THE 30\textsuperscript{TH} INTERNATIONAL ARCTIC WORKSHOP

PROGRAM AND ABSTRACTS

MARCH 16-18, 2000

Institute of Arctic and Alpine Research
University of Colorado, Boulder
1560 30\textsuperscript{th} Street
Campus Box 450
Boulder, Colorado 80309-0450

Organizing Committee:

Anne Jennings
William Manley
John T. Andrews
James Syvitski
Astrid Ogilvie
Nan Elias
Scott Elias
Ashley Holladay
Introduction

The 30th Annual International Arctic Workshop will be held March 16-18, 2000, at the Institute of Arctic and Alpine Research (INSTAAR), University of Colorado at Boulder. This workshop has grown out of a series of informal annual meetings sponsored by INSTAAR and other academic institutions worldwide. In keeping with this tradition, there are no formalized topics, and the workshop has been organized around themes developed from the abstracts submitted for presentation and poster display.

Workshop Location: The Icebreaker, registration, and dinner party will be held in the INSTAAR Conference Room, Bldg. RL-1, 1560 30th St., Rm. 269. Posters will be in the 2nd Floor hallways of Bldg. RL-1, adjacent to the Conference Room. Oral presentations will be in the INSTAAR Auditorium, Bldg. RL-3, Rm. 620. Bldg. RL-3 is immediately east of Bldg. RL-1.

Registration: Please register at the Icebreaker starting at 5 PM on Wed., March 15th, or starting at 8 AM on Thurs., March 16th, in Room 269 in Bldg. RL-1. At registration you will receive the Program and Abstracts, as well as other workshop information.

Posters: Please put up your posters as early as possible, and leave them up as late as possible, during the workshop. Our intention is that posters will be made available for informal review by participants during the Icebreaker, session breaks, and at other times, as well as during the official poster session on the morning of Fri., March 17th. At registration will you receive information on where to set up your poster.

Acknowledgements: The Arctic Workshop each year is partially subsidized for travel costs through a grant from the U.S. National Science Foundation (grant OPP-9614129), for which we are grateful. Efforts of the Organizing Committee, led by Dr. Anne Jennings, made the event possible. We especially wish to thank Dr. John Andrews for his long-term commitment to the workshops.
**SUMMARY AGENDA:**

**WEDNESDAY, MARCH 15th, 2000**

*Icebreaker & Registration*  
5:00-7:00 PM  
RL-1 Rm. 269

**THURSDAY, MARCH 16th, 2000**

*Registration*  
8:00 - 8:45 AM  
RL-1 Rm. 269

*Welcome & Introduction*  
8:45 - 9:00 AM  
RL-3 Rm. 620

*COLDSEIS*  
9:00 - 10:30 AM  
RL-3 Rm. 620

*Paleoceanography*  
10:45 AM - 12:15 PM  
RL-3 Rm. 620

*Lunch Break*

Terrestrial Paleoenvironments 1  
1:30 - 3:00 PM  
RL-3 Rm. 620

Arctic Lakes Paleoenvironments  
3:15 - 5:00 PM  
RL-3 Rm. 620

*PARCS Reception*  
to follow talks  
RL-3 Rm. 620

**FRIDAY, MARCH 17th, 2000**

*Continental Breakfast*  
8:00 - 10:00 AM  
RL-1 Rm. 269

*Poster Session*  
8:00 - 11:30 AM  
RL-1 second floor

*Lunch Break*

Arctic Terrestrial Paleoenvironments 2  
12:45 - 2:45 PM  
RL-3 Rm. 620

Paleoecology and Archeology of SE Alaska  
3:00 - 4:15 PM  
RL-3 Rm. 620

Contributed Papers  
4:15 - 5:45 PM  
RL-3 Rm. 620

*Dinner Party*  
6:30 PM  
RL-1 Rm. 269

**SATURDAY, MARCH 18th, 2000**

*Environmental Geochemistry*  
8:30 - 9:45 AM  
RL-3 Rm. 620

*Human Dimensions of the Arctic*  
10:00 - 11:15 AM  
RL-3 Rm. 620

*Box Lunch (provided)*

Quaternary Geology 1  
12:15 - 1:45 PM  
RL-3 Rm. 620

Quaternary Geology 2  
2:00 - 3:30 PM  
RL-3 Rm. 620
WEDNESDAY, MARCH 15TH

WEDNESDAY, MARCH 15, 2000

ICEBREAKER & REGISTRATION
5:00-7:00 PM
INSTAAR Conference Room, Bldg. Rl-1, Rm. 269

THURSDAY, MARCH 16, 2000

REGISTRATION
8:00-8:45 AM
INSTAAR Conference Room, Bldg. Rl-1, Rm. 269

WELCOME AND INTRODUCTION — James Syvitski
8:45-9:00 am
INSTAAR Auditorium, Bldg. Rl-3, Rm. 620

COLDSEIS
Chair: James Syvitski

9:00-9:15 THE NORWEGIAN-GREENLAND SEA CONTINENTAL MARGINS: LATE QUATERNARY SEDIMENTARY PROCESSES AND ENVIRONMENT
VORREN, TORE O., Laberg and Jan Sverre

9:15-9:30 LATE WEICHSELIAN AND HOLOCENE SEDIMENT FLUX AND SEDIMENTATION RATES IN ANDFJORD AND VAAGSFJORD, NORTH NORWAY
PLASSEN, LIV; Vorren, Tore O.

9:30-9:45 HOLOCENE SEDIMENT ACCUMULATION RATES ON THE CONTINENTAL SHELVES BORDERING DENMARK STRAIT: ESTIMATES FROM 210PB AND COMPARISONS WITH 14C DATA
L. MICALEA SMITH, Clark Alexander, and Anne Jennings

9:45-10:00 THE DYNAMICS OF MARINE GLACIER TERMINI READ FROM MORaine ARCHITECTURE
LØNNE, IDA

10:00-10:15 SEISMIC SEQUENCE ARCHITECTURE OF THE YAKATAGA FORMATION, NORTHEASTERN GULF OF ALASKA
COOPER, JAMES M. and Powell, Ross D.

10:15-10:30 SEDIMENT YIELDS AND EROSION RATES DETERMINED FROM SEISMIC REFLECTION DATA
POWELL, ROSS D. and Cooper, James M.
THURSDAY, MARCH 16TH

10:30-10:45 am MORNING BREAK

Paleoceanography
Chair: John Andrews

10:45-11:00 SEA-SURFACE TEMPERATURE VARIABILITY IN THE NORWEGIAN SEA WITH DECADAL SCALE RESOLUTION DURING THE LAST 3000 YEARS
KOÇ, NALAN; Andersen, Cathrine; Jansen, Eystein; Birks, John

11:00-11:15 SST-RECONSTRUCTIONS FROM THE NORWEGIAN SEA AND THE DENMARK STRAIT DURING THE "LITTLE ICE AGE"
ANDERSEN, CATHRINE; KOÇ, Nalan; Jennings, Anne; Alexander, Clark; Jansen, Eystein

11:15-11:30 ENVIRONMENTAL AND PALEOMAGNETIC RECORD FROM LABRADOR SEA CORE MD95-2024: MILLENNIAL SCALE MARINE SEDIMENT TO ICE CORE CORRELATIONS OVER THE LAST 110 KYR
STONER, Joseph S; Hillaire-Marcel, Claude; Bilodeau, Guy;

11:30-11:45 PATTERNS OF GLACIAL SEDIMENT TRANSPORT TO THE NW LABRADOR SEA: DATA FROM GECHEMICAL PROVENANCE STUDIES
BARBER, DONNY

11:45-12:00 SEDIMENT MINERALOGY OF THE EURASIAN SHELVES AND THE ARCTIC OCEAN
VOGT, Christoph

12:00-12:15 DECADAL VARIABILITY OF THE GREENLAND ICE SHEET MASS BALANCE AS A CAUSE OF SALINITY-ICE-TEMPERATURE ANOMALIES IN THE NORTH ATLANTIC
BELKIN, IGOR

12:15- 1:30 pm LUNCH BREAK

Arctic Terrestrial Paleoenvironments 1
Chair: Bill Manley

1:30-1:45 THE AHKLUN MOUNTAINS PROJECT, FROM TOGIAK BAY TO MT. WASKEY, SW ALASKA
AMP PROJECT MEMBERS*
THURSDAY, MARCH 16TH

1:45-2:00 LACUSTRINE RECORD OF DEGLACIATION IN THE AHKLUN MOUNTAINS, SW ALASKA: ICE RETREAT DURING THE YOUNGER DRYAS
AXFORD, YARROW; Kaufman, D.S.; Gregory-Eaves, I.

2:00-2:15 LATE PLEISTOCENE SEASONAL TEMPERATURES IN EASTERN BERINGIA, BASED ON FOSSIL BEETLE ASSEMBLAGES
ELIAS, SCOTT

2:15-2:30 RECONSTRUCTING THE LATE-HOLOCENE HISTORY OF A SUBALPINE ENVIRONMENT USING FOSSIL INSECTS
LAVOIE, CLAUDE

2:30-2:45 PROMISES AND PROBLEMS OF INFERRING CLIMATIC CHANGE SIGNALS FROM GEOTHERMAL GRADIENTS
TINGJUN ZHANG; Roger G. Barry

2:45-3:00 ONSET OF MID-PLIOCENE PERMAFROST AND THE PRE-GLACIAL TO GLACIAL TRANSITION IN THE KLONDIKE AREA, YUKON TERRITORY
FROESE, DUANE, G., Preece, Shari, and Westgate, John

3:00-3:15 AFTERNOON BREAK

Arctic Lakes Paleoenvironments
Chair: Gifford Miller

3:15-3:30 A 90,000-YEAR RECORD OF FOSSIL CHIRONOMID AND CLIMATE CHANGE AT FOG LAKE, BAFFIN ISLAND
FRANCIS, DONNA ; Wolfe, Alex; Walker, Ian; Miller, Gifford

3:30-3:45 CLIMATIC REGULATION OF ACID-BASE EQUILIBRIUM IN ARCTIC LAKES ON MILLENNIAL TIMESCALES
WOLFE, Alexander Paul

3:45-4:00 AN ANNUAL SNOW MELT INTENSITY RECORD IN LACUSTRINE SEDIMENTS OF SAWTOOTH LAKE, ARCTIC CANADA
FRANCUS PIERRE; Abbott Mark; Bradley Ray; Keimig Frank; Perren, Bianca; Patridge Whit.

4:00-4:15 A LATE QUATERNARY RECORD OF LOESS DEPOSITION IN A MAAR LAKE, ST. MICHAEL ISLAND, WESTERN ALASKA
MUHS, DANIEL R.; Ager, Thomas A.; Dean, Walter E.

4:15-4:30 MIGRATION AND CYCLE OF SULPHUR IN A SUBARCTIC LAKE
DAUVALTER VLADIMIR; Moiseenko Tatyana
THURSDAY, MARCH 16TH

4:30-4:45  MILLENNIAL-SCALE GLOBAL EVENTS RECORDED IN EL'GYGYTGYN CRATER LAKE, EASTERN SIBERIA

4:45-5:00  RAPID ECOLOGICAL RESPONSE TO CLIMATIC CHANGE: THE PRELIMINARY DIATOM RECORD FROM SAWTOOTH LAKE, ELLESMER ISLAND
PERREN, BIANCA; Bradley, R.S.; Francus, P.

PARCS Reception to follow afternoon talks, Bldg. Rl-3, Rm. 620

FRIDAY MARCH 17, 2000

CONTINENTAL BREAKFAST
8:00-10:00 AM
INSTAAR Conference Room, Bldg. RI-1, Rm. 269

POSTER SESSION
8:00 AM- 11:30 AM
Bldg. RL-1, 2ND FLOOR

PERIGLACIAL PROCESSES AND PERMAFROST
1  A HISTORY OF PERMAFROST IN ALASKA: WARMING, THAWING AND THERMOKARST FORMATION
OSTERKAMP, T. E.; Romanovsky, V. E.

2  OBSERVATIONS OF THERMOKARST AND ITS IMPACT ON BOREAL FORESTS IN ALASKA
OSTERKAMP, T. E.; Viereck, L.; Shur, Y.; Jorgenson, M. T.; Racine, C.; Doyle, A.; and Boone, R. D.

3  CHEMICAL COMPOSITION ACCOMPANIED WITH ENZYMATIC ACTIVITY OF GROUND ICE IN CHUKOTKA AND WESTERN SIBERIA
VASIL'CHUK, YURIJ, Alla Vasil'chuk and Nadine Budantseva

4  POLLEN AND SPORES IN Palsa AND PINGO ORIGIN STUDY
VASIL'CHUK, ALLA

5  RE-DEPOSITED POLLEN IN PERMAFROST AS AGE AND ORIGIN INDICATOR OF GROUND ICE
VASIL'CHUK, ALLA
PALEOECOLOGY

6   THE PALEOECOLOGICAL ANALYSIS OF A SUBALPINE PERMAFROST PEATLAND (QUEBEC-LABRADOR)
ZIMMERMANN, CLAUDIA; Lavoie, Claude

ECOSYSTEM DYNAMICS

7   REINDEER POPULATION DENSITY IMPACT ON FORAGE BIODIVERSITY
ODASZ-ALBRIGTSEN, ANN MARIE

ARCHEOLOGY

8   LATE QUATERNARY SEDIMENTS AT 49-PET-408 (ON YOUR KNEES CAVE), SOUTHEASTERN ALASKA
SATTLER, ROBERT A.

9   SEA ICE AND SEAL FAUNAS IN LABRADOR INUIT ARCHAEOLOGICAL SITES
WOOLLETT, JIM

10  TEMPERATURE VARIATION AND DEMOGRAPHY IN LATE PREINDUSTRIAL ICELAND
VASEY, DANIEL E

CLIMATE

11  SUBLIMATION ESTIMATES FOR THE GREENLAND ICE SHEET USING AUTOMATED WEATHER STATION OBSERVATIONS
BOX, JASON E. and Konrad Steffen

12  TOTAL COLUMN MEASUREMENTS OF TROPOSPHERIC GASES IN ARCTIC, SPITSBERGEN, AND MIDLATITUDES, POTSDAM
TORSTEN ALBRECHT, Justus Notholt

13  THE INVESTIGATION AND DATING OF TRANSBOUNDARY AIR POLLUTION FOUND IN SOUTHERN GREENLAND. METHODS, TECHNIQUES, AND PRELIMINARY RESULTS

14  THE ARCTIC FRONTAL ZONE: ANALYSIS, OBSERVATION AND MODELING
SLATER, ANDREW; Beringer, Jason; Chapin, Terry; Clark, Martyn; Lynch, Amanda; McHugh, Ian; Serreze, Mark; Tapper, Nigel

15  GEOSTATISTICAL CHARACTERIZATION OF ICE-SURFACE MORPHOLOGIES - RESULTS FROM EXPEDITIONS MICROTOP 97 AND MICROTOP 99 TO JAKOBSHAUNS ISBRAE, WEST GREENLAND
HERZFELD, UTE C.; Helmut Mayer; Tim Erbrecht
SEA ICE
16 ARCTIC SEA ICE AND CIRCULATION ANOMALIES: THE INFLUENCE OF OSCILLATIONS
CULLATHER, RICHARD; Lynch, Amanda; Maslanik, James

17 SEA ICE MOTION FROM SATELLITE DATA
LIU, ANTONY; ZHAO, YUNHE

ENVIRONMENTAL HAZARDS
18 EFFECT OF GEOMEMAGNETIC FIELD FLUX ON HUMAN AUDITORY AND VISUAL EVENT-RELATED BRAIN POTENTIALS
HARTMANN, ANITA; Geist, Charles

19 ACCUMULATION OF HEAVY METALS IN SEDIMENTS AND WHITEFISH OF KOLA PENINSULA LAKES, MURMANSK REGION, RUSSIA
DAUVALTER VLADIMIR; Moiseenko Tatyana

GLACIAL GEOLOGY
20 SEDIMENTARY ARCHITECTURE OF A WAVE-MODIFIED ICE-CONTACT DELTA: GROUND PENETRATING RADAR STUDY OF THE YOUNGER DRYAS MONA MORaine IN SOUTHERN NORWAY
LØNNE, IDA; Nemec, W.; Blikra, L.H.; Lauritsen, T.

21 THE KREGNES MORAIN IN GAULDALEN: ANATOMY OF A YOUNGER DRYAS PROGLACIAL DELTA IN A PALAEOFJORD
LØNNE, I., Nemec, W. & Blikra, L.H.

22 MODELLING THE VARIATIONS IN GLACIAL COVERAGE OF ICELAND
WEBB, FERN ; Bjornsson, H.; Marshall, S.J.; Clarke, G.K.C.

23 LATITUDINAL VARIATIONS IN THE TIMING OF ALPINE GLACIER RETREAT FROM LGM, SOUTHERN SOUTH AMERICA
JACKOFSKY, D. S.; Gosse, J. C.; Cerling, T. E.; Evenson, E. B.; Klein, J.; Easterbrook, D. J.; Peterson, K. P., Spies, C., Sorenson, C. J.; Caffee, M.

24 THE PALEOGEOGRAPHY OF GLACIAL LAKE CHAMPAGNE, SOUTHERN YUKON: IMPLICATIONS FOR THE LAST DEGLACIATION
BARNES, SCOTT

LIMNOLOGY
25 MODERN SURFACE WATER ISOTOPE RATIOS: RELATIONSHIPS AND INFERENCES FOR LAKE SEDIMENT CORE δ¹⁸O PALEOClimATE RECONSTRUCTIONS
ANDERSON, L.; Abbott, M.B.; Finney, B.P.; Edwards, M.E.
26 A RECENT ASSESSMENT OF THE PHYSICAL LIMNOLOGY AND SEDIMENTOLOGY OF MONTANE MEZIADIN LAKE, NORTHERN BRITISH COLUMBIA, CANADA
BUTLER, RICHARD D.; Gilbert, Robert

27 PROCESSES OF CLASTIC SEDIMENTATION AT BEAR LAKE, DEVON ISLAND LEWIS, TED; Gilbert, Robert; Lamoureux, Scott

PALEOLIMNOLOGY
28 PROBLEMS WITH USING SEDIMENTS FROM SMALL ALPINE LAKES AS PROXIES FOR CLIMATE CHANGE.
MAZZUCCHI, DAVID

29 LAMINATED SEDIMENTS FROM CAPE HURD LAKE, A COASTAL ISOLATION BASIN, SOUTHWESTERN DEVON ISLAND, NUNAVUT, CANADA RETELLE, MICHAEL, Jeffrey Hershberger, Sarah Roberts, Benjamin Trafton

30 CHIRONOMID DISTRIBUTIONS AND THEIR RELATIONSHIP TO PAST AND PRESENT ENVIRONMENTAL CONDITIONS IN NORTHWESTERN CANADA WALKER, IAN R.; Levesque, AndrÈ J.; Pienitz, Reinhard; and Smol, John P.

31 LAKE LEVEL RECONSTRUCTIONS FROM SITES IN CENTRAL ALASKA, THE BROOKS RANGE, AND THE YUKON TERRITORY ABBOTT, MARK; Finney, Bruce ; Edwards, Mary and Anderson, Lesleigh

32 SEDIMENTOLOGICAL EVIDENCE FOR CIRCUMARCTIC CLIMATIC CHANGE FROM ELGYGYTGYN LAKE, NE RUSSIA COSBY, CELESTE A.; Brigham-Grette, Julie

33 MILLENNIAL-SCALE GLOBAL EVENTS RECORDED IN EL'GYGYTGYN CRATER LAKE, EASTERN SIBERIA BRIGHAM-GRETTE, J., Glushkova, O.; Minyuk P.; Melles M.; Nowaczyk, N. R; Lozhkin, A.V.; Anderson P.; Cherepanov, M.V.; Cosby, C.; Layer P.; Forman, S. L.

34 VIVIANITE FORMATION AND IMPLICATIONS FOR CLIMATIC CHANGE FROM EL'GYGYTGYN LAKE, NE RUSSIA HAYDEN, TRENT; Brigham-Grette, Julie; Cosby, Celeste; Minyuk, Pavel; Glushkova, Olga; Melles, Martin

FRIDAY, MARCH 17TH

36 A 12,000 YEAR LACUSTRINE RECORD FROM NIMGUN LAKE (AND CORRELATIONS WITH LITTLE SWIFT LAKE), AHKLUN MOUNTAINS, SOUTHWESTERN ALASKA

37 MAJOR-ELEMENT GEOCHEMISTRY AND SEDIMENT PROVENANCE IN A GLACIALLY-INFLUENCED LAKE: NORTHWESTERN AHKLUN MOUNTAINS, SW ALASKA
CAREY, KATHLEEN R.; Axford, Yarrow L.; Kaufman, Darrell S.

38 EVIDENCE OF HOLOCENE GLACIAL ACTIVITY FROM THE AHKLUN MOUNTAINS, SOUTHWESTERN ALASKA
FEINBERG, ALISON E., Werner, Al

39 A LATE QUATERNARY RECORD OF GLACIER FLUCTUATIONS, WASKEY LAKE AND MIRROR BAY, AHKLUN MOUNTAINS, SOUTHWESTERN ALASKA
LEVY, LAURA; Kaufman, Darrell; Manley, William

MARINE GEOLOGY

40 DEMONSTRATION OF GIS APPLICATIONS TO PALEOGLACIOLOGY, GLACIOLOGY, AND BATHYMETRY, ALASKA
MANLEY, William F.

41 THE INTERNATIONAL BATHYMETRIC CHART OF THE ARCTIC OCEAN (IBCAO): IMPROVING OUR KNOWLEDGE OF THE SEAFLOOR IN THE HIGH NORTH
DIVINS, DAVID L., IOC/IASC/IHO Editorial Board for the International Bathymetric Chart of the Arctic Ocean

42 SEABED MORPHOLOGY OF HUDSON STRAIT AND UNGAVA BAY: A FUNCTION OF BEDROCK STRUCTURES, EROSION, AND SURFICIAL SEDIMENT DEPOSITS
MACLEAN, BRIAN

43 SEDIMENTOLOGICAL ANALYSES OF THREE PISTON CORES FROM HUNAFLOI, NORTH ICELAND SHELF
CASTANEDA, ISLA S.; PRINCIPATO, SARAH M.

44 CHANGES IN THE CARBONATE CONTENT OF CORES ON THE NORTHERN ICELAND SHELF: HIGH-RESOLUTION (DECADAL) RECORDS OF SURFACE PRODUCTIVITY?
ANDREWS, JOHN T., Helgadottir, G., Geirsdottir, A., Sveinbjornsottir, A.

45 LATE GLACIAL AND HOLOCENE SEDIMENTARY PROCESSES AND ENVIRONMENTS, RANAFJORD, NORTH NORWAY: PRELIMINARY RESULTS
Stalsberg, Martha K. Eiliv; Lingva, Oddvar; Sejrup, Hans Petter; & AARSETH, INGE
46  DECIPHERING THE LATEST PLEISTOCENE AND HOLOCENE FLUXES OF FRESHWATER AND ATLANTIC WATER TO THE DEEP NORTHERN BARENTS AND KARA SEAS
LUBINSKI, DAVID; Polyak, Leonid; Forman, Steven

47  COMPARISON OF SEA-ICE SEDIMENT TO ICEBERG RAFTED DEBRIS: GRAIN SIZE, SURFACE FEATURES AND GRAIN SHAPE
DUNHILL, GITA; Reimnitz, Erk

48  SEDIMENT TRAP RECORDS OF DEPOSITION IN LALLEMAND FJORD ADJACENT TO MULLER ICE SHELF, ANTARCTIC PENINSULA
CHONG, ÅSA; Gilbert, Robert

11:30-12:45  LUNCH BREAK

Arctic Terrestrial Paleoenvironments 2
Chair: Alex Wolfe

INSTAAR Auditorium, Bldg. Rl-3, Rm. 620

12:45-1:00  EFFECTIVE MOISTURE AND EARLY-HOLOCENE SPRUCE (PICEA) EXPANSION IN EASTERN INTERIOR ALASKA.
EDWARDS, M.E.; Finney, B.F.; Bigelow, N.H.; and Abbott, M.B.

1:00-1:15  HOLOCENE PRECIPITATION VARIABILITY IN INTERIOR ALASKA
FINNEY, BRUCE; Edwards, Mary; Abbott, Mark; Barber, Valerie; Anderson, Lesleigh; Rohr, Melanie

1:15-1:30  PALYNOLOGICALLY-INFERRED ARCTIC VEGETATIONAL CHANGES RELATIVE TO SUB-MILLENIAL LATE HOLOCENE CLIMATIC VARIABILITY: ARE THE MWP AND THE LIA REGISTERED?
FRECHETTE, BIANCA; Wolfe, Alexander P.; Richard, Pierre J.H. and Miller, Gifford H.

1:30-1:45  THE EDGE PARADOX: A ZONE OF ORDER OR CHAOS? AN ICELANDIC CASE STUDY INVESTIGATING FACTORS CONTROLLING THE HIGH LATITUDE FOREST LIMIT
BROOKE PARRY; Kristiina A. Vogt; Throstur Eysteinsson; Bruce C. Larson; Daniel J. Vogt

1:45-2:00  MICROSCALE PLANT DISTRIBUTION IN A POLAR DESERT COMMUNITY ON AXEL HEIBERG ISLAND, NUNAVUT TERRITORY, CANADA
LIPTZIN, DANIEL
2:00-2:15  STRUCTURE AND BIOMASS OF A POLAR-LATITUDE EOCENE FOREST FROM THE CANADIAN HIGH ARCTIC
WILLIAMS, CHRISTOPHER; LePage, Ben; Johnson, Arthur; Vann, David

2:15-2:30  FREE AMINO ACIDS IN SUB-ARCTIC SALT-MARSH COASTAL SITES AND PLANT NITROGEN NUTRITION
HENRY, HUGH; Jefferies, Robert

2:30-2:45  ANALYSIS OF MODERN AND FOSSIL POLLEN SPECTRA AND PINE MACROFOSSILS FROM THE KOLA PENINSULA, RUSSIA
GERVAIS, BRUCE; MacDonald, Glen

2:45-3:00 PM  AFTERNOON BREAK

Paleoecology and Archeology of Southeast Alaska

Chairs: Robert Sattler and Jim Dixon

3:00-3:15  LATE PLEISTOCENE MARITIME ADAPTATIONS AND THE FIRST HUMAN COLONIZATION OF NORTH AMERICA
DIXON, E. JAMES

3:15-3:30  STUDYING MY ANCESTORS: AN ALASKA NATIVE PERSPECTIVE ON PREHISTORIC ARCHEOLOGY
VAARA, YARROW

3:30-3:45  CLIMATIC CONDITIONS DURING THE LAST GLACIAL MAXIMUM IN COASTAL ALASKA AS SEEN FROM FOSSIL VERTEBRATES OF PRINCE OF WALES ISLAND
HEATON, TIMOTHY H.

3:45-4:00  PRELIMINARY ANALYSIS OF OBSIDIAN ARTIFACTS FROM 49-PET-408, PRINCE OF WALES ISLAND, ALASKA
LEE, CRAIG M.

4:00-4:15  LATE QUATERNARY SEDIMENTS AT 49-PET-408 (ON YOUR KNEES CAVE), SOUTHEASTERN ALASKA
SATTLER, ROBERT A.

Contributed Papers

Chair: Scott Elias

4:15-4:30  SOIL DEVELOPMENT IN THE HIGH ARCTIC: TRUELOVE LOWLAND, DEVON ISLAND, NUNAVUT, CANADA
FISHBACK, LEEANN; King, Roger, H.
FRIDAY, MARCH 17TH

4:30-4:45 HIGH RESOLUTION ARCTIC WINTER SIMULATIONS IN A REGIONAL CLIMATE MODEL
DETHLOFF, KLAUS; Rinke, Annette; Dorn, Wolfgang; Kandlbinder, Thomas; Romanov, Vladimir*

4:45-5:00 ARCTIC HAZE, CLOUDS, AND CLIMATE
RADKE, LAWRENCE F.; Ogren, John; Stone, Robert S.; Andrews, Elizabeth A.; Dutton, Ellsworth G.

5:00-5:15 CLIMATIC EFFECT OF ARCTIC HAZE
RINKE, ANNETTE; Fortmann, Martin; Dethloff, Klaus

5:15-5:30 MINIMUM SNOW COVER EXTENT AND SNOW COVER DYNAMIC OF A LOW ARCTIC SITE (ABISKO, NORTH SWEDEN) DERIVED FROM LANDSAT 7 IMAGES
Stefan Vogel

5:30-5:45 PRODUCTIVITY OF WILLOW-SHRUB TUNDRA IN CONNECTION WITH LANDSLIDE ACTIVITY
N.G. UKRAINTSEVA; M.O. Leibman

DINNER PARTY: 6:30 PM RL-1, INSTAAR, RM 269

SATURDAY, MARCH 18, 2000

Environmental Geochemistry
Chair: Anne Jennings

8:30-8:45 HYDROGEOLOGY AND HYDROGEOCHEMISTRY OF PERMAFROST ZONE OF DALDYN-ALAKIT REGION (WESTERN YAKUTIA)
PINNEKER, EUGENE; Alexeev, Sergey; Alexeeva, Ludmila

8:45-9:00 DYNAMICS OF DRAINAGE WATER COMPOSITION DURING DEVELOPMENT OF DIAMOND MINING QUARRIES (WESTERN YAKUTIA, RUSSIA)
ALEXEEV, SERGEY; Alexeeva, Ludmila; Borisov, Valeriy

9:00-9:15 CONTAMINANT LANDSCAPES OF ARCTIC ALASKA AND SIBERIA
JESSE FORD, BRENDA K. LASORSA, MATTHEW MONETTI, TATIANA VLASOVA, AND DIXON LANDERS

9:30-9:45 A COMPARISON OF LEAD AND MERCURY CONCENTRATIONS FROM A SOUTHERN GREENLAND AND DANISH MIRE
SATURDAY, MARCH 18TH

9:45-10:00 MORNING BREAK

Human Dimensions of the Arctic
Chair: Astrid Ogilvie

10:00-10:15 PIGS, GOATS, AND ANDISOLS: ZOOARCHAEOLOGY AND LANDSCAPE CHANGE IN ICELAND
McGOVERN, THOMAS, PERDIKARIS, SOPHIA, TINSLEY, CLAYTON

10:15-10:30 TEMPERATURE VARIATION AND DEMOGRAPHY IN LATE PREINDUSTRIAL ICELAND
VASEY, DANIEL E

10:30-10:45 TEPHROCHRONOLOGY, ENVIRONMENTAL CHANGE AND HISTORICAL ECOLOGY IN SOUTH ICELAND
DUGMORE, ANDREW; Larsen, Gudrun; Newton, Anthony; Simpson, Ian

10:45-11:00 ADDRESSING THE AGE DISCREPANCY IN MARITIME ARCHAIC INDIAN OCCUPATION OF SOUTHERN LABRADOR AND THE ISLAND OF NEWFOUNDLAND
BELL, TREVOR; Renouf, Priscilla

11:00-11:15 AN ARCHAEOLOGICAL SURVEY OF SKOLAI PASS – WRANGELL - ST. ELIAS NATIONAL PARK AND PRESERVE, ALASKA
MARK L. HOWE

11:15-12:00 BOX LUNCH
INSTAAR Conference Room, Bldg. RL-1, Rm. 269

Quaternary Geology 1
Chair: Mike Kaplan

12:15-12:30 COSMOGENIC NUCLIDE STRATEGIES FOR RELATIVE SEA LEVEL HISTORIES
GOSSE, JOHN; Klein, Jeff; Dyke, Art; Caffee, Marc POST GLACIAL

12:30-12:45 SEA-LEVEL CHANGES AND GLACIAL FOREBULGES AROUND NORTH AMERICA AND ICELAND-IMPLICATIONS FOR FOREBULGE MOVEMENT AND RATES OF CRUSTAL ADJUSTMENT
JOSENHANS, HEINER

12:45-1:00 ICE WEDGES, CRYOTURBATIONS AND ICE-WEDGE CASTS IN THE OUTCROP "MERZLIY YAR" (TUVA REPUBLIC)
ALEXEEV, SERGEY; Arzhannikov, Sergey; Glyzin, Alexander.
<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
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<tbody>
<tr>
<td>1:00-1:15</td>
<td>Lithostratigraphy and Glaciotectonics of Cape Shpindler, Yugorsky Peninsula, Arctic Russia</td>
<td>Lokrantz, Hanna; Ingolfsson, Olafur; Manley, William; Gataulling, Valery</td>
</tr>
<tr>
<td>1:15-1:30</td>
<td>Late Quaternary Palaeoenvironmental History of Prins Karls Forland, Western Svalbard</td>
<td>Andersson, Torbjorn</td>
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<td>1:30-1:45</td>
<td>Erosion Marks in Bedrock at Kangerlussuak, Greenland: Relation to Continental Glacial Processes</td>
<td>Gilbert, Robert</td>
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<tr>
<td>1:45-2:00</td>
<td><strong>Afternoon Break</strong></td>
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**Quaternary Geology 2**

Chair: Heiner Josenhans

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<tr>
<th>Time</th>
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<th>Authors</th>
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<tbody>
<tr>
<td>2:00-2:15</td>
<td>Late Glacial-Early Holocene Landscape Evolution of the Chapman Lake Area, Yukon Territory, Canada</td>
<td>Beierle, Brandon</td>
</tr>
<tr>
<td>2:15-2:30</td>
<td>Has the Northern Gaspe Peninsula Ever Been Invaded by an Ice Sheet from Quebec-Labrador?</td>
<td>Csiki, Magdalena; Gray, James; Hetu, Bernard; Gagnon, Sylvain; Marquette, Genevieve</td>
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<tr>
<td>2:30-2:45</td>
<td>Studies on Felsenmeer-Covered Surfaces in the Torngat Mountains, Northern Quebec-Labrador</td>
<td>Marquette, Genevieve; Gray, James T.; Courchesne, Francois; Gosse, John</td>
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<tr>
<td>2:45-3:00</td>
<td>Morphological Evidence for Late Glacial Invasion of the Western Flanks of the Northern Labrador Peninsula by Hudson Strait and Ungava Bay Ice and 14C Dating of the Sheppard Moraines</td>
<td>Gray, James; Decker, Vincent; Jull, Timothy; Gray, Alexander #</td>
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<tr>
<td>3:00-3:15</td>
<td>The Cirques of Southeast Cumberland Peninsula, Baffin Island: Implications for the Glacio-Climatic History of the Region</td>
<td>Kaplan, Michael, R.</td>
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<tr>
<td>3:15-3:30</td>
<td>Goldilocks' Compromise Looking Good: New Evidence from High-Elevation Baffin Island Lakes</td>
<td>Miller, Gifford; Wolfe, Alex; Steig, Eric; Kaplan, Michael; Briner, Jason</td>
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</table>
Our ongoing research is aimed at documenting the regional pattern of P-E change from the late Pleistocene to present using multi-proxy methods at a network of lakes from central and northern Alaska to the Yukon Territory. We have used seismic surveys and core transects to identify transgression and regression sequences associated with water-level changes. Laboratory work includes sedimentological, geochemical, oxygen isotope, and palynological analyses.

Results from Birch Lake in central Alaska show a pronounced period of aridity ended around 15.3 ka B.P. (12.7 14C ka B.P.) (Abbott et al., 2000). Sediments in Jan Lake also show the same general pattern. Records older then this from central Alaska are rare because the dry lake basins were deflated and the sediment record lost. To date we have not identified any sites with records older than 15.3 ka B.P. in central Alaska. However, at Burial Lake in the Noatak Valley of northwestern Alaska we have a 42 14C ka B.P. record. If Burial Lake remained filled throughout the late Pleistocene it suggests western Alaska was not as arid as the interior. Work is in progress on a transect of cores from Burial Lake. In the eastern and central interior of Alaska we have also shown that the two most prominent regional vegetation changes: from herb to shrub tundra and the expansion of spruce-dominated boreal forest, were both coincident with regional increases in effective moisture.

Results from Meli and Tangled Up lakes in the central Brooks Range indicate there have been both temperature and P-E balance shifts during the Holocene. A long term millennial scale trend towards increased effective moisture since ~8 ka B.P. is indicated by sediment cellulose del18O in Meli Lake. High-resolution del18O analyses of authigenic carbonate from Tangled Up Lake show decadal to century scale temperature variability. Combined, these records reveal climatic changes throughout the region at a variety of temporal scales that create a foundation for future research investigating the timing, spatial extent, and magnitude of these events.

Preliminary results from a transect of eight sediment cores from Jackfish Lake in the Yukon Territory document a complex Holocene lake level history. Jackfish is a small (<1 km²), shallow (<10 m deep) closed basin lake with a relatively high E/I ratio (2.2) and a low watershed to lake area ratio (3.1). Isotope analyses of surface water samples indicate it is sensitive to changes in the P-E balance (see poster by Anderson et al., this session). Basal radiocarbon dates indicate the lake basin was dry prior to 10.6 ka B.P. with water levels remaining low until after 7.1 ka B.P. After 7.1 ka B.P. shallow water cores contain multiple transgression/regression phases suggesting lake levels were lower than present until the latest Holocene. Stable isotope analyses on authigenic carbonate is in progress and combined with lake level, pollen, and geochronological studies will provide a powerful tool for identifying the timing, direction, magnitude, and rate of water balance changes in the region.

TOTAL COLUMN MEASUREMENTS OF TROPOSPHERIC GASES IN ARCTIC, SPITSBERGEN, AND MIDLATITUDES, POTSDAM

TORSTEN ALBRECHT, Justus Notholt

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Solar absorption spectra we perform since 1992 in the high Arctic at Spitsbergen (79°N) by using the high resolution Fourier Transform InfraRed (FTIR) absorption spectroscopy. The spectra allows to retrieve the total column concentrations of about 26 atmospheric trace gases. The results of a few tropospheric trace gases (e.g. CO, C2H2, C2H6, H2CO) will be compared to similar observations which we have been recorded in 1997-1999 in Potsdam, near Berlin. For a few compounds the data reveal higher column in the Arctic compared to Potsdam. The results will be discussed with respect to anthropogenic emissions, biogenic sources and long range transport from the European, Russian and North American industrial areas into the Arctic. Especially, we will discussed the variation of Formaldehyde (H2CO).

DYNAMICS OF DRAINAGE WATER COMPOSITION DURING DEVELOPMENT OF DIAMOND MINING QUARRIES (WESTERN YAKUTIA, RUSSIA)

ALEXEEV, SERGEY; Alexeeva, Ludmila; Borisov, Valeriy*

Institute of the Earth's Crust SB RAS; *Irkutsk State University
salex@gpg.crust.irk.ru

The Daldyn-Alakit region of Western Yakutia is unique one due to variety of hydrogeochemical conditions of mining of rigid useful mineral. The primary deposits of diamonds are distributed there. The most part of them is developed by open minings, i.e. the quarries. The region is within the boundaries of the huge zone of chloride calcium brines distribution, extending from the Yenisei River to the Olenek River. Down the vertical section the groundwaters of other geochemical types almost are absent completely. However by mineralization two brine-bearing zones are selected clearly (Pinneker et al, 1998).

1. The zone of salty waters and weak brines (A) with mineralization 30-200 g/l is situated up to depth 120-270 m. The cation composition is mixed, the relative contents of calcium, magnesium, sodium are close enough (25-40 %). 2. The zone of strong and rather strong brines (B) with mineralization 300-400 g/l is distributed below the depth of 600 m. These brines have mainly chloride calcium composition.

The development of diamond deposits in region is inevitably accompanied by technogenic pressure on the environment (Borisov et al, 1995). The main source of contamination is the drainage brines. The authors studied these brines in natural and technogenic conditions during the development of Udachnaya kimberlite pipe quarry.

The sources of water reflux formation in the quarry are: 1) atmospheric and surface fresh waters, 2) weak brines of subpermafrost aquifer (zone A), 3) strong and rather strong brines(zone B). All types of waters with various composition came to the quarry in unequal ratio and were intermixed forming drainage waters of other composition. Mineralization, anions and cations, sodium - chloride, calcium - magnesium ratios and other parameters distinguish them.

To this time the depth of the quarry has achieved 475 m. The mineralization of drainage waters was increased up to 300-360 g/l.

To trace the changes of qualitative composition of drainage waters the statistical processing of hydrogeochemical data (from 1983 to 1999 years) was made. The average content of macro- and microcomponents of drainage waters was compared with the concentration of
these components of weak, strong and rather strong brines in natural conditions. The results of comparison are presented in Table 1.

The results show that among anions of drainage water chloride occupies the main place (up to 99%). The content of sulphate and hydrocarboante ions does not exceed 0.1-0.2 g/l. The cations are represented by four elements: Ca2+ (40-60%), Mg2+ (20-40%), Na+ (15-20%) and K+ (5-10%). The bromine (up to 4 g/l) constantly presents, the other microcomponents (Sr2+, Li+, Rb+) have rather significant concentrations.

These parameters allow to consider the drainage brines as hydromineral raw materials. The analysis of a correlation matrix shows the good correlation of mineralization practically with all macro- and microcomponents (Table 2). On the diagrams it's clearly seen the tendency of changing of the role of various sources of formation of drainage water composition (Figure 1, 2). At the beginning (1983-1985) the inflow into the quarry consisted of atmospheric and surface waters and subpermafrost brines with average mineralization about 90 g/l. That is why the drainage waters had mineralization 25.5 g/l, reduced significances of sodium - chloride (0.18) and calcium - magnesium (0.82) ratios.

The gradual growth of mineralization (see Figure 1) shows that the strong brines of II aquiferous complex were involving in water reflux and the share of subpermafrost and surface waters was reducing during development of Udachnaya pipe. It is confirmed by increasing of the calcium - magnesium ratio as well (see Figure 1).

The high concentration of Na+ - 20.2 g/l (see Table 1) in drainage waters is explained by opening of lens of chloride sodium waters (in 1984) and inflowing of these waters into the quarry. It was also displayed in sharp rise of sodium -chloride ratio (see Figure 2).

The general tendency of changing of this parameter shows the approach of composition of drainage waters to the same one of waters of zone B.

Thus the analysis of available data shows that, since a 1990, the composition of drainage waters has begun to be stabilized, coming to be equal to the composition of strong brines. During the further development of Udachnaya diamond deposit (up to depth 600 m) the brines of zone B will be the main source of wateryness of the quarry and the mineralization of drainage waters will increase up to 400 g/l.

The study has been carried out with the financial support of Russian Fund for Basic Research (grant's number 00-05-64212).


Table 1. Average content of macro- and microcomponents in subpermafrost groundwater and drainage water.

<table>
<thead>
<tr>
<th>Component</th>
<th>g/l</th>
<th>mg/l</th>
</tr>
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<tbody>
<tr>
<td>M</td>
<td>89.6</td>
<td>1.68</td>
</tr>
<tr>
<td>K⁺</td>
<td>7.71</td>
<td>1.68</td>
</tr>
<tr>
<td>Na⁺</td>
<td>7.51</td>
<td>1.68</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>13.49</td>
<td>1.68</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>57.25</td>
<td>1.68</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>1.05</td>
<td>1.68</td>
</tr>
<tr>
<td>Br⁻</td>
<td>0.98</td>
<td>1.68</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>0.13</td>
<td>1.68</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>35.13</td>
<td>1.68</td>
</tr>
<tr>
<td>Li⁺</td>
<td>1.2</td>
<td>1.68</td>
</tr>
<tr>
<td>Rb⁺</td>
<td>301.18</td>
<td>1.68</td>
</tr>
<tr>
<td>Sr²⁺</td>
<td>301.18</td>
<td>1.68</td>
</tr>
<tr>
<td>Zone A</td>
<td>89.6</td>
<td>1.68</td>
</tr>
<tr>
<td>Zone B</td>
<td>323.68</td>
<td>11.96</td>
</tr>
<tr>
<td>Drainage water</td>
<td>147.7</td>
<td>5.4</td>
</tr>
</tbody>
</table>

M – mineralization, g/l. Number of samples: 57 – from I aquifer, 141 – from II aquifer, 176 – drainage water.
Table 2. Correlation matrix

<table>
<thead>
<tr>
<th></th>
<th>K⁺</th>
<th>Na⁺</th>
<th>Mg²⁺</th>
<th>Ca²⁺</th>
<th>Cl⁻</th>
<th>Br⁻</th>
<th>Li⁺</th>
<th>Rb⁺</th>
<th>Sr²⁺</th>
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</thead>
<tbody>
<tr>
<td>M</td>
<td>0.921</td>
<td>0.840</td>
<td>0.902</td>
<td>0.956</td>
<td>0.998</td>
<td>0.882</td>
<td>0.829</td>
<td>0.890</td>
<td>0.828</td>
</tr>
<tr>
<td>K⁺</td>
<td>1.000</td>
<td>0.921</td>
<td>0.557</td>
<td>0.903</td>
<td>0.726</td>
<td>0.565</td>
<td>0.810</td>
<td>0.623</td>
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</tr>
<tr>
<td>Na⁺</td>
<td>1.000</td>
<td>0.620</td>
<td>0.666</td>
<td>0.833</td>
<td>0.513</td>
<td>0.254</td>
<td>0.683</td>
<td>0.370</td>
<td></td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>1.000</td>
<td>0.906</td>
<td>0.909</td>
<td>0.806</td>
<td>0.773</td>
<td>0.601</td>
<td>0.725</td>
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</tr>
<tr>
<td>Ca²⁺</td>
<td>1.000</td>
<td>0.961</td>
<td>0.906</td>
<td>0.960</td>
<td>0.699</td>
<td>0.866</td>
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<tr>
<td>Cl⁻</td>
<td>1.000</td>
<td>0.892</td>
<td>0.839</td>
<td>0.882</td>
<td>0.832</td>
<td></td>
<td></td>
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<tr>
<td>Br⁻</td>
<td>1.000</td>
<td>0.852</td>
<td>0.830</td>
<td>0.824</td>
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<tr>
<td>Li⁺</td>
<td>1.000</td>
<td>0.758</td>
<td>0.892</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rb⁺</td>
<td>1.000</td>
<td>0.749</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sr²⁺</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
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</table>

M – mineralization

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In the Late Pleistocene owing to active tectonic movements in western part of Todzha depression the Bolshoi Yenisei river has been dammed, resulted in the lake formation. The lake existed about 10 000 years being periodically changed in size. The traces of the lake were saved in the outcrop "Merzliy Yar" (Lat 52°31'48"N, Long 95°21'46"E). The terrace has 20 m height and consists of rhythmically interbedded frozen alluvial deposits, buried peat-soil horizons and trees located in situ. The authors have founded the relict ice wedge, cryoturbations and ice-wedge casts in the section of terrace. New data about paleoclimate and seismotectonic processes in western part of Todzha depression were obtained as the result of investigations of the outcrop "Merzliy Yar".

The scientists studied the outcrop "Merzliy Yar" during twenty years (Chudinov, 1959; Grosvald, 1965; Klimovskiy, Shats, 1975; Orlova, 1980 etc.). The authors have established that the terrace consists of 6 or 13 rhythms. Two layers represent each rhythm. The lower layer consists of sandy loam and the upper layer is formed by peat and buried soils with trees remains and stamps. The lower layers of all rhythms deposited in subaqueous lake conditions. The upper layers were formed on the place of shallowed lake. In that period the bog was existed there. In further it was drained and covered by wood vegetation. Thus, in western part of Todzha depression the lake originated and drained from 6 up to 13 times as the result of strong paleoearthquakes and formation of high tectonic scarp in the Taskyl range.

In the Pleistocene the lowering of air temperature has predetermined permafrost and ice wedges formation in this region. In the Holocene the warming of climate has ceased the growth of ice wedges. The ice wedges were melted and ice-wedge casts were formed in their place.

The outcrop "Merzliy Yar" has extention about 700 m and is totally frozen. The thickness of permafrost exceeds 15 m, and the temperature at the depth of zero annual amplitude amounts to - 2.3°C (Klimovskiy, Shats, 1975). In September the depth of thawing reaches 0.7 m in mixed cedar-larch wood and 1.2 m on the first terrace cusp. The authors stripped the relict ice wedge at the depth 7.6 m (Figure 1). The thickness of ice wedge is 5.4 m.

The morphology of ice wedge and rock structure have a number of distinctive indications: 1) the large vertical thickness of ice wedge; 2) the compound shape of ice wedge, sinuous lateral contacts and irregular width downward to depth; 3) "soldering" of segregated lens ice to lateral contacts of ice wedge, 4) big quantity of spherical gas bubbles in ice, being stretched in line; 5) ground particules and vegetative rests in ice; 6) sharp bending of layers near the ice wedge; 7) peat lenses in the section of outcrop; 8) the monotonous facies conditions of accumulation of deposits as a whole. These indications testify that the ice wedge has syngenetic origin.

The ice wedge has chloride-hydrocarbonate composition. Among cations the magnesium and calcium predominate. The ice mineralization at the top of the wedge is 60.5, at the average part - 57.6 and at the lower one - 74.9 mg/l. The content of SO42- amounts to 2.0, F - 0.1, H4SiO4 -2.0 mg/l. The bromine and boron are not detected.

The ice wedges have the great significance for the permafrost-facial analysis. Studying only syngenetic ice wedges it's possible to obtain data on peculiarities of formation and freezing of deposits. The data obtained by the authors testify that the initial stage of syngenetic ice wedge began during the formatin of coastal facies of the shoal (sandy loams, interlayers of vegetative detritus, allochthonous and autochthonous peat as well). Carbon-14 dating of wood rests located at the initial stage of ice wedge has shown that they have age of 10 820+110 and 11 810+60 years (SB RAS-3992, SB RAS-3993). The ice wedges formed in conditions of severe climate.
and superficial occurrence of frozen substratum. The ice wedge cracks formed in the sandy loam deposits and peats being freezeed syngenetically. The iciness (humidity) of deposits achieved 80-100 and even 160%.

Detected trunks of the fur-tree in horizon of ice-wedge formation and the results of spore-pollen analysis testify to a cold and wet climate. It's indicated also by other author (Grosvald, 1965). At the upper part of outcrop (0.4-7.85m) Pinus sibirica, Pinus sylvestris and Abies sibirica take up the most part of spectrum. Among herbaceous plants Polypodiaceae predominates. It testifies that the upper part of deposits formed in warmer and drier conditions.

The age of the stamp collected above the head of ice wedge is dated per 8820+70 years (SB RAS-3989). Thus, the ice wedge was formed within 2700 - 2800 years with average growth rate of 1.9 mm per year. The growth rate of recent ice wedges varies from 0.4 to 1.6 mm per year (Black, 1973; Mackey, 1976).

