PROGRAM & ABSTRACTS

34TH INTERNATIONAL ARCTIC WORKSHOP

March 10 - 13, 2004
Institute of Arctic and Alpine Research
University of Colorado, Boulder, CO USA
PROGRAM AND ABSTRACTS

THE 34th INTERNATIONAL ARCTIC WORKSHOP

March 10 - 13, 2004

Institute of Arctic and Alpine Research
University of Colorado at Boulder

Organizing Committee:

Tad Pfeffer
David Lubinski
Wendy Roth
Anne Jennings
Bill Manley
Astrid Ogilvie
Stephen DeVogel
Introduction

Overview and history
The 34th Annual International Arctic Workshop will be held March 10 - 13, 2004, 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 started by John T. Andrews and 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.

Web site
http://www.colorado.edu/INSTAAR/AW2004/

Workshop Location
The meeting will be held in two rooms in adjacent buildings on the CU-Boulder East Campus: Bldg. RL-1, also called “LITR”, and Bldg. RL-3, also called “ARCE”.

   RL-1, two stories tall, 1560 30th St., 2nd Floor Conference Rm. 269.
   - Icebreaker, check-in, and registration on Wednesday evening.
   - Check-in and registration on Thursday morning.
   - Poster session on Friday morning in adjacent 2nd Floor hallways.
   - Oral presentations on Saturday.

   RL-3, six stories tall, 3100 Marine St., 6th Floor Auditorium Rm. 620.
   - Oral presentations on Thursday (all day) and Friday (afternoon).

Registration
Please check in or register in Room 269 in Bldg. RL-1 at one of two times: (1) the Icebreaker between 5 - 8pm on Wed. March 10, or (2) between 8 - 8:30am on Thursday, March 11. 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 Friday, March 12. At registration you will receive information on where to set up your poster.

Acknowledgments
The Arctic Workshop each year is partially subsidized for student registration and accommodation costs through a grant from the U.S. National Science Foundation (grant OPP-0133709), for which we are grateful. Efforts by the Organizing Committee, led by Tad Pfeffer and David Lubinski, made the event possible.
# Summary Agenda

## WEDNESDAY 10 MARCH 2004

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00</td>
<td>Icebreaker, Check in, &amp; Registration</td>
<td>RL-1 Rm. 269</td>
</tr>
</tbody>
</table>

## THURSDAY 11 MARCH 2004

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>8:00</td>
<td>Check-in &amp; Registration</td>
<td>RL-1 Rm. 269</td>
</tr>
<tr>
<td>8:40</td>
<td>Workshop Welcome &amp; Introduction</td>
<td>RL-3 Rm. 620</td>
</tr>
<tr>
<td>9:00</td>
<td>PARCS 1*</td>
<td></td>
</tr>
<tr>
<td>10:30</td>
<td>Morning Break</td>
<td></td>
</tr>
<tr>
<td>10:45</td>
<td>PARCS 2*</td>
<td></td>
</tr>
<tr>
<td>12:00</td>
<td>Lunch break</td>
<td>your choice</td>
</tr>
<tr>
<td>1:15</td>
<td>Special Talk: Radiocarbon Calibration</td>
<td>RL-3 Rm. 620</td>
</tr>
<tr>
<td>1:45</td>
<td>Iceland Marine</td>
<td></td>
</tr>
<tr>
<td>2:45</td>
<td>Afternoon Break 1</td>
<td></td>
</tr>
<tr>
<td>3:00</td>
<td>Iceland Terrestrial/Lacustrine</td>
<td></td>
</tr>
<tr>
<td>4:15</td>
<td>Afternoon Break 2</td>
<td></td>
</tr>
<tr>
<td>4:30</td>
<td>North Alaska, Beringia, and Antarctica</td>
<td></td>
</tr>
<tr>
<td>5:45</td>
<td>End of Day</td>
<td></td>
</tr>
<tr>
<td>6:00</td>
<td>Pizza Party (students only)</td>
<td>RL-1 Rm. 269</td>
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## FRIDAY 12 MARCH 2004

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30</td>
<td>Continental Breakfast provided</td>
<td>RL-1 Rm. 269</td>
</tr>
<tr>
<td>8:30</td>
<td>Posters</td>
<td>RL-1 2nd floor</td>
</tr>
<tr>
<td>11:30</td>
<td>Box Lunch provided</td>
<td>RL-1 Rm. 269</td>
</tr>
<tr>
<td>12:30</td>
<td>Greenland</td>
<td>RL-3 Rm. 620</td>
</tr>
<tr>
<td>2:45</td>
<td>Afternoon Break 1</td>
<td></td>
</tr>
<tr>
<td>3:00</td>
<td>E Canada Lacustrine</td>
<td></td>
</tr>
<tr>
<td>4:00</td>
<td>Afternoon Break 2</td>
<td></td>
</tr>
<tr>
<td>4:15</td>
<td>E Canada Glaciers and Cosmogenic Dating</td>
<td></td>
</tr>
<tr>
<td>5:30</td>
<td>End of Day</td>
<td></td>
</tr>
<tr>
<td>6:30</td>
<td>Dinner provided by Arctic Workshop</td>
<td>Koenig Alumni Center</td>
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<tr>
<td></td>
<td>Koenig Alumni Center</td>
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<td></td>
<td>CU-Boulder Main Campus</td>
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<td></td>
<td>1202 University Ave.</td>
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## SATURDAY 13 MARCH

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
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<tbody>
<tr>
<td>9:00</td>
<td>NW Canada</td>
<td>RL-1 Rm. 269</td>
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<tr>
<td>10:30</td>
<td>Morning Break</td>
<td></td>
</tr>
<tr>
<td>10:45</td>
<td>Europe, Russia, and More</td>
<td></td>
</tr>
<tr>
<td>11:30</td>
<td>Lunch break</td>
<td>your choice</td>
</tr>
<tr>
<td>1:00</td>
<td>Alaska &amp; W Canada</td>
<td>RL-1 Rm. 269</td>
</tr>
<tr>
<td>3:00</td>
<td>End of Meeting!</td>
<td></td>
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</table>

*PARCS = Paleoenvironmental ARCTic Sciences, an NSF-supported community performing research and developing science goals related to past climates and environments of the Arctic and sub-Arctic.*
## Detailed Agenda

### WEDNESDAY 10 MARCH 2004

<table>
<thead>
<tr>
<th>Time</th>
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<th>Location</th>
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<tbody>
<tr>
<td>5:00 - 8:00pm</td>
<td>Icebreaker, Check in, &amp; Registration</td>
<td>INSTAAR Conference Room, Bldg. RL-1, Rm. 269</td>
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### THURSDAY 11 MARCH 2004

<table>
<thead>
<tr>
<th>Time</th>
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<tr>
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<td>Check-in &amp; Registration</td>
<td>INSTAAR Conference Room, Bldg. RL-1, Rm. 269</td>
</tr>
<tr>
<td>8:40</td>
<td>Workshop Welcome &amp; Introduction</td>
<td>INSTAAR Auditorium, Bldg. RL-3, Rm. 620</td>
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<tr>
<td></td>
<td>James Syvitski (INSTAAR Director)</td>
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<td></td>
<td>Tad Pfeffer (Workshop Organizer)</td>
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<tr>
<td></td>
<td>Darrell Kaufman / Glen MacDonald (PARCS co-chairs)</td>
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**Oral Session PARCS 1**

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00</td>
<td>VARIABILITY IN SUMMER ARCTIC TEMPERATURE AND ARCTIC OSCILLATION OVER THE PAST 600 YEARS</td>
<td>HUGHEN, KONRAD; Huybers, Peter; High Resolution Working Group, PARCS</td>
</tr>
<tr>
<td>9:15</td>
<td>REPRESENTATIVENESS OF LONG-TERM COASTAL OCEAN OBSERVATIONS FROM THE FAEROE ISLANDS, ICELAND AND GREENLAND</td>
<td>MILES, MARTIN</td>
</tr>
<tr>
<td>9:30</td>
<td>SEASONAL CHARACTERIZATION OF DIATOMS IN THE LORD LINDSAY RIVER, BOOTHIA PENINSULA, NUNAVUT</td>
<td>STEWART, KAILEY A.; Lamoureux, Scott F.</td>
</tr>
<tr>
<td>9:45</td>
<td>CALIBRATING THE SEDIMENT RECORD OF LINNÉVATNET, SVALBARD, NORWAY: PRELIMINARY RESULTS OF A MODERN PROCESS STUDY</td>
<td>WERNER, AL; Roof, Steve R.; Kathan, Kasey M.; Pratt, Emily M.; Brigham-Grette, Julie; Powell, Ross D.; Retelle, Mike J.</td>
</tr>
<tr>
<td>10:00</td>
<td>A 1000-YEAR VARVED SEDIMENT RECORD FROM THE BROOKS RANGE, ALASKA</td>
<td>OSGOOD-KUTCHKO, BARBARA G.; Abbott, Mark B.; Finney, Bruce</td>
</tr>
<tr>
<td>10:15</td>
<td>LATE HOLOCENE PALEOMAGNETIC SECULAR VARIATION (PSV) FROM NUNAVUT, CANADA: DEVELOPMENT OF A DATING CURVE</td>
<td>STONER, JOSEPH S.; Francus, Pierre; Bradley, Raymond S.; Retelle, Michael J.; Abbott, Mark B.; Patridge, Whitney ; Channell, James ET.</td>
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</table>

### Morning Break

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<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
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<tbody>
<tr>
<td>10:30 - 10:45</td>
<td>Morning Break</td>
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</table>
**THURSDAY 11 MARCH 2004**

<table>
<thead>
<tr>
<th>Oral Session</th>
<th>PARCS 2</th>
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<tbody>
<tr>
<td>2</td>
<td>INSTAAR Auditorium, Bldg. RL-3, Rm. 620</td>
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<tr>
<td>Chair:</td>
<td>Darrell Kaufman</td>
</tr>
</tbody>
</table>

10:45 **CIRCUMARCTIC PEATLAND HISTORY AND GLOBAL ATMOSPHERIC METHANE**  
MACDONALD, GLEN M.; Smith, Larry C.; Kremenetski, Konstantine V.; Sheng, Yongwei; Beilman, Dave W.; Andrei, Velichko A.

11:00 **THE HOLOCENE THERMAL MAXIMUM ON NORTHEASTERN BAFFIN ISLAND**  
BRINER, JASON P.; Miller, Gifford H.; Francis, Donna R.; Axford, Yarrow L.

11:15 **THE RAPIDLY DISAPPEARING PLATEAU ICE CAPS OF CENTRAL BAFFIN ISLAND: WHERE WILL IT ALL END?**  
MILLER, GIFFORD; Briner, Jason; DeVogel, Steven

11:30 **MIDDLE HOLOCENE PALEOCEANOGRAPHY IN THE DENMARK STRAIT REGION**  
JENNINGS, ANNE E.; Stoner, Joe; Hall, Ian; Kristjánsdóttir, Gréta

11:45 **SEDIMENT AND MASS ACCUMULATION RATES ON THE ICELAND MARGIN OVER THE LAST 12,000 CALENDAR YEARS**  
ANDREWS, JOHN T.

12:00 - 1:15pm **Lunch break (location is your choice)**

**Special Talk**

<table>
<thead>
<tr>
<th>Radiocarbon Calibration</th>
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<tr>
<td>INSTAAR Auditorium, Bldg. RL-3, Rm. 620</td>
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<tr>
<td>Introduction: Gifford Miller</td>
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</table>

1:15 - 1:45pm **CALIBRATION OF THE 14C TIMESCALE AND CONSTRAINTS OF THE GLACIAL CARBON CYCLE**  
LEHMAN, SCOTT; Hughen, Konrad; Southon, John
### Oral Session 3: Iceland Marine

**Chair:** Chris Caseldine

**INSTAAR Auditorium, Bldg. RL-3, Rm. 620**

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
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<tbody>
<tr>
<td>2:00</td>
<td>TESTING OF THREE NEW COOL-WATER CALIBRATIONS FOR THE MG/CA PALEOTHERMOMETER SUGGESTS REDUCED INFLOW OF ATLANTIC WATER ONTO THE N-ICELAND SHELF IN THE PAST 2000 YRS</td>
<td>KRISTJÁNSDÓTTIR, GRÉTA B.; Jennings, Anne E.; Lea, David W.</td>
</tr>
<tr>
<td>2:15</td>
<td>OCEANOGRAPHIC CHANGES AROUND 8 KYR. BP ON THE NORTHERN ICELANDIC SHELF INTERPRETED FROM SEDIMENTOLOGICAL AND FORAMINIFERAL FAUNAL ANALYSES IN CORE MD992275</td>
<td>SØNDERGAARD, METTE KB.; Eiríksson, Jón; Knudsen, Karen Luise</td>
</tr>
<tr>
<td>2:30</td>
<td>CURRENTS AND CLIMATE ON THE NORTHWEST ICELAND SHELF IN THE LATE QUATERNARY (10-30 KA CAL BP): RECONSTRUCTION BASED ON FORAMINIFERAL AND SEDIMENTOLOGICAL RESEARCH</td>
<td>ÓLAFSDÓTTIR, SAEDÍS; Geirsdóttir, Áslaug; Jennings, Anne E.; Andrews, John, T.</td>
</tr>
</tbody>
</table>

#### Afternoon Break 1

### Oral Session 4: Iceland Terrestrial/Lacustrine

**Chair:** John Andrews

**INSTAAR Auditorium, Bldg. RL-3, Rm. 620**

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
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</thead>
<tbody>
<tr>
<td>3:00</td>
<td>HUMAN ECOLOGY, LOCAL KNOWLEDGE, AND INTERDISCIPLINARY RESEARCH IN MYVATN, NORTHERN ICELAND</td>
<td>OGILVIE, ASTRID EJ.; McGovern, Thomas H.</td>
</tr>
<tr>
<td>3:15</td>
<td>TERRESTRIAL RESPONSES TO HOLOCENE CLIMATIC FORCING - EXAMPLES FROM N/NW ICELAND</td>
<td>CASELDINE, CHRIS; Langdon, Pete; Holmes, Naomi</td>
</tr>
<tr>
<td>3:30</td>
<td>GLACIER MAXIMA, MINIMA AND CLIMATE IN TRÖLLASKAGI, NORTHERN ICELAND</td>
<td>CASELY, ANDREW F.</td>
</tr>
<tr>
<td>3:45</td>
<td>SEISMIC NETWORK ENABLES ASSESSMENT OF FLOOD DYNAMICS BENEATH AN ICELANDIC GLACIER</td>
<td>ROBERTS, MATTHEW J.; Björmsson, Helgi; Pálsson, Finnur; Gudmundsson, Gunnar B.</td>
</tr>
<tr>
<td>4:00</td>
<td>TRAINING MIDGES: CONTEMPORARY CHIRONOMID-ENVIRONMENT RELATIONSHIPS FROM NW ICELAND</td>
<td>LANGDON, PETER G.</td>
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</table>

