within a 20-km-wide zone extending about 130 km from north to south as well as coring results suggest that this region is a large gas-hydrate-bearing province (Soloviev and Ginsburg, 1998). The study area is located in the vicinity of oil and gas-bearing fields on Sakhalin Island and the adjacent shelf.

During the expedition in 1991, gas hydrates were recovered within the gas venting sites at very shallow subbottom depth. They occurred in thin layers sub-parallel to the seafloor and representing lenticullar-bedded hydrate-forming structure (Ginsburg et al., 1993). Beside visual observations, some indirect indications for the hydrates such as gas pockets, sediment fluidization after hydrate decomposition, specific water content distribution, chlorinity anomalies, and occurrence of methane-related carbonate associates were reported (Ginsburg et al., 1993; Cranston et al,. 1994; Soloviev and Ginsburg, 1997).

Further studies of the gas vent area during repeated expeditions within the framework of the Russian-German KOMEX project (Kurile-Okhotsk Marine EXperiment) have revealed up to 150 additional locations with features typical for gas emission. Geophysical data obtained during the 26th cruise of RV "Gagarinsky" indicated that the gas-vent field correlates with certain tectonic zones and is directly controlled by the tectonic regime. It was proved that all known and gas seeps off NE Sakhalin, discovered during KOMEX cruises, are located near reverse faults generated under conditions of NE-SW compression and that the compressional regime still prevails within the study area (Biebow and Hütten, 1999). The tectonic environment in the region creates conditions favorable for the migration of pore fluids and gas toward the seafloor and, therefore, for the formation of gas hydrates.

The gas hydrate occurrence discovered by Ginsburg et al. (1993) was cored during the 28th cruise onboard RV "Akademik M.A. Lavrentyev" (Biebow and Hütten, 1999) and during the 1st cruise of MV "Marshal Gelovany" (Biebow et al., 2000). One of the aims of 29th cruise onboard RV "Akademik M.A. Lavrentyev", carried out within the framework of the KOMEX project from June to August 2002 (Biebow et al., 2003), was to investigate gas hydrates and their indirect indications, and to study pore water geochemistry and isotopes. Cruises 31 and 32 of RV "Akademik M.A. Lavrentyev" within the framework of the CHAOS (Hydro-Carbon Hydrate Accumulations in the Okhotsk Sea) International Research Project (Shoji et al., 2005) were also focused upon the study of the gas hydrate-related processes in the Sea of Okhotsk.

Goals and objectives

Notwithstanding the numerous studies carried out within the gas-vent area, the hydro-geochemical peculiarities of the hydrate formation process remain unknown. Investigations of them is one of the important tasks of the fundamental studies necessary for defining the role submarine gas hydrate plays in the ecosystem of the Sea of Okhotsk. The recent investigations of the vent-related gas hydrates in the NE part of the Sea of Okhotsk seem to be a good basis for comparative and complex gas hydrate studies within this area.

The main goals of this project were to determine the origin and composition of water and gas involved in the accumulation of the gas hydrates associated with venting structures on the seafloor in the Sea of Okhotsk and to reveal the mechanism of their formation. In order to do this, multidisciplinary studies were carried out taking into account different aspects of gas hydrate formation (physical, geochemical, isotope, and lithological aspects). Finally, this study allows us to create a geological model of hydrate accumulation within the gas-vent area.

Research activities

Approach

The proposed study was based on the assumption that submarine gas hydrates are distributed within their PT stability zone as discrete accumulations. Based on this, any hydrate occurrence formed in the shallow sediment depth within an active fluid vent should be considered as a separate geological body existing in the complex of the geological, geochemical, and physical systems of the vent. In order to reveal the origin of the hydrate accumulation and to understand the mechanisms of its formation, a multidisciplinary study was carried out including the following analytical investigations:

- chemical analysis of the pore and hydrate water samples obtained from the KOMEX-2002 and CHAOS-2003 expeditions from within gas vents and revealing the composition and source of hydrate-forming fluids;
- analyses of hydrated gas composition to study the gaseous phase of the recovered hydrates, their origin and source;
- interpretation of data on physical properties of the hydrate-containing sediment;
- organic Carbon (C_{org}) content determinations in sediments obtained from within the gas vents with respect to the origin of gas involved in the gas-hydrate formation process;
- grain-size analysis of sediment taken from the gas-venting structures to reveal possible grain-size control of gas-hydrate formation;
- mineralogical analysis of authigenic carbonates in thin sections aimed at recognizing the composition of the carbonates and its relationship with gas venting on the seafloor and with the gas hydrates as well;
- recognition of anomalous fluids involved in gas hydrate formation and their interrelation with surrounding sediments outside of the fluid-venting structures;
- developing geological models of the gas-hydrate formation within the fluid-venting structures in the Sea of Okhotsk based on the results obtained during our analytical works.

Accomplishments

According to the milestones of our project, the geochemistry of the water samples was determined in the Chemical Laboratory of VNIIOkeangeologia using the analysis described in Reznikov and Mulikovskaya (1956). Cl, Ca, Mg were determined by titration (argento-, acide-, and complexometry, respectively), SO_4 species was determined by weight, and Na and K using the flame-photometric method. The same samples were chosen for the isotopic study. Oxygen ($\delta^{18}O$) and hydrogen (δD) isotopic analyses of the pore water were carried out using an MI – 1201 in the Laboratory of the VSEGINGEO (Moscow) and in the Center of Isotope Studies of the VSEGEI (St. Petersburg). The method described by Craig and Hom (1968) was used for oxygen analyses and the zinc method was employed to determine hydrogen isotopes (Kendall and Coplen, 1985; Polyakov and Bobkov, 1995). The results are represented in per-mil delta notations (‰) relative to Standard Mean Ocean Water (SMOW).

Chromatography of gas released from gas hydrates was carried out in accordance with the working program in the Gas Laboratory of the VNIGRI (ST-Petersburg). The gas was analyzed for O_2, N_2, CO_2 and CH_4 using a catarometer. Heavy hydrocarbons of the gas were measured by means of a flame-ionization detector.

The interpretation of sediment physical properties was completed according to our milestones.

Organic carbon determinations in sediments were partially carried out using the automatic analyzer CH-N VARIO EL of the OSL. The organic carbon measurements were not completed because of technical problems of the OSL analyzer. These tasks are planned to be continued next year.

Grain-size analysis of sediments was carried out partially in the Lithological Laboratory of VNIIOkeangeologia; the combined pipe-sieve method (GOST 12536-79 1988) was employed.

Mineralogical investigations of the authigenic carbonate in the thin sections were not carried out because of repair works in the thin-section laboratory of VNIIOkeangeologia. At the same time, analyses of carbon 13 ($\delta^{13}C$) and oxygen 18 ($\delta^{18}O$) of the carbonates were carried out in addition to the work planned within the frame of the project.

Different types of fluid involved in the gas hydrate formation process and their interrelation with surrounding sediments outside of fluid venting structures were determined. Geological models of gas hydrate formation within the fluid venting structures in the Sea of Okhotsk were developed on the basis of the results obtained during our analytical works.

In total, about 85% of our research was carried out in accordance with our working program.

Results

The relation between chloride ion and other major ions in core LV29-50-1 suggests that off Sakhalin Island water with increased chloride concentration rises upwards through the water column along with free gas expulsion (Fig. 1). A good agreement between obtained chloride values and isotope composition of water suggested that the gas hydrates within the Obzhirov gas hydrate accumulation are formed from the mixture of sea water and enriched by salts water percolating from below. This fact implies not only upward infiltration of free gas but also infiltration of water. The water coming to the zone of hydrate formation differs from near-bottom Okhotsk water (which is close to SMOW by isotope composition of oxygen and hydrogen). Isotopic composition of this water is about -15‰ and -1.8‰ for hydrogen and oxygen, respectively.

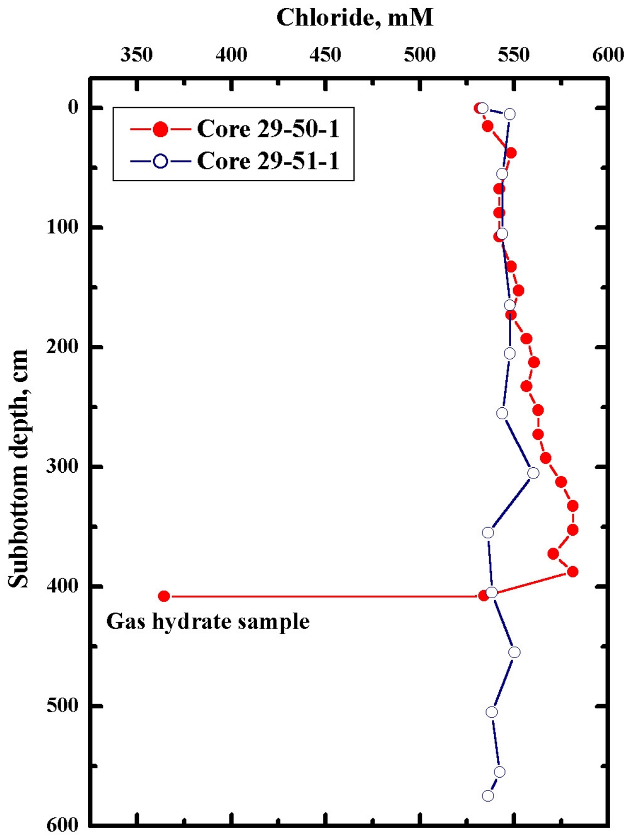

Fig. 1: Distribution of chloride with depth in the pore water from the cores LV29-50-1 and LV29-51-1 (the Obzhirov structure).

Predominance of methane (more than 99%), characterized by a C_1/C_2+C_3 ratio higher than 20000, in the studied gas released from hydrates testifies that the methane, involved in the gas-hydrate formation in the gas-venting area off Sakhalin, was produced through biological reduction of organic matter by microbes in the anaerobic environment below the zone of sulfate reduction. The fact that the values (up to 1.8%) of organic carbon (C_{org}) determined in the gas hydrate-bearing sediment in the gas-venting area are high as compared to background values (0.5-1.2%), measured in cores taken at a considerable distance from the gas vents, allows suggesting that the fluids involved in gas-hydrate formation and those of the hydrate-containing sediments are of common origin (Fig. 2). Increased contents of C_{org} were also measured in sediments recovered at a distance from the fluid-venting areas but within the same sedimentary basin of the Deriugin depression (core LV31-41GC, Fig. 2d). The obtained data suggest that not only the local fluid venting structures but also the studied area as a whole is characterized by high rates of organic-matter accumulation in the sediment and biogenic methane production. This suggestion is supported by the high saturation with gas of the sediments recovered during gravity coring at those areas in the Deriugin Basin which do not belong to the fluid-venting areas. It is necessary to note that decreasing trends of the C_{org} and total organic carbon (TOC) concentrations with sediment depth may testify to upward methane diffusion through the pore space of the sedimentary strata of the Deriugin Basin. TOC concentrations in the studied sediments considerably varies with depth. The fact that TOC concentrations increase downcore at station LV32-09GC (Fig. 2a, the Kitami fluid venting structure) accompanied by constant values of C_{org} suggests that authigenic carbonate accumulation and chemosynthetic organism activity (mainly, of *Calyptogena* bivalve shells) decrease with time. Therefore, it is possible to conclude that the Kitami gas venting structure was more active earlier than at the time of the CHAOS expeditions. At present the velocity of the methane flux in this gas vent decreases. On the other hand, the distribution of TOC and C_{org} concentrations in the core LV31-27HC (Fig 2b, the Chaos venting structure) provides evidence for a intermittent activity of this vent.

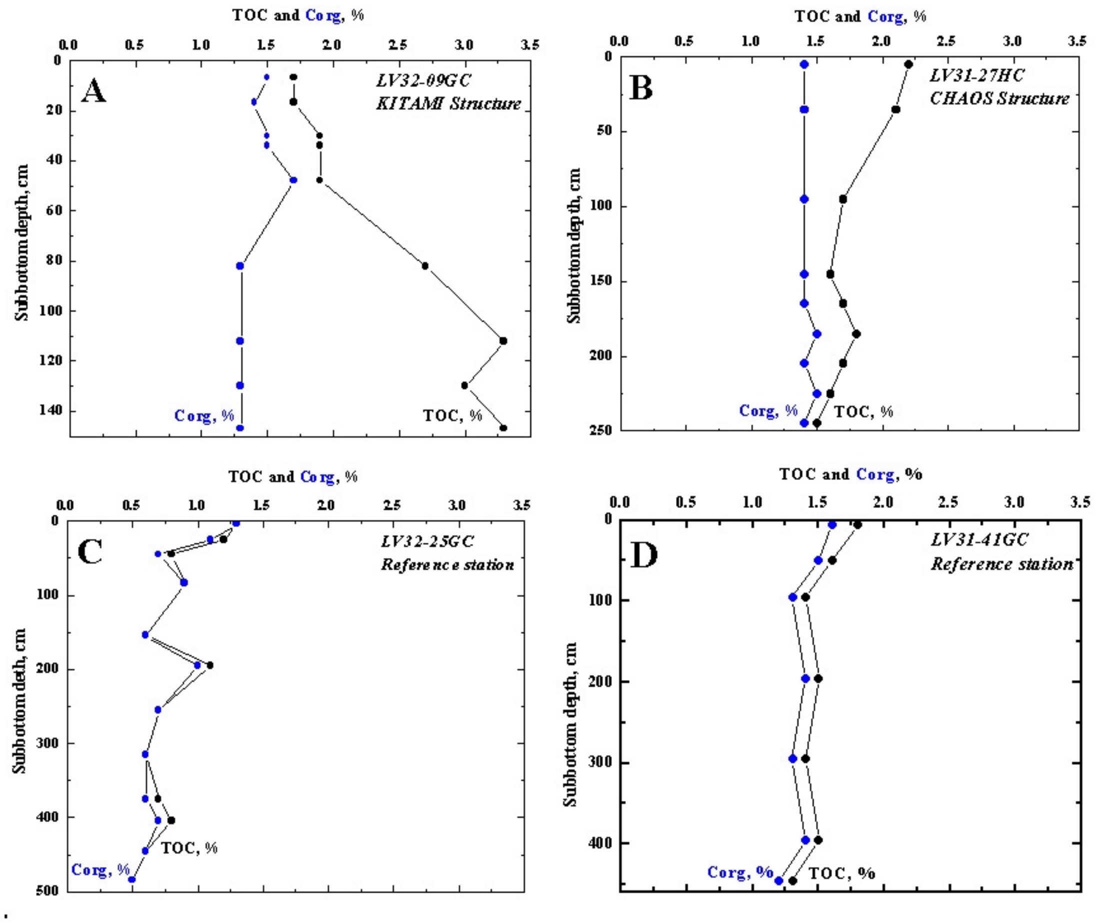

Fig. 2: Distribution of total organic carbon (TOC) and organic carbon (C_{org}) according to depth in the cores LV32-09GC, LV31-27HC, LV32-25GC and LV31-41GC (venting area, off NE Sakhalin slope, the Sea of Okhotsk).

The isotope composition of carbon 13 in the studied authigenic carbonates varies in a wide range (from -1.7‰ to -49‰ PDB), whereas $\delta^{18}O$ measured in the same samples ranges from -0.2‰ PDB to 5.9‰ PDB. The highest $\delta^{13}C$ values were measured in samples containing *Calyptogena* bivalves and just inside their shells. The “light” isotope composition of carbon 13 suggests that all the carbonate formations mentioned above result from irreversible microbial methane oxidation. At the same time, changes of $\delta^{13}C$ values in such a wide range provide evidence of the fact that different sources of methane carbon are involved in carbonate formation. Most probably there are two sources of the methane: microbial biogenic methane formed *in situ* and methane which originates from hydrocarbon reservoirs far below the seafloor but is also biogenic in origin. On the other hand, the high values of $\delta^{18}O$ in the studied carbonate formations suggest that the oxygen 18 isotope is not produced *in situ*. The source of this oxygen, most probably, is fluid infiltrating from below and is characterized by “heavy” isotope composition of oxygen 18.

Revealing of the sources and the composition of original gas hydrate-forming fluids in submarine environments is actual problem of marine geology and geochemistry. Hydrogeochemical studies of gas hydrate-forming fluids offshore NE Sakhalin developed under this Project are one more step in direction for solving of this problem.

Conclusion

The results of our hydrogeochemical studies suggest that not only is free gas emitted off NE Sakhalin but also relatively mineralized water is discharged. The studied water consists of three end-members: gas hydrate water, seawater and water originating from sources deep in the seafloor. The results of isotopic studies on the water show that discharged fluid is characterized by light δD (up to -15‰) and $\delta^{18}O$ (up to -1.8‰). On the other hand, the results of the $\delta^{18}O$ measurements of carbonates suggest that "isotopically heavy" water is discharged within the study area. It is also possible to conclude that the two types of water differ in isotopic composition and that sea water as well is is a component in the formation of carbonates and gas hydrates. Therefore, the sources of fluids uprising from the depth variedwith time.

On the basis of determinations of the organic matter content, composition of hydrated gas, and carbon-oxygen isotope composition of authigenic carbonates, it is possible to recognize two main sources of gas involved in the formation of gas hydrates: (1) microbial biogenic methane that was generated *in situ* in the uppermost sediment horizons of the Derugin Basin and enriched by organic matter and, (2) methane escaping from deeply buried hydrocarbon reservoirs along faulting zones. This methane most probably is also of biogenic origin.

According to the two-phase model of fluid filtration through the PT gas-hydrate stability zone, gas-saturated water is discharged along with the gas venting. In this case, the following two mechanisms of gas hydrate formation take place: (1) precipitation of gas hydrates in pore space under decreasing methane solubility during gas-saturated water input from the depths into the gas-hydrate stability zone and, (2) segregation of water by free gas and seeping of water from adjacent horizons into the zone of gas-hydrate formation.

The results of the analytical works realized under the project allowed us to solve several tasks in studying gas-hydrate forming fluids in the Sea of Okhotsk. At the same time, some questions, such as: (1) relationship of mineralogical peculiarities of carbonates with their isotopic composition and gas hydrate-forming fluids; (2) classification of discharged fluids based on isotopic composition of oxygen and hydrogen depending on fluid-vent position on the continental slope and on their depth; (3) estimation of methane content in gas-hydrate accumulations related to fluid venting off NE Sakhalin and others, require additional studies. The project team has all the necessary material for completing these tasks and the continuation of these studies is of considerable scientific interest.

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NUTRIENT BUDGETS IN THE COASTAL AREAS, ESTUARIES, AND ESTUARINE ZONES IN THE SIBERIAN ARCTIC SEAS

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Introduction

This project was based on the results obtained during previous OSL projects (OSL-00-02; OSL-01-S1; OSL-01-S3) and constitutes a study of nutrient fluxes in arctic coastal systems. It is directly related to the LOICZ (www.loicz.org) approach to the biogeochemical site budgeting. Phosphate, nitrate, ammonia, and silicate, as mineral basis of primary production, control the state, functioning and health of marine ecosystems. Our interdisciplinary studies were focused on laboratory experiments and hierarchical modeling to assess the influence of coastal erosion, river runoff, ice regime, and water mass circulation on the nutrient budgets in the Siberian seas.

<u>Scientific background</u>

The Russian Arctic seas (Kara, Laptev, and East Siberian) are located on the huge Siberian shelf. They are very shallow (depths of less than 50 m dominate over the southern part of the shelf), have extremely severe climatic conditions, and are covered with ice for most of the year. Being influenced by large-scale freshwater impact from the continent and the islands, these open seas freely exchange water with the Arctic Basin. This is a region with highly variable physical processes, and high and variable rates of primary production and organic matter recycling. The considerable influence of freshwater inflow means that the Arctic seas are well stratified throughout the year, except for the coastal sites, where mixing by gales or winter convection are able to erode the halocline. The coastal line is indented; there are many gulfs.

The coasts along the whole length from the Lena Delta to Chauna Gulf are mostly low and consist in places of ice complexes. The coasts are eroded by thermo abrasion during the short Arctic summer. It has been ascertained that coastal erosion is a rich source of suspended matter, nutrients, and greenhouse gases in the coastal area (Semiletov, 2000). Permafrost is widely distributed both on the adjacent land and offshore (Romanovskii et al., 1997). There are more or less permanent coastal currents directed eastward along the shore. However the circulation patterns of the seas are complex and variable. The variability results from the temporal variability of river discharges and wind patterns. Changes in the prevailing wind direction lead to the restructuring of the overall water circulation system, formed in accordance with water density, seabed topography and the Coriolis effect. Water masses typically circulate cyclonically in the central parts of the seas (Atlas of the Arctic, 1980). Very little is known about the currents in the intermediate and bottom structural zones (Dmitrenko et al., 2001).

Nutrient concentrations are both good tracers of water masses and indicators of biological processes. The huge Siberian rivers transport millions of tons of nutrients into the Arctic seas every year (Gordeev et al., 1999). Coastal erosion also contributes an as yet unknown amount of nutrients. And the question is: what happens to the nutrients in the Arctic coastal marine systems? Is the shelf just a transit zone or is it a trap for nutrients? How are nutrients transformed there, and where does this transformation occur? Physical, biological, and geochemical processes on the Arctic shelf define critical pathways for nutrients.

Goals and objectives

The fundamental aim of the project is to understand the physical and biogeochemical processes that link the arctic coasts, estuaries, and river plume areas (estuarine zones) within the context of global change. Hierarchical budgeting studies of coastal areas (small scale), estuaries, and estuarine zones (large scale) can synthesize C-N-P biogeochemical information and provide a valuable assessment of nutrient fluxes in the coastal waters.

Our main attention was focused on laboratory experiments in order to measure nutrient concentrations in the coastal waters and eroded coastal sediments. Accurate estimations of nutrient influx from the eroded coastal ice complexes, budgeting studies in the small bays and in the entire river plume areas, assessment of the nutrient contribution of the region to the Arctic Ocean nutrient budget are necessary for understanding the regional and global biogeochemical cycles and the impacts of global change on the coastal zones.

The objectives of the project were:

- to obtain quantitative characteristics of nutrient composition of the eroded coastal sediments and coastal waters;
- to study nutrient release from bottom and coastal sediments, and the dependence of this process from temperature and salinity;
- to study the stoichiometric relationships between dissolved inorganic phosphorus (DIP) and dissolved inorganic nitrogen (DIN) in the Arctic seas.
- to improve the existing numerical model (Nitishinsky, 2002) describing nutrient fluxes in the Arctic seas;
- to adapt the LOICZ model (http://data.ecology.su.se/MNODE) to the Arctic coastal systems;
- to estimate the input of nutrients to the coastal waters;
- to estimate nutrient budgets in the eroded coastal areas, estuaries, and estuarine zones in the Kara, Laptev, and East Siberian seas;
- to carry out comparative analyses of the budgets and their metabolic performance;
- to synthesize the system C-N-P biogeochemical information for this specific arctic coastal (loading and system flux measures) and relate these to regional and global patterns of system settings, forcing and ecosystem net metabolism.

Research activities

Approach

Our group carried out the following works in the Otto Schmidt Laboratory according to the time schedule:

- silicate, phosphate, nitrate and nitrite were measured in the water samples obtained in the summer 2003/2004 expeditions. We used an autoanalyzer "SKALAR Sun Plus System" and the methods recommended by the producer of the device;
- laboratory experiments were carried out to study nutrient the leaching from coastal sediments. Nutrient leaching from coastal sediments was measured by the following procedure, which is nearly the same as nutrient analysis in soil (Vorob'eva, 1998). Weighed samples of dry sediments were put into a 1 liter retort. We added distillated water and mixed samples for 10 minutes in the dark. After that the water was filtered through a paper filter. Phosphate and nitrate plus nitrite concentrations were measured with the autoanalyzer. We did not measure total nutrient concentrations in the samples because we

were interested in that part of nutrients which is easily dissolved from sediments and takes part in production processes in coastal systems. Nutrient leaching depends on many factors (grain size, amount of organic matter, temperature, microflora etc.). Very important are the duration and intensity of the extraction. That is why we carried out experiments to determine the timenecessary for the most complete leaching. It was necessary to estimate the inaccuracy of our measurements. The sediment sample was mixed in a 2 liter retort for 120 minutes. Part of the water was removed after 10, 20, 30, 60, and finally after 120 minutes of mixing. Nutrient concentrations were measured in the filtered water. The volume of water in the retort was changed and we corrected our calculations of nutrient concentrations;

- the research of stoichiometric relationships, modelling, and budgeting was based on the high-quality data set obtained during the unique Russian-German expeditions (1993-2004) to the Kara and Laptev seas and the archive data set of the AARI (temperature and salinity from 1906 till 2004), and hydrochemistry data compiled in the US-Russian Hydrochemical Atlas of the Arctic Ocean (Nikiforov et al., 2001). The hydrochemistry data (silicate, phosphate, dissolved oxygen, nitrate, nitrite, pH, and alkalinity) from about 21,000 stations and 500 arctic expeditions are found in the atlas;
- the LOICZ model (http://data.ecology.su.se/MNODE) and the hydrochemical model (Nitishinsky, 2002) describing nutrient fluxes on the Arctic shelf were adapted and improved upon;
- field experiments were carried out duringexpeditions to the Kara and Laptev seas onboard the research vessels "Kapitan Dranitsyn" and "Yakov Smirnitsky" in the summer of 2004;
- nutrient budgeting studies in the arctic costal systems were carried out according to the LOICZ approach (Gordon et al., 1996) with regard to coastal erosion influence.