The thickness of seasonally thawed layer occurred above the ice wedge was 0.6 - 0.7 m. The cryoturbations stripped at the depth 6.2 m are confirmed that (Figure 2). They are characterized by chaotic deformations of ground resulted from frost action. The availability of cryoturbations is fixed also within depth interval 1.0 -1.7 m. Many of the trees could tilt as the result of ground movement forming so-called "drunken forest".

The ice wedge casts have special significance for paleoclimatic and paleogeocryological reconstructions. Similar postcryogenic formation was founded at the depth of 3.6 m. The thickness of ice wedge cast is 0.5 m. The soil-vegetative horizon overlies the roof of melted ice wedge. The position of ice wedge cast approximately corresponds to the position of second soil-vegetative horizon, dated in 608045 years (SB RAS-3983). Probably in that time the territory has cropped out. So the thermal influence of lake was small. At first the deposits freezeed and ice wedge formed. Then the global warming of climate has caused increasing of thickness of seasonally thawed layer, melting of ice wedges and ice wedge cast formation their place.

In the structure of outcrop "Merzliy Yar" the series of rhythms indicating the dynamic of paleolake is distinguished. In the Pleistocene the lowering of air temperature has predetermined permafrost and ice wedges formation in western part of Todzha depression. The syngenetic ice wedges began to be formed 10 000-11000 years ago. This process proceeded about 3 000 years. In the Holocene the ice wedges has melted and ice wedge casts was formed on their place.

The study has been carried out with the financial support of Russian Fund for Basic Research (grant's number 00-05-64398).

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Reconstructions of Little Ice Age sea surface temperatures (SSTs) and surface water conditions in the Nordic Seas have been investigated in sediment cores 93030-23A (67°08.19N, 31°52.62W) and 93030-19A (67°08.73N, 30°49.34W) from the southern Denmark Strait and MD95-2011 and JM97-948 (both 66°58.18N, 07°38.36E) from the Vøring Plateau. The main objective of the study was to capture and document rapid climate variability during the last 300 years, and thereby expand available instrumental datasets further back in time. In order to reach the objectives, cores with high accumulation rates were chosen. SSTs are reconstructed using diatom assemblages and statistical methods, which enabled us to resolve Late Holocene climate changes.

The results show that the SSTs were 1.5-2°C lower than the present and rather unstable over the Vøring Plateau between AD 1400 - 1750 (the Little Ice Age), which indicates a reduced Norwegian Atlantic current during this time period. After AD 1750 SSTs show an increasing trend with rapid fluctuations superimposed on it. The Denmark Strait cores cover the last 300 years, and show a clear SST decrease of total 2.5°C from AD 1700 to the present. The diatom assemblages imply a greater influence of the Irminger Current in the 18th century, followed by a cooling caused by the eastward expansion of the East Greenland Front up till the 20th century. The contrasting conditions between the Denmark Strait and the Vøring Plateau during the last 300 years indicates that the climate developed differently during the Little Ice Age in the eastern and the western parts of the Nordic Seas, indicating changes in the oceanic circulation system and the position of the oceanic fronts.

MODERN SURFACE WATER ISOTOPE RATIOS: RELATIONSHIPS AND INFERENCE FOR LAKE SEDIMENT CORE δ18O PALEOCLIMATE RECONSTRUCTIONS

ANDERSON, L.; Abbott, M.B.; Finney, B.P.*; Edwards, M.E.#

Department of Geosciences, University of Massachusetts Amherst, *Institute of Marine Science, University of Alaska Fairbanks, #Norwegian Geosurvey Department of Geography, Dragvoll Norway

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The challenge for utilizing proxies of lake-water δ18O for paleoclimatological and paleohydrological studies, such as authigenic calcite in lake-sediment cores, is to correctly infer the driving mechanisms for δ18O variability for individual lakes. Previous work and experience has indicated that the guiding principle for evaluating controls on lake-water δ18O is individual lake site hydrology and climatology (Anderson et al., in review; VonGrafenstein et al., 1999; Ricketts and Anderson, 1998; Talbot, 1990) Interpretations are based upon the estimated evaporation to input (E:I) ratios; lake-water δ18O from lakes with high E:I ratios is thought to be primarily driven by evaporation, and lake-water δ18O from lakes with a low E:I ratio is
controlled by the $\delta^{18}O$ composition of input waters. However, only a few studies have explored this relationship with a statistically significant number of lake sites or measurements (Abbott et al., in review; VonGrafenstein and Erlenkeuser 1999; Sauer 1997). Here we explore relationships between lake-watershed characteristics and the isotopic composition of modern water samples from 25 closed and open lake basins, rivers, springs, groundwater and precipitation from the central Yukon Territory. The primary objective of this research is to empirically establish the paleohydrological interpretive framework of sediment-core authigenic calcite $\delta^{18}O$ stratigraphies from closed basin lakes in this region.

The sampled lake sites include a wide range of hydrologic characteristics. Larger lakes are up to 40 km$^2$ and small ponds are ~0.2 km$^2$. Watershed areas also range from large (up to 350 km$^2$) to very small (~0.2 km$^2$). Water budgets range from closed basins, to high volume overflowing lakes. Spring, groundwater, rivers and precipitation are found to plot on or very near the Global Meteoric Water Line (GMWL) while significant isotopic modification occurs (~12$\delta^{18}O$-enrichment) within closed basin lake sites due to the preferential evaporation of the lighter $^{16}O$-isotope. Relationships between $\delta^{18}O$, d2H, lake area, lake depth, watershed area, elevation, inflow from precipitation, and estimated E:I are evaluated for the hydrological type associated with ranges of isotopic composition. These hydrologic types are proposed as a calibration or analogue tool for interpreting sediment core $\delta^{18}O$ changes and the inferred paleohydrology. These results will clarify and empirically validate estimates of past moisture balance changes in the upper reaches of the Yukon River watershed.

Changes in the Carbonate Content of Cores on the Northern Iceland Shelf: High-Resolution (Decadal) Records of Surface Productivity?


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Records of the carbonate content of a series of cores on the N. Iceland shelf and within a fjord (Fig. 1), show a remarkable consistency in the pattern of carbonate accumulation over the last 5,000 years (Fig. 2). Carbonate weight % estimates have been derived from the USC Coulometer, model 511, and the WHOI automatic carbonate system. Comparative tests indicate that these two instruments give essentially the same results (i.e. slope = 1.0). The chronologies for the three cores are based mainly on molluscs; 328 has 11 AMS dates 1, whereas 327 has 4 and 330 6 dates. The sediment accumulation rates vary but average 10.1, 15 and 12.6 yrs/cm respectively. Depth/age plots indicate that the rates of sediment accumulation are monotonic over the last 4-5 ka. Thus our common sampling interval of 5 cm results in one sample every 50 to 75 yrs, indicating that we can resolve century-scale variations. In 330 we have carbonate measurements every 2 cm, hence can resolve decadal variations larger than the Nyquist frequency of 25 yrs. Estimates of wet and dry unit sediment densities were also obtained on all cores at 5 cm intervals. Mass accumulation rates (MAR) of g Carbonate/cm2.100yr can now be derived from our data.

Using the program Analyseries 2 the degree of fit between the records from cores B997-328, -327, and -330 is > r=0.8. The pattern of carbonate accumulation over the last 4-5 ka is marked by a distinct series of events, or which the most profound is the carbonate minimum, temporally associated with the Little Ice Age, and two carbonate maxima with dates of ca. 2 and 3.8 ka (Fig. 2). Another minima occurs around 4.4 ka. Between these major events are a series of smaller oscillations which appear to correlate. Thus it appears that carbonate values vary on both millennium and centuries scales in this region.

The carbonate content of marine cores can be associated with three major life forms, the molluscs, foraminifera, or the phytoplankton. Since our procedure effectively excludes molluscs then the source of the variation in carbonate content must be caused by changes in either the sand-size foraminifera, or the < 63 µm fraction which would be primarily coccoliths. The average dry sediment unit density is ca. 0.7 g/cc, the weight% of the sand fraction in these cores averages < 10%, and the %foraminifera in point counts averages ca. 50%. Thus the contribution of foraminifera is of the order of 0.035 g Carbonate/cm3 or a MAR foraminifera of < 0.3 g Carbonate/cm2.100yr. This value can be compared with the MAR carbonate from 328 which had an average estimate of 0.6 g Carbonate/cm2.100 yr. In other-words, the foraminifera only account for about 50% of the total carbonate content in the < 2 mm fraction. A more accurate calculation can be made for 328 as here we have numbers of foraminifera/g dw. Based on the weight and numbers of foraminifera submitted for AMS 14C dating, the average weight of a benthic foraminifera is estimated to be 0.022 ± 0.003 mg. Converting forams/g to forams/cc and taking the average foram weight led to an average MAR foraminifera of 0.02 g Carbonate/cm2.100yr, or an order of magnitude less than the MAR carbonate. The MAR carbonate is of the same order as carbonate production on the shallow banks and intertidal areas of Scotland and Maine 3 where the carbonate content is frequently composed of shell hash. Thus these rates are high for moderately “deep water” cold-water environments 4.

The vast bulk of the carbonate must be associated with large spring and fall phytoplankton blooms 5. On recent decadal time-scales, temperature and salinity of waters off N. Iceland show a
strong positive correlation with the North Atlantic Oscillation (NAO). Thordarddottir\textsuperscript{6-8} showed that replacing Atlantic Water with Polar Water off N. Iceland resulted in a significant drop in marine productivity due to the increased stratification of the water column and a reduction in vertical mixing and nutrient supply.

Our hypothesis is thus that the changes in carbonate, especially in the net carbonate flux (MAR), is a proxy for changes of surface productivity. An alternative hypothesis is that these changes represent dilution of the carbonate by terrestrial inputs \textsuperscript{9,10}---such an hypothesis would appear appropriate for N. Iceland where Neoglacial activity of local glaciers is well documented \textsuperscript{11,12}. However, the linear SAR over the last 4-5 ka does not fully support this concept, although Haflidason \textsuperscript{13} reported evidence for an increased SAR over the last 1 ka, possibly associated with the settlement of Iceland.

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LACUSTRINE RECORD OF DEGLACIATION IN THE AHKLUN MOUNTAINS, SW ALASKA: ICE RETREAT DURING THE YOUNGER DRYAS

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Recent work by Kaufman et al. (in press), Manley et al. (in press), and Briner and Kaufman (2000) examines in detail the late Pleistocene glacial history of the Ahklun Mountains region of southwestern Alaska (for summary see Kaufman et al., this volume). However, the late-glacial and Holocene history of this region remains poorly understood. Little Swift Lake is a small, deep basin (~0.7 km² surface area; 24 m maximum depth) capturing the drainage of Little Swift Creek valley in the northwestern Ahklun Mountains (Fig. 1). Although glaciers are not present in Little Swift Creek valley today, glacial-geologic evidence (Axford et al., 1999) and previously-presented cosmogenic 36Cl ages (Briner et al., 1999) indicate that glaciers were active in the lake’s drainage at least as late as the mid-Holocene. A small moraine 6.5 km upvalley of Little Swift Lake (Fig. 1) records glacial readvance at 5.1 +/- 0.8 36Cl kyr BP (Briner et al., 1999) from a cirque in the lake’s upper drainage. A moraine dated at 13.0 +/- 2.5 36Cl kyr BP (Briner et al., 1999) records the late-glacial presence of a large glacier (~8.5 km long) that emanated from multiple tributary cirques and terminated only 1.3 km from the lake (Fig. 1). The lake apparently post-dates the late Wisconsin glacial maximum.

In summer 1998 four percussion cores and numerous gravity cores (capturing the sediment surface) were recovered from Little Swift Lake. Subsequent laboratory analyses have focused on the longest (5.8 m) percussion core.

Nine AMS radiocarbon dates (obtained on combined terrestrial and aquatic macrofossil fragments) and the probable presence of the well-dated Aniakchak tephra suggest a basal age for the core of 13 cal kyr BP. Most of the core (Fig. 2) is composed of organic-rich laminated brown mud, characterized by only subtle changes in grain size, organic content, and magnetic susceptibility. The 20-cm thick Aniakchak (?) tephra is readily distinguishable by its light color, exceptionally high magnetic susceptibility, abundance of coarse pumice grains, and low organic content.

The core terminates in a unique inorganic silt-rich unit (Fig. 2). The transition from this basal unit to organic-rich mud at ~550 cm depth, or ca. 12.6 cal kyr BP, is accompanied by a shift in the diatom assemblage. Decreases in the relative abundances of Nitzschia spp. and Hannea arcus v. arcus suggest reduced stream inflow. In addition, whole-rock major-element geochemical changes at the transition indicate a reduction in sediment originating from the glaciated granitic upper watershed (see Carey et al., this volume). These changes strongly suggest that glaciers in Little Swift Creek valley were retreating 12.6 cal kyr BP, coeval with the early part of the Younger Dryas. The core contains no comparable evidence for subsequent readvance.

Why would glaciers have retreated at this site during the Younger Dryas, when cooling occurred in the North Atlantic and elsewhere? According to Fairbanks (1989), sea level at this time was ca. 65 m lower than present. The Bering Sea had not yet transgressed onto its shelf and the Ahklun Mountains were positioned far inland from the coast. Even if Younger Dryas cooling affected coastal Alaska, continental heating fueled by near-peak summer insolation (Berger and Loutre, 1991) may have overwhelmed the influence of cool oceans, creating a relatively warm, dry continental Beringian climate. This explanation is consistent with the results of previous research (e.g., Manley and Kaufman, 1999) demonstrating that late Pleistocene glacier extent in the Ahklun Mountains was modulated by the proximity of the Bering Sea moisture source. Furthermore, this hypothesis is consistent with the model results of Bartlein et al. (1998) which simulate warmer-than-present summer temperatures throughout Beringia during late-glacial and
early Holocene time, with maximum summer warmth ca. 14 cal kyr BP. Results of ongoing pollen analyses from Little Swift Lake and other sites in the Ahklun Mountains will provide an opportunity to evaluate this hypothesis.


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PATTERNS OF GLACIAL SEDIMENT TRANSPORT TO THE NW LABRADOR SEA: DATA FROM GEOCHEMICAL PROVENANCE STUDIES

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During the Late Wisconsin glaciation, the marine margin of the northeastern Laurentide Ice Sheet advanced repeatedly into the Labrador Sea and discharged immense quantities of icebergs to the North Atlantic. These episodes of locally accelerated ice flux, known as Heinrich events (Bond et al., 1992; Andrews et al., 1993), dramatically altered the ice sheet configuration and likely also caused changes in oceanic and atmospheric circulation (Broecker, 1994). A primary conduit for these discharges was Hudson Strait (Andrews and Tedesco, 1992). Cumberland Sound, a deep embayment along the southeast Baffin Island coast, also served as an important path for ice flow to the northwest Labrador Sea (Jennings et al., 1996; Kirby, 1997; Kaplan et al., 1999).

A number of studies (Gwiazda et al., 1996; Hemming et al., 1998) have confirmed that sediment in Heinrich layers of the North Atlantic are dominated by erosional products from the Churchill Province of the Canadian Shield. However, due to the widespread outcrop of Churchill rocks on SE Baffin Island, northern Labrador and Quebec, as well as in the Keewatin region, a broad Churchill provenance designation does not tightly constrain the glacial erosion and transport pattern during Heinrich events. For this reason, Sr, Nd and Pb isotopic analyses were made of sediments along the hypothesized former ice sheet flow paths in Hudson Bay, Hudson Strait, Cumberland Sound and northern Labrador, with the goal of determining more specific isotopic compositions to use as sediment-source "fingerprints."

By analyzing lithostratigraphy and sediment provenance using elemental abundances, mineralogy and Sr-Nd-Pb isotopes in cores and till samples from Hudson Bay, Hudson Strait, Cumberland Sound and the Baffin Island shelf, characteristic sediment source signatures were identified for multiple Laurentide ice flow paths. Provenance indicators were analyzed in radiocarbon-dated cores from the deep Labrador Sea to elucidate past changes in ice margin proximity and sediment sources. The Sr, Nd and Pb data indicate that subglacial processes transported isotopically distinct sediment a distance of 800 km, from western Hudson Bay to the northwest Labrador Sea slope, with no significant change in the isotopic composition of this sediment along the transport path. During Heinrich events, slope sediment accumulation rates typically increased 8-fold, indicating the proximity of the advanced ice margin. Sedimentary structures in the detrital carbonate-rich Heinrich layers on the upper slope imply that sediment-laden meltwater plumes coincided with times of increased iceberg flux. The inferred asynchrony between advances of the adjacent Cumberland Sound and Hudson Strait ice streams implies non-climatic or complex climatically forced behavior of the NE Laurentide Ice Sheet.


THE PALEOGEOGRAPHY OF GLACIAL LAKE CHAMPAGNE, SOUTHERN YUKON: IMPLICATIONS FOR THE LAST DEGLACIATION

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Glacial Lake Champagne (GLC) was a major deglacial feature of southern Yukon covering parts of the Alsek River and the Yukon River drainages. At its highest stand, GLC covered 2425 km², had a long axis of 260 km, and a maximum depth of at least 159 m. The lake was centred over Whitehorse, extending west to near Haines Junction, east to Jake's Corner, south to near the White Pass, and north to Lake Laberge (Fig 1). There has been abundant geomorphic activity since deglaciation that has obscured the record of GLC. Poor preservation of landforms and sediments is a result of aeolian deflation, permafrost, slumping, and fluvial processes. Exposures of GLC sediments are commonly truncated at the bottom by slump deposits and at the top by loess deposits. There were no sections that had an entire succession of sediment that was interpreted to span the history of GLC. In spite of this, a paleogeographic reconstruction of GLC can be made as described below.

Deltas at Lime Creek, Watson River, Takhini, and Champagne (Fig. 1) provide the best evidence for lake stage. Lime Creek Delta (LCD) and Watson River Delta (WRD) are comprised of two levels, whereas Takhini Delta (TD) is comprised of two well and one weakly developed level. The Champagne Delta (CD) has only one level. These four deltas constrain the elevation of GLC with two significant stages at 765 m and 725 m, with a minor stage at about 720 m asl.

Numerous paleo-shorelines exist throughout the GLC basin. There are groups of shorelines on the north slope of the Dezadeash River valley, as well as in the Carcross region. Shorelines that lie above 765 m in the western portion of GLC are ascribed to an earlier deglacial lake that did not intrude into the Yukon River drainage. Because paleo-shorelines are discontinuous reconstructions of local isostatic response are not possible.

Glaciolacustrine sediment is common in most of the modern river valleys in the region. Holocene fluvial downcutting has been significant, especially in the Yukon and Takhini River valleys, where up to 60 m of sediment have been exposed. Detailed stratigraphic logs were completed at six sites in the eastern portion of the GLC basin. The stratigraphic record is highly variable from site to site, with sedimentary successions ranging from massive silts to diamicton.
The sedimentology and distribution of deposits is interpreted to be largely a function of ice proximity. The thickest exposures of glaciolacustrine sediments occur in the northeastern portion of the basin, which has the fewest examples of shorelines and deltas.

The paleogeography of GLC is important as it can be used to delineate the position of ice fronts during deglaciation. There are two possible outlets for GLC, both of which must be blocked in order for the lake to exist. The Alsek River outlets were blocked by ice from the St. Elias piedmont lobe complex (Jackson et al., 1991; Duk-Rodkin, 1999). Based on the distribution of sediments and landforms associated with GLC, the Yukon River outlet was blocked north of Whitehorse at or near present day Lake Laberge. The interpretation of dominant ice flow direction was downslope (south to north) through the Yukon River valley with ice sourced in the Coast Mountains (Duk-Rodkin, 1999). This interpretation is inconsistent with the presence of an ice dam at Lake Laberge (LL) north of Whitehorse. Stagnant ice at LL is rejected as the blockage mechanism because there are (at least) two stages of GLC that were stable enough to form delta and paleo-shoreline features. Also, a stagnant ice blockage must have remained competent while ice retreated southward from the dam a distance of 100 km. It is hypothesized that ice responsible for the LL dam was part of the Cassiar Lobe, sourced east of LL in the adjacent highlands, or was part of the Cordilleran Lobe, and spilled over from the Teslin Valley. This ice blockage was active throughout the duration of the stable phases of GLC, leading to at least two stable stages, and geomorphic features consistent with a longer lived GLC.

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Detailed sedimentological, geochemical and macrofossil analysis of two lake sediment cores from Chapman Lake, Yukon (64°51’N, 138°22’W) are used to reconstruct landscape change in the Blackstone River Valley (BRV) over the past 13,000 years. Chapman Lake is the largest of a group of kettle lakes, and is currently a closed basin perched 10 m above present base level in the BRV. A layer of plant detritus and overbank sediments in the cores overlies a fluvial sand facies and is inferred to represent the land surface prior to subsidence of the lake basin after 13,210 +/- 300 BP. Fluvio-lacustrine sediments deposited after this time fine upward and increase in LOI organic carbon, suggesting decreasing fluvial influence on Chapman lake until ca. 11,000 BP when clastic sedimentation drastically decreased and LOI organic carbon increased from <5 % to >40 %. Correlation to dates from a previous study of Chapman Lake (Terasmae and Hughes, 1966) as well as dates from this study suggest that net sedimentation rates decreased by a factor of 3 at this time, and indicate that the lithofacies change resulted mostly from decreased clastic sedimentation despite increased lake productivity.

Surficial and aerial photographic mapping revealed the presence of paleo meandering channels superimposed on the lake system, indicating that the Blackstone River (BR) flowed across the area prior to lake formation. The overbank and fluvial sediments found in the Chapman Lake cores are correlated to this phase of fluvial activity, and indicate that it occurred prior to 13,200 +/- 300 BP. Terracing of the paleo-fluvial system suggests that the river downcut in response to formation of the lake basin and regional incision, with flow from the BR entering the lake from the south and exiting to the north, where it merged with flow from the East Blackstone River (EBR). The fining upwards sequence between ca. 13,200 and 11,000 BP in the lake cores is interpreted to represent formation of the lake, with progressively decreasing fluvial influence resulting in increasing deposition of silt and clay versus fine sand.

The BR now enters the EBR upstream of Chapman Lake as a result of capture by the EBR. The transition from clastic to organic sedimentation in the Chapman Lake cores at ca. 11,000 BP is thought to represent this capture, with an immediate and dramatic reduction of fluvial sediment flux to the lake as flow was diverted. This drainage diversion also resulted in the abandonment of the northern outlet of the lake, which as a result no longer downcut in response to changing base level in the BRV. Thus, the difference between the current lake surface elevation and base level in BRV (~10 m) is a minimum estimate for post-capture incision of the BRV. Topographic profiling of the BR and EBR and the surface of the non-incised remnants of glacial valley fill indicate that the ~20 m of total incision in the BRV at Chapman Lake is a result of dissection of the terminal moraine in which Chapman Lake lies. The profile of the moraine surface is such that it would not have impounded a lake upstream in either the BR or EBR valleys, suggesting that incision of the moraine must have occurred immediately after its deposition.

The occurrence of at least half the total incision of the BRV within the Holocene is consistent with a ca. 13,200 BP age of formation for Chapman Lake and a ca. 11,000 BP age for capture of the BR and abandonment of the northern outlet of the lake. The timing of these events suggests the moraine at Chapman Lake was likely deposited during the last glacial maximum (LGM). An LGM age for the terminal moraine at Chapman Lake is, however, inconsistent with the current understanding of regional glacial stratigraphy (Duk-Rodkin, 1996), which places its age at greater than 200,000 years (Berger et al., 1996). Previous research has suggested that the climate of the LGM was extremely arid in Eastern Beringia, resulting in the desiccation of lakes and deflation of lake sediments. This mechanism is thought to lead to truncated lake records which cannot be used to date the surfaces in which they lie. The relationship between Chapman

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Lake and the surrounding landscape does not preclude such arguments, but does strongly suggest that the age of Chapman Lake reflects that of the glacial deposits in which it lies and indicates that other lake records in eastern Beringia previously thought to be incomplete may in fact accurately date the landscape around them.


**DECADAL VARIABILITY OF THE GREENLAND ICE SHEET MASS BALANCE AS A CAUSE OF SALINITY-ICE-TEMPERATURE ANOMALIES IN THE NORTH ATLANTIC**

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1. Introduction. Strong decadal variability of the North Atlantic hydrography manifested in large-scale salinity-ice-temperature anomalies, termed "Great Salinity Anomalies" (GSA), that propagated around the Subarctic Gyre [1,2]. The GSA'70s originated in the Greenland/Iceland Seas due to the enhanced Arctic freshwater/ice export via Fram Strait [1]. On the contrary, the GSA'80s and, possibly, GSA'90s formed in the Labrador Sea-Baffin Bay due to extremely strong wintertime atmospheric forcing, likely associated with the enhanced Arctic freshwater/ice export via the Canadian Archipelago [2]. The above mechanisms explain the GSAs quite well. It was noted, however, that all three GSAs were associated with sharp increases in the number of icebergs in the Northwest Atlantic [2]. Since the main source of these icebergs is the Greenland Ice Sheet (GIS), we have to consider variations of the GIS iceberg discharge and runoff as a probable cause of the GSA formation.

2. GSAs and their main characteristics. The GSAs observed to date had a low-S/low-T anomalies, with initial magnitudes of ~1.0 ppt/1°C respectively; and a positive anomaly of sea ice cover, of ~33 x 104 km² in the Greenland/Iceland Seas during the GSA'70s, and of ~41 x 104 km² in the Labrador Sea/Baffin Bay during the GSA'80s [2]. The initial salt deficit of the GSA'70s was ~72 Gt [1]. Thus ~2,000 km³ of fresh water were needed to form the GSA'70s [3]. Given a ~4,000- km³/yr Arctic freshwater transport via Fram Strait, the GSA'70s might have been formed by a 25% increase of the Fram Strait freshwater transport sustained for two years [3]. Freshwater content of the GSA'80s and GSA'90s is assumed to be roughly the same as of the GSA'70s given the observed similarity of their characteristics.

3. The GIS attrition hypothesis. Variations of the GIS icebergs discharge and meltwater runoff could produce a low-salinity anomaly because:
   (1) The entire GIS freshwater discharge (solid and liquid) end up in the East/West Greenland Currents (EGC/WGC) that deliver most of it to the Labrador Current (LC), that exports the freshwater to the Northwest Atlantic;
   (2) The EGC looses freshwater only north of the Denmark Strait, where the East Icelandic Current splits away from the EGC; however, this area receives little GIS discharge and is not important;
   (3) The southern Greenland receives the bulk of precipitation, hence the GIS discharge occurs mainly south of the Denmark Strait, where the EGC/WGC receive water, not lose it.
Thus the GIS iceberg discharge and runoff remain mostly trapped in the EGC-WGC-LC system, and therefore can fully contribute to the GSA formation.

4. The GIS mass balance. Main components of the GIS mass balance are precipitation, runoff, and iceberg calving. The mean annual precipitation for entire Greenland is 346 mm (753 km³) [4]. The iceberg calving is 222-318 km³/yr of water equivalent (w.e.) [5, 6]. The bulk of it directly feeds the EGC-WGC system south of the Denmark Strait [6]. Most of the rest (the northern and northeastern Greenland discharge) inevitably finds its way south via the Denmark Strait owing to the clockwise circulation around Greenland. The runoff is 237-330 km³/yr w.e. [5], occurring mainly in the southern Greenland and therefore feeding the EGC and WGC. Together, the iceberg calving and runoff, on the average, supply 459-648 km³/yr w.e. to the ocean. A sustained 30% increase of the GIS attrition (~200 km³/yr w.e.) would provide enough fresh water to fully account for a decadal GSA with the freshwater content of 2000 km³.

Rates of change of the GIS mass balance vary widely, from the GIS-averaged net loss of 110 Gt/yr, or 7 cm/yr w.e. [5], hence a relatively rapid thinning, to a net thickening of 23 ± 6 cm/yr [7]. The GIS is thought to exhibit decadal-scale fluctuations comparable with the above figure [8]. Aircraft laser-altimeter surveys revealed a rapid attrition of the GIS [9], hence enhanced freshwater discharge (including iceberg calving), conducive to the formation of GSAs. The above-cited data show a rapid thinning (~10 cm/yr) in the SE Greenland, after taking into account rock uplift of ~0.5 cm/yr [10]. Since a 10-cm/yr GIS-wide thinning would release ~160 Gt/yr of fresh water, a decade-long, GIS-averaged 10-cm/yr thinning would produce a GSA with the freshwater content of 1600 km³, close to the GSA’70s content of 2000 km³ [1].

5. Decadal variability of the GIS mass balance. Variability of individual components of the GIS mass balance is a key issue in regard with the GSA origin. Since the GSAs seem to have the decadal-scale periodicity (at least, in the second half of the 20th century), one has to consider the decadal variability of the GIS mass balance and its components as the most likely cause of the GSAs.

Decadal variability of the GIS precipitation contains a significant decadal trend, as well as a strong correlation with the North Atlantic Oscillation (NAO) [11]. A similar correlation between the GIS precipitation and the NAO was also found from ice core data used to reconstruct an annual proxy NAO index for the last 350 years [12, 13]. It is noteworthy that the most energy is located in the frequency band with periods less than 15 years [13].

Significant quasi-decadal variability of the surface characteristics of the GIS was found from scatterometer data between 1978 and 1996 [14]. The data shows dramatic changes in the GIS surface melt signatures on the interannual and, especially, decadal time scale. It also appears that the above variability has increased lately. For example, both the minimum (8.1 x 104 km²) and maximum (25 x 104 km²) melt extent in the last two decades occurred in the 1990s (in 1992 and 1996 respectively).

Solid discharge (iceberg calving) might be very episodic, thus eventually producing fresh water pulses that might contribute to the GSA formation. The International Ice Patrol data reveal three prominent peaks of the iceberg index (the total number of icebergs crossing 48(N) in the early 1970s, 1980s, and 1990s [2]. These peaks might have been manifestations of such iceberg surges or massive iceberg releases from near-coastal areas. The latter appears more plausible. Indeed, the GIS iceberg discharge is thought to have a relatively long response time to the decadal variations of the GIS accumulation. One cannot exclude however the possibility of a rapid increase of basal sliding, hence glacier velocity and calving rate, due to an increased precipitation and melting [9]. Another likely explanation of the iceberg pulses involves their temporary arrest by the near-shore fast ice, followed by the rapid ice melting and release of the icebergs accumulated in the near-shore area over an extended period time (several years). This phenomenon was observed many times in Antarctica and the same mechanism seems viable off Greenland.
6. Paleo-GSAs and Heinrich events. The GIS attrition mechanism of formation of large-scale salinity-ice-temperature anomalies was apparently operational in the past. Over the last 60,000 years, armadas of icebergs have been periodically released, mainly from the Laurentide Ice Sheet and also from the GIS, into the North Atlantic Ocean, where they subsequently melted and deposited distinct sediment strata, Heinrich (H) layers [15-19]. These huge melting events decreased the sea surface salinity at 1.5-3.0 ppt and the sea surface temperature at ~2°C, between 40°-50°N [19]. Thus, the salinity-ice-temperature anomalies associated with H-events were of the same order of magnitude as the GSAs of the 20th century, being just a few times larger. The main difference between the former and the latter is the time scale: H-events lasted hundreds and thousands years whereas each GSA spanned between 6 and 10 years [1, 2].

7. Summary. The iceberg discharge and meltwater runoff from the GIS might have been an alternative, or a complementary, mechanism accountable for the formation of the GSAs, observed in the second half of the 20th century. Under different climatic conditions, however, this mechanism might be solely responsible for the GSA origin. Such conditions had occurred in the past, leading to Heinrich events, and they might be encountered in the future.


ADDRESSING THE AGE DISCREPANCY IN MARITIME ARCHAIC INDIAN OCCUPATION OF SOUTHERN LABRADOR AND THE ISLAND OF NEWFOUNDLAND

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One of the outstanding questions in the prehistoric record of Newfoundland and Labrador is the apparent discrepancy in the timing between the first arrival of Maritime Archaic Indians (MAI) in southern Labrador about 9000 BP and their much later occupation of the Island of Newfoundland between 5000 and 5500 BP. In our paper we argue that the absence of earlier dated sites on the Island may be the result of two factors. First, the early to mid Holocene sea
level history of most of the Island, except the Great Northern Peninsula, was one of sea levels lower than present. Considering that the MAI were a marine-adapted culture who located their living sites close to the active shoreline, it is possible that the oldest sites on the Island have been submerged by rising sea level. Second, on the Great Northern Peninsula - the only region of the Island that has experienced continuous postglacial emergence and therefore should preserve a complete record of coastal occupation - the archaeological record has been reconstructed from sites mostly uncovered during local development in coastal communities. We propose, however, that the 6000-9000 BP shorelines, which would most likely preserve evidence of earliest MAI occupation, lie in the undeveloped, heavily forested regions inland of these communities, where no systematic archaeological survey has taken place.

In order to investigate the sea level factor we compiled data on documented archaeological sites from selected regions of the Island where Holocene sea level history was reasonably well constrained. In all cases, it appears that the magnitude of mid to late Holocene sea level rise was sufficient to submerge sites located within 5 m or so of their contemporary sea level between 5000 and 9000 BP. Therefore, it is likely that MAI sites of this age will only be found above present sea level on the Great Northern Peninsula. Once mapped, we plan to strategically test these shorelines using landscape variables which we believe influenced MAI site selection. These variables, which include resource and coastal accessibility, open water viewshed and shoreline configuration, were successfully employed by us to locate the MAI Gould site at Port au Choix on the west coast of the peninsula. The site was found where predicted under a thick peat cover in the woods on the edge of the community. It has provided the oldest date (5500 BP) so far recorded for MAI occupation on the Island.

SUBLIMATION ESTIMATES FOR THE GREENLAND ICE SHEET USING AUTOMATED WEATHER STATION OBSERVATIONS

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Surface micrometeorological observations from the Program in Arctic Regional Climate Assessment (PARCA) Greenland Climate Network (GC-Net) are employed to estimate seasonal and net annual sublimation rates for different sites on Greenland’s inland ice. The mass balance of the Greenland ice sheet affects both global sea level and ocean circulation. Yet, the magnitude of the sublimation mass flux to and from the ice sheet surface is a relatively poorly known component of the mass balance. Variations in sublimation caused by climate changes will affect accumulation rates and in turn accumulation rates. Sublimation estimates are used to gauge the sensitivity of the surface mass balance to climate fluctuations in parameters such as temperature and specific humidity. Water vapor fluxes are determined using bulk aerodynamic profile methods adjusted for atmospheric stability variations. Seasonal moisture fluxes are compared with accumulation rates from recent co-located PARCA ice cores.

Our results indicate that sublimation rates are significant to the surface mass balance where accumulation rates are small and at the lower elevations where energy fluxes are typically largest. In the ablation region at 950 m elevation in western Greenland at 70 N, evaposublimation contributes annual losses as great as 25 cm water equivalent. 15 km up-glacier from this site at equilibrium line altitude (1150 m), evaposublimation consumes 5-15 cm. Monthly sublimation rates are occasionally as large as ____. In northern Greenland, annual evaposublimation is between 1 and 5 cm water equivalent. Such rates are significant when compared with accumulation rates of 5-15 cm indicating significant sensitivity of accumulation to sublimation losses. Undulation scale sublimation variations are large with losses 2-3 times greater at undulation crests compared to an adjacent trough 6 km away. Near Greenland’s crest (GC-Net sites: Summit; NGRIP; South Dome; Saddle) the monthly water vapor mass transfers are very small. Sublimation results in comparison with surface height records form sonic
ranging instruments imply that frost deposition is the dominant accumulation mechanism at high elevations in central Greenland.

Furthermore, climate change scenarios are investigated with reference to the surface mass balance using projected temperature increases from the NASA GISS SI99 global climate model.

**MILLENIAL-SCALE GLOBAL EVENTS RECORDED IN EL'GYGYTGYN CRATER LAKE, EASTERN SIBERIA**


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El'gygytgyn Lake, located 100 km north of the Arctic Circle in northeast Russia (67° 30' N latitude and 172° 05' E longitude), was created 3.6 million years ago (n=11 Ar/Ar ages, Layer, in press) by a meteorite impact that generated a crater roughly 20 km in diameter. An international expedition to the lake in May, 1998, successfully recovered sediment cores from the center of the 15 km wide basin, penetrating nearly 13 meters in 175 m water depth using a percussion piston corer from the lake ice surface. The sediments consist of massive to finely laminated grayish to greenish muds with discrete intervals containing authigenic vivianite and perhaps lake ice-rafted clay clasts. Sub-millimeter laminated sections vary in thickness from 10 to 40 cm and represent intervals when the lake floor became anoxic. Distinct fluctuations in various sedimentological (stratification, clasts), physical (susceptibility), biochemical (TOC, TN, TS, del 13TOC), and paleoecological (pollen, diatoms) parameters provide firm evidence that El'gygytgyn Lake and its catchment respond to environmental change at millennial time scales.

Geochronology on the core, including the timing of pollen transitions, the occurrence of the Blake (ca. 110 ka) and Laschamp (ca. 42 ka) magnetic excursions, optical luminescence ages and new AMS 14C ages, confirms that our 13 m core extends back possibly as old as 400 ka; we are most confident to MIS 6. Assuming our age model is correct, then Holocene and interglacial sedimentation rates averaged about 8-10 cm/1000 yrs., while rates during the Last Glacial Maximum may have been as low as 4 cm/1000 yrs. Nevertheless, magnetic susceptibility clearly records the Younger Dryas event, stronger Dansgaard/Oeschger-Henrich tandems (like D/O-H4) but especially D/O interstadials 19 and 20, an inter-stage 5d event, and the "YD-like" event at the stage 5/6 transition. The striking similarity between the El'gygytgyn magnetic susceptibility record, the GISP2/GRIP δ18O records from the Greenland Ice Sheet (to 110 ka, Grootes et al., 1993), and some events recorded in carbonate records from the Bermuda Rise (Adkins et al. 1997) and Bahama Outer Ridge (Keigwin et al., 1994), provides the possibility for evaluating circumarctic and global teleconnections between ice core, marine, and terrestrial archives. Our geochronology is not good enough (yet?) to determine leads and lags.


A 12,000 Year Lacustrine Record from Nimgun Lake (and Correlations with Little Swift Lake), Ahklun Mountains, Southwestern Alaska


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The Ahklun Mountain Project (AMP) has produced one of the most complete and well-dated regional records of Quaternary glaciation in Alaska. Recently, AMP members have focused on high-resolution lacustrine records of paleoenvironmental change from the Ahklun Mountains. These lake cores come from ecologically and elevationally diverse sites, and from old (early Wisconsin) and young (late Wisconsin) lake basins. Here, we focus on a 5.5-m-long 12,000 yr old core from Nimgun Lake (core NG2), in the west-central Ahklun Mountains, that was obtained in 1997 (Fig. 1). Combined with data from other lakes from across the range (Arolik Lake (Briner et al., this volume); Little Swift Lake (Axford et al., this volume; Carey et al., this volume); Sunday Lake (Feinberg and Werner, this volume); Waskey Lake (Levy et al., this volume); and Onguvinuk and Grandfather lakes (Hu et al., 1995)), data from Nimgun lake will contribute to a continuous, regional picture of glacial, deglacial, and Holocene paleoenvironmental change for this part of SW Alaska.

Nimgun Lake (59° 33’ N, 160° 46’ W) is 1.0 km long, 0.4 km wide, and 13 m deep with a lake area constituting ~15% of its total catchment area. Nimgun Lake, impounded by early Wisconsin drift, lies ~7 km downvalley from late Wisconsin moraines. The lake sediments consist predominantly of weakly laminated silt-rich clay and tephra beds. Eight 14C ages (five macrofossil, three humic acid) have been obtained from Nimgun Lake core NG2 (Fig. 2). Additional 14C dates are pending and we emphasize that the ages presented here are only preliminary. Plant macrofossils from 494 cm (~30 cm above the base) yield an age of 12.1 14C ka. The available chronology suggests an average sedimentation rate of 4 cm per 100 years. The upper third of the core is dominated by the probable Aniakchak tephra (ca. 3.3 14C ka (Waythomas and Neal, 1998) as both a 45-cm-thick primary deposit and ~1 m of reworked tephra). Macrofossils from within the primary tephra deposit yield an age of 3.6 14C ka. The presence of dark-gray, fine sand characterized by high MS values at the base of the core suggest that the core terminates in a ca. 12 14C ka tephra found in Arolik Lake sediments (Briner et al., this volume).

Bulk organic matter content (LOI) increases from 2% at the base of the core, and after a reversal from 9% to 5% (between 12 and 10 14C ka), increases to an early Holocene high of 17% by ca. 9 14C ka. The reversal in LOI indicates decreased organic productivity during this time. Preliminary pollen counts show that the base of the core corresponds to the transition between the herb and birch zones seen at Arolik Lake (Briner et al., this volume). Similar to other sites in southwestern Alaska (e.g., Hu et al., 1995), Betula pollen percentages are relatively low (up to only ~30%) within the birch zone. In addition, there appears to be a period of decreased Betula abundance accompanied by a conspicuous Poaceae peak centered around 9 14C ka. High percentages of a number of pollen-spore types, including Sphagnum, Tilletia sphagnii, Sanguisorba, Apiaceae, and monolete suggest that the second phase of the birch zone was particularly wet. Alnus dominates pollen assemblages of the middle and late Holocene, and its percentages fluctuate during this period.

A record spanning the same time interval has been obtained from Little Swift Lake in the northern Ahklun Mountains, 90 km northeast of Nimgun Lake (see Axford et al., this volume). A
core from Little Swift Lake (LSA) is correlated with NG2 based on numerous radiocarbon ages and their respective MS records which indicate that the cores contain several of the same tephras. The highest LOI values in both cores occur during the early Holocene, and are lowest at the base of the core and where influenced by the Aniakchak (?) tephra. Preliminary pollen data from Little Swift Lake yields trends similar to those seen in Nimgun Lake. For example, a reversal in Betula coincident with a Poaceae peak is found near the Pleistocene-Holocene transition in both cores, as well from elsewhere in the Ahklun Mountains (e.g., Hu et al., 1995). Pending data from these lake cores, combined with information gained in the near future from other Ahklun Mountain lakes, will facilitate our regional paleoenvironmental reconstruction.

Figure unavailable in electronic version.
LACUSTRINE RECORD OF THE LAST GLACIATION FROM AROLIK LAKE, AHKLUN MOUNTAINS, SOUTHWESTERN ALASKA


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Beringia holds high potential to preserve lacustrine proxy records of climate change beyond the last deglaciation because of limited ice extent during the late Wisconsin. Long, continuous records of lacustrine sediments, capturing the full glacial period in its entirety, have been obtained from Arolik Lake, which escaped late Wisconsin glaciation in the Ahklun Mountains, SW Alaska. Our goals in using these lacustrine records are to (1) compare the continuous sedimentological record of late Wisconsin glacier fluctuations with our recent and ongoing research of the terrestrial glacial geology, (2) produce one of the longest, continuous pollen records in Alaska; one that records vegetation changes through the LGM, (3) utilize frequent tephras to facilitate correlations between cores and across the region, and (4) use multiple proxies to evaluate paleoenvironmental changes during the late Wisconsin, the deglacial interval, and the Holocene. Of particular interest is the clear evidence for the timing of late Wisconsin ice extent as identified sedimentologically in Arolik Lake cores as a pulse of meltwater-derived sediment from the overflow of an adjacent ice-dammed lake.

Preliminary pollen, diatom, geochemical, sedimentological, and seismic data, placed into chronologic context by 14C dating and into a glacial-geologic context through extensive field work in the area, are presented from a suite of cores from Arolik Lake (Figs. 1 and 2). Four sediment cores (up to 8.5 m long) were recovered from Arolik Lake in 1997 and 1999. We used a 7.5-cm-diameter percussion coring system operated from a floating platform, and acoustic profiling to locate the best coring sites in Arolik Lake. The cores penetrated sediments deposited during the last ~30 ka. Here, we focus on core AL3 from which we have preliminary 14C age control. In addition, we present data from two other cores from Arolik Lake (AL2 and AL4) from which 14C ages are currently pending.

Arolik Lake (59° 28' N, 161° 07' W) is 3.7 km long, 0.6 km wide, and 53 m deep with a surface area of 2.0 km² constituting ~20% of its catchment area. The lake occupies a broad glacial trough excavated through Mesozoic siliciclastic metasedimentary rocks by outlet glaciers that expanded down the Goodnews River valley during the Arolik Lake (early Wisconsin) glaciation (~60 ka; Briner, 1998). It is impounded by an early Wisconsin moraine (the reference locality for the Arolik Lake glaciation) and is situated ~5 km from the maximum late Wisconsin ice limit (Briner and Kaufman, 2000).

We obtained subbottom geophysical images using an acoustic profiler. The data indicate a total sediment thickness between at least 10 and 20 m. Comparison of acoustic profiles with core stratigraphy indicates that tephra layers and prominent textural changes in the core are associated with most of the strong acoustic reflectors. The oldest strata observed consist of well-layered acoustic reflectors (up to 9 m thick) interpreted as ice-proximal early Wisconsinan sediment. Overlying this basal unit is a 2-m-thick homogenous interval that may represent interglacial sediment deposition during OIS 3. This unit is capped by 1-2 m of acoustically layered strata. We correlate this interval with the clay-rich unit occurring from 570 - 670 cm in core AL-4 interpreted as renewed glacio-lacustrine sedimentation during the LGM when meltwater spilled into the lake (see below). The late glacial and early Holocene part of the record is represented by 2-3 m of acoustically homogenous strata, whereas the late Holocene (top 1.5 m) section exhibits strong acoustic reflectors related to tephra beds.
Currently, 14C ages have been obtained for five plant macrofossil, six humic acid, and two humin extract samples from Arolik Lake core AL3 (Fig. 3). For samples younger than ~12 ka, the three sample types yielded similar ages; ages on older samples, however, are strongly discordant. For example, at ~620 cm in AL3, macrofossil, humic acid, and humin extract dates are ~22, ~30, and ~34 14C ka, respectively. We presently accept the macrofossil ages as providing a more accurate chronology, but emphasize that the ages presented here will be refined as additional samples are dated.

Sediments recovered in AL cores vary from weakly to strongly laminated silt-rich and clay-rich mud (0.2-0.5-cm-thick laminations). Laminations are defined by slight increases in sand content and by variations in color. The cores contain interbeds of mud with abundant detrital organic material and multiple tephras. The tephras facilitate intrabasin correlations, and correlations with our lacustrine records from elsewhere in the Ahklun Mountains. They appear as distinct units of very fine to coarse angular sand, with color variations from nearly black to light gray and white. The tephra is predominately bubble wall, bubble-wall junction, and pumiceous shards. Two of the most distinct tephras appear from 30-53 cm and 315-330 cm in AL4. The uppermost tephra contains abundant white and gray pumice grains, and is likely the 3.3 14C ka Aniakchak tephra (Waythomas and Neal, 1998). This tephra exerts a dominant control on grain size, bulk density, magnetic susceptibility (MS), and organic content (loss-on-ignition (LOI)) in the upper portion of the cores. The lower prominent tephra is black to dark-gray fine sand, produces the highest MS peak in the core, and is ~12 14C ka. At least five other thinner tephra beds (<1 to ~3 cm thick) exist throughout the core.

A distinctive ~1-m-thick unit of weakly bedded clay (70-85% clay) containing abundant angular granules (and one large pebble) is found in the lower portion of the three longest cores. The unit is clearly traceable in the acoustic stratigraphy, it exhibits low MS values, and contains low diatom concentrations. We interpret the interval of clay-rich sediment to represent the overflow of an ice-dammed lake in the Goodnews River valley during the LGM (Fig. 2). As the outlet glacier from the Ahklun Mountain ice cap expanded down the Goodnews River valley and reached its LGM position, it dammed the tributary valley adjacent to Arolik Lake. Evidence for the ice-dammed lake includes a large kame delta, discontinuous shorelines, an outcrop of well-sorted, laminated (lake) mud, and the notch of an overflow channel along the divide between the paleo-ice-dammed lake and Arolik Lake. On the basis of the available 14C ages, the clay-rich interval in AL3, and thus the LGM limit of this ice-cap outlet glacier, is bracketed between ~20 and 18 14C ka. As the outlet glacier retreated, the lake drained and an end moraine was deposited ~20 km upvalley (Fig. 2). The age of this moraine is constrained by a close minimum-limiting date of 16.9 14C ka (Manley et al., in press).

Total organic content (LOI) and preliminary pollen analysis give insight into paleoenvironmental change from prior to the full glacial to the present for the Arolik Lake area. The LOI record from all AL cores shows a similar trend. LOI values are relatively high (6-8%) at the base and top of the cores, and are lower (2-4%) in the middle (Fig. 3). The chronology in AL3 suggests that the lowest LOI values occur ~18-16 14C ka (~275-375 cm). This period coincides with the maximum extent of late Wisconsin alpine glaciers in the region based on 36Cl exposure ages (Briner, 1998). Preliminary pollen analysis (Fig. 3) shows a protracted herb zone dominated by Poaceae, Cyperaceae, and Artemisia. Pollen-spore assemblages vary within this zone. For example, in the middle portion (250-520 cm, ~21-15 14C ka), Poaceae, Thalictrum, Chenopodiaceae, Liguliflorae, and Encalypta increase in abundance at the expense of Salix, suggesting sparse vegetation cover and intensive soil erosion (consistent with the interpretation of maximum ice positions during this time interval). The climate of the Arolik Lake area was likely colder and drier during this period than during earlier and later periods of the herb zone. The herb zone is followed by a birch zone and then by an alder zone which represents Betula shrub tundra during the early Postglacial and Alnus shrub thickets during the middle-to-late Holocene, respectively.

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A RECENT ASSESSMENT OF THE PHYSICAL LIMNOLOGY AND SEDIMENTOLOGY OF MONTANE MEZIADIN LAKE, NORTHERN BRITISH COLUMBIA, CANADA

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An ongoing examination of Meziadin Lake in the northern Coast Mountains of British Columbia, Canada (56° 5' N; 129° 20' W), provides insight into the physical limnology and sedimentology of a glacially oversteepened fiord lake. Drainage basin characteristics such as the presence of glaciers, proximity of the lake to glaciers, and the lack of sediment sinks en route to the lake basin provide the potential for an annually or sub-annually resolved sedimentary record. The use of a lacustrine record as a proxy for other environmental variables is practical only when processes within the drainage basin and the integrated response of the lake can be assessed. As such, the examination of the physical limnology of Meziadin Lake provides an understanding of the interaction between inflowing water and subsequent patterns of sedimentation and, therefore, the genesis of a sedimentary record. Of particular importance to this study is the influence of weather-related events on inflow and response of the lake system (i.e. significant changes to inflow influenced by weather may dominate a lacustrine system depending on the seasonal evolution of limnic conditions).