#### Afternoon Break 2
<table>
<thead>
<tr>
<th>Time</th>
<th>Session Details</th>
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</thead>
</table>
| 4:30  | **WALRUSES, SEALS, AND CLIMATE CHANGE**  
KELLY, BRENDAN P. |
| 4:45  | **SPATIAL ANALYSIS OF COASTAL EROSION OVER FIVE DECADES NEAR BARROW, ALASKA**  
MANLEY, WILLIAM F. |
| 5:00  | **MODELING LONGSHORE TRANSPORT AND COASTAL EROSION DUE TO STORMS AT BARROW, ALASKA**  
PECKHAM, SCOTT D.; Syvitski, James PM. |
| 5:15  | **HOLOCENE VEGETATION, FIRE, AND CLIMATE HISTORY FROM THE SOUTHERN BROOKS RANGE, ALASKA**  
HIGUERA, PHILIP E.; Brubaker, Linda B.; Anderson, Patricia M.; Hu, Feng Sheng; Clegg, Ben; Brown, Tom; Rupp, Scott |
| 5:30  | **RADIOGENIC ISOTOPE PROVENANCE STUDIES OF GLACIAL TILLS IN ROSS SEA AND VICINITY, ANTARCTICA**  
FARMER, G. LANG; Licht, Kathy; Andrews, John T.; Swope, R. Jeffrey |
<p>| 5:45  | <strong>End of the Day</strong> |
| 6:00  | <strong>Pizza Party (students only), INSTAAR Bldg. RL-1, Rm. 269</strong> |</p>
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Details</th>
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<tbody>
<tr>
<td>8:30 am -</td>
<td>Continental Breakfast provided</td>
<td>INSTAAR, Bldg. RL-1, Rm. 269</td>
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<td></td>
<td></td>
<td>(Box lunch provided at end of poster session)</td>
</tr>
<tr>
<td>8:30 - 11:30 am</td>
<td>Posters</td>
<td>INSTAAR, Bldg. RL-1, 2nd Floor</td>
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<td></td>
<td></td>
<td>Chair: William Manley</td>
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</tbody>
</table>

### Cryosphere Posters

1. **AN ATTEMPT TO ESTIMATE WATER BALANCE COMPONENTS IN PAN-ARCTIC**  
   Dyrgerov, Mark B.; Balaeva, Vera; Pichugina, Yelena

2. **A MASS BALANCE PROFILE ALONG THE WESTERN SLOPE OF GREENLAND**  
   Albert, Todd H.

3. **AN AUTONOMOUS WIRELESS SENSOR NETWORK FOR HARSH-ENVIRONMENT DATA ACQUISITION**  
   Fatland, Dennis R.; Anandakrishnan, Sridhar; Grissom, Brad

4. **GLACIAL ARCHEOLOGY: A NEW RESEARCH FRONTIER**  
   Dixon, E. James; Manley, William F.; Lee, Craig M.

### Glacial Geology Posters 1

5. **ALASKAN TEMPERATURE CHANGE OVER THE PAST MILLENNIUM: SOLAR FORCING MODULATED BY THE ARCTIC AND PACIFIC DECADAL OSCILLATIONS**  
   Wiles, Gregory C.; D'Arrigo, Rosanne D.; Villalba, Ricardo; Barclay, David J.; Calkin, Parker E.

6. **TREE-RING AND HISTORICAL EVIDENCE FOR A LARGE AND RAPID ADVANCE OF AN ALASKAN TIDEWATER GLACIER**  
   Barclay, David J.; Barclay, Julie L.; Calkin, Parker E.; Wiles, Gregory C.

7. **TREE-RING DATED 1000-YEAR ADVANCE OF COLUMBIA GLACIER**  
   Beckwith-LAube, Matthew J.; Wiles, Greg C.; Calkin, Parker E.; Post, Austin

8. **TILTED TREES AND LOST LAKES: DENDROGLACIOLOGICAL INSIGHTS INTO LITTLE ICE AGE GLACIER ACTIVITY IN THE NORTHEAST ST. ELIAS MOUNTAINS, YUKON TERRITORY**  
   Reyes, Alberto V.; Luckman, Brian H.; Smith, Dan J.; Jensen, Britta J.; Clague, John J.

9. **A POTENTIAL MODEL FOR PEDAGOGICAL TECHNIQUES IN UNDERGRADUATE FIELD GEOLOGY: AN EXAMPLE FROM SOUTH-CENTRAL ALASKA**  
   Vogan, Nathan W.; Lennon, Brendan; Robinson, Stephen D.; Lamoureux, Scott

10. **LOCAL ICE ON WESTERN MELVILLE ISLAND, NWT, CANADA**  
    Nixon, ChanTEL F.; England, John H.
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<thead>
<tr>
<th>FRIDAY 12 MARCH 2004</th>
<th>Glacial Geology Posters 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 ORIGIN OF THE EAST-WEST ASYMMETRY OF PALEO-GLACIERS IN THE SIERRA NEVADAS</td>
<td>KESSLER, MARK A.; Anderson, Robert S.; Stock, Greg M.</td>
</tr>
<tr>
<td>12 PREDICTING SEDIMENT FLUX TO THE ADRIATIC SEA; THE SIGNIFICANCE OF THE LGM ALPINE GLACIERS</td>
<td>KETTNER, ALBERT J.; Syvitski, James PM.</td>
</tr>
</tbody>
</table>

**Paleoceanography Posters**

| 13 HOW DYNAMIC ARE FLUVIAL-DELTAIC SYSTEMS DRAINING LAND-ICE? A CASE-STUDY OF CLYDE RIVER, BAFFIN ISLAND | OVEREEM, IRINA; Briner, Jason P.; Kettner, Albert J. |
| 14 SEDIMENTATION IN TEMPELFJORDEN, SPITSBERGEN, HIGH ARCTIC - PRELIMINARY RESULTS | FORWICK, MATTHIAS; Vorren, Tore O. |
| 15 LATE HOLOCENE PALEOCEANOGRAPHIC VARIATIONS OF ISAFJARDARDJUP, NW-ICELAND | QUILLMANN, URSULA |

**Paleolimnology Posters 1**

<p>| 16 INVESTIGATING HOLOCENE CLIMATE CHANGE IN GLACIAL LAKE HVITÁRVATN, ICELAND | BLACK, JESSICA L.; Miller, Gifford H.; Geirsdóttir, Áslaug |
| 17 EVIDENCE OF JÖKULHLAUPS AND SEISMIC INTERPRETATION OF HESTVATN, SOUTHERN ICELAND | HANNESDÓTTIR, HRAFNHILDUR; Geirsdóttir, Áslaug ; Miller, Gifford H. |
| 18 TESTING A NEW ISOTOPIC PALEO-THERMOMETER IN A MULTI-PROXY CONTEXT: CHIRONOMID d18O AS A PROXY FOR HOLOCENE TEMPERATURE CHANGE IN ICELAND | AXFORD, YARROW; Miller, Gifford H.; Wooller, Matthew J.; Francis, Donna; Geirsdóttir, Áslaug |
| 19 THE USE OF CHIRONOMIDS IN RECONSTRUCTING HOLOCENE PALAEOCLIMATE IN NORTHWEST ICELAND | HOLMES, NAOMI |
| 20 A CHIRONOMID BASED PALAEOENVIRONMENTAL RECONSTRUCTION OF ANTIFREEZE POND IN YUKON, CANADA | Barley, Erin M.; WALKER, IAN R. |
| 21 COMPARISON OF SEISMIC STRATIGRAPHY FROM TWO LAKES IN EASTERN BERINGIA | HILL, ERICA L.; Abbott, Mark; Finney, Bruce |</p>
<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Authors</th>
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<tbody>
<tr>
<td>22</td>
<td>LIMNOLOGICAL AND PALEOLIMNOLOGICAL INVESTIGATIONS OF ENVIRONMENTAL CHANGE FROM MELVILLE ISLAND, NU/NWT, CANADIAN HIGH ARCTIC</td>
<td>Keatley, Bronwyn E.; Douglas, Marianne SV.; Smol, John P.</td>
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<tr>
<td>23</td>
<td>MARKED 20TH CENTURY STRATIGRAPHICAL CHANGES IN LAKE SEDIMENTS FROM WESTERN SPITSBERGEN</td>
<td>Holmgren, Sofia; Wolfe, Alex P.; Ingolfsson, Olafur</td>
</tr>
<tr>
<td>24</td>
<td>LATE QUATERNARY VEGETATION HISTORY AND CLIMATE RECONSTRUCTION INFERRED FROM WESTERN ALASKA AND NORTHERN YUKON LAKES</td>
<td>Kurek, Joshua; Cwynar, Les C.</td>
</tr>
<tr>
<td>25</td>
<td>THE CAPE BOUNTY INTEGRATED PALEOClimATE EXPERIMENT: CALIBRATING THE SEDIMENTARY AND SUBFOSSIL RECORD CONTAINED IN VARVES</td>
<td>Lamoureux, Scott F.; Cockburn, Jaclyn MH.; Stewart, Kailey A.; Forbes, Andrew C.; Francus, Pierre</td>
</tr>
<tr>
<td>26</td>
<td>DESIGNING A SEMI-AUTOMATED AND REMOTE SYSTEM TO RETRIEVE VARVED IMAGES FROM THIN-SECTIONS AT THE SCANNING ELECTRON MICROSCOPE</td>
<td>Francus, Pierre</td>
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<td>Selbie, Daniel T.; Finney, Bruce P.; Lewis, Bert; Smol, John P.</td>
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<td>A NEW METHOD TO RECONSTRUCT BARK BEETLE OUTBREAKS: RECURRENT INTERVALS AND HISTORY OF SPRUCE BARK BEETLE (Dendroctonus rufipennis) INFESTATION IN SOUTHWEST YUKON, CANADA</td>
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#### Geomorphology Posters

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<td>Roberts, Matthew J.; Stefánsson, Ragnar; Halldórsson, Páll</td>
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FRIDAY 12 MARCH 2004

11:30-12:30  Box Lunch provided
INSTAAR Bldg. RL-1, Rm. 269

Oral Session 6  Greenland
INSTAAR Auditorium, Bldg. RL-3, Rm. 620
Chair: Tad Pfeffer

12:30  HOLOCENE LAKE ONTOGENY IN RELATION TO CLIMATIC FORCING AND
CATCHMENT DEVELOPMENT IN THE KANGERLUSSUAQ REGION, WEST
GREENLAND
PERREN, BIANCA B.; Anderson, N. John; Birks, Hilary H.; Douglas, Marianne SV.

12:45  A HIGH RESOLUTION CLIMATE RECORD FROM THE NORTHGRIIP DEEP ICE
CORE
SCHMIDT, KAREN G.; Dahl-Jensen, Dorthe; Johnsen, Sigfús J.; NorthGRIIP members

1:00  PETERMANN GLETSCHER'S FLOATING TONGUE IN NORTHWESTERN
GREENLAND: PECULIAR SURFACE FEATURES, BOTTOM MELT CHANNELS,
AND MASS BALANCE ASSESSMENT
STEFFEN, KONRAD; Cullen, Nicolas; Huff, Russel; Stewart, Craig; Rignot, Erioc

1:15  SURFACE ABLATION ON A FLOATING ICE TONGUE IN NORTHERN
GREENLAND
CULLEN, NICOLAS J.; Huff, Russell; Steffen, Konrad

1:30  SPATIAL TEMPORAL DISTRIBUTION OF GREENLAND MELT ANOMALIES
HUFF, RUSSELL D.; Steffen, Konrad

1:45  CYCLONE OCCURRENCE IN THE NORTH ATLANTIC: IMPACTS ON GREENLAND
ICE SHEET MELT CYCLES 1979-2002
MCALLISTER, MOLLY J.; Huff, Russell

2:00  LONG DISTANCE POLLEN TRANSPORT TO SOUTHERN GREENLAND: IS
THERE A REGULAR PATTERN?
ROUSSEAU, DENIS-DIDIER ; Schevin, Patrick ; Duzer, Danielle ; Jolly, Dominique ;
Cambon, Genevieve

2:15  A VALIDATION OF THE MODIS CLOUD MASK OVER GREENLAND
STARKWEATHER, SANDY; Steffen, Konrad

2:30  OZONE UPTAKE TO POLAR AND MID-LATITUDE SNOWPACKS
BOCQUET, FLORENCE; Rick, Ursula K.; Helmig, Detlev

2:45 - 3:00  Afternoon Break 1
### E Canada Lacustrine

**Chair:** Gifford Miller

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<td>3:00</td>
<td><strong>ARE CURRENT RATES OF ATMOSPHERIC NITROGEN DEPOSITION INDUCING BIOGEOCHEMICAL Shifts IN LAKES OF THE EASTERN CANADIAN ARCTIC?</strong>&lt;br&gt;WOLFE, ALEXANDER P.; Cooke, Colin A.</td>
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<td>3:15</td>
<td><strong>ASYNCHRONOUS ECOLOGICAL RESPONSES TO CLIMATIC CHANGE IN CANADIAN HIGH ARCTIC LAKES AND PONDS</strong>&lt;br&gt;ANTONIADES, DERMOT; Douglas, Marianne SV.; Smol, John P.</td>
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<tr>
<td>3:30</td>
<td><strong>QUANTITATIVE PALEOClimATE RECONSTRUCTION FROM POLLEN ASSEMBLAGES PRESERVED IN ARCTIC LAKE SEDIMENTS</strong>&lt;br&gt;FRÈCHETTE, BIANCA; de Vernal, Anne; Wolfe, Alexander P.; Fredskild, Bent; Kerwin, Micheal W.; Miller, Gifford H.; Richard, Pierre JH.</td>
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<tr>
<td>3:45</td>
<td><strong>CLIMATE CHANGES AND EVOLUTION OF NORDIC ECOSYSTEMS OF CANADA</strong>&lt;br&gt;BHIRY, NAJAT</td>
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#### 4:00 - 4:15 Afternoon Break 2