<u>Accomplishments</u>

Our research was carried out in accordance with our working program:

- silicate, phosphate, nitrate and nitrite were measured in 746 water and 12 ice samples. New data on nutrient distribution enriched our database and were used for the nutrient budgeting studies. Young scientists and PhD students became familiar with new methods of chemical analyses using the autoanalyzer "SKALAR Sun Plus System" and the fluorometer TD-700;
- 29 laboratory experiments were carried out to study nutrient leaching from coastal sediments. The samples were obtained at the eroded coasts in the Laptev and East Siberian seas, in the Lena Delta, on Makar, Stolbovoy and Bolshoy Lyakhovskiy islands and were courteously provided by M. Grigoriev;
- stoichiometric studies of nitrogen and phosphorus in the Kara and Laptev seas were carried out. We subdivided the Kara and Laptev seas into regions in which nutrient ratios are more or less constant. This subdivision coincides with regional studies proposed earlier (Rusanov et al., 1979) and water mass classification in the Kara Sea (Pivovarov et al., 2003);
- we used the two-layered LOICZ model (Gordon et al., 1996; David et al., 2000) to calculate nutrient budgets in marine systems. The model was improved and adapted to the Arctic coastal systems by M. Nitishinsky. Fluxes specific for arctic systems were added to the model, namely: fluxes connected with ice formation and melting, and coastal erosion. Ice formation and melting affect matter fluxes inside the system. Concentration of matter in water decreases as a result of ice melting in summer. Nevertheless its total amount increases in the surface layer because ice contains some amount of matter. In winter,

concentration increases as a result of ice formation but the total amount of the matter in the surface layer decreases;

- M. Nitishinsky and O. Morozova participated in the expedition NABOS-2004 on board of the icebreaker “Kapitan Dranitsyn” from September 5-28. A. Novikhin took part in the expedition TRANSDRIFT X onboard R/V “Yakov Smirnitsky”. Both expeditions operated in the Laptev Sea. The NABOS expedition operated over the continental slope and the TRANSDRIFT expedition operated on the shallow shelf of the sea. The young scientists were responsible for carrying out the hydrochemical programs in the expeditions. For the first time concentrations of ammonia were measured with new method (Holmes et al., 1999) in seawater during the arctic expeditions of the AARI. In spite of the fact that there are some methodological problems (report of L. Dobrotina (OSL)), the results of the measurements are very important for a better understanding of the nitrogen cycle in the Arctic seas;
- nutrient budgets were calculated for the eroded coastal areas, estuaries, and estuarine zones in the Arctic seas. We carried out comparative analyses of the budgets and their metabolic performance. Input of nutrients to the coastal waters was estimated.

Results

The new data obtained during the expeditions confirmed our concept of nutrient distribution in the Arctic seas. The comparison of new data with historical data shows the stability of the water column structure in the Arctic seas. Nutrient concentrations in the water masses and parameters of structural elements varied, but the principal qualitative distinctions of structural elements and their positions in the structural zones remained stable.

For example, the minimum of silicate concentration was revealed in the intermediate structural zone in the shallow part of the Laptev Sea north of the Lena Delta in summer 2003 and 2004. This pattern of silicate distribution is typical for this region and time (Rusanov et al., 1979; Pivovarov, 2000).

The results of the laboratory experiments on nutrient leaching from coastal sediments are presented in Table 1. These data allow us to suppose that 20 grams of mineral phosphorus and 15 grams of nitrogen enter into the coastal water from one ton of eroded coastal sediments. The nutrient amount in coastal sediments is certainly inhomogeneous and varies in a wide range. Leaching depends on many natural conditions. It is assumed that the greatest part of terrestrial organic matter is refractory to decomposition and oxidation (Hansell and Carlson, 2002). Nitrogen and phosphorus incorporated into organic matter are accumulated in bottom sediments and do not play a role in metabolic processes. Mostly, easily leached mineral nitrogen and phosphorus influence the productivity of coastal regions.

Preliminary budgeting studies have shown that nutrient fluxes due to coastal erosion are only comparable with fluxes from another sources (river discharge, winter convection) in a narrow coastal strip of 500-1000 m from the coast. This additional nutrient flux significantly influences medium marine systems, for example Olenek Bay, but it is absolutely negligible for large systems like the Laptev Sea shelf. The metabolism of medium (Olenek Bay) and large systems does not change if we include coastal erosion fluxes into the model.

Table 1: Results of the nutrient leaching experiments

Samples of coastal sediments	Weight	Concentration in the solution		Concentration in the soil	
		Phosphate	Nitrate + nitrite	Phosphate	Nitrate + nitrite
	g	µmol/l	µmol/l	µmol/g	µmol/g
Makar Island	7.66	0.87	9.61	0.11	1.25
	7.66	1.03	9.36	0.13	1.22
Bol'shoy Lyakhovsky Island	9.30	1.09	17.02	0.12	1.83
	9.30	0.97	17.39	0.10	1.87
MG-29	3.19	1.37	1.97	0.43	0.62
	2.93	0.91	1.75	0.31	0.60
MG-22	3.77	2.75	3.48	1.46	1.85
	5.76	2.03	3.97	0.70	1.38
MG-26	2.69	1.00	2.37	0.74	1.76
	3.05	0.79	2.37	0.52	1.55
MG-27	3.10	0.63	2.38	0.41	1.53
	2.55	1.58	2.38	1.24	1.87
MG-19	5.57	1.53	2.96	0.55	1.06
	5.77	1.76	3.22	0.61	1.12
MG-18	6.12	1.62	3.07	0.53	1.00
	6.35	1.54	3.06	0.48	0.96
MG-23	9.63	1.59	3.56	0.33	0.74
	5.99	2.64	4.25	0.88	1.42
MG-25	5.94	7.88	3.77	2.65	1.27
	5.82	5.04	3.33	1.73	1.14
MG-17	8.46	0.72	0.99	0.17	0.23
	11.03	0.99	1.43	0.18	0.26
MG-21	7.80	3.44	4.93	0.88	1.26
	7.42	1.25	3.9	0.34	1.05
MG-12	7.72	3.82	0.99	0.99	0.26
	7.95	3.97	1.86	1.00	0.47
MG-13	7.73	2.63	1.86	0.68	0.48
	6.93	2.84	1.71	0.82	0.49
MG-09	11.06	1.55	1.14	0.28	0.21
	13.38	2.13	1.2	0.32	0.18
MG-20	5.97	0.85	1.97	0.28	0.66
	7.61	1.48	2.36	0.39	0.62
MG-15	8.02	0.75	0.4	0.19	0.10
	8.34	0.90	0.59	0.22	0.14
MG-24	6.54	2.64	3.4	0.81	1.04
	7.15	5.61	3.27	1.57	0.91
MG-47	6.02	0.39	19.6	0.13	6.51
	6.81	0.79	21.38	0.23	6.28
MG-28	5.45	1.54	1.66	0.57	0.61
	5.97	5.32	1.66	1.78	0.56
MG-16	9.99	0.85	0.9	0.17	0.18
	11.96	0.69	0.79	0.12	0.13
MG-39	4.64	1.16	1.5	0.50	0.65
	4.37	1.09	1.22	0.50	0.56
MG-41	2.73	1.19	2.02	0.87	1.48

The results of the metabolism assessment in the arctic marine systems according to the budgeting studies taking into account coastal erosion are presented in the Table 2.

Table 2: Metabolism of the arctic coastal systems as a result of the budgeting studies

<table>
<tr><th rowspan="2">Gulfs</th><th colspan="2">Total system</th><th colspan="2">Surface layer</th><th colspan="2">Bottom layer</th></tr>
<tr><th>Summer</th><th>Winter</th><th>Summer</th><th>Winter</th><th>Summer</th><th>Winter</th></tr>
<tr><td rowspan="2">Buor-Khaya</td><td colspan="4">net autotrophic</td><td colspan="2">net heterotrophic</td></tr>
<tr><td colspan="6">net denitrifying</td></tr>
<tr><td>Yana</td><td colspan="4">net autotrophic
net nitrogen-fixing</td><td colspan="2">net heterotrophic
net denitrifying</td></tr>
<tr><td rowspan="2">Khat-anga</td><td colspan="4" rowspan="2">net autotrophic
net nitrogen-fixing</td><td>net autotrophic</td><td>net heterotrophic</td></tr>
<tr><td colspan="2">net denitrifying</td></tr>
<tr><td rowspan="2">Olenek</td><td colspan="4">net autotrophic</td><td colspan="2" rowspan="2">net heterotrophic
net denitrifying</td></tr>
<tr><td>net denitrifying</td><td>net nitrogen-fixing</td><td>net denitrifying</td><td>net nitrogen-fixing</td></tr>
<tr><td>Anabar</td><td colspan="4">net autotrophic
net nitrogen-fixing</td><td colspan="2">net heterotrophic
net denitrifying</td></tr>
<tr><td rowspan="2">Yenisei</td><td colspan="4">net autotrophic</td><td>net hetero-trophic</td><td>net autotrophic</td></tr>
<tr><td>net denitrifying</td><td>net nitrogen-fixing</td><td>net nitrogen-fixing</td><td>net denitrifying</td><td>net denitrifying</td><td>net nitrogen-fixing</td></tr>
<tr><td>Ob</td><td colspan="6">net heterotrophic
net denitrifying</td></tr>
<tr><td rowspan="2">Laptev Sea</td><td colspan="5">net autotrophic</td><td>net heterotrophic</td></tr>
<tr><td colspan="6">net nitrogen-fixing</td></tr>
</table>

The average ratio between carbon, nitrogen and phosphorus in oceanic phytoplankton, the so-called Redfield ratio, is 106:16:1. The ratio is the same in the deep waters of the ocean. It varies, however, in a wide range in the shallow Arctic seas. These variations lead to an altered phytoplankton species composition and influence the entire ecosystem. It is necessary to know the actual ratios between nutrients for assessing the metabolism of marine systems on the basis of budgeting studies.

As a result of our studies we determined regions where nutrient ratios and correlations between them are different in the intermediate and bottom structural zones in the Arctic seas. The correlation between nitrate and phosphate is annihilated in the surface structural zone in summer. We subdivided the Kara and Laptev seas into regions in which nutrient ratios are more or less constant. This subdivision coincides with regional studies proposed earlier (Rusanov et al., 1979) and water mass classification in the Kara Sea (Pivovarov et al., 2003).

N:P ratios range from 5 to 12 in the intermediate and bottom waters in the coastal marine systems and in the river plum areas. The low ratios are explained by the fact that terrestrial organic matter is recalcitrant and its labile part contains a little amount of amino acids, which are the main source of nitrate in the coastal waters (Hansell and Carlson, 2002). Moreover, nitrate and phosphate concentrations are very low in river waters in summer.

The average N:P ratio is about 14 in the Atlantic and Barents Sea waters. The ratio is the same in the deep waters of the Arctic Ocean.

Conclusion

New data on nutrient distributions were obtained as a result of our work on the project. They enriched our database and were used for the nutrient budgeting studies.

Our comparison of new and historical data shows that there is a significant variability of nutrient concentrations in the Arctic seas. The data allow us to assert that some specific features of the water column are stable and reappeared in the Laptev Sea every summer.

The laboratory experiments provided information on nutrient leaching from eroded coastal sediments. For the first time we obtained data which allowed us to assess nutrient fluxes into the Arctic marine systems as a result of coastal erosion. We can conclude that coastal erosion contributes much less to the total nutrient budget than nutrient input by rivers. It was assumed earlier that these fluxes are equal (Semiletov, 2000).

The influence of coastal erosion on the nutrient budgets of coastal systems is confined to a narrow coastal belt. At the distance of 50 km from the coast, the nutrient flux as a result of coastal erosion contributes less than 1% to the total sum of the nutrient budget. Nevertheless, nutrient fluxes from eroded coasts significantly influence the system metabolism in small and even medium systems like Olenek, Yana, and Anabar bays.

The results of our nutrient budgeting studies (Table 2) show that almost all marine systems in the Kara and Laptev seas are net autotrophic despite their diverse systems and hydrography. This means that production is higher than respiration in the systems. The northern part of the Ob Gulf is an exception; it belongs to the type of heterotrophic systems. However, the bottom layers in many systems are heterotrophic, especially in winter when decomposition of organic matter exceeds its production.

These findings should be considered as preliminary results because many so called “winter” data were obtained in March-May but the biological spring – the most productive time of the seasonal cycle – might have had started already in some of the systems. Moreover, the role of polynyas in water and nutrient exchange between the coastal systems and the open sea is poorly studied. Nutrient fluxes in connection with ice formation and melting need further studies and more accurate definitions.

The contribution of different sources to the nutrient budgets depends on system dimensions, and hydrological and ice conditions. River runoff as a source of nutrients dominates in those bays which directly receive the discharge of the great Siberian rivers Yenisei, Ob and Lena. Nutrient fluxes as a result of coastal erosion dominate in a 500 m coastal belt. The main nutrient flux into shallow systems like Anabar and Yana bays comes from the open sea. For large systems, whose dimensions are comparable with the scale of the sea, the main nutrient fluxes come from the bottom layer and from the Arctic Basin.

The budgeting studies will allow us to estimate possible scenarios of metabolism altering in the marine systems as a result of global changes.

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COMPARISON OF POSTGLACIAL SHELF EVOLUTION BETWEEN THE KARA AND LAPTEV SEAS USING FOSSIL ALGAE ASSEMBLAGES

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Introduction

The shallow and wide Siberian shelf is regarded as a key area for the supply of freshwater and sea ice to the Arctic Ocean (e.g., Aagaard and Carmak, 1989; Zakharov, 1996; Kassens et al., 1998, 1999; Stein, 2000). Intermixing of freshwater and marine waters determines the major spatial peculiarities of the hydrological and sedimentation processes on the modern Laptev and Kara shelves. The inundation history of the Laptev and Kara seas has been reconstructed in detail (e.g., Bauch et al., 2001; Stein et al., 2004). A diachtonous reduction in average sedimentation rates from the outer to the inner shelf region, which was related to the southward migration of the coastline as the primary sediment source, was recognized. However, changes in hydrological conditions (e.g., water mass circulation, surface water salinity, sea-ice regime) have been insufficiently studied. Our fossil microalgae records from the western Laptev outer shelf and the adjacent continental slope and the southeastern Kara Sea shelf provide evidence for the evolution of hydrological, sea-ice and sedimentation processes during the last ~16 cal. ka.

Scientific background

A viable approach for reconstructing paleohydrological environments in Arctic shelf seas is to study diatom and aquatic palynomorph assemblages because in river-proximal sediments these groups are comprised of both marine and freshwater species (Polyakova, 1997; Cremer, 1999; Kunz-Pirrung, 1999, 2001; Matthiessen et al., 2000; Polyakova, 2003). The established quantitative linkage between hydrographical parameters (e.g., summer surface-water salinity, sea-ice conditions) and the composition of surface sediment diatom assemblages from the Laptev and Kara shelves (Polyakova, et al., 2000; Polyakova, 2003) can be used successfully to reconstruct paleoenvironmental conditions (Bauch and Polyakova, 2000, 2003; Polyakova and Stein, 2004; Polyakova et al., in press).

Goals and objectives

The main goals of our study are to reveal the temporal and regional peculiarities of hydrological and sedimentation processes in the study regions of the Laptev and Kara seas, influenced by extensive riverine discharge, on the basis of investigation of fossil algae assemblages in sediment cores and detailed radiocarbon age control.

To accomplish our goal we studied diatoms and aquatic palynomorphs (dinoflagellate cysts, chlorococcalean algae, and other organic-walled remains) from four cores. Selected cores were obtained from the western Laptev Sea (PS51/154-11 and PS51/159-10) and the southeastern Kara Sea (BP00-07/7, BP01-42/2) during the TRANSDRIFT and “Akademik Boris Petrov” expeditions of the past years (Kassens et al., 1998; Stein and Stepanets, 2001). According to radiocarbon chronology these cores encompass up to 16 cal. ka (Bauch et al., 2001; Stein et al., 2003, 2004). Previously obtained sedimentological and organic-geochemical records from these cores suggest the stepwise development of depositional environments related to the postglacial sea-level rise and changes in riverine discharge and coastal erosion input onto the Central Siberian shelf. To successfully meet the stated objectives, several research activities concerning geology, geochronology, sedimentation processes, sea ice and hydrological conditions were carried out in collaboration with German and Russian participants of the Laptev and Kara Sea projects from the IFM-GEOMAR, AWI, AARI, and OSL.

Research activities

Approach

Our research activities were focused on the following:

- detailed (5-10 cm sampling intervals) investigations of downcore distribution of fossil algae assemblages: diatoms and aquatic palynomorphs (dinoflagellate cysts and chlorococcalean algae, and other organic-walled remains) in the selected cores from the northwestern Laptev Sea and the southeastern Kara Sea;
- use of micropaleontological proxies determined in surface sediments of the Laptev and Kara seas and ecological preferences of microalgae species to extract temporal variability of hydrological parameters (e.g., water mass circulation, surface-water salinity, sea-ice regime) on the Central Siberian shelf during the late Pleistocene and Holocene;
- comparison of postglacial evolution of the riverine discharge and hydrological conditions in the western Laptev Sea and southeastern Kara Sea on the basis of detailed radiocarbon chronology and extracted paleoenvironmental events.

Accomplishments

According to our working program sampling of cores sediments and the following freeze-drying of samples was carried out by T. Klyuvitkina at the IFM-GEOMAR (Kiel, Germany). Treatment of samples for the purposes of palynomorph study was carried out by T. Klyuvitkina at the AWI (Potsdam), and for diatom analyses in the Laboratory of Pleistocene Paleogeography (Moscow State University) by E. Golovnina and T. Klyuvitkina. In total 360 samples were prepared for studying fossil algae assemblages. We analyzed the diatom and aquatic palynomorph assemblages at the Laboratory of Pleistocene Paleogeography. Also we analyzed and synthesized diatom and aquatic palynomorph records and carried out paleoenvironmental reconstructions.

By applying micropaleontological methods the following major paleoenvironmental results were achieved:

- influence of the Atlantic waters on the northwestern Laptev Sea and southeastern Kara Sea during the postglacial time was determined;
- variations of the surface water paleosalinities in the southeastern Kara Sea during the Holocene were reconstructed;
- changes in the riverine discharge and the overwhelming influence of the postglacial transgression on the evolution of Siberian Arctic shelf water masses were determined.

Unfortunately, because of very low concentrations of diatom valves in cores PS51/154-11, PS51/159-10 and BP01-42/2 it was impossible to use the extracted diatom assemblages for correct paleoenvironmental reconstructions.

Results

<u>Microfossil records from the Laptev Sea cores</u>

Diatom and aquatic palynomorph assemblages were studied in two sediment cores obtained from 60 m water depth on the western Laptev outer shelf (core PS 51/159-10) and from 270 m water depth at the adjacent continental margin (core PS 51/154-11). Based on calibrated AMS ^{14}C dates, these cores encompass the last ~12 cal. ka and the post-glacial time between ~16.0 and 10.0 cal. ka BP, respectively (Bauch et al., 2001).

A preliminary study of approximately 50 diatom samples from both cores revealed low concentrations of diatom valves in the core sediments. Modern marine and freshwater diatoms occur in most of the studied sediment samples, but their concentrations are very low. The studied assemblages are mainly represented by reworked Palaeogene marine diatom species (e.g. *Coscinodiscus payeri, Hemiaulus* spp., *Gladius* spp., *Pyxidiscula* spp., *Paralia sulcata v.siberica, P. sulcata v. crenulata*) along with reworked Palaeogene silicoflagellate species.

In these assemblages aquatic palynomorphs are mainly represented by dinoflagellate cysts and freshwater chlorococcalean algae along with marine acritarchs and organic linings of benthic foraminifers. The distribution patterns of the different groups of aquatic palynomorphs are characterized by a high variability throughout the core section reflecting fluctuations in hydrological conditions and riverine discharge into the western Laptev Sea influenced by the Anabar and Khatanga rivers outflow.

Total concentrations of marine dinoflagellate cysts in the assemblages of core PS51/159-10 generally increase upcore (up to 2200 cysts/g sediment, Fig. 1) with the maximum abundances being observed approximately between 9.9 and 9.0 cal. ka BP. On the basis of the relative abundances, dinoflagellate cysts were generally dominant after 9.5 cal. ka BP. Total concentrations of freshwater chlorococcalean algae (*Pediastrum* spp. and *Botryococcus cf. braunii*), which are regarded as indicators of riverine discharge to the shelf area (Kunz-Pirrung, 2001; Matthiessen et al., 2000) varies between 0.1 and 4100 algae/g sediment with maximum abundances being observed in the timespan of approximately 10.0-9.6 cal. ka BP. Relative abundances of freshwater chlorococcalean algae generally decrease upcore (Fig. 1), and the maximum C/D ratio (chlorococcalean algae/dinoflagellate cysts) observed for the time interval of approximately 11-12 cal. ka BP, which shows that the river-proximal area was located at this site during this time.

The dinocyst assemblages in this core sediments are dominated (up to 100%) by *Islandinium minutum, Islandinium cesare, Echinidinium karaense,* which are currently characterize the cold polar to subpolar freshened shelf waters with an extensive seasonal sea-ice cover (e.g., Kunz-Pirrung, 2001; de Vernal et al., 2001; Mudie and Rochon, 2001). Maximum relative abundances (up to 50%) of the *Brigantedinium* species group (cysts of heterotrophic protoperidinioid dinoflagellates), typical for the upper continental slope assemblages (Kunz-Pirrung, 2001), are observed in the lowermost part of the core (~12 cal. ka BP). Characteristic for the dinocyst assemblages of this core are the high concentrations of relatively warm Atlantic water indicative species (*Operculodinium centrocarpum, Pentapharsodinium delei,* e.g., Matthiessen, 1995; Rochon et al., 1999; de Vernal et al., 2001). These species are abundant in most of the core assemblages (up to 80%), and their minimum concentrations are observed after 6.0 cal. yrs BP.

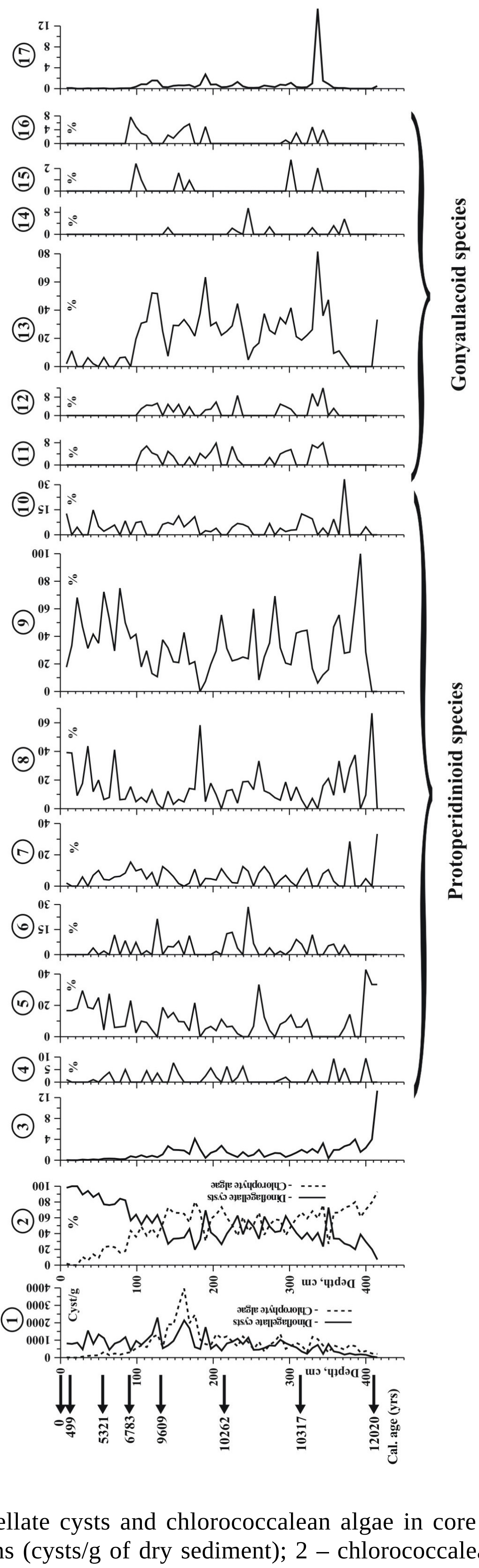

Fig. 1: Distribution of dinoflagellate cysts and chlorococcalean algae in core PS-51/159-10, Laptev Sea. 1 – dinoflagellate cyst concentrations (cysts/g of dry sediment); 2 – chlorococcalean algae concentrations; 3 – CD (chlorococcalean algae/dinoflagellate cyst) ratio; (4-16) – relative abundances of dinoflagellate cyst species: 4 – *Brigantedinium* spp.; 5 – *Brigantedinium simplex*; 6 – Cyst of *Pentapharsodinium dalei*; 7 – Cyst of *Polykrikos* sp. (Arctic morphotype); 8 – *Echinidinium karaense*; 9 – *Islandinium minutum*; 10 – *Islandinium? cezare* s.l.; 11 – *Operculodinium centrocarpum* (short processes form); 12 – *Operculodinium centrocarpum* (Arctic morphotype); 13 – *Operculodinium centrocarpum*; 14 – *Nematosphaeropsis labyrinthus*; 15 – *Spiniferites* spp.; 16 – *Spiniferites elongatus*; 17 – GP (gonyaulacoid/protoperidinoid species) ratio.