Field observations were carried out on site for 12 weeks from late May to early August 1999. Monitoring of Strohn Creek, which carries a significant portion of the inflow to the lake, provided a continuous record of discharge from June 1 to August 10. Point samples of suspended sediment taken from Strohn Creek and other inflows allow calculation of the suspended sediment flux to the lake over the same period of time. Repeated measurements of temperature, conductivity, and turbidity (suspended sediment concentration) were taken using a Hydrolab Dataloger from 18 sites throughout the lake. Bottom temperature near the delta was continuously recorded using a submerged datalogger.

Eleven sediment trap moorings were established prior to spring melt and recorded deposition from suspension from the water column for the entire lake over the course of the summer. Each mooring consisted of two pairs of funnel-shaped traps. One pair was located 40 m below the surface and the other 1 m above the lake floor, thereby distinguishing suspended sediment flux by depth.

The shape and size of Meziadin Lake, in proportion to the volume of inflow creates the potential for distinct proximal and distal depositional environments within the lake basin. Sedimentation in Meziadin Lake is controlled primarily by nival (spring) and glacial (summer) melt. Significant rain events during the 1999 field season were relatively infrequent, with fewer than 5 reaching 5 mm. However, the timing the largest rainfall events (8-16 mm per day) correlated with melt-induced discharge peaks and significantly increased suspended sediment entering the lake. Increased discharge and sediment concentration due to rainfall events, timed with a lack of significant thermal stratification allowed inflow to generate an underflow event (initiated on June 17, persisting in the distal arm until June 21). While the presence of underflow activity may not represent an extreme event as understood in established literature (i.e. an externally forced event in which sedimentary characteristics depart significantly from an established mean (Desloges and Gilbert, 1994), its relation to the lake’s poorly established thermal condition allowed inflow to surpass a density threshold and became a significant underflow event. This event was recorded particularly well in proximal sediment traps by a significant change in sediment grain size and rate of deposition, as well as showing a strong signature in CTD profiles. The distal arm of Meziadin showed a greatly reduced impact to the underflow event.
MAJOR-ELEMENT GEOCHEMISTRY AND SEDIMENT PROVENANCE IN A GLACIALLY-INFLUENCED LAKE: NORTHWESTERN AHKLUN MOUNTAINS, SW ALASKA

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Little Swift Lake (~0.7 km² surface area; 24 m maximum depth) is located in the Ahklun Mountains of southwestern Alaska, downvalley from the well-preserved moraine sequence (late Wisconsin to Holocene in age) of Little Swift Creek valley (Fig. 1A). Work by Axford et al. (this volume) examines sediment cores from Little Swift Lake in an effort to reconstruct deglacial and Holocene glacier fluctuations and paleoenvironmental change. This project investigated the use of whole-rock geochemistry to determine the provenance of late Quaternary sediment in Little Swift Lake; specifically, the aim of this study was to use the major-element geochemistry of sediment delivered to the lake as a proxy for upvalley glacier activity through the past 13 ka. Reasoner et al. (1994), among others, have used bulk sediment geochemistry to assess lake sediment provenance.

Two different types of samples were analyzed: (1) four important sources of clastic sediment delivery to the lake (a floodplain, debris fan, landslide, and an up-valley moraine, Fig. 1B), and (2) 30 down-core samples taken from a ~6-m long, ~13,000-year-old continuous lake core (Axford et al., this volume). The sediment sources consist of distinct lithologies, making the geologic setting of Little Swift Lake important to this study (Fig. 1A). A small landslide on the lake's northern shore, for example, formed in andesitic tuff while the steep upper portion of the lake's drainage basin -- formerly host to glaciers -- exposes a granitic pluton. All samples were sieved (to retain only the <106-micron grain-size fraction), pulverized, and analyzed (by a contracted lab) for bulk major-element geochemistry. An initial suite of samples was also analyzed for trace-element geochemistry. Analyses were performed using ICP-MS, which permitted analysis of a much smaller sample (~1.0 g for major elements and ~2.0 g for trace elements) than the more traditional XRF method while providing comparable results.

The first goal of data analysis was to identify geochemical "fingerprints" of the sediment source materials. Similarity coefficients (Borchardt et al., 1972) were used to identify the specific major elements that best distinguished each sediment source sample. Although the lithologies of the sediment sources are relatively similar geochemically (felsic/siliciclastic), each source exhibited distinguishing elemental characteristics. For example, the moraine-matrix sample showed a high percentage of K and Si, typical elements found in the primary minerals (quartz and feldspar) of granite.

Secondly, data from the long sediment core were compared with the sediment source samples. Most notably, the down-core data show a dramatic change in elemental composition near the base of the core (at 5.47 m, Fig. 2). The compositions of all the elements change significantly at this transition. The geochemical similarity between the moraine sediment and the lake sediment from the base of the core appears to reflect an influx of upvalley-derived granitic material. One of the greatest shifts is in Al content, which decreases from 16.4% to 13.8% at the transitional unit; this is consistent with the many aluminous phases present in granite. We interpret the transition above the basal unit (with a marked decrease in similarity to the moraine geochemistry for all elements) as representing glacial retreat and a decrease in meltwater supply. The age of the transition has been dated at ca. 12.6 cal kyr BP (Axford et al., this volume).
Although this technique appears to have successfully identified the transition from ice-proximal to deglacial sedimentation in the lake core, subsequent re-advances of smaller glaciers could not be identified in the core. For example, no geochemical evidence was found associated with a re-advance moraine located ~6.5 km upvalley that was previously dated at 5100-5700 36Cl yr (Briner et al., 1999).

A mixing model that mathematically combined the elemental compositions of the matrix of the upvalley moraine (representing glacial input) with that of modern "ambient" lake sediment (represented by the uppermost long core sample) was used to reconstruct a possible origin for the core's basal unit. Mixing the elemental compositions of ambient and moraine sediment in a ratio of 2:1 yielded a mixture that is 87% similar to the basal sample, suggesting that the basal sediment is a combination of non-glacial and glacially-derived sediment.

Analysis of the geochemistry of nine short-core lake sediment surface samples and their potential relationship to the four sediment sources is in progress. Furthermore, ongoing XRD analyses will characterize the mineralogic composition of the four sediment sources and samples from down core. It is expected that both sets of results will complement the geochemical data by providing additional evidence for sediment provenance.

In conclusion, down-core, whole-rock geochemical data afford a quick and relatively inexpensive method for assessing changes in sediment provenance not otherwise obvious, or reinforcing interpretations based upon other proxies (e.g., particle size). Of course, this method will be useful only in settings where sediment sources consist of geochemically distinct lithologies, and in cases where a suite of sediment source samples is collected during fieldwork.

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SEDIMENTOLOGICAL ANALYSES OF THREE PISTON CORES FROM HUNAFLOI, NORTH ICELAND SHELF

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Three cores, B997-332, -331, and -329, from W. Hunafloi, N. Iceland record variations in oceanographic and climatic conditions over the last 13,000 14C years BP. These 2-5m piston cores were raised in 1997 on the Bjarni Saemundsson B9-97 cruise. Cores 332, 331, and 329 were collected from water depths of 108m, 46m, and 111m and are 447cm, 210cm, and 520cm in length, respectively. Core 331 is located in the fjord, closest to the present Icelandic shoreline, and cores 329 and 332 are located on the Iceland shelf (Fig 1). Sedimentological analyses of the core sediments include bulk density, moisture content, mass magnetic susceptibility, total organic and inorganic carbon, and percent carbonate. Visual descriptions of the cores and x-rays provide additional data. Age control is provided by radiocarbon dates on marine macrofossils and by the presence of a volcanic ash layer in cores 332 and 329.

Cores 332 and 329 consist of two primary lithofacies. In these cores the first lithofacies extends from 0cm to ~150cm core depth, and consists of olive black fine sand with intermittent shell layers throughout this interval. In general, this lithofacies is homogeneous, but some faint laminations and banding are visible. The second lithofacies present extends from ~150cm to the core base and consists of olive black silty clay, with increasing abundance of oxidized sulfur streaks near the base. Shells are less abundant in this lithofacies, and a basaltic ash is present at 240cm and 230cm in cores 332 and 329, respectively. The ash is recognized visually by its texture, dark color, and by a sharp decrease in water content and total organic carbon. Ice rafted debris (IRD) is present below the ash interval in both cores. In contrast, core 331 is composed of one lithofacies, a shell hash. This shell hash has a salt and pepper appearance with medium to coarse sand present in the matrix, and no ash layers are visible.

Preliminary laboratory analyses of cores 332 and 331 show a decrease in carbonate and an increase in magnetic susceptibility with increasing core depth. This represents the shift from glacial marine to marine conditions on the shelf, corresponding to the glacial to interglacial transition in N. Iceland. The ash layer present in 332 and 329 is interpreted as the Saksunarvatn Ash based on a corrected radiocarbon date of 9080+/-70 14C yr. BP on a shell located directly beneath the ash layer. An increase in IRD below the Saksunarvatn Ash further supports the transition from glacial marine to marine conditions in N. Iceland.

Additional laboratory analyses are in progress and include stable isotope work on benthic and planktic foraminifera, faunal assemblage data, IRD counts and fabric measurements, mollusc counts, acquisition of more radiocarbon dates, and geochemical analyses of the ash layers.
Figure unavailable in electronic version.
SEDIMENT TRAP RECORDS OF DEPOSITION IN LALLEMAND FJORD ADJACENT TO MULLER ICE SHELF, ANTARCTIC PENINSULA

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Ice shelves in Antarctica are responding by retreat and disintegration to climatic warming in the late twentieth century. Thus, studies are focusing on their marine sedimentary environments to document process, and to obtain records of their past fluctuations with implications for potential future behaviour. The M’ller Ice Shelf, situated at the head of Lallemand Fjord on the west side of the Antarctic Peninsula at 67°S, 66°W, is one site of concerted study. Mean annual air temperature is –5°C (Reynolds, 1981) which is the limit for the existence of ice shelves (Vaughan and Doake, 1996). Formed during the Little Ice Age (Domack et al. 1995), it has been retreating since 1974 (Stein, 1992).

As part of a larger study of the sedimentology of Lallemand Fjord, we deployed sediment traps near the face of the M’ller Ice Shelf in March 1998. The cone-shaped fibreglass traps with a baffled opening of 0.139 m² have plexiglass reservoirs 0.0016 m² in cross section and 0.3 m long, representing a concentration factor of 86.6. Three sets of four traps each were moored in (A) 550 m, (B) 625 m, and (C) 650 m of water, 0.6, 0.4, and 3.7 km from the ice face, respectively. In each case, one trap was within about 5 m of the sea floor, and the others were spaced through the water column. The traps were recovered by grappling in April 1999, 394 days after deployment. Eleven survived despite vigorous calving of the ice shelf. Each of the upper traps was damaged but eight traps provided usable records.

The results from the sediments recovered are summarised as follows:

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<th>Mean size mm</th>
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<th>Silt wt.%</th>
<th>Clay wt.%</th>
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<td>C3</td>
<td>565</td>
<td>0.4504</td>
<td>2.34</td>
<td>3798</td>
<td>12.36</td>
<td>2.15</td>
<td>56.52</td>
<td>41.35</td>
</tr>
<tr>
<td>C4</td>
<td>645</td>
<td>0.3269</td>
<td>1.94</td>
<td>3058</td>
<td>12.70</td>
<td>2.40</td>
<td>56.82</td>
<td>40.78</td>
</tr>
</tbody>
</table>

Temporal variation based on the statigraphy of the trapped sediment was seen in both physical and biologic materials. Layers of aeolian or ice-rafted coarser debris near the top and bottom of the records in some of both proximal and distal traps represent processes of the summer and autumn shortly after deployment and before recovery. In other traps (C2 and C3) coarse material occurs more uniformly throughout the record, indicating that either there was some deposition of ice-rafted material through the year, or more likely that both rafting and fine-grained deposition from suspension during winter decreased to near zero. In a number of the traps biogenic silica also shows subtle peaks near top and bottom interpreted as representing seasonally increased diatom productivity.

The presence of the coarsest material in the proximal site corresponds with the core record (Stein, 1992) and may reflect an aeolian or meltwater origin. However, the most distal site has coarser material than the middle site. The proximal and distal sites also have higher total flux by weight than the middle site. This corresponds with the subbottom acoustic records that show
thicker sediment deposition in these two areas. Yet, when flux is expressed as thickness (mm a-1) there is a smaller difference between the two proximal sites, and the distal site still has the highest accumulation. Higher flux at the distal site may be caused by resuspension of matter by the upwelling Circumpolar Deep Water current near the ice shelf, as suggested by CTD measurements (see also Brandon, 1998; Domack and Ashley, in prep.). There were low amounts of biogenic silica in all traps compared to Andvord Bay, 250 km the north (Mammone, 1992). The proximal site had the highest values of all traps at mid depth but lowest values at the bottom. As suggested from cores, this might reflect dilution of biogenic material by terrigenous input at proximal sites (Domack et al. 1989), or it might be caused by resuspension.


Domack E.W., and Ashley, G. in preparation, Glacial meltwater in nearshore regimes of the Antarctic Peninsula.


**SEISMIC SEQUENCE ARCHITECTURE OF THE YAKATAGA FORMATION, NORTHEASTERN GULF OF ALASKA**

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Glacimarine process theory predicts that unique depositional successions will be produced under different glacimarine regimes, which vary primarily as a function of ice source, its thermal state, and type of marine terminus (Powell, 1984). The Yakataga Formation, northern Gulf of Alaska, is composed of glacimarine sediments deposited by temperate glacial ice terminating in grounded tidewater fronts (Powell and Molnia, 1989). These sediments represent an end member of the glacimarine continuum whose depositional architecture is shaped by meltwater processes (Powell and Domack, 1995; Powell and Alley, 1997). Seismic facies and seismic architecture of late-Pleistocene glacimarine sequences, forming the continental shelf seaward of the Bering Glacier System, are described and compared with architecture from other glaciated continental margins.

Nine seismic facies (SF) and two seismic facies associations (SFA) are defined within single-channel mini-sparker seismic profiles (Fig. 1). SFA-A is composed of slope-prograding deposits of oblique-tangential (SF-1) to complex-sigmoid (SF-2) facies, overlain by and interdigitating with chaotic facies of linear (SF-3) to hummocky (SF-4) morphology. Up-dip
terminations of prograding clinoforms are both truncated by and root within hummocks interpreted as morainal banks. Towards shore, these facies grade conformably into a reflection-free facies (SF-5), interpreted deposits of a grounding-line depositional system. SFA-B is composed of reflection-free facies (SF-6), chaotic shoal (SF-7), and slope drape (SF-8) facies, which occur in mid-shelf basin, outer-shelf, and slope settings, and are interpreted as ice-proximal diamicton, winnowed-lag, and sediment gravity flow lithofacies, respectively. SFA-B overlies SFA-A, forming a glacimarine seismic sequence whose architecture reflects the erosional and depositional processes of one complete ice-sheet advance/retreat cycle across the shelf. The youngest sequence is overlain by a seaward-thinning wedge of post-glacial sand and mud (SF-9) on the inner shelf.

Architecture of Alaskan glacimarine sequences reflects characteristics analogous to a broad spectrum of glacial environments. Similar vertical successions of seismic facies associations have been described from the fjords of Glacier Bay, where only retreat deposits are preserved (Cai, 1994; Seramur and Powell, 1997). In profile along dip, prograding-slope architecture of Alaskan sequences is very similar to that of Antarctic Type IIA and particularly Type IA sequences, which represent stages of Cenozoic preglacial and glacial deposition, respectively (Cooper et al., 1991). Sediments of those ages are interpreted as being deposited by grounded ice sheets under temperate to subpolar conditions (Cooper et al., 1991; Powell et al., 1998; in press). At a finer scale, complex interfingering of shelf-edge morainal-bank complex and slope-front fill is very similar to that observed from the Hebridean margin, a subpolar environment (Stoker, 1990). Hummocky to tabular ice-contact morphology is strikingly similar to that of retreat deposits observed from the mid-Norwegian shelf, whose architecture was produced in a subpolar environment (King, 1993). However, unlike Norwegian architecture, wedge (still-tongue) geometries are not observed within Alaskan continental shelf sequences.

A model is proposed to describe the temporal and spatial variation of seismic facies forming the architecture of Alaskan glacimarine sequences. As the ice sheet advances across the shelf and approaches the shelf break, stacked sediment-gravity-flow deposits build a thick glacigenic apron that progrades the continental slope. The ice sheet advances across the prograding ramp to a terminal position where a shelf-edge morainal bank is formed. As the ice sheet retreats, a complex terrain of morainal-bank deposits, modified by erosion, is deposited above the slope-front apron and across the shelf. Ice-proximal diamicton fills inter-morainal basins and drapes over grounding-line deposits. Retreat of the ice sheet onto land is marked by a switch to glaciﬂuvial outwash along the coastal margin and deposition of a stratified wedge of sand and mud on the inner shelf.


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SEDIMENTOLOGICAL EVIDENCE FOR CIRCUMARCTIC CLIMATIC CHANGE FROM ELGYGTGYN LAKE, NE RUSSIA

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Elgygytgyn Lake, located 100 km north of the Arctic Circle in northeast Russia (67.30 N lat.; 172.05 E long.) was created 3.6 million year ago (Ma) by a meteorite impact that generated a crater roughly 23 km in diameter. In the May 1998 field season, a multinational team collected 25 meters of sediment core with a total depth of 12.5 m was collected from the center of the lake. Preliminary results suggest that the lake record contain sediment whose composition parallels the climatic and environmental history of northeastern Siberia over several glacial/interglacial cycles. Optical stimulated luminescence (OSL) dating (by Steve Forman, University of Illinois at Chicago) at 259-262 cm, 650-665 cm, and 1224-1232 cm depth yields ages of 48.2 +/- 3.9 ka, 163.6 +/- 12.2 ka and >>155 ka respectively. These data along with the identification of the Blake and Laschmp Events, gives us an age model for the core with variable sedimentation rates between about 4 and 10 cm/1000 years. The base of the recovered record may extend back over 400 ka. These ages are consistent with distinctive shifts in pollen assemblages marking the last interglacial period.

The cores consist of massive to finely laminated mud with discrete intervals. We hypothesize that during glacials when the lake ice cover is more persistent, clastic input to the system is very low producing anoxic conditions allowing for microlamination (no bioturbation) to occur. During interglacial or warmer periods, clastic input from the crater catchment is higher and in this oxygen rich lake bottom more active bioturbation takes place (no laminations).

Embedded mostly within the laminated sections of the core are numerous blebs of yet unidentified matrix. Petrographic study of thin-sections taken from the laminated sequences indicates that the blebs contain quartz, mafic minerals, and littoral zone diatoms. Possible interpretation of the blebs includes; stream flow onto the ice during closed catchment intervals, fecal pellets, or slump activity. The complexities of the laminated sequences and bleb matrix will be examined with the scanning electron microscope to develop a model not only for their origins, but also to develop a proxy for paleo-climate reconstruction.

Grain-size analysis indicates both a bimodal and trimodal particle-size distribution for the lake sediments, defined by grain-sizes between 0.4 micrometers (clay) and 60 micrometers (coarse silt). These patterns may relate to the weathering properties of the surrounding catchment and slow sedimentation rate of the lake.

In the field season for summer 2000, proposed programs of study will include entire water column analyses, geomorphology and seismic reflection studies to understand the modern ecological conditions in the lake as a framework for interpreting the paleo data.

No other terrestrial basin like this exists in the entire Arctic. Elgygytgyn Lake will allow us to study environmental changes in eastern Siberia over several glacial/interglacial cycles and compare this record with other long marine and terrestrial records in the region. While sedimentation rates are low in Elgygytgyn, by most standards, we suggest that the entire 3.6 Ma history of the basin could by contained in a much as 225 to 300 m of basin fill.
HAS THE NORTHERN GASPÉ PENINSULA EVER BEEN INVADED BY AN ICE SHEET FROM QUÉBEC-LABRADOR?

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Glacial models proposed for Gaspé Peninsula have evolved from simple to complex, over the last century, on the origin and extent of the glacial ice cover. Most research has been concentrated on the high plateaux and summits of northern Gaspé, where the absence of erratics and glacial striae and the presence of felsenmeer, have fed a long standing controversy concerning the origin, thickness and basal dynamics of the local ice sheets. In the most recent syntheses on the question, David and Lebuis (1985), Chauvin and David (1987) and Charbonneau and David (1993) indicate the co-existence during the Last Glacial Maximum of local ice caps in the central and eastern parts of the peninsula and the Laurentide ice sheet in the western part and in the Baie-des-Chaleurs basin, but favour the extension of the continental ice sheet across the entire peninsula during an earlier glacial stage. This view is based on a long southeastward trending erratic train of erratics from a granitic intrusion in northern Gaspé and on extremely rare occurrences of precambrian erratics in eastern Gaspe (McGerrigle, 1952). As a counterbalance to this research in the interior of the peninsula, the evidence presented in this talk is derived from a sector along the north coast (Figure 1). This region is situated only 150 km from the edge of the Canadian Shield on the opposite shore of the Saint-Lawrence Estuary, and is characterised by sedimentary and volcanic lithologies, allowing easy recognition of Canadian Shield erratics, composed of granite gneiss and anorthosites.

In this region a thin ice cover of local origin for this region is suggested by both erosional and depositional evidence. The trunk valleys descending to the north from the interior plateau display U-shaped cross sections in their lower reaches, and several possess low level cols, indicative of watershed breaching by ice flowing northward from the high plateaux (Hétu and Gray, 1985). However, glacial erosion appears to have been minimal on the coastal plateau at 300 - 400 m elevation - the back-walls of glacial cirques which incise the coastal plateau have not been breached by glacial erosion, and other large and medium scale forms (flyggbergs, roches moutonnées and glacial grooves are totally missing from the plateau surface. Glacial striae, observed only rarely in the glacial troughs, and on the plateau surface, because of the friable substrate, demonstrate only one ice flow direction - from the interior toward the Saint Lawrence estuary. On a more regional scale, mapping of the numbers and surface area of lakes as indicators of contrasts in areal scouring by ice sheets reveal a much greater concentration in western Gaspé and on the high summit plateaux, than in the coastal plateau region of northern and eastern Gaspé. Glacial till cover is sporadic and thin on the coastal plateau, up to some tens of centimeters where present. In the coastal valleys, glacial deposits are also quite thin, except in locally developed lateral moraines. Eskers, as meltwater forms requiring a substantial ice thickness and abundant flows of subglacial meltwater for their formation, are missing. Stratigraphic exposures in glacial and proglacial deposits above the postglacial marine limit reveal only clasts of Gaspésie lithologies. Also there are no glaciolacustrine sediments which could have suggested progressive retreat of a Laurentide ice margin towards the north. The basal units, in exposures below the marine limits, are, on the contrary, fossiliferous marine clays of the earliest phase of the Goldthwait Sea, overlapped by diamictons and northward dipping proglacial deltaic beds as a result of Late Glacial recurrences of valley glaciers (Hétu and Gray, 2000).

With regard to the question of glacial erratics, Canadian Shield derived lithologies have been found solely below the postglacial marine limit - usually in linear accumulations, within Late Glacial and early postglacial marine facies. Their presence is explained by the transport of icebergs across the St Lawrence Estuary from the calving front of the Laurentide Ice Sheet.
during the deglaciation phase, and not by down-wasting of this ice sheet on the Gaspé Peninsula. There are, however, numerous erratics with a source in the igneous intrusive massifs on the high plateaux (Veillette and Cloutier, 1993). Their distribution supports the concept of flows northward from dispersion centers in the highlands of the Peninsula (Chauvin and David, 1987).

Their rare occurrence on the coastal plateau indicates a thin ice cap centred further south on the higher level Chic-Choc and McGerrigle Mountain plateaux, which was canalised rapidly into outlet glaciers, which during the course of many glaciations, sculpted the coastal valleys, before merging with a tongue of the Laurentide ice sheet moving eastward down the St Lawrence estuary.

Glacio-isostasy is an other element in favor of the existence, at least during the last glacial episode, of a relatively thin ice cap in the northern Gaspé Peninsula. According to the morphological evidence from the highest proglacial delta in the coastal valleys, the maximum level attained by the Early Goldthwait Sea was ca 55 m at the moment the coast became deglaciated, towards 13,500 BP. In the Sept Iles sector on the north shore of the St Lawrence, this limit is more than 130 m. Westernmost Gaspé Peninsula, where the passage of the Laurentide Ice Sheet during the Late Wisconsin has left its traces on the landscape, also recorded higher total postglacial uplift (112 m). However the postglacial marine limit levels off in eastern Gaspé, and remains isometric on the north and south coasts of the peninsula. This suggests symmetrical glacio-isostatic loading of all of eastern Gaspé under a local ice dispersal centre, with more or less equal rebound around the entire coastline.

The enigma of the rare occurrences of erratics from the eastern Gaspé Peninsula, interpreted as Precambrian remains to be resolved, however. Since gneissic phases are occasionally present in the local igneous massifs of Lower Paleozoic age (McGerrigle, 1952), they cannot be considered for the moment as reliable evidence for overriding of the eastern Gaspé Peninsula by Laurentide ice during the penultimate glacial phase - the early Wisconsinan phase, as suggested by David and Lebuis (1985). If such erratics can be relocated, their Canadian Shield origin will have to be confirmed, on the basis of thin sections or radiometric ages.

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ARCTIC SEA ICE AND CIRCULATION ANOMALIES: THE INFLUENCE OF OSCILLATIONS, TRENDS, AND BOUNDARY CONDITIONS

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Recent analyses of observations have identified interesting variations in the North Atlantic and Arctic Oscillations, the North Atlantic thermohaline regime, the sea ice distribution, precipitation, permafrost distribution and many other climate variables. It remains to be determined whether these variations are consistent with, or indicators of, the type of polar amplification predicted by global climate model experiments. Since the late 1980's, during the period of persistence and intensification of the positive mode of the pattern now associated with the Arctic Oscillation, Arctic sea ice extent has continued its net decrease seen since the late 1970s, but with larger interannual variability in ice extent and with larger regional reductions in ice cover than are seen in records dating back to the early 1900's. The results suggest that synoptic-scale and even local processes exert a considerable influence on the strength of regional variations in ice cover.

To understand how such local, regional, and hemispheric conditions interact to affect the observed regional changes in ice cover requires a combination of observational studies and model diagnostic analyses. Analyses suggest a positive feedback between ice dynamics and ice melt that contributed to the formation of specific ice extent anomalies. The Arctic Regional Climate System Model (ARCSyM) was able to reproduce the general patterns seen in atmospheric and sea ice fields, but the discrepancies significantly affected the model's ability to simulate details of sea ice transport and warm air advection linked to the unusual ice conditions.

Recent efforts have focused upon these strict requirements for accuracy in coupled climate models of the Arctic. Several tests have been undertaken to assess the response to lateral and upper boundary forcing. When a non-specific local lateral boundary condition is used, a broader forcing zone enhances the skill of the results somewhat, but the effect is not as dramatic as introducing improvements to the upper boundary condition and simulation of the stratosphere. These results show that a non-specific local upper boundary condition which absorbs, rather than reflects, vertically propagating planetary and gravity wave energy is an important contributor to skillful simulations within the Arctic Basin.

ACCUMULATION OF HEAVY METALS IN SEDIMENTS AND WHITEFISH OF KOLA PENINSULA LAKES, MURMANSK REGION, RUSSIA

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On the basis of researches of whitefish pathology and concentration of heavy metals (Ni, Cu, Zn and Co) in its organs and tissue, which have been carried out for the last 20 years in Kola Peninsula lakes, subject in various degree to influence of the emissions and waste of mining and metallurgical enterprises, the dependences of metal accumulation and pathologies of whitefish from total and bioavailable concentrations of heavy metals in sediments were determined. Whitefish is chosen as test-organism because it is benthophage and final part in foodweb of metal accumulation from water column and sediments, and its state is good index of lake water quality.

The highest accumulating ability in relation to Ni and high correlation with total and bioavailable concentration of this element in sediments has been noticed in the most functionally
important whitefish organs - kidney, liver and gills. It can be the good indicator of pollution of surface waters by this metal. With increasing total and bioavailable concentrations of Cu and Zn in sediments there are decreasing contents of these heavy metals in the functionally important whitefish organs, that is caused both features of metal metabolism and antagonistic interaction with other elements, first of all - Ni. The influence of the increasing concentrations of Cu, Zn and Co in sediments on whitefish state under water pollution by a number of heavy metals conducts to increasing disease incidence. The correlations of whitefish disease incidence with bioavailable concentrations are higher (r=0.56-0.85), but even with total concentration they are sufficiently high (r=0.34-0.85). Combination of increased concentrations of Ni, Cu, Zn and Co in water and sediments for fishes are more toxic in many times, than each element separately.

MIGRATION AND CYCLE OF SULPHUR IN A SUBARCTIC LAKE

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Lake Imandra, the largest oligotrophic and ultrafresh water reservoir in the Kola Peninsula, north-west of Russia, has been contaminated by wastewater from mining and metallurgical enterprises during more than 60 years. This lead to increasing sulphate concentration in the lake water class form bicarbonate to sulphate. Contamination with municipal wastes gave rise to active eutrophication processes, which resulted in the formation of oxygen deficiency in the bottom water layers under ice cover. The oxycline boundary is not stable: in the period of ice cover existence, this boundary coincides with the interface of water-sediments, in summer it dips into sediments. The sulphur concentration in pore water (under anaerobic conditions) dramatically decreased because of bacterial reduction of sulphate to sulphide. The resulting sulphate concentrations in pore water in the 8-10 cm layer of sediments are 50 times as small as those in water column. Increasing sulphate concentration in water, the accelerated sedimentation of dying organisms (seston), the sulphate diffusion fluxes towards the oxycline boundary, and the reduction of sulphate to sulphide within sediments in anaerobic environment enhanced the accumulation of sulphur in lake sediments. The evident drop in sulphur concentration is controlled by the gradient of the redox potential and reflects a decrease in the anthropogenic sulphur loads on the lake during last decade. It appears likely that the abrupt drop in the output of mining and metallurgical activity in the region in the early 1990s along with increasing sulphate contents of their wastewaters have made the sediments a secondary source of sulphur input into the water column. The concentrations of sulphur in sediments cannot be used for detailed reconstruction of the current anthropogenic sulphur load on the lake under conditions of oxygen deficiency in bottom water layers and lake sediments.

HIGH RESOLUTION ARCTIC WINTER SIMULATIONS IN A REGIONAL CLIMATE MODEL

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Arctic climate simulations with the high resolution regional climate model HIRHAM show some deviations from station data in the planetary boundary layer (PBL) during winter, which indicates the necessity of improvements in the atmospheric PBL parameterization for a better
description of the vertical stratification and atmosphere-surface energy exchange. A one-
dimensional single column model scheme has been used to investigate the influence of two
different PBL parameterizations in monthly integrations for January 1991 and July 1990. The
first scheme uses the boundary layer parameterization of the atmospheric circulation model
ECHAM3, including the Monin-Obukhov similarity theory in the surface layer and a mixing
length approach above. The second scheme applies the Rossby-number similarity theory for the
whole PBL, connecting external parameters with turbulent fluxes and with universal functions
determined on the basis of Arctic data. For both schemes the heat and humidity advection has
been determined as residual term of the PBL balance equations. Diabatic sources have been
computed from the current model solution and local temperature and humidity changes are
estimated from radiosonde data. The simulated vertical structure and the atmosphere-surface
energy exchange during January strongly depends on the used PBL parameterization scheme.

These different PBL parameterization schemes were then applied for simulations of the
Arctic climate in the three-dimensional regional atmospheric climate model HIRHAM, using
ECHAM3 with Monin-Obukhov similarity theory, ECHAM3 with Rossby-number similarity
theory and ECHAM4 parameterizations with a turbulent kinetic energy closure. The near surface
temperature, the large-scale fields of geopotential and horizontal wind are simulated
satisfactorily by all three schemes, but strong regional differences occur. The results show a
sensitivity to the type of turbulence exchange scheme used. The comparison with ECMWF
analyses and with radiosonde data reveals that during January ECHAM3 with Rossby number
similarity theory more successfully simulates the cold and stable PBL over land surfaces, whereas
over the open ocean ECHAM3 with Monin Obukhov similarity works better. ECHAM3 with
Rossby-number similarity theory delivers a better adapted vertical heat exchange under stable
Arctic conditions and reduces the cold bias at the surface. The monthly mean surface turbulent
heat flux distribution strongly depends on the use of different PBL parameterizations and leads to
different Arctic climate structures throughout the atmosphere with the strongest changes at the
ice edge for January.

Rinke, A. et al.1999, Arctic winter climate and its interannual variations simulated by a regional
Dethloff, K. et al., 2000, Sensitivity of Arctic climate simulations to different boundary layer
parameterizations in a regional climate model, Tellus, accepted.

THE INTERNATIONAL BATHYMETRIC CHART OF THE ARCTIC OCEAN (IBCAO):
IMPROVING OUR KNOWLEDGE OF THE SEAFLOOR IN THE HIGH NORTH

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Even though it was developed from sparse data, for over two decades the Arctic Sheet of the
Fifth Edition of the General Bathymetric Chart of the Oceans (GEBCO) served as an
authoritative portrayal of the seafloor north of 64N. While this document provided a general
description of major seabed forms, a mounting body of evidence was accreting to indicate that
many of the smaller and scientifically significant features were poorly or wrongly defined.

In response to a growing accumulation of bathymetric measurements collected during
past and recent expeditions in the Arctic, an international undertaking was initiated in 1997 to
construct a coherent data base containing all available depth observations, and from that to create
a modern map that would provide a more faithful representation of the seafloor. This endeavor
has so far engaged the volunteer efforts of investigators who are affiliated with eleven
institutions in eight countries: Canada, Denmark, Germany, Iceland, Norway, Russia, Sweden,
and the USA. The activity has also been endorsed and/or supported financially by the Intergovernmental Oceanographic Commission (IOC), the International Arctic Science Committee (IASC), the International Hydrographic Organization (IHO), the US Office of Naval Research (ONR), and the US National Geophysical Data Center (NGDC).

To construct the database, several vintages of public-domain observations were extracted from world and national data centers, and complemented by newly released measurements that were collected by US and British submarines operating beneath the permanent polar pack from 1958 to 1988. These were further enhanced by original observations that were collected in recent years by US Navy submarines during unclassified SCICEX missions from 1993 to 1999, and by Swedish and German icebreakers from 1990 to 1997. The sum of these digital holdings represented a substantial quantity of information, but their geographical distribution was not uniform, therefore in several areas, additional depth values in the form of point soundings or bathymetric contours were derived from charts and maps published by Russian and US agencies. To portray surface relief above sea level, a copy was obtained of the GTOPO30 grid, which models land topography at intervals of about one kilometer.

A mix of proprietary and public-domain software was applied: (a) to combine the data sets; (b) to create a square Cartesian grid with a cell size of 2.5 km; and (c) to construct shaded relief maps of the study area. The new grid and its derivative plots reveal the seafloor in considerably more detail than do previous maps, portraying the complex morphology of several major features, including the Lomonosov, Alpha, and Gakkel Ridges. Details of the Chukchi Borderlands are rendered clearly for the first time, and paleo-river channels, whose depth variations are on the order of only tens of meters, are clearly visible on the enormous Siberian continental shelf.

The new IBCAO grid and map represent a substantial improvement over previous descriptions of Arctic seafloor morphology, but important refinements can be expected over the next several years as new expeditions collect more data, and as access is granted to proprietary holdings that so far remain out of reach.

LATE PLEISTOCENE MARITIME ADAPTATIONS AND THE FIRST HUMAN COLONIZATION OF NORTH AMERICA

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The concept of the Bering Land Bridge is a cornerstone in American archeology, and the existence of the former land bridge has been used to explain the exchange of terrestrial mammals and humans between Asia and North America during the Pleistocene. However, there is a growing body of data suggesting that the earliest human migration to North America may have occurred with the use of water craft along the southern margin of Beringia and then southward along the northwest coast of North America. Prior to the early 1970's it had been assumed that the Cordilleran ice extended westward to the margins of the continental shelf (Coulter et al. 1965, Nasmith 1970, Prest 1969) creating a barrier to human migration. Recent research documents deglaciation and the existence of ice-free areas throughout major coastal areas of British Columbia by c 13,000 14C BP and possibly earlier (Blaise et al. 1990, Bobrowsky et al. 1990, Mann and Peteet 1995, Josenhans et. al. 1997, Fedje and Christensen, 1999).

Archeological evidence necessary to evaluate the coastal migration hypothesis (Fladmark 1979, 1983, Dixon 1993, Gruhn 1994) is difficult to detect because rising sea level at the close of the Pleistocene inundated much of the continental shelf. However, the coastal migration hypothesis is supported by the discovery of large mammal remains in regions believed to have been glaciated during the late Pleistocene (Heaton 1995, 1996, Heaton et. al. 1996) and archeological excavations at 49-PET-408, a cave site located on Prince of Wales Island,
Southeast Alaska (Dixon et al. 1997), where human remains of an adult male dated to 9,880 +/- 50 BP delta \(^{13}\)C -12.1 o/oo (CAMS-32038) (pelvis) and 9,730 +/- 60 BP delta \(^{13}\)C -12.5 o/oo (CAMS-29873) (mandible) have been recovered (Dixon et al. 1997). AMS \(^{14}\)C results indicate these are the oldest reliably dated human remains yet recovered in Alaska and Canada.

The human remains are disarticulated. Delta \(^{13}\)C values demonstrate a diet based on marine foods and the \(^{14}\)C age should be adjusted to c 9,200 based on the regional marine carbon reservoir (Josenhans et al. 1997). The human remains appear to be contemporary with a cultural occupation dated by three \(^{14}\)C AMS dates on charcoal (8,760 +/- 50 BP (CAMS-43991), 9210 +/- 50 BP (CAMS-43990) and CAMS-439899, 9,150 +/- 50). Obsidian, microblades, bifaces, and other tools have been recovered from this stratigraphic unit. Undated underlying stratigraphic units contain bone fragments and possible evidence of an earlier human occupation. Bone tools from different chambers of the cave are \(^{14}\)C AMS dated to 10,300 +/- 50 BP (CAMS-42381) (Dixon 1999) and 5780 +/- 40 (CAMS-42382), suggesting several periods of use/occupation of the cave. These data indicate that by c 9,200 BP humans along the Northwest Coast of North America were coastal navigators with an economy based on maritime subsistence resources with established trade networks for obsidian. This suggests a much earlier human occupation in order to explain these broad regional adaptations by 9,200 BP and may support the theory that humans may have first entered the Americas using watercraft along the Northwest Coast of North America during the late Pleistocene.

The first identifiable human impacts on the Icelandic environment came with the Norse colonisation or Landnám of the ninth century AD. The colonisation represents a fundamental environmental change that is both rapid and profound. In this paper we assess geomorphological dimensions of subsequent human impacts on the landscapes of south Iceland using a chronology based on 18 tephra isochrones. We present six reconstructions of Icelandic landscapes at precise times through the last 1,200 years and develop related models of landscape change.

From the fifth to ninth century AD, the landscapes of Iceland were without people and resilient to climate change. The initial impact of human settlement in the ninth century AD was most profound in ecologically marginal areas, where major anthropogenic modifications of the ecology drove geomorphological change. Aeolian sediment accumulation rates show five geomorphological responses to settlement that differ in both the rate and trajectory of change. These distinct anthropogenic signals are the result of spatially variable sensitivity to grazing and deforestation, and reflect the extent of local soil erosion. This critical erosion threshold was variable in space and time.

During the early historical period in the uplands, overgrazing contributed to the formation of a dense patchwork of breaks in the vegetation cover where soil erosion developed and resulted in the rapid denudation of large areas. As the upland soils were shallow (generally < 0.5 m), the overall impact of erosion on aeolian sediment fluxes before 1510 AD was modest. Later erosion of the deeper lowland soils (generally > 2 m) involved a lower spatial density of eroding fronts and a slower loss of soil cover, but a much greater movement of sediment.

Land management strategies, extreme weather events and climate changes have combined in differing degrees to initiate and drive rates of soil erosion. We assess the extent to which common land domestic grazing pressures were the primary external force causing soil erosion and assess the 'tragedy of the commons' explanation of degradation by evaluating historical records and modelling past grazing pressures in comparison to our environmental reconstructions. Historical records show that regulatory mechanisms were in place to limit overgrazing from 13th century onwards and grazing models suggest that there was sufficient biomass to support all known historical stocking levels. We suggest that failure to remove domestic livestock before the end of the growing season and an absence of shepherding were more likely to contribute to land degradation than absolute numbers of livestock. The unsustainable use of common grazing areas may have been due to the inability of management
systems to respond to the substantial, unpredictable and rapid climatic fluctuations of the 'Little Ice Age'.

**COMPARISON OF SEA-ICE SEDIMENT TO ICEBERG RAFTED DEBRIS: GRAIN SIZE, SURFACE FEATURES AND GRAIN SHAPE**

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Grains that have been transported and released by drifting ice floes (sea ice), and grains that have been transported and deposited by icebergs differ only slightly in terms of grain size and shape, but have extremely different surface features. Grain size analysis shows that icebergs transport and deposit generally coarser, more poorly sorted material than does sea ice. Grain shape analysis suggests that quartz medium to very fine sand grains entrained into sea ice tend to have a more elongate form with rounded edges, while iceberg-rafted-quartz grains have a more spherical form with angular edges. These differences, however, are too subtle to reliably identify the ice transport mechanism. However, the analysis of surface features under a scanning electron microscope (SEM) suggests that the two sediment types can be differentiated by the abundance or absence of specific groups of surface features. The surfaces of glacial grains are dominated by mechanical breakage features such as high relief, breakage blocks, conchoidal fractures and step-fractures, while the surfaces of sea ice grains have an abundance of chemical features such as pitted surfaces and show evidence of silica dissolution, precipitation, and oriented etching pits. Identification of sea ice rafted debris (SIRD) and glacial ice rafted debris (IRD) in deep sea deposits has important climatic implications.

**EFFECTIVE MOISTURE AND EARLY-HOLOCENE SPRUCE (PICEA) EXPANSION IN EASTERN INTERIOR ALASKA.**

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It is becoming increasingly evident that land-surface properties, particularly the nature of the vegetation cover, can influence local and regional climates via their effects on exchanges of water, energy, and carbon between land and atmosphere (e.g., Foley et al. 1994, Bonan et al. 1995). The Arctic and sub-Arctic are considered both sensitive to climate change and important regions in which changes in land-atmosphere relationships may feed back positively to the global climate system (see TÉMPO 1996). Thus the potential exists for positive or negative feedbacks to further modify a climate change that induces a major change in land cover - or to initiate a climate change when non-climatic factors alter land cover.

While attention is most commonly focused on temperature variation, precipitation should also be considered, particularly in the sub-Arctic, where strong summer heating can lead to moisture deficits. The arctic frontal zone is related to the occurrence of summer cyclonic activity over Eurasia, Alaska and Canada and hence plays an important role in determining high-latitude summer precipitation patterns. The front is often spatially associated with the forest-tundra boundary, its position apparently related - at least partly - to patterns of moisture availability and albedo across this ecotone (Pielke and Vidale 1996). Studies by Walsh et al. (1994) of the Mackenzie basin indicate that a considerable fraction of summer precipitation results from within-basin recycling of water vapor via evapotranspiration, which suggests that on a regional
scale vegetation may influence precipitation. If vegetation can influence contemporary climatology, it is possible that past climatic variations had similar linkages.

We have reconstructed paleohydrological changes based on lake-level changes in semi-arid sub-Arctic Alaska. Sediment stratigraphies of core transects gave quantitative estimates of past water levels and single-core data (aquatic pollen, stable isotopes, organic carbon, sediment composition and diatom assemblages) provided data for semi-quantitative/relative reconstructions. Modern hydrologic budgets were made for two lakes from monitoring data. Simple hydrologic models were then used to estimate changes in precipitation associated with past changes in lake levels (Abbott et al., in press, Barber and Finney, in press, Edwards et al., in press).

Data from five lakes in eastern interior Alaska suggest precipitation was significantly lower than present in the early Holocene. A major increase in effective moisture occurred at ca 8.5 14C ka B.P., and moisture levels continued to rise over the next several thousand years. AMS radiocarbon dating suggests a later establishment date for spruce (Picea) forest than that indicated by conventional dating of pollen profiles from eastern Alaska. The spruce rise is broadly coincident with the 8.5-ka moisture increase, and virtually synchronous in the lowlands eastern interior of Alaska.

The Yukon and Tanana valleys of the eastern interior are the most likely migration routes for the post-glacial recolonization of Alaska by spruce from regions to the east, and thus what happened in this region may have influenced the subsequent dispersal of populations further west. Several hypotheses can be developed to explain the coincidence of spruce expansion and effective moisture increase at 8.5 ka B.P: 1) spruce expansion was inhibited by low moisture levels in the eastern interior - until the 8.5 ka B.P. moisture increase; 2) spruce expansion was not related to moisture but rather to some other climatic factor, although moisture levels increased simultaneously; 3) the spruce expansion was not climate-related, but a moisture increase was coincident with it. Inherent in all three hypotheses is the possibility that a major change in land-cover - from a mosaic of open communities, shrub-tundra, and deciduous woodland to evergreen conifer forest - may have enhanced an increase in regional effective moisture. It should be possible to test the likelihood of this through modeling.

On the modern landscape of eastern interior Alaska and the south-western Yukon Territory, a moisture-controlled ecotone between forest and grassland is expressed azonally on south-facing slopes that are steep and/or have well-drained soils. Hypothesis 1) suggests that during part of the Holocene distribution of the boreal forest biome in Alaska may have been controlled by effective moisture rather than temperature alone. If this were the case, depending upon how temperature and precipitation respond to anthropogenic warming, drought may also play a significant role in determining the nature of the future vegetation mosaic, and thus of land-surface properties.


The Mutual Climatic Range method (MCR) of paleotemperature estimation allows the reconstruction of seasonal temperatures, based on fossil beetle assemblages. This method has recently been applied to thirty-one fossil beetle assemblages from central and eastern Beringia (Alaska, the Yukon Territory, and the now-submerged Bering Land Bridge). This study has yielded temperature estimates for the interval 43,550-9250 ^14C yr BP, including estimates of the mean temperature of the warmest (TMAX) and coldest (TMIN) months.

During the mid- to late Wisconsin interval in Eastern Beringia, the amplitude of change in temperature regime appears to have been greatest in the north and west, and least in the south and east. Fossil beetle assemblages from the interior regions of both Alaska and the Yukon provide evidence that summer temperatures remained well below modern levels during the mid-Wisconsin interstadial, whereas summer temperatures in the arctic regions and on the Seward Peninsula reached at least to modern levels, if not 1-2°C warmer than modern. The timing of maximum warming during the mid-Wisconsin interval appears to have been between about 35,000 and 30,000 yr BP. There is little or no beetle evidence for the spread of coniferous forest in Eastern Beringia during this interstadial, except for parts of the Yukon Territory. Older assemblages, beyond the range of radiocarbon dating but stratigraphically positioned early in isotope stage 3, show colder-than-modern TMAX estimates (Elias, 2000). This result is unlike the MCR reconstructions made for eastern United States and Britain, where fossil beetle data indicates that the peak of interstadial warming occurred between 44,000 and 41,000 yr BP (Coope, 1977; Elias, 1999). However the Eastern Beringian record agrees well with the reconstruction made by Ponel (1995) for the Grand Pile site in France, where interstadial warming peaked at 34,000 yr BP.

During the last glacial maximum, TMAX values were depressed by about 2-2.5°C in Arctic regions of Beringia, and by about 4°C in the interior; TMIN values were about 8°C colder in both regions. TMAX and TMIN values rose rapidly at northern sites after 12,000 yr BP. Seasonal temperatures peaked at 11,000 yr BP, just as the Bering Land Bridge was inundated. This was followed by a sharp climatic cooling between 11,000 and 10,000 yr BP, the equivalent of a Younger Dryas cooling in Eastern Beringia. The cooling shown in northern Alaska, while similar in scale to the estimated from the North Atlantic region (a decline in TMAX of 7°C over a period of at most 350 years), brought mean summer temperatures down only to the same level they are today. A number of mechanisms have been invoked as the cause of the Younger Dryas cooling in the North Atlantic that may also apply to a synchronous cooling in Arctic Beringia, including the southward drifting of Arctic sea ice, changes in the size of the Polar cell (changes in atmospheric catchment area), and changes in thermohaline circulation of oceanic waters. A climatic cooling during the Younger Dryas interval has also been noted in pollen records from Kodiak Island (Petee and Mann, 1994) and central Alaska (Bigelow and Edwards, 1999). A study by Anderson et al. (1989) sought modern analogues for pollen spectra from the late glacial period in the interior regions of Eastern Beringia. The authors found few modern analogues for the late glacial pollen spectra, either because environmental shifts were too rapid for plant populations to follow, or because environmental conditions were substantially unlike any modern ones. The pollen and beetle evidence both strongly indicate that the late glacial period in Eastern Beringia saw a series of large-scale, rapid environmental changes, especially between about 12,500 and 10,000 yr BP.
EVIDENCE OF HOLOCENE GLACIAL ACTIVITY FROM THE AHKLUN MOUNTAINS, SOUTHWESTERN ALASKA

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Our study of a lake sediment core recovered from the Ahklun Mountain Range in southwestern Alaska documents Holocene climate change in the region. This study complements previous work in the area, which has focused on the Pleistocene record of climate change (Briner and Kaufman, 2000). Cores were recovered from Sunday Lake, located in the western Ahklun Mountains (Figure 1) and within the late-Wisconsinan glacial limit. While not currently glaciated, the Holocene moraines fronting the cirque headwall of Sunday Creek valley suggest Holocene glacial activity. Sunday Lake is thus in a good position to record an "on/off" glacial signal from its inflow source. Several tephra units within the cores, originating from the Aleutian volcanic chain, provide confident core correlation and important chronological control. This study focuses on one 7 meter long core, SLC1, recovered from a water depth of 8 meters in Sunday Lake (Figure 2). The upper 2 meters of the core contains a likely candidate for the Aniakchak tephra, dated to ~3.5 ka BP (Waythomas and Neil, 1998), which would provide an important marker-bed for the late Holocene. The basal 3 meters of SLC1 consist of layered blue-gray mud exhibiting low organic content and moderately high magnetic susceptibility values (Figure 3). This unit is interpreted as late-Pleistocene glacial sediment. The transition from sterile glacial muds to organic-rich Holocene sediments is associated with a complex stratigraphy of organic-poor and organic-rich zones, indicating environmental change. Atop these transitional units is 406 cm of organic-rich Holocene sediment containing several prominent stratigraphic units and tephra layers. The principal tephra unit, believed to be the Aniakchak tephra (143 cm to 209 cm), immediately overlies two "blue layers" (213 cm to 223 cm, and 234 cm to 235 cm) exhibiting low organic matter content. These units are similar in color to the basal glacial sediment, and are interpreted as periods of renewed glacial growth in the up-valley cirque, suggesting cooler temperatures and/or increased precipitation. Diatom samples from these layers are currently being analyzed, and should provide information on the water temperature and turbidity associated with these layers. There is no prominent stratigraphy above the Aniakchak tephra which can be attributed to glacier activity during the late Holocene.