### E Canada Glaciers and Cosmogenic Dating

**Chair:** Jason Briner

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<td>4:15</td>
<td><strong>RECENT CHANGES IN THE ICE CAPS AND GLACIERS OF CANADA'S ARCTIC ISLANDS</strong>&lt;br&gt;SHARP, MARTIN; Copland, Luke; Burgess, David ; Williamson, Scott; Filbert, Katie ; Cawkwell, Fiona</td>
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<tr>
<td>4:30</td>
<td><strong>GLACIER FLUCTUATIONS AND LICHEN SIZE-FREQUENCY DISTRIBUTIONS (NUNAVUT - CANADA)</strong>&lt;br&gt;MERCIER, GENEVIEVE; Lauriol, Bernard</td>
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<td>4:45</td>
<td><strong>TRIMLINES AND RECENTLY EXPOSED TERRAIN AS INDICATORS OF RAPID CLIMATIC CHANGE IN THE QUEEN ELIZABETH ISLANDS, ARCTIC CANADA</strong>&lt;br&gt;WOLKEN, GABRIEL</td>
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<td>5:00</td>
<td><strong>LATE FOXE GLACIATION OF THE ASTON LOWLAND, BAFFIN ISLAND, NUNAVUT: SUPPORT FOR AN INTERMEDIATE ICE EXTENT IN THE EASTERN CANADIAN ARCTIC</strong>&lt;br&gt;COULTHARD, ROY D.; Davis, P. Thompson; Briner, Jason P.; Miller, Gifford H.</td>
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<td>5:15</td>
<td><strong>CONSIDERATIONS FOR THE DEVELOPMENT OF THE UNIVERSITY OF ALBERTA COSMOGENIC ISOTOPE LABORATORY</strong>&lt;br&gt;DOUPÈ, JONATHAN P.; England , John H.; Litherland, A.E.; Zhao, X.-L.</td>
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#### 5:30 End of Day

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**6:30 - 10:00pm**<br>Dinner provided by Arctic Workshop<br>Koenig Alumni Center, CU-Boulder Main Campus, 1202 University Ave.<br>(shuttle service provided from Boulder Inn to Koenig)
### SATURDAY 13 MARCH

**Oral Session**

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<td>9:00am</td>
<td>PACKRATS OF BERINGIA: PALEOECOLOGY OF SMALL MAMMAL MIDDENS IN CENTRAL YUKON</td>
<td>ZAZULA, GRANT D.; Mathewes, Rolf W.; Froese, Duane G.; Storer, John E.; Westgate, John A.; Sanborn, Paul T.</td>
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<td>9:15</td>
<td>RELICT MIDDLE PLEISTOCENE PERMAFROST IN CENTRAL YUKON TERRITORY</td>
<td>FROESE, DUANE G.; Westgate, John A.; Preece, Shari J.; Mayer, Bernhard; Zazula, Grant D.; Reyes, Alberto V.</td>
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<td>9:30</td>
<td>DECADAL HYDROClimatic Variability as evidenced by the sedimentary record of mirror lake, northwest territories, canada</td>
<td>TOMKINS, JESSICA D.; Lamoureux, Scott F.</td>
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<td>9:45</td>
<td>TREE-RINGS AS A HYDROMETEOROLOGICAL PROXY IN THE CARCROSS DESERT, YUKON TERRITORY, CANADA</td>
<td>YOUNGBLUT, DON; Pisaric, Michael FJ.</td>
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<td>10:00</td>
<td>POTENTIAL CLIMATE CHANGE IMPACTS AND ADAPTATION FOR INFRASTRUCTURE IN NORTHERN COMMUNITIES UNDERLAIN BY PERMAFROST</td>
<td>ROBINSON, STEPHEN D.; Couture, Rejean; Burgess, Margo M.; Smith, Sharon L.</td>
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<td>10:15</td>
<td>CENTENNIAL PHASING OF PACIFIC DECADAL VARIABILITY IN NORTHWEST NORTH AMERICA DURING THE PAST SEVEN CENTURIES</td>
<td>COCKBURN, JACLYN MH.; Lamoureux, Scott F.</td>
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**Morning Break**

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<td>HUMAN EVOLUTION AND THE COLONIZATION OF THE HIGHER LATITUDES</td>
<td>HOFFECKER, JOHN F.</td>
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<td>11:00</td>
<td>TOWARDS A TEPHROCHRONOLOGY FRAMEWORK FOR THE LAST GLACIAL/INTERGLACIAL TRANSITION IN SCANDINAVIA AND THE FAROE ISLANDS</td>
<td>WASTEGÅRD, STEFAN; Davies, Siwan M.; Turney, Chris SM.; Wohlfarth, Barbara</td>
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<td>11:15</td>
<td>THE CELTIC DEEP PALAEOLAKE: EVIDENCE FOR A LARGE DEGLACIAL LACUSTRIANE SYSTEM AT THE SOUTHERN MARGIN OF THE BRITISH ICE-SHEET AND IT’S IMPLICATIONS FOR DEGLACIAL SEA-LEVELS ON THE NW EUROPEAN CONTINENTAL SHELF</td>
<td>FURZE, MARK FA.</td>
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**Lunch break (location is your choice)**
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<td>1:00</td>
<td>INTRABASINAL VARIABILITY OF HOLOCENE TEPHRA IN A SMALL KETTLE LAKE, LORRAINE LAKE, UPPER COOK INLET, ALASKA</td>
<td>Kathan, Kasey; Werner, Alan; Kaufman, Darrell; de Fontaine, Christian; Kingsbury, Esther</td>
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<td>1:15</td>
<td>A COMPLEX ORIGIN FOR LATE QUATERNARY LOESS IN CENTRAL ALASKA, USA</td>
<td>Muhs, Daniel R.; Budahn, James R.</td>
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<td>1:30</td>
<td>A TIME-TANGRESSIVE TILL ACCRETION AND BED DEFORMATION HYPOTHESIS</td>
<td>Larsen, Nicolaj K.; Piotrowski, Jan A.; Kronborg, Christian; Wysota, Wojcieck</td>
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<td>1:45</td>
<td>SLIDING AND THE GROWTH AND DECAY OF CAVITIES BENEATH AN ALPINE GLACIER: RESULTS FROM BENCH GLACIER, ALASKA</td>
<td>Anderson, Robert S.; Anderson, Suzanne P.; MacGregor, Kelly R.; Waddington, Edwin D.; O'Neel, Shad; Riihimaki, Catherine A.; Loso, Michael G.</td>
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<td>2:00</td>
<td>A FORCE BALANCE ANALYSIS OVER THE LOWER REACHES OF COLUMBIA GLACIER, ALASKA DURING ITS RAPID RETREAT</td>
<td>O'Neel, Shad; Pfeffer, Tad; Krimmel, Robert; Meier, Mark</td>
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<td>TESTING A GLACIAL EROSION RULE USING STEP HEIGHTS OF HANGING VALLEYS, JASPER NATIONAL PARK, CANADA</td>
<td>Amundson, Jason M.; Iverson, Neal R.</td>
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<td>THE MECHANICAL-CHEMICAL WEATHERING LINKAGE: GLACIER EROSION AND SOLUTE FLUXES</td>
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<td>2:45</td>
<td>COLUMBIA GLACIER, TIDEWATER INSTABILITY AND UPGLACIER PROPAGATION OF KINEMATIC WAVES</td>
<td>Pfeffer, W Tad.; O'Neel, Shad; Krimmel, Robert M.</td>
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<td>3:00</td>
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Thanks for participating!
Abstracts

A MASS BALANCE PROFILE ALONG THE WESTERN SLOPE OF GREENLAND

ALBERT, TODD H.

University of Colorado; todd.albert@colorado.edu

The Pakitsoq region (west-central Greenland) is presently one of the most intensely monitored portions of the Greenland Ice Sheet, and is the major focus of a recent PARCA initiative. A profile of 11 autonomous measurement stations has been established along a transect between Summit, Greenland, and the margin of the ice sheet just north of the Jakobshaven Isbrae. Data from these stations has been supplemented with shallow pit and ice core data from 174 sites in the area between Summit and the western margin to establish a mass balance profile along the transect. Each component of the mass balance is presented, and spatial and temporal variability is discussed.
Glacial erosion plays an important role in landscape evolution, geochemical cycling, and uplift of mountain belts. Models of these processes are hindered by limited knowledge of the factors affecting glacial erosion rates. Glaciers erode bedrock primarily through abrasion and quarrying. Mechanical models demonstrate that abrasion rates depend on sliding velocity. There is little consensus, however, regarding the factors that control rates of quarrying, arguably the most important mechanism of erosion. Studies of quarrying mechanics suggest that quarrying rates should depend on water-pressure fluctuations at glacier beds. For convenience, however, most modelers neglect the role of water-pressure fluctuations and assume that erosion rates are a simple function of basal sliding velocity. Thus, there is strong motivation to test, over the large time and length scales of erosion models, if erosion rates can be adequately characterized with a simple rule based on sliding velocity.

Our hypothesis is that the difference in elevation between the floors of hanging valleys and their trunk valleys, herein called the step height, can be used to determine whether long-term erosion rates are proportional to sliding velocity. Hanging valleys form because tributary glaciers erode bedrock more slowly than trunk glaciers. Step height, which is easily measurable, is therefore an indicator of relative erosion rate. Thus, if the sliding velocities of former tributary and trunk glaciers can be estimated, step heights can be used to determine if and how sliding velocity and erosion rate are related.

We use a well-accepted approximation for basal shear stress, a widely applied empirical rule that relates basal shear stress to sliding speed, and mass continuity to express the sliding velocity of a valley glacier in terms of its area, width, and slope. This expression, when substituted into a power-law erosion rule \( \frac{de}{dt} = C_1 U_s^n \), where \( \frac{de}{dt} \) is erosion rate, \( U_s \) is sliding speed, and \( C_1 \) and \( n \) are constants, yields the step height as the product of a constant \( C_2 \) and a variable \( Y \) that depends on drainage areas, widths, and slopes of tributary and trunk glaciers. Embedded in \( C_2 \) are factors such as accumulation rate, the fraction of glacier speed due to sliding, effective normal stress on the bed and \( C_1 \), which are assumed to be uniform and the same for tributary and trunk glaciers.

We studied 46 hanging valleys and their three trunk valleys in southern Jasper National Park, Alberta, Canada. The drainage areas, widths, and slopes of the glaciers that occupied these valleys were estimated from topographic maps and used to calculate \( Y \). Step heights for each hanging valley were measured and then linearly correlated with \( Y \) to test the erosion rule. The correlation was weak for the hanging valleys considered as a single group for all values of \( n \), but was quite strong for hanging valleys of a particular trunk valley. For two of the three sets of hanging valleys, the correlation was optimized when \( n=1 \), yielding coefficients of determination of 0.52 and 0.65. For the other set, a coefficient of determination of 0.79 was achieved when \( n=2 \). The correlation between step heights and values of \( Y \) was surprisingly strong, given the likely spatial variability of the many parameters lumped in the constant \( C_2 \). This spatial variability was probably responsible for the weak correlation when hanging valleys were considered as a single group.
Our results indicate that erosion rate is indeed proportional to sliding velocity and that a linear or mildly nonlinear erosion rule accounts best for the step heights of hanging valleys. Sliding velocity, therefore, apparently controls or limits quarrying rates. This result is consistent with the likely effect of water-pressure fluctuations on subglacial rock fracture if quarrying rates are limited, not by crack-growth rates, but by the removal rate of detached rock fragments from the bed.
We report the spatial and temporal pattern of sliding on the 7-km long Bench Glacier, Alaska. Using five continuously recording GPS receivers at monuments drilled into the surface ice, distributed at 1 km spacing along the glacier centerline, we documented surface ice motion over 50 days during summer 2002. Surface speeds in two previous winters constrain the motion components associated with ice deformation and any steady basal motion, allowing isolation of the sliding speed history. We observed two speedup events bracketing two weeks of steady slow sliding. The first event did not correspond to a meteorological trigger, was more subtle than the second, and propagated up-glacier at a rate of several hundred meters per day. The second event coincides with a warm up-valley wind, which enhanced the melt rate of the glacier surface. Sliding speeds in this event reached 30 cm/day, and began almost simultaneously at all sites in the ablation area. Both the horizontal and vertical displacement time series can be explained with growth by sliding, and collapse by viscous creep, of cavities in the lee of inclined steps in the bedrock bed. We posit that effective pressure, averaged over some large area of the bed, is inversely proportional to the sliding speed. This effective pressure then controls the collapse rate of cavities, whose dimensions are estimated from a plausible, stepped-bed geometry. This model explains well the horizontal and vertical surface displacement history through the first event and beginning of the second event. The vertical record demands a substantial and abrupt drop in water pressure that departs from the posited sliding-effective pressure relationship. We argue that this pressure drop reflects establishment of efficient subglacial drainage, as manifested in a nearly simultaneous step-increase in water discharge in the exit stream. The establishment of an efficient conduit system defeats sliding; its maintenance inhibits further sliding over the remainder of the summer. This behavior is not unique to Bench Glacier. The general relationship between sliding and the state of the hydrological system we have deduced from Bench Glacier is supported by analysis of the trajectories of surface targets on the much larger Kennicott Glacier during its annual outburst flood.
Field studies suggest a linkage between high physical erosion rates and rates of chemical denudation. Temperate glaciers are responsible for exceptionally high erosion rates, in which this linkage should be clear. Silicate-weathering fluxes from glaciers are consistent with the low temperature, dilute water chemistry, and high mineral surface area production in these environments. Low temperatures reduce silicate-weathering rates sufficiently to explain the difference between silica fluxes from glaciers and from non-glacierized basins. By analogy to laboratory flow-through reactors, glacial solute flux should depend on surface area production and mineral weathering rate constants. The surface area production is significant: a typical glacial erosion rate and grain-size distribution produces on the order of 10^4 km^2 of mineral surface area per square kilometer per year. Mineral weathering rates decline with surface age; hence this new surface area is highly reactive. Application of the “reactor” model yields results consistent with measured solute fluxes for the example of Bench Glacier, Alaska. In part this reflects the far-from-equilibrium conditions in glacial runoff, so that mineral weathering rate constants are not limited by saturation state. In glacial catchments, both annual silica fluxes and mean concentrations increase with water discharge. This suggests that mineral surface area increases with water discharge from glaciers, an effect plausibly linked to erosion rates. A small set of glaciers for which both erosion rate and silica flux data are available support the idea that production of new reactive mineral surface area by glacial erosion drives silicate-weathering fluxes.
SEDIMENT AND MASS ACCUMULATION RATES ON THE ICELAND MARGIN
OVER THE LAST 12,000 CALENDAR YEARS

ANDREWS, JOHN T.