Aquatic palynomorph assemblages from core PS 51/154-11 are characterized by a general upcore increase in concentration of dinoflagellate cysts (up to 2000 cysts/g) and chlorococcalean algae (up to 1200 algae/g). On the basis of the relative abundances chlorococcalean algae were generally dominant till 12.0 cal. ka BP. The maximum species diversity of dinocysts and theirs concentrations in sediments are observed in the upper part of the core (later 11.1 cal. ka BP). Cold-water *Islandinium minutum* and related morphotypes typical for the shelf area dominate in dinocyst assemblages from this core (up to 60-80%). *Brigantedinium simplex* is common to abundant in most core samples with a peak in relative abundance (up to 45%) observed approximately at 12.0 cal. ka BP. Species indicating relatively warm water temperatures (*Operculodinium centrocarpum*, *Pentapharsodinium dalei*, *Nematosphaeropsis labyrinthus* and *Selenopemphis quanta*) are most abundant from approximately 13.6 cal. ka BP onwards.

Microfossil records from the Kara Sea cores

Diatom and aquatic palynomorph assemblages were studied in two sediment cores (BP00-07/7 from 33 m water depth, and BP01-42/2 from 49 m water depth) obtained from the southeastern Kara Sea. Thsi area is currently influenced by the Yenisei River discharge. Based on calibrated AMS ^{14}C dates these cores encompass the last ~8.5 cal. ka and ~9.8 cal. ka, respectively (Stein et al., 2003, 2004).

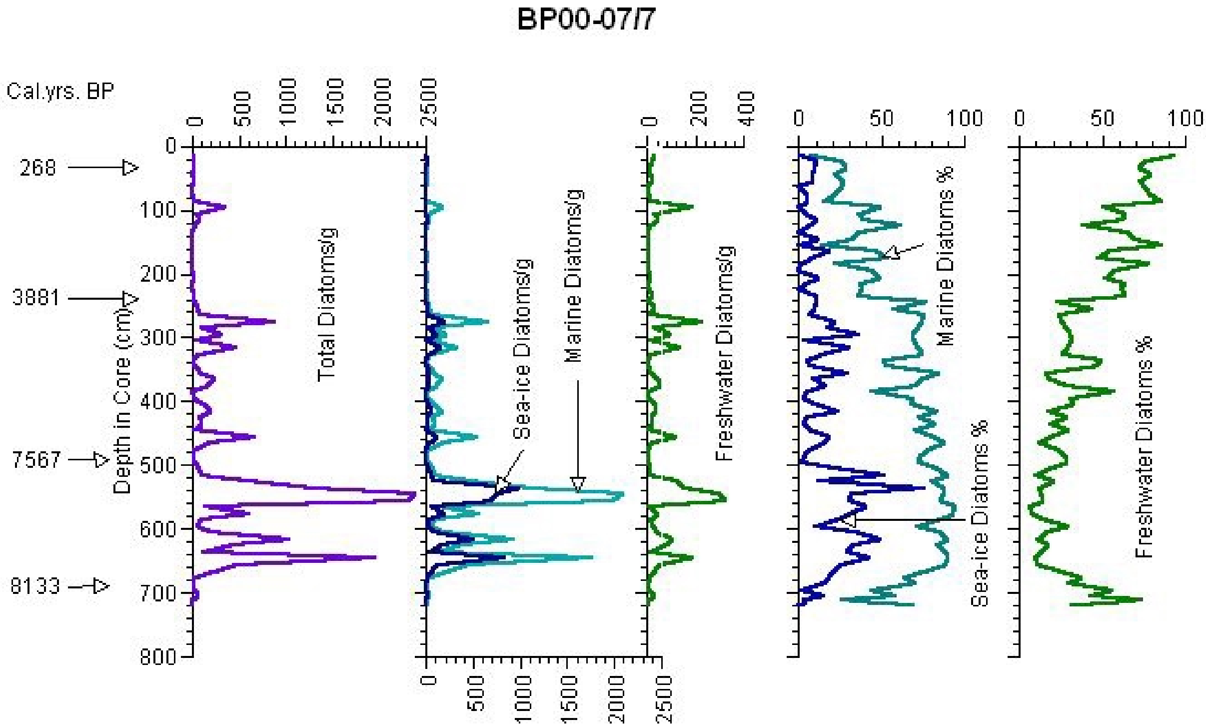

Fig. 2: Downcore abundances (in thousand valves/g dry sediment) and percentages of the main ecological groups of diatoms in core BP00-07/7, southeastern Kara Sea.

Abundant diatom and aquatic palynomorph assemblages were derived from core BP00-07/7 (Fig. 2). The total concentrations of diatom valves in the sediments show a high variability throughout the core, with the maximum abundance peak (up to 2.4 mln valves/g, approximately 7.7-8.0 cal. ka BP) being mainly related to marine and brackish-marine diatoms (up to 92%). The lowest concentrations of diatoms (average ~1,000 valves/g) were recorded for the last 3.8 cal. ka. Two main ecological groups of diatom species were determined: freshwater diatoms (riverine and boggy species) indicating riverine discharge, which are mainly represented by planktic taxa of the genus *Aulacoseira* (*A. islandica, A. italica, A. subarctica, A. granulata* and *Asterionella formosa*), and marine and brackish-marine diatoms. The relative abundances of freshwater diatoms vary between 10 and 95%, and their maximum abundances are observed in the time intervals of approximately >8.1 and <3.8 cal. ka BP. The lowest relative abundances of freshwater diatoms are characteristic for the middle part of the core corresponding to the time interval between approximately 8.1 and 6.2 cal. ka BP. The group of marine and brackish-marine diatoms in the core largely consists (up to 20%) of euryhaline species (*Thalassiosira baltica, T. hyperborea, Melosira juergensii, M. moniliformis*) typical of the freshened areas of the Arctic shelf (Polyakova, 1997, 2003). The marine diatoms also include a specific group of sea-ice species (*Fossula arctica, Fragilariopsis oceanica* and *F. cylindrus, Navicula vanhoeffeni*) indicating sea-ice conditions in the Eurasian Arctic seas (Polyakova, 1997; Cremer, 1999). A sharp increase (> 10-20%) in relative abundances of sea-ice diatoms observed at ~8.1 cal. ka BP may indicate that the mean interannual position of the winter polynya was located around the study site at this time (Polyakova, 2003). The other marine diatoms are represented mainly by cold-water arctic-boreal and bipolar planktic species (e.g., *Thalassiosira antarctica, T. gravida, T. nordenskioeldii, Chaetoceros diadema, C. mitra*) and benthic species (e.g., *Diploneis smithii, D. interrupta, Trachineis aspera*), which are common in the Arctic seas.

The total concentrations of marine dinoflagellate cysts dominating in the aquatic palynomorph assemblages of this core vary between 400 and 3500 cyst/g with the maximum abundances being observed approximately between 8.0 and 3.9 cal. ka BP (Fig. 2). Concentrations of freshwater chlorococcalean algae, which generally decrease upcore, do not exceed 400 algae/g, and their maximum relative abundances (up to 50%) were recorded for the time >8.1 cal. ka BP. The dinoflagellate cyst assemblages show a species composition comparable to that of the modern Kara and Laptev Sea (Voronina et al.; 2001, Kunz-Pirrung, 2001). The assemblages are dominated (up to 90%) by *Islandinium minutum* and related morphotypes, which are typical for arctic inner-shelf assemblages. The *Brigantedinium* group, which seems to be related to highly productive outer-shelf waters, shows maximum relative abundances (up to 35%) in the core assemblages of ~8.1 cal. ka BP. The persistent occurrence of species indicating relatively warmwater temperatures (e.g., *Operculodinium centrocarpum*) suggests the inflow of relatively warm Atlantic waters to the southeastern Kara shelf possibly via the Yamal current. Their maximum relative abundances (up to 50%) were marked out for the time >7.6 cal. ka BP.

Conclusion

On the basis of the fossil microalgae records and detailed radiocarbon chronology of the cores obtained from the western Laptev Sea and the southeastern Kara Sea the following major paleoenvironmental stages associated with the postglacial global sea-level rise could be determined:

- between 15 and 11.1 cal. ka BP and during the time interval of 12.0-9.6 cal. ka BP the paleoenvironmental conditions on the western Laptev Sea continental slope and on the western outer Laptev Sea shelf, respectively, were characterized by increased precipitation of river-loaded matter, primarily riverine plankton in a river-proximal environment;
- since ~11.0 cal. ka an increased influence of Atlantic water at the Siberian continental margin is recorded by a sharp increase in abundances of dinocysts species indicating relatively warmwater temperatures;

- modern-like environments were reached at 11.0 cal. ka BP on the western Laptev Sea continental slope and ca. 4000 years later on the western outer Laptev Sea shelf, at approximately 7.0 cal. ka BP;
- until ~8,1 cal. ka BP the southeastern Kara Sea shelf was inundated; a river-proximal environment with surface-water salinities of 10-13 were reconstructed for around 8.1 cal. ka BP (site BP00-07/7, 33 m water depth) and for the interval of 9.8 to 8.0 cal. ka BP (site BP01-42/2, 49 m water depth);
- between 8.0 and 6.0 cal. ka BP there was a more internsive discharge of Yenisei waters through the sub-marine channels towards the east and northeast (outside of site BP00-07/7), which is indicated by low abundances of freshwater diatoms and the reconstructed relatively high surface-water salinity (approximately 15-16). Maximum paleosalinity was also likely caused by the increased inflow of Atlantic waters into the Kara Sea, which confirmed by the abundance of dinocysts indicating Atlantic water and corroborated by previously obtained data (Polyakova and Stein, 2004);
- the time interval of 0.3-3.8 cal. ka BP was marked by a sharp decrease in water salinity (down to 9-11%) at the core site BP00-07/7; this suggests possible changes in Yenisei-water pathways, which may have passed northward through this sub-marine channel.

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PALYNOLOGICAL STUDY OF THE CORES FROM THE LAPTEV SEA SHELF IN ORDER TO INVESTIGATE PALEOCLIMATE AND PALEOVEGETATION EVOLUTION

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Introduction

Scientific background

Despite the fact that research on the Laptev Sea shelf has been strongly intensified during the past years, pollen composition and distribution data have so far been insufficiently investigated. This project focused on the Laptev Sea shelf system using high-resolution cores obtained from near the largest freshwater source on inner and outer shelf of the Laptev Sea. We present the outlines of the palynological research of these the cores.

Studies on pollen of the cores from the shelf of the Laptev Sea can provide valuable information on changes in the vegetation and climate in the adjacent terrestrial areas. As the shelf areas in which the cores were recovered from are close the coast, the pollen data could also enhance our knowledge on river discharge to the Arctic Basin and land-ocean linkages.

Goals and objectives

The main goal of this project was to reconstruct in detail the short-term variability of freshwater discharge to the Eurasian Siberian shelf during the Holocene and the late Pleistocene according to pollen and spore composition and distribution. Another task was to improve our understanding of how recent and Late Holocene climate changes have affected the freshwater discharge to the Arctic Ocean by studying the transported pollen such as coniferous or secondary (of pre-Quaternary species) pollen. To achieve this goal, we analyzed pollen from the cores PS51-154-11, PS-51-159-10 and the borehole KI001 sediment sequences obtained from the Yana River paleodelta.

Research activities

Approach

The samples from the borehole KI001 were processed in the OSL in January-February using the preparation technique with HCL and NaOH addition. On the whole 28 samples were processed for pollen counting. The samples from cores PS51-154-11 and PS-51-159-10 were processed by T. Klyuvitkina in Potsdam in spring-summer 2004 using the technique of adding cold HF and acetolysis. Exotic markers were added to the samples to calculate the concentration of pollen grains and spores for a more precise interpretation. 38 samples were analyzed in terms of pollen and spore content.

During the first part of the project our activities were focused on analyzing spores and pollen with the use of a microscope Olympus BX-60. The second part of the project was mainly focused on electronically processing the results in order to compile pollen diagrams.

Accomplishments

Our research was accomplished in accordance with our working program. All figures, showing the percentage results described below, are available at the OSL.

Results

The core from KI001 was obtained from the depth of 42 meters in the Yana paleovalley. According to the radiocarbon dating (10310 and 10360 years BP) we assume that the recovered sediments were formed at the end of the Late Pleistocene to the early Holocene. The bottom part of the core contains the permafrost sediments, and on this part of the core micropaleontological studies have not yet been carried out. During the past years the observations on aquatic palynomorphs and diatoms have been completed. AMS dating shows that the marine sedimentation conditions obviously began about 10.5 kyr.

The pollen spectra content of this cores show rapid paleoclimatic and landscape changes with a tendency to climate warming based mainly on the high percentage of arboreal pollen from depths of about 200 cm. Two pollen zones reflect the Holocene warming and suggest that pollen zones 2 and 3 might be referred to the PB time. This conclusion is based not only on the dating but also on the rapid increase of the arboreal pollen up to 55-60%, presented mainly by birch pollen and shrubs. Pollen zone 1 of this core shows a low content of arboreal pollen (not more than 15%), and a very low content of herbaceous species. The only herbaceous species defined are species typical for cold and dry conditions, such as sedge pollen, which reaches its maximum in the studied section, and the pollen of several xerophytes species. Compared to this we see a rapid increase and variety of the herbaceous pollen in the upper pollen zones. Another clue for the beginning of the Holocene is provided by several findings of *Selaginella Selaginoides* spores, which are typical for the Pleistocene-Holocene transition. According to these conclusions pollen zone 1 can be referred to the Younger Dryas cooling.

Core PS51-154-11 was recovered from the depth of 270 m on the continental slope. According to radiocarbon dating (13120-1540 years BP) the sediments of the core started to form between the end of the Late Pleistocene and the Late Holocene. The percentage pollen diagram (Fig. 1) was compiled taking the entire pollen sum as 100%. The concentration pollen diagram was compiled using the formulas proposed by Iversen (Faegri and Iversen, 1989):

A = (Fossil pollen counted x Total number of markers)/Markers counted

where A= Total fossil pollen.

Concentration of fossil pollen (pollen per cm^3) =A/volume of the sediment; Pollen influx=concentration x rate of sedimentation.

The percentage pollen diagram was divided into three pollen zones reflecting changes in the main dominants. Pollen zone 1 shows a similarly high content of both arboreal (AB) and nonarboreal (NAB) pollen (approximately 40% each). Spores are observed in the amount of 10-15%. The group of trees is represented mainly by Pinus s/g Haploxylon, which is considered to be secondary pollen. *Picea* and shrubs pollen content is extremely low with approximately 1%. In the herbaceous group *Poaceae* pollen predominates with 30%. As it is typical for tundra conditions, herbs such as *Artemisia, Asteraceae, Caryophyllaceae* and *Ericaceae* are found in a very low content, not exceeding 5%. In the spores group *Polypodium* spores dominate (up to 70%) with a mixture of *Shagnum* and *Lycopodium*.

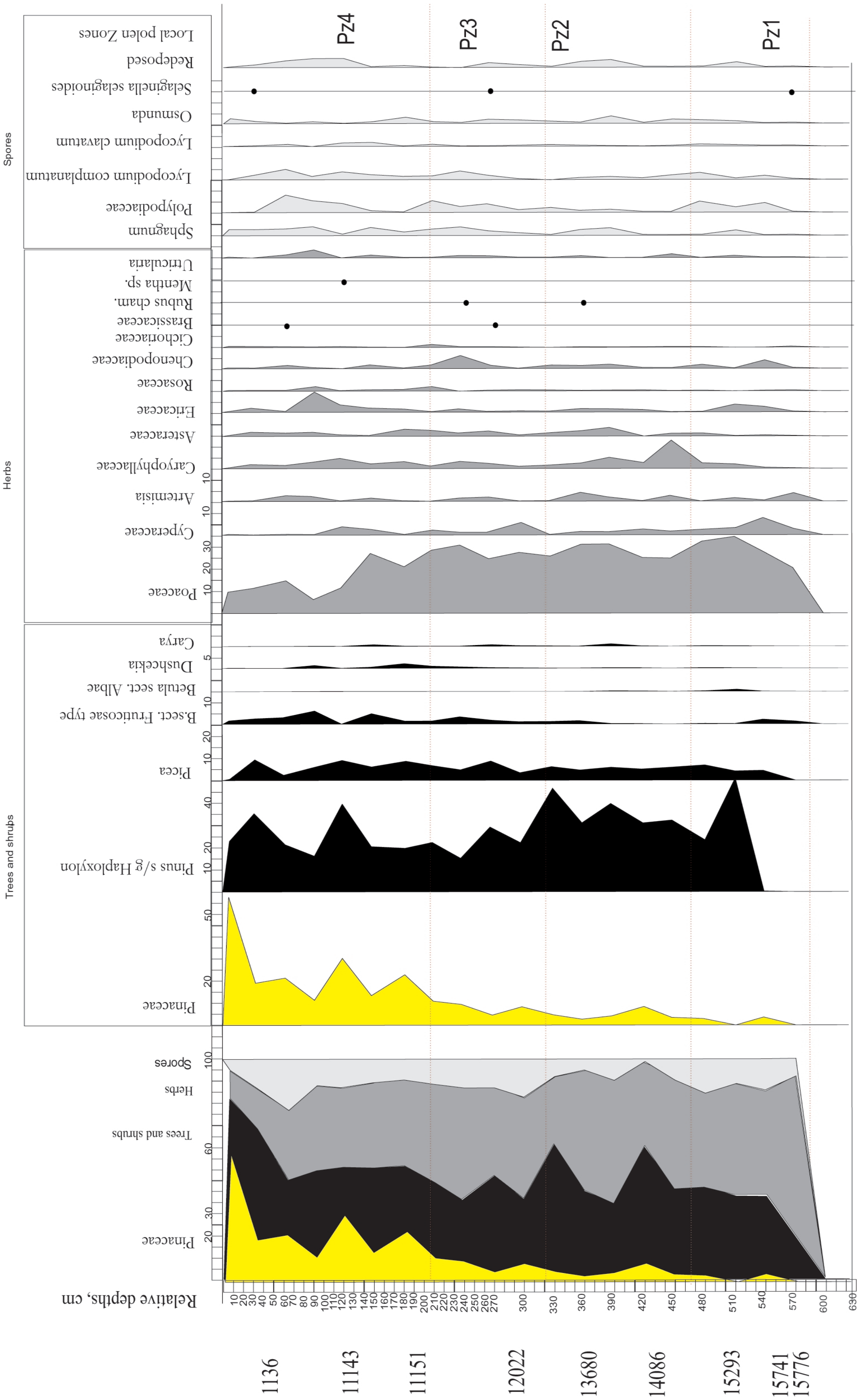

Fig. 1: Percentage pollen diagram for PS51-154-11.

In general, pollen zone 2 shows a rather similar ratio of AB/NAB. Arboreal pollen is also represented by *Pinus s/g Haploxylon* mainly together with *Picea* pollen, but the percentage of transported *Pinaceae* pollen increases gradually. Birch shrub and alder pollen is extremely rare although in comparison with the lower spectra their presence becomes meaningful as reflecting the transition to the warmer Holocene conditions. Among the herbs *Poaceae* pollen dominates (25-30%). The diversity of herbs increases. *Artemisia* pollen is found in the amount of 5-7%. *Caryophyllaceae* pollen has its maximum at the depths of 480-420 cm (up to 10%). The *Artemisia* pollen curve shows an increasing trend up to 6%. *Chenopodiaceae* pollen is also found in maximum quantity (7-8%). In the group of spores *Sphagnum* and *Polypodiaceae* dominate. *Osmunda* curve is characteristic for this pollen zone (up to 5%).

Pollen zone 3 shows a rapid increase of the secondary *Pinaceae* pollen leading to an increase of the AB pollen in the general content up to 80%. AB pollen is represented by *Pinus* s/g *Haploxylon, Picea*. Shrub birch percentage increases up to 7%. *Duschekia* is typical for this pollen zone (3-4%). In the group of herbs a rapid decrease of Poaceae pollen was noticed (down to 15%). Among the tundra species Ericaceae pollen reaches its maximum (up to 10%). Pollen of Artemisia, Asteraceae, Rosaceae and Chenopodiaceae families reaches not more than 5%. Aquatic pollen (*Utricularia*) is found (reaching 5% in the upper part of the zone). In the group of spores Polypodium spores dominate with Sphagnum, Osmunda and Selaginella being also found.

For core PS-51-159-10 (Fig. 2, Table 1) it was found that pollen zone 1 is characterized by domination of both arboreal and herbaceous pollen. Arboreal pollen is represented by *Pinus s/g Haploxylon* mostly (up to 40%), *Picea* (10-25%) and *Betula sect. Fruticosae* (up to 5%). Coniferous pollen is supposed to have been transported here from far-away areas. Birch pollen is likely to have been transported here from the nearby surroundings. The group of herbs is represented mainly by *Poaceae* pollen (30%, up to 50 %). *Cyperaceae* reaches its maximum at these depths (5-12%). Other typical tundra flora is represented by *Artemisia, Asteraceae, Caryophyllaceae* and *Ericaceae* families (not exceeding 5%). Varia content is poor and is characterized by the following families: *Brassicaceae, Lamiaceae, Rosaceae, Rosaceae, Polygonaceae*. Among aquatics Utricularia pollen is observed.

Pollen zone 2 was determined on the basis of a increase in arboreal pollen (up to 75%). It is again represented by *Pinus s/g Hyploxylon* (50-60%), *Picea* (15-25%), and *Betula* sect. Fruticosae (up to 10%). In the group of herbaceous pollen Poaceae also dominates in the spectra but decreases to 35%. The content of *Cyperaceae* pollen decreases rapidly to 3%. Typical for this pollen zone is an increase of Asteraceae, Caryophyllaceae, and Caryophyllaceous pollen (up to 7%). Another characterizing factor is the presence of redeposed broad-leaved pollen such as *Ulmus, Pterocarya*, and *Tilia* in the highest amount of the whole section. Varia spectra are found in a very poor amount and abundance. This zone has a maximum of aquatics pollen (*Utricularia*). In the group of spores the Sphagnum curve rises up to 70 percent. Also *Osmunda* pollen is found in the amount of 10-25%.

Pollen Zone 3 is characterized by the predominance of arboreal pollen in general. Arboreal vegetation is mainly represented by coniferous pollen (*Pinus s/g Haploxylon* 50-60%, Picea content decreases down to 10% as well as birch pollen down to 5%). Among the herbaceous pollen *Poaceae* pollen predominates while *Cyperaceae* gradually decreases until it completely disappears. The amount of *Artemisia, Ericaceae Asteraceae and Caryophyllacae* decreases rapidly. Varia diversity is poor. In the group of spores *Polypodiaceae* and *Sphagnum* dominate (up to 40%). *Osmunda* and *Selaginella* spores are found.