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HOLOCENE PRECIPITATION VARIABILITY IN INTERIOR ALASKA

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In semi-arid interior Alaska, precipitation is critical in regulating many important ecological and biogeochemical processes. For example, the growth of upland white spruce is strongly limited by growing season precipitation, and greenhouse trace gas fluxes are controlled in part by soil moisture. We have used a variety of tools at a network of sites in interior Alaska to determine variability in precipitation during the Holocene. On the millennial scale, data suggest a general increase in P-E during the Holocene. This trend is supported by lake level-reconstructions based on core transects at multiple sites, and by stable isotope analysis of cellulose, authigenic carbonates, and organic matter at several sites. The general increase in moisture balance is consistent with the sequence of major vegetation changes, such as the establishment of white spruce (ca. 8.5 ka BP; all ages in radiocarbon years), alder (ca. 6.5 ka BP), and black spruce (ca. 5 ka BP). Hydrologic models indicate that precipitation at 9 ka BP was 25 to 45% less than modern in the eastern interior. Data from several sites suggest relatively rapid increases in effective moisture at about 9 - 8.5 ka BP, and from about 4 - 3 ka BP. Records from sensitive closed basin sites suggest that near modern water balances were only established within the past 2 ka. Some deviations from this pattern occur, and may be due to regional climate variability, or to differences in the sensitivity of the hydrology at a particular site. Higher frequency variability is evident in proxy records from high sedimentation rate sites, and from tree ring analysis. In general, the data suggest significant decade-to-century scale changes in effective moisture, with evidence for both abrupt, and possibly cyclic variability (~ 100 yr). Several records show significant changes from the 19th to the 20th century. There is evidence in both lake-level and tree ring data that significant arid periods occurred during the latter stages of the little ice age.

SOIL DEVELOPMENT IN THE HIGH ARCTIC: TRUELOVE LOWLAND, DEVON ISLAND, NUNAVUT, CANADA

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High arctic soils, besides being extremely youthful, reflect a number of environmental factors, foremost among which is the prevailing hydrothermal regime and the presence of continuous permafrost. Locally, topography, parent materials, and a complex interplay between pedogenic, geomorphic and biologic processes, generally combine to produce a complex ill-defined soil mosaic.

The Holocene raised beaches of the Truelove Lowland, however, yield insights into the specific effects of these environmental factors on soil development and provide an opportunity to model soil variability. The beaches, comprised of poorly sorted beach sands and gravel of mixed lithologies, provide a range of slope conditions, from the nearly level elevated beach ridge crests, to the gently sloping back- and foreslopes, that grade into low-lying meadows that often border freshwater ponds and lakes.

The soils at these sites form a catena, in that they are related to the slope gradient and different soils occupy different positions on the slope. Regosolic Static Cryosols occur on the raised beach crests where the permafrost table is at its deepest. Brunisolic Eutric Static Cryosols
have formed on the upper foreslopes and backslopes and further downslope, Brunisolic Eutric Turbic Cryosols are associated with a hummocky microtopography. At the foot of the slope, where the active layer is very shallow, waterlogged Gleysolic Turbic Cryosols are forming on a silty lacustrine substrate. Within the various slope zones, pedogenic processes interact with periglacial processes to produce microscale soil variability.

CONTAMINANT LANDSCAPES OF ARCTIC ALASKA AND SIBERIA

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Landscapes of relatively pristine arctic Alaska and relatively industrialized Siberia were studied for accumulation of heavy metals and organochlorines in lichens, mosses, soils, and sediments. Concentrations of several contaminant elements in remote Alaskan populations of the monitoring moss, *Hylocomium splendens*, are low. Concentrations of lead (Pb), a common index of long-range atmospheric deposition, were among the lowest recorded globally. Because contaminant concentrations in arctic Alaska were low, we looked at the same kinds of samples from the Taimyr Peninsula, home of the major industrial complex of Norilísk (annual emissions ca. 30,000 tonnes metallurgical dusts and heavy metals). It has been believed that Norilísk is an important source of transpolar pollution. Surprisingly, concentrations of Pb, copper (Cu), cadmium (Cd), and vanadium (V) at sites in the central, northern, and eastern Taimyr Peninsula were generally similar to the low levels found in arctic Alaska, rather than to the markedly higher levels on the Kola Peninsula and in the northern polar Urals. Further, a lake sediment core from the eastern Taimyr Peninsula showed no recent enrichment of contaminant elements. These results suggest that the impact of the Norilísk smelting complex is localized and does not extend northward beyond about 100 km. Likewise, elevated concentrations of Pb and Cu from samples taken adjacent to the Dalton Highway (Alaskan Haul Road) and from Prudhoe Bay, AK appear to be the result of local sources. These samples have contaminant fingerprints similar in some respects to those from samples taken near heavily industrialized areas of Siberia.

Further studies were initiated to compare inputs of long range atmospheric transport to lithological contributions for vegetation samples. Enrichment factors were calculated for several contaminant elements by taking the ratio of contaminant concentrations to concentrations of a conservative element (in this case Al) in the vegetation sample, and dividing by the same ratio in the local soil parent material. Using this technique, samples high in V from both the Dalton Highway and the Kola Peninsula appear to result from remobilization of lithological material. By contrast, both Cd and mercury (Hg) appear strongly enriched from atmospheric sources, even though their concentrations are low in lichens and mosses. Enrichment of Cd and Hg in vegetation samples is not consistent with the lack of upcore increases in these elements in lake sediment cores from northern Alaska and the eastern Taimyr Peninsula. Because Cd and Hg are both of potential biological concern, and because a diversity of terrestrial and aquatic transformations, including post-depositional diagenesis and diffusion, may affect stratigraphic sequences, we suggest that increased attention needs to be paid to these two elements. One potential mechanism for Hg enrichment is global fractionation (Wania and Mackay 1993), as this element has a high vapor pressure. Mechanisms controlling Cd enrichment are less obvious, and deserve increased attention.

A 90,000-YEAR RECORD OF FOSSIL CHIRONOMID AND CLIMATE CHANGE AT FOG LAKE, BAFFIN ISLAND

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To address questions concerning future global climate change, it is necessary to understand natural climate variation over a range of timescales in the past. The Canadian Arctic is a particularly sensitive area, and is critical for our understanding of past climate change at high latitudes. One proxy measure of temperature/climate that remains essentially unexplored in arctic records is the fossil remains of the aquatic insect group Chironomidae (Diptera). Chironomid remains are being examined in a 137-cm core from Fog Lake on the Cumberland Peninsula, Baffin Island. The core was collected as part of the NSF-PALE initiative. Fog Lake probably remained unglaciated during the late Wisconsinan period. The core includes both Holocene sediments (Unit 5, gyttja), and pre-Holocene layers. Although sedimentation may not have been continuous in this lake, and dating of older strata remains problematic, it is believed that Units 1-4 represent a time period extending from the Holocene back to the penultimate glaciation.

Chironomid assemblages show dramatic shifts in species composition throughout the core, corresponding in part to the lithological units. Concentrations of head capsules were extremely high at the base of Unit 3, which is dated at approximately 90,000 yrs BP. In Unit 3, which was probably deposited during the last interglacial (OIS 5), inferred water temperatures are warmer than present. Warm conditions at this time were also suggested by the diatom and pollen data. In Unit 4, a minerogenic laminated silt that probably represents OIS 2-4 during the last glacial maximum, Oliveridia is the dominant taxon, but is rare or absent in other sections of the core. Preliminary results indicate that water temperatures during this interval were around 10°C, although there may have been hiatuses in sediment accumulation during this period. The sediments in this unit may have been deposited during interstadials. Concentrations of head capsules were lowest in this time interval. Some taxa, such as Abiskomyia, are present only in the most recent Holocene intervals.

This work represents one of the first stratigraphic studies of chironomid remains in Arctic Canada, and one of few anywhere to examine pre-Holocene assemblages. In addition to the Fog Lake core material, surface samples from a suite of lakes on a north-south transect of the Cumberland Peninsula are being enumerated to provide additional data for chironomid-based temperature inference models.

AN ANNUAL SNOW MELT INTENSITY RECORD IN LACUSTRIINE SEDIMENTS OF SAWTOOTH LAKE, ARCTIC CANADA

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Sawtooth Lake, Ellesmere Island (79° 20’ N, 83° 51’ W), contains annual clastic laminations in its deep distal basin: coarse and fine silt sediment during the snow melting season, followed by the settling of clays during the ice covered winter season. We present preliminary results obtained using an image analysis technique that provides multivariate quantified data for each varve. Petrographic and backscattered electron microscope micrographs of thin-sections are
processed to produce black and white images, where white pixels represent the clay-rich sedimentary matrix and black pixels represent particles in the matrix: silt- or sand-sized, terrigenous or authigenic particles, diatoms or organic debris (Francus, 1998). Computer-assisted measurements of the size, shape, orientation and packing of the particles forming the varves allow for their multivariate quantification.

Present day on-site meteorological, hydrological and sedimentological studies have been used to understand how the climatic signal is recorded in the varved sediments. The value of this has been demonstrated in our previous work, leading to more confidence in the underlying controls on sediment flux and varve formation in the lakes (Bradley et al., 1996).

The data obtained on each single varve of the uppermost sections of the cores have been compared with meteorological and climatological data, e.g. temperature, snow melt, wind, and discharge. From the Eureka meteorological data set, we computed a snowmelt intensity index (SMI) for each year as the maximum snow depth decrease over a time period of 10 days. For the last 33 years, SMI correlates well with the median grain-size measured for each annual lamina. Lamination thicknesses do not correlate with mean summer temperature over the same period. Summer rain events are also recorded as thin beds of sand. The 90th percentile of the grain-size of each lamina detects and quantifies the intensity of those rain events.

This comparison allows for the clarification of the climatic control on sediment fluxes to the lake and construction of a model linking sediment to climate. This model will be used to infer paleoclimate with annual resolution from downcore laminae.


PALYNOLOGICALLY-INFERRED ARCTIC VEGETATIONAL CHANGES RELATIVE TO SUB-MILLENNIAL LATE HOLOCENE CLIMATIC VARIABILITY: ARE THE MWP AND THE LIA REGISTERED?

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The response of Arctic plant communities to climate change is complex due to the interplay between factors such as atmospheric CO₂ concentrations, air and soil temperatures, precipitation, and available resource levels. Long life spans, low dependence on sexual reproduction, broad ecological tolerances, and low nutrient requirements all suggest that Arctic plants may be highly resilient to climate change. This stabilist viewpoint of Arctic plants in relation to climate change (Sonesson and Callaghan, 1991; Jonasson, 1997) is contrary to observations of a close relationship between species richness and summer temperature (Rannie, 1986; Billings, 1997), which implies that climate exerts a profound and direct effect on plant community structure. In this study, high-resolution palynological analyses were undertaken on 42 samples from Aqvaqiak Lake (66 47’N, 63 57’W, 45 m asl) gravity core in order to assess how stable - or how sensitive - was the vegetation to late Holocene climate variability. Improvement of our understanding of the Medieval Warm Period (MPW: ca A.D. 900-1350 or 1050-600 B.P.) and the Little Ice Age
(LIA: ca A.D. 1350-1800 or 600-150 B.P.) impact on Arctic plant communities is needed for a better assessment of the magnitude of Arctic climate changes.

Subtle changes in the pollen and spore relative frequencies characterize the MWP and the LIA (fig. 1). Numerical analyses were used to better describe the pollen and spore assemblages (fig. 2). Squared chord distance and rate of change between successive samples show that pollen spectra characterizing the LIA are more variable than the ones characterizing the MWP. Stratigraphic plot of axis 1 principal component sample scores shows that this variability is mainly expressed by the Betula, Poaceae, Salix representation (+) and the Ericaceae representation (-).

Marked changes in the pollen and spore net accumulation rate (influx) characterize the transition from the MWP and the LIA (fig. 3). A notable decrease of about 60% in the pollen and spore production is observed. Influx values were transformed into standardized deviates (by substracting the mean for the sequence and dividing by standard deviation for each taxon) to determine significant shifts from mean values through time (Fuller, 1998) independently of the pollen and spore productivity and the taphonomical processes of each taxon. The standardization shows that Betula and Ericaceae, two taxa abundant in Low and Mid Arctic environments, had their maximal production in the MWP, whereas Salix and Poaceae, two taxa best represented in High Arctic environment, had their maximal production during the LIA.

These new results provide insights into vegetation response to late Holocene climate variability and provide a context for understanding the magnitude of Arctic climate variability in older records. These results raise interesting questions about the vegetation reproduction and the relation between vegetational formation (shrub, herb tundra) and the sensitivity to climate variation. Even if no evidence of the 20th century climate warming was discerned in the Aqvaqiak Lake sediments, we think that Arctic vegetation could change and how it could feed back to climate change is now a challenge for scientists in the North.

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ONSET OF MID-PLIOCENE PERMAFROST AND THE PRE-GLACIAL TO GLACIAL TRANSITION IN THE KLONDIKE AREA, YUKON TERRITORY

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Recent stratigraphic, geochronologic, and palynologic investigations of the Klondike goldfields, west-central Yukon, reveal a rich record of Plio-Pleistocene deposits interbedded with over 30 tephas recording much of the last 4 Ma (Froese et al. in press, Schweger et al. 1999, Preece and Westgate 1999; Fig.1, 2). Surprisingly, these tephas are largely distinct from those found in the Fairbanks area, with only 3 known correlatives (NT, Sheep Creek and Old Crow). The Klondike deposits are of particular interest since they include sediments that immediately precede and follow the onset of glaciation in the region, and provide an important dataset relative to other Pliocene records in northwestern North America. Since work on tephas and the younger stratigraphic record (mid-late Pleistocene) is still in progress (palynology, regional correlation and fission track dating), aspects of this dataset will most certainly be refined in the near future. This presentation focuses on the mid-Pliocene record of permafrost, and the earliest evidence of glaciation in the Klondike area.

Early-mid Pliocene pre-glacial sedimentation is recorded by the lower White Channel gravel that is well exposed in thick terrace sequences throughout the goldfields. Polarity of the unit is mixed (reverse-normal-reverse-normal) from multiple sites, and pollen is characterized by Pinus (up to 40%) and Picea (up to 30%) (Schweger et al. 1999, in prep). An upper White Channel gravel unit marks latest aggradation, and includes ice-wedge casts characterized by a dominant normal polarity. At one location, Quartz Creek, an ice-wedge cast infill includes the Quartz Creek tephra which has a 40Ar-39Ar age on hornblende of 2.64 +/- 0.24 Ma (Kunk 1995), which agrees with the minimum age of the L-shaped spectrum of 2.71 Ma- the step least likely to contain extraneous argon. This age is consistent with a normal polarity (Gauss >2.6 Ma). Slightly earlier evidence of permafrost is found at Jackson Hill in which a reverse magnetization was found immediately overlying an ice-wedge cast. Presumably, this reverse represents a sub-chron within the Gauss (Kaena or Mammoth?). However, some caution should be reserved since this reverse magnetization was not found associated with the other ice-wedge casts in the area (all normally magnetized). Pollen from the upper White Channel and collected from within Quartz Creek tephra, shows a decrease in pinus abundance (~10%) and likely represents the latest age of a taxonomically richer boreal forest that existed in Yukon-Alaska prior to the onset of glaciation (Schweger et al. 1999, in prep; J. White pers. com 1999).

The first evidence of glaciation in the Klondike area is recorded by the Klondike gravel, an extensive glaciofluvial outwash derived from the first Cordilleran ice sheet advance in the region (Fig.2). The lower portion of the Klondike gravel interbeds with the White Channel in the Klondike valley and is also magnetically normal, indicating an equivalent magnetostratigraphic unit. A lower terrace (incised 100 m) in the upper White Channel/Klondike gravel terrace is overlain by approximately 15 m of loess and reworked loess, called the Midnight Dome loess (MDL). The MDL contains multiple tephas (at least six), and at least three interglacial organic horizons (Schweger et al. 1999). The deposits have a reverse-normal-reverse-normal polarity sequence assigned to the late Matuyama chron, including Jaramillo sub-chron (1.07-0.99 Ma), and early Brunhes chron (<0.78 Ma). The basal tephra has been correlated as the NT tephra from Gold Hill Loess at Fairbanks (Westgate et al. 1990, Preece et al. 1999). At Gold Hill, NT occurs 4 m above PA tephra (2.02 ±0.14 Ma) and 4 m below AT (~1.0 Ma- Jaramillo sub-chron), suggesting an age of about 1.5 Ma for the base of the MDL, consistent with the pre-Jaramillo reversed polarity (Fig.3).

Based on the close association of the Klondike gravel with the first evidence of permafrost in the upper White Channel gravel and Quartz Creek tephra (2.64 +/- 0.24 Ma) we
think the first glaciation also occurred within the Gauss sub-chron (>2.6 Ma), suggesting large ice volumes in the northern Cordillera by this time. This is consistent with age estimates for the onset of major glaciation (ice-rafting) in the North Pacific (Krissek et al. 1995). However, what is perhaps more difficult to understand is the association of permafrost, indicated by ice-wedge casts (perhaps by 3.1 Ma), during what has been considered the mid-Pliocene warm interval (Dowsett et al. 1994).


Kunk, MJ. 1995. 40Ar/39Ar age spectrum data for hornblende, plagioclase and biotite from tephras collected at Dan Creek and McCallum Creek, Alaska and in the Klondike Placer district near Dawson, Yukon Territory, Canada. USGS Open File Report 95-217.


Figure unavailable in electronic version.
ANALYSIS OF MODERN AND FOSSIL POLLEN SPECTRA AND PINE MACROFOSSILS FROM THE KOLA PENINSULA, RUSSIA

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Lake surface sediments were taken from thirty-one lakes along a north-south transect on the Kola Peninsula, northwestern Russia. These surface samples were analyzed for their modern pollen and pine needle stomate deposition in order to determine contemporary pollen rain and vegetation relations. The major vegetation zonations established in the field (tundra, birch tundra, pine limit and forest) are consolidated into three groupings of tundra, birch-pine transition and forest in the principal components analysis. CONISS clustering analysis groups the vegetation zones out similarly and reflect those established in the field. These data indicate the pollen rain along our study transect is a reliable indicator of major vegetation types found in the region.

These results are preliminarily applied to long-core lake sediments taken along the same transect north of the current treeline position in order to detect northward movements of treeline during the last 9700 14C years. Twenty-one radiocarbon-dated pine macrofossils taken from the same study transect are also discussed in terms of treeline movement.

EROSION MARKS IN BEDROCK AT KANGERLUSSUAK, GREENLAND: RELATION TO CONTINENTAL GLACIAL PROCESSES

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Evidence mounts that fast-flowing water beneath continental glaciers on North America (Shaw 1996), Europe (Dahl 1965) and elsewhere significantly shaped landscape on scales from millimetres to hundreds of kilometres. Small-scale erosional marks in bedrock (s-forms) are an important part of this evidence. Following Allen (1982) and Kor et al. (1991), their forms may be classified as spindle flutes (elongate troughs downflow), muschelbr÷che (pelecypod-shaped depressions), sichelwannen (crescent-shaped erosional forms), and potholes. Each is created by abrasion (corrasion) by sediment-bearing turbulent flow. They normally occur in fields where individual forms are a response to the overall pattern of the field.

S-forms also occur commonly on bedrock in modern rivers (Tinkler and Wohl 1998), providing a means of studying their origin and development as an analogue to subglacial conditions. In the bed of Watson River at Kangerlussuak (Søndre Strøm), Greenland (67°01'N, 50°41'W) is found a remarkable field of very well-developed s-forms. They are formed on Precambrian gneiss containing the remnants of metadolerite dykes in a zone of accelerated flow created by a constriction over a bedrock sill.

The area covered by s-forms (about 10.5 x 103 m2) consists of an undulating surface cut by two channels 10 - 15 m wide and 1 - 3 m deep that carried the normal summer flow in Watson River and its tributaries of up to about 100 m3/s. During road construction in the 1940s one channel was enlarged by blasting to about 10 m deep. Thus, normal flows probably did not inundate most of the surface, and certainly have not since road construction. However, several ice-dammed lakes along the margin of the Greenland Ice Cap drain catastrophically, creating measured peak flows of about 1200 m3/s every 2 to 8 years (Sugden et al., 1985; Russell, 1989). Individual flows last less than 24 hours but inundate the entire surface to depths of 1 - 5 m, and
flow velocities exceed 10 m/s according to anecdotal accounts. Standing waves in supercritical flow occur over much of the surface, and suspended sediment concentrations are estimated to exceed 10 g/L (cf. values documented in other jökulhlaups: Gilbert, in press).

The surface covered by s-forms can be divided into three regions: an upstream section where the steep, flow-facing surface generates large vortices, a relatively plane, horizontal mid section over which flow is smooth, and a downstream section where steeper, irregular slopes allow greater flow separation. Each interfingers with the next over a distance of up to 50 m. The upstream section is dominated by deep potholes and furrows metres to several tens of metres long with depths greater than widths. Small (centimetres to decimetres), shallow muschelbreche dominate the mid section where large areas are covered by forms all about the same size and shape, occurring en echelon, each one upstream affecting the flow pattern, and therefore the position and shape of those downstream. Bedrock joints in this region exert a strong influence on the location and size of s-forms; individual joints are enlarged and faceted where they disrupt water and sediment flow over them. Downstream, s-forms are larger (up to several metres) and deeply eroded scours are created anomalously on the surface. Each consists of erosional elements at scales from millimetres to metres, suggesting varying turbulent structure in the flow with varying discharge, velocity and water depth. A large part of the surface in this region is stepped, with treads of about 1 m covered with interrelated forms, and risers of about 0.3 m into which the forms of the tread below have eroded headward. Furrows dominate in this region, although many forms do not fit well into the classification of s-forms set out above.

Rates of erosion of the s-forms are unknown. Nor is it known whether these features are principally subglacial in origin (that is, Pleistocene) and are now inactive, or whether they are of post-glacial origin in open channel flow. Measured rates of bedrock erosion in rivers elsewhere are of the order of 0.3 - 10 mm/a (Hancock et al., 1998), suggesting that even relatively short-lived, infrequent jökulhlaup events are probably sufficient to have generated the s-forms at Kangerlussuaq during the Holocene. As well, the entire surface is unweathered except by corrosion; minute, millimetre-scale features are perfectly preserved, suggesting that the s-forms are at least maintained by modern fluvial processes. Finally, there is no cavitation pitting on these s-forms. Cavitation as a process of erosion is uncommon in open channel flow (Hancock et al., 1998) but pitting is commonly observed on forms created by large pressure fluctuations in the closed pipes of subglacial flow (Shaw, 1996).

Ongoing research is directed to detailed field measurements of form, a wind-tunnel simulation of the creation of s-forms in ice. Specific goals are to better classify s-forms, to relate forms to the processes creating them, to understand the interrelation between neighbouring forms, and to document the relation between form, process, substrate and the regional environment, especially due to slope and channel shape (c.f. Hallet, 1990). Additionally, addressing questions of scale will facilitate comparison of s-forms in different media (unconsolidated sediment, ice, and rock), between open and closed systems (and so by extension of open channel processes to the subglacial environment), and between the small features observed in most rivers and large-scale (kilometres to tens of kilometres and more) forms ascribed to the same process in continental glacial landscapes.


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**A COMPARISON OF LEAD AND MERCURY CONCENTRATIONS FROM A SOUTHERN GREENLAND AND DANISH MIKE**

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In order to develop a new method of dating modern contaminant profiles in the Arctic, total lead, lead isotopes, and mercury concentrations from peat from an ombrotrophic (atmospherically nourished) raised bog in Denmark and peat from a minerotrophic (groundwater nourished) mire in Greenland were measured and compared. The profiles are down to a depth of one meter. They are presently being dated by C14 accelerator mass spectrometry (AMS) and Pb210. The AMS dating technique utilizes the C14 atmospheric bomb-pulse in order to obtain high resolution (+/- 2 years) dating of maxima and minima in the past 50 years. Measurements are compared with values reported in other archives (snow, ice, and sediments). The two mires are compared to see if trophic status of a peat archive affects the concentration maximum peaks. Requiring only a small (0.1 - 1 mg) sample, AMS is good for projects that investigate remote regions where the identifiable macrofossils may be difficult to identify in the limited amount of material removed from the site and the rate of response to changes in human activity is of great interest. Combined with environmental isotope radio dating such as 210Pb, the method provides a complete chronology of the last century with high-resolution points of interest within the last 50 years. The authors acknowledge and thank DANCEA, GKSS and the Swiss NSF for their funding and support.
THE INVESTIGATION AND DATING OF TRANSBOUNDARY AIR POLLUTION FOUND IN SOUTHERN GREENLAND. METHODS, TECHNIQUES, AND PRELIMINARY RESULTS


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In order to temporally investigate contaminants in the Arctic (as defined by AMAP) we went to Tasiusaq, Narsaq, Greenland to locate a peat deposit and obtain a peat core. The core was analyzed geochemically to determine the trophic status of the mire. The core was analyzed for heavy metal contaminants, lead and mercury. Lead isotopes were determined as well. The cores are presently being dated to determine if high resolution dating within the past fifty years (through utilization of the atmospheric bomb-pulse and 14 C accelerator mass spectrometry) is feasible. The cores are being dated with 210 Pb radiometry for comparison purposes. By comparing well investigated maxima from the ice core data, it is hoped to be demonstrated that the dating method can be utilized in Arctic peats, and that Arctic peat deposits are valid archives of transboundary air pollution.

COSMOGENIC NUCLIDE STRATEGIES FOR RELATIVE SEA LEVEL HISTORIES

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Crustal emergence records are useful but hard to obtain. In high-latitude regions, emergence histories reveal styles and rates of tectonic and isostatic (glacial and non-glacial) processes. Relative sea-level data help constrain glaciological models used to predict ice thicknesses and glacial retreat histories. Emergence rates reflect viscosities, layering, and other rheological properties of the lithosphere and mantle. Unrecognized fault blocks may be detected with emergence shoreline data over a large area. Only after global and local sea-level changes are reconciled can the history of Quaternary sea transgression and regression be understood.

In high-latitude regions in the absence of living corals, relative sea-level records have mainly been compiled from radiocarbon dates on marine and terrestrial fauna (mostly bowhead-whale ear bone and shells) and driftwood on emerged shorelines. In particular, the dating of raised deltas with shells in the bottomsets and minimum limiting radiocarbon ages from bog-bottom samples have bracketed the timing of topset-foreset contacts used to infer relative sea level at a geological instance. The chronology of deltas and shoreline records from radiocarbon and other methods has been very successful in areas where datable media exist in stratigraphically meaningful positions. Unfortunately, datable material is often not available where we need it, and even if available, uncertain marine reservoir corrections, unknown thermal histories, and other factors limit the reliability of the dates.

Cosmogenic nuclides produced in rocks would seem to be a logical dating method at high latitudes. An array of six nuclides makes it possible to date virtually any rock type. Cosmogenic-nuclide production rates are well understood at high latitudes making uncertainties in the
exposure-age calculations comparable to the uncertainties in many calibrated radiocarbon dates. Relative sea-level curves can be constructed from a choice of direct ages on (1) raised beach sediment (cobbles and boulders); (2) emerged bedrock cliff faces; and (3) topsets or other sediment (sand through cobbles) of a delta.

Cobbles and boulders on raised beaches and glacially plucked bedrock surfaces on a sea cliff face were collected along the northern coastline of Prescott Island, off the east coast of Prince of Wales Island, Central Arctic, Canada. The concentrations of cosmogenic 10Be produced in quartz phases of Precambrian gneiss and quartz veins were used to calculate the exposure ages of the emerged beach ridges and cliff surfaces. Samples were prepared at the University of Pennsylvania and analyzed at Lawrence Livermore National Laboratory. Our sampling strategy effectively avoided geological factors such as post-depositional beach sediment movement due to sea-ice push or gelifluction, cryoturbation, differential partial shielding due to snow or ice cover, and anthropogenic displacement of cobble-size quartz clasts. The concentrations were corrected for small (<2%) increases in production rate due to a decrease in atmospheric shielding during emergence. A small correction was also made to account for subaqueous production in the rocks before emergence above sea level. Sensitivity tests for reasonable effects of surface erosion and partial shielding due to snow cover indicate the exposure ages would be at most 3% too low.

Despite the apparent appropriateness of these strategies, our results are discouraging. Multiple cobble samples collected along single paleoshorelines show large variations about the mean beach age (n=12). Ages on plucked bedrock cliff surfaces were also variable (n=5). Boulder ages were the least variable (n=5) but did not define a simple exponential curve similar to the driftwood curve of Dyke et al. (1991). Because all of the exposure ages are older than the calibrated radiocarbon date for a given elevation, inheritance from pre-exposure is probably the most important source of the scatter. Support for this explanation is afforded by dates from samples collected within the present tidal zone. Collected as geological blanks, they reveal high and variable concentrations of inherited 10Be (as large as 21 kyr!). In the only other published beach sediment study, Trull et al., (1993), also obtained highly variable ages with 3He that were older than expected on beach sediments in Death Valley. However, Zreda et al. (personal communication) has indicated recently that beach sediments dated with 36Cl in the eastern Canadian arctic appears to conform with independent estimates of Holocene emergence. For future studies, a simple pre-test to measure the inherited concentration on modern beach sediments can help determine if the method will be reliable in a particular area.

We have recently initiated a project to determine if cosmogenic nuclide dating of raised delta topset/foreset beds is feasible. Subsurface samples of sand, granules, and pebbles were collected in undisturbed fluvial crossbeds in the upper 1m of the topsets of a 150 m high kame delta at Ushuaia, Argentina. The approach is similar to dating fluvial terraces where inheritance is expected or where surface samples have been disturbed. The cosmic ray flux is predictably attenuated with depth into the delta, so concentrations will decrease exponentially with depth. The concentration and variation in the concentration of the 10Be can be used to calculate the age of the topsets and if necessary compensate for any inheritance in the sediment. Additional samples will be collected in Maine and Atlantic Canada this summer.

Striae and fluting forms on the western flanks of the Torngat Mountains between the Koroksoak estuary and the northern tip of Labrador show a contrast between a dominant northwesterly ice flow pattern from the Torngat Mountains into Ungava Bay for the southern sector, and a ENE to ESE flow pattern for the northern sector, north of Sheppard Lake (Gray et al., 1996; Gray, in press). This contrast in flow patterns coincides with a similar contrast in erratic distribution and carbonate rich drift - the southern zone displaying only local Torngat lithologies and no carbonates in till, the northern zone showing limestone erratics derived from the floor of Ungava Bay/Hudson Strait, and occasional ironstone conglomeratic clasts transported from the Fenimore iron formations on the western and southwestern coasts of Ungava Bay. Only the northernmost part of the Labrador Peninsula, with relief up to 500 m was overrun during the Last Glacial Maximum by continental ice from the west and southwest - the southern sector harbouring important local centres of ice dispersion into both Ungava Bay and the Labrador Sea.

Coinciding with this northerly zone of easterly flow is a linearly contiguous end moraine, outwash plain and outwash delta complex, mapped and described by Løken (1962, 1964) as the Sheppard moraines. This feature runs NNE - SSW along the peninsula for a distance of 100 km between Killinek Island and Sheppard Lake, at an altitude of 250 - 350 m. It represents the latest recognisable eastern margin of the continental ice sheet in northern Labrador. There has been much uncertainty as to whether this moraine complex represents a still-stand during westward retreat of the front of the continental ice sheet, or a renewed and very late thrust eastward of ice in eastern Hudson Strait. The unusually high carbonate values obtained from the moraine crest, and the existence of moraine lobes cutting across pre-existing WNW-ESE fluting features near Ikudlayiuk Lake, along with burial of marine sediments beneath glacial outwash at the latter locality suggest a readvance, however.

At the Ikudlayiuk Lake site, shell fragments principally of Balanus balanus and Balanus crenatus spp, were collected from stratified silty clays, beneath 8 m of deltaic sands. The stratigraphic context suggests a sparse mollusc population in an infra-littoral situation, near the head of a Labrador coastal fjord, into which a large proglacial delta sequence of sands was constructed by meltwaters flowing east from a prominent terminal moraine, 2 km to the west. Kettle-hole lake filled depressions were noted on the highest level of the delta at 34m, which is considered to represent the postglacial marine limit at this locality, and also on a lower level of 15m, indicating the former presence of blocks of buried glacial ice detached and floated forward during the early stages of the outwash delta construction. Ages of 8.3, 8.4 and 8.7 ka, with low error ranges, were obtained for 3 of 4 mollusc fragments at the University of Arizona AMS facility. A fourth sample containing only .05 mg carbon was dated at 9.4 ka with a quoted error range of 0.4 ka. A reasonable inference from these dates is that they immediately pre-date the Sheppard re-advance or ice front position. Thus ice moving east onto the northern Labrador coast across the limestone basin of northern Ungava Bay and/or Hudson Strait subsequent to 8.7 ka invaded the tip of the Labrador Peninsula to a minimum elevation of ca 350 m. That this must have been a short-lived readvance is indicated by the following morphological and chronological data. No retreat phase moraines or outwash deposits were noted between the Sheppard moraine and the west coast of the Labrador Peninsula, and 14C ages of molluscs from the base of a marine core in eastern Ungava Bay (Manley and Jennings, 1996), and from onshore marine deposits on NE Akpatok Island (Gray et al., 1993) indicate re-establishment of marine conditions towards 8.2 ka.
South of the sector characterised by the Sheppard moraine complex, glacial lakes dammed up in NW trending valleys may also be associated with the last readvance phase of Ungava Bay ice, after retreat up-valley of local glaciers. A complex of glacio-lacustrine shorelines, at elevations of 200 - 300m, with northerly draining spillways have been identified for the valleys between Keglo Bay and Abloviak Fjord. A well-defined glacio-lacustrine terrace at 190 - 208 m in the Abloviak and Vent de l'Ouest valleys, first identified by Ives (1957), mark the shoreline of Glacial Lake Abloviak which drained eastward by a low pass to the Labrador coast. Its western ice dam margin is characterised by locally developed De Geer moraines.

As yet it has not been possible to clearly establish the direction of the ice flow causing the ice dam in SE Ungava Bay, but the evidence for N to NNE trending ice flow into Ungava Bay from Central Qu/bec-Labrador, coupled with the absence of limestone erratics or carbonates in till, suggest that the glacial lakes were associated with a northerly flow, impinging on the coast, between the Korok estuary and Abloviak Fjord. This ice may or may not have converged with the easterly flow responsible for the Sheppard moraines. Drainage of the glacial lakes can be chronologically associated with the earliest postglacial marine conditions in southeastern Ungava Bay, prior to 7.4 ka (Allard et al., 1989) for the George River sector, and probably prior to the above mentioned basal marine core age of 8.2 ka in eastern Ungava Bay.

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EARLY HOLOCENE DEGLACIAL SURGES AND MEGAFLOODS PROCEEDING FROM THE CONTINENTAL SHELF OF THE KARA SEA ONTO NW MAINLAND RUSSIA: THEIR PALEOGLACIOLOGICAL IMPLICATIONS.

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During the height of the Late Weichselian glaciation, mainland NW Russia, namely Kola Peninsula and the White Sea, were glaciated by the Scandinavian Ice Sheet, while during deglaciation, when that ice sheet retreated, the area was re-invaded by glacier ice that surged from the NE. The latter conclusion comes from the geometry of such landforms as the lateral Tersky Keiva Moraine, the loops in the northern belt of end moraines, and the glaciotectonic features in the southern belt of end moraines; it is also supported by orientation of certain boulder trains. Judging by 14C dates and correlation with the Younger Dryas moraines of Karelia and Kandalaksha Bay, the surging occurred immediately after 10 kyr, i.e., during the Early Holocene (Grosswald, 1998).

The ice mass that impinged upon Kola Peninsula and the White Sea after 10 kyr ago had the form of a thin (about 300 m thick) slab with a gently, by about 1/1000, sloping surface, which is conclusive evidence for surging dynamics of the ice mass. As the adjacent Barents Sea was ice free since 13-12 kyr ago (Landvik et al., 1998), the source area for surging ice could be nowhere but on the continental shelf of the Kara Sea, strongly implying that at about 10 kyr BP the Karan shelf still supported a thick and extensive ice sheet, and that, to produce the glacial surges, the ice sheet had to collapse shortly after that date. It also implies that, in order to reach Kola Peninsula, the surging ice had to proceed up to 1000 km across the continental shelf of the Barents Sea. In that case, Karan ice could not help but concurrently invaded the adjacent lowlands of the Pechora Catchment, northern West Siberia, and Taimyr Peninsula.

The “long travel” of the surging ice implies that the ice was underlain by a thick pillow of water. On reaching Kola Peninsula, that water moved upslope and forced its way from beneath the ice onto the land surface, resulting in cataclysmic outburst floods. Pathways of the floods were reconstructed, based on assemblages of parallel ridge-and-furrow landforms similar to Baer’s mounds of South Russia and Siberian “grivas”. Thus we believe that the assemblages are *prima facie* footprints of cataclysmic floods which occurred in conjunction with the glacial surges. From the footprints, we discern three closely spaced in time episodes of flooding, with the third flood directed submeridionally, across the pathways of the first and the second ones, turning their parallel features into a unique gridiron-shaped complex.

Judging by this geomorphology, there is little doubt that the Kolan deglacial floods were cataclysmic events characterized by huge water discharges and velocities. Thus we suggest that the probable source of their water and energy could be the Ice Age central Arctic Ocean, which seems to demonstrate that the hypothesis, developed for explaining the trans-Eurasian megafloods, is also applicable here (Grosswald, 1999). We further hypothesize that, in the south, the flood water cascaded into the Baltic Ice-lake, forcing its catastrophic outburst at Mount Billing at about 9.8-9.9 kyr BP, and turning that ice-lake into the Yoldia Sea.

To conclude, we state the following: (i) this surging, its Holocene age and NE-to-SW direction make it obvious that the existing concepts of deglacial history of NW Russia should be reconsidered; (ii) the evidence presented here strengthens the concept of an “unabridged” Late Weichselian Arctic Ice Sheet; (iii) it also supports our case for the Ice Age Arctic Ocean as a main source of water and energy for the Eurasian megafloods; (iv) this evidence helps in resolving our differences with the QUEEN Project members. In spite of their claim for having “proven beyond any doubt that Grosswald’s reconstruction of the Late Weichselian glacial maximum for the Russian Arctic is incorrect and depicts ice sheets that are much too large” (Svendsen et al., 1999: 240), we remain confident that the reconstruction in question is generally...
sound. On the other hand, the above evidence does clearly cast doubt upon validity of the QUEEN’s version of her Arctic glacial history. Besides, this version appears inconsistent with the Late Weichselian climate as revealed by deep drilling in Greenland.


EFFECT OF GEOMAGNETIC FIELD FLUX ON HUMAN AUDITORY AND VISUAL EVENT-RELATED BRAIN POTENTIALS.

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INTRODUCTION. The 1989 report of the Interagency Arctic Research Commission identified the need to investigate factors relating to human performance at high latitude. Additionally, the World Health Organization identified the need for more data concerning magnetic field effects on human biology and health. At the Sixth International Symposium on Circumpolar Health, it was suggested that "... it is more than likely that the strong magnetic disturbances which occur around the geomagnetic poles and within the auroral zone, interact with brain activities." The upper latitudes of the North American continent form an especially convenient natural laboratory for studying geomagnetic effects, due to the proximity of the Earth's magnetic pole, the fact that auroral activity and its effects center on the magnetic poles, and the summer attitude of the pole relative to the sun. In the region of this investigation, 64o North 141' West, engineers studying geomagnetically-induced currents have measured earth-surface potentials between ground electrodes varying 1-10 v/km during strong geophysical events such as: strong auroral activity, solar flares, coronal holes, and disappearing filaments.

In the literature studying humans, geomagnetic field flux has been linked with: increased incidence of psychiatric admissions, outbursts of aggressive behavior among the mentally disturbed, changes in reaction-time performance, time estimation, ability to navigate, and other cognitive abilities such as vigilance and attention. The both animal and human studies, periodicity of the geomagnetic field is reported to demonstrate zeitgeber effects and also effect melatonin production by pinealocytes, a system that has been linked to human Seasonal Affective Disorder. Although not yet causally attributable to any specific environmental factor, portions of the human EEG have been shown to manifest seasonal changes among Norwegian shift workers within the Arctic Circle, and among normal adults in the Alaskan subarctic.

Answering the question of whether fluxes in earth-strength magnetic fields are able to influence humans has been a controversial inquiry. Until the mid-1980's, research mostly focused on the electric, rather than magnetic, field effects; now both are under extensive investigation. In many instances, the concept of electromagnetic field appears to be confused with that of the magnetic field. The present investigations are limited to naturally occurring fluxes within the Earth's geomagnetic field, which is approximately: 10 Hz, 500 milligauss, and exhibits daily, monthly, seasonal and decennial variability. In this report, two experiments took
advantage of an 11-year peak in geomagnetic storms. Experiment one captured an eight-day period of geomagnetic storms triggered by an area of active solar flares moving with the sun's rotation. Experiment two longitudinally studied a group of normal humans through 12 consecutive calendar months of geomagnetic flux. Both investigations measured the auditory and visual event-related brain potentials, ERP, components of the EEG as dependent variables. The purpose of the studies was to explore whether there were detectable geomagnetic field-flux effects in these late-cortical, cognitive components, of the human EEG.

METHODS. In both experiments, earth-surface geomagnetic activity, the k-indices, were obtained from the College Alaska Observatory, Geological Survey Office, National Oceanic and Atmospheric Administration. The k-index (0-9) is calculated from continuous magnetograms for every 3-hour epoch from midnight-to-midnight (Greenwich Civil Time) and reflects the amplitude of the most disturbed component. The k-indices are summed over the 24-hour day, sum 24-hour k, and then converted to daily equivalent amplitudes, Ak. Strong auroral activity disrupts the horizontal component of the field more than other components.

In both experiments, the laboratory is located two floors below ground surface. The horizontal and vertical vectors of the ambient magnetic field in the cubicle were measured with a fluxgate magnetometer at each of the 4 electrode placement sites (Au1, Au2, Cz, forehead ground). The readings from the 4 sites were averaged to estimate the total magnetic field, TMF, for each subject's head at the time of ERP recording. Over two-years' monitoring of the below-ground cubicle have shown it to be relatively stable, with a range of 460-540 milligauss, even during periods of strong geomagnetic storms.

In both experiments, normal human volunteers gave fully informed consent. Both auditory and visual event-related brain potentials, ERPs, were recorded noninvasively from the scalp surface using a Cadwell Quantum-84 four-channel neuroelectrophysiologic recording device. The Quantum-84 is a distributed processing system with 8-bit resolution at 18 kilohertz; the bandpass filter was set at 1-100 hertz along with a common-mode high-voltage rejection filter, per manufacturer's recommendation. Manufactured magnetically shielded 9-mm gold cup nonferrous electrodes were used for both the auditory and visual ERP recordings. Two channels of signal-averaged EEG were obtained from each side of the subject's head, separately but simultaneously, beginning 15 msec prior to onset of the auditory or visual sensory stimuli. The third positive wave, P3, is an endogenous potential generated when the subject detects a target stimulus; since P3 is the most investigated component of the ERP it was selected as the dependent variable. Two characteristics of the component were obtained by the first derivative test for relative extrema: amplitude (amount of voltage, microvolts) and latency (time of maximal response, milliseconds).

In both experiments, the auditory oddball detection paradigm required a subject to listen (binaurally via balanced audiometric headphones, 80 dB each ear) to a four-minute sequence of randomly generated tones, rate of 1/sec., and to silently maintain a running count of target higher-pitched tones (2000 Hz, 15% of trials) detected amid the tones to be ignored (1000 Hz, 85% of trials). Each tone was cosine-ramped with equal rise, plateau and decay times. In both experiments, the visual oddball detection paradigm required a subject to watch (via eye-level 49 cm monitor, at a distance of 0.6 m) pattern-reversing black-&-white checkerboard patterns, and maintain a silent running count of the number of smaller-squares target screens. The entire visual screen subtended 30.51 degrees of visual arc, the pattern to be ignored ("large," 5-cm squares) subtended 6.50 degrees of visual arc and occurred randomly on 85% of trials, and the pattern to be detected ("small," 2.5-cm squares) subtended 2.60 degrees of visual arc and occurred randomly on 15% of trials.

EXPERIMENT ONE: GEOMAGNETIC STORM. An N.O.A.A. advisory predicted an 8-day period of geomagnetic storms. During this 8-day window, 17 normal human subjects volunteered for ERP recordings: 11 men, 6 women, mean age = 24.6 years). Recordings from these subjects were sex-matched and age-matched to similar volunteers recorded during quieter periods before the storms. The recorded surface geomagnetic activity was considerably stronger, and more
variable, than that recorded below-ground in the laboratory: surface k-indices ranged 1-8, daily sum-k ranged 14-48 (mean = 35.7), the reported Ak ranged 7-100 (mean = 55.4) with two episodes of sudden commencements. The after-effect of exposure to increased magnetic field has been reported to persist for "at least 1.5 hours" and our testing period fell well within that time frame.

A two-independent-group (Storm, Control) t-test was applied to each ERP characteristic (P3 amplitude, P3 latency) and sensory modality (auditory, visual) separately. The Storm group manifested significantly greater auditory P3 amplitude than the controls: \( t = 4.368, df=30, p<0.001 \); significantly greater visual P3 amplitude than the controls: \( t=4.038, df=30, p<0.001 \); significantly shorter auditory P3 latency than the controls: \( t=2.395, df=30, p=0.023 \); and significantly delayed visual P3 latency than the controls: \( t=3.077, df=3, p<0.005 \).

EXPERIMENT TWO: LONGITUDINAL STUDY. A group of normal subjects volunteered to participate in ERP recordings for 12 consecutive calendar months, to encompass the full range of variability during a predicted a geomagnetically-active year. During the study period, sudden magnetic activity occurred in six of 12 months. All subjects were recorded, in both auditory and visual ERP protocols, during their normal diurnally active period between 8 am and 4 PM. Of the initial cohort recruited, eight subjects completed all 12 months: four men (mean = 24.75 years) and four women (mean = 25.75 years). At the end of the recording year, the ERP data were sorted into three field-strength groups based on the average daily equivalency, Ak, of the day prior to ERP testing: Low = 0-34, Moderate = 35-50, and High > 50.

The most significant ANOVA finding was for auditory P3 amplitude (\( F=2.82, df=2.93, p=0.064 \)). Auditory P3 amplitude showed larger voltages during the high Ak period when compared to the low Ak period. Conversely, the visual P3 amplitude showed lower voltages at the higher field strengths. Both the auditory and visual P3 latency tended toward delayed response times at the higher field strengths.

CONCLUSIONS. What emerges from both experiments is that, in these three groups of normal humans, the amount of voltage generated during auditory signal-detection tasks was significantly greater during periods of strong geomagnetic field. It remains to be further studied whether this increased brain voltage during strong geomagnetic fields might be a part of the explanatory understanding for claims of auroral audibility in the numerous traditional oral literature of the North, as well as emerging scientific inquiry. In both groups, visual signal-detection response time was consistently delayed (longer latency). This delayed response to a visual attention task might contribute to human error in other visual monitoring tasks, and would be a meaningful inquiry.

The mechanisms of magnetoreception in humans remain a mystery, as does knowledge of the range of behaviors affected, such as hearing the aurora or perhaps some role in the seasonal depression common to higher latitudes. It also remains to be demonstrated that polar geomagnetic storms or strong auroral activity actually induce any of the potentially explanatory neurophysiological mechanisms: anodal polarization of the brain, transretinal polarization, or ionic resonance. Nonetheless, emerging EEG and ERP studies suggest that all are strong possibilities worth pursuing, to investigate factors affecting human performance at high latitude.
El’gygytgyn Lake was formed 3.6 million years ago by a meteor impact that produced a crater approximately 23 km in diameter. The lake is located in the Anadyr Mountains, 100 km north of the Arctic Circle in northeast Russia 67° 30’ N. latitude and 172° 05’ E. longitude. In May of 1998, 25 meters of core from the center of the lake was successfully collected penetrating 12.5 m in 175 m of water. Initial analysis suggests the lacustrine sediment composition reflect the climatic and environmental history of northeastern Siberia over several glacial/interglacial cycles of the past 200 ka, and probably to the mid-Pliocene. Fluctuations in various sedimentological, physical, biochemical, and paleoecological parameters provide firm evidence that El’gygytgyn Lake responds to environmental change. Present reasearch is focused on determining the modern ecological conditions in the lake as a framework for accurately interpreting the paleodata.

Large vivianite crystals (~1 cm in length) were first noticed in the core upon collection in the field. In the lab, these crystals were found to aggregate in laminated sections where no bioturbation was evident. Further investigation revealed smaller crystals (~1 mm in length) and thin crusts of vivianite concentrated in the non-laminated sections of the core where bioturbation was prevalent. The larger crystals were analyzed using a Cameca SX-50 electron microprobe to determine bulk composition. P and Fe were the dominant elements with slight traces of Mn and Si throughout the sample. The large vivianite crystals probably formed authigenically in an anoxic environment at the sediment/water interface. Anoxic conditions prevailed in the bottom lake sediments when the lake was closed off by persistant ice cover during glacial cycles. This ice cover reduced wind shear and meltwater induced mixing of the water column and the lake became meromictic with stagnant bottom water. Microlaminations were deposited at this time due to the lack of biological activity. This also enabled unhindered growth of the vivianite crystals and a constant supply of phosphate (presumably from dissolved bone material) as well as Fe(II) and Mn from pore waters running through the sediment.