University of Colorado; andrewsj@colorado.edu

Because Iceland was finally deglaciated only 8-9 14C ka, has abundant precipitation in the form of both rain and snow, has high relief, and easily erodable soils, it is reasonable to suggest a priori that the rates of late glacial/Holocene sediment transfer from land to sea would be efficient and high. Furthermore, observations from other formerly glaciated continental margins, plus theory of sediment transport, predicts that the rates of sediment accumulation will decrease in a non-linear fashion away from the coastline. The Iceland shelf is crossed by 18 large troughs with depths between 200 and 600 m. The intervening banks are 100 m or so. The shelf area ≤ 200 m water depth is similar to the area of Iceland, or around 110,000 km². The troughs represent about 20% of the shelf area and are the main sites of Holocene sediment accumulation. However, numerous fjords provide efficient sediment traps for glacial and fluvially transported sediments. Data on sediment accumulation rates (SAR, cm/ky) and total mass accumulation rates (MAR, g/cm².ky) from 40 sites around the Iceland margin (Fig. 1) between 18° and 29°W and 63° and 67°N are presented for the last 10,000 radiocarbon years. The 9,000 14C yrs Saksunarvatn tephra provides a regional isochron for deposition especially on the N-central and NW margins of Iceland. Dates from core tops vary in age from modern to as old as 1500 yrs, probably associated in many cases with sediment retrieval during the coring process. The sites vary in location from being within fjords, to those lying within large cross-shelf troughs, and finally to sites at the base of the NW Iceland continental slope (Denmark Strait). Data on average dry sediment density and carbonate weight percentage are available for 33 cores, as are data on the consolidation of sediment with depth. The MAR carbonate represents a measure of marine productivity and/or sediment transport and is subtracted from the MARtotal to obtain MARsediment. The contribution of carbonate to the sediment pile varies spatially, and temporally, but can be as high, on average, as ~40%. Over the last 10 14C ka SAR has varied from ≥650 to 3 cm/ky with a median value of 44 cm/ky; thus “on average” 22 yrs is represented in one centimeter of sediment whereas at some sites 1 cm of sediment represents only ~2 years of accumulation (Andrews et al., 2003a) Therefore, the Iceland sediment packages will archive multi-year to multidecadal records of paleo-environmental conditions around the Iceland margin. There is an extremely strong predictive association (r²=0.9) between estimates of MAR derived from integrating level by level in a core and those determined by simply using the average sediment density times core length. For the 33 cores where we have sufficient data the median MAR is 222 with a variation between 19 and 3150 g/cm².ky. The amount of sediment accumulated between 10 and 9 14C ka B.P., at a time when deglaciation was still underway, divided by the average SAR/ky for the last 9 14C ka B.P. varies from around 2 to >20, indicating that at many sites the rate of sediment accumulation over the last 10 14C ka B.P. was not monotonic but decreased significantly after the retreat of the Iceland Ice Sheet. Spatially the smallest difference between sediment accumulation 9-10 14C ka B.P. /SAR <9/ky is in the north-central troughs, and the largest difference occurs in outer Djupall (NW Iceland).

Although we do not have adequate, nor representative, coverage of Icelandic fjords in the sites from Vestfirdir the sediment accumulation within this fjords is not substantially high than sites from the inner shelf. Indeed, the sites with the highest rates of Holocene sediment accumulation are the troughs which lie 10’s km outside the coastline and the sites where maximum sediment accumulation might be predicted based on fluvially and glacially transported sediments to fjord heads. The disconnect in SAR and MAR values from the fjords/inner shelf troughs, to the mid/outer shelf troughs suggests extensive sediment reworking and transport on
the shallow shelf banks, leading to the accumulation of “drift-like” sediment bodies in select locations (Andrews et al., 2003b).

In 1997 the 3.5 kHz system was employed in several of the troughs off N and NW Iceland. A prominent acoustic reflector, subsequently identified as the basaltic Saksunarvatn tephra, allows us to track variations in SAR along the troughs. This exercise indicates significant spatial variations in SAR that cannot be explained by a simple land‡sea sediment transfer, but rather points to the accumulation in certain troughs of what might be termed “shelf sediment drifts” with maximum accumulations over the last 10 cal ka of 50 m or so of sediment.


Fig 1. Location of core sites around N, NW, and SW Iceland
ASYNCHRONOUS ECOLOGICAL RESPONSES TO CLIMATIC CHANGE IN CANADIAN HIGH ARCTIC LAKES AND PONDS

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The Canadian High Arctic is recognized as a critical reference area for the detection of global environmental change, as research indicates that it has been disproportionately affected by recent climatic change. Predicted future climate change is also expected to have dramatic effects on lakes and ponds in the Canadian High Arctic. Because there is a paucity of historical climate data from this large region, proxy records developed from paleolimnological techniques are crucial to understanding the climate history of the High Arctic. Studies have been published detailing distinct qualitative changes in diatom sedimentary records over the last ca. 200 years from several high arctic sites. However, almost no studies exist which apply transfer functions to quantify these environmental changes.

Diatom inference models were constructed using samples collected from ninety lakes and ponds from Ellef Ringnes, Ellesmere, and Prince Patrick islands. These sites range in latitude from 76°13' to 82°31' N, and from 61°31' to 119°21' W longitude, and, despite broad similarities in climate regime across this area, the diversity of geological and vegetational characteristics resulted in large limnological gradients (i.e. pH 5.1-8.9, median 7.9, conductivity 10-2130 µS, median 162 µS, TPU 3.4-256.9 µg/L, median 11.6 µg/L). Transfer functions for pH (RMSEP = 0.40, r2boot = 0.77) and conductivity (RMSEP = 0.28, r2boot = 0.70) were developed using this biological and limnological dataset.

An examination of sediment cores from Isachsen, Ellef Ringnes Island, and Alert, Ellesmere Island, revealed marked shifts in the stratigraphic record in both regions. Assemblages with relatively few species dominated the lower portions of all sediment cores examined. These dominant species diminished in importance within the upper several centimetres of the cores, and were replaced by new assemblages with much greater species diversity.

The application of diatom transfer functions to these cores suggested relatively stable pH and conductivity throughout most of the history of these cores, with large inferred increases both variables in the during the last two centuries at Isachsen, but only during the last decade at Alert. The trends in conductivity and pH mirror temperature records from high arctic weather stations, and may reflect higher productivity and evaporation resulting from warmer observed temperatures over the last decade.
TESTING A NEW ISOTOPIC PALEO-THERMOMETER IN A MULTI-PROXY CONTEXT: CHIRONOMID $\delta^{18}O$ AS A PROXY FOR HOLOCENE TEMPERATURE CHANGE IN ICELAND

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Additional quantitative paleoclimate records are needed for further testing general circulation models and for understanding the magnitudes and rates of natural climate changes. Here we describe initial tests of a new paleo-thermometer, which uses the oxygen isotopic composition ($\delta^{18}O$) of subfossil chironomid larval head capsules as a proxy for past mean annual air temperatures (MATs).

$\delta^{18}O$ of precipitation is highly correlated with MAT in cold regions. In suitable stream-fed arctic lakes, $\delta^{18}O$ of precipitation determines $\delta^{18}O$ of lakewater, which in turn controls $\delta^{18}O$ of chironomid larvae living at the sediment-water interface. In a pilot study by Wooler et al. (2003), $\delta^{18}O$ of chironomid chitin extracted from lake sediments at four sites in Greenland, arctic Canada, and Massachusetts, was well correlated with local precipitation $\delta^{18}O$ and MAT. The work described here is focused on characterizing the relationship between lakewater $\delta^{18}O$ and MAT across Iceland, and identifying any confounding effects of meteorology and/or watershed processes. Our results indicate that the $\delta^{18}O$ of large lakes in Iceland is indeed strongly correlated with MAT; thus the chironomid $\delta^{18}O$ paleothermometer holds promise for reconstructing paleotemperatures in Iceland.
Fig 1. The δ18O of lakewater in large Icelandic lakes is well correlated with mean annual air temperature.

\[ y = 0.6336x - 9.6719 \]

\[ R^2 = 0.62 \]
TREE-RING AND HISTORICAL EVIDENCE FOR A LARGE AND RAPID ADVANCE OF AN ALASKAN TIDEWATER GLACIER

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Icy Bay in southern Alaska extends 40 km inland from the Gulf of Alaska (Figure 1). Surficial stratigraphy and landforms show that the tidewater glacier termini of this system have coalesced and advanced from the deep-water inner fjords to the shallow outer bay several times during the late Holocene. We use tree-ring cross-dates of glacially killed trees and historical data to reconstruct the most recent of these expansions.

The coalesced margin of Yahtse, Guyot and Tsaa glaciers advanced southeastwards through the inner bay in the 1640s (Figure 1). Maps and descriptions by European explorers suggest that in the 1790s the coalesced ice margin had reached the turn at mid-bay and that the southeastern side of the outer bay was significantly farther east than today. Trees killed at three widely spaced locales record rapid expansion during the 1810s and 1820s; these tree-ring data are corroborated by E. Belcher who observed in 1837 that Icy Bay had largely disappeared beneath the advancing glacier. Climbing parties in the 1880s described the Icy Bay glacier as extending out into the Gulf of Alaska and outwash prograding rapidly into the area between Old Point Riou and the eastern Icy Bay glacier margin. Ice retreat began in the 1900s and left the whole bay deglaciated by the 1980s.

Advance through the deep-water inner bay between the 1640s and 1790s was at an average rate of 25 m/yr (Figure 2), a rate that is typical for tidewater termini in similar settings today. However, the 1790s to 1880s expansion of ~380 km2, an along-flowline distance of ~26 km at an average of 280 m/yr, is far larger and faster than any previously documented advance of an Alaskan tidewater glacier. The rapid advance appears to have begun as the ice margin entered shallow water in outer Icy Bay (Figure 2), and so we suggest that a decrease in iceberg calving was the primary cause of this rapid advance. This interpretation is consistent with observations of dense floating ice and large icebergs in Icy Bay the 1780s and 1790s, in contrast to 1837 when there was relatively little floating ice and a muddy beach at the ice margin.
Fig 1. Icy Bay, southern Alaska, with reconstructed ice margin positions.
Fig 2. Bathymetric profile of Icy Bay with dated ice margin positions.
A CHIRONOMID BASED PALAEOENVIRONMENTAL RECONSTRUCTION OF ANTIFREEZE POND IN YUKON, CANADA

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In Eastern Beringia (Yukon and Alaska), the transition from the full glacial (26,000 to 14,000 14C yr BP) to the Holocene (10,000 14C yr BP to present) was marked by increasing moisture and temperatures. However little quantitative paleoclimatic data exists to document the extent of full glacial conditions, or the timing and rate of climatic amelioration. Chironomid (non-biting midge) assemblages show strong correlation with their environments, and are a useful proxy for reconstructing past temperatures. A training set of 121 lakes in Alaska, Yukon, Northwest Territories, and British Columbia was used to develop a transfer function relating mean July air temperatures to chironomid assemblages. The strongest model was produced by WA-PLS (2 components) with a bootstrapped error of 1.35°C and an r2(boot) of 0.51.

The model was applied to the chironomid record of Antifreeze Pond in southwestern Yukon. The lowest zone (pre-Late glacial; AMS basal dates submitted) revealed mean July air temperatures 2.5°C colder than present, though comparable assemblages in the high arctic suggest even colder conditions. A sharp rise to near present temperatures is followed by a hiatus in the chironomid record suggesting Antifreeze Pond (currently 120 cm deep) dried up. At 12,400 14C yr BP chironomids re-appear and indicate temperatures near present; the appearance of semi-terrestrial taxa (Limnophyes, Parametriocnemus/Paraphaenocladius, and Doithrix/Pseudorthocladius) suggests fluctuating water levels. Holocene temperatures are not significantly different from present, and peaks of semi-terrestrials again suggest fluctuating pond levels.
TREE-RING DATED 1000-YEAR ADVANCE OF COLUMBIA GLACIER

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An almost 14-kilometer catastrophic retreat of Columbia Glacier initiated in the early 1980s has exposed thousands of hemlock logs overrun by a previous 1000-year ice advance. Over 400 tree-ring dates from this forest suggest advance began before AD 1020 and reached its most recent maximum about AD 1810. An early expansion through the deepest reaches of the upper fjord averaged 20 m/yr attaining a mid-fiord position about AD 1450. At this position the ice margin laterally expanded into tributary valleys increasing the width of the calving margin and stalling the down fjord progress.

The next evidence of advance into forest is detected just south of the AD 1450 position with calendar dates in the mid- to late-1700s. Tree-ring dates here show a near-continuous ice expansion to the recent terminal moraine shoal at Heather Island. This latter 6-kilometer expansion attained advance rates of up to 150 m/yr.

Based on these data, fjord geometry and especially water depth appear to be the dominant controls on the advancing Columbia glacier. The increasing rates of advance documented by tree-ring dating along the 14-kilometer fiord reflect the overall decreasing water depth from the deep water of the upper fiord to the relatively shallows near the terminal moraine shoal. This reconstruction of ice advance is consistent with the model put forth for Columbia Glacier by Post (1975) and Meier and Post (1987) who suggested a relatively slow advance of the tidewater margin down its fiord for millennia and then after an extended phase, catastrophic retreat.

Continued retreat and subsequent exposure of subfossil forests will reveal more of Columbia’s glacial history into the first millennium AD.


CLIMATE CHANGES AND EVOLUTION OF NORDIC ECOSYSTEMS OF CANADA

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Grain size, macrofossil and pollen analyses were used to reconstruct paleoecological and paleoenvironmental conditions of small lakes in northern Quebec, Canada. After the retreat of the Laurentide Ice Sheet around 8000 yr B.P., the area was submerged by the Tyrrell Sea. The transition from marine to lacustrine environment occurred between 6000-5400 yr B.P. Two major periods of water-level fluctuations were inferred from organic and mineral sediments: a high-water level that occurred after 3200 yr B.P. and a low water-level that started before 2200 yr B.P. Our chronological data for the first period are consistent with those from nearby Lac des Pluviers and from other lakes in east-central Canada and in the northeastern United States. During the low water-level period, however, there is no evidence for minor fluctuations, whereas other lakes in northern Quebec and east-central Canada underwent several brief lowerings.

Fig 1. Lake Kachishayoot lacustrine terrace
Fig 2. East (LK99-cp1) and west (LK99-cp2) lacustrine terrace sections

Fig 3. Loss-on-ignition, grain size and macrofossil diagram of core LK99-cr2
INVESTIGATING HOLOCENE CLIMATE CHANGE IN GLACIAL LAKE HVÍTÁRVATN, ICELAND

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Subtle shifts in either atmospheric or oceanic circulation produce strong changes in the terrestrial environment of Iceland. Despite the large amplitude of climate change expected for Iceland during the Holocene, and numerous large ice caps that would respond to these changes, there are no complete records of terrestrial environmental change for the Holocene of Iceland, and the status of Icelandic glaciers in the early Holocene remains debated. It is not known whether Iceland’s large ice caps disappeared in the early Holocene, and if they did, when they re-grew. To answer these questions, four continuous cores were recovered in Summer 2003 from a deep, high-sedimentation-rate lake basin (Hvítárvatn), selected because the sediments were expected to provide high-resolution, quantitative evidence of environmental change over the past 10 ka.

Hvítárvatn is a glacier dominated lake located on the eastern margin of Langjökull Ice Cap in central-western Iceland. The Hvítárvatn cores have three major periods: a glacially dominated lake system (LIA), an early neoglacial period that is still influenced by Langjökull Ice Cap, and the thermal optimum with no apparent glacial signal in the sediments and a high organic content. Preliminary studies of these sediments revealed distinctive varve and diatom assemblages that reflect these broad changes. In progress is a detailed varve and diatom study to test if the early Holocene summer insolation maximum was sufficient to completely melt Iceland’s large ice caps and to capture a sub-decadal record of late Holocene climate variability. Icelandic lakes are particularly well suited to answer these questions because: 1) Glacial erosion and soft bedrock result in high lacustrine sedimentation rates, 2) Diagnostic tephras of known age aid the geochronology. Iceland’s sensitivity to changes in North Atlantic circulation is expected to produce clear signals in key environmental proxies (diatoms, varve thickness) preserved in lacustrine sequences, and 4) Ice-cap profiles are relatively flat; consequently, small changes in the equilibrium line altitude (ELA) result in large changes in accumulation area. Hence, large changes in ice-sheet margins during the Holocene are likely, and these will impact sedimentation in glacier-dominated lakes and the diatom assemblages at those times.