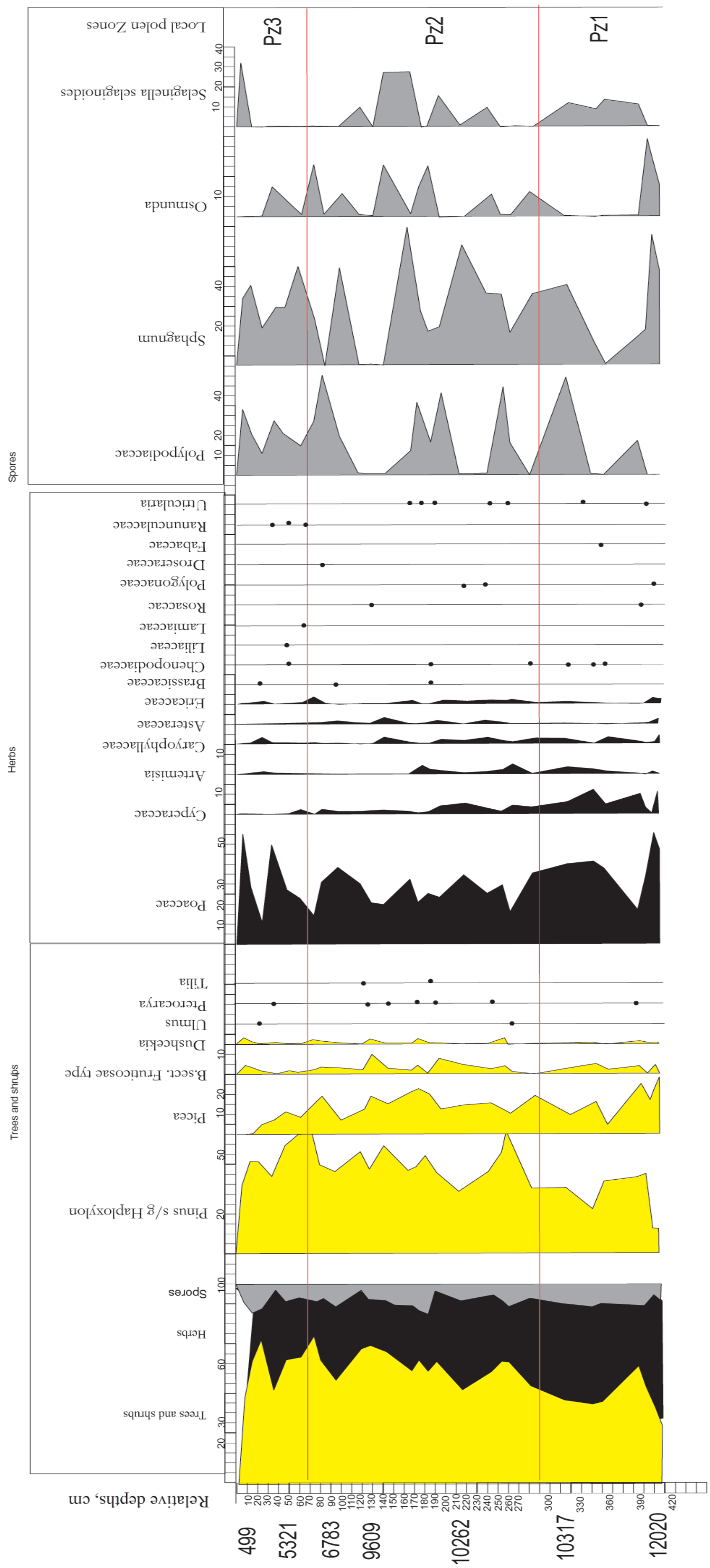

Fig. 2: Percentage diagram for PS-51-159-10.

Table 1: List of concentrations of pollen grains per sample/per gram for PS-51-159-10

Depth (cm)	Pinus s/g Haplpxylon	Picea	Betula sect. Fruticosae	Dushckia fruticosa	Poaceae	Artemisia	Asreaceae	Caryo-phyllaceae	Ericaceae	Brassicaceae	Cheno-podiaceae	Lamiaceae	Ranuncula-ceae	Droseaceae
8	329		65	65	509									
15	277		29		170									
22	319	29	9		69	9		18	9	9				
36	949	192			1200				14				14	
50	921	226	26		440				13				13	
64	675	100			250							15	15	
71	988	200	38	19	200				76					
78	94	216	50	15	200									15
92	591	100	50		533		10			10				
120	1468	400	66	66	900									
127	1400	700	266		600	12	5			66	66			
141	1500	250	116		500	116		58						
169	800	30	69		600		23		69					
176	1700	550	98	65	550	130		30		30				
183	1005	282			600	62		3	31		31		31	
190	600	209	150		418	36	36		36			38		
218	734	250	111	22	750	22		11		11			11	
246	350	50		21	150	32		18		23				9
253	700	150	100		600	50	10	10			10			
260	800	115	26		233	90	23			23	23			
281	700	300	14		700			35		35			74	
316	700	150		50	750		100		65					
337	300	164	80		550	20	40		20	40		40		
351	450	80			470	12		40		20		12		

Conclusion

According to the pollen data (both percentage and concentration diagrams) and the reliable radiocarbon dating we assume that all the sediments from the studied cores started to form under the severe environmental conditions of the Pleistocene as several samples from the bottom parts of the cores are extremely poor in terms of pollen and spores content or other microfossils. Also the concentrations of the pollen dominating in the lower parts of the cores are very low. The occurrence of *Selaginella selaginoides*, typical for the Pleistocene environments, and *Osmunda* spores also provide evidence for the Pleistocene age of the bottom samples.

The Holocene percentage of pollen spectra from the cores might at first glance show rather unchangeable conditions with the dominance of transported coniferous pollen in the spectra. Nevertheless, based on the concentration variability it is clear that pollen production varied during the Holocene. At the beginning of the Holocene the Laptev surroundings were dominated by xerophytos and steppe sedge vegetation with tundra grasses. Shrubby vegetation began to spread widely until 8,000 years ago.

Most arboreal pollen in the spectra are presented by pollen of coniferous trees, transported by wind and rivers, and redeposited pre-Quaternary (secondary) pollen of broad-leaved vegetation. Mainly the transported pollen (*Pinus s/g Haploxylon*, for example) originates from the central arctic regions.

The obtained pollen data clearly show the Late-Pleistocene/Holocene transition on the basis of the presence of several typical Pleistocene species and the increase/decrease of concentrations for the dominant species. Thus, it becomes possible to understand the changes in freshwater discharge to the Siberian shelf during the Holocene and the Late Pleistocene.

References

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EVOLUTION AND MODERN CONDITION OF THE PERMAFROST AND THE GAS HYDRATE STABILITY ZONE ON THE ARCTIC SHELF OF EASTERN SIBERIA

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Introduction

The research investigations within the framework of the joint Russian-German marine and terrestrial studies provided the opportunity to extend the representations about the environment of the Arctic shelf of Eastern Siberia. Studies on permafrost and the gas-hydrate stability zone (GHSZ) evolution on the Arctic shelf are a relatively recent focus of research. During the last years investigations have been carried out within the Russian-German programs “Laptev Sea System” and “Laptev Sea System 2000.” In this project the boundaries of the investigated area were expanded. Our study area also includes the western part of the eastern Siberian shelf. Marine and terrestrial studies have recently been carried out in these areas. The obtained results allowed us to expand the area of modeling.

Scientific background

It is known that for the Eurasian Arctic shelf areas, especially those of the Kara, Laptev and East Siberia seas, submarine permafrost and gas-hydrate occurrences are characteristic features. In some of the shelf areas oceanic rift zones extend to the continent, as for example in the Laptev Sea area where the Lomonosov Ridge continues on the land. Great differences in geothermal heat flow values (q_{gt}) and rock properties in undisturbed blocks of the lithosphere and in fault zones in this region are assumed as they are known from continental rifts (such as Momskii and Baikalskii rifts). As a result differences in the thickness of permafrost and the gas-hydrate stability zone (GHSZ) within these structures are expected. The thickness of permafrost and the GHSZ essentially and irregularly vary during the different stages of regressions and transgressions of the sea. For the investigation of permafrost and GHSZ evolution, and their dynamic and interaction in rift structures, a two-dimensional mathematical model has been elaborated. The paleogeographic scenario used in calculation covers the time from middle/late Pleistocene to the Holocene (c. 400 kyr), i.e. the last four climatic and glacioeustatic cycles. Model calculations for rift structures of different sizes and different q_{gt} values, which are typical for the different geographic situations on the shelf and, consequently, have a different paleogeographical history, have been carried out. (Eliseeva et al., 2004).

Goals and objectives

The main goals of the project were to study the distribution, evolution and parameters of permafrost and the gas-hydrate stability zone on the Laptev and East Siberian shelves and to investigate permafrost and GHSZ thickness fluctuations in the rift structures which are typical for the Laptev and East Siberian shelves. The main objectives of the project were:

- to draw schematic maps of GHSZ and permafrost thickness on the Arctic shelf of Eastern Siberia; the maps will be compiled on the basis of the modeling results;

- to determine a pattern in the “fluctuations” of thicknesses and to define the conditions for leading to the formation of open taliks and a permafrost and GHSZ “cover” above these structures;
- to mark and map shelf zones with permanent open taliks and zones with temporary taliks at the end of the transgression stages.

An additional task was to determine the conditions in which gas is emitted and to estimate the concentration of hydrates or gas in the dome parts of the rift structures. This specific scientific aim was very difficult to achieve and, therefore, this task could not be completely carried out within the framework of this project.

Research activities

The project team took part in “The 1st OSL Spring School for Analytical Methods in Marine and Polar Sciences” from March 29-April 2, 2004. As a consequence of the advanced analytical training the participants of the project became familiar with the methods of modern laboratory research and with the equipment available in the OSL.

Our series of experiments on lake, thermokarst, alas and sea deposits from the Laptev Sea region with respect to the quantitative determination of carbon and nitrogen in sediments and the chemical structure of the pore waters and ice was coordinated with the management of the OSL. V. Tumskoy and A. Kholodov selected the samples in April 2004 from the deposits recovered from a zone of sea/land interaction. The main objective of our research was to establish the differences in chemical composition and maintenance of carbon in the continental sediments flooded by sea water on the one hand and in the marine sediments fallen dry due to regression and frozen through under the influence of the severe Arctic climate on the other hand.

In June 2004 A. Belan, and in July 2004 A. Eliseeva had the opportunity to work in the OSL. They carried out experiments on more than 140 samples. The results are still being processed. A. Belan participated in the joint Russian-German expedition to the Laptev Sea TRANSDRIFT X, in September 2004. A. Belan and A. Eliseeva carried out a survey of the international journals available at the OSL. Besides this A.Eliseeva used the OSL computer laboratory for carrying out modeling of the evolution of the permafrost and the gas-hydrates stability zone in rifts on the Arctic shelf of Eastern Siberia. She tested and then used the new, improved versions of computer programs for her calculations. These programs are being created together with G.S. Tipenko from the Institute of Geophysics of the University of Alaska Fairbanks, USA, within the framework of a grant.

Results

A preliminary result of our research is the conclusion that the long-term dynamics of the permafrost and GHSZ thickness on the shelf creates significant distinctions in their thicknesses in faults and in undisturbed blocks of the lithosphere. These distinctions are caused by different q_{gt} values (geothermal heat flux magnitude in fault zones of various sizes) and create anticlinal structures of different size on the permafrost bottom (Figs. 1, 2). It is possible, that under changing P-T conditions (periodical changes of external pressure (P) values are the result of the sea level fluctuations during the transgressions, and changes of temperature (T) values of the rocks and aggradation of the permafrost can be observed during the regressions of the sea) there can be observed a concentration of hydrate gases.

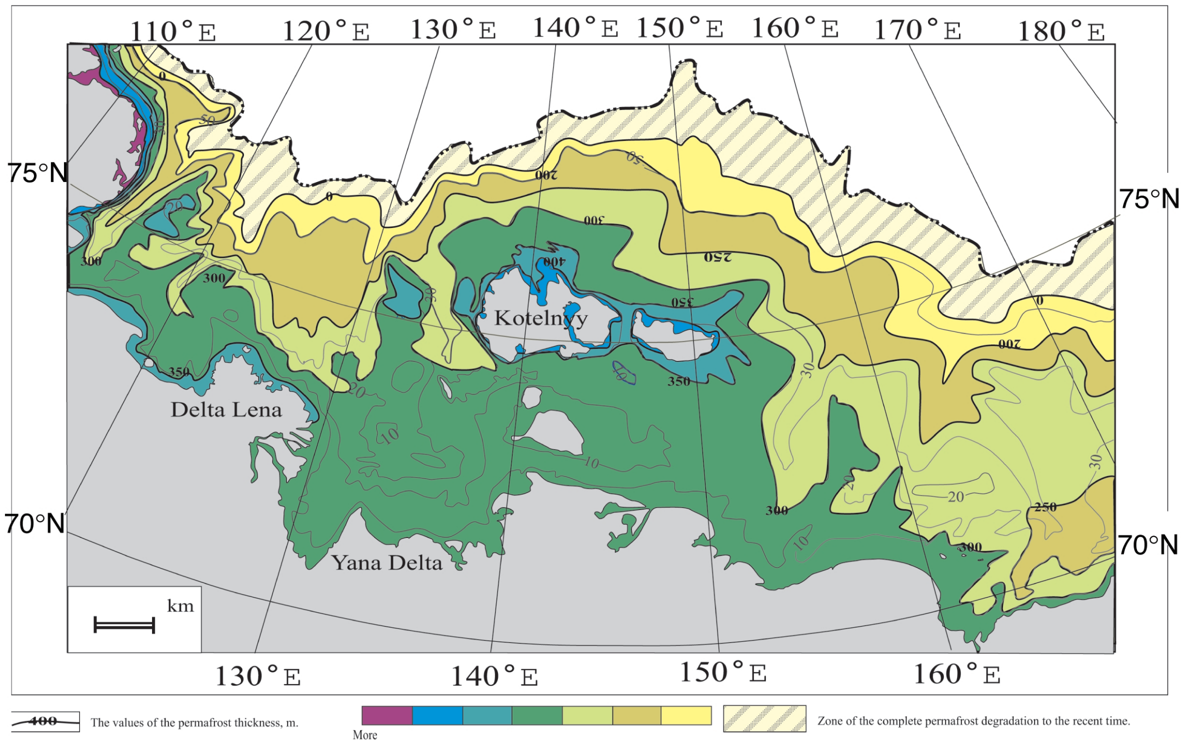

Fig. 1: Map of recent submarine permafrost thickness. Results of simulation for unconsolidated Quaternary deposits geological profile. Geothermal heat flow (q_{gt}) equals 70 mW/m^2.

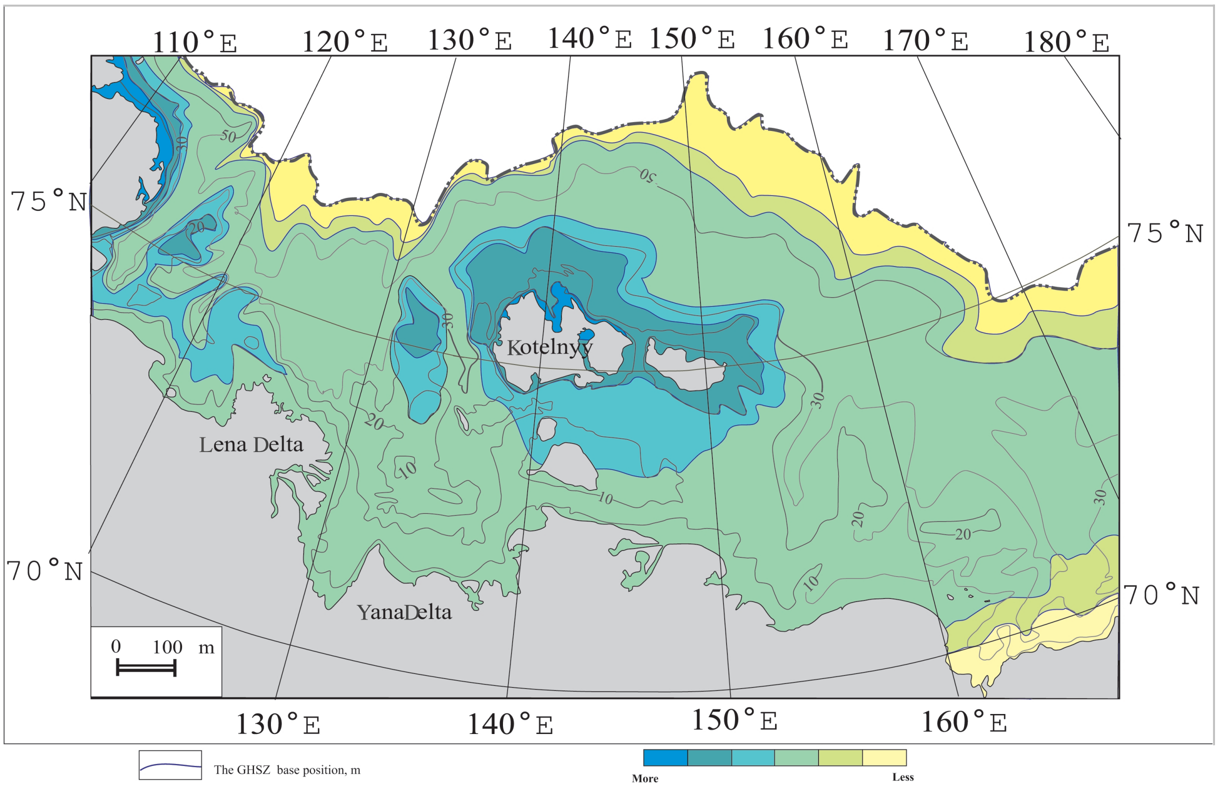

Fig. 2: Map of the recent position of the GHSZ base. Results of modeling based on the unconsolidated geological profile of Quaternary deposits. Geothermal heat flow (q_{gt}) equals 70 mW/m^2.

The fact that the submarine permafrost formed such a long time ago is the reason for its full degradation and the disappearance of the GHSZ in the external part of the shelf. The periodical emission of greenhouse gases from relict sub-permafrost layers on the periphery of the shelf can be estimated. In contrast to this, the permafrost and GHSZ have note completely degraded in the internal part of the shelf, and conditions for a long accumulation of gases and/or their hydrates prevail.

The following results were obtained during this project:

- during transgressions permafrost thicknesses essentially decrease in rift structures in comparison with the consolidated blocks of the earth's crust, containing them, with lower q_{gt} values (Fig. 1);
- variations of permafrost and GHSZ thicknesses in rift zones and in single faults depend on their parameters, sizes and q_{gt} values;
- upward seepage of artesian waters from under the permafrost and emission of underground gases can be widely distributed at the shelf periphery through the open taliks, due to zones of tectonic faults with high q_{gt} values (100-150 mW/m^2);
- the modeling results show that at the lower boundary of the permafrost in rift zones, "anticlinal" structures form as well as open taliks, which form due to the thawing of the relict permafrost under the influence of heat fluxes. Such taliks are characterized as open submarine and endogenic taliks;
- it is possible that these "anticlinal structures" can serve as sites for the concentration of underground gases and their hydrates under the lower boundary of the permafrost. At the same time emission of greenhouse gases to the atmosphere can take place through the open submarine and endogenic taliks, which periodically formed at the end of transgression cycles for at least 400,000 years;
- the results of our studies, however, pose a new problem, namely the question where and how the underground gases on the Arctic shelf of Eastern Siberia are redistributed as a result of periodic changes of distribution, permafrost and GHSZ thickness, and also of P-T conditions in the layers of the lithosphere under the lower permafrost boundary.

Conclusion

The modeling results show that in the stages of climatic warming and transgressions, the thickness of submarine permafrost considerably decrease, though rather extremely irregularly. The permafrost thickness decreases in fault zones to a much greater extent than in the consolidated blocks with lower q_{gt} values. The processes of GHSZ thickness variation are similar. Variations in the thickness of permafrost and the GHSZ depend on fault zones and single faults sizes, and q_{gt} values. For example, in recent times an open talik and a "break" in the GHSZ have existed under a 20-km-wide fault zone at q_{gt} = 100 mW/m^2, but they have not formed under an only 5-km-wide fault zone at the same value of q_{gt}. The calculations were carried out for the present water depth of 10 m at 71°N. According to the results of the simulations, a first estimation of the regularities of the variations in permafrost and GHSZ thicknesses has been carried out. The possibilities and the boundary conditions for the occurrence of open taliks and "breaks" in the GHSZ, which may result in an emission of greenhouse gases from relict sub-permafrost layers, have been estimated. This effect, first established during our modeling, has an influence on the gas concentration in the rift structures and requires further investigations.

In subsequent stages of investigations it is desirable to receive quantitative regularities of formation and duration of existence of such anticlinal “traps” and endogenic open taliks in rift structures on the shelf of Eastern Siberia taking into consideration parameters of the taliks, their geographical position and q_{gt} values.

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PATHWAYS AND FLUXES OF NATURAL AND ANTHROPOGENIC TRACERS IN THE WESTERN RUSSIAN ARCTIC SEAS

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Introduction

Scientific background

The Arctic has a strong influence on the environment of the Earth. The very fragile equilibrium between its physical, chemical and ecological parameters (depending on low rates of reproduction of biological resources) makes the Arctic an indicator of global change. The Arctic Ocean and its vast and shallow marginal shelf seas are considered to be a significant component in the understanding of the modern global climate system and its variations (Stein et al., 2003).

The maximum river discharge (of Ob, Yenisey, Lena and others) takes place during 1-2 spring months (Gordeev et al., 1996). During this short time the main part of mineral suspended matter and allochthonous organic matter is delivered to the arctic seas. When river and seawaters mix, significant chemical and biogeochemical transformations take place. The mixing zone in the river estuary can be regarded as a global filter for the suspended and dissolved river load (Lisitzin, 1995).

Traditionally, riverine input was assumed to be the main geochemical pathway of terrestrially and anthropogenically derived compounds from their sources to the marine environment, but there is much evidence that atmospheric input contributes significantly to marine areas (Lisitzin, 1996). Numerous studies have shown that atmospheric and ice-rafted transport are of importance for the Arctic environment (Nürnberg et al., 1994; Pfirman et al., 1995; Hölemann et al., 1999; Lisitzin, 2002; Shevchenko, 2003; Shevchenko et al., 2003).

Much more research has been devoted to revealing the pathways of sedimentary matter into the Laptev, Kara and Barents seas and to studying the biogeochemical cycles of many elements in these basins so important for the Arctic environments (Kassens et al., 1999; Stein and Macdonald, 2003). However, the processes of modern sedimentation in the White Sea habe been studied insufficiently. The relations between atmospheric and ice-rafted input of natural and anthropogenic substances and vertical particle fluxes in the water column in Russian Arctic seas are as yet largely unknown.

Goals and objectives

We studied the role of atmospherically derived elements and compounds, suspended matter, ice-rafted sediments, and vertical particle fluxes in the processes taking place in the shelf seas of the Western Russian Arctic (the Laptev, Kara, Barents, Pechora and White seas). Our work was focused on samples from the White Sea because here we had the possibility to realize ideas and principles of the multidisciplinary studies of the Russian-German program "Laptev Sea System." Academician A.P. Lisitzin organized these investigations in the White Sea within the framework of the "White Sea System" program and we studied the composition of aerosols, suspended particulate matter, sedimentary matter from sediment traps and bottom sediments collected during 17 expeditions to the White Sea. We compared our results of the White Sea studies with our and literature data from the other Arctic seas.

Research activities

Approach

In 2004 participants of our project took part in 4 expeditions to the White Sea area (Fig. 1) (in the expeditions to the Chupa Inlet from March 26 to April 8, 2004, to the Northern Dvina delta in May 2004, in the expedition onboard the RV "Ekolog" to the Onega Bay and in the 64[th] expedition of the RV "Professor Shtokman") and in the ARK XX/3 expedition of the RV "Polarstern" to the Yermak Plateau and Fram Strait in September.

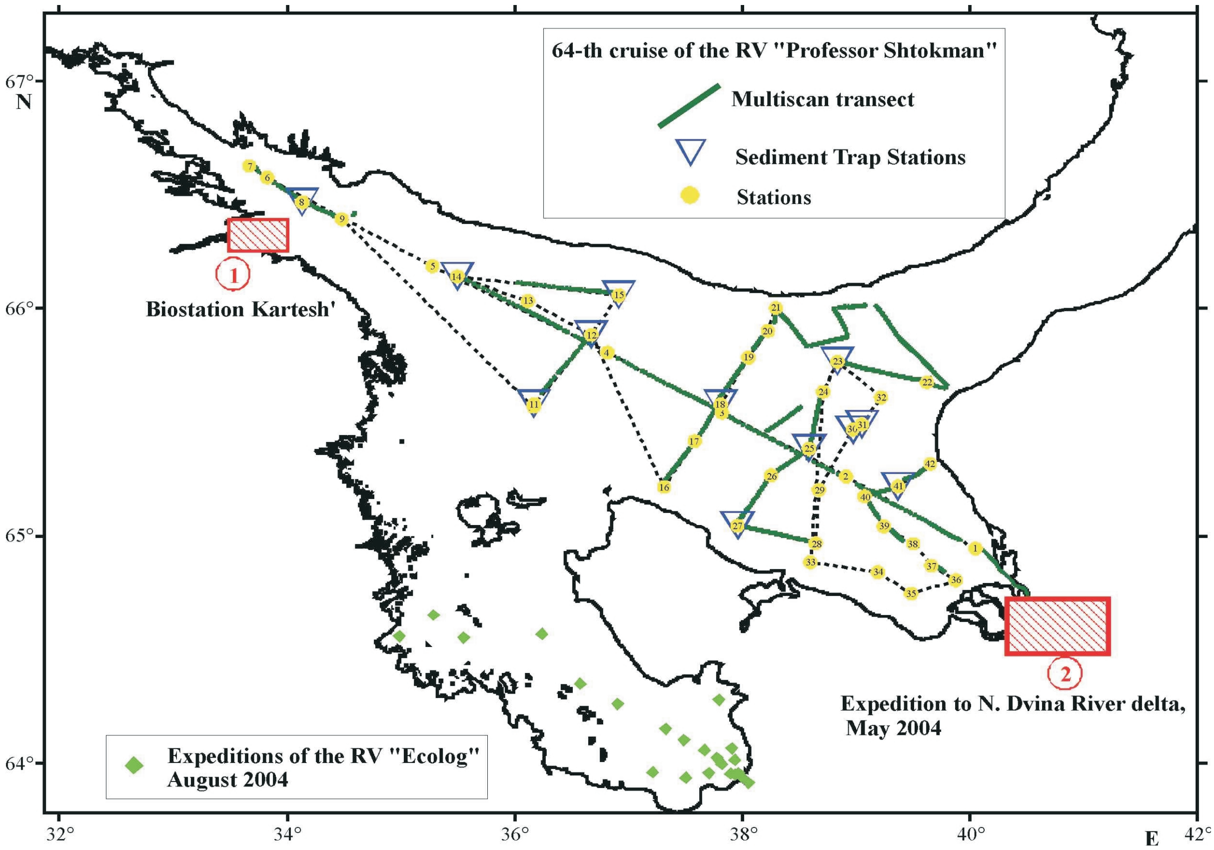

Fig. 1: Working areas of expeditions to the White Sea in 2004.