During interglacial cycles the lake was open (ice free in summer) and oxic conditions prevailed. Vivianite formation was limited to smaller millimeter scale crystals and thin but laterally continuous iron phosphate crusts. No laminations exist for presumed interglacial cycles in the lake. This change in precipitation and sedimentation is most likely due to the increased bioturbation and availability of oxygen at the sediment/water interface. There is clearly a relationship between laminated/non-laminated sediments and vivianite formation. Further study could potentially link vivianite crystal size and formation of iron phosphate crusts to glacial/interglacial cycles through the opening and closing of the lake.
Ten years of paleontological excavation on Prince of Wales Island, Southeast Alaska, has yielded a nearly complete fossil record across the Last Glacial Maximum. The island is currently a dense temperate rainforest, but limestone caves have been found containing vertebrate fossils with excellent preservation. Most caves contain only postglacial fossils, either exposed or buried in shallow sediments, dating as old as 12,300 years B.P. But two caves have been found with older sedimentary deposits. On Your Knees Cave has by far the most complete and extensive fossil record discovered thus far, extending across the Last Glacial Maximum into the Middle Wisconsin interstadial, and excavation has been ongoing for the last six years and is still underway. Because human remains and artifacts were discovered at this site in 1996, the excavation has become a joint archaeology and paleontology project (Dixon et al., 1997).

Prior to the cave excavations, most researchers believed that Southeast Alaska was overridden by glaciers during the Last Glacial Maximum and that all Holocene terrestrial mammals on the islands were postglacial immigrants from either north or south of the Cordilleran Ice Sheet (Klein, 1965). While most modern forest species do fit this model, the fossil record documents a long and complex history of colonizations and extinctions through changing climatic conditions. Most significantly, it demonstrates that coastal refugia were present during all or much of the Last Glacial maximum that were capable of sustaining communities of large mammals, possibly including humans (Heaton et al., 1996).

Several carnivores were using On Your Knees Cave as a den during the Middle Wisconsin interstadial, including Arctic fox (Alopex lagopus), black bear (Ursus americanus), and brown bear (U. arctos). Foxes appear to have been the main accumulators of bone in the cave, and their prey consisted of hoary marmots (Marmota caligata), heather voles (Phenacomys ? intermediate), brown lemmings (Lemmus sibericus), and a wide variety of sea birds, particularly alcids. Remains of two large herbivores have also been found: caribou (Rangifer tarandus) and a bovid that resembles the saiga (Saiga tatarica). Among marine mammals, remains of harbor seal (Phoca vitulina) and Stellar sea lion (Eumetopias jubatus) have also been dated to this period. Fish remains resembling the scats of river otter (Lontra canadensis) are present in small quantities in these older sediments. This fauna is most consistent with a coastal tundra where terrestrial and marine foods are providing the basis of the food web in roughly equal proportions.

The Last Glacial Maximum marks the end of most terrestrial herbivores on Prince of Wales Island, including saigas, marmots, lemmings, and heather voles, suggesting a sharp reduction in available vegetation (the youngest marmot dates to 23,560 years B.P.). The most common animal dating to the glacial maximum is the ringed seal (Phoca hispida), which is a climatic indicator of sea ice, and radiocarbon dates on this species range from 23,260 to 13,690 years B.P. Bite marks of both bears and foxes appear on these remains, and bones matching both Arctic fox and red fox (Vulpes vulpes) have been dated to approximately 19,000 years B.P. While no bones of black or brown bear or caribou have yet been correlated to the Last Glacial Maximum, their presence both immediately before and afterward strongly suggests that these large mammals survived in refugia along the coast. Currently there is a gap in the On Your Knees Cave fauna between 19,060 and 13,690 years B.P., so the cave may have been unavailable for denning during this part of the Last Glacial Maximum.

Early postglacial deposits contain remains of brown and black bears, foxes, and caribou. On Your Knees Cave contains abundant remains of sea birds, which must have been the main staple for foxes following the loss of rodents and ringed seals. The oldest artifact dates to 10,300 years B.P. and marks the beginning of a long archaeological record at the site. About 10,000
years ago, presumably due to forest development, caribou was replaced by mule deer (Odocoileus hemionus), the foxes disappeared (eventually replaced by wolves), and other modern mammals appeared such as river otters, beavers (Castor canadensis), northern flying squirrels (Glaucomys sabrinus), and long-tailed voles (Microtus longicaudus). Brown bears survived until at least 7,205 years B.P. before dying out on Prince of Wales Island, but black bears remain as one of the mostly commonly-seen animals in the modern rainforest.

The biotic history of Prince of Wales Island has been controlled both by climatic changes and colonization potential across marine barriers (Heaton and Grady, in press). It is noteworthy that marmots and lemmings failed to recolonize the island in the early postglacial period when prime tundra habitat must have been available, and that other tundra-adapted mammals such as snowshoe hares (Lepus americanus) and pikas (Ochotona collaris) never succeeded in colonizing the island at all. Birds and fishes have much greater diversity than mammals in the island's fossil record because the fjords do not pose barriers for them.

Excavations in caves on Prince of Wales Island are providing a paleontological and archaeological record that were never thought possible ten years ago, and which are allowing the reconstruction of the biotic and climatic history of coastal Alaska.


FREE AMINO ACIDS IN SUB-ARCTIC SALT-MARSH COASTAL SITES AND PLANT NITROGEN NUTRITION

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The role of free soil amino acids in plant nitrogen nutrition was investigated in a coastal sub-arctic salt-marsh near Churchill, Manitoba, Canada. Until recently, it was assumed that inorganic forms of nitrogen (i.e. ammonium and to a lesser extent nitrate) were the dominant forms of nitrogen taken up by northern plants. Nitrogen mineralization rates in northern soils are low, however, due to the inhibition of microbial activity brought about by low soil temperatures, a short growing season and low precipitation. Consequently, the availability of inorganic nitrogen in these soils is often low relative to organic nitrogen, particularly early in the growing season when nitrogen uptake is essential for plant growth. In sub-arctic salt-marshes, this relative scarcity of inorganic nitrogen may be exacerbated by high salinity, which inhibits nitrification and decreases the uptake of inorganic nitrogen into plant roots. We propose that sub-arctic salt-marsh plants may rely on free amino acids in the soil solution to compensate for this reduced inorganic nitrogen uptake and maintain growth under increasingly saline conditions.

In order to test the hypothesis that free amino acids are an important contributor to plant growth in sub-arctic salt-marshes, we quantified the concentrations of soluble organic and inorganic nitrogen present in the soil on a seasonal basis through the analysis of soil water extracts and determined the uptake rates of 15N-labelled organic and inorganic nitrogen by roots excised from tillers of Puccinellia phryganodes grown in hydroponic culture. The results from
the soil solution sampling indicated a relatively high variability in the concentrations of soluble organic and inorganic nitrogen between sites and between sampling dates, with ammonium typically present at the highest concentrations (4-221 micromoles/liter), followed by free amino acids (25-77 micromoles/liter) and nitrate (3-17 micromoles/liter). The maximum uptake rate of ammonium (73 micromoles/g/h) exceeded that of the amino acid glycine (15 micromoles/g/h), however, the affinity of roots for ammonium (Km = 57 micromoles) was lower than that of glycine (Km = 41). At high salinity (150 mM NaCl), rates of ammonium and glycine uptake were reduced by 22% and 14% respectively. By modelling plant nitrogen uptake based on soil solution concentrations and root uptake rates, it was estimated that free amino acids may contribute substantially (20 percent on average) to the annual nitrogen uptake of sub-arctic salt-marsh graminoids.

GEOSTATISTICAL CHARACTERIZATION OF ICE-SURFACE MORPHOLOGIES - RESULTS FROM EXPEDITIONS MICROTOP 97 AND MICROTOP 99 TO JAKOBSHAVNS ISBRAE, WEST GREENLAND

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The surface of the Greenland Inland Ice may be segmented into provinces of characteristically different morphologies. The fast-moving Jakobshavns Isbrae has a heavily crevassed surface with flow-line parallel units that are homogeneous in crevasse type. In the Jakobshavns Isbrae drainage basin’s slower moving ice, typical morphologies are those generated by wind and surficial-melting-and-refreezing processes. The objective of geostatistical surface characterization is to devise a set of parameters that describe each morphologic type uniquely.

Large features are visible in satellite data (SAR data), and intermediate scales are best observed in video data. To observe small-scale features, we designed and built a multi-channel instrument, called "Glacier Roughness Sensor" (GRS). The GRS measures ice surface roughness at a resolution of 0.2 meters across track and with a 10 Hertz sampling rate along track. During expeditions MICROTOP 97 and MICROTOP 99 to the Greenland Inland Ice, the GRS was utilized to collect surface roughness data in the drainage basin of Jakobshavns Isbrae. Kinematic processing of GPS data which are recorded simultaneously to the GRS data aids in accurately referencing GRS data to position. ERS-2 SAR data acquired contemporaneously to the field surveys and aerial video data collected during the flights into the field provide the basis for lower scale analyses. Geostatistical surface characterization was applied to SAR data, video data, and GRS data. As one result of the GRS data analysis, surficial melting processes dominate over wind structures in the study area, as derived from a seasonal comparison based on 1997 data, collected in May, and 1999 data, collected in late July.

LATITUDINAL VARIATIONS IN THE TIMING OF ALPINE GLACIER RETREAT FROM LGM, SOUTHERN SOUTH AMERICA

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Recent evidence from ice sheet gas and isotope records (Sowers and Bender, 1995; Blunier, et al., 1998), deep sea oxygen isotope records (Charles, et al., 1996), and terrestrial (Singer, et al., In Review) and shallow marine (Anderson and Archer, 1999) records of glacier retreat suggest that deglaciation from the LGM at high latitudes in the southern hemisphere preceded that of the northern hemisphere by at least 1.5 kyr. These data are among the first to provide evidence for an antiphasing of hemispheric climates predicted from a combination of orbital forcing effects and the difference in ocean/land/ice areas in both hemispheres. Previous results suggested that climate changes in both hemispheres were actually in phase (Mercer, 1984; Lowell, et al., 1995; Clapperton, 1998), although all of those interpretations have been contested.

We are dating end moraines to help decipher the glacial chronology at Rio Mendoza (Lat. 32°S), Rio Atuel (35°S), Lago Alumine (37°S), Lago Nahuel Huapi (41°S), and nested moraine complexes throughout southern Patagonia and Tierra del Fuego (50-56°S). Although we focussed on the timing of retreat from the LGM in each area, we also sampled moraines that-on the basis of geomorphology, stratigraphy, soil characteristics, and terminus elevations-represent significant advances before and after the LGM.

The exposure chronology was derived from carefully sampled boulder erratics (most >2.5 m high) and bedrock surfaces. Boulders that were covered by thick ash deposits, significantly weathered, or less than 1.5 m high were avoided. Unlike many alpine valleys in the western United States, sufficiently large boulders in most regions are extremely limited due to the high fracture densities that produce smaller boulders in the rapidly uplifting Andes. The search for boulders therefore relied heavily on dissertations of previous mapping projects, working with regional experts in the study areas (e.g. Jorge Rabassa and others at CONICET), and mapping the surficial geology of the unmapped valleys.

Extremely low chemical blanks were possible because the 9Be carrier used was prepared by J. Klein from a shielded beryl crystal. Uncertainties in the ages reflect uncertainties in production rate and analytical error. We used 5.1±0.2 10Be atoms g-1 yr-1 at sea level (J. Stone, in prep), and scaled in a similar fashion as Lal (1991) but assuming 3% muon contribution at sea level. Exposure ages on LGM and post-LGM surfaces are not significantly affected by even high erosion rates, so may be considered average exposure ages. Exposure ages on pre-LGM moraines should be considered minimum ages because they are not corrected for potential loss of 10Be by erosion. However, erosion rates for one common lithology (Darwin Granite) are now being determined by using 10Be in quartz with 36Cl in biotite concentrates. No adjustments in production rate due to surface geometry or shielding (snow, loess, or ash) are needed for any of the samples taken.

Approximately 50 samples have been collected from sites in Tierra del Fuego, Patagonia, and the central Andes for 10Be, 26Al, and 36Cl dating. Based on the available data, the LGM was attained along the entire 24º of latitude by 21 to 24 kyr or earlier. A single 10Be date from the Penitantes moraine (mapped as LGM) at Rio Mendoza, yields an age of 22.3 ± 3.3 kyr. This age is concordant with the minimum ages constrained by Bengochea et al. (1987) and Espizua (1993) of 22.8 to 24.2 kyr from U-series dates of overlying travertines. At Lago Nahuel Huapi, a date of 28.1 ± 2.6 kyr was measured on a stoss-lee bedrock landform, that was located approximately 2.5 km inside of the LGM limit. This age probably contains some inherited 10Be, an assumption that can be tested by further 26Al analysis.

Three erratics on the terminal moraine surrounding Bahia Inutil (53.5°S) yield ages of 22.8 ± 0.8, 20.8 ± 0.8, and 56.5 ± 5.6 kyr. The granodioritic boulders of the Darwin Granite are > 3 m high and were among more than 100 boulders within a boulder train approximately 150 m wide oriented parallel to ice flow direction. The boulder train extends from the very front of the LGM terminal moraine across every recessional moraine into bay. Because they are situated within a linear array, are of the same lithology, and are the only large boulders within 100 km,
we interpret these to be the result of a debris slide that was subsequently transported supraglacially to the moraines. I. Dalziel has recently pinpointed a source of these boulders in the Darwin Cordillera that is consistent with a simple ice flow line along the piedmont lobe. Assuming that these boulders were the result of a single debris slide event, the retreat at around 21 kyr from the LGM terminal moraines was extremely rapid (this assumption will be tested by the exposure ages of the recessional samples).

Post-LGM deposits have been recognized throughout southern South America. In the Rio Atuel, a single 10Be date of 12.5 ± 1.8 kyr, was obtained on the Arroyo Malo moraines which rest a few km above the LGM terminus (Arroyo El Freno). This exposure age is a minimum because this boulder was smaller than all others sampled and likely shielded by snow. Therefore, the timing of the deposition of this boulder likely pre-dates the Younger Dryas event.

At this preliminary stage, the exposure ages indicate that retreat from the LGM in southern South America (~21 kyr or older) occurred slightly before the glacial maxima on alpine moraines in the Rocky Mountains dated using the same method (18-19 kyr at Pinedale, Wyoming). Our ages are consistent with new radiocarbon dates for retreat in the Strait of Magellan (21-27 kyr calibrated) by Anderson and Archer (1999) and a 40Ar/39Ar age of 25 kyr for glacier retreat at 36oS (Singer et al., in review). The data therefore suggest that the high latitude southern hemisphere began deglaciation approximately 3 kyr before similar latitudes in the northern hemisphere.

AN ARCHAEOLOGICAL SURVEY OF SKOLAI PASS - WRANGELL - ST. ELIAS NATIONAL PARK AND PRESERVE, ALASKA

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In the Summer of 1998, an Archaeological survey was conducted by the National Park Service in Wrangell ñ St. Elias National Park / Preserve. The study was conducted to assess the impact modern day campers have done to the prehistoric sites and historic structures of Skolai Pass. The study was also to locate and record any new prehistoric and historic sites within the confines of the Skolai creek watershed. Although no prehistoric sites were found, one new historic site was recorded and two others were documented in detail. A thorough pedestrian reconnaissance of Skolai Pass along with the Chitistone Pass to the west was conducted. Documentation of trash dumps, a plane wreck and a 1960’s research camp were also examined.

POST GLACIAL SEA-LEVEL CHANGES AND GLACIAL FOREBULGES AROUND NORTH AMERICA AND ICELAND-IMPLICATIONS FOR FOREBULGE MOVEMENT AND RATES OF CRUSTAL ADJUSTMENT

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A comparison of well-documented post-glacial sea level changes around North America and Iceland reveals rates of change that are much higher and of greater local variability than suggested by geophysical models of crustal adjustment. Slow rates of crustal adjustment have become entrenched in the literature in part because, in many instances, only the terrestrial components have been considered. Studies that combine onshore and offshore sea-level indicators demonstrate relative sea-level adjustments as much as 0.051 m/year. Sea-levels at the continental shelf edge in the Queen Charlotte Islands (QCI) in northwestern British Columbia were at least 150 m below present 12,380 radiocarbon years before present (RYBP). This date was obtained from an insitu pine tree stump. A very high-resolution sea-level curve (fig. 1) has been developed which demonstrates that by 11,080 RYBP, sea levels had risen to 125 m below present and by 10,180 were at 110 m. Eustatic sea-levels at 10,000 RYBP were at about 70 m below present. This difference of 40 m between local relative sea-level values and eustatic sea-level, likely represents the QCI forebulge height at that time. The discrepancy between local and eustatic sea-level is described through time and may indicate the rate of forebulge migration/dissipation. Ongoing studies of sea-level history near Prince Rupert Harbour (located at the mainland coast of B.C. 80 km east of QCI), indicate raised marine deposits at 50 m elevation dated 12,970. The maximum marine limit is located 100 km eastward at Kitimat and occurs at an elevation of 200 m dating 10,500-11,000 RYBP.

Drowned beach deposits at 110 m water depth just 40 km seaward of Prince Rupert, dated 12,160 RYBP- provide further evidence for rapid and very localized crustal adjustment.

In this presentation, sea-level histories are reviewed for the Queen Charlotte Islands (QCI), British Columbia coast, the Canadian Arctic, Gulf of Maine and Iceland; areas which represent very different tectonic regimes.
Figure unavailable in electronic version.
THE CIRQUES OF SOUTHEAST CUMBERLAND PENINSULA, BAFFIN ISLAND: IMPLICATIONS FOR THE GLACIO-CLIMATIC HISTORY OF THE REGION

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During glacial cycles, southern Cumberland Peninsula (Fig. 1) is an important boundary between continental (i.e., Laurentide) ice sheet glaciation and local glaciation. Recent marine and terrestrial studies have documented that Cumberland Sound, adjacent to Cumberland Peninsula, contained a low surface slope outlet glacier of the Laurentide Ice Sheet during and prior to the last glacial maximum (LGM) (Jennings 1993; Jennings et al. 1996; Kaplan 1999). Well-developed glacial cirques along southeastern Cumberland Peninsula indicate that this area has also experienced prolonged alpine glaciation. Study of these mature cirques thus helps to constrain the glacial history of Cumberland Sound and also provides additional insight into the general glacio-climatic history of southern Baffin Island during the Late Quaternary Period.

Low elevation empty cirques are characteristic of the coastline along the middle to outer Cumberland Sound; the latter is adjacent to the Labrador Sea. Cirques are not found in inner Cumberland Sound. From the head towards the mouth of the sound, the appearance of the cirques is spatially associated with the beginning of the deep part of Cumberland Sound. The cirques are typically carved into the high relief landscape that fringes the coastline and they are either spatially distinct from, or connected to, valleys and fiords. The cirques show no sign of having been overridden by the Laurentide outlet glacier that filled Cumberland Sound. Cirque floors below sea level are found at the mouth of Cumberland Sound; floor elevations rise towards the middle of Cumberland Sound (e.g., > 100 m asl; Fig. 1). The cirques in the outer sound show no consistent orientation whereas in the mid-sound they typically trend northwest and southwest (Fig. 1). Cirque headwalls are approximately 300-400 meters high.

The distribution of the cirques along southeastern Cumberland Peninsula reflects the dominant mode of glaciation. The lack of cirques in inner Cumberland Sound (Dyke et al. 1982) and presence of areal scouring suggest that ice sheet coverage has been the dominant mode of glaciation. In contrast, the presence of cirques with floors at and below sea level (Fig. 1) places constraints on the "average" Quaternary conditions for middle and outer Cumberland Sound. Although a marine-based section of the Laurentide Ice Sheet was present in outer Cumberland Sound during the LGM, this may have been the exception and not the rule during past glacial cycles. For the LGM, the inferred low surface slope of Laurentide ice in Cumberland Sound (Kaplan 1999) explains how the cirques remained unmodified while the continental-scale ice sheet was present. Higher ice surface elevations within cirques compared to that in the sound would have dictated the ice flow direction. The spatial distribution of cirques may also suggest that the deep part of Cumberland Sound prevents Laurentide ice (i.e., continental ice) from crossing below critical ice fluxes (Kaplan et al. 1999).

The maturity of the cirques indicates that glaciation of the eastern Canadian Arctic most likely began in the Tertiary Period, and continued throughout the Quaternary Period. Given the estimated rates of glacial erosion in this region, 8 to 76 mm k/a, it would take $10^5$ to $10^6$ years for the cirques to reach their present form (Anderson 1978; Bierman et al. 1999; Kaplan 1999), assuming these erosion rates have been relatively constant through time. Formation of cirque floors at and below present sea level is most consistent with a lower relative sea level and a lack of glacial ice in Cumberland Sound. The formation of the cirques can most easily be explained by invoking "average" glacial conditions, such as within marine isotope stage 3, when climatic conditions are intermediate in character between glacial maxima (e.g., stage 2) and interglacials, when eustatic sea level is still lower than the present, and when the Laurentide outlet glacier is absent. In addition, much of the cirque development may have occurred early in glacial cycles during conditions of relative warmth and high precipitation, but prior to cold, arid conditions associated with high latitude glacial maxima and the presence of the continental ice sheet.
Cirque characteristics also provide information on the area's paleoclimatology during glaciations, including by inference the LGM. Cirque floors are lower and lack preferential aspect in the outer sound compared to the middle sound (Fig. 1). This may represent greater availability of moisture due to the proximity of the adjacent Labrador Sea, which would facilitate glacial growth. Conversely, the increase in elevation of cirque floors towards the northwest or middle of Cumberland Sound represents an increase in continentality. The preferential aspect within the middle sound area also may be due to other climatic differences (e.g., cold winds from the west and a northwestward decrease in ablation), or a stronger structural influence on cirque development. Climatic differences, such as an increase in continentality from the mouth to the head of the sound, exist presently. Thus, within glacial cycles, the Labrador Sea influenced the climate of outer Cumberland Sound despite the proximity of the Laurentide Ice Sheet (Andrews 1989).


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THE AHKLUN MOUNTAINS PROJECT, FROM TOGIAK BAY TO MT. WASKEY, SW ALASKA

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The Ahklun Mountains Project (AMP) began in 1996 with a goal of using the extensive coastal outcrops of surficial sediment, and glacial-geomorphic features inland, to reconstruct major regional paleoenvironmental changes of the Pleistocene. This effort was bolstered by an array of geochronological methods and datable materials. The project was recently expanded to include lake coring to obtain more continuous records of late Quaternary paleoenvironmental changes within the uplands of the Ahklun Mountains. This report ties together the various investigations that comprise AMP and highlights our most important findings to date. The discussion is organized along a spatial and temporal transect that progresses from the oldest (middle Pleistocene) glacial marine deposits around Togiak Bay to the youngest (late Holocene) moraines of the highest summits (Fig. 1).

Our stratigraphic and geochronologic data from the Togiak Bay area, at the southern end of the Ahklun Mountains, indicate at least three and as many as six major advances of glaciers onto the continental shelf prior to the late Wisconsin (Kaufman et al., in press). The oldest glaciations are represented by glacial-marine sediment in coastal exposures on Hagemeister Island. The extent of amino acid (isoleucine) epimerization in fossil molluscs indicates that at least one, and possibly four, older middle Pleistocene glacial intervals are represented, with age estimates spanning ~500 to 280 ka and averaging ~400 ± 100 ka. The youngest glacial-marine drift on Hagemeister Island may correlate with the eruption of the Togiak tuya. A 40Ar/39Ar age on basalt that overlies pillow lava indicates that the volcano erupted through glacial ice at least 300 m thick 263 ± 22 ka.

The youngest drift in the Togiak Bay region overlies the Old Crow tephra (OCt) in several coastal exposures. These new O Ct localities are the most proximal sites yet discovered and yielded relatively coarse-grained glass for new fission track (FT) analysis. A new isothermal plateau FT age of 131 ± 12 ka provides the most precise age on the O Ct to date.

One remarkable 18-m-high coastal bluff of Togiak Bay exposes marine, lacustrine, fluvial, glacial, volcanic, and organic deposits that record the 50,000-year transition from the peak of the last interglaciation to the early Wisconsin. The basal unit of the exposure is dominated by stratified sand and silt up to 4.3 m above sea level and contains marine diatoms and pollen with a relatively high proportion of spruce and shrubs. An infrared stimulated luminescence (IRSL) age of 144 ± 13 ka from near the base of the exposure overlaps at 2σd with the peak of oxygen-isotope stage (OIS) 5e. The marine sand and silt are overlain by peaty silt with diatoms that record the transition from marine to lacustrine conditions. Spruce and shrubs are nearly absent from the pollen assemblage during this interval, which, on the basis of the tundra pollen assemblage and an IRSL age of 113 ± 10 ka from 0.6 m below the lacustrine mud, probably corresponds with OIS 5d. The organic-rich mud is overlain by stratified sand and organic-rich silt that apparently records shallowing of the lake, during which time spruce and shrubs reappear in the pollen assemblage (OIS 5c ?); a subsequent deepening of the lake (OIS 5b ?); followed by floodplain aggradation (OIS 5a ?). Sometime after, the eruption of the 70 ka lava, an outlet of the Ahklun Mountains ice cap advanced over the site and deposited ~7 m of bouldery drift.

The sedimentary sequence at Togiak Bay contains at least four tephra beds. Major- and trace element chemistry provide the basis for correlating two of the tephras with tephra at nearby sites. A third tephra (the Togiak tephra) closely resembles the widespread O Ct in geochemistry and morphology, and may record a late OIS 5 eruption of the same volcano. The tephras,
luminescence ages, and correlations with marine isotope stages, have provided the geochronological control to place the paleoecological changes recorded at Togiak Bay into a regional and global context. The evidence indicates that temperatures lowered before eustatic sea level fell.

The surficial drift of the Togiak Bay area also overlies a 70 ± 10 ka basaltic lava flow dated by thermoluminescence (TL) analysis of underlying baked sediment (Kaufman et al., in press). A recently published 36Cl age on moraine boulders from the Goodnews River valley indicates an age of ~60 ka for an ice margin that we correlate with the Togiak Bay drift 125 km to the northwest (Briner and Kaufman, 2000). The drift delimits flat piedmont lobes that spread out onto the continental shelf and terminated >100 km from their source areas during the early Wisconsin.

Inland, within the Ahklun Mountains proper, we have completed first-generation glacial-geologic mapping over much of the southern (Briner and Kaufman, 2000; Manley et al., in press) and northern (Axford et al., 1999) Ahklun Mountains. We mapped moraines and associated glacial lacustrine and glacial-fluvial features, measured relative-weathering features (soil development and moraine morphology), and studied stratigraphic exposures along the principal drainages. Paleo equilibrium line altitudes (ELA) were estimated for 211 valley glaciers, and for 97 modern glaciers that occupy the highest reaches of the Ahklun Mountains using a, raster-based Geographic Information System (GIS) approach (Manley and Kaufman, 1999). The estimated ELA lowering of 300-550 m is less than half the lowering recorded over much of the globe, and suggests that drier-than-present conditions prevailed during the LGM. A reduction in winter snowfall is consistent with retreat of a moisture source to the west as the Bering Sea shelf emerged with falling sea level. The southwestward decrease in ELA's suggests that the Bering Sea was a significant source of moisture, despite extensive sea ice and emergence of the continental shelf.

Cosmogenic ages provide a chronology for Wisconsin glaciation in the western Ahklun Mountains (Briner and Kaufman, 2000). Cosmogenic exposure (36Cl) ages were obtained from six late-, and two early-Wisconsin moraines. The ages agree with 14C analyses on other Wisconsin moraines in the Ahklun Mountains. They indicate restricted late Wisconsin glacier advances ~24-26 and ~17-20 36Cl ka, and a more extensive early Wisconsin advance ~60 36Cl ka. The ages suggest a maximum late Wisconsin advance late during the LGM.

New lake cores provide evidence for the timing of late Quaternary glacier fluctuations. Pollen, diatom, and sedimentological analyses from the same cores provide information on the paleoenvironmental and paleoclimatic changes associated with the glacial fluctuations. Our longest record comes from Arolik Lake in the southwestern Ahklun Mountains, which lies just beyond the limit of late Wisconsin ice (Briner et al., this volume). Three 7- to 8-m-long cores captured the full-glacial period in its entirety, and extend to at least 25 14C ka. The three cores penetrated a ~1 m-thick, basin-wide, clay-rich zone containing abundant angular granules. We interpret this deposit as a melt-water pulse from the overflow from an ice-dammed lake that spilled into Arolik Lake from the Goodnews River valley. Although a firm chronology awaits pending 14C analyses, preliminary estimates date the ice-dammed lake, and therefore, the maximum extent of late Wisconsin ice in the Goodnews River valley, between ~20 and 18 14C ka. The pollen assemblage from one of the cores is dominated by a protracted herb zone with minor variability during the late Pleistocene.

In addition to Arolik Lake, we have multiple lake cores from four other lakes in the Ahklun Mountains that encompass the late glacial and Holocene intervals. Preliminary sedimentologic, geochronologic, and pollen data are reported elsewhere in this volume from Nimgun Lake (Briner et al., this volume) and Little Swift Lake (Axford et al., this volume), located in the western and northern parts of the Ahklun Mountains, respectively, and separated by ~90 km. The base of one core from Little Swift Lake penetrated mud with grain-size, diatom (Axford et al., this volume), and geochemical (Carey et al., this volume) evidence for ice-proximal sedimentation. New AMS 14C ages date the transition to non-glacial sedimentation at ~11.0 14C ka. The core chronology can be compared with a 36Cl age of 13.0 ± 2.5 ka on a
prominent moraine 1.3 km upvalley from Little Swift Lake, and 5.1 ± 0.8 36Cl ka on a readvance moraine in the upper reaches of the basin (Briner et al., 1999).

Our most recent efforts have focused on extracting a record of Holocene glacier fluctuations from lakes located downvalley of active glaciers. The glaciers emanate from a few of the highest summits of the Ahklun Mountains that are underlain by granitic rocks. Fluctuations in meltwater from these glaciers should provide a distinctive mineralogical and geochemical signature to their ice-distal lakes. Preliminary data on cores from Sunday Lake (Feinberg and Werner, this volume) and Waskey Lake (Levy et al., this volume) show variability in magnetic susceptibility and grain size that might record changes in glacier activity within the drainages. Analyses are ongoing. Several distinctive tephra beds in all cores will facilitate precise correlations among lakes.

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SEA-SURFACE TEMPERATURE VARIABILITY IN THE NORWEGIAN SEA WITH DECADAL SCALE RESOLUTION DURING THE LAST 3000 YEARS

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High resolution sea-surface temperature reconstructions have been generated on core MD 95-2011 collected during the IMAGES 1 cruise of the R. V. Marion Dufresne and on a box core. The cores are located (66°58.18N; 07°38.36E, 1050 m water depth) along the main axis of northward flowing warm Atlantic water and are therefore in an ideal position to monitor changes in the northward heat flux to northwestern Europe. The cores are dated by AMS C-14 and Pb 210 isotope profiles. They have been studied at about 10-20 years resolution through the last 3000 years. Sea surface temperature (SST) variations are estimated by means of 3 different diatom transfer function methods and isotopes. The records show SST variability of 1-2 degrees on timescales less than 100 years. There is clear evidence for late Holocene climatic events such as the ‘Little Ice Age’ and the ‘Medieval Warm Period’. The LIA starts in our record with a SST fall of 1.5°C within a decade around 1400 AD and lasts until about 1750 AD. Spectral analysis of the SST record of the last 3000 years and cross-spectral analysis of the SST and planktic δ¹⁸O records will be presented.

RECONSTRUCTING THE LATE-HOLOCENE HISTORY OF A SUBALPINE ENVIRONMENT USING FOSSIL INSECTS

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In southern Quebec (Charlevoix, Canada), I reconstructed the changes in insect assemblages from subalpine environments that were transformed by fire during the late-Holocene epoch (since 4500 BP). The ecological requirements of beetle species likely to be found as fossils were studied by collecting living beetles in pitfall traps in forest, subalpine, and alpine environments. The late-Holocene changes of insect assemblages were reconstructed by recovering fossil insects from 13 peat sections. Modern beetles trapped demonstrate that they are valuable indicators of tree cover. Well-developed podzol under peat as well as numerous spruce charcoal remains overlaying the podzol in all sampling sites suggest that a dense spruce cover was present before the beginning of the accumulation of peat, and was eliminated by fire (4570 - 800 BP). Ground beetle and bark beetle assemblages at the base of the peat sections are formed by a mix of forest and open-environment species, indicating that the postfire environment was a subalpine one with a tree cover of 30-50%. The most recent fire in the area (AD 1915) increased the openness of the landscape (tree cover <30%). Forest ground beetles and bark beetles disappeared almost completely; only open-environment species remained. The late-Holocene history of the Charlevoix mountains as reconstructed using fossil insects is similar to that reconstructed using charcoal remains. However, fossil insects add significant information (tree cover, health of trees, forest composition) that is difficult to obtain using other macrofossils. This opens up new opportunities for paleoecological studies in the boreal forest, which was formed during the Holocene epoch, and was frequently disturbed by fire and insect outbreaks.
The artifact assemblage from archaeological site 49-PET-408 (On Your Knees Cave) contains evidence of both microblade and bifacial technologies dated to circa 14C 9200BP (Dixon et al. 1997). In contrast to other sites of similar antiquity in southeastern Alaska, such as Hidden Falls and Ground Hog Bay 2 (Davis 1990), the simultaneous occurrence of these technologies is unique. Representing approximately 23% of the total lithic assemblage the obsidian artifacts exhibit both microblade and bifacial reduction strategies.

The obsidian artifacts from 49-PET-408 were classified on the basis of visual distinctions into 10 sub-types that were grouped together into two main types. The defining characteristics of Type I obsidian were its opacity and greenish appearance. The defining characteristics of Type II obsidian were its translucency and brownish appearance. A sample of obsidian artifacts selected to represent the 10 sub-types and the two main types was submitted to a lab for x-ray fluorescence (XRF).

The results of the analysis indicate the presence of obsidian from both Mt. Edziza (most likely Godfrey-Smith's [1985] Flow #3, the Spectrum Formation) to the northeast in interior British Columbia and Obsidian Cove, Suemez Island, to the southeast of the site (Figure 1) (Hughes 1999). These results indicate that all of the material classified as Type I obsidian was from Suemez Island, and all of the material classified as Type II obsidian was from the Mt. Edziza source.

Preliminary analysis, based on the visual distinctions and corroborated by the XRF analysis, indicates that 70% of the microblades appear to be from the Mt. Edziza source, 23% appear to be from the Suemez Island source and 6% appear to be from an unknown source. The remaining obsidian artifacts, including the bifaces and fragments not definitively associated with microblade production, consist of 64% Mt. Edziza obsidian, 36% Suemez Island obsidian, and <1% obsidian from an unknown source. The remaining specimens of obsidian not yet subjected to XRF will be submitted for analysis to verify the current assumptions based on the visual qualities.

The presence of obsidian from sources both to the north and south of the site is indicative of the familiarity the inhabitants had with their surrounding environment and their ability to take advantage of the available resources.

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A LATE QUATERNARY RECORD OF GLACIER FLUCTUATIONS, WASKEY LAKE AND MIRROR BAY, AHKLUN MOUNTAINS, SOUTHWESTERN ALASKA

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The Ahklun Mountains, southwestern Alaska, are one of the few regions in Alaska outside of the Alaska Range with active glaciers. The fluctuations of these glaciers provide an important indicator of Holocene climate changes in the region. The aim of this study is to use the sediments delivered to proglacial lakes and recovered in sediment cores to reconstruct the timing of glacier fluctuations within the drainage basin. Here we report preliminary results based on our initial investigations at Waskey Lake last summer.

We chose Waskey Lake as a promising lake to core because of its proximity (5 km downvalley) to an active glacier, and directly behind a remarkably well-preserved end moraine (Figure 1), and because the Holocene glacier advances emanated from an isolated granitic massif that should supply a distinctive geochemical or mineralogical signature to the ice-distal, proglacial Waskey Lake. Waskey Lake is also a manageable size for coring (0.5 km²) and 8.5 m deep. We attempted acoustic-stratigraphic profiling to locate the optimal coring site and to determine the total thickness of the lake sediments, but the signal was degraded by abundant trapped gas within the sediments.

Multiple small moraines are located ~0.5 km beyond the margins of the modern glaciers and preliminary lichen measurements indicate that these moraines pre-date the little ice age. Field reconnaissance in 1999 and aerial photographs from 1973 indicate that six glaciers exist within the Waskey Lake watershed (Figure 1). Four are small cirque glaciers. The larger glaciers, occupying the southern and eastern walls of the drainage, span areas of 2.4 km² and 4.1 km², respectively. Based on preliminary GIS analysis, the two larger glaciers have equilibrium line altitudes (ELA’s) of ca. 760 m and 920 m, respectively. With a hypothetical lowering in ELA of only 50 m for all glaciers, accumulation areas would increase on average from ca. 60% to ca. 70% of the glacier surface areas. If the glaciers came into equilibrium with the lower ELA, they would expand ca. 17%, increasing in aerial extent from 7.2 km² to about 8.4 km². Thus, an analysis of area-altitude relations for the cirque glaciers feeding sediment laden meltwater to Waskey Lake indicates that the glaciers are sensitive to climate-induced changes in accumulation and ablation.

During the summer of 1999, we used a 7.5-cm diameter percussion corer operated from a floating platform to recover two sediment cores from Waskey Lake. Core 1 (WL1) is 6.5 m long and was recovered from a water depth of 7.0 m in a sub-basin distal from the inflow. Core 2 (WL2) is 4.5 m long and was recovered from the deepest part of the main basin at 8.5 m. A suite of short cores was taken at both of the core sites to capture the sediment-water interface. The basal 0.5 m of WL1 is mud with abundant muscovite and biotite flecks distributed evenly (Figure 2). Above this unit is a 172 cm interval of weakly bedded mud with a 2-cm thick mafic tephra at 512 cm depth with a granite dropstone located directly above it. From ~428 cm to 288 cm, the core contains silty sand and then makes a sharp transition into weakly bedded mud with intermittent organic layers for the remainder of the core above. The basal 45 cm of WL2 contains silty sand and then makes a sharp transition into weakly bedded mud at 405 cm. The bedding continues upward, with organic rich layers becoming more frequent. A new AMS age of 9710 ± 90 14C yr BP (10,830 ± 160 cal yr) on plant macrofossils from the base of WL1, indicates that the lake contains a nearly complete Holocene record.

Whole-core (volume) magnetic susceptibility (MS) has been measured on the two cores (Figure 2). The bottom 0.5 m of WL1 exhibits relatively high MS; values decrease over the middle section of the core and then rise again above 3.2 m. The MS from WL2 shows relatively low values at the base and increases steadily upward. Based on preliminary sediment descriptions, the relationship between grain size and MS is unclear; however, MS appears to be
positively correlated with tephras, and inversely correlated with organic matter content (Figure 2). Other analyses such as grain size, loss on ignition, sediment geochemistry (e.g. Carey et al., this volume; Leonard and Reasoner, 1999), radiocarbon dating, and tephra major element geochemistry (using an electron microprobe) will be conducted in the following years to assess the timing and magnitude of glacier fluctuations.

An additional attraction of Waskey Lake is its moraine dam. The "Waskey Lake moraine" is located 77 km upvalley of the late-Wisconsin ice limits and marks a significant readvance during the latest Pleistocene. The end moraine is a ~3 km long, single-crested, continuous bouldery ridge that delimits a former lobate terminus ~8 km downvalley from the modern glacier. Evidence that the moraine marks a readvance includes a perched delta at the mouth of the adjacent tributary valley that may record an ice-dammed lake within the trunk valley (Figure 1). The delta that was deposited into the lake could not have formed unless ice within the main trunk valley had retreated to allow the glacier from the Waskey Lake tributary to readvance. The radiocarbon age of 9.7 14C ka from the base of WL1 yields a minimum age for the moraine dam. Determining the age of the Waskey Lake moraine is important for comparing the late glacial history of the Ahklun Mountains with global patterns of climate change and understanding the mechanisms that drive climate change in southwestern Alaska.

During the summer of 2000, we plan to recover sediment cores from Mirror Bay located on Nuyakuk Lake approximately 6 km downvalley of Waskey Lake (Figure 1). This lake should contain a longer stratigraphic record that we hope will include the sedimentological evidence for the readvance to the Waskey Lake moraine. In addition, J.P. Briner (University of Colorado) is presently using cosmogenic isotopes to date the boulders on the Waskey Lake moraine. This study will provide an important comparison to the cosmogenic ages.

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It has become increasingly evident that the processes of lacustrine clastic sedimentation have numerous controls, and their relationship with discharge, temperature, and precipitation is not necessarily simple (Lemmen, 1988; Hardy, 1996). As a result, a detailed account of temporal and spatial variability of sedimentation, climate, weather and hydrology is required before reliable paleoenvironmental conclusions can be drawn from proxy records. However, a detailed study of the processes controlling clastic sedimentation has never been attempted on a glacial lake in the High Arctic. During the summer of 1999 at Bear Lake, Devon Island, air temperature, precipitation, water temperature, sedimentation rates, discharge, and bottom currents were monitored. Bear Lake is situated on the northeast coast of Devon Island, between the Devon Island Ice Cap and Jones Sound (75° 28' N, 85° 13' W).

Lake level was recorded with a Steven’s Type F chart recorder from June 16 to August 18. The peaks occurred at 03:30 on average, which represents a response lag from the peak air temperature of the preceding day. Based on a linear regression, stage peaks occurred on average 82 s earlier each day (Fig. 1), likely a result of the maturation of englacial conduits throughout the melt season (Church and Gilbert, 1975). Discharge estimated from outflow reached a peak of 278 m3/s on August 11, while the mean discharge for the 1999 melt season was 116 m3/s. Suspended sediment was captured with baffled cone-shaped sediment traps (opening diameter, 17.8 cm). Twelve arrays were placed throughout the lake, with either two or three traps per array. Each trap set was collected weekly or bi-weekly. Excluding one exceptional site (see below) mass accumulation rate (MAR) varied from 0.04 g/m2 per day for a distal site during the early melt season, to 57.69 g/m2 per day for a delta-proximal site during a period of high glacial melt. Average MAR values were much lower than those reported for a Swiss alpine glacial lake, a reflection of the lower air temperature, lower glacial melt, and lower organic content of this High Arctic watershed.

Aeolian transport is an important process of sedimentation at Bear Lake. In the summer of 1999, a sandy dune-like patch was observed on the lake ice. The patch covered an area of approximately 1 km², and extended from the east to west shore of the lake. It was located about 1 km from, and parallel to, the front of the sandur. Median grain size was measured at 0.26 mm. As the melt season progressed, the lake ice under this area thinned rapidly, with open water developing at least two weeks prior to nearby areas. A sediment trap array was moored directly under the area of the sandy patch that had the densest accumulation of sediment. The first trap rotation (June 16-23; mean 425 m ASL air temperature, +0.4 oC) produced a MAR similar to other traps in the area, when ice thickness was around 2.2 m. By the third rotation (July 7-21; mean 425 m ASL air temperature, +6.9 oC), the MAR from the uppermost trap (15 m depth) under the sandy patch was 92 times greater than from a trap at the same depth, located 380 m distal to the trap under the sand (Fig. 2). By this time the ice under most of the dune had melted, and only candles remained. By the end of the final trap rotation (July 21-August 4), the dune area was almost completely ice-free, and the majority of sediment had melted through. Nevertheless, the uppermost trap collected 10 times more sediment than any other trap at the same depth for this period.

From June 23 - July 21, when other trap sites were experiencing sediment focusing and underflows, the array under the dune experienced extraordinarily high MAR, especially for the upper and middle traps (Fig. 2). It is hypothesized that the sand spread laterally with depth, and mixed with less turbid ambient water.

The movement of aeolian depots from ice to water bodies has been recorded in Arctic and Antarctic literature (McKenna-Neuman, 1990; Squyres et al, 1991). At Lake Hoare, Antarctica, isolated mounds of sand up to 1 m in height have been reported (Squyres et al, 1991).
The mounds are the product of aeolian material accumulating on the ice surface, and gradually melting through the ice cover. At Bear Lake isolated mounds are not present, since the sand patches are laterally extensive, and the deep water would allow for ample dispersal and mixing. Currents may serve to further mix the sediment as well.

Bottom currents and bottom temperatures were monitored with a magnetic current meter and a logging thermistor near the delta at 65 m depth from July 17-August 8. Six discrete bottom current events were recorded, with the largest occurring on July 23 and 24. This event represents 75% of all current activity recorded in the study period, and was followed 14.25 hours later by a rapid lake level increase of 0.63 m (second only to the nival stage increase). Lake level continued to rise for approximately 24 hours following the cessation of underflow.

The July 23 - 24 event was synchronous with a short-lived increase in bottom temperature of 0.5 °C. At least seven other positive anomalies in bottom temperature were recorded in the study period (mean T, 0.4 °C). All temperature anomalies occurred between 22:00-23:00 hours, except the July 23-24 event, when the temperature peak occurred at 18:35. The temperature anomalies appear to be responses of glacial melt to high air temperatures and clear skies.

A remarkable precipitation event was recorded on June 29, when 50 mm of rain fell in 18 hours. The maximum one-day precipitation event from 1947 to 1991 at Resolute is 25.1 mm, with only 5% of rain events exceeding 10 mm. The June 29 event occurred when the majority of winter snow pack was still on the ground, and had profound geomorphic and sedimentological consequences. Stage increased 0.64 m in 38 hours. The bottommost sediment trap near the mouth of a small delta recorded a strong underflow produced by the storm. The trap collected 4.78 g of sediment (13.76 g/m² per day), 76 times the next largest MAR for that trap.

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MICROSCALE PLANT DISTRIBUTION IN A POLAR DESERT COMMUNITY ON AXEL HEIBERG ISLAND, NUNAVUT TERRITORY, CANADA

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The distribution and abundance of plants and soil characteristics were measured in a polar desert community. The study site, on Axel Heiberg Island, Nunavut Territory, Canada, was located on the southeast slope of a 100 meter tall hill consisting of flat-lying beds of unconsolidated Eocene-age mudstones, channel sands, and coals, which form the parent material of the modern soils. Unlike most previous polar desert studies, which have examined polar oases or patterned ground landscapes, the present study examined a barrens landscape. All vascular plants were identified and counted along two-meter wide transects. Five soil types were distinguished based on obvious sedimentological differences. Several soil properties from two depths were measured in order to explain the apparent non-random distribution of plants. There was no evidence of cryoturbation or horizon development in the soils. Given that the microenvironments were consistent throughout the study site (i.e. similar slope, aspect, elevation), we expected soil properties to control plant distribution. Twelve vascular plant species were identified along the transects. Notably, non-vascular species were absent from all transects. Some species were found frequently and in all soil types (Alopecurus alpinus, Erysimum Pallasii, Papaver radicatum, Cerastium alpinum, Stellaria laeta, Puccinella angustata). Some species occurred infrequently but in any soil type (Luzula confusa, Melandrium sp., Draba sp.). Still other species occurred infrequently and were associated predominantly with the sandy soil type (Oxyria dignya, Arnica alpina, Taraxacum pumilum). The sandy soil had the highest density of plants and greatest mean diversity (4.5 species per meter) while the blocky clay soil often had no plants for several consecutive meters along the transects and the lowest mean diversity (1.8 species per meter). The mean percent cover at the site is low (5%); thus, inter-plant competition for resources should be minimal. The gravimetric water content of the soils ranged from 5-24% with a mean of 15%. The percentage of large clay aggregates, which may be related to plant available water, ranged from 4% in the white soil to 60% in the blocky clay soil. Surprisingly, the most obvious soil variable in a polar desert environment, water, failed to explain the observed distribution of plants. However, since the distribution of plant species was often horizontally continuous with the flat-bedded sediments, it appears that the patchiness may be due to some other property related to the sedimentology. Some soil factor or combination of factors in various beds seem to provide a more productive substrate for plants. Another possible explanation for the paucity of plants and their patchy distribution pattern may be related to seedling establishment. Soil water availability may play a more important role in regulating seedling establishment than established plant growth. High rates of evaporation cause the surface soil to be drier than the deeper soils (13% water at 0-8cm and 18% water at 21-29 cm). In addition, the high rates of erosion at the site may limit seedling establishment. Two of the most ubiquitous species (A. alpinus and S. laeta) reproduced asexually but seedlings of several species were observed. The survival rates of these seedlings is unknown.
A new method for time-varying signal analysis, the Wavelet Transform, has been developed for imaging processing at NASA/GSFC during the past six years, and provides spectral decompositions via the scale concept. The two-dimensional wavelet transform is a highly efficient band-pass filter, which can be used to separate various scale processes and show their relative phase/location information. The Gaussian wavelet transform of a SAR image for small scale features can be used with a threshold as an edge detector. The evolution of mesoscale features such as upwelling, ice edge, ice floes, and eddies can be tracked by the wavelet analysis using RADARSAT SAR (Synthetic Aperture Radar) data received from Alaska SAR Facility (ASF). The tracking of ice edges and ice floes by wavelet analysis of SAR images has been studied by Liu et al. (1997a). The wavelet analysis of SAR, AVHRR, and SeaWiFS images for oceanic feature tracking (e.g., fronts and oil spills) has been developed for NOAA CoastWatch Program (Liu et al., 1997b).

The two-dimensional wavelet transform is a highly efficient band-pass filter, which can be used to track features in satellite images from sequential paths. Wavelet analysis of NSCAT backscatter and DMSP SSM/I radiance data have been used to obtain daily sea ice drift information for the Arctic region (Liu and Cavalieri, 1998; Liu et al., 1998; Zhao et al., 2000). This technique provides improved spatial coverage over the existing array of Arctic Ocean buoys and better temporal resolution over techniques utilizing data from satellite SAR. Comparisons with ice motion derived from ocean buoys give good quantitative agreement (Liu et al., 1999). Both comparison results from NSCAT and SSM/I are compatible, and the results from NSCAT can definitely complement that from SSM/I when there are cloud or surface effects. This outcome allows for three sea-ice drift daily results from NSCAT, SSM/I, and buoy data merged as a composite map by some data fusion techniques. The ice flow streamlines are highly correlated with surface air pressure contours. Examples of derived ice-drift maps illustrate large-scale circulation reversals over a period of four days. These calibrated/validated results indicate that NSCAT, SSM/I merged daily ice motion are suitably accurate to identify and closely locate sea ice processes.