Smear slides revealed the presence of large concentrations of diatoms. The presence of such a plentiful number of diatoms throughout the cores was a surprise, as the silt-laden nature of the glacial lake was a deterrent to the presence of almost any other form of life (TOC<0.3%). Further study revealed the uppermost 3 to 4 m of all Hvítárvatn cores display sediment characteristics of a glacially dominated lake system. These sediments have large packages of ice-rafted detritus (IRD) and have thick annually laminated varves with white clay caps representing the winter layer when ice cover allowed the fine clay particles to settle out. The diatom assemblages here are dominated by planktonic, silica-demanding taxa that suggest a high dissolved silica and turbid water environment that would be consistent with high fluxes of glacial flour. Deeper in the cores are what are likely early Neoglacial sediment, deposited when Langjökull Ice Cap was active, but outlet glaciers were not in contact with the lake. The varves are predominantly gray in color with much thinner clay caps, and there is very little IRD. The diatom assemblage resembles the uppermost sediments, but a much closer look at the diatoms is necessary in order to qualify the differences. The bottom 1 m of sediment shows a change in the sedimentation of the cores. The sediments are lightly stratified with no evidence of varves or clay caps. There is a much higher organic component to this part of the core, with diatoms comprising a large portion of the sediments. The diatom assemblage here is a diverse suite of taxa dominated by benthic diatoms suggesting clear water with long growing seasons likely found in an environment with warmer
summers than present and with no glacial erosion occurring. We believe these lowermost sediments were deposited during the Holocene Thermal Maximum when Iceland’s ice caps completely disappeared. However, we need to prove this and believe that diatoms and an in depth varve study hold the key. To test the sensitivity of the glacial lake to climate parameters, the uppermost 50 years of varves will be compared to instrumental records from a nearby weather station. This work is currently in progress.
Previous research in Polar Regions has demonstrated that chemical and physical interactions between the snowpack and the overlying troposphere have a substantial impact on the composition of the lower atmosphere. The deposition of atmospheric trace gases and aerosols during the cold and dark winter results in an accumulation in the snowpack, which subsequently acts as a chemical reservoir. During polar sunrise, under conditions of increasing temperature and solar radiation, this reservoir is activated by photochemical reactions which result in the formation, depletion and cycling of important atmospheric gases.

During the Northern hemisphere summer of 2003, atmospheric and snowpack ozone chemistry was studied at Summit, Greenland (72.34°N, 38.29°W, 3200 m). Diurnal trends in the boundary layer, ozone deposition to the snowpack and photochemical depletion of ozone in the firn air (30 cm depth) were investigated. Ambient ozone levels were between 40 and 50 ppbv. Ozone in the firn air exhibited distinct diurnal cycles which correlated with incoming solar radiation. During nighttime, ozone in the snowpack equilibrated with ambient levels, whereas under conditions of high incoming shortwave radiation, ozone in the snowpack was substantially depleted. These data strongly support the hypothesis that ozone deposition to the polar snowpack is driven by solar radiation and consequently has strong diurnal and seasonal dependencies.

During the winter 2003-04, a similar ozone study was conducted at the Soddie site, Niwot Research Station, Colorado (40.04°N, 105.54°W, 3340 m). Besides in ambient air, ozone was measured in the seasonal snowpack at ground level and at 30, 60 and 90 cm above ground. In contrast to the Summit observations, very low ozone levels were found in the Niwot ridge snowpack. It appears that the snow physical and chemical properties (seasonal versus perennial snow) influence the degree of ozone uptake to the snowpack.

Previous literature reports conflicting findings on ozone depletion or ozone accumulation in the snowpack. These observations may be due to the varying snowpack characteristics. Our continuing research will investigate ozone snowpack chemistry in other Arctic, Antarctic, as well as mid-latitude environments to further elucidate ozone fluxes and their dependency on the snowpack chemical composition and physical micro and macro structure.
New lake cores from the Clyde region, northeastern Baffin Island, provide continuous records of Holocene environmental conditions. A core from 6 m depth in lake CF3, which has a surface area of ~0.4 km2, a drainage basin of ~1 km2, and no significant inflow stream, has received the most attention. Macrofossil 14C ages from six depths provide a chronology from ~11.5 ka, the timing of regional deglaciation, through to the 20th century via an overlapped surface core. Magnetic susceptibility, sediment appearance, grain size, loss-on-ignition (LOI), and total carbon measurements from CF3 show a strong trend from early to late Holocene. We hope to show chironomid taxonomy-based summer temperature estimates from a dozen levels in the core.

Among all of our downcore data, LOI values have been obtained at the highest resolution (~60 yr.), and are supported by total carbon measurements from overlapping levels to represent fluctuations in organic carbon. Due to the simplicity of the hydrologic system, we interpret LOI as a proxy for lake productivity. LOI rises to intermediate values (~20%) at ~11.5 ka, and to their highest values of the Holocene (~35%) by ~10.4 ka. LOI values decrease significantly after ~9.5 ka, indicating a Holocene thermal maximum (HTM) between ~10.4 and ~9.5 ka. The decreasing LOI values through to the Little Ice Age (LIA) are punctuated by several millennial-scale variations. A surface core from the same site records a transition from LOI values of ~10% during the LIA to values of >20% in the most recent (20th century) sediments, the highest values in the last ~8 ka. The Holocene LOI pattern is repeated in several cores from the Clyde Region, and the surface core pattern is virtually identical to a 210Pb-dated surface core from a neighboring lake.

The LOI-defined HTM at Clyde is earlier than in adjacent Baffin Bay (Dyke et al., 1996), but is later than lake core estimates for the HTM from southern Baffin Island (e.g., Miller et al., 1999). These comparisons suggest that southern Baffin Island warmed before northern Baffin Island, even though both locations were deglaciated at roughly the same time. The CF3 LOI record is very similar to the Agassiz ice cap melt layer record (Fisher and Koerner 2003), and may indicate that warming at these sites leads the initial warming of Baffin Bay.

Dyke, A. S., Dale, J. E., and McNeely, R. N., 1996, Marine molluscs as indicators of environmental change in glaciated North America and Greenland during the last 18,000 years: Géographie physique et Quaternaire, v. 36, p. 5-14.
Fig 1. North-south transect of continuous records of summer temperature proxies from the eastern Canadian Arctic. A) Melt record from Agassiz Ice Cap (Fisher and Koerner 2003) and July insolation at 70 °N. B) Changes in the number of thermophilous mollusk taxa present in Baffin Bay (Dyke et al., 1996). C, D, E) Loss-on-ignition profiles from Baffin lakes (Robinson: Miller et al., 1999). Lakes on southern Baffin Island reach maximum summer temperature indicators about 1000 years earlier than at higher latitudes, and peak sea-surface temperatures lag another thousand years behind the northern terrestrial sites.
TERRESTRIAL RESPONSES TO HOLOCENE CLIMATIC FORCING - EXAMPLES FROM N/NW ICELAND

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Understanding Holocene climatic change relies on an ability to both identify and interpret variations in proxy records which can be attributed solely to climatic forcing. These records come from a variety of sources that have different forms and rates of response, usually closely linked to threshold conditions and the resilience of the organism/community to change. Examples are used from terrestrial sites in N and NW Iceland to demonstrate the way in which forcing affected ecosystem responses over the Early to Middle Holocene. Periods of significant vegetation change indicated from pollen evidence are compared to chironomid-based temperature reconstructions and placed within the broader regional context by comparison with offshore records of sea-surface temperature. Particular attention is paid to a number of “snapshots” of Holocene time - before and after the deposition of the Saksunarvatn tephra (9.6-8.6 14C yr BP), a period of vegetation retrogression ca 8.5 14C yr BP, and the establishment of “optimal” birch woodland, an event which appears to have been diachronous across N Iceland. Implications of the results are considered for use of vegetation change as an indicator of climatic change in Iceland emphasising the importance of using other proxies such as chironomids, where regional calibration against climate appears feasible, as demonstrated in accompanying posters.
GLACIER MAXIMA, MINIMA AND CLIMATE IN TRÖLLASKAGI, NORTHERN ICELAND

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Glacier fluctuations are commonly used as a proxy for climatic changes. This is achieved primarily through the mapping and investigation of moraines as indicators of glacier highstands. Consequently, the record is frequently incomplete due to censorship of the record by subsequent advances (Kirkbride and Brazier, 1998), and there is rarely evidence of glacier retreat. In the Tröllaskagi region of northern Iceland, there are landforms linked to present activity of ice, including corrie and small valley glaciers, as well as rock glaciers. Vatnsdalur contains six small corrie glaciers of c.0.9km - 2km length, c.0.1 - 1km$^2$ area, situated between 900m and 1200m altitude (Fig. 1). There is also considerable geomorphological evidence of past glacier highstands, including moraines dated to c.6000BP - 4700±205 14C BP and <3470±160 14C BP by Stötter (1991), as well as several Little Ice Age highstands. Advance and retreat of glaciers in this region has been linked to climatic variables by Caseldine (1987; 1991) showing sensitivity to precipitation as well as rapid response, and they are thus potentially important in understanding Late Holocene climatic change in Iceland. These glaciers have retreated up to 1.7km from their maximum Holocene extents.

A 2.5m long core, Skeidsvatn III, was extracted from the lake Skeidsvatn (Fig. 2) in Vatnsdalur, containing sediments dating to at least 1380±45 14C BP (between 636 and 686 cal. AD to 1σ). Results from the anaysis of sediments in this core are presented. The sediments contain evidence that the catchment may have been ice-free prior to c.650AD, or that the ice masses in the catchment were sufficiently small so as to be inactive. Using geomorphology and tephrochronology as well as the lake sediments, this paper explores the significance of glacier retreat in the catchment, as well as the influence of other geomorphic activity (including rock glaciers, landslides and periglaciation) on both the lake sediments and the geomorphic record of glacier extent.

Fig 1. Perspective view of Vatnsdalur, showing the context of Skeidsvatn and the six corrie glaciers. Image created from a preliminary DEM.

Fig 2. Looking south towards Vatnsdalsjökull from Skeidsvatn
CENTENNIAL PHASING OF PACIFIC DECADAL VARIABILITY IN NORTHWEST NORTH AMERICA DURING THE PAST SEVEN CENTURIES

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Annually laminated (varved) lake sediments serve as useful proxies for past climate variability. In this study, the subannual structures within varved sediments from Summit Lake (875 m a.s.l.) in the Coast Mountains along the northern British Columbia/Alaska border were used to investigate interannual variability specific to nival-glacial and rainfall runoff for the past 700 years. The frequency and thickness of rainfall-induced sedimentary events increased abruptly at 1675 AD suggesting that there was an increase in Pacific airmasses at this time. In addition to the rainfall increase in the late 17th century, there was a distinct decrease in event frequency in the later half of the 19th century and subsequent increase at the beginning of the 20th century. At an adjacent lake (Meadow Lake), continuous varve deposition began at 1667 AD, and we interpret this as an indication of a glacial advance in the watershed caused by increased autumn precipitation. The subannual autumn rainfall record from Summit Lake in combination with the onset of continuous varve formation in Meadow Lake suggests that there was a major ocean-atmosphere shift over the North Pacific Ocean in the last part of the 17th century.

The northern Pacific Ocean exhibits known multi-decadal variability in the 20th century and our results suggest the onset of behaviour resembling the current ocean-atmosphere regime occurred at 1675 AD and was weak or absent in the preceding 375 years. The waxing and waning of Pacific decadal variability identified in our record may explain why it has been difficult to consistently reconstruct PDO from proxy records prior to 1900 AD. However, comparison between the Summit Lake varve record and other proxy records indicates a coherent phasing of the ocean-atmosphere system. These results suggest that long term variability in the northeastern Pacific region may have been more complex than indicated by instrumental records and point to the need for more well-dated proxy records from a range of environments.
PREDICTING LAIR ABANDONMENT BY RINGED SEALS BASED ON PHYSICAL PROPERTIES OF THE SNOWPACK

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Ringed seal (Phoca hispida) populations may be responding to habitat changes associated with industrial activity and climate change in the arctic. Population assessment, however, has relied on visual surveys of the extensive sea ice habitat, and interpretation of those surveys has proven difficult. Throughout most of the year, ringed seals are not visible because they are feeding underwater or resting in lairs excavated in the snow covering the ice. They are visible on the surface only in the window between the onset of snowmelt, when lairs are abandoned, in late spring and ice breakup in summer. Surveys are meant to take place during that window, but the relationship between the onset of snowmelt and the timing of lair abandonment is not well understood. We used radio-telemetry to determine when 16 seals abandoned their lairs and compared the timing of lair abandonment with changes in cold content of the local snowpack. Snowpack cold content is the amount of energy required to raise the average temperature of a snowpack to its melting point (0°C). Thus, cold content integrates average density, average temperature, and depth of the snowpack—all of which are directly related to the structural integrity of the snowpack. Our findings suggest that cold content is an accurate gauge of the structural integrity of ringed seal lairs. Cold content also was strongly correlated with snow temperature at the ice surface and that parameter may prove to be a more convenient predictor of lair abandonment. Predicting the timing of lair abandonment will allow for more accurate aerial surveys of ringed seal populations.
LATE FOXE GLACIATION OF THE ASTON LOWLAND, BAFFIN ISLAND, NUNAVUT: SUPPORT FOR AN INTERMEDIATE ICE EXTENT IN THE EASTERN CANADIAN ARCTIC

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The extent of glaciers and ice sheets during the last (late Foxe) glaciation of eastern Baffin Island has been debated for over 40 years. Ice was originally posited to have inundated the entire coastal region and terminated in the sea at the continental shelf break (cf. Flint, 1943). Research since the 1960’s largely discredited the “big” ice model based upon undisturbed sediments of pre-late Foxe age found adjacent to fiord troughs and the relatively advanced weathering of bedrock and glacial debris on surrounding landscapes (cf. Ives and Andrews, 1963; Løken, 1966; Boyer and Pheasant, 1974). In east-central Baffin Island, the Aston delta, a >25 km2, 80 m asl raised marine delta on the Aston Lowland with undisturbed sediments became the widely-cited type locality for this small late Foxe ice model, buoyed by in situ marine molluscs dated >54,000 yrs BP (Løken, 1966).