The expedition to the Chupa Inlet was carried out at the end of winter/beginning of spring. The distribution and composition of aerosols, particulate matter in snow, ice and in the water column, and vertical particle fluxes were studied. In May we studied the biogeochemistry of the Northern Dvina delta (aerosols, particulate matter in water, bottom sediments) during the maximum flood.

During our project we analyzed the samples collected earlier and processed the data. Part of our analytical work was carried out in the OSL by A. Novigatsky (analysis of suspended particulate matter and sedimentary matter from the White Sea with the C/N analyser VARIO EL III and microscopy with the Olympus BX50 microscope). In more detail the methods of our studies are described elsewhere (Shevchenko et al., 2003, 2004a,b).

In accordance with our working program, we carried out:

- analysis of aerosols collected during the expeditions to the White Sea to estimate the proportion of marine, terrigenic and anthropogenic sources of aerosols;

- calculation of back trajectories of air masses to sampling sites and areas of interest in the Laptev and White seas, that could help to identify the source of anthropogenic pollution;
- study of composition of snow, with respect to aerosols in dissolved phase and as particulate matter. Microscopy can help to identify the role of different sources (biogenic, terrigenic, anthropogenic) in the formation of aerosol particles deposited in the snow cover;
- microscopy examination and chemical analysis of ice-rafted sediments from the Laptev and Barents seas and Central Arctic in comparison with samples from the White Sea to find pathways of sedimentary matter;
- study of the distribution and composition of suspended particulate matter in the White Sea and comparison of these results with our and literature data from the other regions of the Western Russian Arctic. According to the system approach in oceanology, the suspended matter was studied in parallel with particulate organic carbon, Chlorophyll *a*, for the whole sea using satellite data and verification in expeditions (Lisitzin, 2003). This approach helps us to reveal peculiarities of modern sedimentation processes in the White Sea;
- study of biogeochemical processes in marginal filters (river-sea barrier zones) and comparison of marginal filters of Siberian rivers and rivers flowing into the White Sea;
- study of vertical particle fluxes using samples from short-term and annual deployment of sediment traps in the White Sea (new samples) and other seas of the western Russian Arctic (previously obtained samples and data). We determined the values of fluxes, their seasonality, and the dominating mechanism of sedimentation.

Accomplishments

With the applied method we studied the role of atmospherically derived elements and compounds, suspended matter, ice-rafted sediments, and vertical particle fluxes in the processes taking place in th eshelf seas of the western Russian Arctic (the Laptev, Kara, Barents, Pechora and White seas). The research was mostly in accordance with our working program, but we focussed our work on the White Sea. The main reason of this focusing, as it was mentioned above, is the good logistic possibility to realize the ideas and principles of the Russian-German program “Laptev Sea System” in the White Sea.

Results

Aerosols and aeolian input

Concentrations of aerosols in the Chupa Inlet area at the end of March/beginning of April 2004 were very low and typical for background areas. Aeolian transport of polluted air masses to the studied area was not registered. The fluctuations of aerosol particle concentrations in the period of the expedition were caused by local factors (variations of temperature, humidity, wind speed and direction). In two samples the concentrations of heavy metals were by a few times higher than the average value. The reconstruction of back trajectories testifies to the fact that air masses came to the studied area from the industrial centers of the Kola Peninsula.

The thickness of snow cover over the sea ice was 5-15 cm. On the adjacent land it varied from 10 to 70 cm. Particulate matter concentration in the snow varied from 0.33 to 2.63 mg/l. The average value was 0.84 mg/l (n = 16 samples). This value is a typical background concentration for a pristine environment (Shevchenko et al., 2004b). The thickness of ice cover in the Chupa Inlet was around 30 cm in the axial part and 70-100 cm in Krivozerskaya Inlet. Particulate matter concentration in most parts of the ice cores was 0.7-3.6 mg/l, increasing to 13.4-26.3 mg/l in the lowest 2 cm of the ice sheet where microalgae bloom took place (Fig. 2). The concentration of heavy metals in snow and ice in the Chupa Inlet was low, corresponding to the background level. The concentrations of Cd, Pb and Ni are higher in snow, which could testify to the dominance of atmospheric source of these elements. In general, the results of multidisciplinary studies in the Chupa Inlet at the end of winter show that this area could be regarded as a pristine region.

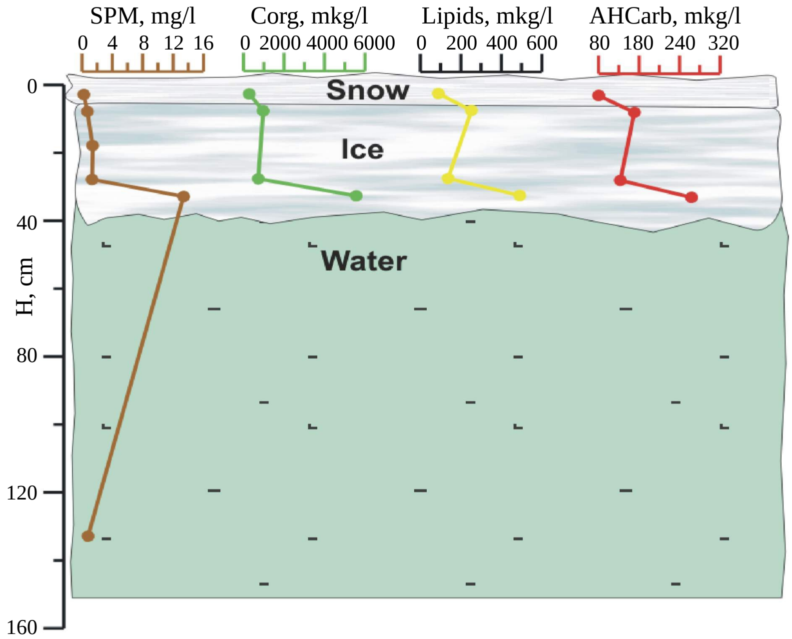

Fig. 2: Suspended particulate matter (SPM), organic carbon (C_{org}), lipids and aliphatic hydrocarbons (AHC_{arb}) concentrations in the snow, water and ice in the Chupa Inlet at the end of March/beginning of April 2004.

Our studies of the White Sea aerosols show that the average concentration of insoluble aerosols is around 0.17 µg/m^3. This value is close to the average for Arctic seas, so using the value of flux (597 mg m^{-2} y^{-1}) (Shevchenko, 2003) and the area of the White Sea (90,000 km^2), we could estimate the annual flux to be around 54000 t y^{-1}. The composition of White Sea aerosols is similar to the composition of aerosols of the Arctic seas. In general, the concentration of heavy metals in the White Sea aerosols corresponds to the background level, but for some chemical elements (Pb, V, Cd) aeolian input into the White is important (the same was shown for other seas of the Russian Arctic (Shevchenko, 2003; Shevchenko et al., 2003)).

The marginal filters of the White Sea

The Northern Dvina is the main source of riverine suspended matter supply to the White Sea (Gordeev et al., 1996). We studied the distribution of SPM in the Northern Dvina mouth during several expeditions.

Our field studies during the peak of flood in May 2004 demonstrated that the concentration of SPM at the Ust'-Pinega cross-section varied from 4 to 14.7 mg/l (8.9 mg/l on average, n = 16 samples). Almost the same values were registered upstream from this cross-section in the Pinega River (6.7-11.3 mg/l) and in the Northern Dvina 10-50 km upstream from the Ust' Pinega (7.3 mg/l). In the Maimaksa Branch from the Solombala Island to Lapominka the concentration of SPM in the surface layer varied from 5.8 to 13.9 mg/l (10.2 mg/l on average, n = 11). It is at the same level as it was previously reported (Shevchenko et al., 2004a) for this branch for the end of the flood on June 11, 2003 (13.2 mg/l); in mid-April 2003 it was 2.48 mg/l and on August 20, 2003, 6.14 mg/l. All these values were much lower than the concentrations in the marginal filters of the large Siberian rivers (Gordeev et al., 1996; Lisitzin, 2003).

In the mixing zone the concentrations of SPM sharply decrease with the increase of salinity. In the marginal filter of the Northern Dvina as in Siberia (Lisitzin, 2003), the following processes follow one after the other on the way from the river to the sea: gravitational sedimentation, physico-chemical processes in colloid system (coagulation and flocculation, formation of sorbents), and, finally, biological processes (growth of phytoplankton with conversion of dissolved elements to biogenic suspended matter and the process of biofiltration).

The Onega provides the third-largest SPM discharge to the White Sea. The concentration of SPM in its mouth in September 2002 was 53 mg/l and of POC 1220 µg/l. The content of POC in riverine suspended matter was 2.3%. In the mixing zone the concentration of SPM and POC sharply decreased to 3.88 mg/l and 227 µg/l, respectively at a salinity of 21.5‰. At the same time the contents of POC in the SPM increase up to 5.8%. In the outer part of the marginal filter where salinity increases to 25‰, the SPM concentrations decrease to 1-2 mg/l and POC to 129-387 µg/l, but the content of POC in SPM increases up to 32-39.7%.

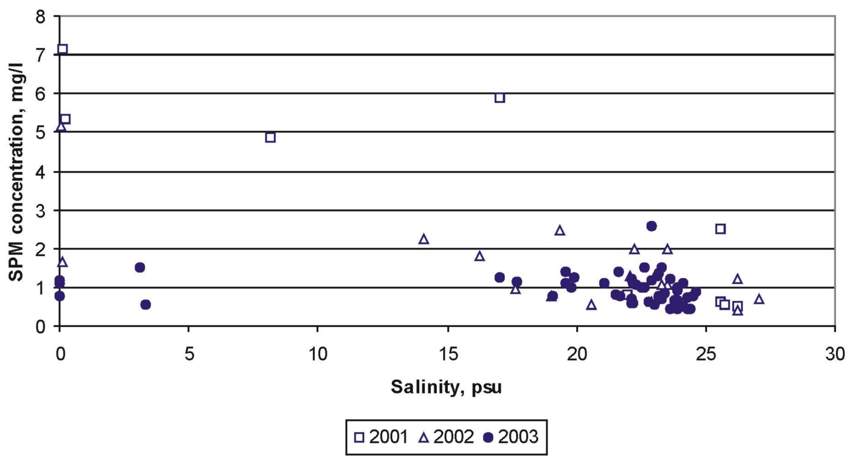

Fig. 3: Suspended particulate matter (SPM) concentration vs salinity in the surface layer of the Kem' mixing zone in July 2001, August 2002 and July 2003.

Biogeochemistry of the river-sea interface was studied in the Kem' River estuary and the adjacent area of the White Sea in summer 2001-2004. The Kem' is the largest river flowing to the White Sea from the Karelian coast. At the beginning of July 2001 the highest SPM concentrations (5-7 mg/l) were registered in the Kem' mouth. These values are much lower than in the estuaries of the large Siberian rivers in the same season (Rachold and Hubberten, 1999; Lisitzin et al., 2000). Such low SPM concentration in the Kem' River mouth could be the result of the low weathering rate of hard crystalline rocks in the catchment area of the Kem'. SPM concentrations sharply decreased to values <1 mg/l towards the sea where salinity increased (Fig. 3). At the end of August 2002 SPM concentrations decreased from 5.17 mg/l in the river mouth to 0.42-1.20 mg/l in the marine part of the mixing zone. At the end of July/beginning of August 2003 SPM concentration in the Kem' was very low (0.77-1.17 mg/l) due to unusually low precipitation rates. The distribution of SPM in the surface layer was irregular. In general, there was no significant decrease of SPM concentration in the direction river-sea. SPM concentrations during flood tide were higher than during the ebb tide at the same stations. This shows the input of riverine terrigenic material.

The vertical distribution of suspended matter in the outer part of the estuary and adjacent sea is characterized by a pronounced three-layer structure with two maxima of suspended matter concentration: above the pycnocline and near the bottom (nepheloid layer). The increase of SPM concentrations in the nepheloid layer is caused by resuspension of bottom sediments by tidal currents. The same character of SPM vertical distribution is described in the White Sea and other Arctic seas (Lisitzin et al., 2000; Lisitzin 2003).

These studies show that the main part of suspended matter in the Kem' estuary is deposited near the river mouth in the marginal filter area within the 20 psu isohaline, where avalanche sedimentation of the suspended matter takes place. In phytoplankton the role of freshwater species decreases and the role of marine species increases from the river to the sea. In this direction the percentage of green algae decreases and the role of diatoms increases. C_{org}/N ratio in both suspended matter and bottom sediments decreases from river to the marine part of the mixing zone, demonstrating that content of terrestrial-derived organic matter decreases and content of marine organic matter increases in the direction from the river mouth to the sea.

In the marginal filter of the Northern Dvina, Onega, Kem' and some other White Sea rivers as in Siberia, the following processes follow one after the other on the way from the river to the sea: gravitational sedimentation, physico-chemical processes in colloid system (coagulation and flocculation, formation of sorbents), and, finally, biological processes (growth of phytoplankton with conversion of dissolved elements to biogenic suspended matter and the process of biofiltration). The character of geochemical processes in the Northern Dvina, Onega and Kem' estuaries is similar to that of the large Arctic estuaries, described elsewhere (Lisitzin, 1995; Dittmar and Kattner, 2003).

The vertical section is characterized by a pronounced three-layer structure with two maxima of suspended matter concentration: above the picnocline and near the bottom (nepheloid layer). A similar type of SPM distribution was described for the seas of the Russian Arctic earlier (Lisitzin et al., 2000). In general, the concentration of SPM in August (in time of low water and after the phytoplankton bloom) is lower than in June/beginning of July.

The seasonality of SPM distribution is reflected in the seasonality of vertical particle fluxes (Shevchenko et al., 2004a). The values of flux increased at the end of December and beginning of January possibly due to activization of the near-bottom nepheloid layer. In spring the increase of flux is connected with the increase of biological productivity, typical for this season (Berger et al., 2001).

Conclusion

The results of the project can be summarized as follows:

- the strong seasonality of aerosol and suspended matter distribution and composition in the White Sea was demonstrated;
- the composition of White Sea aerosols is similar to the composition of aerosols of the Arctic seas. For some chemical elements (Pb, V, Cd) aeolian input into the White Sea is very important;
- the highest concentrations of SPM are registered during the spring flood; terrigenous material dominates in the composition of SPM at this time. In summer a smaller peak of SPM concentration takes place due to phytoplankton bloom. The lowest concentrations of

both terrigenous and biogenic SPM are registered in winter. The seasonality of SPM concentrations is reflected in the seasonality of vertical particle fluxes;

- the character of geochemical processes in the Northern Dvina, Onega and Kem’ estuaries is similar to that of the large Arctic estuaries.

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LATE PLEISTOCENE-HOLOCENE AND RECENT OSTRACODS OF THE LAPTEV SEA (ARCTIC SIBERIA): DETAILED TAXONOMIC STUDIES AND APPLICATIONS TO PALEOENVIRONMENTAL RECONSTRUCTIONS

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Introduction

Scientific background

The Arctic, in particular the Laptev Sea, has been investigated absolutely insufficiently in terms of its ostracod associations although investigating this environmentally important benthos group is rather necessary. During the last glaciation the world sea level was 100-120 m lower than the present and the vast shelf of the Laptev Sea was exposed and not covered with glaciers. Due to the following rapid sea-level rise during the Late Pleistocene and Holocene the shelf was inundated. During the past decades a lot of material was obtained during Russian-German expeditions to the Laptev Sea, thus making detailed reconstruction of this transgression possible. In marine sediments paleoenvironmental changes caused by sea-level rise and variations in freshwater inflow are reflected in changes of the taxonomic composition of fossil organisms such as ostracods, foraminifers and mollusks. Among these ostracods are the organisms most sensitive to water depth and salinity changes. The analysis of ostracodal assemblages allowed us to reconstruct paleoenvironments in detail. Considering the importance of this group for paleoreconstructions, we undertook the complex investigation of recent and fossil ostracods of the Laptev Sea.

Goals and objectives

The main aim of the present work was to prepare a comprehensive study of the Late Pleistocene-Holocene and recent Ostracoda of the Laptev Sea and on this basis to reconstruct postglacial paleoenvironmental changes during the transgression. For this purpose it was necessary to:

- study spatial distribution patterns of recent ostracods from the surface samples in relation to different environmental parameters, such as water depth and salinity;
- compare recent ostracodal assemblages of the Laptev Sea with those from other Arctic seas and adjacent high-latitudinal areas;
- analyze data on the distribution of fossil ostracods in AMS^{14}C-dated cores of the Late Pleistocene-Holocene from the eastern shelf and western continental slope of the Laptev Sea; to use previously obtained data on the distribution of recent Ostracoda in the surface samples and to reconstruct the paleoenvironments of the Late Pleistocene and Holocene;
- identify all ostracod species and to prepare their monographical description.

Research activities

Approach

During the last four years within the framework of the OSL Fellowship Program, I studied modern and late Pleistocene-Holocene ostracods of the Laptev Sea. Using this material I defended my Bachelor’s and Master’s theses. Partially the obtained results are described in three papers (Stepanova et al., 2003, 2004; Taldenkova et al., in press) and were discussed at a number of meetings and conferences (XIV Conference on Marine Geology, Moscow, 2003; Climate Drivers of the North, Kiel, 2002; 3rd Conference on Environmental Micropaleontology, Microbiology and Meiobenthology, Vienna, 2002; Annual Meeting of Paleontological Section of Moscow Society of Naturalists, Moscow, 2003; SIRRO Workshop, Moscow, 2003; European Ostracodologist Meeting (EOM-V), Cuenca, 2003; 8th International Conference on Paleoceanography, Biarritz, 2004).

All these data were summarized in my PhD thesis entitled “Pleistocene-Holocene and Recent Ostracoda of the Laptev Sea and Their Importance for Paleoenvironmental Reconstructions.”

Accomplishments

I studied samples from the AMS^{14}C-dated cores PS51/138-12(10), PS51/135-4, PS51/080-13(11), PS51/92-12(11) from the eastern Laptev Sea and core PS51/154-11 from the western continental slope and 44 surface samples from 26 stations from different parts of the Laptev Sea. The surface samples and cores were obtained during the TRANSDRIFT V expedition to the Laptev Sea in August 1998. Additionally surface samples from nearshore locations, obtained during earlier expeditions (TRANSDRIFT I, II, III in 1993, 1994, 1995) to the Laptev Sea were studied.

In total 250 samples from cores and 44 surface samples were studied; 280 samples contained ostracods. In total 3073 valves and 104 carapaces from cores and 1287 valves and 583 carapaces were picked and studied.

For my research I used the equipment of the OSL. Especially helpful for my work was the microscope “Olympus SZX-12”, which was used for a more precise identification of ostracods. The facilities of the computer laboratory were of great importance as well. I managed to prepare 20 posters for the PhD thesis defense, which were highly estimated by the academic council.

I managed to implement all the objectives of the project outlined in my proposal. The research was carried out in accordance with the working program: I successfully passed the procedure of the defense of my PhD thesis on November 10, 2004.

Results

Recent ostracod fauna of the Laptev Sea is represented by 41 species. They form 3 assemblages according to their geographical position: a) western-central assemblage of the continental slope, characterized by deep-living species, known from the North Atlantic and Central Arctic oceans; b) assemblage of the eastern mid-shelf, mainly represented by normal marine shallow-water species; and c) brackish-water assemblage of the southern part of the sea with predominance of euryhaline taxa (Fig. 1).

The ostracod associations of the Laptev Sea is most similar to the ostracod fauna of the Kara and Beaufort seas, which is likely to be the result of similar environmental conditions in these seas.

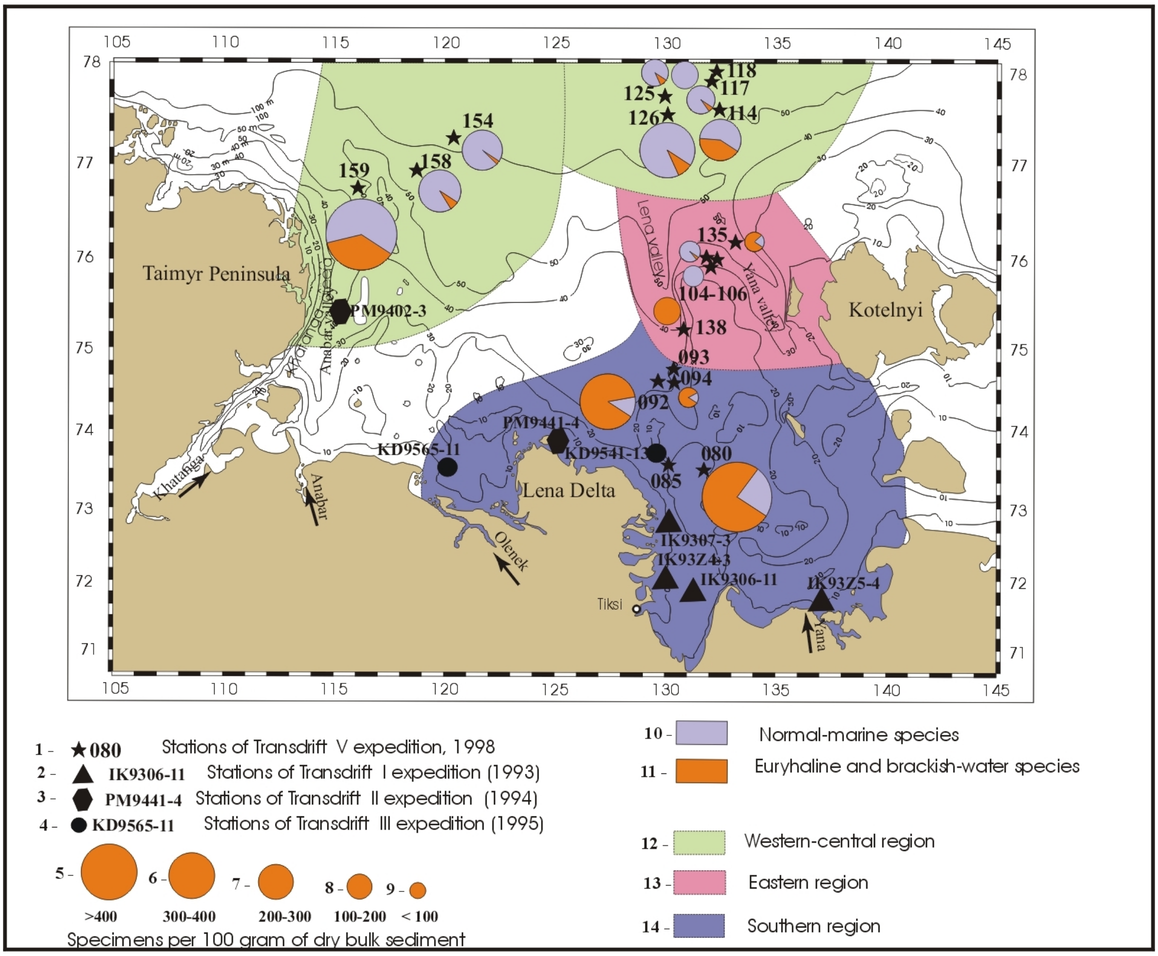

Fig. 1: Site locations and ostracod assemblages in the Laptev Sea.

Based on analysis of the downcore distribution of ostracods and replacement of their fossil assemblages in three AMS^{14}C-dated sediment cores, the following stages of the Holocene transgression in the eastern part of the sea were established: (1) ca. 11.3-11.1 cal. ka in the Yana palaeovalley, and ca. 11.2-10.8 cal. ka in the Lena palaeovalley: nearshore brackish-water environment with depths of less than 10 m, reduced (about 18-20) and seasonally variable bottom salinity, high sedimentation rates (up to 500 cm/kyr in the Yana palaeovalley) and active input of terrestrial plant debris due to shelf-coastal erosion and fluvial runoff; (2) until ca. 10.3 cal. ka in the Yana paleovalley and ca. 8.2 cal. ka in the Lena paleovalley: shallow-water environment affected by fluvial runoff, water depths around 20-25 m, average bottom salinity around 26-28, decreasing, but still high (~100 cm/kyr) sedimentation rates indicating close location to the main river depocenters; (3) since ca. ~10.3 cal. ka in the Yana paleovalley and ca. 8.2 cal. ka in the Lena paleovalley: sharply increasing taxonomic diversity marks transition to the onset of present marine environment with bottom salinity around 30-32, low sedimentation rates (~15 cm/kyr) and strong bottom currents (very low sedimentation rates in the Yana palaeovalley since ca. 5 cal. ka) (Figs. 2, 3). In the inner shelf zone, starting from 6.4 cal. ka, near-shore brackish-water environment with low sedimentation rates (~30 cm/kyr) was distinguished, from 2.7-1.5 cal. ka the influence of fresh waters increased, and the environment turned to modern-like.