Based on the composite maps, the ice flow streamlines are highly correlated with surface air pressure contours. In order to quantify the wind effects on ice motion, empirical orthogonal functions (EOF) are used in the principal component analysis by isolating generalized patterns inherent in six months of daily sea-ice motion data. It’s found 30% of sea-ice motion is highly correlated with 50% of pressure field in the low modes. For the higher modes, sea-ice motion is probably also affected by ocean current, bathymetry, and coastal boundary and therefore is not highly correlated with the wind field. The wavelet analysis algorithms for daily sea-ice motion (including shear and divergence) by using the QuikSCAT data have been developed in the automated near-real time processing. The limitations of QuikSCAT backscatter data for sea ice motion during the summer have been investigated by optimizing the scales chosen in wavelet transform. Such results of daily sea-ice motion map can also be used to improve our current knowledge of sea-ice dynamics and processes through data assimilation of ocean-ice numerical model.


LITHOSTRATIGRAPHY AND GLACIOTECTONICS OF CAPE SHPINDLER, YUGORSKY PENINSULA, ARCTIC RUSSIA

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The extension and timing the Eurasian Late Pleistocene ice sheet, which covered parts of north-eastern European Russia and western Siberia, as well as parts of the adjacent shelf, are not well known. Field research at Cape Shpindler, Yugorsky Peninsula, during the 1998 and 1999 field seasons, was aimed at deciphering depositional environments, ice sheet dynamics and the timing of Late Quaternary glacial and climatic oscillations along the southern Kara Sea. Litho- and chronostratigraphic work, together with measurements of glaciotectonic structures, were conducted along 20-km-long coastal cliffs. The following six sedimentary units, labelled A-F from bottom to top, were recognised in the cliffs:

Unit A is a dark silty-clayey diamicton. It is usually massive, but occasionally laminated, and contains numerous paired molluscs. The molluscan fauna may correlate with the boreal fauna from marine sediments of the "Boreal transgression", whose sediments are widespread along the arctic coast of Russia. Unit A is interpreted as a shallow marine sediment, possibly deposited during the Eemian interglacial.

Unit B consists of trough cross-stratified sand, deposited in channels that were erosively cut into the underlying unit. The cross-stratified sand grades upwards into beds of planar, parallel-laminated silt, rhythmically interbedded with clay seams. At one locality laminated silt and sand contains sub-littoral paired shells. Unit B is interpreted to be of estuarine or pro-deltaic origin.

Unit C is divided into two subunits. Subunit C1 comprises ripple cross-laminated fine sand, alternating with silty clay beds. Laterally, it undergoes a facies change to planar cross-stratified, planar parallel-laminated and ripple cross-laminated sand, denoted subunit C2. Unit C is interpreted to have been deposited in a low-gradient delta plain with a coastal plain-delta association (C1) and a floodplain association (C2). Three samples of moss and non-woody vascular plant detritus from subunit C1 gave AMS radiocarbon dates older than 40 ka BP.

Unit D is massive ground ice and unit E associated massive, matrix supported diamicton, Units A, B and C have been truncated, deformed and thrust during the emplacement of units D and E. The massive ground ice, unit D, occurs directly below unit E. It is stratified and has deformation structures such as folds and occasional large intraclasts from underlying sand strata, suggesting that it is relict glacier ice. The diamicton (unit E) contains striated and bullet-shaped stones and shell fragments. Unit E is interpreted as a subglacial till.

Unit F occurs on the top of the coastal cliffs. It contains a variety of lithologies, e.g., peat, laminated silt and silty peat and massive fine sand and silt. The environmental settings are interpreted to have been shallow lacustrine and peatland, with minor eolian, low-energy fluvial, and colluvial deposition. AMS 14C dates from unit F range from 12.5 ka to 4.4 ka.
Observed structural features in the sub-till units of A-C include low-angle thrust faults, normal faults, folds, drag folds and shear planes. Measurements of these structures indicate contradictory directions of displacement and glacial movement. Some glaciodynamic structures indicate a glacial advance from the north, while other measurements indicate a glacial advance from the south. Glaciotectonic evidence for both southward and northward glacier movements leads us to infer that the Cape Shpindler sections document two separate periods of glacier activity.

In conclusion we have a sequence of marine, deltaic, fluvial, glacial and post-glacial sediments. We suggest that units A, B, and C were deposited during a single interglacial event, before 40 ka, possibly during the Eemian interglacial. After the interglacial period, but before 12.5 ka, the area experienced two separate glacial advances, represented by units D and E. Our best estimate is that first a regional ice advance inundated the area from the Kara Sea, probably in the Early/Middle Weichselian, and was followed some time later by a glacier expanding from the Pai-Khoi upland (approximately 20 km south of Cape Shpindler). Unit F represents lateglacial and Holocene terrestrial sediments.

THE DYNAMICS OF MARINE GLACIER TERMINI READ FROM MORAINE ARCHITECTURE

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The research interest in moraines has traditionally been focused on their significance as the indicators of former ice-margin positions, with the steep topographic surface on the glacier side of a moraine ridge considered to be the “ice-contact slope”. However, it has recently been demonstrated through detailed mapping of the facies architecture of ice-contact systems that these sedimentary ridges may bear also an important record of syndepositional ice-front movements. Based on a series of such studies, the architectural development of ice-contact marine systems has been synthesized in the form of a high-resolution allostratigraphic model (Fig. 1; Lønne 1995). Five allostratigraphic units are distinguished in the model to represent the series of principal morphogenic changes that can occur in an evolving ice-marginal sedimentary system. Units A and B comprise the ice-contact facies formed during the ice-front advance and stillstand, respectively, whereas unit C is the deltaic part formed once the sedimentary system has aggraded to the sea surface. Unit D comprises facies deposited during the abandonment of the delta and represents ice-distal sedimentation accompanying the ice-front retreat. Unit E includes facies formed during the glacioisostatic uplift of the moraine ridge. The geometry, internal bedding architecture, facies range and sedimentary processes that characterize each unit have been recognized and documented.

Each of these units is further divided into subunits, or lateral segments, corresponding to the different morphological parts of the system: (1) the steep ice-proximal side, (2) the top, (3) the ice-distal foreset slope, and (4) the foreset toe passing into basinal plain (e.g., unit C is divided into subunits C1-C4, respectively). The sloping surface of the ice-proximal side of the sedimentary ridge, widely considered to be the “ice-contact slope”, is often an apparent ice-contact surface (AICS), because the true ice-contact surface (TICS) may be covered with subunits D1/E1 or eroded during phase E. The identification of TICS thus requires recognition of the deformed subglacial facies A1-C1 in the ice-proximal part of the ridge.

The model has proved to be a highly effective conceptual guide for disentangling the sedimentary architecture of glaciomarine moraines based on outcrops and/or sections derived by high-resolution seismics or ground penetrating radar (Lønne and Syvitski 1997; Nemec et al. 1999). The model is sufficiently comprehensive to serve as an interpretive and predictive tool for the mapping of the internal facies architecture of ice-contact systems, and can serve also as a
useful basis for their correlation and comparison. Importantly, the model allows to reconstruct syndepositional ice-front movements and to distinguish between monoepisodic and polyepisodic systems (with simple or compound unit A as main criterion). A high-resolution mapping of the internal facies architecture of glaciomarine moraines can thus lead to a better understanding of the glacier behaviour and ice-front dynamics in marine settings, and can improve also our knowledge of the sedimentation dynamics and basinfill stratigraphy in fjords and other glaciated marine basins.

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The Kregnes “moraine” ridge in Gauldalen, a north-trending valley south of Trondheim, is a Gilbert-type delta formed at a Younger Dryas glacier terminus. The gravelly delta consists of a north-dipping foreset, 150 m thick, comprised of turbidites, debrisflow beds and debrifall deposits. The bottomset consists of turbiditic sand and mud layers. Topset, 2-3 m thick, is a braided-river colluvium with local beach deposits, matching the marine limit of 175 m a.s.l. The fjord-wide delta front had an extent of 3 km and prograded over a distance of 1.5 km, in probably less than a hundred years, with the delta toe climbing by 50 m against the basin’s rapidly aggrading muddy floor. The delta advanced through the alternating episodes of its toe aggradation and progradation, related to the increases and decreases of the delta-slope gradient. Slope steepening led to intense sediment sloughing by chutes and occasional large-scale failures. The fjord’s wave fetch was low and the wave base no deeper than 1.5-2 m, but storm waves occasionally reworked the delta front to a depth of 5-12 m. Glacitectonic deformation was limited to the system’s upfjord end. Allostratigraphic analysis suggests that the proglacial system commenced its development as an ice-contact submarine fan that was deformed, quickly aggraded to the sea surface and turned into an ice-contact delta, which further evolved into the large glaciofluvial delta. The Kregnes ridge represents an episode of the ice-front re-advance due to climatic deterioration and is tentatively correlated with the Hoklingen substage.
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SEDIMENTARY ARCHITECTURE OF A WAVE-MODIFIED ICE-CONTACT DELTA: GROUND PENETRATING RADAR STUDY OF THE YOUNGER DRYAS MONA MORAINE IN SOUTHERN NORWAY

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The Mona moraine in the Øyeren paleofjord in southeastern Norway is a 3.5 km long sedimentary ridge formed during the southward advance of a tidewater glacier in the Younger Dryas time. The moraine’s sedimentary architecture, depositional processes and record of ice-front dynamics have been reconstructed in an allostratigraphic framework on the basis of ground-penetrating radar profiles (50 and 200 MHz, with up to 35-40 m and 23-25 m penetration depth, respectively) and sedimentological analysis of outcrop sections (Fig. 1).

The lowest part of the moraine ridge, overlying a bedrock threshold capped with an inferred older sedimentary sill, represents a submarine ice-contact fan formed at the grounding line of an advancing glacier (Fig. 1A). Unit A is the latest part of a prograding fan wedge that was successively overridden, eroded and redeposited by the advancing glacier, until the latter came to a halt on the local bedrock threshold. The ice-front stillstand allowed the submarine fan to aggrade to the contemporaneous sea level, resulting in unit B (Fig. 1B). The fan foreset deposits, truncated by a zone of glaciectonic deformation defining the ice-contact surface (TICS-A in Fig. 1E), consist of well-bedded and sorted gravel that indicates abundant sediment supply from subglacial meltwater channels (temperate glacier). After reaching the sea surface, the submarine fan evolved into an ice-contact delta with a short (160 m) subaerial distributary plain. The deltaic unit C includes a foreset, 50-60 m high, comprised of gravelly massflow deposits, with the associated turbiditic bottomset and fluvial topset (Fig. 1C). The marine limit (topset base) is at 205 m altitude.

The deformed deposits on the ice-proximal side of the delta are covered with a thin unit of marine mud and slope resedimentation products, which indicates that the delta was abandoned by a rapid ice-front retreat (Fig. 1D). A shell sample from the mud has yielded a radiocarbon age of 10,100(±75) yr BP (Tua-1035). The abandoned delta ridge thus became surrounded by the sea and subject to reworking by waves and tides (unit D), with tidal channels developed across the delta-top platform. The downstepping pattern of the youngest wave-formed features on both sides of the ridge, with well-developed regressive beaches and stairway-like erosional terraces, indicates contemporaneous emergence due to glacioisostatic uplift (unit E in Fig. 1E). As a whole, the deltaic ridge has a crescentic plan-view shape, convex seaward, and shows three coalescent depocenters that are thought to represent confluent ice-flows with separate subglacial systems of meltwater drainage.

The allostratigraphic architecture of the moraine ridge, as mapped in the field, indicates that the toe of the submarine fan body (subunit A4 in Fig. 1E) is at a higher altitude than would be expected from the local height of the bedrock surface. The Mona moraine is thus thought to be underlain by an older ice-contact sedimentary ridge, cannibalized by the glacier during the re-advance. The redeposition of older sediments might explain also the highly varied radiocarbon dates derived from the Mona moraine, particularly from its ice-distal side.
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DECIPHERING THE LATEST PLEISTOCENE AND HOLOCENE FLUXES OF FRESHWATER AND ATLANTIC WATER TO THE DEEP NORTHERN BARENTS AND KARA SEAS

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Sediment cores from the Nordic Seas document dramatic shifts in thermohaline circulation and sea-surface temperature patterns since the LGM. The propagation of these shifts into the adjacent Eurasian Arctic, however, remains poorly known (Fig. 1). In turn, there is limited knowledge whether Eurasian Arctic freshwater fluxes (e.g., sea ice, glacier ice, and meltwater) modulated observed reductions in Nordic Seas thermohaline circulation. Arctic Ocean records show a series of low δ18O events between c. 16 and 11.5, but poor resolution limits determination of their number, ages, and sources. Higher resolution records from the Eurasian shelves are needed to delimit freshwater fluxes from the northern margins of the Barents and Kara ice sheets and the large northward-flowing Eurasian rivers. Higher resolution shelf records are also critical to understand changes in meridional Atlantic water flux since the last deglaciation. The Barents and Kara ice sheets probably obstructed passage of Atlantic water over the shelf during glacial times, potentially causing a deflection of this water flow. Later, during deglaciation, Atlantic flow over the shelf may have even been enhanced due to glacio-isostatic deepening of the shelf. At present, up to half of the net Atlantic water flow into the Arctic Ocean passes through the Barents Sea.

The >500 m-deep Franz Victoria (FVT) and Saint Anna troughs (SAT) at the northern margin of the Barents and Kara seas (Fig. 1) are well-situated to decipher variations in meltwater and Atlantic water systems in the Eurasian North since the last deglaciation. The northern margin of the LGM Barents Sea Ice Sheet lay near both troughs, which are presently bathed by Atlantic Intermediate Water, derived from Barents and Fram Strait sources (Fig. 1). Sedimentation rates in these shelf troughs range between 10 and 100 cm/ka, at least an order of magnitude higher than in the adjacent Arctic Ocean. Previous studies of sediment cores from these troughs show (1) grounded LGM glacier ice, (2) initial deglaciation by 13 ka, possibly as early as 15 ka, (3) discontinuous retreat, and (4) a glacial-marine to marine transition c. 10 ka (Lubinski et al., 1996; Polyak et al., 1997; Hald et al., 1999). Our new study uses six cores collected from 440-630 m in the troughs to assemble century-scale records of stable isotopes and foraminiferal assemblages. To increase our understanding of foraminiferal δ18O and assemblages, we also studied the modern distributions of seawater δ18O and foraminiferal species. When combined with ongoing studies of palynomorphs and mineralogy, the core and modern data provide a valuable history of Atlantic and freshwater variation for each trough since 13 ka.

Foraminifera in glacial-marine sediments (*13 to 10 ka) were often absent, but abundant c. 13, 11.5, and 10 ka (14C yrs/1000). At these times, the δ18O and δ13C of planktonic Neogloboquadrina pachyderma (s) and benthic foraminifera Elphidium excavatum were up to 1.4 à lower than present, showing substantial freshwater inputs (Fig. 2). The presence of terrestrial pollen, freshwater algae, and pyroxenes in deglacial sediments from the SAT and northern Kara Sea suggest that the low foraminiferal δ18O may reflect ice-sheet melting simultaneous with reworking of pre-existing riverine sediments with sea-level rise on the unglaciated portions of the Kara shelf. Alternatively, the low δ18O in SAT mostly reflects direct riverine influence when the Ob and Yenisei river mouths were much further north due to lowered sea level. Dinoflagellate cysts and foraminiferal linings in these deglacial sediments are much more rare than in postglacial sediments, suggesting low productivity during deglaciation. Nevertheless, benthic foraminifera Cassidulina teretis was abundant c. 13 and 10 ka in both SAT and FVT (>40%), indicating several Atlantic-derived intermediate water penetrations of the troughs and slightly elevated subsurface temperatures during deglaciation.
The transition to postglacial marine conditions is marked by a ~1 ° rise in foraminiferal δ¹⁸O and a > 40% fall in % C. teretis shortly after 10 ka. The increased foraminiferal δ¹⁸O reflects a lack of marine-based glacial ice available for melting and retreat of the Ob and Yenisei river mouths toward their present position with continued sea-level rise. This result is consistent with glacial geologic data from Novaya Zemlya and Franz Josef Land as well as stable isotopic and pyroxene data in the Kara Sea. The reduced % C. teretis shows a low Atlantic water influence, which remained minor until c. 7.5 ka. We hypothesize that these conditions reflect an enhanced transport of relatively cool Barents Sea Branch Water (BSBW) associated with glacial-isostatically induced shoaling of the northern Barents Sea by ~ 100 m during the Holocene. Atlantic water flowing into the Barents Sea during the Holocene was more easily modified into BSBW than before 10 ka because of the lack of meltwater and associated reduced stratification. Subsequent isotopic and foraminiferal assemblage variations show a c. 7 ka flow of relatively warm and unmodified Atlantic-derived water associated with the Atlantic maxima "upstream" in the Nordic Seas and reduced glacio-isostatic shoaling. This was followed by a middle Holocene shift toward a dominance of the relatively warm Fram Strait Branch of Atlantic water in FVT and colder BSBW in southern SAT. We hypothesize that this shift mostly reflects continued shoaling which reduced flow of BSBW to FVT but did not greatly affect its path to SAT. The subsequent period includes a small FSBW maximum in FVT, and to a lesser extent in SAT, c. 3 to 2 ka. Atlantic water conditions have been relatively stable for much of the past 2,000 years.

REFERENCES FOR PRIOR WORK ON THE FRANZ VICTORIA AND ST. ANNA TROUGH CORES
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The seabed morphology of Hudson Strait and Ungava Bay has been shaped by bedrock structures, erosional processes, and deposition of Quaternary sediments. Lower Paleozoic sedimentary rocks, primarily carbonates, underlie most of Hudson Strait (MacLean et al., 1986). These strata are bounded near the coast by Precambrian metamorphic and igneous rocks that form the bedrock of the adjacent terrestrial areas of Ungava and Labrador peninsulas and southern Baffin Island. Younger strata, possibly of Mesozoic age, occur locally in basin floors (Grant and Manchester, 1970, MacLean et al., 1986, Wheeler et al., 1996).

The most prominent bathymetric and morphological features in Hudson Strait are three half-graben basins, which are elongated in east-west and northwest-southeast directions. The largest of these, Eastern Basin, lies in the eastern part of the strait and contains depths in excess of 900 m. Western and Southwestern basins lie in western Hudson Strait. They are en-echelon features, each containing water depths in the 400-500 m range. The three basins are characterized by steep morphology at their downdropped southern margins, narrow elongated deep floors, and long southward sloping northern flanks. The central part of Hudson Strait is a broad gentle syncline with depths mainly in the order of 200-300 m. The dominant morphological features are tectonic in origin.

In addition to structural influences in Hudson Strait, the bedrock has been extensively bevelled by erosional processes. These are thought to have included subaerial, fluvial, and glacial erosional mechanisms. Resulting features include cuesta ridges composed of Lower Paleozoic sedimentary rocks that occur near the contact with Precambrian rocks high on the northern flanks of Eastern and Western basins. These form low ridges that trend approximately parallel to the coast.

In Ungava Bay, prominent relief and steep morphology is the result of erosional processes that have left a large shallow central platform area composed of Lower Paleozoic sedimentary rocks surrounded by a marginal channel on the east, south, and west. Vertical and steeply stepped walls up to 250 m in height separate the platform from the marginal channel. Water depths over the platform range from <50 m in the southwest to 150 m in the east and north. Shallowest depths occur adjacent to Akpatok Island, which lies near the western margin of the platform. Depths in the marginal channel range from 250 m in the southwest to 365 m in the east. The southern margin of the Eastern Basin half-graben structure in Hudson Strait forms the northern boundary of the central platform in Ungava Bay.

Quaternary sediments are important contributors to the present seabed morphology through: (a) development of constructional features, and (b) as infill in basinal and other localities where sediment deposits reduce relief, and provide a smoother seabed morphology than exists on the underlying bedrock. Large constructional features formed by deposition of multiple sequences of ice-contact sediments occur in three localities. The largest of these, up to 360 m in thickness, lies on the shelf adjacent to the sill at the eastern entrance to Hudson Strait. Other large multi-sequence deposits of ice-contact sediments, which reach 100 and 150 m in thickness, respectively, occur southwest of Nottingham Island in western Hudson Strait and in eastern Ungava Bay. Smaller morainal features, which range in height from 70 m to <10 m, contribute to seabed morphology locally.

Smoothing and relief-reducing effects of Quaternary sediment deposits are most significant in basin areas, which have acted as sediment catchment localities. Sediments in the deep floor of Eastern Basin, for example, commonly are in the order of 70 to 130 m in thickness, but locally reach 260 m. In western Hudson Strait, sediment deposits up to 130 m in thickness in the western part of Western Basin provide both shallower and smoother seabed morphology.
across an area where the surface of the underlying bedrock is very irregular. Deposits of Quaternary sediments fill smaller bedrock depressions, and smooth seabed morphology in various other localities, as exemplified by deposits up to 100 m or more in thickness, which mask the bedrock morphology in the area east of Charles Island. Similar shallowing and smoothing of seabed morphology imparted by thick surficial sediment deposits occurs in south central Hudson Strait, and in southern Ungava Bay. Seabed morphology subsequently has been modified locally in Eastern Basin by debris flow events, which have cut as much as 20 m into seabed sediments (MacLean, 1994).

The extensive bevelling and alteration of the bedrock morphology in Hudson Strait and Ungava Bay are the product of erosional processes and episodes that have occurred during the long time span since those rocks were emplaced. The presence of cuesta ridges point to subaerial erosional conditions, and channels cut into the bedrock are indicative of fluvial erosion. Some of the latter may have originated as subglacial drainage channels. That erosional processes also included removal of bedrock material by glacial ice, is evidenced by the presence in the Labrador Sea and North Atlantic sediment sections, and on the Labrador Shelf, of calcareous sediments that are considered to have been derived from Hudson Strait by glacial transport and ice-rafting (e.g. Andrews and Tedesco, 1992; Andrews et al., 1998; Bond et al., 1992; Kirby, 1996; and Josenhans, et al., 1986), and also by turbidity current transport of glacially derived sediments (Hillaire-Marcel et al., 1994). The thick multiple sequence deposit of ice-contact sediments, which lies on the shelf in the lee of the sill at the entrance to Hudson Strait, emplaced by glacial ice streams exiting Hudson Strait, is further evidence of glacial erosion within the strait. The amount of erosion in Hudson Strait and Ungava Bay due to glacial versus other erosive processes, however, is not known. Removal of material and deepening due to glacial action may have occurred in some basin areas, as well as in other localities. The basins, however, are primarily structural features. In many areas glacial erosion likely was mainly associated with major ice streams that flowed seaward along Hudson Strait and onto the continental shelf. Preservation of multiple sequence ice-contact deposits such as those in Eastern Basin indicate that several of the later ice streams did not erode bedrock in some of the deep basin floors. Shallow areas, however, may have been subjected to erosion by those ice streams.

As Geographic Information Systems (GIS) become more powerful and user-friendly, quantitative spatial analysis will realize new opportunities for research within Quaternary Science. In addition to presenting recent results, this "poster" will include both guided and self-paced demonstrations of raster GIS on desktop workstations. Workshop participants will be able to move through web-formatted pages describing three related projects (see below), as well as to work "hands-on" with an efficient raster GIS package, MFWorks (www.thinkspace.com). Participants will thus be introduced to the data structure of raster GIS, a graceful user interface, a variety of operations, and a few "scripts". Datasets available for browsing include low- to high-resolution Digital Elevation Models (DEM's) of Alaska, and a 1-km-spaced grid of both terrain elevation and bathymetry for Beringia and the Bering Sea. The three highlighted projects are further summarized below.

PALEO-ELA’S: New data and methodologies enable us to quantify past winter precipitation (ppt) from glacial-geologic records for direct comparison with paleoclimate models. The extents of 211 late Wisconsin (LW) valley glaciers in the Ahklun Mountains of southwestern Alaska were determined from ice-marginal landforms on aerial photographs and in the field. We have relative-age, 14C, and 36Cl chronologic control on some of the landforms. Glacier outlines were digitized into a GIS, and Equilibrium Line Altitudes (ELA’s) were calculated with a DEM using a new Median Bed Elevation approach. Reconstructed LW ELA’s fall from 600-800 m in the Eek Mountains to 280-480 m near Goodnews Bay and Cape Newenham, 150 km to the southwest. LW ELA’s were only about 200-400 m lower than modern ELA’s. We next utilized modern climate estimates (PRISM grids), assumed a LW summer temperature depression of 10°C based on GCM simulations, and applied an empirical ELA/climate regression (for 92 modern glaciers), whereby winter ppt is predicted from summer temperature, continentality, and latitude (r² = 0.77; absolute values ca. ±35%). Estimated LW winter ppt was on average about 35% lower than present (in close agreement with GCM simulations), from ca. 50% drier in the northeast to ca. 5% wetter in the southwest. Although winters were generally drier, the spatially coherent pattern indicates that the proportion of moisture derived from the southwest (the Bering Sea) was greater than at present. Significantly drier-than-present winters probably resulted from increased continentality, decreased sea-surface temperatures, increased sea ice, growth of the Cordilleran ice sheet as a ppt barrier, and reduction in global atmospheric water vapor. The GIS-based approach provides new opportunities for obtaining quantified proxy records of paleoclimate from paleoglaciologic evidence.

MODERN ELA’S: Recent advances in GIS make it possible to analyze the extent, area-altitude relations, microclimatic, and major climatic relationships of all glaciers within a region. A case study for the Ahklun Mountains, southwestern Alaska, demonstrates the feasibility,
resolution, and glacier-climate significance of the new approach. Data sources include high-resolution DEM’s (grid-cell spacing of 62 m), gridded PRISM climate estimates, and digitized glacier outlines from 1:63,360 topographic maps. Using raster GIS, 32 parameters were calculated for each of the 106 cirque and small valley glaciers in the Ahklun Mountains, including area, elevation, slope angle, aspect, curvature, potential insolation, backwall height, "long-term" ELA (based on an AAR of 0.6), summer temperature, winter precipitation, and sensitivity to ELA change. The 106 cirque and small valley glaciers have a median size of 0.26 km², a total area of 59.6 km², and a statistically preferred aspect of 334°. Steady-state ELA averages 929 m ± 127 m. Ten percent of the ELA variation is explained by a trend surface dipping 5 m/km southwestward toward the Bering Sea as a moisture source. Inclusion of aspect, a basin coefficient, backwall height, distance from lakes, and upslope area in stepwise multiple regression brings explanation to a level of 52%, and highlights the importance of microclimatic/topographic controls on ELA. Furthermore, 73% of ELA variation is explained by winter precipitation, summer temperature, aspect, and other microclimatic variables. Sensitivity to a rise in ELA is estimated from area-altitude relationships. With an increase in steady-state ELA of only 50 m, accumulation areas would shift from ca. 60% of each glacier surface to only 28% on average, and total glacier area would decrease 40% to about 36 km². Errors for the parameters are insignificant in comparison with high local variability. Results include not only datasets, but the ability to draw meaningful relationships from spatial trends. The Ahklun glaciers comprise a small fraction of glacier ice in Alaska, but are greater in total area than the glaciers of Montana, and will be strongly affected by climate-induced changes in accumulation or ablation.

A work in progress is a raster map of Eastern Beringia, Western Beringia, and the Bering & Chukchi Seas at 1-km grid-cell spacing. Data sources for terrain elevation were taken from the GTOPO30 (30 arc sec) dataset, transformed to an Albers equal area projection. Primary sources of vector-formatted bathymetric data (depth contours) were downloaded from the USGS Alaska Biological Science Center (absc.usgs.gov). The five Arc Info coverages vary in extent and resolution – from a relatively large-scale polygon coverage derived from 1:250K NOAA-NOS charts with 10-meter contours for the eastern Bering and Chukchi shelves, to a small-scale polygon coverage derived from 1:2,500K USGS Open File Reports with 10-400-meter contours encompassing much of the study area. The coverages were gridded to the Albers projection, and then "stacked", taking advantage of the high-resolution data wherever possible. Bathymetric grids rescaled from the ETOPO5 (5 arc min) dataset were also utilized to fill in portions of the Gulf of Alaska and edges of the Arctic Ocean. Finally, a variety of interpolation methods have been tested to adequately quantify grid cells within the bathymetric contours. The resulting grid can easily be recoded to reveal the extent of the Bering land bridge at times of lower former sea level, to identify targets for marine-geologic surveys, and to evaluate the effects of changing continentality on past environments.

STUDIES ON FELSENMEER-COVERED SURFACES IN THE TORNGAT MOUNTAINS, NORTHERN QUÉBEC-LABRADOR

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Over the last century two fundamentally opposing views have been expressed concerning the felsenmeer covered summits of the Torngat Mountains. From observations along the Labrador coast, Daly (1902), Coleman (1921), Dahl (1946), Ives (1958, inter alia) and Clark (1991) have suggested that they represent, either 1) nunataks, not covered by the Laurentide ice sheet during the Last Glacial Maximum (LGM), or 2) summits protected from glacial erosion by cold-based
ice. Odell (1933) and Tanner (1944) argued for the production of the felsenmeer by postglacial weathering, and suggested that the summits had been overridden by the continental ice sheet. Excavations by Gangloff (1983) into three of the felsenmeer surfaces revealed a matrix with grain size and shape characteristics and clay mineralogy totally indistinguishable from tills of the last glaciation at low altitudes. Recently the concept of a Torngat mountain ice dispersal centre during the LGM, with subsequent invasion of the valleys by the continental ice sheet from the west has been invoked for the Ungava Bay flank of the northern Torngat Mountains (Gray et al., 1996; Gray (in press)), and the existence of felsenmeer surfaces at relatively low elevations (ca 750 m) on isolated plateau surfaces appears to support this concept.

Against this background, a research program aimed at studying the nature, the spatial and vertical distribution and the chronology of the felsenmeer covered surfaces of the Torngat Mountains began in the summer of 1999. Three overall objectives have been defined for this program: 1) computer and remote sensing assisted mapping of the spatial and vertical distribution of the felsenmeer surfaces; 2) examination of the relative weathering characteristics of the fine matrix for selected felsenmeer summits; and 3) exposure dating of stable rock surfaces using terrestrial cosmogenic nuclides. We are also compiling results of recent glacial studies by others in the region. The ultimate objective is to use the field observations, mapping, and exposure ages as boundary conditions for a refined ice sheet model of the Québec-Labradorean sector of the Laurentide Ice sheet.

In this talk, our remarks will be restricted mainly to the initial results. Firstly, field observations made up to and including 1999 by us, and by previous researchers (Ives, 1957; Loken, 1962), for approximately 30 summit zones along an east-west transect through the northern Torngat Mountains, along with isolated observations obtained during a brief visit to a summit zone in the Kaumajet Mountains on the Labrador coast (Figure 1) will be used as training sites to classify the felsenmeer surfaces. Initially, for a local area mapping of the lower felsenmeer limit for low gradient surfaces used a combination of newly acquired Radarsat fine mode imagery with a resolution of 10 m and digitised air photographs draped over a DEM. The potential of such imagery for detecting the contrast between smooth glaciated bedrock or till covered surfaces and high rugosity felsenmeer surfaces will be discussed. Extension of such mapping to a regional scale will be attempted using a newly acquired Landsat enhanced thematic mapper, with a 15 m spatial resolution panchromatic channel, and 6 visible and short wave infrared channels for defining the spectral and textural signatures of the felsenmeer surfaces.

Secondly, we will present the result of some pedological analyses of samples from three soil pits dug beneath the angular surface rubble of three summits, two transitional zones and one summit overridden by an ice sheet (Figure 1). These analyses are designed to assess the degree of relative weathering of such surfaces and will complement the results of ongoing terrestrial cosmogenic nuclide exposure dating. Initially they have included the measurement of pH, percentage of organic carbon and clay mineralogy. Planned analyses also include the quantification of iron and aluminum oxides and SEM analyses of quartz grains.

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Figure unavailable in electronic version.
PROBLEMS WITH USING SEDIMENTS FROM SMALL ALPINE LAKES AS PROXIES FOR CLIMATE CHANGE

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During the last few decades, an increasing number of studies have focussed on the reconstruction of Holocene environments from subalpine and alpine lacustrine sediments (eg. Reasoner and Hickman, 1989; Spooner et al., 1997). These studies reconstruct paleoenvironments based on changing concentrations of fossil pollens, diatoms and/or macrofossils. Small subalpine and alpine lakes are considered ideal for paleoenvironmental reconstruction as their proximity to timberline and small surface area enhance the local vegetation signal within the lake sediments (Jacobson and Bradshaw, 1981). However, very little is known about the processes that distribute sediment in small alpine lakes.

To gain insight into the nature of sediment distribution in small alpine lakes, 3 cores from Pyramid Lake in northwestern British Columbia (59°53'N, 129°50'W) have been analysed. Pyramid Lake is located at 1435 m asl which is presently ca. 50 m above timberline, has a measured maximum depth of 9 m, a surface area of ca. 8 ha, and a maximum fetch of 480 m. The lake has a predominantly north-facing watershed that is divided into two basins with a combined surface area of about 365 ha. A groundwater fed stream enters the south shore of the lake and the outlet is controlled by bedrock. Three vegetated alluvial gullies trail into the east shore of the lake with the west shore of the lake bound by steep talus slopes.

Within the Pyramid Lake sedimentary sequences are a maximum of 12 felsic tephra beds identified on the basis of magnetic susceptibility, thin-section analysis, and optical mineralogy. These tephra beds provide unique markers to assess distribution patterns of sediment within the lake through time. The amount of sediment between tephra beds varies from core to core with some tephra beds absent in 2 of the cores. The inconsistent sedimentation rates between the tephra beds suggest that sediment accumulation may not be continuous but rather that deposition is irregular in time and space as a function of varying depositional processes and an evolving lacustrine morphology. The small size and depth of the lake and its location in a steep alpine valley with vigorous wind suggest that re-suspension of sediment by wind or alluvially generated bottom currents create unconformities that can be distinguished in thin-sections.

The implication of the depositional regime in Pyramid Lake is that proxy records derived from such depositional environments may not represent a continuous record of climate. Variable depositional processes in small alpine lakes stochastically deposit sediments that can be episodically reworked by bottom currents, producing a discontinuous record of sedimentation. Sub-sampling of proxy climate indicators at regular intervals without consideration of the sedimentology may result in inferred changes in environment that do not accurately depict changes in the climate. Because of these inaccuracies, it is suggested that sub-millennial resolution of climate may not be possible from small alpine lakes such as Pyramid Lake.

PIGS, GOATS, AND ANDISOLS: ZOOARCHAEOLOGY AND LANDSCAPE CHANGE IN ICELAND

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Animal bones recovered from archaeological excavations across the North Atlantic region provide valuable proxy evidence for past economic patterns and their change through time, as well as evidence for unexpected and unintended human interactions with environment. Work by many scholars over the past two decades has provided a large number of analyzed archaeological animal bone collections (archaeofauna) from the North Atlantic, and over sixty archaeofauna are known from Iceland alone. These collections span the whole period from the Viking age landnam down to the 19th century, and provide a view of economic change and human response to climate fluctuation and external markets.

In Iceland, the impact of early human settlement in the 9th-10th c AD is increasingly well documented by inter-disciplinary research involving modeling, geomorphology, history, climatology, and archaeology. This paper discusses current and ongoing zooarchaeological work in Iceland that provides evidence for an early stocking pattern very different from later Icelandic farming, which was dominated by cattle and sheep. Bone collections from Herjolfsdalur, Tjarnargata in S Iceland and Granastadir, Hofstadir, and the newly discovered small site of Sveigakot in N Iceland indicate that early settlers brought substantial numbers of pigs and goats and made major use of wild resources (mainly birds and fish) to supplement their domestic stock. Cod, haddock, and other marine fish remains have been recovered from 9th-10th c sites over 60 km inland attesting to an early production of preserved fish for domestic consumption, and revealing a geographically widespread subsistence network.

While analysis continues, it would appear that the initial mix of domestic stock mirrors contemporary patterns in Norway, and appears to reflect a set of cultural expectations formed in the homelands. When this mix of grazing, browsing, and rooting domesticates (cattle, sheep, goat, pig, horse) was loosed upon an environment not previously impacted by land mammals the results appear to have been dramatic. After ca AD 975, the domestic mammal mix was altered, and pigs and goats become very rare in collections. The clearance of the Icelandic forests and the beginning of upland destabilization of erosion-prone Icelandic andisols (as well as the formation of the Icelandic commonwealth government system by powerful chieftains ) all appear to have taken place under this old agricultural regime. Rapid social and environmental change appear to have been features of this same 50-75 year period, now increasingly well documented by cooperative research. Current work focusing on this critical period of landscape formation is taking place as an international cooperative effort involving US, UK, and Scandinavian researchers at U Edinburgh, U Stirling, Icelandic Inst of Archaeology, INSTAAR, and CUNY all operating as parts of the NABO (North Atlantic Biocultural Organization) research cooperative.
GOLDILOCKS’ COMPROMISE LOOKING GOOD: NEW EVIDENCE FROM HIGH-ELEVATION BAFFIN ISLAND LAKES.

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The position and timing of Laurentide Ice Sheet advances on northeastern Baffin Island, and the basic style of glaciation in Arctic Canada have been much debated in recent years. At the 1998 Arctic Workshop we argued that the available evidence from terrestrial and marine archives was best reconciled by last glacial maximum ice limits much farther seaward than in previous reconstructions, but that these outlet glaciers were characterized by low surface gradients (Miller et al., 1998). The primary new evidence that led to these conclusions was from cosmogenic exposure dating in the Pangnirtung area (Bierman et al., 1999; Marsella et al., 2000), along Cumberland Sound (Kaplan, 1999), and on the north side of Cumberland Peninsula (Steig et al., 1998), coupled with radiocarbon dating of lake sediments from Cumberland Peninsula (Steig et al., 1998; Wolfe et al., in press) and from Brevoort Island (SE Baffin Is.; Miller et al., 1999).

To test our reconstruction, we undertook an extensive lake coring campaign in 1998, complemented by sampling for cosmogenic exposure dating. We pre-selected lakes that contained the highest probability of lying above/beyond the maximum limits of actively eroding glacial ice at the last glacial maximum. The simple test for our model is that these lakes should contain undisturbed sediment accumulations that extend beyond the range of radiocarbon dating. Four lakes were cored that we predicted to have "old" sediment records: Canso Lake (CAN), Kekertalujuaq Lake (KLJ), Amarok Lake (AKL) and Brother-of-Fog Lake (BRO). CAN is moraine-dammed, AKL occupies a cirque basin, KLJ and BRO occupy bedrock hollows. Multiple cores were recovered from each of these lakes using a modified Nesje corer from the ice platform.

Magnetic susceptibility (MS) and lithostratigraphic changes in BRO, AKL and CAN suggested the sediments contained complex sedimentation cycles, whereas KLJ showed only a single sediment cycle in both proxies. Radiocarbon dating supported these interpretations.

In BRO (350 m asl), moss from a low-MS mossy gyttja unit at 140 cm depth, beneath a high-MS minerogenic unit, had a radiocarbon age of >60 ka. Stratified sediment with similar characteristics extends from 130 to 190 cm in the core, where it is replaced by a second minerogenic unit. The lowest 30 cm in the core indicates a return to lacustrine environments, dominated by mossy gyttja.

Cores from CAN (330 m asl) show a similarly complex oscillation in MS and lithostratigraphy from gyttja-dominated to clastic dominated units. Humic acids from the base (78 cm) of the uppermost gyttja unit are 11,250 yr BP, whereas humic acids from 92 cm in the underlying lacustrine unit are 36,900 yr BP, and moss fragments deeper in the same unit (116 cm) are 43,200 yr BP.

AKL (900 m asl) was cored previously by Wolfe (1992), and known to contain "old" lacustrine sediment. Our goals were to better evaluate the transition from Holocene to "old" lacustrine sediment, and to capture a more complete record of the "old" lacustrine record. Paired radiocarbon dates on moss macrofossil and humic acids from 124 cm depth confirm the antiquity of the deeper lacustrine levels (moss: 46,000 yr BP; humic acids: 38,600 yr BP). Furthermore, the dates indicate a major sedimentary hiatus between the base of the postglacial sequence and the underlying lacustrine phase that is beyond the range of radiocarbon dating.

KLJ (390 m asl) is situated at the very outer coast. It is a deep lake (50 m), with a broad, nearly flat elongate central floor (ca. 100 m x 50 m). Its elevation, coastal location, and deeply weathered surrounding terrain suggested the sediment record should be old. However, we were unable to recover more than 2 m of sediment; the basal lacustrine sediments have a radiocarbon age of about 9500 yr BP.
The three lakes with stratified lacustrine sediments beyond the range of radiocarbon
dating, and lacking any evidence of a diamict separating them from the overlying Holocene
gyttja, complement the three lakes with similar records recovered earlier (FOG, GNR and SAD).
All are above 300 m elevation. Four of the lakes (FOG, GNR, BRO, CAN) record waterlain,
stratified minerogenic sediment between the two gyttja-dominated lacustrine cycles. The
equivalent interval in the other two lakes (SAD, AKL) is represented by a depositional hiatus.
The thickest minerogenic sequences (FOG, CAN) are lakes situated where meltwater from a
maximum advance could deliver glacially derived sediment to these basins, whereas MKL and
SAD are isolated basins, detached from any meltwater channels.

Based on the bulk of the evidence available, we contend that neither "Big Ice" nor "Little
Ice", but indeed "Just Right Ice", as proposed in 1998, is the most consistent glacial style for this
region. We plan to test this model by a program of cosmogenic exposure dating of the extensive
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A LATE QUATERNARY RECORD OF LOESS DEPOSITION IN A MAAR LAKE, ST.
MICHAEL ISLAND, WESTERN ALASKA

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Loess is one of the most extensive surficial deposits in Alaska, and can provide an important
record of atmospheric circulation during the time of deposition. Most studies of Alaskan loess
have focused on the interior of the region, but loess is also extensive in western Alaska. In the
course of palynological studies of lake sediments in western Alaska, a 15 m core was recovered
from Zagoskin Lake on St. Michael Island, in southeastern Norton Sound. Zagoskin Lake
originated as a maar (volcanic crater) during basaltic volcanism in the late Cenozoic. Twelve
radiocarbon ages provide a chronology and indicate that the base of the sediment record in the
core dates to >39,000 14C yr B.P. The core contains a particularly detailed record of deposition
from ~27,000 to ~5,000 14C yr B.P., the last glacial period and early Holocene. Throughout the
entire core, the sediments are fine-grained, with little sand but very high (66-89%) silt content.
Bulk chemical analyses, done at ~50 cm intervals, indicate that SiO2 contents range from 58 to 63%, Na2O contents from 0.16 to 0.52%, CaO contents from 1.27 to 1.82%, and MgO contents from 1.06 to 1.99%, typical of a felsic sediment composition. In contrast, the host basalt is petrologically similar to other late Cenozoic volcanic rocks in western Alaska (Hoare et al., 1968), where SiO2 contents range from 43 to 51%, Na2O contents from 2.8 to 6.6%, CaO contents from 7 to 10%, and MgO contents from 8 to 12%. The particle size and chemical data suggest, therefore, that the host rock of the lake basin is not the primary source of the lake sediments. It is more likely that the sediments are eolian and derived from distant sources. The composition of Zagoskin Lake sediments is very similar to loess found in the interior of Alaska near Fairbanks, and in southern Alaska near Kenai.

If our interpretation of a loess origin is correct, eolian deposition rates vary within the core from ~0.24 mm/yr to ~0.77 mm/yr and were generally higher during the last glacial period than during the Holocene. Holocene loess deposition rates of 0.24 to 0.38 mm/yr in Zagoskin Lake are somewhat lower than Holocene rates of 0.45 mm/yr for deposition of loess in the Fairbanks area. The higher rates of sedimentation in Zagoskin Lake during the last glacial period (~0.7 mm/yr) compared to the Holocene (~0.2-0.3 mm/yr) could be due to both stronger winds and higher sediment availability from either or both of two sources: (1) glaciofluvial silts derived from the Yukon River (up to 200 km or more to the southwest) and (2) the exposed shelf of the Bering Sea (immediately north, west, and southwest of St. Michael Island). Extensive glaciation of mountainous areas drained by the Yukon River would have delivered much more glaciogenic silt during the last glacial period than during the Holocene. In addition, however, sea level lowering of up to 120 m during the last glacial period would have exposed most of the present Bering Sea area and created the large land area connecting Asia and North America, collectively known as the Bering land bridge. Extensive areas covered by silt-sized sediment would have been exposed by this process and subject to eolian entrainment. Available chemical data from Bering Sea shelf sediments to the southwest of St. Michael Island (Gardner et al., 1980) and Yukon River sediments (Gough et al., 1988) indicate felsic compositions similar to sediments in Zagoskin Lake, supporting the view that either or both sources could have been important.

If the Yukon River or parts of the Bering Sea shelf to the southwest of St. Michael Island were the most important sources, paleowinds would have been from the southwest, which is consistent with climate model results (Bartlein et al., 1998) for the last glacial period. In contrast, if the shelf beneath what is presently Norton Sound was the most important source of loess, then paleowinds would have been from the north or west. Further studies, using trace element geochemistry and isotopic methods, could identify sources of the Zagoskin Lake eolian silts and test these hypotheses.

REINDEER POPULATION DENSITY IMPACT ON FORAGE BIODIVERSITY

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How does a quickly expanding reindeer population affect forage biodiversity and soil in an Arctic habitat? After about 100 years of absence, 15 Svalbard reindeer, (Rangifer tarandus platyrhynchus) were reintroduced to Brøggerhalvøya, western Svalbard, Norway. The total area is ca. 180 km²: 25% glaciers, 50% barren land and 25% potential forage vegetation. The reindeer population increased to ca. 30 animals in 1980, ca. 100 animals in 1985 and to more than 360 animals by 1994 before crashing to less than 70 animals. Impact of the rapidly growing reindeer population, from 2.2 animals/m² in 1985 to 8 animals/m² in 1994, on Dryas dominated vegetation and soil was analysed. Dryas vegetation on the elevated beach ridges is snow-free in late winter and early spring when reindeer are in search of food after surviving the long winter. Total species biodiversity decreased significantly from 1985 to 1994. Bryophytes and lichens, including the total cover of preferred reindeer lichens, decreased while vascular plant diversity remained unaffected. The total biodiversity decreased from 23.6 to 11.5 species/m², bryophytes decreased from 9.3 to 1.2 species/m² and lichens decreased from 7.4 to 4.2 species/m². The important reindeer lichens, Cetraria ericitorum and C. nivalis were eradicated. The surviving reindeer population was supported by less-preferred forage and less diverse vegetation. Plant-cover removal and reindeer trampling on the thin Arctic humus layer resulted in a buildup of carbon, smaller soil particles (<2 mm) and higher calcium and magnesium content.

A HISTORY OF PERMAFROST IN ALASKA: WARMING, THAWING AND THERMOKARST FORMATION

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The first permafrost on earth occurred prior to or in conjunction with the first glaciation about 2.3 billion years ago and since then has expanded and contracted in response to climate. Permafrost in the lowlands of Northern Alaska was initiated during the climatic cooling that began about 2 1/2 million years ago. This led to repeated glaciations including the last one some 20 thousand years ago. At that time, thick permafrost formed in the continental shelves of the Arctic Ocean and the occurrence and thickness of terrestrial permafrost increased. These considerations suggest that the earth may be approaching a new glacial period. However, for the next century, global circulation models predict a warming of 2 to 5 °C in response to increases in greenhouse gas concentrations in the atmosphere. Permafrost in Northern Alaska warmed 2 to 4 °C over the last century and there was a concurrent warming of discontinuous permafrost at this time. Modeling indicates that continuous permafrost at Barrow generally cooled from 1950 until the latter 1970s and has generally warmed since then. Observations of permafrost temperatures north of the Brooks Range since 1983 indicate that the active layer and permafrost warmed about 2 to 3 °C at West Dock and Deadhorse from the mid-1980s to the present. This is within the range of warming predicted during the next half-century but has not been detected by "summer" studies apparently because this warming has occurred primarily in the nine month "winter" season. Active layer temperatures, processes and thicknesses in continuous permafrost are not correlated with this warming because they are primarily controlled by "summer" conditions. There is widespread warming and thawing of discontinuous permafrost and extensive areas of
thermokarst terrain are now being created as a result of climatic change. Estimates of the magnitude of the warming at the discontinuous permafrost surface are 1/2 to 1 1/2 °C. Warming rates near the permafrost surface were 0.05 to 0.2 °C yr⁻¹. Decreases in thickness of the discontinuous permafrost are too small to be detected yet. In warm discontinuous permafrost, thermal offset allows mean annual temperatures at the permafrost surface to remain below 0 °C while ground surface temperatures are positive, up to 2 1/2 °C. The observed warming has caused discontinuous permafrost in marginal areas to begin thawing. Thawing permafrost and thermokarst have been observed at several sites in Interior Alaska. Thawing rates at the permafrost table at two sites were about 0.1 m yr⁻¹. Calculated thawing rates at the permafrost base are an order of magnitude smaller. Modeling at a site in discontinuous permafrost shows that the observed warming is part of a warming trend that began in the late 1960s. Thermokarst drastically modifies and remolds the ground surface. This process can severely change or disrupt ecosystems, human activities, infrastructure, and the fluxes of energy, moisture and gases across the ground surface-air interface.

OBSERVATIONS OF THERMOKARST AND ITS IMPACT ON BOREAL FORESTS IN ALASKA

OSTERKAMP, T. E.; Viereck, L.; Shur, Y.; Jorgenson, M. T.; Racine, C.; Doyle, A.; and Boone, R. D.