New air photograph and field mapping of the Aston Lowland confirmed the presence of two extensive raised marine features: an ~ 80 m asl marine limit shoreline sub-parallel to the modern coast that can be traced for ~ 30 km northward from the Aston delta; and a roughly 25 m asl shoreline that extends ~ 45 km parallel to, and seaward of the 80 m shoreline. Nine new radiocarbon ages confirm the pre-Last Glacial Maximum age (>54,700 yrs BP) of the Aston delta and the 80 m asl marine limit shoreline. A finite radiocarbon age of 36,490 yrs BP on ice-transported molluscs collected from the surface of the Aston delta, and post-depositional lateral meltwater channels crossing the delta and lowland indicate the area was inundated by minimally erosive cold-based ice during the late Foxe glaciation. These meltwater channels drain to the 25 m asl shoreline, which represents the early Holocene marine limit, and outline the retreat of three glaciers emanating from the local fiords that inundated the outer coast but were insufficiently thick to overwhelm the outermost summits and valleys. These uplands and valleys may have supported local snow and ice carapaces or alpine glaciers.

The chronology of initial ice retreat is provided by cosmogenic exposure ages of erratic boulders and basal radiocarbon ages on macrofossils from lake cores. Twenty-nine erratic boulder ages indicate ice retreated from the outer coast between about 13 and 15 ka (cal). Seven calibrated basal lake core radiocarbon ages from the Aston Lowland and Clyde Foreland to the north indicate the outer coast was ice-free before 12 ka (cal). Ice retreated to the fiord mouths before ~9.5 ka (cal; Andrews, 1990), and was at or inland of the fiord heads of Clyde Inlet and Inugsuin Fiord by ~8.6 ka (cal; Løken, 1965).

This study supports an extensive, but relatively thin Laurentide Ice Sheet cover of the Aston and adjacent lowlands during the late Foxe glaciation, terminating beyond the modern shoreline on the Baffin Shelf. Ice advanced some time after 36 ka BP, and retreated before 12 ka (cal). The preservation of older Quaternary sediment and landform assemblages indicates the most distal portion of the Laurentide Ice Sheet was composed of minimally erosive cold-based ice throughout the late Foxe and older glaciations. Erosive, warm-based ice was probably restricted to the centres of the major fiords during these glacial episodes. This suggests that much of the eastern Baffin Island landscape is ancient in origin and has not been substantially modified during the most recent glacial cycles. Late Quaternary glacial climate was probably too cold and dry to support large, warm-based ice sheets along the outer Baffin coast.
Andrews, J. T., 1990. Fiord to deep sea sediment transfers along the north-eastern Canadian continental margin: models and data. Géographie Physique et Quaternaire 44: 55-70
Fig 1. Schematic reconstruction of the maximum extent of the Laurentide Ice Sheet on the Aston Lowland during the late Foxe glaciation. Areas that may have been ice free during the late Foxe maximum are indicated by question marks.
A combination of field data, remote sensing observations and modeling is enabling a detailed investigation of bottom and surface melt processes of a major outlet glacier in northern Greenland. The area of interest is the Petermann Gletscher (81°N, 60°W), one of the fastest flowing outlet glaciers in northern Greenland. The Petermann Gletscher is unique because it has a large floating section, or ice tongue, that is 20-km wide by 70-km long. To determine the mass balance of the floating section of the Petermann Gletscher both surface and bottom melting, as well as strain and tidal measurements, were made during 2 field seasons in 2002-3. Measurements from a transmitting automatic weather station installed on the floating section of the glacier before melt in 2002 show a surface lowering of 1.3 m yr⁻¹, which agrees well with ablation stake data. The ablation over the entire floating section using a degree day model reveals that less than 2 km³ ice yr⁻¹ is melted on the surface, which is about 15% of total ice mass loss. This result confirms that basal melting is the most important process contributing to ice loss on the floating section of the Petermann Gletscher. Although surface melting does not appear to dominate the mass budget of the Petermann Gletscher, field observations indicate that it may be relevant towards weakening and fracturing the floating tongue.
Several near-shore sediment cores collected off the coast of Vestfirdir, the northwest peninsula of Iceland, contain abundant fossil molluscs dating back at least 2000 years. Twenty-four Arctic bivalves were collected from notable warm and cold intervals (based on other proxy data) in the cores, in order to establish a high-resolution record of seasonal variation during these periods. Bivalves have been micromilled using a three-dimensional, computer-controlled micromilling device that generates carbonate powder concordant with growth bands of the shells at ~weekly resolution (~1,200 samples to date). Age control of the specimens is provided by interpolation between AMS radiocarbon dates of the cores. Temperatures were calculated using standard temperature-fractionation relationships. Example data from several bivalves are presented below in Figures 1-3.

Data reveal a general trend in both summer (maximum) and winter (minimum) temperatures (Fig. 4). Mean temperatures calculated for both seasons are highest in the oldest shell (dated at 80BC), decreasing by 460AD, and subsequently increasing in the late 800s (approximately the onset of the Medieval Warm Period). Temperatures decrease again towards the youngest shell dated at 1562AD (during the Little Ice Age). The greatest variability is found in summer maximum temperature, which ranges from 6.9 and 7.0°C in years 460AD and 1562AD respectively, to a maximum of 12.4°C in 870BC.

Variation in carbon isotope values can be attributed to species-specific differences in metabolic rate, dietary influences and temperature effects on metabolism.
Fig 1. Thyasira flexuosa specimen B99-341_66.25 from 870AD displaying maximum summer temperatures in excess of 12 degrees.

Fig 2. Thyasira flexuosa specimen MD99-2266_112 from 876AD demonstrating the resolution obtained by analyzing all samples recovered from a mollusc. Temperatures in this period range from less than 1°C to nearly 9°C at the onset of the Medieval Warm Period.
Fig 3. Macoma calcarea specimen MD99-2266_9.5 from 1562AD. This mollusc from the Little Ice Age displays the lowest temperatures of all molluscs sampled to date.

Fig 4. Summary plot of initial data demonstrating variation in summer maximum and winter minimum temperatures over the last ~2,100 years for the North Atlantic.
Approximately 10% of the earth's land surface is covered by ice. Global warming is rapidly melting ice and exposing rare archeological remains. These sites are important to understanding the role of high latitude and high altitude environments in human adaptation and cultural development. GIS modeling is being used to identify areas exhibiting high potential for the preservation and discovery of frozen archeological remains. Areas holding the highest potential for archeological site discovery are: 1) ice-covered passes used as transportation corridors, and 2) glaciers and areas of persistent snow cover used by animals that attracted human predators. The primary goals of this research are to first predict site potential throughout Alaska’s Wrangell St. Elias National Park and Preserve, and then to make the model applicable to other glaciated regions of Beringia and other high altitude and high latitude environments.

In 2001 and 2003 numerous archaeological and/or paleontological sites were discovered on melting glaciers and perennial snow patches (aniuvat in Inuit, Kusugak 2002:vi). Historic artifacts included horse hoof rinds and horseshoe nails, cans, tools, historic debris, and even the remains of an entire building. Historic artifacts are most commonly discovered below the equilibrium line altitudes (ELA’s) of large valley glaciers at an elevation of approximately 3400’ (~1036m) that were used as trails and passes over mountain ranges. Prehistoric artifacts include antler projectile points, wooden arrow and atl atl shafts, a birch bark container, and an atl atl foreshaft with a hafted stone projectile point. Prehistoric artifacts are commonly associated with caribou and sheep hunting on snow patches, or aniuvat (c. 2000m), and cirque glaciers (c. 2000m). Elevation, aspect, slope, and vegetation may be used to identify “fossil” snow patches. Numerous paleontological specimens including mammalian hair and fecal material, the remains of sheep, caribou, carnivores, and other medium sized mammals, rodents, birds, and fish, have been discovered.

Glaciers and perennial ice patches most probably used by humans in the past can be detected using GIS modeling using three types of data layers, or coverages: 1) social/cultural, 2) biological, and 3) physical. The areas of highest archeological potential were presumed to be those geographic locals where the three data sets overlapped spatially. Influential layers included biologic and geologic factors such as mineral licks, lithic sources, transportation corridors, and large mammal species ranges caribou, sheep, goats, moose and bears. The social/cultural coverages were compiled from historic, ethnographic and archival sources as well as through interviews with knowledgeable individuals. In addition to historically documented trails, proximity and accessibility to known archeological and historic sites are important variables. Large mammal species distribution data were developed through analysis of the biological literature, studies conducted by the Alaska Department of Fish and Game and the National Park Service, and informant interviews. The physical data layers are derived from the geologic literature, low level color aerial photography, satellite imagery, USGS maps and open file reports, and in consultation with knowledgeable researchers and resource managers. When used in conjunction with data on elevation, aspect, and slope, the statistical analysis of hyperspectral imagery and thermal bands are important variables for predicting potential site locales on relatively small perennial snow and ice patches. These data layers, along with factor proximity weighting using exponential decay with distance from ice and multiple regression analyses, are used to further analyze and predict potential site locales. Field survey is then used to test and refine the site potential model.
Globally averaged mass balance measurements derived from glaciers with 20-year, or longer, records demonstrate that net glacier melting is increasing globally (Dyurgerov 2001:281). Global warming presents an unprecedented opportunity to identify glaciers, ice fields and similar environments that hold high potential for the exposure and discovery of frozen archeological remains. This is an exciting new archeological frontier from which rare, unique and important artifacts made from organic materials are being discovered across the globe. These discoveries provide new insights relating to high altitude and high latitude adaptations to human colonisation. Global warming has created an urgent need to develop scientific methods to locate and preserve frozen organic remains because these depositional environments are ephemeral. Exposed organic materials soon decompose or are destroyed.

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Kusugak, Jose A.
2002 Where a Storm is a Symphony and Land and Ice are One. From the Forward: The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change. Edited by Igor Krupnik and Dyana Jolly. Arctic Research Consortium of the United States and the Arctic Studies Center, Smithsonian Institution. Pp. v-vii.

Fig 1. Map illustrating the location of Alaska’s Wrangell-St. Elias National Park and Preserve.
Fig 2. Artifacts discovered on ice patches in Alaska’s Wrangell-St. Elias National Park and Preserve include this stone projectile point which still retains traces of red ochre and the sinew used to lash it to a wooden shaft.
NATURAL RISKS AND FREQUENCY OF DEBRIS FLOWS IN AKSHAYUK PASS (NUNAVUT, CANADA)

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Akshayuk Pass in Auyuittuq National Park is located in the Eastern Canadian Arctic (Baffin Island). This national park has many debris flows, which can be hazardous to the safety of tourists. These debris flows are a moving mass of rock fragments, soil, and mud, with more than half of the particles being larger than sand size. Thirty-two debris flows have been studied between Summit Lake and Overlord Peak. The objectives of this study is to evaluate the active frequency periods of these debris flows and to date their activities. Also, this study provides information concerning the potential natural risk for hikers and park’s infrastructures.

The lichenometric approach is based on size/age correlations of the lichen Rhizocarpon geographicum. This method of dating is based on the measurements of the longest axis of individual thalli. Each boulder surface was searched to measure every single thalli until 150 measurements per quadrat was reached. A comparison can then be established between two techniques: (1) maximum thalli measurement and (2) mean of the ten largest thallus measured. The age and frequency result of debris flows were statistically analyzed.

The results from this study indicate that (1) debris flows were more active 450 and 1000 years ago, (2) presently they are very active in spring when ice and snow melt and (3) they are a source of hazards for the tourists during this season.

In conclusion, debris flows are more active during periods of climatic warming. The phenomenon is explained by the fact that ice and snow melting are important during these periods and produce large quantity of water on slopes.
CONSIDERATIONS FOR THE DEVELOPMENT OF THE UNIVERSITY OF ALBERTA COSMOGENIC ISOTOPE LABORATORY

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The University of Alberta is developing a sample preparation laboratory for surface exposure dating with cosmogenic isotopes (Be-10, Al-26, and Cl-36). This talk will present some of the challenges encountered in the planning of this laboratory, and with surface exposure dating in general. Each phase of the procedure is critical to obtaining accurate measurements: sample selection, chemical preparation, Accelerator Mass Spectrometry (AMS) measurement, and data interpretation. Uncertainties in the production rates of cosmogenic nuclides, and the strength of the cosmic ray flux over time must be considered. Additionally, there are a number of analytical issues involved in this work. In the case of Be-10 analysis, the removal of meteoric Be-10 through acid etching is of critical importance for surface exposure dating. The use of hydrofluoric and perchloric acids during sample processing raises a number of laboratory design and safety issues. There have also been a number of new developments in Accelerator Mass Spectrometry (AMS) that should allow measurements on much smaller accelerators than previously thought possible. Work at the IsoTrace Laboratory of the University of Toronto has shown that Be-10 can be analyzed as the negative ion BeF- without interference from B-10 due to the instability of the ion BF-. Similarly, in the case of Cl-36, ion-molecule reactions at eV-energies have been shown to attenuate the isobar S-36. These developments promise to greatly expand the availability and application of cosmogenic isotope measurements in the future.
AN ATTEMPT TO ESTIMATE WATER BALANCE COMPONENTS IN PAN-ARCTIC.

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We estimate the water balance components for two large parts of pan-Arctic basin: (1) continental in N. America and Eurasia where results of river runoff discharge provide reasonable, water balance estimate; (2) Arctic Archipelagos, where the main water balance components are melt-water runoff from glaciers, no river discharge data available for this part. Both parts contribute fresh water to the Arctic Ocean.

In the first part we have chosen 9 largest river basins. Comparison of river runoff results with annual precipitation data provides the residual in the water balance. The residual includes change in the storage, such as thawing of permafrost, dammed artificial lakes, glacier ice and all uncertainties.

For the Arctic archipelagos glaciers are substantial source of fresh water inflow to the ocean. Glaciers constitute 92% of all pan-Arctic glacier-area, more than 300*10^3 km2 (Greenland ice sheet is not included). Glacier volume change is the part of the permanent storage and thus the main water contributor to the Arctic basin, sea level rise in time of climate warming and glacier-mass wastage.

We show changes in time of major components, precipitation, river runoff and residuals for two parts of pan-Arctic basin.
RADIOGENIC ISOTOPE PROVENANCE STUDIES OF GLACIAL TILLS IN ROSS SEA AND VICINITY, ANTARCTICA

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Competing hypothesis exist for the relative roles of the East and West Antarctic ice sheets (EAIS, WAIS) in providing ice to the Ross Sea during the LGM. Some reconstructions of the Ross Ice Sheet during the LGM that include ice streams indicate that West Antarctica supplied most of the ice (e.g., Stuiver et al., 1981). In contrast, a numerical ice sheet model reconstruction by Licht and Fastook (1998), using geologic data as constraints, indicates that East Antarctic-derived ice extends from the western to the east-central Ross Sea and that ice streams derived from West Antarctica are not present during the majority of ice retreat. The difference between these two reconstructions has major implications for constraining the style of LGM ice retreat; ice streams are a primary mechanism by which large volumes of ice can be rapidly removed from an ice sheet, causing or contributing to unstable behavior of the ice sheet.