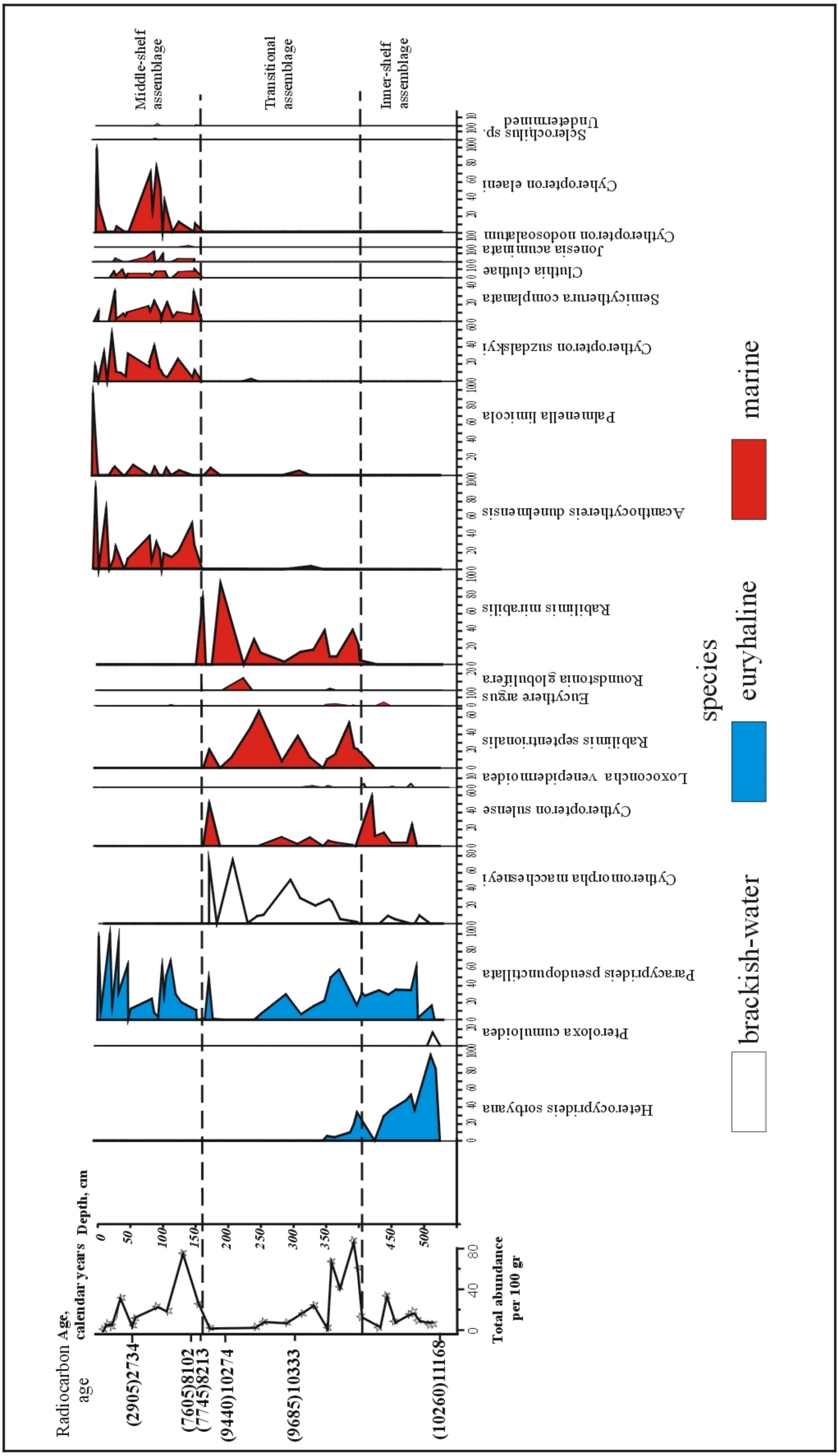

Fig. 2: Distribution of ostracods in core section PS-51/138-12, Lena paleovalley.

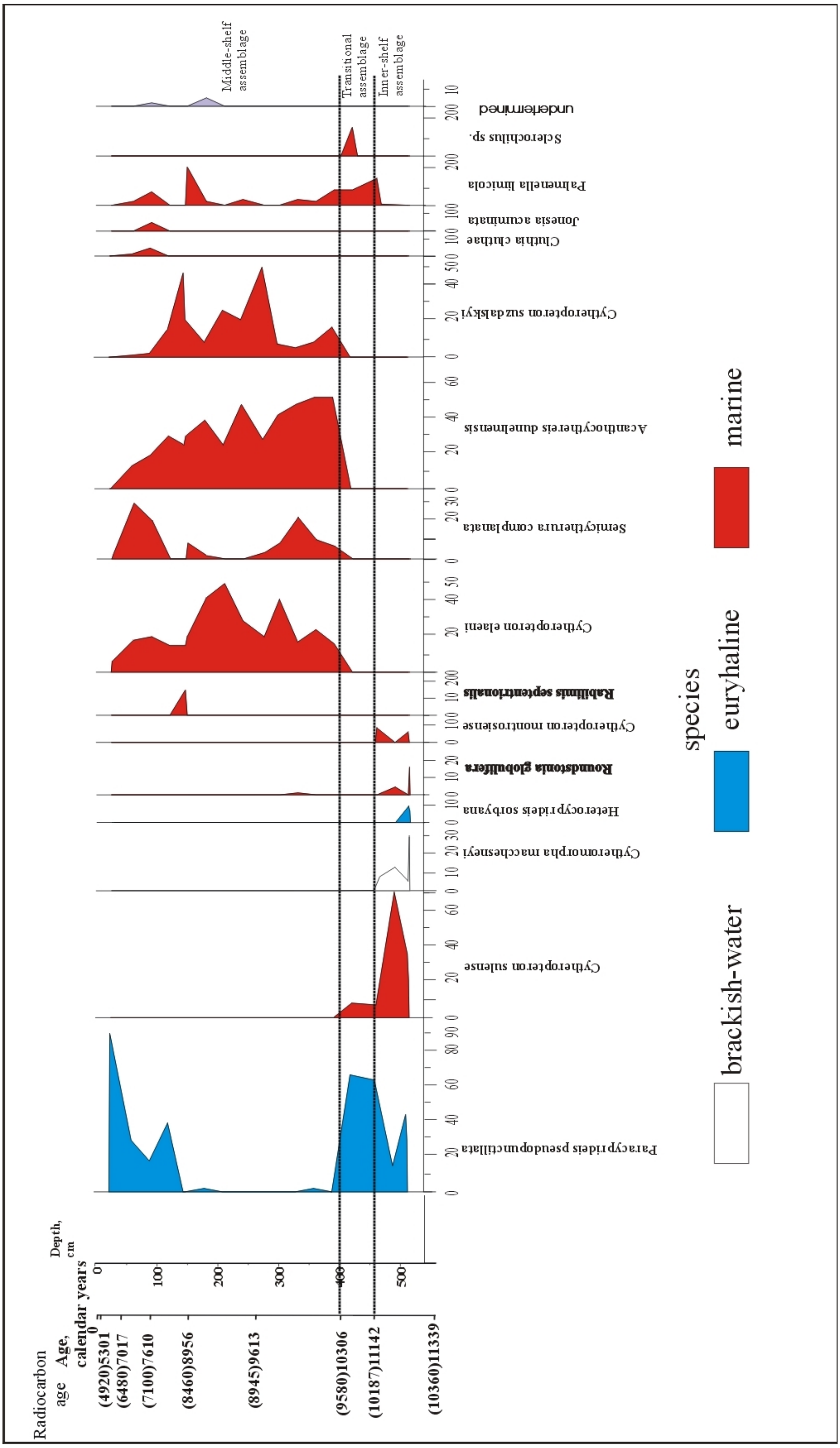

Fig. 3: Distribution of ostracods in core section PS-51/135-4, Yana paleovalley.

Morphological analysis of ostracod assemblages revealed the correlation between a considerable increase of smooth forms and reduced salinity. The size of the carapace does not reflect different environmental parameters.

In total 22 genera and 45 species of ostracods were described, one species (*Cytheropteron laptevensis* Stepanova, 2004) was described as new.

Conclusion

The main result of my work as my PhD thesis amounting to 248 pages, 29 figures and a reference list consisting of 227 names. This work consists of an introduction and 6 chapters:

- Chapter 1. Material and methods;
- Chapter 2. Environmental setting of the Laptev Sea;
- Chapter 3. Quaternary deposits and paleoenvironmental history of the Laptev Sea;
- Chapter 4. Recent Ostracoda of the Laptev Sea and their ecological assemblages (4.1.1 History of investigation of the Ostracoda from the Russian Arctic; 4.1.2. History of investigation of the Laptev Sea Ostracoda; 4.2 Ecology of the Laptev Sea Ostracoda; 4.3.1 Western-central region of the Laptev Sea; 4.3.2 Eastern region of the Laptev Sea; 4.3.3 Southern region of the Laptev Sea; 4.4 Results; 4.5 Comparison of the Laptev Sea ostracod fauna with faunas of other Arctic areas; 4.6 Morphological characteristics of the ostracodal assemblages);
- Chapter 5. Fossil assemblages of ostracods (5.1 Holocene ostracodal assemblages of the eastern middle shelf region of the Laptev Sea; 5.2 Holocene ostracodal assemblages of the eastern inner shelf region of the Laptev Sea; 5.3 Late Pleistocene-Holocene ostracodal assemblages of the western continental slope region of the Laptev Sea);
- Chapter 6. Paleontological description (6.1 Morphological essay; 6.2 Description of species);
- Conclusion and a supplement with descriptions of core sections and photoplates of ostracods.

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POSTGLACIAL ENVIRONMENTAL CHANGES IN THE WESTERN LAPTEV SEA: EVIDENCE FROM FOSSIL BENTHIC ASSEMBLAGES, ISOTOPE COMPOSITION OF MICROFOSSILS AND GEOCHEMICAL DATA

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Introduction

Scientific background

During recent years extensive studies of sedimentary records from the Nordic seas and Arctic Ocean revealed new important features of the Last Glacial Maximum (LGM) environment and dramatic changes in thermohaline circulation, sea-ice extent, sea surface temperatures, and Atlantic water inflows that took place during the transition to interglacial Holocene conditions (e.g. Nørgaard-Pedersen et al., 1998, 2003; Spielhagen et al., 2004; Svendsen et al., 2004; Sarnthein et al., 2003; Hald et al., 1996; Lubinski et al., 2001; Duplessy et al., 2001). However, how far into the Eurasian Arctic seas the warm Atlantic water influence reached as well as its interaction with the local freshwater outflows are still poorly known. This especially concerns the remote Siberian seas eastward from the Barents-Kara ice sheet, which remained ice-free during the LGM (Svendsen et al., 2004; Forman et al., 1999; Polyak et al., 2000). In this project we proposed to perform a high-resolution study of two sediment cores from the western Laptev Sea, one from the upper continental slope (PS51/154-11), and the other one from the outer shelf (PS51/159-10). The cores document the major part of the postglacial transition epoch and the whole Holocene, thus providing the longest age-controlled record for this period in the Laptev Sea. Especially the first core, due to its remarkable AMS^{14}C chronology aging back to >15.8 cal.ka (Bauch et al., 2001) and its location close to the northern edge of the Kara ice sheet (Svendsen et al., 2004) and Severnaya Zemlya in the position of the former Olenek delta, gives a remarkable opportunity to trace the environmental changes during the Late Glacial to Holocene transition. The previously studied cores from the continental slope yielded the oldest radiocarbon datings of 12.3 ^{14}C ka (14.2 cal.ka) in the eastern Laptev Sea (Boucsein et al., 2000) and 12.5 ^{14}C ka (14.6 cal.ka) in the western Laptev Sea (Stein and Fahl, 2000).

On the basis of different proxies the first well-documented postglacial inflow of Atlantic water into the Laptev Sea has been recorded in the early Holocene, between approximately 10.4-8.4 ^{14}C ka with a maximum at 8.4 ^{14}C ka (~9 cal.ka) (Fahl and Stein, 1999; Stein and Fahl, 2000; Stein et al., 2001; Boucsein et al., 2000; Matthiessen et al., 2001). It was combined with the highest discharge of terrestrial material to the continental slope due to increasing river runoff, coastal erosion, and the proximity of the river mouths at that time. In the Barents and Kara seas, foraminiferal and isotope data evidence that Atlantic water entered these seas already at 13 ^{14}C ka (~15 cal.ka) but was reduced during the Younger Dryas interval (Lubinski et al., 2001). The strong influence of modified Atlantic water between 10.5-8.6 ^{14}C ka (~ 11.6-9 cal.ka) has been recently traced in the core located as far eastward as the Beaufort Sea slope (Andrews and Dunhill, 2004). In the Arctic Ocean, Atlantic water inflow and interglacial conditions with frequent leads in the sea ice cover were fully established about 8-9 ka (Spielhagen et al., 2004).

So far no studies on macro and microfossils have been carried out in the cores from the Laptev Sea encompassing the last glacial-interglacial transition period. Within the framework of the current project we performed a detailed investigation of fossil benthic assemblages (molluscs, ostracods, foraminifers), isotopic composition of planktic and benthic foraminifers, and geochemical and lithological parameters. Comparison of the obtained results from the two cores made it possible 1) to reconstruct the general paleoenvironmental history of the western Laptev Sea upper slope and outer shelf since the early postglacial to recent times and 2) to perform the shelf-to-slope coupling for the period of drastic changes related to the early stage of shelf flooding between 11.1 and 9.0 ^{14}C ka (12.7-9.6 cal.ka), which encompasses the Younger Dryas cold event and the early Termination 1b.

Goals and objectives

The current project was aimed at the reconstruction of the postglacial paleoenvironmental history of the western Laptev Sea outer shelf and continental slope on the basis of a multiproxy approach (high-resolution benthic assemblage studies, oxygen isotope composition of microfossils, bulk geochemical parameters). The main research tasks were the following:

- high-resolution benthic assemblage studies (molluscs, ostracods, foraminifers) in cores PS51-154 and PS51-159; analysis of newly obtained surface samples from the TRANSDRIFT IX and X expeditions to enlarge our database on the distribution of modern assemblages (Stepanova et al., 2003; Taldenkova et al., in press); comparison of fossil assemblages with their modern analogues;
- oxygen isotope measurements on benthic (*Cassidulina teretis*) and planktic foraminifers from core PS51-154 to estimate past changes in salinity;
- determination of bulk geochemical parameters (TOC and C/N) in sediments of cores PS51-154 and PS51-159 to evaluate past changes in organic matter input and the ratio between its terrestrial and marine components;
- paleoenvironmental reconstructions of the western Laptev Sea outer shelf and upper continental slope based on correlation of the obtained results (patterns of water depth growth and coastline retreat, changes in freshwater discharge and Atlantic water inflows).

Research activities

Approach

High-resolution benthic assemblage studies of molluscs, ostracods, and foraminifers included studies of fossil assemblages from the sediment cores PS51-154 , PS51-159 and of modern assemblages from surface sediment samples. Both cores were sampled completely in 2-cm-thick intervals. The samples for benthic assemblage studies were freeze-dried, weighed, and subsequently washed over a 63 µm mesh-size sieve. Valves and tests were picked, counted, described, identified, and some photographed (SEM). The total abundance of microfossils is expressed as specimens per 100 g of the dry bulk sediment.

In order to carry out oxygen and carbon isotope measurements, we picked tests of planktic foraminifers (*Neogloboquadrina pachyderma* sin., *Globigerina bulloides*) and of the benthic foraminifer *Cassidulina teretis* from the samples of core PS51-154. Analysis of isotope composition of their carbonate will be carried out at the Leibniz Laboratory, Kiel University.

As shown previously (Stein et al., 1999, 2001; Boucsein et al., 2000), downcore variations of the total organic carbon (TOC) in the cores from the Laptev Sea outer margin could be correlated to changes in fluvial freshwater supply, Atlantic water inflows, and sea-ice extent. Estimation of carbon/nitrogen (C/N) ratio allows roughly distinguishing between marine organic matter (mainly phyto- and zooplankton) and terrestrial organic matter (mainly from higher plants) (Stein et al., 1999). We believe that estimating the bulk geochemical parameters in our cores will considerably help interpret the observed changes in composition of benthic assemblages. Cores PS51-154 and PS51-159 were sampled in 1-cm-thick slices with an interval of 3 cm. Sample processing and TOC and TN measurements will be carried out at the OSL.

The obtained results from both cores were correlated in order to establish paleoenvironmental reconstructions of the western Laptev Sea outer shelf and upper continental slope under postglacial sea-level rise (patterns of water depth growth and coastline retreat, changes in freshwater discharge and Atlantic water inflows).

Accomplishments

The work on fossil benthic assemblages from core PS51/154-11 which partly started in 2003 is still being continued. At the beginning we identified microfossils which had already been picked from sediment samples. This year we had to process original samples, and this work turned out to be very time-consuming since our strategy was to pick all microfossils from >63 µm fraction of the total sediment sample in order to have a most representative picture of the former benthic communities.

Core PS51-154 was the main focus of the project. Of the total of 285 fossil-bearing samples from this core, macro and microfossils were picked and identified from 240 samples. The obtained results have allowed us to preliminarily reconstruct paleoenvironmental changes in the studied area reflected in downcore occurrences of species (see below).

Of the total of 240 samples from core PS51-159, fossils were picked and identified from 60 samples. This year A. Strezh compiled her bachelor thesis devoted to paleoenvironmental reconstructions of the western Laptev Sea outer shelf based on ostracod assemblages from core PS51-159 and their correlation with ostracod assemblages of the eastern Laptev Sea outer shelf (Taldenkova et al., in press).

Thirty-three surface sediment samples from the shallow southeastern part of the Laptev Sea collected during the TRANSDRIFT IX (2003) and X (2004) expeditions were processed in the OSL. Now the samples are being studied for species identification; processing of the samples from the last expedition is finished.

Foraminiferal tests of planktic foraminifers and *C. teretis* from all studied samples have been picked for isotope studies. When the whole series of samples will be ready, isotope measurements will be performed. Since we have not finished our reconstruction of paleoenvironmental changes according to the results of processing core PS51-154 samples, we have not yet got analytical results on isotope measurements.

Task 3. Both sediment cores were sampled only at the end of the project, in December 2004. In April 2005 the samples will be processed at the OSL (grinding) and later measurements on the C/N analyzer will be carried out. We expect to get analytical results by June 2005.

Currently, we are preparing the draft of a paper on distribution of fossils in core PS51-154 and paleoreconstructions derived from the downcore changes in taxonomic composition of their assemblages. The first results have already been presented at several conferences.

Results

Fossil benthic assemblages of core PS51-154 and postglacial paleoenvironmental changes on the western Laptev Sea continental slope

Core PS51-154 was recovered from the western Laptev Sea upper continental slope (water depth 270 m) during the TRANSDRIFT V expedition aboard “Polarstern” in 1998. It is located in the area where the present bottom water environment is occupied by relatively warm Arctic Intermediate Water derived from the Atlantic water masses entering the Arctic Ocean with the West Spitsbergen Current (Volkmann, 2000). The influence of this water is clearly reflected in the composition of the modern benthic assemblages from this site. They contain abundant deep-water species also known from the North Atlantic (Stepanova et al., 2003; Taldenkova et al., in press).

The total core recovery is 674 cm (708 cm with core catcher) (Fig. 1). The lowermost radiocarbon dating at 569 cm core depth is 13,570±110 yrs. BP (ca. 15.8 cal.ka) (Fig. 1). A total of 9 datings ensure a good chronological framework for paleoreconstructions (Bauch et al., 2001). The whole core was continuously sampled in 2-cm thick intervals, which makes high-resolution studies of changes in species composition possible.

The lower core unit up to 575 cm is barren of any fossils (Fig. 1), but enriched in small-size plant debris, vivianite and mica, thus evidencing the proximity of the paleocoast to the slope break prior to15.8 cal.ka. The fact that benthic and planktic faunistic remains were not found might be a result of oxygen deficiency in bottom waters probably caused by perennial ice cover. Dissolution of carbonate tests should not be ruled out, either.

The distribution of fossil macro and microfossils in the remaining part of the core shows evident variations in taxonomic composition and abundance roughly expressed as five assemblage zones, each corresponding to certain paleoenvironmental changes.

Assemblage zone 1 (ca. 15.8-15.1 cal.ka) is represented by the taxonomically poorest fossil assemblages (12 ostracod species, 3 bivalve species, 8 benthic foraminifer species). *Portlandia arctica* is dominant among molluscs. This species is able to survive in harsh arctic environments with considerable sedimentation rates and high input of plant debris (Syvitski et al., 1989; Aitken and Gilbert, 1996). Few relatively deep-water ostracod species predominate. The dominance of *Krithe glacialis* is indicative of cold, low-nutrient habitats (Cronin et al., 1995). A low total abundance of benthic forams marks rather unfavorable bottom conditions. The typical cold Arctic species *Cassidulina reniforme* predominates among benthic foraminifers. Two other species are also abundant: the opportunistic species *Elphidium excavatum f. clavata* surviving under harsh conditions (Polyak et al., 2002; Hald et al., 1994) and the relatively deep-living *Cassidulina teretis* (also called *C. neoteretis;* Seidenkrantz, 1995). The presence of *C. teretis* is especially remarkable since its occurrence in the Arctic Ocean is clearly associated with the subsurface Atlantic-derived waters (Lubinski et al., 2001 and references therein). Thus, already at 15.8 cal.ka, transformed Atlantic waters reached the western Laptev Sea continental slope, where the bottom environment was characterized by cold, low-nutrient bottom waters and high sedimentation rates. *C. teretis* is present throughout the core sequence indicating that the core site has remained affected by the Atlantic waters since 15.8 cal.ka until today.

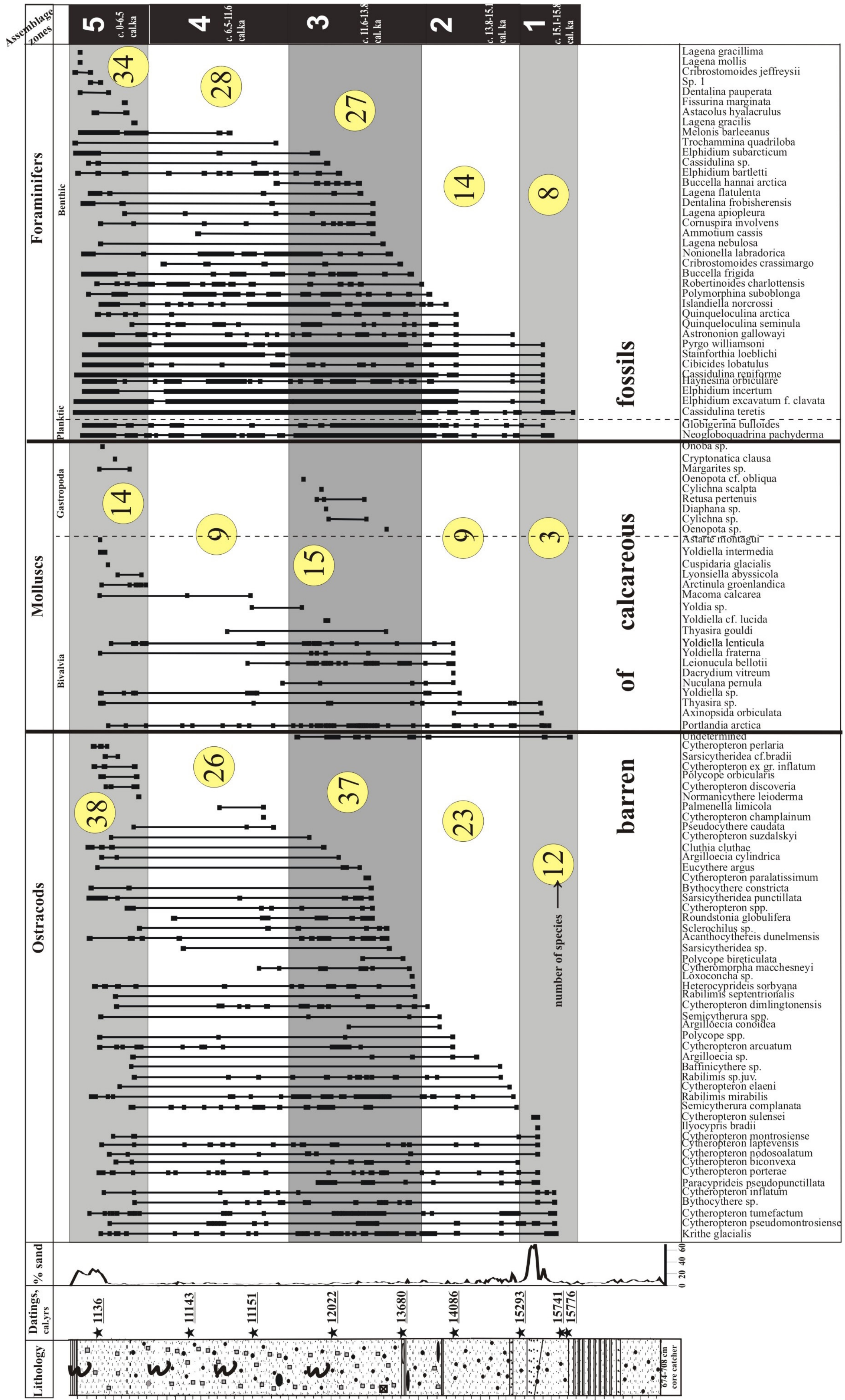

Fig. 1: Downcore data of core PS51/154-11, western Laptev Sea, 270 m water depth.