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Thermokarst is developing in the boreal forests of Alaska where ice-rich discontinuous permafrost is thawing. Thawing destroys the physical foundation (ice-rich soil) on which boreal forest ecosystems rest causing dramatic changes in the ecosystem. Impacts on the forest depend primarily on the type and amount of ice present in the permafrost and on drainage conditions. At sites generally underlain by ice-rich permafrost, forest ecosystems can be completely destroyed. In the Mentasta Pass area, wet sedge meadows, bogs and thermokarst ponds and lakes are replacing forests. An upland thermokarst site on the University of Alaska Campus consists of polygonal patterns of troughs and pits caused by thawing ice wedge polygons. Trees are destroyed in corresponding patterns. In the Tanana Flats, ice-rich permafrost supporting birch forests is thawing rapidly and the forests are being converted to minerotrophic floating mat fens. At this site, an estimated 84% of 2.6*10⁵ ha was underlain by permafrost a century or more ago. About one half of this permafrost has partially or totally degraded and is influenced by thermokarst. Thaw subsidence at the above sites is typically 1 to 2 m with some values up to 6 m. Much of the discontinuous permafrost in Alaska is extremely warm so that it is highly susceptible to thermal degradation. Additional warming will result in the formation of new thermokarst.
THE EDGE PARADOX: A ZONE OF ORDER OR CHAOS? AN ICELANDIC CASE STUDY INVESTIGATING FACTORS CONTROLLING THE HIGH LATITUDE FOREST LIMIT

PARRY, BROOKE; Kristiina A. Vogt; Throstur Eysteinsson*; Bruce C. Larson; Daniel J. Vogt

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This research will examine the resistance and resilience of the forest limit to disturbance, using mountain birch (*Betula pubescens*) ecosystems in Iceland as a case study. If the edge zone associated with the forest limit can serve as an early warning sign of ecosystem change on multiple spatial and time scales, this research seeks to answer how. The purpose of this study is to understand how multiple disturbance factors control the location, as well as the trajectory of movement, of edges at forest limits.

Edges have been called an ecosystem's skin, the condition of which can indicate the "health" of an entire landscape. Thus, edges may harbor one of the clues that ecologists and policy makers are searching for - an early warning sign of ecosystem change. However, edges have been described primarily in terms of edge effects. In other words, they have been characterized and understood as a particular distance (and degree) to which abiotic and biotic gradients occur. To understand the role of an edge in the landscape, it is important to move beyond looking at an edge as an aggregate of edge effects.

Preliminary research has been conducted to identify early warning indicators that may track the trajectory of edge movement. A pilot study was conducted during the summer of 1999 in four mountain birch ecosystems in Iceland. The study assessed carbon and nitrogen concentrations of birch foliage both at different elevations and at sites under different disturbance regimes. Results from the carbon and nitrogen analyses suggest that these factors may serve as indicators of changing health in the birch ecosystems. Carbon and nitrogen concentrations increase with elevation where grazing is minimal. However, this pattern disappears under conditions of heightened grazing and climatic stress. The implications of the results for ecosystem health, tree-line location, and the potential for edge environments to be used as early warning indicators of change in ecosystem state will be discussed.

RAPID ECOLOGICAL RESPONSE TO CLIMATIC CHANGE: THE PRELIMINARY DIATOM RECORD FROM SAWTOOTH LAKE, ELLESMERES ISLAND

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Diatoms from the annually laminated sediments of Sawtooth Lake (79°20'N, 81°51'W) on the Fosheim Peninsula in Central Ellesmere Island, Canada are being analyzed to qualitatively and quantitatively assess the temporal extent and magnitude of climatic change in the High Arctic during the late Holocene.

We estimate (pending radiometric dating) that the complete record recovered spans the last 3.5ka. Initial diatom results from the sediment cores show an absence of diatoms throughout these ~3.5ka (4.6m). However, circa 1960 (5cm depth) a rapid colonization of diatoms in the lake occurred. Within the uppermost section of the core (~1960 to ~1991), the diatom flora shift from a small Fragilaria dominated assemblage to a more diverse assemblage which is dominated by large planktonic taxa (*Cyclotella bodanica* et al.) and large raphid benthic species. The postglacial nature of this assemblage change and the lack of evidence of dissolution suggests a
decrease in ice cover and a concomitant increase in light availability for diatom growth over the last ~40 years.

These results are consistent with other diatom records of massive species shifts over the past 150 yrs in the High Arctic (Douglas et al., 1994; Wolfe, in press). They are also temporally consistent with the diatom records from Lower Dumbell Lake near Alert (Doubleday et al., 1995) and DV09 on Devon Island (Gajewski et al., 1997) which show large diatom population changes occurring ~40 yrs ago. The size differences between the lakes and the North-South transect that they encompass indicate a regional, rather than local climatic signal.

In addition, the absence of diatoms in the past ~3.5ka and the rapid increase in diatom population within Sawtooth Lake circa 1960 suggest that melting intensity in the High Arctic ~40 years ago may have exceeded the critical threshold for ice cover on the lake thereby altering the diatom community. Of particular significance is this absence of diatoms which indicates that environmental conditions of the last ~40 years are unlike any of the previous ~3500 years. A higher resolution analysis of the uppermost section of the core is currently in progress.


HYDROGEOLOGY AND HYDROGEOCHEMISTRY OF PERMAFROST ZONE OF DALDYN-ALAKIT REGION (WESTERN YAKUTIA)

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pinneker@gpg.crust.irk.ru; salex@gpg.crust.irk.ru

The complex of prospecting works conducted for the last 30 years has allowed collecting a vast actual material on regional hydrogeological and hydrogeochemical features of Western Yakutia. The industrial development is conducted in its central part, e.g. Daldyn-Alakit region (DAR). Though the area of region does not exceed 10000 km², the main deposits of diamonds are concentrated there. DAR is characterized by severe natural conditions resulting from a regional distribution of continuous permafrost and subpermafrost chloride sodium-magnesium-calcium salty waters and brines. The groundwaters of other geochemical types are absent.

Hydrogeological conditions of the region

In DAR the Upper Cambrian aquifer is distributed below the permafrost base. The aquifer is coincided with carbonate deposits of morkoka and markha suites. The thickness of the aquifer varies from several meters up to 10-30 meters, and effective one does not exceed 3-5 m (Kovalsky, Bilanenko, 1986; Pinneker et al, 1998). The coefficient of transmissivity amounts to n10-2 - n10-4 m2/d, excepting of fault zones. In the fault zones this coefficient increases to 7.3-31.6 m2/d. Practically impermeable sedimentary rocks with thickness of 50-200 m occur at the base of aquifer.

The Middle Cambrian aquifer is tapped in clay-carbonate deposits of chukuka suite of the Upper Cambrian and in carbonate rocks of the Middle Cambrian. Three aquiferous horizons are selected, their thickness varies from 10-20 to 400-500 m. The first aquiferous horizon has pore collectors, and other horizons have fissure-cavernous ones. The hydraulic connection between the whole of horizons is established. The same connection also exists between the Middle Cambrian aquifer and aquifers of kimberlite pipes.

The Lower Cambrian aquifer is tapped by parametrical wells at depth more than 1500 m. It's coincided with fracture carbonate collectors of kuonamskaya suite. In the central part of DAR the permeability of aquifer is high. The coefficient of transmissivity achieves 30-50 m2/d. The hydraulic connection of aquifer with other aquiferous complexes is absent.

The Upper Proterozoic aquifer is coincided with fracture carbonate collectors of starorechenskaya suite. It's tapped by three wells at 1810-1830 m. Hydrodynamic parameters of aquifer are rather low. The hydraulic connection of aquifer with other complexes is not investigated.

Hydrogeochemical conditions of the region

In the hydrogeochemical structure of DAR two zones are clearly selected. The first zone includes groundwaters of the Upper Cambrian aquiferous complex. The second zone unites the groundwaters of the Middle-, Lower Cambrian- and the Upper Proterozoic aquiferous complexes (Grudinin, Kiselev, 1987).

To evaluate the stability of chemical composition of groundwaters and migration properties of their macro- and microcomponents the authors have carried out statistical processing of the results of chemical analysis. The total number of samples was 198, including 57 groundwater tests sampled from the first brine-bearing zone and 141- from the second one. Chloride sodium-magnesium-calcium salty waters and weak brines represent the first zone. Their mineralization varies from 31 to 203 g/l. The wide range of mineralization is interpreted as a result of cryogenesis of underground hydrosphere and corresponds to different stages of cryogenic concentration of groundwater during their freezing from the end of Early Pleistocene (Alexeev, 1997).

Magnesium (up to 48 %) predominates among cations in the most cases. Ratio Ca/Mg=0.7-2.1 confirms this peculiarity. The content of sulphate-ion is 0.98, and
hydrocarbonate-ion - 0.13 g/l. Table 1 characterizes the composition of groundwaters of the first zone.

The correlation matrix shows the close correlation between sodium, magnesium, calcium, chlorine and groundwater mineralization (Table 2). The coefficients of correlation vary from 0.77 to 0.96. Bromine has positive connection not only with mineralization and the macrocomponents, but with lithium and strontium as well. Both the chlorine - bromine (40-80) and the sodium - chlorine (0.1-0.4) ratios are stable for all values of mineralization.

Strong and rather strong calcium chloride brines represent the second zone (with thickness 2000 m and more). Their mineralization varies from 224 to 404 g/l, while average value is 324 g/l. The mineralization of brines increases depending on depth of groundwater occurrence. The groundwaters of the second zone are geochemically common (Table 3). Among anions, chlorine predominates (98-99%).

The average content of sulfate- and hydrocarbonate-ions does not exceed 0.3 g/l. Among cations the calcium dominates. The positive correlation connections between macrocomponents are saved as a whole (Table 4). Chlorine - bromine ratio has smaller divergence (34-66). The dependence of Cl/Br from mineralization is well circumscribed by logarithmic (Cl/Br = -7.3Ln (M)+92.36) and power (Cl/Br = 104.37M-0.125) functions. The value of the sodium - chlorine ratio varies within the limits of 0.1-0.5. The equations rNa/rCl = -0.07Ln (M)+0.63 and rNa/rCl=0.96M-275 circumscribe the dependence this ratio from mineralization quite well.

Thus, the chloride salty waters and brines represent the subpermafrost groundwaters of DAR. Their geochemical type is common. The groundwater mineralization increases from 30-40 g/l at the contact with permafrost base up to 300-400 g/l at the roof of the platform basement. In the present time some new kimberlite pipes with the high contents of diamonds (Sredne-Marhinskoe kimberlite field) are opened in DAR region. The hydrogeological conditions of these pipes weren't investigated still.

The study has been carried out with the financial support of Russian Fund for Basic Research (grant's number 00-05-64212).


Table 1 The distribution of macro- and microcomponents in salty waters and weak brines

<table>
<thead>
<tr>
<th>Component</th>
<th>g/l</th>
<th>mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>K⁺</td>
<td>Na⁺</td>
</tr>
<tr>
<td>Contents</td>
<td>max</td>
<td>203.3</td>
</tr>
<tr>
<td></td>
<td>min</td>
<td>31.1</td>
</tr>
<tr>
<td></td>
<td>average</td>
<td>89.6</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>41.53</td>
<td>1.07</td>
</tr>
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</table>

M – mineralization, g/l
### Table 2. The correlation matrix of salty water and weak brines

<table>
<thead>
<tr>
<th>Component</th>
<th>K⁺</th>
<th>Na⁺</th>
<th>Mg²⁺</th>
<th>Ca²⁺</th>
<th>Cl⁻</th>
<th>Br⁻</th>
<th>Li⁺</th>
<th>Rb⁺</th>
<th>Sr²⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>0.542</td>
<td>0.797</td>
<td>0.760</td>
<td>0.922</td>
<td>0.966</td>
<td>0.922</td>
<td>0.622</td>
<td>0.193</td>
<td>0.742</td>
</tr>
<tr>
<td>K⁺</td>
<td>1.000</td>
<td>0.412</td>
<td>0.612</td>
<td>0.586</td>
<td>0.613</td>
<td>0.529</td>
<td>0.346</td>
<td>0.193</td>
<td>0.742</td>
</tr>
<tr>
<td>Na⁺</td>
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<td>0.462</td>
<td>0.763</td>
<td>0.772</td>
<td>0.686</td>
<td>0.324</td>
<td>0.077</td>
<td>0.277</td>
<td>0.654</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>1.000</td>
<td>0.640</td>
<td>0.810</td>
<td>0.816</td>
<td>0.754</td>
<td>0.213</td>
<td>0.716</td>
<td>0.213</td>
<td>0.716</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>1.000</td>
<td>0.960</td>
<td>0.926</td>
<td>0.926</td>
<td>0.608</td>
<td>0.228</td>
<td>0.860</td>
<td>0.228</td>
<td>0.860</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>1.000</td>
<td>1.000</td>
<td>0.726</td>
<td>0.726</td>
<td>0.651</td>
<td>0.205</td>
<td>0.846</td>
<td>0.205</td>
<td>0.846</td>
</tr>
<tr>
<td>Br⁻</td>
<td>1.000</td>
<td>1.000</td>
<td>0.762</td>
<td>0.762</td>
<td>0.680</td>
<td>0.226</td>
<td>0.860</td>
<td>0.226</td>
<td>0.860</td>
</tr>
<tr>
<td>Li⁺</td>
<td>1.000</td>
<td>1.000</td>
<td>0.726</td>
<td>0.726</td>
<td>0.651</td>
<td>0.205</td>
<td>0.846</td>
<td>0.205</td>
<td>0.846</td>
</tr>
<tr>
<td>Rb⁺</td>
<td>1.000</td>
<td>1.000</td>
<td>0.726</td>
<td>0.726</td>
<td>0.651</td>
<td>0.205</td>
<td>0.846</td>
<td>0.205</td>
<td>0.846</td>
</tr>
<tr>
<td>Sr²⁺</td>
<td>1.000</td>
<td>1.000</td>
<td>0.726</td>
<td>0.726</td>
<td>0.651</td>
<td>0.205</td>
<td>0.846</td>
<td>0.205</td>
<td>0.846</td>
</tr>
</tbody>
</table>

M – mineralization

### Table 3. The distribution of macro- and microcomponents in strong and rather strong brines

<table>
<thead>
<tr>
<th>Component</th>
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<th>mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
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<td>Na⁺</td>
</tr>
<tr>
<td>max</td>
<td>404.3</td>
<td>23.1</td>
</tr>
<tr>
<td>min</td>
<td>223.6</td>
<td>2.4</td>
</tr>
<tr>
<td>average</td>
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<tr>
<td>Standard deviation</td>
<td>46.28</td>
<td>3.84</td>
</tr>
</tbody>
</table>

M – mineralization, g/l

### Table 4. The correlation matrix of strong and rather strong brines

<table>
<thead>
<tr>
<th>Component</th>
<th>K⁺</th>
<th>Na⁺</th>
<th>Mg²⁺</th>
<th>Ca²⁺</th>
<th>Cl⁻</th>
<th>Br⁻</th>
<th>Li⁺</th>
<th>Rb⁺</th>
<th>Sr²⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>0.115</td>
<td>0.662</td>
<td>0.827</td>
<td>0.970</td>
<td>0.996</td>
<td>0.962</td>
<td>0.636</td>
<td>0.048</td>
<td>0.830</td>
</tr>
<tr>
<td>K⁺</td>
<td>1.000</td>
<td>1.000</td>
<td>0.859</td>
<td>0.883</td>
<td>0.930</td>
<td>0.871</td>
<td>0.688</td>
<td>0.520</td>
<td>0.783</td>
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<tr>
<td>Na⁺</td>
<td>1.000</td>
<td>0.881</td>
<td>0.872</td>
<td>0.953</td>
<td>0.965</td>
<td>0.965</td>
<td>0.746</td>
<td>0.457</td>
<td>0.843</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>1.000</td>
<td>1.000</td>
<td>0.883</td>
<td>0.887</td>
<td>0.930</td>
<td>0.965</td>
<td>0.746</td>
<td>0.457</td>
<td>0.843</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>1.000</td>
<td>1.000</td>
<td>0.965</td>
<td>0.965</td>
<td>0.965</td>
<td>0.965</td>
<td>0.746</td>
<td>0.457</td>
<td>0.843</td>
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<tr>
<td>Cl⁻</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
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<td>1.000</td>
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<td>Br⁻</td>
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<td>Li⁺</td>
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<td>1.000</td>
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</tr>
<tr>
<td>Rb⁺</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
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</tr>
<tr>
<td>Sr²⁺</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
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</table>

M - mineralization
The aim of the talk is to elucidate the Late Weichselian and Holocene sediment flux and sedimentation rates in a continental shelf trough, Andfjord, and its inshore continuation, Vågsfjord. The study is based on sediment cores and high resolution acoustic data (3.5 kHz and sparker profiles). In Andfjord, a general radiocarbon dated lithostratigraphy have been correlated to the seismic stratigraphy. Andfjord is an 80 km long, north-south directed, glacial trough located at the continental shelf of southern Troms. The trough is 500 m deep in the central parts and covers an area of about 2 600 km². It comprises three basins. Vågsfjord is separated from Andfjord by several thresholds of crystalline rocks. It is a complex fjord basin about 900 km² that comprises many small basins separated by ridges. Maximum depth is 500 m. Eastwards the Vågsfjord basin continues into a system of many tributary fjords. Andfjord was deglaciated 16-13 \(^{14}\)C ky. The ice margin had receded to the inner parts of Vågsfjord before 12.5 \(^{14}\)C ky.

In Andfjord, the total volume of glacimarine and marine sediments is about 9 km³. The maximum thickness is 60 m. A total average sediment flux of 1300 kg/m\(^2\)/ky and a sedimentation rate of 90 cm/ky is estimated. In Vågsfjord, the maximum thickness of the glacimarine and marine sediments is between 125 and 150 m, and the total volume is about 6 km³. The total average sediment flux and sedimentation rate is estimated to 3 100 kg/m\(^2\)/ky and 220 cm/ky, respectively. A presentation of the individual results for the Late Weichselian and Holocene, in addition to results for the different parts of the Andfjord trough, will be given. The study is a part of the strategic university program SPINOF ("Sedimentary processes and paleoenvironment in northern fjords").

ALASKAN SEDIMENT YIELDS AND EROSION RATES DETERMINED FROM SEISMIC REFLECTION DATA

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ross@geol.niu.edu; JCooper@anl.gov

Sediment fluxes from modern Alaskan glacier systems have been determined previously (e.g. Powell, 1988; Powell, 1991; Hunter et al., 1996; Cai et al., 1997) and those data have been used to show that these glacierized basins have the largest sediment yields in the world (Hallet et al., 1996; Elverhoi et al., 1998). This is an attempt to evaluate yields over a longer time period within the same temperate glacial systems and evaluate changes in yield, if any, over a glacial cycle.

The seismic facies and seismic architecture of late Pleistocene glacimarine sequences forming the continental shelf seaward of Bering Glacier, along the south central coast of Alaska, have been described by Cooper and Powell (this volume) from USGS single-channel mini-sparker seismic reflection profiles. The youngest sequence (Sequence III) is divided into three units interpreted as representing the last maximum glacial advance, glacial retreat, and Holocene depositional systems. The current Bering Glacier System, has a drainage basin area of 5174 km² (Molnia and Post, 1995); however, the glacierized area was larger (ca 8828 km²) during the last glacial maximum and deglaciation. Dating of bounding surfaces of each unit within Sequence III has not been possible because no cores have penetrated to the required depths. We constrain ages
by what is known about the timing of glacial fluctuations along the coast. The last major Wisconsinan glaciation in southern Alaska is taken to have begun ca 24 ka (Hamilton, 1994), and a maximum advance to the shelf edge (at least of local systems) was reached by ca 21-16 ka (cf. Blaise et al., 1990). Deglaciation of the continental shelf commenced ca 15 ka and was completed by 13 ka (cf. Blaise et al., 1990).

Minimum and maximum sediment volumes were calculated with SurferÆ for each glacial unit. Uncertainties in volumetric calculations arise from uncertainties in p-wave velocity (taken to range from 1500 to 2700 m/s) and sediment bulk density (taken to be 1.77 t/m³ for Holocene sediment and 2.1 t/m³ for older sediment).

We have no record of pre-glacial advance or early advance deposits. Slope clinoform sediments of Unit 3 (the oldest unit) were deposited at and near maximum advance at the edge of the paleo-continental shelf and slope. They are only partially imaged by the seismic grid available, with coverage limited to the outer shelf and upper slope. Sediment yields were determined by using middle to lower continental slope isobaths and modeling two different clinoform geometries, that of a wedge and a sheet. The wedge model tapers to zero at a depth of 3000 m, whereas the sheet model retains a uniform thickness of 100 m to that depth. We believe these models provide reasonable absolute minimum and maximum sediment volumes. Using a time interval of 5 ka, sediment yields and erosion rates were determined using the wedge and sheet models (Table 1).

Table 1: Sediment yields (x10**3 t/km**2/a) and erosion rates (mm/a) from the Bering Glacier area on the south-central Alaskan continental shelf through the last glacial cycle, determined from seismic reflection records.

<table>
<thead>
<tr>
<th></th>
<th>MAX. ADVANCE</th>
<th>RETREAT</th>
<th>HOLOCENE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Ice Marginal</td>
</tr>
<tr>
<td>Sediment Yield</td>
<td>13.0</td>
<td>29.2</td>
<td>16.1</td>
</tr>
<tr>
<td>Erosion Rate</td>
<td>6.2</td>
<td>13.9</td>
<td>7.7</td>
</tr>
</tbody>
</table>

Unit 2 was deposited during glacial retreat and is divided into two seismic facies associations interpreted as ice-marginal and ice-proximal glacimarine deposits. An unconformity, possibly representing the 13 ka to 10 ka time interval, is marked by erosion of this retreat sequence along the inner to middle shelf, perhaps due to isostatic rebound after glacial retreat from the shelf. Ice-marginal and ice-proximal glacimarine sediments deposited during glacial retreat have absolute minimum volumes of ca 135 km³ and 49 km³, respectively. These volumes were used to determine sediment yields and erosion rates for both depositional systems, as well as for the total minimum values for glacial retreat (Table 1).

The Holocene unit, Unit 1, extends westward from Bering Trough, across the inner continental shelf to Kayak Island with a total volume from 151 km³ to 181 km³. Sediment yields and erosion rates were determined (Table 1) using an accumulation interval for Holocene sediments on the shelf of at least ca 10 ka (Hampton et al., 1986).

These ranges of sediment yields are well over one order of magnitude greater than those determined for equivalent deposits of polythermal glaciers on Svalbard (Elverhoi et al., 1995; 1998). When compared with the worldwide database of glacial sediment yields and erosion rates, these results are similar to or greater than those from temperate glaciers in New Zealand and Iceland. Importantly, the longer term data for glacial sediment are similar to those of modern southern Alaskan glaciated basins (cf. Hallet et al., 1996). They also confirm that, although on a world-wide basis the Holocene continental-shelf yields in southern Alaska are high, most Holocene sediment is being trapped in fjords (the modern glacial basin data) resulting in
relatively lower yields on the continental shelf. Thus, these data also reflect that erosion rates and sediment yields were generally constant through the glacial cycle, and that net volumes of accumulated sediment depend upon the moving depocenter (ice marginal and ice-proximal glacimarine depositional systems) associated with the glacial advance and retreat cycle. Also important are erosion of inshore areas during advance and sediment starvation of the continental shelf during glacial retreat.


Elverhoi, A., Svendsen, J.I., Solheim, A., Andersen, E.S., Milliman, J.D., Mangerud, J. and Hooke, R.LeB., 1995. Late Quaternary sediment yield from the high Arctic Svalbard area. J. Geology, 103: 1-17.


### ARCTIC HAZE, CLOUDS, AND CLIMATE

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The Arctic Ocean's ice pack thickness and open water fractions have long been suspected of being sensitive to polar cloud and surface albedo feedback mechanisms (Maykut and Untersteiner 1992), but until recently the sensitivity of the radiation balance to cloud microphysics was thought to be modest (Curry and Ebert 1992). However recently Stone (1997) has demonstrated an unexpectedly strong and intimate link seasonally controlling surface temperature (Ts) namely, low cloudiness, the near surface temperature inversions, and Long Wave Downwelling (LWD) radiation. Given that some seventy- percent of the total radiation...
received annually is LWD (Maykut and Church 1973), such sensitivity should perhaps not be entirely a surprise. However, recently Garrett et al. (2000) have shown a strong link between arctic haze pollution, arctic cloud microphysics, and LWD. The aerosol-induced changes in cloud microphysics are such that LW cloud emissivity can be substantially increased.

The cloud microphysical changes being observed in the Arctic Haze impacted clouds exactly mirror those observed when ship exhaust aerosols mix upward into clean marine stratus clouds to form long-lived "Ship Tracks" (Radke et al. 1989, King et al. 1993 and 1995). Droplet concentration increases the optically effective droplet radius decreases, drizzle halts, and long wave cloud emissivity increases.

In the winter time arctic such cloud microphysical changes could lead to sudden warmings such as observed by Persson et al. (1999). Simple calculations suggest emissivity changes of ten percent or more and resultant changes in Ts of 5-10° C.

As a result of these observations, we are reviewing data from the National Oceanic and Atmospheric Administration (NOAA) Global Monitoring for Climatic Change (GMCC) site at Point Barrow, Alaska for cases where observations of the arrival of arctic haze aerosols are linked to sudden or anomalous increases in Ts and LWD. Our initial review of this extensive data set is both encouraging and dramatic. Tens of cases per year are being found where, with the advection of a polluted airmass to the station and an increase in the aerosol light scattering coefficient of about an order of magnitude, Ts then increases more than 10° C after an as yet poorly defined lag period.

Case studies further linking cloudiness, LWD, Ts, and aerosols will be presented, as will our efforts to establish broader climate relevance of this aerosol-cloud-climate forcing mechanism.

Field research was undertaken in summer 1999 on Cape Hurd Lake, southwestern Devon Island (74°34' N, 89°38' W) as part of a study of a transect of lakes along the eastern Northwest Passage between Devon and Bathurst Islands in the Queen Elizabeth archipelago. The overall goal of the study is to reconstruct the late Holocene paleoclimate history of the region using laminated lacustrine and marine sediments. The transect of sedimentary basins crosses a prominent precipitation gradient from northern Baffin Bay in the east to the more arid polar desert of the central archipelago. A number of coastal basins in this region are marine inlets that are still connected to the sea, or coastal lakes that have recently emerged due to glacioisostatic uplift. The deeper basins of the inlets and lakes commonly contain trapped "old" anoxic seawater that precludes occupation of a burrowing infauna and related bioturbation. Thus, the basins commonly contain finely laminated sediments, which may be varves, or annual sediment couplets.

Cape Hurd Lake is presently at sea level and is connected to Lancaster Sound by a narrow, shallow channel incised through a gravelly emergent spit. The lake is fed by snowmelt from two inlets; the major inlet stream additionally contributes glacier melt runoff from an adjacent plateau ice cap. In mid-to-late August 1999, the basin was ice-free and "fresh" marine water exchanged through the narrow tidal channel. Bathymetric and limnological surveys were conducted in the basin to determine optimum coring sites. The deep central basin (maximum depth of 55 m) contains hypersaline bottom water (43ppt) below 35 meters overlain by a cap of less saline marine water. A set of four Reasoner-type percussion cores up to 3 meters in length were recovered along a transect from the main inlet to the outlet. Short, undisturbed K-B gravity cores were collected at the same sites and additional sites across the basin. The long cores contain up to 2.8 meters of laminated fine sediment overlying a massive mud that contains foraminifera and mollusc shells and fragments.

Analyses of the sediments in both long and short cores are in progress and include lithostratigraphic (grain size, loss-on-ignition, petrographic and SEM analysis of laminae) and paleomagnetic techniques (susceptibility, NRM intensity, declination, inclination). The magnetostratigraphy will provide an independent chronostratigraphic scheme for intra- and interlake correlation and assisting further comparisons of lamination stratigraphy with 14C and 210Pb analyses.

Preliminary examination of laminated sediments in petrographic thin section shows that the laminae consist of several distinct types: (1) laminated terrigenous sediment couplets or multiply laminated consisting of a coarse-grained light "summer" unit deposited from snow and glacier ice runoff and darker fine-grained winter layers deposited by suspension settling after the end of the summer melt season, (2) inter-laminated biogenic and terrigenous couplets that reflect seasonal fluxes of siliceous algal remains from springtime blooms of ice algae and/or phytoplankton blooms alternating with fine-grained terrigenous layers sediments that have been transported by overland stream flow during the melt season, (3) Disturbed biogenic/terrigenous couplets where the dark terrigenous layers are thinned, pinched, and sometimes discontinuous, and (4) massive to graded terrigenous layers that likely originate from gravity flow down prodelta slopes. Reconstruction of past climate from the laminated sediments will necessitate construction of a composite lamination stratigraphy in the basin using multiple cores to alleviate non-climatic noise in the sediment record that results from post-depositional disturbance of the varve record.
Motivation

Aerosols influence directly and indirectly the radiative balance of the atmosphere and at the surface. Therefore they play an important role in the climate system. In the Arctic we know the phenomena Arctic Haze (Heintzenberg, 1989; Shaw, 1995). Although the Arctic is free from anthropogenic aerosol sources, an increased aerosol concentration is observed in late winter and spring with optical depth values comparable with mid-latitudes. These tropospheric aerosols are transported from industrial areas in mid-latitudes.

Aerosols generally decrease the planetary albedo and increase the total energy, which is absorbed in the system surface-atmosphere. In the global mean the atmospheric aerosol has a cooling effect and therefore counteracts the carbon dioxide signal (see for overview e.g., Ramaswamy et al., 1994). But, we have to have in mind that the confidence in the calculated estimations is limited (IPCC, 1996).

Under Arctic conditions, the signal of the tropospheric aerosols on the energy budget is still not clear, especially for the surface budget. It seems, that the signal depends on the chemical composition and vertical distribution of the aerosols, on the emissivity of the atmosphere and on the surface albedo. There exist modelling studies concerning the influence of Arctic aerosols on the radiative balance (e.g., Wendling et al., 1985; Blanchet and List, 1987; Emery et al., 1992), but the input for these models are mostly idealised aerosol layers and therefore the model results are different from each other. The lack of consistent observations of the spatial and time variations of the aerosol concentrations, including their optical properties, prevents up to now a realistic estimation of the climate signal due to aerosol. For a realistic estimation of the climatic effect of Arctic Haze, it is necessary to incorporate aerosol in a climate model. Since the aerosol is a non-homogeneously distributed atmospheric component, one could expect that it has a more regional effect. Therefore we apply a regional high resolution climate model of the Arctic to study the effect of Arctic Haze on the radiative balance and circulation both in the large- and the meso-scale.

Simulations

The regional atmospheric climate model HIRHAM (Christensen et al., 1996) is used over an Arctic integration area covering the whole Arctic north of 65°N. HIRHAM uses the physical parameterizations of the global circulation model ECHAM4 (Roeckner et al., 1996). The physical parameterizations describe the radiation, cumulus convection, stratiform clouds, land surface and sea ice processes, hydrology and the turbulent exchange in the planetary boundary layer. The HIRHAM simulations are performed with a horizontal resolution of 50 km. At the lateral and lower boundaries the model is forced by ECMWF analyses. The model was integrated over winter and summer months (Dethloff et al., 1996; Rinke et al., 1999a) and over a whole year (Rinke et al., 1999b) and the comparison of the model results with observations showed, that the model simulates the monthly mean structures of the meteorological variables very well, both in the vertical distribution and in the annual cycle. Due to the high horizontal resolution of the model the simulated geographical patterns show many regional details which are neither seen in satellite data nor climatological maps.

For studying the Arctic Haze phenomenon an aerosol block has been incorporated in HIRHAM taking into account scattering and absorption of aerosols. This aerosol block is based on the Global Aerosol Dataset (GADS; Koepke et al., 1997) and define the optical aerosol parameters (spectral extinction, absorption, asymmetry coefficients) of 11 aerosol types. In our
study we mixed the soot, sea salt and water soluble components of GADS to describe Arctic Haze but we tuned the calculated aerosol optical depth with that what has been measured by photometer (Nagel et al., 1998; Becker et al., 1999).

HIRHAM has been integrated over seasons where Arctic Haze typically occurs, more precisely over March to May 1990-1995. To calculate the aerosol effect, both a control simulation (without any aerosol loading) and an aerosol simulation (with taking into account direct Arctic Haze effect) have been carried out for each of these months. We found an aerosol signal in the near surface temperature of up to 2 K. Further, it has been investigated which influence does have the aerosol on the radiative fluxes and to what extent do the changes of the heating rates influence the monthly mean atmospheric circulation due to changed vertical exchange processes. A pronounced interannual variability of the aerosol signal has been found. The dependence of the aerosol signal on the vertical layering and optical properties has been investigated on the basis of different sensitivity studies.


LATE QUATERNARY SEDIMENTS AT 49-PET-408 (ON YOUR KNEES CAVE), SOUTHEASTERN ALASKA

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49-PET-408 is a relict solution feature in the extensive karst terrain of southeastern Alaska and contains a diverse assemblage of late Quaternary fill sediments. The cave is situated above the high limit of late Pleistocene sea-level, but was within the zone of late Pleistocene glaciation. Profiles of sediments inside and outside the cave reflect different depositional environments. Diverse organic and inorganic sediments are preserved in the cave. Sediments outside the dripline consist of ablation till on limestone that is overlain by a paleosol, diamicton, and forest organics. Radiocarbon ages of ca. 9,200 B.P. on charcoal at the lower boundary of the forest organics indicate that forest detritus began accumulating at the cave during the early Holocene. The forest organics are thickest below the dripline and include limestone blocks that indicate a phase of headward retreat of the cave brow.

Sediments inside the cave are more variable and consist of fine-grained surface organics, fluvially reworked sand and gravel with glacially striated cobbles, angular blocks of roof fall, and speleothem fragments. Facies from endogenous and exogenous sedimentary processes are under investigation by using a variety of techniques such as biogenic stratigraphic markers and soil properties of the cave sediments (organic carbon, carbonate, and magnetic susceptibility). The diversity of sediments reveal different paleoenvironments.

THE ARCTIC FRONTAL ZONE: ANALYSIS, OBSERVATION AND MODELING

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The Arctic frontal zone has been identified as an area of frequent mesoscale frontal activity in northern high latitudes distinct from the commonly known polar front. Mechanisms previously cited as responsible for the emergence of the Arctic frontal zone include the differential heating between snow-free land and cold Arctic Ocean in summer; the interactions between these coastal contrasts and orography; and contrasts in surface heating between the tundra and boreal forest.

The work presented here spans examinations of NCEP/NCAR reanalyses, field observations, and regional model simulations to determine the structure and seasonality of the Arctic front and the necessary and sufficient factors dictating the formation of the front.

Results thus far suggest that differential land-sea heating and orographic contrasts are more likely to be responsible for the Arctic frontal zone, rather than the influence of the boreal treeline. Objective front diagnosis of the NCEP/NCAR reanalyses fields for the period 1979-1998 suggests that enhanced baroclinicity is produced by differential heating between the Arctic Ocean and snow-free land during summer, with winter signals being less coherent. Field observations also suggest that the contrast in surface fluxes between tundra and boreal forests in summer is an order of magnitude lower that that required to be responsible for creating a distinct
frontal zone. Finally, a suite of climate system model integrations is being undertaken in an effort to examine the seasonality and isolate the causes of frontal formation.

HOLOCENE SEDIMENT ACCUMULATION RATES ON THE CONTINENTAL SHELVES BORDERING DENMARK STRAIT: ESTIMATES FROM $^{210}$PB AND COMPARISONS WITH $^{14}$C DATA

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Accurate chronology is a fundamental requirement of arctic marine paleoenvironmental reconstructions. Radiocarbon dating is the most frequently used chronological tool, but it has drawbacks. Firstly, it is not always easy to obtain sufficient material for dating in high latitude marine environments, and secondly, the fluctuating $\Delta^{14}$C of the atmosphere over the last 1000 years makes it difficult to develop high-resolution chronologies for the most recent past.

Conversely, $^{210}$Pb is a frequently used tool for developing chronologies for recently deposited sediments but, it is limited to the last 150 years. We obtained $^{210}$Pb profiles from 6 box cores recovered from the East Greenland shelf and three fjords (Kangerlussuaq, Miki, and Nansen) and the SW Iceland shelf in 1993 and 1996 to examine sediment accumulation rates from a range of high latitude marine to glacial marine environments (Fig. 1). The $^{210}$Pb data allow us to compare modern sediment accumulation rates with earlier $^{14}$C-based estimates (Smith, 1997 and references therein). The goal of this work is to determine the sediment accumulation rates in the fjords and on the shelves, which is the basis for determining sediment fluxes from land to sea and for estimating basal ages of fjord sediments.

The sedimentological and climatic conditions on the East Greenland and Iceland shelves differ greatly. East Greenland is glaciated and cooled by the southward flowing East Greenland Current whereas SW Iceland is deglaciated and warmed by the northward flowing Irminger Current. On the East Greenland shelf, marine sediments enriched in biogenic silica, and containing a small component of iceberg rafted detritus are deposited; glacial marine sediments with a large component of ice-rafted debris are deposited in the fjords. On the SW Iceland shelf the sediments are characterized as marine sediments composed largely of tephra grains and biogenic carbonate material agglomerated into fecal pellets. Within the three East Greenland fjords, the differences in the physiography, glaciology, and oceanography result in distinct glacial marine sediment sequences (Smith and Andrews, 2000).

The East Greenland and SW Iceland continental shelves have similar rates of sediment accumulation but different mass accumulation rates. On the outer East Greenland shelf (HU93030-019 box core) $^{210}$Pb sediment accumulation rates are 0.20 cm/yr and mass accumulation rates are a factor of two lower, 0.09 g/cm$^2$ yr. $^{210}$Pb sediment accumulation rates on the SW Iceland continental shelf (HU93030-03 box core) are 0.18 cm/yr, with mass accumulation rates of 0.14 g/cm$^2$ yr. The large difference between the mass accumulation rates of the two shelf sites is attributed to the high porosity of the East Greenland sediments, owing to abundant biogenic detritus (esp. sponge spicules). The sediment accumulation rates of the shelf sites are similar to those measured on the Antarctic Peninsula (Harden et al., 1992), but up to two times greater than in the NE Water Polynya in northern Greenland (Roberts et al., 1997).

Kangerlussuaq Fjord is the largest of the three fjords studied and is dominated by sediment supply from iceberg rafting, resulting in a sediment accumulation rate of 0.42 cm/yr (HU93030-023 box core). Miki Fjord is the smallest of the fjords with glacial-fluvial dominated sedimentation and a sediment accumulation rate 0.31 cm/yr (JM96-1212 box core). Nansen Fjord is intermediate in basin size with sedimentation dominated by iceberg rafting. The sediment accumulation rate of 1.36 cm/yr at mid-fjord (JM96-1209 box core) decreases to 0.22
cm/yr at the fjord mouth (JM96-1210 box core). The $^{210}$Pb sediment accumulation rates for the East Greenland fjords are much lower than those $^{210}$Pb estimates for meltwater dominated glacial marine settings in Alaska (Jaeger et al., 1999).

Differences in the $^{210}$Pb sediment accumulation rates among the East Greenland fjords is easy to reconcile given differences in the physiography, glaciology, and oceanography of the fjords. Kangerlussuaq and Nansen fjords have higher rates of sediment accumulation than Miki Fjord. These two fjords are dominated by iceberg rafted sedimentation, whereas in Miki Fjord glacial flour entrained in a river that drains a proglacial lake is the dominant sediment source (Smith and Andrews, 2000). The differences in sediment accumulation rates between Kangerlussuaq and Nansen fjords can be attributed to the differences in the glacial marine characteristics of the two fjords. In Kangerlussuaq Fjord, the tidewater margin is fronted by a sikkusaq, a melange of sea ice and icebergs. The sikkusaq traps calved icebergs for up to two years, and the majority of the coarser grained iceberg rafted sediment is deposited within the time of entrapment in the sikkusaq (Syvitski et al., 1996). After the icebergs escape the sikkusaq, they continue to transit down fjord and release predominantly silt and clay-sized sediment. Nansen Fjord does not have a sikkusaq at the tidewater ice margin, and hence, the icebergs are free to calve and float out the fjord depositing sediment away from the tidewater ice margin in the fjord basin. This difference in iceberg rafted sediment deposition is also substantiated in the sediment infill pattern of the fjord basins. In Kangerlussuaq Fjord, sediment thins down the length of the fjord, whereas in Nansen Fjord, sediment thickens down fjord.

The $^{210}$Pb estimates of sediment accumulation rates are usually higher than those rates based on radiocarbon dates from the same or nearby cores (cf. Andrews et al., 1994; Jennings and Weiner, 1996; Syvitski et al., 1996), except in Kangerlussuaq Fjord. And, although the $^{210}$Pb rates are usually higher than $^{14}$C estimates, neither technique is always able to resolve instantaneous sedimentation events. Thus, these rates are in general applicable to steady state “rain-out” sedimentation processes only, and not to instantaneous sedimentation events, such as sediment gravity flow deposits or iceberg rafted sediment dumps. Knowledge of the types of sediment deposition is needed in order to apply these sediment accumulation rates to estimates of the onset of deposition of thick sediment piles in the fjords.

The $^{210}$Pb based reconstructions for the onset of sediment accumulation are younger than the $^{14}$C based estimates because of the higher estimates of sediment accumulation rate from $^{210}$Pb profiles. In Miki and Nansen fjords, both the $^{210}$Pb and $^{14}$C estimates indicate that the fjords were not completely scraped clean of sediment at the LGM, but would need at least the last 100,000 years to fill to their current amount of sediment. Or, these rates are an underestimate of sediment accumulation rate during full deglacial conditions. In contrast, in Kangerlussuaq Fjord the $^{14}$C estimates are higher than the $^{210}$Pb estimates indicating that Kangerlussuaq Fjord was scraped clean of sediment during the LGM, and that the fjord began to receive sediment at 14 kcal yrs. $^{210}$Pb estimates for Kangerlussuaq Fjord require 70 kcal yrs to fill the basin.

On the shelf environments adjacent to the Denmark Strait, $^{210}$Pb is a sufficient chronological tool for dating carbonate-poor sediments and studying sediment flux from the land to the ocean. In the East Greenland fjords, the use of $^{210}$Pb estimated sediment accumulation rates is dictated by the lack of sufficient material for $^{14}$C dating, but the rates should only be applied with a full knowledge of the sedimentological regime.


Figure unavailable in electronic version.
The purpose of the present study which is a subproject within the NORPAST project (Past Climates of the Norwegian region) is to develop better knowledge on fjords as sedimentary basins and how these respond to and reflect climatic changes by obtaining a detailed stratigraphy and a detailed sedimentology of the outer and inner fjord basins. A cruise with Haakon Mosby, in October 1999 gave interesting seismic data as well as sediment cores covering the late glacial-deglacial and Holocene record in Ranafjorden.

The area of Ranafjorden is located within the catchment area of Svartisen, Håtuvbreen, and Okstindbreen. The fjord is approximately 70 km long and comprises three basins separated by moraine thresholds. The moraines represent the Tjøtta event (Younger Dryas, 11,200-10,400 BP), The Nordli event (10,200-10,100 BP) and the Narvik II event (9600± 200 BP) (Andersen et al.,1982;1995). The outer fjord basin (max. 430 m deep) is located in-between the Nordli and the Tjøtta event and is covered by 40-50 m of stratified sediments. The middle fjord basin (max. 440 m deep) is situated in-between the Narvik II and the Nordli event. More than 50 m of sediments are deposited within the middle basin where avalanche deposits overlying stratified glacimarine sediments are often found below stratified sediments (tentatively of late Holocene age). The inner fjord basin (max. 510 m deep) is situated inside the Narvik II event and 40-50 m of stratified sediments is deposited within this basin. According to existing Boomer seismics the Holocene sediments in Ranafjorden are relatively undisturbed which should favour a high resolution study of the record.

Preliminary results to be presented: MST data (density, p-wave velocity, susceptibility), x-ray images of sediment cores, seismic data.


of deep-water production and modification. Variations in these processes have been implicated as factors causing Dansgaard-Oeschger type oscillations during the last glacial. Because sediments from this basin preserve proximal records of ice sheet instabilities, and water mass conditions, they provide a template for interpreting how these processes interact with the millennial scale climate system. The recent development of relative geomagnetic paleointensity as a millennial scale, environmentally independent, global correlation tool allows Labrador Sea sediments to be placed on a common temporal framework with the Greenland Summit (GRIP/GISP2) and Antarctic (Vostok) ice cores. Magnetic measurements on Labrador Sea piston cores (MD95-2024 & HU91-045-094) from a Labrador Rise site near Orphan Knoll, provide a high resolution records of magnetite grain-size variations delineating the rapid fluctuations of the Laurentide ice sheet during the last climate cycle. Here we use records of relative geomagnetic field paleointensity, that are constrained by oxygen isotopic and lithologic data, in order to develop a millennial scale chronostratigraphy for the last climate cycle. These records are correlated to the Greenland (GISP2) and Vostok ice core by comparing the inverse relationship between the cosmogenic isotope flux measured in the ice and geomagnetic paleointensity recorded from marine sediments. These correlations suggests that the lithologic record of Laurentide ice sheet instability as recorded in MD95-2024 leads the interstadial warming in Greenland, but are synchronous with warming in Antarctica.

SURFACE AND SUBGLACIAL TOPOGRAPHY OF EYJAFJALLAJOKULL, ICELAND

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Radio echo-sounding of glacier ice is an established method used to determine ice thickness, subglacial topography, bedrock characteristics, and englacial materials. It is a technique widely used on large-scale cold polar ice sheets and small-scale temperate alpine valley glaciers. The data derived from radio echo-sounding surveys provide input for modelling glacial systems and establish important geometric parameters that increase understanding of the past, present, and future behavior of glaciers, which are currently one of the most popular indicators of climate change.

This poster presents preliminary radio echo-sounding results from a survey of Eyjafjallajokull, a 90 km² ice cap sitting astride an active volcano in southwest Iceland. The point data were collected during the summers of 1998 and 1999 for the purpose of providing bed topography data for a flow model, creating a benchmark for possible post-eruption surveys, and linking available geomorphological research from the edge of the icecap to its physical characteristics. The bed morphology data can also be applied to jokulhlaup hazard assessment, adding Eyjafjallajokull to the growing archive of surveyed Icelandic ice caps, which includes Vatnajokull and Hofsjokull.

A Mark II mono-pulse low-frequency transmitter was used to collect approximately 500 depth soundings. Points were taken at 200 meter intervals along transects on the east and west flanks, in the caldera, and on the caldera rim. A separate survey covered the foot of Gigjokull, the main outlet glacier draining the caldera. Grids of the surface and bed topography were generated by kriging, a geostatistical interpolation method, using Surfer software. Geolocation of survey points were determined by differential GPS.
PRODUCTIVITY OF WILLOW-SHRUB TUNDRA IN CONNECTION WITH LANDSLIDE ACTIVITY

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The biologists and geographers studying the nature of Arctic, for a long time paid attention to widespread occurrence of highly productive willow tundra on Yamal [Andreev, 1935; Avramchik, 1969; Ukraintseva, 1998]. However, till now there are no quantitative data concerning lateral distribution, height and productivity of shrub communities, and reasons of their existence in such high latitudes.

The essential factors defining distribution of highly productive willows in our opinion is near-surface occurrence of saline soils and active landslides. It has determined necessity of analysis of soil and plant chemical composition and regularities of their location on various slope forms.

The most representative material is assembled in typical tundra of Yamal Peninsula. The ratio of communities with various dominants of shrub layer: willow, dwarf-birch-willow mix, and dwarf birch. Computing has shown, that in typical tundra, more than 55 % of slopes is covered by willows, the coverage of dwarf-birch communities is about 15%. Dwarf-birch-willow mix occupies 28 % of the area. Subdivided communities differ in shrub height. Willows height ranges from 0.3 to 2.0 m, with average values of 0.7 m. Dwarf birch and the mixed communities have height up to 0.3 m.

The regularities were established at study of ground vegetative cover of shrub communities in typical tundra. All shrub communities were subdivided into four groups according to composition of herb-undershrub and moss-lichen layers (Table 1).

### Table 1

<table>
<thead>
<tr>
<th>Groups of communities</th>
<th>Shrub dominants</th>
<th>Shrub dominants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salix glauca</td>
<td>Salix glauca + Betula nana</td>
<td>Betula nana</td>
</tr>
<tr>
<td>I</td>
<td>30.0</td>
<td>11.8</td>
</tr>
<tr>
<td>II</td>
<td>39.6</td>
<td>32.4</td>
</tr>
<tr>
<td>III</td>
<td>18.3</td>
<td>28.0</td>
</tr>
<tr>
<td>IV</td>
<td>12.1</td>
<td>27.8</td>
</tr>
</tbody>
</table>

It was found that 70 % of willows belong to the first two groups. In their ground-level cover, the herb vegetation dominates, and moss layer is low and fragmentary: I - Poa alpigena subsp.colpodea, Puccinellia sibirica, Dupontia fischeri, Tripleurospermum hookeri, Ranunculus lapponicus, Trollius asiaticus, Valeriana capitata, moss coverage is as high as 0-30%. II - Carex concolor, —. arctisibirica, Calamagrostis holmii, Dechampsia borealis, Nardosmia frigida, Polemonium acutiflorum, Rubus arcticus, the small involvement of Equisetum arvense subsp.borealis and undershrub, more often bilberry and polar willow is characteristic. The coverage of moss layer is increasing up to 30-60%. Drepanocladus uncinatus, Polytrichum juniperinum are most typical here. Dwarf-birch tundra, vice-versa, differs by well-developed moss layer and belongs to group ŷ (75 % of communities). Dicranum elongatum, Hylocomium splendens, Aulacomnium turgidum, Ptildium ciliare etc. are dominating, with small (up to 10%) addition of Cetraria cucullata, Peltigera aphtosa. The coverage of herb-undershrub layer decrease up to 30-50%, with Eriophorum vaginatum and Vaccinium vitis-idaea subsp. minus, Vaccinium uliginosum, Salix polaris dominating.

Group IV includes boggy moss-sedge-cotton-grass shrub community, which is not considered in this article.
The essential differences in ground vegetative cover of dwarf-birch and willow tundra, in our opinion, are controlled by slope processes. Dwarf-birch shrubs occupy stable slopes, where moss cover can unobstructed develop a long time. Willows are linked to shearing surfaces of landslides, transit areas and zones of landslide bodies accumulation. Instability of a substratum, as well as increased salinity of soil water due to saline-soil distribution [Leibman, Streletskaya, 1997], precludes development of moss cover. Succession of vegetative communities at various-aged landslides end up with formation of willow communities with herbs dominating in ground vegetative cover.