In this study, we use Nd and Sr isotopic data from surface tills in the source areas and Ross Sea till (Fig. 1) to attempt to distinguish between a West and East Antarctic source for Ross Sea glacial sediment. In East Antarctica, the Nd isotopic compositions of surface and core tills from eastern Ross Sea and vicinity show regular geographic variations that reflect isotopic compositions of exposed basement rocks. The tills with the lowest eNd (-15) values are from the Mt. Achernar and Darwin Glacier regions (Fig. 1) along the western limit of the Ross Ice Shelf, reflecting the presence of reworked Archean rocks in the central Antarctic Mountains (Borg et al., 1990). Tills related to the Hatherton Glacier, in contrast, have isotopic compositions similar to those determined for Cambro-Ordovician granitic rocks in the Transantarctic Mountain (eNd = -6 to –9; Borg et al., 1990). Further to the north, surface tills at the western margin of the Ross Sea have the highest measured eNd (-3.8) of any of the analyzed tills and were likely derived at least in part from adjacent Cenozoic volcanic rocks.

In West Antarctica, tills related to ice streams B, C, D all have similar Nd (eNd =-6 to –9) and 87Sr/86Sr ranging from 0.719-0.731. None of these are dominated by detritus derived from higher eNd West Antarctic volcanic rocks thought to underlie much of the WAIS, but are isotopically similar to the Antarctic Cambro-Ordovician igneous rocks. These data reveal that there is significant overlap between the isotopic compositions of sediment provided to the Ross Sea by the WAIS and EAIS, but only the EAIS delivered detritus with eNd < -10, or >-5.

Tills beneath the Ross Ice Sheet (RISP site) are isotopically indistinguishable from the West Antarctic tills and suggest that these sediments were derived exclusively from the Western Antarctic Ice Sheet (Fig. 2). Surface tills from the central Ross Sea have eNd values ranging from -7 to –11, but tills from the western margin of the central trough (Fig. 1) have distinctly lower eNd values than those from the eastern margin (-9 to –11 vs. -7 to –8; Fig. 2). These data indicate that tills from the eastern trough margin may contain a component of low eNd (< -10) sediment delivered to the Ross Sea by the EAIS. Tills along the western trough margin have isotopic compositions similar to both the central Ross Ice Sheet and Western Antarctic tills, and indicate that these sediments could have been derived exclusively from the WAIS. Although additional data from the Ross Sea are needed, our data thus far demonstrate important roles for both the WAIS and EAIS in providing glacial detritus to this region during the LGM.


Fig 1. Sample Locations
Fig 2. Measured Nd and Sr isotopic compositions of Antarctic tills. Note the distinctly lower eNd values for central Ross Sea sediments on the western margin of the central trough.
AN AUTONOMOUS WIRELESS SENSOR NETWORK FOR HARSH-ENVIRONMENT DATA ACQUISITION

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The objective of this NASA-funded development program is to bring the power and flexibility of a wireless computer network to harsh-environment fieldwork. By integrating a small computer with GPS, a multi-channel digitizer and a wireless communication link we have created a network node which is low cost, low power, adaptable to practically any electronic instrumentation, and capable of storing large volumes of data. These network nodes colloquially BRICKs run the Linux operating system facilitating development under the open source paradigm. BRICKs can be easily programmed to intelligently manage and share data, either as equivalent (ad hoc) network components or under the control of a single Mother computer (client/server model). They are intended for long dwell-time monitoring applications (weeks/months) in extreme temperatures with limited sunlight. A BRICKs wireless capability permits data-sharing redundancy. Wireless also facilitates data retrieval, for example via daisy-chain reporting from a field array to an internet connection, via over-flight telemetry to an airplane (in lieu of landing at each station), or via satellite.

This project originates partly in the ANUBIS seismic network emplaced by S. Anandakrishnan in Antarctica where individual seismic stations used satellite phones to report their state of health. Thus inspired our prototype instrument includes 3-axis geophones and basic GPS. The BRICK currently communicates wirelessly at a range of 200+ meters and operates properly down to 60 Celsius in the laboratory; we are improving both range and hardness as we continue the project. Data tagging is done using GPS-driven interrupts, resulting in better than 10 microsecond sample-time accuracy. The project near-term objective is to field test prototype units near the Columbia Glacier calving face in summer 2004. Other possible 'beta test' experiments include additional glaciology research (GPS and passive seismics) in Alaska and Greenland, bat ecosystem work and wireless infrastructure development in Juneau Alaska, volcanology applications in Hawaii, and bistatic radar sounding experiments and active seismology on Antarctic ice sheets. A longer-term objective is to use BRICK networks upgraded to geodetic (sub-cm accuracy) GPS to directly observe glacier vertical surface motion driven by sub-glacial hydrology (as implied by radar interferometry). We are interested also in finding additional collaborators and applications for BRICK networks.


Fig 1. BRICK prototype with 3-axis geophone (orange cylinder), GPS antenna (coiled black wire) and wireless antenna (blue, protruding at right from BRICK chassis). At left is a Linux laptop "Mother station" network controller.
SEDIMENTATION IN TEMPELFJORDEN, SPITSBERGEN, HIGH ARCTIC – PRELIMINARY RESULTS

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The fjord Tempelfjorden is the easternmost tributary to Isfjorden, which is the largest fjord on Spitsbergen, Svalbard. Two major sources contribute sediments to Tempelfjorden: the glaciers Tunabreen and Von Postbreen at the fjord head, as well as the river Sassenelva close to the mouth of the fjord. Whereas the sediments released from the glaciers are of reddish colour, the suspension from Sassenelva is brown. Since Sassenelva is frozen during winter (from September/October to June) the brown sediments can be used as markers for summer deposition. Plassen et al. (in press.) analysed one sediment core from the same position and they suggest that the stratified deposits at this location are glacimarine warves.

During a scientific cruise in 2003, the suspensions off Sassenelva and the glaciers were sampled. X-Ray Diffraction (XRD) analyses revealed different mineralogical compositions for the two suspensions. The suspension from Sassenelva comprises mostly quartz, but also mica, gypsum and clay minerals. However, the mineralogical composition of the suspension from the glaciers is dominated by dolomite and calcite, but it also contains quartz, mica and clay minerals.

A series of gravity cores along several transects across the fjord has been retrieved. They indicate that the impacts of the two sources on the sedimentation pattern change laterally within the fjord. Whereas sediments in the outer part of the fjords almost exclusively are delivered from Sassenelva, deposition in the inner part of Tempelfjorden is dominated by sediment input from the glaciers. However, in central parts of Tempelfjorden, the impact of both sources is almost equal. The gravity core JM03-048-GC from central parts of Tempelfjorden comprises intercalated reddish and brownish sediments. High-resolution (2-mm steps) geochemical analysis of core JM03-048-GC, using a X-Ray Fluorescence (XRF) Core Scanner shows marked elemental differences between the different coloured strata: the more brownish the strata, the higher the Fe- content, and the more reddish the strata, the higher the Ca-content. Measurements of the magnetic susceptibility show a similar pattern: the browner the sediment, the higher the magnetic susceptibility.

Throughout the sediment column, the thickness of reddish and brownish strata varies, indicating varying impact of the two sediment sources on accumulation at the location over time. Since water circulation in Tempelfjorden is relatively slow and surface water movement is predominantly wind-driven, the varying thicknesses might be an indicator for prevailing wind directions in central Spitsbergen during the summer months.

DESIGNING A SEMI-AUTOMATED AND REMOTE SYSTEM TO RETRIEVE VARVED IMAGES FROM THIN-SECTIONS AT THE SCANNING ELECTRON MICROSCOPE.

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Paleoenvironmental reconstructions from long (>500 years) varved sequences using image analysis techniques have a strong potential to increase our knowledge of climate variability (Francus et al., 2002). In Arctic lakes that contain little biogenic remains, textural analysis at the varve scale is often the only way to obtain reliable information about past environments. However, the acquisition and the processing of a large number of images is quite a tedious task even if the existing algorithms are efficient.

In this poster, we present the design of a system that will allow the semi-automated acquisition and processing of images of individual varve from thin-section. The system will be designed around a Scanning Electron Microscope (SEM) using its backscattered electron detector.

First, the user needs to cut a thin-section from sediment, including some positioning jigs. Then, the user will mark manually the Region of Interest (ROI) on a flat bed scanner image of the thin-sections or a photo mosaic taken at the SEM at low magnification. The system will drive a motorized stage in order to take a high quality image of the ROI. The automated acquisition system should be able to correct for the drift of the SEM. For calibration and laboratory intercomparison purposes, some reference materials that have a wide range of backscattered coefficients will be embedded in the sample holder itself. The system should acquire an image of reference material every 10-20 images for calibration purpose (Soreghan and Francus, in press). Then the ROI will be processed using image analysis routines (Francus, 1998). All images, data and metadata will be stored in a customized database in order to allow the user to easily compile a long paleoenvironmental sequence. By using the same database for holding sample information, defining processing requirements and for holding results, it will be possible to examine and verify the entire processing chain that was used to calculate any and all results (audit trail).

In order to allow for collaborative work, the system will be accessible through a web interface: users should be able to design and run an experiment remotely. They will just have to send their set of thin-sections to our facility and an operator will place them in the SEM chamber. However, it will be the user’s responsibility to assess the annual character of the laminations.

Finally, since the system is still in development, I do welcome any suggestions from potential users to increase the usefulness of the system.

DISSOLVED ORGANIC CARBON IN PEATLAND WATERSHEDS OF WEST SIBERIA

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Since the Last Glacial Maximum, West Siberia has accumulated a major fraction of the global soil carbon pool in the form of peat, which now represents the most extensive peatlands in the world (Smith et al. 2004). This store of carbon is a significant source of dissolved organic carbon (DOC) to the region’s watersheds that ultimately discharge to the Arctic Ocean. Field campaigns to West Siberia have yielded DOC concentrations from 98 watersheds throughout the region (Fig. 1). A strong dependence of DOC concentration on average annual surface air temperature and/or permafrost is observed in these sampled streams and rivers. Preliminary results reveal a robust contrast between cold permafrost watersheds with uniformly low DOC and warm non-permafrost watersheds with DOC increasing rapidly as a function of peatland abundance. A critical surface air temperature threshold, which is also approximately coincident with the permafrost boundary, appears to separate the two DOC regimes. Climate model scenarios predict significant warming of West Siberia in the next century. Given similar hydrological conditions, this suggests a likely increase in DOC export both to West Siberian peatland watersheds and the adjacent Arctic Ocean.


Fig 1. West Siberia and the locations of 98 water samples collected throughout the region.
RELICT MIDDLE PLEISTOCENE PERMAFROST IN CENTRAL YUKON TERRITORY

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Models of projected surface air temperatures changes suggest significant increases in active layer thickness and consequent loss of permafrost from large areas of the discontinuous permafrost zone (Stendel and Christensen, 2002). These projections have some support from paleo-studies in the Fairbanks area of central Alaska, which suggest that permafrost completely melted out during the last interglaciation (Péwé, 1975; Péwé et al., 1997). Indirect evidence from speleothem growth in northern Yukon, however, suggests that permafrost may have persisted throughout much of the Brunhes Chron (last 780 ka) (Lauriol et al., 1997). Here we report the occurrence of relict permafrost dating to the middle Pleistocene in central Yukon Territory. Our discovery of ancient permafrost, which appears to be widespread in central Yukon, implies that large areas of relict permafrost should exist throughout northwestern North America.

At the Dominion Creek site in the southern Klondike goldfields, at least three generations of ice wedges are recognized in association with two independently-dated tephra beds (Fig.1). The first generation wedges, locally exceeding 10 m in depth, cross-cut underlying in-situ forest paleosols with rooted Picea stumps. Sheep Creek tephra (190 ± 20 ka) is present in the paleo-active layer above the first generation ice wedges, but is cross-cut and folded along the margins by the second generation ice wedges. At least one first generation ice wedge includes a bed of Sheep Creek tephra parallel to the ice foliation, indicating ice wedge cracking was contemporaneous with tephra deposition. Dominion Creek tephra (170 ± 20 ka) is present within a weakly developed graminoid-rich paleosol above the second generation ice wedges, but is cross-cut and folded by a third generation of ice wedges. The association of the ice wedges with the tephra beds dates the relict ice to the early part of marine isotope stage (MIS) 6, while the ice-rich silt associated with the underlying forest bed dates to MIS 7. The isotopic composition of the ice wedges supports this interpretation. Ice sampled from the wedges is strongly depleted in δD with values ranging from -230 to -233 ‰, while ice from the underlying forest beds has δD values of -175 to -189 ‰, comparable to Holocene values in the region (Kotler and Burn, 2000). These findings indicate that ground ice has persisted, at least locally, in interior Yukon Territory from MIS 7 through the present. This exceptional record of permafrost provides the opportunity for paleoenvironmental reconstruction using permafrost pore-ice and permafrost-preserved fossils through at least the last two glacial cycles, and presumably much longer in large areas of northwestern North America.


Fig 1. A. Syngenetic ice wedge (IW) folding Sheep Creek tephra (SCt) along ice margin. Vertical arrows indicate locations of SCt. B. SCt recovered from frost crack within ice wedge to a depth of 4 m. C. At least three thaw unconformities (ice contacts) are recognized within the cryostratigraphy (1) First generation wedges up to 5 m wide, (2) Second generation wedges up to 1.5 m wide, (3) Third generation wedges less than 30 cm wide. SCt is present within the paleo-active layer above the first generation ice wedges. D Large ice wedge cross-cutting, and compression folding the MIS 7 forest bed (FB).
QUANTITATIVE PALEOCLIMATE RECONSTRUCTION FROM POLLEN ASSEMBLAGES PRESERVED IN ARCTIC LAKE SEDIMENTS

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Surface sediment pollen assemblages from 390 lakes in northwestern Canada, northern Québec, the Canadian Arctic Archipelago and Greenland have been analyzed in order to provide modern analogs for quantitative paleoclimatic reconstruction. This represents a modern environmental gradient spanning 2400mm of mean annual precipitation, 14.7°C of July temperature, and 32.7°C of January temperature. The modern pollen data includes relative frequencies of the 35 most common taxa.

Correspondence analysis (CA) was used to explore spatial distribution of pollen assemblages and relationships with climatic parameters. The CA demonstrates a clear latitudinal pattern, with Axis 1 (27.1% of variance) positively and significantly correlated (r=0.85) with July air temperature. The use of closest modern analogues for quantitative paleoclimatic reconstruction was evaluated by estimating modern climate from surface pollen spectra. The best results were obtained using a chord distance dissimilarity metric and the 5 closest analogues. Observed versus estimated modern variables produced root-mean-squared errors of prediction (RMSEP) of ±1.98°C and ±0.71°C for the January and July temperatures, respectively, and ±175.32mm for annual precipitation.