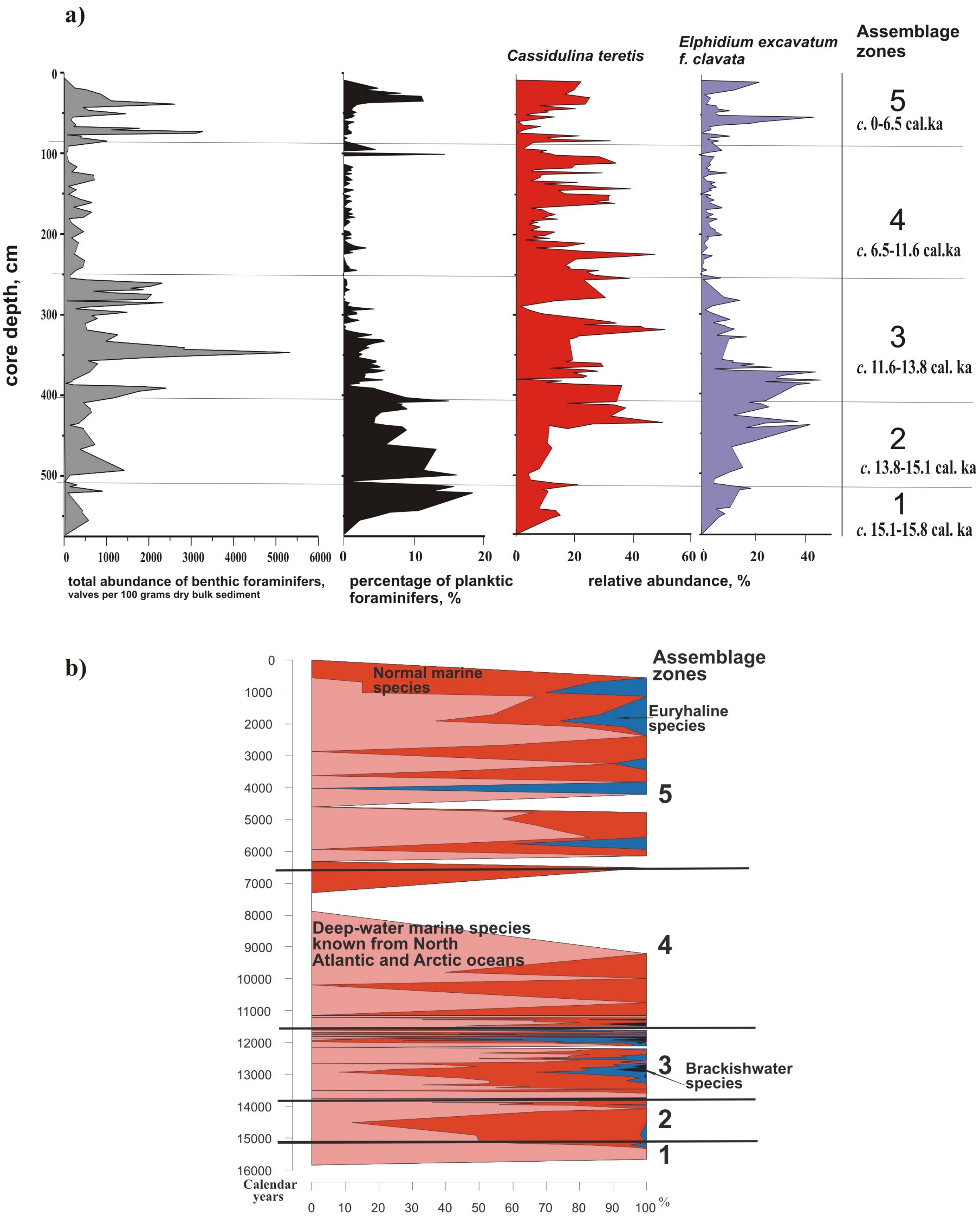

Fig. 2: Some features in distribution of a) foraminifers and b) ostracods in core PS51/154-11.

Assemblage zone 1 is characterized by the highest percentage of planktic foraminifers (Fig. 2). These are represented by the typical Arctic Ocean species *Neogloboquadrina pachyderma* sin. with a small admixture of *Globigerina bulloides*. The high abundance of planktic foraminifers probably indicates a local situation which is totally unusual for the present environment, when the proximity of the paleocoast to the steep shelf break resulted in limited or no fast-ice formation and in the formation of nearshore polynya through offshore winds.

These conditions were favorable for planktic forams (Volkmann, 2000) due to the abundance of food at the pack-ice edge and the absence of shelf areas with freshwater affected water masses. Such a paleoenvironment might also be similar to the conditions reconstructed for the northern Barents Sea margin during the LGM (Nørgaard-Pedersen et al., 2003), when open waters along ice sheet margins probably caused upwelling of Atlantic water and a high biological productivity.

Another important feature of this zone is the presence of deposits corresponding to a kind of debris flow between 520 and 540 cm core depth. These are sandy sediments with an evident inclination (Fig. 1). They have a remarkable composition of ostracods with some shallow-water euryhaline and brackish-water species (*Paracyprideis pseudopunctillata, Cytheromorpha macchesneyi*) and one valve of the freshwater species *Ilyocypris bradii.* In none of our samples from the Laptev Sea shelf cores were freshwater ostracods present, and the studied site was located at a depth close to 180-200 m at that time. This debris flow provides additional evidence for an open-water (at least seasonally) coastal environment where storm events produced downslope sediment movement.

Assemblage zone 2 (ca. 15.1-13.8 cal.ka) is similar to the previous zone, but an increasing taxonomic diversity in all three groups (19 ostracod species, 5 bivalve species, 14 benthic foraminifer species), as well as an increasing total abundance of benthic forams (Fig. 2) indicate a general amelioration of the paleoenvironmental conditions. The remaining high percentage of planktic foraminifers and abundant *C. teretis* give evidence for a widespread water exchange with the ocean and Atlantic water inflow.

Assemblage zone 3 (ca. 13.8-11.6 cal.ka) shows the most evident changes in fossil assemblages due to a considerable increase in taxonomic diversity (37 ostracod species, 15 bivalve and gastropod species, 27 benthic foraminifer species) and the total abundances of benthic forams (Fig. 2) and ostracods, which reach their maximum values around 13.0 cal.ka. The presence of numerous shallow-water euryhaline and brackish-water ostracods (*Paracyprideis pseudopunctillata, Cytheromorpha macchesneyi, Heterocyprideis sorbyana, Loxoconcha* sp.) with their maximum also at 13.0 cal.ka (Fig. 2) could be indicative of especially high freshwater discharge and active sea-ice transportation of these species to the continental slope. The high content of *E. excavatum f. clavata*, especially in the layers dating back to approximately 13.8-13.0 cal.ka (Fig. 2), probably corresponds to the strongest meltwater event, as high percentages of this species are known to be indicative of meltwater-affected environments (Hald et al., 1994). Also, the high total abundance of benthic foraminifers is known to be an indicator of meltwater events (Nees, 1997). The decreasing percentage of planktic foraminifers and *C. teretis* evidences a weakening Atlantic water inflow, probably due to formation of a freshened surface water layer and increasing water stratification. All these data are remarkably coincident with the extremely strong freshwater outflow previously recorded in the isotopic composition of planktic foraminifers and the strong freshwater signal in the composition of organic matter in core PS2458 from the eastern Laptev Sea continental margin located just off the Lena paleovalley (Boucsein et al., 2000).

Assemblage zone 4 (ca. 11.6-6.5 cal.ka) is distinguished by relatively low taxonomic diversity, which is less than in the underlying assemblage zone (26 ostracod species, 9 bivalve species, 28 benthic foraminifer species), low total abundance of benthic foraminifers and ostracods, low percentage of planktic forams. This might primarily be the result of poor preservation of tests and valves due to a sharp reduction in sedimentation rates at the site after 11.1 cal.ka (Fig. 2). This reduction in sedimentation rates corresponds to the flooding of the Laptev Sea outer shelf by approximately 11.1-11.3 cal.ka (Bauch et al., 2001; Taldenkova et al., in press). In the deeper areas of the Arctic Ocean dissolution of benthic foraminiferal fauna was shown to be linked to the interglacial periods of Atlantic water advection and enhanced productivity (Wollenburg et al., 2001). In our core, the fossil benthic assemblages of this zone are clearly dominated by typical Arctic Ocean species. The core site was affected by Atlantic water as shown by the constant presence of *C.teretis* and planktic foraminifers and the high proportion of deep-living ostracods with clear North Atlantic affinities (*Cytheropteron tumefactum, C. pseudomontrosiense, C. porterae, C. dimlingtonensis, Pseudocythere caudata*, and others). At the same time, the share of shallow-water euryhaline and brackish-water ostracods strongly decreases, as does that of *E. excavatum f. clavata.* It seems that this was, in fact, the period of the strongest Atlantic water inflow to the western Laptev Sea continental margin, which is in good accordance with other evidence (see references in Introduction).

Assemblage zone 5 (ca. 6.5-0 cal.ka) corresponds to the establishment of a modern-like environment related to stabilization of sea level at its present position about 6 cal.ka (Bauch et al., 1999, 2001) and the onset of the modern water circulation pattern. It shows the highest taxonomic diversity (38 ostracod species, 14 bivalve and gastropod species, 34 benthic foraminifer species), high total abundance of forams and ostracods, dominance of deep-living species, high content of planktic forams and *C. teretis* characteristic of the recent benthic assemblage from the coretop sample (Figs. 1, 2). Interestingly, from about 2.5 cal.ka a sharp increase in coarse fraction percentage is recorded in the core (Fig. 1). The preliminary analysis of sediment material shows that this peak is due to the appearance of abundant IRD (grains >2-2.5 mm in size) and not to an increase in sand content like the peak in the lower part of the core where debris-flow sediments accumulated (540-520 cm core depth). This is in accordance with the previous investigations indicating a smaller extent of the Severnaya Zemlya glaciation during the LGM than in recent times (Raab et al., 2003). However, a systematic analysis of the composition of the fraction >2.5 mm from all core samples is necessary to speculate about the origin of the observed lithological changes and their relation to climate variations.

Conclusion

Our analysis of the lithology and downcore variations of benthic assemblages in core PS51/154-11 allows preliminarily distinguishing some major features of paleoenvironmental changes on the western Laptev Sea continental slope:

- prior to 15.8 cal ka: proximity of the paleocoast to the slope break, absence of calcareous faunistic remains (perennial sea-ice cover?);
- 15.8 cal.ka: first evidence of Atlantic-derived water inflow to the western Laptev Sea continental slope, which is ~0.8 kyr earlier than in the Barents and Kara seas (Lubinski et al., 2001);
- 15.8-13.8 cal.ka: proximity of the paleocoast to the shelf break resulted in no or little fast-ice formation and existence of a nearshore polynya as shown by the high percentage of planktic forams;
- 15.8-11.1 cal.ka: high sedimentation rates. Sharp reduction in sedimentation rates after 11.1 cal.ka due to outer-shelf flooding;
- ca. 13.8-11.6 cal.ka: seasonally changeable environment, highest total abundance of benthic microfossils (increasing organic matter supply) due to maximum freshwater outflow at ca. 13.0 cal ka and shelf flooding (started 12.7 cal.ka);
- ca. 11.6-6.5 cal.ka: maximum influence of Atlantic water inflow upon the western Laptev Sea continental slope;

- since ca. 6.5 cal.ka: establishment of modern-like environments generally correlative with the sea-level stabilization;
- since ca. 2.5 cal.ka: high IRD content due to active iceberg-rafting.

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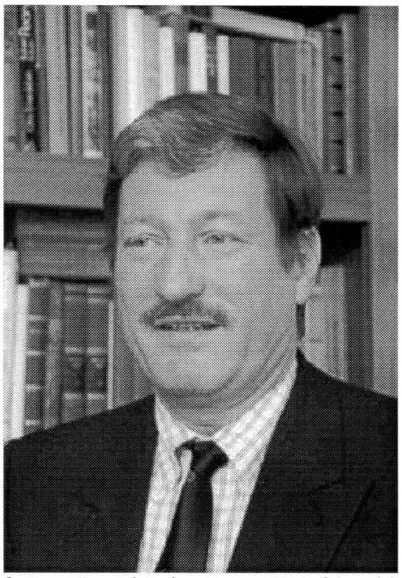
Presseberichte

Homepage des Alfred-Wegener-Instituts – Pressemeldung vom 30.05.2003

AWI-Direktor zum Mitglied der Russischen Akademie der Wissenschaften gewählt



Prof. Dr. Jörn Thiede. Foto: AWI (druckbar)

Prof. Dr. Jörn Thiede, Direktor des Alfred-Wegener-Instituts für Polar- und Meeresforschung, wurde am 22. Mai von der Generalversammlung der Russischen Akademie der Wissenschaften (RAS) zum auswärtigen Mitglied gewählt.

Jörn Thiede ist Paläo-Ozeanograph und beschäftigt sich wissenschaftlich vor allem mit Fragen des Klimas in der Erdgeschichte. Er ist in zahlreiche internationale wissenschaftliche Projekte eingebunden und in einer Reihe von nationalen und internationalen Gremien tätig. Dieses Engagement ist mit einer Vielzahl von Preisen und Ehrungen anerkannt worden. Seit 1989 engagiert er sich für eine Intensivierung der deutsch-russischen Zusammenarbeit und hat in der Meeres- und Polarforschung zahlreiche gemeinsame Projekte auf den Weg gebracht, z. B. das Otto-Schmidt-Labor und den Masterstudiengang POMOR an der Universität St. Petersburg. "Die Mitgliedschaft in der Akademie ist eine große persönliche Ehre", sagt Thiede, "und sie ist eine Auszeichnung für die deutsche Meeres- und Polarforschung, die sich auf einem international sehr hohen Niveau befindet." Thiede ist zurzeit an Bord des Forschungseisbrechers „Polarstern" auf Arktisexpedition.

Wissenschaftliche Akademien pflegen seit Jahrhunderten den wissenschaftlichen Austausch über die Grenzen von Disziplinen, Fakultäten und Universitäten hinweg. Die Russische Akademie der

Wissenschaften wurde 1724 von Zar Peter dem Ersten gegründet. Sie betreibt angewandte und Grundlagenforschungen zu den Schwerpunktproblemen der technischen, humanitären und Naturwissenschaften und kooperiert dazu auch mit anderen Forschungsorganisationen und Hochschulen. Die Nobelpreisträger Alexander Solschenizyn und Andre Sacharow waren ebenso Mitglieder der RAS wie Pavel Cherenkow (Nobelpreis Physik 1958) und Zhores Alferow (Nobelpreis für Physik im Jahr 2000). Bekannte deutsche Mitglieder sind Klaus von Klitzing, Jürgen Habermas und Roman Herzog.

"Wir hoffen, damit die wissenschaftlichen Bande zwischen unseren beiden Ländern weiter zu stärken", so der Präsident der Akademie, Yuri Sergeewitsch Osipow, in seinem Glückwunschschreiben an Thiede vom 26. Mai.

Bremerhaven, den 30. Mai 2003

TOP

Nordsee-Zeitung vom 02.06.2003

Leute

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Prof. Dr. Jörn Thiede, Direktor des Alfred-Wegener-Instituts für Polar- und Meeresforschung, ist von der Generalversammlung der Russischen Akademie der Wissenschaften (RAS) zum auswärtigen Mitglied gewählt worden. Thiede ist Paläo-Ozeanograph und beschäftigt sich wissenschaftlich vor allem mit Fragen des Klimas in der Erdgeschichte. Er ist in zahlreiche internationale wissenschaftliche Projekte eingebunden und in nationalen und internationalen Gremien tätig. Seit 1989 engagiert er sich für eine Intensivierung der deutsch-russischen Zusammenarbeit und hat in der Meeres- und Polarforschung zahlreiche gemeinsame Projekte auf den Weg gebracht, beispielsweise das Otto-Schmidt-Labor und den Masterstudiengang Pomor an der Universität St. Petersburg. „Die Mitgliedschaft in der Akademie ist eine große persönliche Ehre", sagt Thiede, „und sie ist eine Auszeichnung für die deutsche Meeres- und Polarforschung, die sich auf einem international sehr hohen Niveau befindet."

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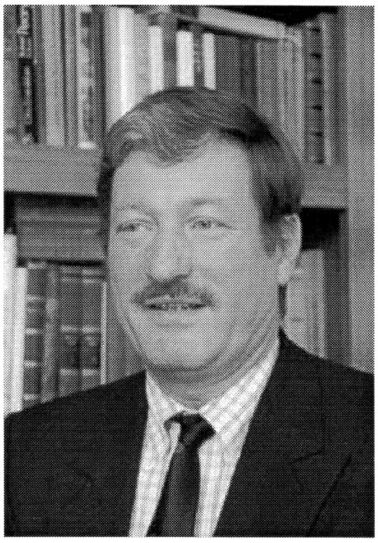
Auszeichnung für Prof. Thiede



AWI-Direktor erhält Hans-Stille-Medaille

Für seine Verdienste bei der Erforschung der Arktis und in der deutschen Meeresforschung erhielt Prof. Dr. Jörn Thiede, Direktor des Alfred-Wegener-Instituts für Polar- und Meeresforschung (AWI), die Hans-Stille-Medaille der Deutschen Geologischen Gesellschaft (DGG). Der Vorsitzende Prof. Dr. Friedrich-Wilhelm Wellmer überreichte die Auszeichnung kürzlich im Rahmen der 155. Jahreshauptversammlung auf der Tagung URBAN 2003 an der Ruhr-Universität in Bochum.

Die nach dem deutschen Geowissenschaftler Hans Stille (1876 - 1966) benannte Auszeichnung ist einer der renommiertesten Preise der deutschen Geowissenschaft. Er wird jährlich vergeben. Thiede erhielt ihn für seine "wegweisende Rolle in der deutschen Meeresforschung, die (...) maßgeblich zur Gründung von GEOMAR beigetragen hat". Am GEOMAR Forschungsinstitut für marine Geowissenschaften in Kiel werden seit 1987 Aufbau, Entstehung und Geschichte des Meeresbodens und seiner Wechselwirkung mit dem Meerwasser untersucht. Darüber hinaus, so Wellmer, ehre die DGG insbesondere auch Thiedes „Verdienste zur Erforschung der Arktis, die in der letzten Dekade zu einer intensiven Zusammenarbeit mit Russland führte, wodurch der nachwachsenden Wissenschaftlergeneration ungeahnte Möglichkeiten erschlossen wurden."

Die Deutsche Geologische Gesellschaft (DGG) ist die älteste und größte deutsche Vereinigung in den Geowissenschaften. Sie wurde bereits im Jahre 1848 in Berlin als ein wissenschaftlicher Verein für alle an der Geologie Interessierten gegründet. Zu den Gründern gehörten Alexander von Humboldt und Leopold von Buch. Die DGG zählt heute etwa 3.000 Mitglieder. Ihr Hauptanliegen ist die Förderung der Geologie in Forschung und Lehre, in Wirtschaft und Verwaltung.

Bremerhaven, 8.10.03

Nordsee-Zeitung vom 10.10.2003

Ehre für Awi-Direktor

Professor Dr. Thiede erhält Hans-Stille-Medaille

Der Direktor des Alfred-Wegener-Instituts (Awi), Professor Dr. Jörn Thiede, hat einen der wichtigsten Preise für Geologen bekommen: Er erhielt die Hans-Stille-Medaille der Deutschen Geologischen Gesellschaft (DGG). „Es ist eine Ehre“, freute sich Thiede. Die Auszeichnung färbe auf das Awi ab.

Thiede, der seit November 1997 das Awi leitet, bekam den nach dem deutschen Geowissenschaftler Hans Stille (1876-1966) benannten Preis für seine „wegweisende Rolle in der deutschen Meeresforschung“. Sie habe maßgeblich zur Gründung von Geomar – Forschungsinstitut für marine Geowissenschaften in Kiel – beigetragen. Dort untersuchen Wissenschaftler seit 1987 Aufbau, Entstehung und Geschichte des Meeresbodens und seine Wechselwirkung mit dem Meerwasser.


Professor Dr. Jörn Thiede

Die DGG würdigt mit der Auszeichnung außerdem Thiedes „Verdienste zur Erforschung der Arktis, die in der letzten Dekade zu einer intensiven Zusammenarbeit mit Russland führte“.

Pressemitteilung
Verleihung der Ehrendoktorwürde der Staatlichen Universität St. Petersburg an den Direktor des Alfred-Wegener-Institutes für Polar- und Meeresforschung
Prof. Jörn Thiede (St. Petersburg, den 12.5.2004)

Jörn Thiede wurde 1941 in Berlin geboren und ist in Schleswig-Holstein aufgewachsen. Durch die Fossilien in der eiszeitlich geprägten Landschaft seiner Heimat wurde früh sein Interesse an der Erdgeschichte geweckt. Konsequent war daher nur ein Studium der Geologie an den Universitäten in Kiel, Buenos Aires, Wien und Aarhus. Früh an sein zentrales Forschungsthema - die Vereisungsgeschichte unseres Planeten – herangeführt, promovierte Jörn Thiede 1971 an der Universität Kiel über die Verbreitung von planktischen Foraminiferen am iberomarokkanischen Kontinentalrand. Geprägt wurde er dabei von seinem Doktorvater Prof. Eugen Seibold, der die Meeresgeologie in Deutschland aufgebaut und ihr zu großem internationalem Ansehen verholfen hat.

Über Bergen, Corvallis und Oslo hat ihn dann sein wissenschaftlicher Weg an die Universität Kiel zurückgeführt. 1982 wurde er auf den Lehrstuhl für Paläontologie und Historische Geologie berufen und konnte nun viele wichtige Initiativen zur meeresgeologischen Erforschung der hohen nördlichen Breiten starten. Erste wichtige Meilensteine waren der DFG-Sonderforschungsbereich 313 „Sedimentation im Europäischen Nordmeer“ und das ODP-Leg 104 zum Vøringplateau. Es folgten die ersten Vorstöße in den Arktischen Ozean mit dem neuen deutschen Forschungseisbrecher „Polarstern“, die ihre Höhepunkte 1991 in der Expedition zum Nordpol und 1993 in der ersten ODP-Bohrung im Nordpolarmeer fanden. Unterstützt haben ihn dabei fast 70 Doktoranden und viele Diplomanden, von denen einige ihn noch heute in seinem Team begleiten. Große neue Herausforderungen waren 1987 die Gründung des GEOMAR Forschungszentrums für Marine Geowissenschaften in Kiel, zu dessen erstem Direktor Jörn Thiede berufen wurde, und 1997 die Bestellung zum Direktor des Alfred-Wegener-Instituts für Polar- und Meeresforschung in Bremerhaven.

Die wissenschaftlichen Ergebnisse seiner ersten Polarexpeditionen hatten Jörn Thiede schnell klar gemacht, dass die Entschlüsselung der arktischen Klimageschichte nicht ohne Einbeziehung der sibirischen Schelfmeere gelingen kann. Er nutzte daher rasch die sich Anfang der 90er Jahre bietenden neuen Möglichkeiten zur Zusammenarbeit mit russischen Wissenschaftlern. Bereits 1991 brach eine erste gemeinsame Expedition zu Forschungsarbeiten in die Laptevsee auf. Entwickelt hat sich daraus ein umfassendes Netzwerk von deutschen und russischen Wissenschaftlern, die gemeinsam die Ursachen und Auswirkungen von globalen Klimaveränderungen in der sibirischen Arktis studieren. Hervorzuheben ist dabei das Otto-Schmidt-Labor für Polar- und Meeresforschung am Staatlichen Institut für Arktis- und Antarktisforschung in St. Petersburg und POMOR, ein Masterstudiengang für angewandte Polar- und Meereswissenschaften an der Staatlichen Universität St. Petersburg .

Insgesamt wurden seine wissenschaftlichen Arbeiten in den letzten Jahren durch viele Auszeichnungen, wie den Leibniz-Preis der Deutschen Forschungsgemeinschaft im Jahre 1988 und die Ernennung zum ausländischen Mitglied der Russischen Akademie der Wissenschaften im Jahre 2003, auf nationaler und internationaler Ebene gewürdigt.

Auch privat spielt der Norden eine große Rolle im Leben von Jörn Thiede und seiner Frau Sigrid. Gemeinsam mit ihren vier Söhnen verbringen sie ihre Ferien am liebsten in ihrer Datscha in Norwegen. Außerdem ist er leidenschaftlicher Sammler von historischen Reise- und Expeditionsberichten in die Polargebiete.

Abb. 1: Jörn Thiede und sein norwegischer Freund und Kollege Tore Vorren führen meeresgeologische Studien an einem Sedimentkern vom Nordpol durch (POLARSTERN, 1991).