Detailed analysis and sampling of landslide-affected slopes in a sub-zone of typical tundra had shown, that the specific forms of landslide-affected slopes differ by salinity and distribution of main anions and cations in soil water, above-surface phytomass and biological accumulation of chemical elements in vegetative communities.

On background slopes, the salinity of soil water is 0.05-0.1 g/l. The highest salinity is characteristic for soil water of shearing surfaces (0.4-2 g/l). The landslide bodies occupy an intermediate position. The mineralized soil water feeding the root system of plants is characterized by the increased contents of K, Ca, Mg, Cl, S, P. This means that the growth of a willow can be explained by active accumulation of these very elements. Sampled were various structural parts of the largest bushes of a willow (big and small branches, foliage, trunk, bark). In foliage and small branches the increased contents of K, Ca, and S is marked. These elements have major physiological value for plants and can cause their abnormal growth.

The above-surface phytomass was estimated at various layers and slope forms. In shrub layer, the phytomass of willows reach a maximum on ancient landslide bodies (1200-1500 g/m²), and minimum - on background slopes (50-200 g/m²). Herb layer is characterized by the greatest productivity on young shearing surfaces (300-750 g/m²) and approximately identical productivity on landslide bodies and background slopes (100-200 g/m²). Moss, on the contrary, is most productive on background slopes (800-900 g/m², up to 80% of total phytomass), and are least productive on young shearing surfaces (0-150 g/m²). Dwarf-birch shrubs occur only on background slopes, their productivity ranging at 150-300 g/m².

Main indicator of a surface age is distribution of trace elements in various parts of plants. The branches of a willow are characterized by a maximal contents of trace elements, especially zinc, strontium and boron. In willow foliage, the amount of all trace elements is considerably decreased. Moss accumulates predominantly manganese and cobalt, and the herbs have noticeably lower contents of the majority of trace elements compared to willows and moss.

It is established that the chemical composition of soils and plants is controlled by the age of disturbance by landslide. Various components of vegetative communities and parts of a willow have shown different chemical responsiveness to age. For example, in branches of a willow, concentration of trace elements essentially grows in a row: modern landslides - old landslides - ancient landslides - stable slopes. Simultaneously, the more low concentration of trace elements in foliage and annual herbs (youngest formations) is marked. Conclusions: 1. Areal of shrub tundra with the increased productivity coincides with areal of near-surface distribution of saline marine deposits and landslides. 2. The increased willows productivity is controlled by chemical composition of soil water, especially increased contents of K, Ca, S. 3. The chemical composition of soil water and plants, especially contents of trace elements in plants, is controlled by the age of surface and can thus be used as indicator of the age.

The study was supported by RFBR, grant # 98-05-65061.

Leibman, M.O., Streletskaya, I.D., 1997, Land-slide Induced Changes in the chemical Composition of Active Layer soils and surface-water run-off, Yamal Peninsula, Russia:
STUDYING MY ANCESTORS: AN ALASKA NATIVE PERSPECTIVE ON PREHISTORIC ARCHEOLOGY

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After the discovery of ancient human remains in Southeast Alaska, scientists, Federal agents, and native people have been brought together in a quest for knowledge of the prehistory of this region. The resulting NAGPRA agreement included the participation of native students in the fieldwork of this excavation. Five native Interns have had this opportunity since 1997.

The intentions of this paper are to present the perspective of one of these students who has continued participation in the project for the past three years. Excavations have resulted in the significant discovery of the oldest human remains recorded within Alaska, found within the traditional territory of Klawock tribes. It is important to remember that this is not just scientific data, this man was a living human being nearly 10,000 years ago, and as such deserves the utmost respect and honor. Oral history says that native people have been here since "Time Immemorial." In Southeast Alaska, life today is not so different than what we have learned about this prehistoric man.

TEMPERATURE VARIATION AND DEMOGRAPHY IN LATE PREINDUSTRIAL ICELAND

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Two methods were used to assess the demographic effects of temperature variation in Iceland up to and including 1900. One was time series analysis, the other an examination of seven livestock crises between 1784 and 1888, including six in which unusual cold or severe weather was the main cause. Availability of annual data limited the starting date of the time series analysis to 1817 where livestock numbers (Hagstofa 1997) were used and 1823 where temperature observations were a variable. The latter comprised official observations starting in November, 1845 and earlier private observations calibrated with them (T. Jonsson, n.d.)

Both direct effects and those acting through the farm food chain were under scrutiny. Direct effects are those which act in the short term, within days or weeks. The farm food chain led from grass to livestock to humans, taking progressively more time for temperature effects to be manifest. Livestock sources provided about 78% of food energy intake in 1819, 64% in 1855, and 57% in 1880 (G. Jonsson 1997). Fishing was an important supplement, while gathering and gardening played minor roles. Grain cultivation made no meaningful contribution, but imported cereals became a substantial part of the diet over the course of 19th century.

The data utilized included temperature means, numbers of sheep, cattle, and horses, and human population size, birth rates, and death rates. Grass growth was estimated from temperature, its main determinant in Iceland. Bergthorsson (1985) concluded from a series of trials across Iceland, after controlling for the modern practice of adding combined nitrogen, that grass growth in hayfields decreases 0.30 for each degree decline in the October-April mean. He found a lesser effect from May-September temperature but did not quantify it.

Where temperature was the independent variable and human demographic variables were dependent, time series analysis indicated significant direct effects, but not significant delayed effects. The association was most significant when monthly series were used, regressing the non-infant death rate on temperature in the same month. Over most of the year the association was negative, so that unusual cold apparently elevated mortality. In May and June the regression coefficients were the largest, -0.098 and -0.143, respectively. The only positive associations found were in August and September, but they too were strong and significant. The respective regression coefficients were 0.176 and 0.122. Thus, either a one degree decrease in the monthly mean temperature in May or June or a one degree increase in the August or September mean resulted in a predicted 10-18% increase in non-infant mortality in the same month.

The results of time series analysis point to the existence of large buffers along the farm food chain. Part of the analysis involved data on temperature and livestock numbers, the other those on livestock numbers and human population size and vital rates.

The regressions of livestock numbers on temperature indicated that livestock numbers varied inversely with temperature, as expected, but a tenth or less as much as the projected variation in grass growth. Bergthorsson's formula corresponds to a coefficient of 0.43. When a composite value of livestock units, weighted by their demand for hay, was regressed on October-April mean temperature, lagged zero to two years, the coefficient was 0.022 at a one-year lag, and the lag sum was 0.042. Associations of livestock numbers with May-September mean
temperature followed a similar pattern but the predicted effects were generally less than half as large at the same lags. That the predicted effect peaked at a one year lag is consistent with the interpretation that unusual cold mostly acted on livestock numbers by reducing the hay crop, forcing excessive culling in the autumn and resulting in a low count the following summer.

Demographic variables were regressed on another livestock composite, one weighted for pasture consumption, a proxy for contribution to food supply. The regression coefficients represent the predicted variation of the dependent variable as a fraction of variation in pasture units. The results indicate that the human population varied as a consequence of livestock variation, about a twentieth as much in the same year. The most significant demographic effect of livestock variation was that on mortality in the spring following the main autumn culling, suggesting that hunger played a role. Spring was the lean season, when food stores were down and new pasture had not yet brought on renewed milk production.

The crisis study provides a look at the apparent effectiveness of buffers in especially trying circumstances. Crises in 1784-85, 1801-05, and 1811-14, before temperature observations began, were included for additional information on the relationship between livestock numbers and human demographic effects. They are particularly valuable because the crisis in 1784-85, primarily caused by a volcanic eruption, was the worst historically documented event in Iceland’s history, for animals and humans alike, while large livestock reductions also occurred in 1801 to 1803-04, for which severe winters were to blame. Figure 1 displays October-April temperature deviations in runs of cold winters in 1835-37, 1866-67, 1881-82, and 1885-86, livestock reductions in 1784, 1801-03/04, 1811/13-13/14, 1835-37, 1867-68, 1882-83, and 1886-87/88, and human population declines in 1784-85, 1802-05, 1811-14, 1869, 1882-83, and 1887-88.

Missing livestock data in some years are the reason for ambiguous starting or finishing dates in the livestock crises.

The apparent buffers are still large, although for the most part the differences between grass and livestock and livestock and humans are narrower than in the time series analysis. In the four crises for which temperature data are available, actual livestock reductions were 0.24 to 0.65 as much as the projected decrease in grass growth. In all seven crises human population decrease averaged 0.17 as much as livestock reduction. The range was nil to 0.27 as much.

Prior livestock holdings explain much of the variation in the size of buffers. Two scattergrams illustrate the apparent relationships. The independent variable in Figure 2 is the ratio of hay-consuming units to human population the year before each crisis, while the dependent variable is the ratio of reductions in hay-consuming units to projected decline in grass yield. The independent variable in Figure 3 is the ratio of pasture-consuming units to human population the year before each crisis, while the dependent variable is the ratio of population change to change in pasture units. In each scattergram the crises are numbered in the same chronological order, beginning with 1784-85. Figure 2 thus begins with number 4, the 1835-37 livestock crisis.

These comparisons indicate that a high prior ratio of herd size to human population tended to make livestock more vulnerable to reductions but increased the measure of protection to humans. The correlations between prior holdings and the dependent variables are high, \( r = 0.76 \) and \( r = -0.74 \) between the variables in Figures 2 and 3, respectively. The outlier in Figure 3, number 5, is the 1867-68 livestock crisis and human population decline of 1869. Very likely buffers against hunger were improving. The two later events, numbers 6 and 7, are close to the regression line, but they were different events in that excess mortality was not their main cause.

Iceland’s first large-scale emigration began in the 1880s. It was 60% as large as population decline in 1882-83 and exceeded it in 1887-88. Had the emigrants stayed and mostly survived, the 1880s population crises would join that of 1869 near the bottom of Figure 3.

The results point to conclusions which appear to be prosaic if stated as principles, i.e., that temperature had affected mortality and buffers existed, yet the magnitude of both phenomena is perhaps surprising. One part of the concluding discussion concerns the factors which may have made the population vulnerable to temperature fluctuations, including unheated earth houses, high tuberculosis morbidity, and a pattern of epidemics peaking in midsummer. Another part describes likely buffers against farm food chain effects, notably alternative sources
of fodder and food. Certainly the buffers were large despite the marginal nature of cattle, sheep, and horse farming in the subarctic climate and the poverty of much of the population.

Hagstofa Islands (1997), Hagskinna: Sogulegar Hagtolur um Island, G. Jonsson and M. Magnusson (eds.). Hagstofa Islands, Reykjavik IS.
Jonsson, Trausti (n.d.). [Data Series on Diskette].
Figure unavailable in electronic version.
RE-DEPOSITED POLLEN IN PERMAFROST AS AGE AND ORIGIN INDICATOR OF GROUND ICE

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Ground ice existence in permafrost gives an additional possibilities for palaeoenvironmental study. Pollen and spores often found in ground ice enough for reconstructions. Simultaneous palynologic study of ground ice and host sediments has much potential for yielding information about ice origin (atmospheric, segregated or another). In this case ground ices are considered as various facies.

Re-deposited pollen and spores can be used as facial indicator. There were developed facial criteria for pollen spectra of different facies of permafrost areas. For example, marine pollen spectra are characterized by the highest percentages of re-deposited pollen and spores and pollen concentration varied in great extent.

Pollen can be used as indicator of water origin of ground ice which has been formed from. If the ground ice has atmosphere origin the re-deposited pollen grains are unique, however if marine, lakes or river water participated in ground ice formation re-deposited pollen could be found at about 1-5% or more.

When we have no re-deposited pollen in ice-wedge ice we can suppose that the ice has atmospheric origin. Comparing pollen spectra of host sediments with those in ice wedges we can separate that part of pollen which come to the area in the spring, when ice wedges are forming (regional spring pollen rein). Thus it is possible to find the local components in pollen spectra of the host sediments for palaeotemperature reconstructions.

Of special interest 14C-dating problems in context of re-deposited pollen content. If distinctly (Tertiary and older) re-deposited pollen and spores are abundant in dated sediments it is possible to evaluate that the 14C-age, can be older than true. This approach was used for study of two similar in appearance peat sediments in the North of Western Siberia. Both of them are 5 m in thickness. The first located in the South of Yamal Peninsula in Shchuch’ya River valley, the second is in the North of Gydan Peninsula in Salemlekabtamba River mouth. The participation of allochthonous material was evaluated by re-deposited pollen and spores study. In the first one re-deposited pollen and spores content was not more than 3%. In this case we have obtained a number of 14C dates without age inversions. The content of the re-deposited pollen in the second peat is 10-12%, in some samples more than 20-25%. Very chaotic number of 14C-dates has been obtained here, the dates varies from 31 to 5 ka BP.

Thus we can conclude that if the Holocene and Pleistocene sediments contain obviously re-deposited pollen and spores it is likely that they another kinds of old organic material. High percentages of re-deposited pollen and spores (more than 20%) will most likely to obtain old radiocarbon dates among younger ones.

POLLEN AND SPORES IN PALSA AND PINGO ORIGIN STUDY

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We have studied sections of the various kinds of mounds in Lower Ob areas and in Yamal Peninsula.
It is notable that tree pollen are found more often in the sections of pingos, and pollen of shrubs and spores in the sections of palsa although they located in southern areas (Table 1). This can be explained by subaqueous sedimentation in lake or bog basins, where pingos had been formed after freezing.

Table 1
Pollen spectra of palsa in Azovy peat-bog, Lower Ob area, pingo-palsa in Tanloyayakha River valley (south of Yamal Peninsula) and pingo in Yer'yakha River (central Yamal Peninsula) three pollen (T), pollen of cedar and common pines (CP), shrubs (Sh), herbs (H), spores (S)

<table>
<thead>
<tr>
<th>Type of frozen mouth</th>
<th>Percentages of pollen and spores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
</tr>
<tr>
<td>Palsa</td>
<td>22-77</td>
</tr>
<tr>
<td>Pingo-palsa</td>
<td>22-74</td>
</tr>
<tr>
<td>Pingo</td>
<td>8-64</td>
</tr>
</tbody>
</table>

Whereas palsas are formed in subaerial conditions and their pollen spectra represent local vegetation cover. Certainly the pollen spectra of palsa sections are of wide diversity, because they have been formed in different time. It is possible to find palsas of various age at the same place. For example, we observed both very young and old palsa at the Azovy settlement, the difference of the age is represented in pollen characteristic.

Pollen spectra in palsa near Azovy settlement are characterized by essential percentages of tree pollen with even participation of Pinus sibirica and Picea sp pollen. However we can follow changes in Betula sect. Albae pollen percentages caused changes of peat accumulation conditions. These changes also reflected on Varia pollen composition and on appearance of Equisetum sp spores.

In pollen spectra of pingo-palsa section in the floodplain of Tanloyayaha river it might be followed some rithmical variations. They could be correlated with repeated thawing – freezing processes, because these are changes of local components of the pollen spectra such as Betula sect.Nanae, Varia and Bryales. Superimposed climatic changes we can separate on the base of regional component changes as follows: Pinus sibirica, Picea sp., Alnus sp.

Cross-section of pingo in Yer'yakha River floodplain gives us a possibility to follow growth stages. We can see alternation of subaerial and subaqueous conditions of pollen spectra formation. Innundation stage is marked by high percentages of tree pollen at the depth 4,5 m, particularly Pinus sibirica and Picea sp.

As pollen accumulation caused by peculiarities of mounds formation we can use pollen data as good indicators of formation stages.

CHEMICAL COMPOSITION ACCOMPANIED WITH ENZYMATIC ACTIVITY OF GROUND ICE IN CHUKOTKA AND WESTERN SIBERIA

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Analysis of the chemical composition (total dissolved solids – TDS) and enzymatic activity of Holocene and Late Pleistocene Siberian ice wedges and massive ice, together with chemical composition and enzymatic activity of structureforming ice (segregated ice, ice lenses) their host.
sediments was made in the north of Chukotka (Table.1 – Ayon Island, Ledovy Obryv in Mayn River valley and Onemen Bay near Anadyr’ town cross-sections) and in the north of Western Siberia (Table.2 – Eastern Yamal Peninsula – Seyaha River mouth, Southern Yamal Peninsula – thick peat in Shchuch’ya River valley, mouth Edem’yaha Creek, Central Yamal Peninsula near Bovanenkovo Settlement, western coast of Yamal Peninsula near Marresale Settlement).

Table 1
Chemical Composition and Enzymatic activity of different types of ices of Chukotka permafrost

<table>
<thead>
<tr>
<th>TDS mg/l</th>
<th>Ionic composition, mg/l</th>
<th>Elements, mg/l</th>
<th>PA, e.u./l</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anions</td>
<td>Cations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HCO₃⁻</td>
<td>Cl⁻</td>
<td>SO₄²⁻</td>
</tr>
<tr>
<td>Ayon, Late Pleistocene ice-wedge ice (70°N, 168°E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36-108</td>
<td>15,3-67,1</td>
<td>6-19,6</td>
<td>4,9-26,3</td>
</tr>
<tr>
<td>Ledovy Obryv, Late Pleistocene ice-wedge ice (65°N, 171°E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32-110</td>
<td>15-92</td>
<td>5-14</td>
<td>4-12</td>
</tr>
<tr>
<td>Onemen Bay, Late Pleistocene ice-wedge ice (64°N, 176°58'E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-98</td>
<td>7,3-48,8</td>
<td>2,7-22,2</td>
<td>7,4-18,1</td>
</tr>
<tr>
<td>Onemen Bay, Chukotka, 64°N, 176°58'E Holocene ice-wedge ice (64°N, 176°58'E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-62</td>
<td>3,7-21,4</td>
<td>5,8-17,3</td>
<td>6,7-13,5</td>
</tr>
</tbody>
</table>

The concentration of the major ions indicates that ice of most ices is dominated by HCO₃⁻ and Na⁺, however except ices at the seas coast line of which contain more Cl⁻ and SO₄²⁻. Here the concentration of the major elements (Mn, Zn, Cu) attain 0,5 mg/l, and in several case they are as much as 1-2 mg/l, whereas inland ices contain these elements, as a rule not more than 0,1 mg/l. The distribution of Fe is alternative, its domination often connected with bog processes, so in several case its concentration in inland ices could be more than 10 mg/l. Enzymatic proteolytic activity (PA – tested as enzyme reaction by change of substratum concentration [Vasil’chuk et al., 1996]) of different types of ices range from 20 to 150-200 enzymatic units per liter (e.u./l), but if sea water is the source (even partially) for the ice a proteolytic activity could be as great as 250-500 e.u./l.

Table 2
Chemical Composition and Enzymatic activity of different types of ices of Yamal Peninsula (north of Western Siberia) permafrost

<table>
<thead>
<tr>
<th>TDS mg/l</th>
<th>Ionic composition, mg/l</th>
<th>Elements, mg/l</th>
<th>PA, e.u./l</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anions</td>
<td>Cations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HCO₃⁻</td>
<td>Cl⁻</td>
<td>SO₄²⁻</td>
</tr>
<tr>
<td>Seyaha Late Pleistocene ice-wedge ice (70°N, 72°E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-309</td>
<td>7-175</td>
<td>4-66</td>
<td>0,1-46</td>
</tr>
<tr>
<td>Seyaha Holocene ice-wedge ice (rose ice) (70°N, 72°E)</td>
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<tr>
<td>24-27</td>
<td>6-10</td>
<td>7-8</td>
<td>4</td>
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<tr>
<td>25</td>
<td>5</td>
<td>7</td>
<td>8</td>
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<td></td>
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<td></td>
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<tr>
<td>Seyaha Modern ice-wedge veinlet (70°N, 72°E)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>43-819</td>
<td>23-628</td>
<td>5-220</td>
<td>4-11</td>
</tr>
<tr>
<td>Seyaha Late Pleistocene segregated ice (ice lenses) (70°N, 72°E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-576</td>
<td>2-476</td>
<td>5-14</td>
<td>4-6</td>
</tr>
<tr>
<td>Seyaha Holocene segregated ice (ice lenses) (70°N, 72°E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-77</td>
<td>6-50</td>
<td>3-5</td>
<td>4-10</td>
</tr>
<tr>
<td>Shchuch’ya Holocene ice-wedge ice (67°N, 69°E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-210</td>
<td>5-181</td>
<td>3-5</td>
<td>4-8</td>
</tr>
<tr>
<td>Shchuch’ya Holocene segregated ice (ice lenses) (67°N, 69°E)</td>
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<tr>
<td>Bovanenkovo settlement Late Pleistocene segregated ice (ice lenses) (70°N, 69°E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>169-1533</td>
<td>21-524</td>
<td>17-370</td>
<td>8-138</td>
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<tr>
<td>Bovanenkovo settlement Holocene ice-wedge ice (70°N, 69°E)</td>
<td></td>
<td></td>
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<tr>
<td>26-28</td>
<td>1-5</td>
<td>7-8</td>
<td>8</td>
</tr>
<tr>
<td>Bovanenkovo settlement Holocene segregated ice (ice lenses) (70°N, 69°E)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>30-31</td>
<td>2-3</td>
<td>4-5</td>
<td>8</td>
</tr>
<tr>
<td>Marresale Late Pleistocene ice-wedge ice (69_, 66_)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22-70</td>
<td>5-32</td>
<td>8-17</td>
<td>4</td>
</tr>
<tr>
<td>Marresale Late Pleistocene segregated ice – ice lenses (69_, 66_)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>

The study was supported by Russian Foundation for Basic Research (grant 99-05-65075), and by Russian Program of Integration (grants 5.1 – 425, 4.1. – 729-05 and 2.1. – KO802).

**MINIMUM SNOW COVER EXTENT AND SNOW COVER DYNAMIC OF A LOW ARCTIC SITE (ABISKO, NORTH SWEDEN) DERIVED FROM LANDSAT 7 IMAGES**

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Climatic studies show that mean annual temperature in the Arctic increased by up to 2º C within the last 30 years (Chapman and Walsh in Weller 1998). In Scandinavia, however, the temperature change was slightly negative during summer and slightly positive during winter. Looking closer to the site of this investigation in the Abisko Region (Northern Sweden), the temperature data from Abisko Scientific Research Station shows an increase in the annual mean
temperature during the last 100 years of nearly 1º C. The biggest increase (more 1º C) took place in mean summer and spring temperature, while the mean winter and autumn temperature increased by less than 0.5º C.

Whereas many of climatic impact studies were done for glaciers, there are only a few studies focusing on the interaction of climatic change and snow patches. The distribution and extent of snow patches varies from year to year with the individual yearly weather conditions. The question is whether the trend of the variation in the minimum extent of a snow cover can be used as a fast indicator for changes in the regional weather or climate pattern?

To look closer at this question a first mapping of the snow patch extent was done in the period from the 18th till the 20th of July 1999 in the Abisko region between Kargevagge, Gohpascorru, Luaktacohkka and Latnjacohkka. The mapping was done photographically and provided a base for generating a map with the aerial distribution and extent of the snow patches.

This point evaluation was used to calibrate Landsat 7 TM scenes, to study the regional snow patch evolution during summer 1999. From the period from 30th of June 1999 till 25th of September 1999 six cloud free Landsat 7 images are available for the study area. During June and July the snow cover extent decreased. Meteorological data, from Abisko Station, gave evidence that an accumulation period started in early August, which lasted until early September. The low resolution preview images obtained at the 15th of August 1999 and 9th of September 1999 clearly show an increase in snow coverage in the investigation area. With higher temperature in September the thin snow cover in the mountains from August melted away. The image obtained at September 25th 1999 gives no evidence that snow that has fallen in August and early September rested until end of September, so that the snow cover extent mapped from the image obtained on September 25th 1999 can represent the minimum snow cover extent of 1999.

Due to it’s high resolution (30m x 30m) this investigation showed that snow cover mapping from Landsat 7 images is a reasonable method to obtain the seasonal minimum snow cover extent in a region.

SEDIMENT MINERALOGY OF THE EURASIAN SHELVES AND THE ARCTIC OCEAN

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For this study several hundred surface samples were investigated and analyzed by means of X-ray diffraction and the QUAX software (Quantitative Phase-Analysis with X-ray Powder Diffraction). QUAX has successfully been used at the KTB site (German Continental Deep Drilling) to determine mineral assemblages fast and automatically on a huge amount of samples (> 40,000). During the last years the full pattern database of QUAX has been adapted to the investigation of young and poorly crystalline sediments, in particular those of the Arctic Ocean which contain high amounts of clay minerals.

Quantification of the clay minerals from the bulk sediment is highly desirable due to their importance for paleoceanographic reconstruction. Determination of the clay minerals from the clay fraction is extremely variable depending on the laboratory routine. Separation of the clay fraction and further laboratory processing make it extremely difficult to recalculate the content of a particular clay mineral in the bulk sediment. Hence, sedimentation and accumulation rates of a distinct clay mineral contain variable and large systematical errors. Determination of clay minerals are performed rather in a qualitative than quantitative manner.

A paleoceanographic reconstruction of source material, sedimentation and sediment transport can only be based on differences between the source regions. Luckily, the source regions for the Eurasian Arctic Ocean, the Barents, Kara and Laptev Sea show these differences in mineralogy. Maps of the distribution of major clay fraction minerals and clay minerals special
to particular source regions will be presented. Clay minerals are extremely well suited to determine ocean current transport, riverine input of the large Siberian river and sea ice transport. The inner Kara and Western Laptev Sea exhibit a very important marker mineralogy. The clay mineral assemblage is dominated by smectites and montmorillonites from the erosion of the Putorana Siberian Flood Basalts and tuffites. The material is transported to both shelf regions by the Yenisei and Khathanga river systems, respectively. The Eastern Laptev Sea shows an illite/mica and chlorite dominated clay mineral assemblage.

In sediment cores from the Laptev Sea continental slope distinct changes in clay mineral assemblages in the bulk fraction are indicative of the early flooding of the Kara Sea and the late flooding of the Laptev Sea during the last glacial to Holocene transgression. The recognition of Kara Sea material in Laptev Sea slope sediments during the very early Termination I implies a very small Kara Sea Ice Sheet with an early deglaciation between 15,000 and 13,500 radiocarbon years. This study is supported by the Deutsche Forschungsgemeinschaft (grant Fi 442-6/3) and the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven (Priv.-Doz. Dr. R. Stein).

THE NORWEGIAN-GREENLAND SEA CONTINENTAL MARGINS: LATE QUATERNARY SEDIMENTARY PROCESSES AND ENVIRONMENT.

VORREN, TORE O. and Laberg, Jan Sverre

The continental margins surrounding the Norwegian-Greenland Sea are to a large degree shaped by processes during the late Quaternary. An overview of the morphology and the processes responsible for the formation of three main groups of morphological features: slides, trough mouth fans and channels, will be given.

Several large late Quaternary slides have been identified on the eastern Norwegian-Greenland Sea continental margin. The origin of the slides may be due to high sedimentation rates leading to a build-up of excess pore water pressure, perhaps with additional pressure caused by gas bubbles. Triggering might have been prompted by earthquakes or by decomposition of gas hydrates.

Trough mouth fans (TMF) are fans at the mouths of transverse troughs on presently or formerly glaciated continental shelves. In the Norwegian-Greenland Sea seven TMFs have been identified varying in area from 2700 km² to 215,000 km². The Trough Mouth Fans are depocentres of sediments accumulated in front of ice streams draining the large Northwest European ice sheets. The sediments deposited at the shelf break/upper slope by the ice stream were remobilized and transported downslope, mostly as debris flows. The Trough Mouth Fans hold the potential for giving information about the various ice streams feeding them with regard to velocity and ice discharge.

Two large deep-sea channel systems have been observed along the Norwegian continental margin, the Lofoten Basin Channel and the Inbis Channel. Along the East Greenland margin, several channel systems have been identified. The deep-sea channels may have been formed by dense water originating from cooling, sea-ice formation and brine rejection close to the glacier margin or they may originate from small slides on the upper slope transforming into debris flows and turbidity currents.
CHIRONOMID DISTRIBUTIONS AND THEIR RELATIONSHIP TO PAST AND PRESENT ENVIRONMENTAL CONDITIONS IN NORTHWESTERN CANADA

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The distributions of freshwater midges (Diptera: Chironomidae) is evident from their remains preserved in the surficial sediments of lakes. We analysed their remains in sediment samples collected along a transect extending north from Whitehorse (Yukon Territory) to the Beaufort Sea.

Canonical correspondence analyses reveal that the midge distributions are most clearly correlated with summer surface water temperature, maximum lake depth, nitrogen concentration, and pH or pH-related environmental variables (e.g., Mn).

Strong correlations between chironomids and temperature have previously been documented across treeline in the Canadian Cordillera, Labrador, Norway, Finland, and Switzerland - thus, they are being increasingly valued as palaeotemperature indicators. The development of a chironomid - palaeotemperature inference model for northwestern Canada will facilitate an independent assessment of earlier palaeobotanical climate reconstructions in the region.

MODELLING THE VARIATIONS IN GLACIAL COVERAGE OF ICELAND

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Glaciers are an integral part of the Icelandic landscape. Since the last glacial maximum coverage of land by ice has varied from complete flooding of land and coastal shelf to near complete deglaciation. The rapid dynamic response time of Icelandic glaciers makes this an ideal location to investigate the effects of climate change on ice extent on a range of time scales.

Glaciated sites have been identified in all parts of Iceland. Bedrock striations and molded forms are common, especially in coastal areas although post-glacial volcanism has obscured the glacial record in some inland regions. Recent state of thought accepts an early Holocene retreat from the Weichselian maximum punctuated by multiple readvances and stillstands. Extremely low ice volumes in the mid Holocene were followed by renucleation and advance of modern ice caps beginning around 2500 BP.

We employ a three-dimensional finite difference ice sheet model as described in Marshall and Clarke (1997). Climate evolves with time through a perturbative model with prescribed end-member climates at present day and the LGM. Mass balance is calculated using the degree-day method and is coupled to topographic evolution. Important ancillary components of the model are isostatic response to ice load, development of ice shelves and calving along marine margins, eustatic changes in sea level.

We compare model results to existing marine and terrestrial sediments records.
STRUCTURE AND BIOMASS OF A POLAR-LATITUDE EOCENE FOREST FROM THE CANADIAN HIGH ARCTIC

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Abundant fossil plant remains are preserved in the high-latitude middle Eocene deposits of the Buchanan Lake formation on Axel Heiberg Island, Nunavut Territory, Canada. Intact leaf litter, logs, and stumps preserved in situ as mummified remains present an opportunity to determine forest composition, structure, and productivity of a Taxodiaceae-dominated forest that once grew north of the Arctic Circle (paleolatitude 75-80° N). We excavated 37 tree stems for dimensional analysis from mudstone and channel-sand deposits. Stem length ranged from 1.0 m to 14.8 m (average = 3.2 m). Stem diameter ranged from less than 10 cm to greater than 75 cm (average = 32.2 cm). All stem wood was tentatively identified as Metasequoia sp. Annual ring counts indicate that the forests stood for > 150 y (trees of > 250 y have been identified). A parabolic taper function was generated from the excavated stems and used to estimate canopy height as a function of stump diameter. Assuming that canopy dominant trees were represented by the largest in situ stumps we calculated a canopy height of 39 m (+/- 6 m). On the basis of excavated fossil tree tops we estimate the length of live crown to be ca. 9 m. Buried knots and the presence of branch-free bole wood indicate that this was most likely a closed canopy forest. We used stump diameter data (n =107, diameter > 20 cm) and a minimum canopy height of 33 m to calculate parabolic stem volume and stem biomass for a 2227 m² area of fossil forest. Stem volume equalled 2190 m³/ha and stem biomass equalled 591 Mg/ha. We are currently developing allometric equations for modern plantation grown Metasequoia glyptostroboioes to refine and test our standing biomass estimates. Preliminary results indicate that production of branch wood and foliage may increase our estimate of standing biomass by an additional 17 and 3 Mg/ha, respectively.

CLIMATIC REGULATION OF ACID-BASE EQUILIBRIUM IN ARCTIC LAKES ON MILLENNIAL TIMESCALES

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Lake-water pH is typically the most faithfully reconstructed environmental parameter from diatom assemblages in cores from dilute lakes. Data from the Alps have suggested that a linkage exists between lake acidity and climate over the past 200 yrs, but extensive anthropogenic overprinting complicates some elements of this interpretation. On Baffin Island in the eastern Canadian Arctic, the combination of a relatively pristine environment and a somewhat understood record of late Holocene paleoclimatology provide suitable conditions to test climate-pH hypotheses on millennial timescales. On Baffin Island, several lines of paleoclimate data independently suggest a pattern of progressive late Holocene cooling (Neoglacial) culminating in the Little ice Age, then followed by marked warming in the present century. Diatom reconstructed lake-water pH values from two high-resolution gravity cores from northern Cumberland Peninsula reveal gradual Late Holocene acidification trends, in the order of 0.7 pH units since 5 ka BP. One site furthermore shows recovery in the present century. Thus it appears that climate is intimately linked to the main controls of lake acidity, these being catchment weathering rates (base cation supply) and lake productivity (regulation of lake DIC dynamics).
This talk explains this research project showing examples from the present century as well as OIS 5. It is estimated that lake-water pH tracks summer temperatures at the rate of about 0.2 pH units per degree C.

**SEA ICE AND SEAL FAUNAS IN LABRADOR INUIT ARCHAEOLOGICAL SITES**

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In recent years, increasing scientific attention has been paid to sea mammals as biological indicators of arctic environmental change. The usefulness of such species as ringed seal (Phoca hispida), harp seal (Phoca groenlandica), bearded seal (Erignatus barbatus) and harbour seal (Phoca vitulina) as indicators is due to the close relationship of their range, reproductive cycles and life histories to sea ice. The behaviour and distribution of these species correlates with modal ice conditions in the areas in which they are encountered. The proportions of seal species represented in archaeological deposits may therefore reflect, at least in part, environmental conditions obtaining in past landscapes.

This paper examines zooarchaeological data from several prehistoric Thule and historic Inuit archaeological sites in Labrador, occupied during the last 400 years, to determine if a relationship can be demonstrated between between subsistence economies, seal populations and and sea ice conditions in selected areas. Arctic archaeologists have often placed central importance upon subsistence economies in their discussion of life ways and cultural change. Accordingly, many archaeologists have concentrated upon the role of environmental change as a stimulus for culture change, primarily through accompanying changes in the distribution, behaviour or availability of vital prey species. Recent ice core studies have produced a much more detailed, fine-grained picture of past climate change than was previously available. These studies may offer an opportunity to re-examine the environmental context of hypothesized shifts in late Thule/Inuit subsistence economy in the eastern arctic.

In this study, ratios of ringed, harbour and bearded seal bone remains from several archaeological sites are analyzed and discussed in light of new proxy sea ice and regional palaeoenvironmental data. This exploratory study suggests changes in the seal species compositions of these assemblages appear to be related to recent sea ice reconstructions. However, a regional comparison of a larger number of more precisely-dated archaeological sites are required for a full examination of these relationships.

**MESOFAUNA OF THE KOLA PENINSULA SOILS IN CONDITIONS OF INDUSTRIAL POLLUTION**

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Northern-taiga ecosystems are function in extreme natural conditions therefore they appear especially sensitive to industrial influence. This problem is actual for the Kola peninsula which is a region with advanced mining industry. The "Severonikel" smelter (Monchegorsk town) is the largest industrial enterprise in Murmansk region. It operated since 1938. Arise from it aerial emissions the heavy metals (copper, nickel, cobalt) and the sulphur dioxide are main environmental pollutants. Annually it throws out in an atmosphere more than 3000 t of Ni, 2500 t of Cu, 200-250 thousand tons of SO₂ (Krychkov & Makarova, 1989). Pollutants accumulated in
the upper soil horizon mainly (Evdokimova et al., 1984; Nikonov & Lukina, 1994) in which the basic amount of soil fauna dwell.

Soil-zoological researches were carried out in 1996-1999. Communities of invertebrates animals dwelling the organogenic horizon \(_0\) including the litter layer of podzol Al-Fe-humus soils under the pine forests were studied. For an estimation of influence of industrial pollution on soil fauna the sample plots removed at the distance of 5 (S5), 15 (S15), 40 (S40) and 60 km (S60) from the smelter (on south, on a direction of prevailing winds) were established. The sites of the plots correspond to the following zones of ecosystems degradation (Krychkov, 1993): completely destroyed ecosystems (S5), strongly destroyed (S15), initial damaged and zone of undamaged ecosystems or a control plot (S60).

Contents of the Ni, Cu and the pH(H_2O/KCl)value in horizon \(_0\) were determined for the soil of the each sample plot (Table). Statistically significant increase of the H_ concentrations in soil and decrease of pH along the contamination gradient are testified to the growing industrial press on natural ecosystems.

Arise from investigation the following groups of soil invertebrates were found out: Lumbricidae, Enchytraeidae, Gastropoda, Aranea, Opiliones, Acari, Lithobiidae, Collembola, Blattoidea, Homoptera: Cicadellidae, Psyllidae, Aphididae, Hemiptera, Coleoptera: Cantharididae, Carabidae, Curculionidae, Elateridae, Staphylinidae, Lepidoptera (larvae), Diptera, Thysanoptera, Formicidae and other Hymenoptera. The 23 groups in total. Numerous taxa of Nematoda has been not taken into account.

Arthropods (Acari and Collembola) were the dominant groups of soil fauna in the all sample plots. Their share reached 98% from the total density of invertebrates. High density of the both groups provided a total amount of invertebrates too significant for northern-taiga soils (about 20 thousand ind/m\(^2\) in background area).

Mesofauna was consist about 2% only from the total amount of invertebrates. The 21 groups of mesofauna were collected during the research. The 19 groups from them were present in soil of control plot excluding Hemiptera and Blattoidea. Lumbricidae and Gastropoda have been found out on this plot only and can be regarded as bioindicators of such kind of soil pollution.

As approaching to the smelter both numerous and rare taxa of mesofauna characteristic of the control soil eliminated from community and the new groups were occur. Due to disappearance of Lumbricidae and Gastropoda from the community of S40 plot the number of taxa decreased from 21 in control to 19. In soil of S15 plot the Opiliones taxa disappeared but Blattoidea and Hemiptera have been founded. So a diversity reached up to 20 groups. As known, biodiversity, density and biomass of soil animals can be more increasing in comparison with background zone with average intensity of pollution. But that is testified to an unstable condition of communities (Bengtsson & Rundger, 1988; Fritzlar et al., 1986; Stepanov et al., 1991).

The soil of S5 plot differs by poorness taxonomic structure - 16 groups of mesofauna only. Except the taxa listed above the Blattoidea, Psyllidae, Aphididae and Lepidoptera were eliminated. Representatives of the three last groups belong to phytophages which consume the vegetative juices and organs. Destruction of organogenic soil horizon and significant rare of a vegetative cover in vicinities of the smelter can be a real reason of elimination of these taxa from mesofauna structure.

Comparison of the taxonomic content of mesofauna communities on the S60-S5 plots with control was spent using the index of a similarity on Jaccard and on Mountford. Both indexes reflected the least similarity of taxonomic diversity of the S5 plot with control and the increase of this parameter on a distance from the smelter (see the Table). This is testified to the greatest degree of a damaged of the soil near the source of pollution.

As approaching to the smelter the total density of soil fauna authentically decreases, its seasonal dynamics is broken and a dominant structure is change. Density of such taxa as Enchytraeidae, Lithobiidae, Aranea, Diptera, Thysanoptera, Cantharidae, Carabidae, Staphylinidae and also Acari and Collembola authentically reduced. Dynamic density of mesofauna and arthropods are reduced in 5.9 and in 5.3 times correspondently near the smelter in comparison with the control.
Total biomass of mesofauna authentically reduced in vicinity of the smelter. Because of elimination of *Lumbricidae* it reduced in 10, 22 and 66 times approximately on the S40, S15 and S5 plots in comparison with the control and consisted accordingly 530, 238 and 77 mg/m² against 5143 mg/m² on S60 plot (see the Tab.). Without the *Lumbricidae* the total biomass reduced in 1.5, 3.3 and 10 times. Authentic reduction of the biomass of *Enchytraeidae*, *Diptera*, *Lithobiidae*, *Aranea* and all taxa of *Coleoptera* except *Cantharidae*. The fall of biomass (in %) consisted: for *Lithobiidae* - 99.9, *Thysanoptera* - 99.0, *Elateridae* - 98.4, *Aranea* - 96.1, *Carabidae* - 96.0, *Diptera* - 95.4, *Enchytraeidae* - 92.1, *Coleoptera* - 87.2, *Homoptera* - 84.5, *Staphylinidae* - 81.8, *Cantharidae* - 74.0 and 98.5% for mesofauna as a whole.

With growth of soil contamination the coefficient of variation (CV, %) of density authentically increased for *Enchytraeidae*, *Lithobiidae*, *Aranea* and the coefficient of variation of biomass increased for *Enchytraeidae*, *Lithobiidae*, *Aranea*, *Homoptera*, *Thysanoptera*, *Hemiptera*, *Staphylinidae*, *Curculionidae*. This testified to the destabilization of community. For total biomass the CV increased from 60% (from 79% without the *Lumbricidae*) up to 97%. It is possible to explain by reduction of taxa diversity and replacement of long-living *Lumbricidae* which dominated on biomass in control soil by taxa temporary for communities, for example, by *Diptera*.

*Formicidae* the only group for which the authentically growth both density and mass near the smelter was marked. Similar observations were done by some authors in vicinities of metallurgical combines (Hunter et al., 1987; Nekrasova, 1993).

Thus, in process of increase of a soil contamination degree by the heavy metal compounds and sulphur dioxide the communities of soil invertebrates with the simplified structure, lowered taxonomic diversity and decreased number and biomass are formed. Changes of other parameters of soil fauna along the pollution gradient is given in Table.
Table. Change of chemical parameters of soil and characteristics of soil fauna along the pollution gradient.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Distance from the source of pollution, km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60 (S60)</td>
</tr>
<tr>
<td>pH value, n=12</td>
<td></td>
</tr>
<tr>
<td>$\text{H}_2\text{O}$</td>
<td>5.66±0.10</td>
</tr>
<tr>
<td>$\text{KCl}$</td>
<td>4.57±0.14</td>
</tr>
<tr>
<td>Content of heavy metals (mg/kg), n=10</td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>72.0±14.2</td>
</tr>
<tr>
<td>Cu</td>
<td>37.3±4.8</td>
</tr>
<tr>
<td>Characteristics of soil fauna (n of soil samples = 55)</td>
<td></td>
</tr>
<tr>
<td>Total number of taxa</td>
<td>21</td>
</tr>
<tr>
<td>Similarity of taxonomic content with control, %</td>
<td></td>
</tr>
<tr>
<td>on Jaccard</td>
<td>90.00</td>
</tr>
<tr>
<td>on Mountford</td>
<td>98.87</td>
</tr>
<tr>
<td>Total density, $D \pm m_D$:</td>
<td></td>
</tr>
<tr>
<td>of mesofauna, ind/m$^2$</td>
<td>484 ± 35</td>
</tr>
<tr>
<td>of arthropods$^a$</td>
<td>18.28±2.05</td>
</tr>
<tr>
<td>of all fauna$^b$</td>
<td>18.95±2.06</td>
</tr>
<tr>
<td>$D_{\text{max}}$, ind/m$^2$</td>
<td>1177.8</td>
</tr>
<tr>
<td>$D_{\text{min}}$, ind/m$^2$</td>
<td>112.0</td>
</tr>
<tr>
<td>$\text{Lim} = D_{\text{max}} - D_{\text{min}}$</td>
<td>1065.8</td>
</tr>
<tr>
<td>$CV \pm m_{CV}$, % of density</td>
<td></td>
</tr>
<tr>
<td>of mesofauna</td>
<td>52.0±5.0</td>
</tr>
<tr>
<td>of arthropods</td>
<td>65.2±7.9</td>
</tr>
<tr>
<td>of all fauna$^c$</td>
<td>63.5±7.7</td>
</tr>
<tr>
<td>Biomass of mesofauna, $B \pm m_B$, mg/m$^2$</td>
<td>5143±1050</td>
</tr>
<tr>
<td>$CV \pm m_{CV}$, % of biomass</td>
<td>60.4±11.0</td>
</tr>
<tr>
<td>Index of aggregation on Lexis</td>
<td></td>
</tr>
<tr>
<td>of mesofauna density</td>
<td>11.45</td>
</tr>
<tr>
<td>of mesofauna biomass</td>
<td>56.68</td>
</tr>
<tr>
<td>Concentration of domination on Simpson, $C$</td>
<td></td>
</tr>
<tr>
<td>of mesofauna density, $C_D=\sum(D/D)^2$</td>
<td>0.12</td>
</tr>
<tr>
<td>of mesofauna biomass, $C_B=\sum(B/B)^2$</td>
<td>0.72</td>
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<tr>
<td>Coefficient on Pielou, $e=H'/\log N$</td>
<td></td>
</tr>
<tr>
<td>of mesofauna density</td>
<td>0.78</td>
</tr>
<tr>
<td>of mesofauna biomass</td>
<td>0.26</td>
</tr>
<tr>
<td>Index of Shannon, $H=-\sum P_i \log P_i$</td>
<td></td>
</tr>
<tr>
<td>of mesofauna density bit/ind</td>
<td>3.38</td>
</tr>
<tr>
<td>of mesofauna biomass bit/mg</td>
<td>1.07</td>
</tr>
</tbody>
</table>

The note. The authentic differences from control by t-criterion of Student are received with various significance values: * - $p \leq 0.05$; ** - $p \leq 0.01$; *** - $p \leq 0.001$. Density of arthropods$^a$ and of all fauna$^b$ are given in thousand ind/m$^2$. 

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Air temperature changes propagating through the ground interface, with intervening vegetation and seasonal snow cover, are recorded in the subsurface as perturbations on the long-term equilibrium geothermal gradient. It has long been recognized that past surface temperature history can be estimated by analyzing the perturbations to the equilibrium geothermal gradient. Indeed, data obtained at various locations around the globe show that temperature gradients are in fact disturbed for the first several hundred meters. It has been established that surface temperature in Alaska and elsewhere has increased up to 4 degree Celsius over a time scale ranging from decades to centuries (Lachenbruch and Marshall, 1986; Pollack et al., 1998). This climatic information obtained from deep borehole temperature profiles has been used as a robust complement to the existing paleoclimatic databases and as evidence of global warming (Harris and Chapman, 1997; and Overpeck et al., 1997).

Soil temperatures are linked to the climate through the active layer in permafrost regions and the seasonal freezing layer in non-permafrost regions, as well as through the ground surface interface, intervening vegetation and seasonal snow cover. The number of processes governing the heat and water exchange between the atmosphere and the land surface is large, and the interrelation between these processes is extremely complex (Nelson et al., 1993). Over a period from a few decades to a century, changes in soil temperature are mainly controlled by changes in air temperature, with modifications through changes in snow cover due to its insulating effect and soil moisture due to its effect on soil thermal properties and surface evaporation. However, how the changes in soil temperature, seasonal freeze/thaw, and permafrost conditions respond to the changes, individually or in combination, in climatic variables and surface properties (such as vegetation, soil type, and landforms) at local, regional, and hemispheric scales is still poorly understood.

The warming signals detected from the geothermal gradient in northern Alaska indicate that the warming generally started between the 1900s and the 1940s (Lachenbruch and Marshall, 1986). This suggests that air temperature increases in the late 1800s and early 1900s in North America preceded warming of the permafrost. Climatological data and numerical modeling results reveal that changes in air temperature alone can not explain the permafrost surface warming by 2 to 4 degree Celsius on the North Slope of Alaska. Changes in seasonal snow cover might significantly modify the impact of air temperature on geothermal gradient in the region (Zhang and Osterkamp, 1993).

One major obstacle to understanding the relationship between the soil thermal regime and its environmental conditions is the lack of long-term observations of soil temperature and related climatic variables. These data are available from the former Soviet Union, mostly starting from the middle of the 1930s with some can be as early as the late 1800s and early 1900s. Data from the long-term measurements at Irkutsk, Russia, indicate that changes in mean annual air temperature and soil temperature at 40 cm depth were about the same magnitude (2.0 to 2.5 degree Celsius) during the past century, but the patterns of change were substantially different. Air temperature during winter months increased by 4 to 6 degrees Celsius and was essentially unchanged during summer months. Soil temperature at 40 cm depth increased up to 9 degree Celsius during winter months and decreased up to 4 degree Celsius during summer months. Increase in snowfall during early winter might account for the winter soil temperature increase due to the snow insulating impact and higher soil moisture content might explain soil cooling during summer months due to the evaporative effects.

This study demonstrates that when changes in soil temperature are used as evidence of climatic warming, caution is required because changes in soil temperature are a combined
product of changes in air temperature and precipitation, especially snowfall and snow cover on ground. Present findings of the surface warming of permafrost at high latitudes and ground warming at a certain depth below the ground surface elsewhere in the world could be fortuitous and may be misleading since air temperature alone cannot account for such a ground warming. It is safe to state that warming is evidence of climatic change due to the impact of changes in air temperature, precipitation, and other climatic variables rather than the impact of changes in air temperature alone.


THE PALEOECOLOGICAL ANALYSIS OF A SUBALPINE PERMAFROST PEATLAND (QUÉBEC-LABRADOR)

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Subalpine and alpine ecosystems can be considered as key environments because of their high sensitivity towards several natural ecological disturbances. For this reason, the few peatlands existing in high altitude sites have a high value for paleoecological reconstructions since their organic deposits are rich in remains of biological indicators. A complete macrofossil analysis (vascular plants, mosses, lichens, mycorrhiza, cladocera, insects, charcoal) has been conducted in a peat section recovered from a peatland containing a permafrost layer surrounded by subalpine vegetation on the summit of the Lac des Cygnes Mountain (Charlevoix, Québec, Canada). Peat accumulation began about 5800 years BP, and was probably induced by climatic factors. The further development of the peatland has been mainly influenced by autogenic factors. The macrofossils give information not only about the characteristics of the peatland, but also about the development of the forest vegetation surrounding the study site. The sudden decline of tree macrofossils about 4000 years BP indicates a heavy deforestation event of the top of the mountain during this period. The factors explaining this deforestation are still unknown. The permafrost layer of the peatland was probably formed during the 20th century as a result of a second deforestation event. The forest fire of AD 1915 has probably modified the snow conditions on the summit, allowing a deeper penetration of the frost wave in the peat deposit. Consequently, the permafrost on the summit of the Lac des Cygnes Mountain is not directly related to a climatic event.
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