DIE WELT

Chef des AWI erhält Ehrendoktor

Bremen

Mit der Ehrendoktorwürde der Staatlichen Universität St. Petersburg ist am Mittwoch der Bremerhavener Wissenschaftler Professor Jörn Thiede ausgezeichnet worden. Der Direktor des Alfred-Wegener-Instituts für Polar- und Meeresforschung (AWI) erhielt die Auszeichnung für seine wissenschaftlichen Beiträge zur Polarforschung und für sein Engagement bei der Zusammenarbeit mit Russland. Dieses habe zum Aufbau eines Netzwerks von deutschen und russischen Wissenschaftlern geführt, teilte das AWI am Mittwoch mit.

Artikel erschienen am 13. Mai 2004

Artikel drucken

Leute

0471 - 597 263

Für seine wissenschaftlichen Beiträge zur Polarforschung sowie sein Engagement in der Zusammenarbeit mit Russland erhält Professor **Dr. Jörn Thiede**, Direktor des Alfred-Wegener-Instituts für Polar- und Meeresforschung (Awi), heute die Ehrendoktorwürde der Staatlichen Universität St. Petersburg.

Seit Anfang der 90er Jahre setzt sich Prof. Thiede für die Zusammenarbeit zwischen Deutschland und Russland in Bildung und Forschung ein. Die wissenschaftlichen Ergebnisse seiner ersten Polarexpeditionen hatten Thiede gezeigt, dass die sibirischen Schelfmeere für die Einschätzung der Entwicklung des weltweiten Klimas und der Folgen möglicher Klimaveränderungen von unschätzbarem Wert sind. In den vergangenen Jahren hat sich ein umfassendes Netzwerk von deutschen und russischen Wissenschaftlern entwickelt, die gemeinsam die Ursachen und Auswirkungen von globalen Klimaveränderungen in der sibirischen Arktis studieren. Im Oktober 2001 mündete diese Zusammenarbeit in die Einrichtung eines internationalen Masterstudiengangs für angewandte Polar- und Meereswissenschaften an der Staatlichen Universität St. Petersburg (Pomor). Der Unterricht wird von russischen Dozenten der Universität St. Petersburg und russischer Forschungsinstitute wie dem Staatlichen Institut für Arktis- und Antarktisforschung (Aari) und deutschen Kollegen vom Alfred-Wegener-Institut, der Universität Bremen und den anderen Hochschulen im Verbund Norddeutscher Universitäten (Hamburg, Greifswald, Kiel, Oldenburg, Rostock) sowie dem Forschungszentrum IFM-Geomar erteilt.

Professor Dr. Jörn Thiede

Thiede wurde 1941 in Berlin geboren. Er studierte Geologie und Paläontologie an den Universitäten Kiel, Buenos Aires, Aarhus und Wien und promovierte 1971 an der Universität Kiel. Nach weiteren Stationen folgte 1997 schließlich die Berufung zum Direktor des Alfred-Wegener-Instituts für Polar- und Meeresforschung in Bremerhaven.

NORDSEE-ZEITUNG Mittwoch, 12. Mai 2004

По северным морям

Вручение диплома и мантии Почетного доктора СПбГУ профессору Йорну Тиде

В Петровском зале прошла торжественная церемония вручения диплома Почетного доктора Санкт-Петербургского государственного университета директору Института морских и полярных исследований им. Альфреда Вегенера профессору Йорну ТИДЕ (Германия).

Йорн Тиде изучал геологию в университетах Киля, Буэнос-Айреса, Вены и Аархуса. История оледенений Земли стала центральной темой его научно-исследовательской работы. В 1971 г. Йорн Тиде защитил диссертацию и получил ученую степень доктора наук университета г.Киль. Длинный научный путь Йорна Тиде прошел через Берген (Норвегия), Аархус (Дания), Корваллис (США) и Осло (Норвегия) и в 1982 году привел обратно в университет города Киль, где его пригласили заведовать кафедрой палеонтологии и исторической геологии. Эта должность открыла ему возможность инициировать многочисленные важные исследовательские проекты по изучению морской геологии высоких северных широт. Первыми из этих исследований стали специальный проект исследований «Осадконакопление в Европейском Северном море» Германского исследовательского общества (DFG) и экспедиция по Программе глубоководного океанского бурения (ODP). Были сделаны «шаги в Арктику» на новом немецком научно-исследовательском судне «Полярштерн», которые завершились в 1991 г. экспедицией на Северный полюс и в 1993 г. первым бурением в Северном Ледовитом океане по программе ODP. Поддержку профессору оказывали его многочисленные студенты и аспиранты, многие из которых до сих пор работают в его коллективе. Новыми важными этапами на профессиональном пути Йорна Тиде было основание Научно-исследовательского центра по морским геологическим наукам ГЕОМАР в г.Киль, где он стал первым директором, и последовавшее приглашение Тиде на должность директора Института полярных и морских исследований им. Альфреда Вегенера в г.Бремерхафен.

В 1991 г. состоялась первая совместная российско-немецкая экспедиция для исследования моря Лаптевых. Инициатива Йорна Тиде открыла пути к многолетнему тесному взаимодействию немецких и российских ученых, совместно изучающих основы глобальных изменений климата и их воздействие на сибирскую Арктику. Важными результатами совместных проектов Йорна Тиде с российскими учеными стали основание Лаборатории полярных и морских исследований им. Отто Юльевича Шмидта при Государственном научном центре Российской Федерации, Научно-исследовательском институте Арктики и Антарктики, и ПОМОР, магистерская программа «Прикладные полярные и морские исследования» в Санкт-Петербургском государственном университете.

Йорн Тиде

В последние годы за научные достижения Йорну Тиде были присуждены многочисленные национальные и международные награды и премии, в том числе премия им. Лейбница Германского исследовательского общества (DFG). Он избран почетным иностранным членом Российской Академии наук.

Zeitschrift der Staatlichen Universität St. Petersburg, Juni 2004

AWI

Hamburger Abendblatt	**18.05.04**	G **301,1** (Sa: 388,1) Auflage x 1000
Hamburg Hamburg		Tages-Zeitung VR erscheint 6 mal pro Woche

MEERESFORSCHUNG

Ehrendoktor für Prof. Thiede

Mit der Ehrendoktorwürde der Staatlichen Universität St. Petersburg ist der Bremerhavener Wissenschaftler Prof. Jörn Thiede ausgezeichnet worden. Der Direktor des Alfred-Wegener-Instituts für Polar- und Meeresforschung erhielt die Auszeichnung für seine Beiträge zur Polarforschung und für sein Engagement bei der Zusammenarbeit mit Russland. Dieses habe zum Aufbau eines Netzwerkes von deutschen und russischen Wissenschaftlern geführt. *(dpa)*

Politische Unterstützung der deutschen Küstenländer

Die
Ministerpräsidentin
des Landes
Schleswig-Holstein

Frau
Dr. Heidemarie Kassens
Leiterin des Otto-Schmidt-Labors
in St. Petersburg
ul. Beringa 38

RF - St. Petersburg
Russische Föderation

Kiel, den 24. September 2003

Sehr geehrte Frau Dr. Kassens,

für Ihre freundliche Aufnahme in Otto-Schmidt-Labor danke ich Ihnen sehr herzlich.

Mit großem Interesse habe ich dabei aus Ihren Informationen entnehmen können, wie weit die Heranbildung von russischen NachwuchswissenschaftlerInnen zu gemeinsamen wissenschaftlichen Forschungsarbeiten der Polar- und Meeresforschung bereits fortgeschritten ist. Ich begrüße die Ausbildungsprojekte mit den russischen Partnern und freue mich, dass auch Schleswig-Holstein durch GEOMAR in Kiel an der vom Otto-Schmidt-Labor durchgeführten Qualifizierung russischer WissenschaftlerInnen beteiligt ist.

Ich hoffe und wünsche, dass dieses Modell einer neuen Form von internationalen Kooperationsprojekten zu Ausbildungs- und Forschungsaufgaben zu komplexen und langfristigen Vorhaben gemeinsamer russisch-deutscher Polar- und Meeresforschung führt. Ich messe der Ausbildung- und Forschungsarbeit des Otto-Schmidt-

Düsternbrooker Weg 70
24105 Kiel
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Telefax (0431)988-1965
Bus: Linie 41/42, 51

Labors angesichts der globalen Klimas- und Umweltveränderungen erhebliche Bedeutung bei und wünsche Ihnen weiterhin bei Ihrer wichtigen Arbeit viel Erfolg.

Mit freundlichen Grüßen

Heide Simonis

Die Ministerpräsidentin
des Landes
Schleswig-Holstein
· Staatskanzlei

Die Ministerpräsidentin · Staatskanzlei
Postfach 71 22 · 24171 Kiel

Stiftung Alfred-Wegener-Institut
Herrn Prof. Dr. Jörn Thiede
Postfach 12 01 61

27515 Bremerhaven

Ihr Zeichen / vom	Mein Zeichen / vom	Telefon (0431)	Datum
Ihr Schreiben vom 05.09.03	StK 22 315.6	988 – 1726 E-Mail: Joachim.Schuldt@stk.landsh.de	4 November 2003

Sehr geehrter Herr Professor Thiede,

wie verabredet übersende ich Ihnen einen Auszug aus dem Protokoll der Sitzung der Arbeitsgruppe der Chefs der Staats- und Senatskanzleien der norddeutschen Länder vom 08.10.03 zur Kenntnis. Sie können daraus ersehen, dass Schleswig-Holstein über den Besuch in St. Petersburg berichtet und angeregt hat, die Aktivitäten des Otto Schmidt-Labors als gemeinsame Initiative der deutschen Küstenländer mit St. Petersburg auf politischer Ebene zu unterstützen. was jetzt daraus wird, müssen wir abwarten.

Mit freundlichen Grüßen

Joachim Schuldt

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Sitzung der Arbeitsgruppe der Chefs der Staats- und Senatskanzleien der norddeutschen Länder am 8. Oktober 2003 in Kiel

Ergebnisprotokoll

TOP 4 **Otto Schmidt-Labor/GEOMAR, St. Petersburg**
Mündlicher Bericht über den Besuch der Ministerpräsidentin und der Chefin der Staatskanzlei am 02.09.2003

SH berichtet über den Besuch der Ministerpräsidentin und der Chefin der Staatskanzlei des Landes Schleswig-Holstein am 02.09.2003 beim Otto-Schmidt-Labor für Polar- und Meeresforschung in St. Petersburg und geht dabei insbesondere auf die bilateralen Forschungsprojekte russischer und deutscher Wissenschaftler im Nordmeer, die Ausbildungsprojekte, das Projekt POMOR sowie die Finanzierung des Labors ein. SH hatte in dem Gespräch in St. Petersburg angeregt, die Aktivitäten des Otto-Schmidt-Labors als gemeinsame Initiative der deutschen Küstenländer mit St. Petersburg auf politische Ebene zu unterstützen.

Informationen zum Fram-Labor

FRAM Arctic Laboratory (FAL) for climate research

Young scientists support program (fellowship)

The FRAM Arctic Laboratory (FAL) is a climate research program in support of young Russian scientists administrated by the Arctic and Antarctic Research Institute (AARI), the Norwegian Polar Institute (NPI) and the University Centre in Svalbard (UNIS). It will provide an opportunity for young Russian scientists such as MSc and Ph.D students and post-doc's to participate in research projects focusing on integrated climate studies as described below.

The researchers will carry out their investigations using the FAL modern facilities including an updated computer and softwark park. In addition, it will be possible to use the up-to-date analytical laboratory facilities of the Otto Schmidt Russian-German polar and marine studies laboratory located at AARI of Roshydromet in St.Petersburg.

The FAL wishes to attract young Russian scientists with sufficient skills and knowledge in various fields of Arctic climate science, in particular within the following scientific disciplines: physical oceanography, sea ice, atmosphere, glaciology and hydrology. The young Russian scientists may in collaboration with Russian and Norwegian senior scientists apply for support in order to carry out their research during 2004 and 2005. The scholarship covers a salary for the young scientists. The funding does not offer financing for full-scale field studies, search projects, secrecy class research, neither for the development of scientific products for commercial use. However, some funding will be available for participation in field programs, short-term visits exchange programs at AARI and NPI/UNIS as well as attending courses at UNIS.

Selelection Criterias and Duration

The FAL Advisory Board consisting of three Russian and three Norwegian senior scientists will evaluate the proposals and select candidates. The priority in selection of candidates will first of all be based on quality and relevance to the topics described at (Annex) Also, the qualifications of the scholar and her/his supervisors will be considered in the evaluation. The period of the projects' financial support will be up to 2 years covering the period of 2004-05. An evaluation of all projects and candidates will be done after one year at if progress is successful decision about prolongation will be done The candidates will use FAL facilities at AARI as working place.

Application Procedures

No strict form of application is needed. However, the applications must be relevant to the scientific themes described at (Annex) Additionally, the applications should contain the following:

· Accompanying letter from the organization including name, address, CVs, list of publications, other relevant experience and personal data of the applicants (i.e. the young scientist and supervisor(s))

· Plan of the research work (no more than 5 pages, including figures), i.e. scientific rationale, detailed plan of the research studies, containing full description of the discipline, methods, purposes, schedule of the supposed research work

· Recommendation letter from at least one authoritative specialist in this particular field

· Applications from students should be signed and approved by their supervisor(s)

· All the documents should be submitted both in Russian and English language.

The applications should be sent to the FAL addresses within the deadline. If necessary, in order to obtain reference information you are welcome to address the Secretariat of the Fram Arctic Laboratory: mailto:fal@fram.nw.ru or NPI (Contact person Vladimir Pavlov at **pavlov@npolar.no).**

Application submission deadline - 19 December 2003.

The applications should be sent to both the Russian office of FAL and the Norwegian Polar Institute:

1. Joint AARI/NPI Fram Arctic climate studies Laboratory, SRC of RF, the Arctic and Antarctic Research Institute of Roshydromet
38 Bering str, 199397
St.Petersburg, Russia,
Fax: 7 812 352 2883
E-mail: fal@fram.nw.ru
and

2. The Norwegian Polar Institute, Polar Environmental Centre, N-9296 Tromso, Norway. Att.: Dr. Jan-Gunnar Winther. Fax: +47 77750501, E-mail: mailto:winther@npolar.no

If the application is sent by e-mail the copy of application should be sent also by fax (including the signed cover sheet).

THE FRAM ARCTIC LABORATORY - SCIENTIFIC DIRECTIONS

Summary

The overall direction of the Fram Arctic Laboratory (FAL) is to carry out joint Norwegian-Russian research on Arctic climate change. Thematically the focus is on studies of long-term changes in the physical system including the marine system (ocean and sea ice), the atmosphere and the terrestrial system (glaciers and fresh water). Geographically the focus is on the Euro-Arctic region, with special emphasis on Svalbard and the Greenland- and Barents Seas. The collaboration will include joint research programmes implemented in Barentsburg, Ny-Alesund and Longyearbyen

Introduction

The Arctic environment has undergone significant temperature swings over the last 100 years. Over the last 30 years trends show surface temperature warming, melting permafrost, reduced sea-ice, longer growing seasons and changes in the character of ocean fluxes. It is important to recognize that these events have already occurred or are under way, and that it is desirable to anticipate their future course or at least assess their potential range. Largely because global warming simulations suggest an amplified climate response in the Arctic, it has been argued that Arctic climate provides an early warming of global change. It has also been pointed out, however, that climate variability in the Arctic is large, so that a weak ignal-to-noise ratio may initially mask climate trends. It seems likely that both the amplified climate response and the large natural variability are connected with the strong feedbacks that characterize the Arctic climate system. The long-term climate data series and Arctic expertise available in Norway and Russia represent a unique platform for obtaining scientific achievements in Arctic climate change research. The FAL is an appropriate instrument for reaching such goals. In the following, scientific directions of the FAL are shortly presented. In the appendices, specific project ideas that have been identified jointly between the Arctic and Antarctic Research Institute (AARI) and the Norwegian Polar Institute (NPI) are described.

Sea ice

Sea ice has a dramatic effect on the physical characteristics of the ocean surface. It modifies the surface radiation balance due to its high albedo, and it influences the exchange of momentum, heat, and matter between atmosphere and ocean. It also results in much lower surface air temperatures over the ice-covered areas in winter than are maintained by the ocean immediately underneath. Freezing of sea ice expels brine which deepens the surface mixed layer and can, through convection, influence the formation of deep and bottom water. Melting, in contrast, produces relatively fresh water that stratifies the oceanic surface layers (i.e. the mixed layer retreats to shallower depths). In contrast to low latitudes, the mixed layer evolution in Polar Regions is dominated by surface fluxes of salt or fresh water (positive or negative freezing rates). Through these effects, sea ice plays a key role in the global heat balance and the global thermohaline circulation. A retreat of sea ice associated with climate warming can therefore have global consequences and contributes, through various feedback processes, to enhanced climate change, particularly at high latitudes. In the FAL collaboration we wish to focus on a wide variety of studies connected to sea ice and climate, in particular variability and trends of sea ice concentration, sea ice thickness, and sea ice fluxes (in the Fram Strait) as well as physical and optical properties of sea ice. Special emphasis on sea ice-albedo feedback mechanisms will be given.

Physical oceanography

The past decade has seen remarkable changes in the marine Artic, including changes in the distribution of Atlantic source waters and the subsurface temperature. The exchange through the Fram Strait is of special importance in this context. In particular, the West Spitsbergen Current has been shown to cause large changes in the Atlantic layer of the Arctic Ocean. This West Spitsbergen Current temperature variability has in turn been related to major changes in the atmospheric circulation via the Arctic Oscillation and/or the North Atlantic Oscillation. The FAL will utilise long-term hydrographical data from the Greenland- and Barents Seas to study variability and trends of ocean fluxes including changes in transport of heat and salt. Additionally, emphasis will be made on studies of long-term variability of sea level in the Arctic Ocean.

Atmosphere

The proximity of open water in the Norwegian Arctic has potentially large effects on the cloud-radiative interactions that determine surface climate and, potentially, climate change over a substantial portion of the Northern Hemisphere. Climate models must accurately simulate radiative controls of the ice-albedo-temperature feedback if simulations by these models are to be realistic. In addition, the use of remote sensing techniques in this region is complicated by surface melt during warm-air intrusions, by thick clouds that accompany winter storms, and by the complex interactions involving aerosols and clouds. Consequently, remote-sensing algorithms developed for other regions of the Arctic may need important modifications when applied to this "warm Arctic" region. For ground truth measurements, there exist excellent ground facilities both in Barentsburg and Ny-Alesund. In addition, both these research stations maintain long-term meteorological data series. In FAL comparative studies between Barentsburg and Ny-Alesund with respect to solar radiation should be attempted. Further, it is recommended that satellite-based studies of surface albedo should be made.

Glaciology and hydrology

Svalbard is located at the climate boundary of the polar front. Any shift in the position of this boundary would have a noticeable effect on the archipelago's glaciers and ice caps. Svalbard's glaciers and ice caps are large enough to hold a few decimetres of sea level equivalent, which, if released to the ocean, would have a significant impact on low-lying regions of the world, yet they are small enough that they react quite rapidly to changes in climate. Since the late 1960ies, an annual glacier mass balance monitoring programme of two glaciers (Austre Broggerbreen and midre Lovenbreen) has been carried out by NPI. These two glaciers represent the longest continuous glacier mass balance records from the Arctic. While low-lying glaciers along West Spitsbergen currently are retreating, little is known about the status of the glaciers and ice caps further east on Svalbard. Runoff measurements are made at some locations at the west coast of Spitsbergen. Generally, the peak of spring melt occurs in early to mid-June. However, severe rain events in the autumn can produce higher discharges, even though these runoff events have much less duration. In Ny-Alesund, there is also regularly sampling of sediment loads in Bayelva. In western Svalbard, the winter is commonly punctuated by warm intervals during which moist, warm Atlantic air sweeps over the area. This air mass produces heavy snow, slush, and rain as it converges with cold Arctic air. Liquid water delivered to the snow surface percolated through the snow pack and freezes inside the snow pack or at the soil surface. These events are important because significant energy can be delivered to the base of the snow pack. Further, they represent a major problem for reindeer since the ice layer may cover the moss and lichens. Within FAL, it will be focused on mass balance investigations of glaciers and ice caps on Svalbard. Innovative field programs and/or satellite remote sensing techniques that can provide information of glacier mass balance over larger areas of Svalbard than made today are particularly welcomed. Also, it is recommended that hydrological studies of water balance and water quality should be carried out.

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Topics of competitive studies

1. Project: “Meteo-glaciological monitoring of the mass-heat exchange processes of the active layer of glaciers and climate change of the Spitsbergen archipelago."

Topic of competitive study: “Comparative analysis of the atmosphere climatic variability characteristics of the Spitsbergen archipelago and the North-European region based on the meteorological network data”

In the course of accomplishing this project, a young specialist is proposed to address the following tasks:
1. Perform an analysis of the studies of atmosphere climatic variability characteristics of the Spitsbergen archipelago on the basis of literary sources.
2. Create a climatic database using observations over a network of meteorological stations for the study area (Spitsbergen archipelago, Franz Josef Land archipelago and northern Europe).
3. Perform a comparative analysis of relationships between the individual climatic variability components in the different parts of the study area.
Participation of the young specialist in the expedition studies carried out by the AARI on the Spitsbergen archipelago glaciers is envisaged.
The proposed candidate should have experience of programming, know the modern climatic analysis methods and have experience of field studies.

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2. Project: “Study of radiation and thermal-physical properties of the snow-ice cover (glaciers, drifting and landfast ice) in the Spitsbergen archipelago area”.

Topic of competitive study: “Study of radiation and thermal-physical properties of the snow-ice cover of the Spitsbergen archipelago during the period of melting

Within the framework of the indicated topic, a young specialist will be proposed to perform an analysis of the available in the open press Russian and Norwegian data relating to the full-scale and theoretical studies made by AARI and NPI specialists at the Spitsbergen archipelago. Main efforts should be focused on the analysis of data describing the melting processes. Participation of the young specialist in the AARI and NPI expedition studies undertaken at present at the archipelago and in adjoining waters is envisaged.
The candidate should have experience of field studies and be familiar with the modern methods of mathematical modeling of physical processes.

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3. Project: ”Study of the water discharge from the glacial basins of West Spitsbergen”

Topic of competitive study: “Reconstruction of the annual river runoff of the Gronfjord watershed of West Spitsbergen using river-analogues method”

A young specialist will be proposed to perform an analysis of the available Russian and Norwegian literary sources covering the formation of the discharge from the glacial basins of the Spitsbergen archipelago. The study will be focused on the collection, processing and statistical analysis of hydrological information obtained in the course of the expedition studies by AARI and NPI specialists. As a result of the study, it is planned to derive the reconstructed series of the annual river runoff of the Gronfjord watershed.
The candidate should have experience of field studies and be familiar with the modern methods of statistical analysis of hydrological information.

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4. Project: ”Long-period level oscillations of the Barents and the Norwegian Seas including the Spitsbergen archipelago, their causes and consequences”

Topic of competitive study: ”Study of the character of long-period level oscillations of the Barents and the Norwegian Seas including the Spitsbergen archipelago, revealing the causes forming them and estimates of the possible sea level changes in the near future”

In the course of accomplishing this project, a young specialist is proposed to address the following tasks:
• Perform an analysis of the studies of long-period level oscillations of the world ocean and the Arctic Ocean seas, in particular, of the Barents and the Norwegian Seas from literary sources.
• Create the climatic database on the basis of sea level observations and hydrological and meteorological characteristics over a network of hydrometeorological stations for the study area (water area and coast of the Barents and the Norwegian Seas).
• Perform a spatial-temporal analysis of sea level and some climatic variability components in different parts of the study area.
• Reveal and analyze the cause-effect relations of long-period sea level oscillations and of the factors determining them.
• Give an estimate of the possible changes in the average level of the Barents and the Norwegian Seas for the next 25–50 years.

Participation of the young specialist in sea level observations at the Spitsbergen archipelago coast is envisaged.
The candidate should have experience of programming and be familiar with the modern methods of analysis of hydrometeorological characteristics.

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5. Project: “Study of ice- and water exchange between the Kara and the Barents Seas and the adjoining part of the Arctic Basin and of the climatic variability of the water circulation structure in the Spitsbergen archipelago area from Fram Strait to the Franz Josef Land."

Topic of competitive study: : "Long-period variability of thermohaline structure and circulation of water in Fram Strait and Euro-Arctic Seas".

In the course of the study, the young specialist is proposed to accomplish the following work based on the analysis of archived AARI and NPI oceanographic data for the period 1950-2000:
• Determination of climatic changes of water circulation in the Euro-Arctic Seas and in Fram Strait
• Obtaining characteristics of the temporal variability of 3-dimensional thermohaline structure of the ocean in the Arctic Basin from Fram Strait to the Franz Josef Land.
• Estimates of the water exchange between the Arctic and the North-European basins at different levels from the surface to the bottom over the period 1950 to 2000.

The candidate is supposed to have knowledge and practical skills of programming and statistical methods of analysis of oceanographic databases.

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