Detailed pollen analyses and paleoclimate reconstructions have been undertaken on Holocene sediments from two well dated lake cores on Cumberland Peninsula, Baffin Island. Squared chord distances between successive pollen spectra were first used to identify periods of vegetation change. Notable transitions occurred at 8000, 3000 and 500 cal BP. Although climate reconstructions from both sites indicate some local differences, there are generally consistent features on a regional scale, including a progressive 1.5°C decrease in July temperature since 8000 cal BP, a progressive 5°C increase in January temperature since 7000 cal BP and an increase in annual precipitation. These reconstructions are therefore consistent with a progressive reduction in the seasonal amplitude of Holocene paleotemperatures, which is tentatively attributed to enhanced oceanic influences at the regional scale.
Fig 1. From left to right are illustrated: (1) Squared chord distance (SCD) between successive pollen spectra. (2) Relative frequency of selected taxa expressed as z-score. (3) Climate reconstruction. The vertical line marks the mean for the post-8300 cal BP period.
THE CELTIC DEEP PALAEOLAKE: EVIDENCE FOR A LARGE DEGLACIAL LACUSTRINE SYSTEM AT THE SOUTHERN MARGIN OF THE BRITISH ICE-SHEET AND IT’S IMPLICATIONS FOR DEGLACIAL SEA-LEVELS ON THE NW EUROPEAN CONTINENTAL SHELF.

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The pattern of deglaciation and sea-level change across the now submerged continental shelf of the Celtic and Irish Seas has been a controversial topic in British Quaternary studies and continues to raise both important glaciological and sea-level questions.

Evidence is presented here for a large freshwater lacustrine system on the southern margin of the retreating Irish Sea Ice-Stream (ISIS) occupying the Celtic Deep Basin (CDB) existing from deglaciation until well into the Late Glacial Interstadial. This freshwater body is evidenced by laminated basal muds containing sparse reworked marine floras. Marine ingress into the lake, c.12 ka BP, by the breaching of its southern sill is evidenced by iron-oxide stained gravels representing a lag deposit of winnowed lacustrine dropstones. Iron-oxide precipitation and staining is envisaged to have occurred due to the resuspension of anoxic lake bottom sediments by oxygenated marine waters during lag formation. A marine breaching of a southern sill is further supported by massive mollusc-rich 14C-dated marine sands. These deposits, occurring above the laminated facies at the southern end of the CDB, are interpreted as wash-over sediments recording initial marine ingress into the basin. Interdigitating lacustrine, marine and estuarine sediments at the northern margin of the basin along with the modern height of the southern sill enable estimates of the former lake level and area. The stratigraphy within the CDB can be contrasted with that occurring outside it, characterised by massive basal muds containing rich in situ boreo-arctic assemblages and lag deposits attesting to marine inundation, but lacking the iron staining found within the basin.

The existence of such a lake body in the Late Pleistocene Celtic Deep has marked implications for models of deglacial sea-levels in the region. The controversial reconstructions of Eyles & McCabe (1989) suggest deglaciation occurred in a marine setting with rapid calving back up the Irish Sea. However, their interpretation of many of the classic coastal exposures bordering the region as being of glacimarine origin has received considerable criticism. In the light of recent micropalaeontological, sedimentological and geomorphological work (e.g. McCarroll, 2001; Scourse & Furze, 2001; Ó Cofaigh & Evans, 2001) at these sites the high deglacial sea-level hypothesis is generally considered to be incorrect. The occurrence of a freshwater lake system during deglaciation lends its weight to the low deglacial sea-level hypothesis as well as extending the argument into the critically important offshore zone. Additionally, the nature and timing of lake formation and marine ingress fits in well with recent evidence suggesting that the southern limit of the Last Glacial Maximum ISIS did not, as is generally considered, lie across the southern entrance to St George’s Channel. Rather a lobe continued down the Celtic Sea to impinge on the northern Isles of Scilly and terminate in a tidewater setting near the shelf edge (Scourse, 1991; Scourse & Furze, 2001; Hiemstraal et al., in prep).

The occurrence of such a lake also has considerable biogeographical implications. Implicit in its existence is the presence of a large, though perhaps low-lying, isthmus of land between Britain and Ireland separating the lake from the advancing Atlantic to the south. By establishing the approximate timing of marine ingress into the lake the lifespan of this land-bridge can be estimated with its consequent implications for the arrival (or non-arrival) of terrestrial fauna in Ireland.
IMAGING POTENTIAL HYPORHEIC ZONE EXTENT BENEATH ARCTIC STREAMS USING GROUND PENETRATING RADAR

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We are investigating the responses of arctic tundra stream geomorphology, hyporheic zone hydrology, and biogeochemical cycling to climate change. In particular, we expect that hyporheic exchange dynamics in tundra streams are controlled by 1) channel features (pools, riffles, etc.), and 2) depth-of-thaw beneath the stream channel. A key objective of this effort is monitoring sub-stream thaw through the thaw season using ground-penetrating radar (GPR).

In general, GPR is a well established tool for imaging terrestrial active layer thickness. However, sub-stream imaging presents a unique set of challenges. This is primarily related to strong frequency dependence and high levels of attenuation as the radar signal propagates through water. To test the effectiveness of GPR imaging of sub-stream permafrost we conducted a field investigation near the end of the thaw season when we expected the depth of thaw to be near its maximum. We investigated three sites located within the Kuparuk River and Toolik Lake basins, north of the Brooks Range, Alaska. The sites were characterized by low energy water flow, organic material lining the streambeds, and water depths ranging from 20 cm to 2 m. Water saturated peat with some pooled water was present along the stream banks. We acquired data using a pulsed radar system with high-power transmitter and 200 MHz antennas. We placed the radar antennas in the bottom of a small rubber boat, and pulled the boat across the bank and through the stream while triggering the radar at a constant rate. We verified depth to permafrost by pressing a metal probe through the active layer to the point of refusal.

Although there is significant shift toward the low end of the frequency spectrum due to frequency dependent signal attenuation, we achieved excellent results at all three sites with a clear continuous image of the permafrost boundary both lateral to, and beneath the stream. Depth migration was applied to the profiles to provide an accurate image of both the streambed and top-of-permafrost geometry. We found thaw bulb thickness to increase with stream depth, with a maximum thaw depth of 1.5 m measured beneath the 2 m deep stream. It should be noted that the maximum thaw depth occurred beneath the site with not only the greatest water depth but also the lowest flow rate.

Our results demonstrate that GPR is an excellent tool for measuring sub-stream thaw depth. We conclude that GPR can effectively identify the thawed-frozen interface in the permafrost under Arctic streams dominated by organic substrates. Modeling results suggest that we should be able to detect this interface in streams dominated by gravel and cobble. We plan to verify these results in the 2004 field season.
EVIDENCE OF JÖKULHLAUPS AND SEISMIC INTERPRETATION OF HESTVATN, SOUTHERN ICELAND

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In summer 2003 new long (>20 m) sediment cores were obtained from Lake Hestvatn, South Iceland, using the DOSECC GLAD-200 core rig. A total of 4 cores amounting to 60 m of sediment were collected. Hestvatn is a low-elevation lake that meets the necessary requirements to answer questions on the deglaciation and the early Holocene environmental change in Iceland. It is strategically situated below the highest marine limit in the area and contains both a lower marine and an upper lacustrine phase, providing continuous time-series of key proxies. It is also situated approx. 60 km in front of the most prominent moraines in Iceland dated from deglacial times.

The new cores offer for the first time an accurate dating on the isolation of the Hestvatn basin in early Holocene as this part of the Hestvatn sediment has not been recovered before. The boundary between the marine and the lacustrine sedimentation in Hestvatn is apparent from both the seismic record and visual inspection of the new cores. Repeated melt-water pulses/turbidites characterize the boundary or the lowest part of the lacustrine section, indicating frequent jökulhlaups at that time. We propose that these jökulhlaups mark the establishment of the Hvítá river that drains Hvítárvatn by Langjökull ice cap (see Black et al., this volume). Below the melt-water pulses, we have found a thick basaltic tephra layer, which marks the boundary between the lacustrine and the marine section of the core. A tephra layer with similar affinities is also found in the basal part of the Hvítárvatn sediment (Black et al., this volume). Just below this tephra layer in the Hestvatn sediment core are several mollusk lenses, which will facilitate the 14C dating of the sediment, the tephra layer at the boundary between sections and the isostatic rebound.

We are using a multiproxy approach to reconstruct environmental change by studying physical characteristics of the sediment, lacustrine primary productivity changes, palynology, and marine micropaleontology. The lake core from the southern basin provides an excellent opportunity to capture the earliest phase of deglaciation in the area and >20 m long core from the northern basin, comprising 10-12 m of lacustrine sedimentation provides a continuous high-resolution Holocene record of environmental change (last 11.5 ka). This sediment will provide the first direct evidence of near-shore marine environments around Iceland during the abrupt climate shifts that occurred between 15 and 10 ka.

A detailed study of seismic profiles from the lake and a comparison with the sediment cores, indicate >25 m of sediment fill, with an average sedimentation rate during the Holocene of >1 m/ka. The seismic profiles have been digitized and by using SURFER 8.0 3-d images of the sediment have been obtained. The aim of this work is to reconstruct the sediment flux into the lake basin during specific time slices.
This work compares three computer instream flow models. The models are the Physical HABitat SIMulation System, SALMOD and CompMech model. The National Environmental Policy Act of 1969 and its requirement for instream flow water allocations spurred the development of two Federal instream flow models: the Physical HABitat SIMulation System and SALMOD.

The Physical HABitat SIMulation System models the physical properties of stream habitat (hydrology) and then conceptually represents the fish habitat requirements by weighted useable area or habitats theoretically suitable for fish. The SALMOD model is an extension of the Physical HABitat SIMulation System model. SALMOD simulates the addition of various fish cohorts throughout their life cycle. These two models represent the state of the art for instream flow models used by the Federal government.
Interactions between climate, vegetation, and fire regimes are poorly understood but will likely play key roles in determining boreal forest response to future climatic change. With paleo records from lakes across the southern Brooks Range we are documenting how vegetation and fire regimes have interacted, and how each has responded to climatic changes over the past 10,000 years. Centennial-scale changes in temperature and vegetation are documented with fossil chironomid assemblages and pollen/stomate records, respectively. Continuous records of macroscopic charcoal document landscape burning at decadal time scales. Charcoal analysis is aided by the use of a statistical model based on fire regime parameters observed in modern Alaskan boreal forests. This model creates hypothetical sediment-charcoal records that help us understand the accuracy of our records and explore the potential mechanisms causing variations in fossil charcoal stratigraphy.

Our records show evidence of fire regimes changing both between and within dominant vegetation types. Infrequent but distinct charcoal peaks during the early Holocene offer some of the first evidence of fires in the shrub tundra during this period. The replacement of shrub tundra with forest ca. 5000 years ago is accompanied by increases in both charcoal accumulation and the frequency of charcoal peaks. The absence of a step change in our climate proxies at this time suggests that vegetation, rather than climate, explains this increase in burning on the landscape. During the late Holocene, vegetation assemblages remained stable, but changes in charcoal accumulation suggest that fire frequency varied during this period. The details of these variations are still being resolved, but shifts in fire regimes in the absence of vegetation change would imply that fire regimes can be sensitive to climatic changes that do not affect vegetation assemblages. While climate ultimately controls both vegetation and fire, our records suggest that vegetation can play an important intermediary role between climate and fire.
COMPARISON OF SEISMIC STRATIGRAPHY FROM TWO LAKES IN EASTERN BERINGIA

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As part of a larger study focused on reconstructing lake-levels across the interior of Alaska and the Yukon Territory seismic surveys were done on a series of lakes using a Triton Elcis-Edgetech full spectrum (4 to 24 kHz) sub-bottom profiler with a SB-424 tow-fish. This system has a maximum penetration depth of 10 to 30 m, depending on the composition of the sediments, and a resolution of 4 to 8 cm. The data was recorded, geo-referenced and reprocessed using Delphseismic 2.5 software. Results from two of the four lakes that were surveyed are presented here. Birch Lake, Alaska, was resurveyed to compare the results obtained using the new system to those obtained using a Geopulse system in 1994. Eighteen cross-lake seismic reflection profiles from Jackfish Lake and fourteen from Birch Lake were used to trace acoustic stratigraphy and identify surfaces associated with water-level changes. The seismic surveys are compared with results from cores collected from the same locations.

The seismic profiles from Jackfish and Birch lakes were used to identify onlap sedimentary sequences and erosion surfaces associated with water-level changes and compared with data from core transects. Two problems limit the ability to interpret the results in shallow water. First, acoustic signals may be obscured by gas produced by the decomposition of organic matter. This effect is often visible in places on seismic lines that cross the depo-center of the lake basins and in patches in shallow water. A second problem occurs where sediment thickness exceeds the water depth and ringing of the sonic signal within the water column masks the seismic stratigraphy by overprinting multiples. Despite these complications the acoustic stratigraphy is remarkably correlative with the physical and geochemical stratigraphy identified from sediment core transects taken from shallow to deep water.
HUMAN EVOLUTION AND THE COLONIZATION OF THE HIGHER LATITUDES

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Although the hominid lineage was established by 5-6 mya, early hominids—the australopithecines—did not extend their range out of the equatorial zone (to which our closest living relatives remain confined). Colonization of latitudes above 20o North took place after the appearance of the genus Homo. Over the course of roughly two million years, representatives of Homo occupied increasingly high latitudes, achieving sustained settlement above the Arctic Circle by the beginning of the Holocene.

The colonization of higher latitudes was tied closely to the evolution of the genus Homo. Expansion into areas above 20o North was linked to new anatomical or behavioral adaptations to lower temperatures, increased seasonality, and reduced biotic productivity. Most of the major episodes of expansion coincided with the appearance of new forms of Homo. Climate change, however, played a significant role in the process.

Human settlement of higher latitudes did not occur as a result of the gradual northward drift of populations and cultures. Instead, each major advance seems to have taken place relatively quickly as climate change or new adaptations suddenly opened new regions and habitats for occupation. Moreover, because of the influence of oceans and continents on terrestrial climate, many of these advances were longitudinal rather than latitudinal—movements along a climate gradient that ran from east to west as much as from north to south. This is particularly evident in northern Eurasia, where the “oceanic effect” of the North Atlantic brings milder climates to Western Europe, while colder and drier conditions prevail in Eastern Europe and Siberia.

Five major stages in the colonization of higher latitudes may be identified:

Stage 1: Occupation of the Middle Latitudes: Between roughly 1.8 and 0.8 million years ago, early humans expanded out of their tropical African base and colonized Eurasia as far as latitude 41-42o North. This stage is primarily associated with Homo erectus and changes in anatomy and behavior that allowed humans to forage across open and comparatively dry landscapes. Although perhaps rarely—if ever—exposed to subfreezing temperatures, Homo erectus populations coped with less productive and more seasonal environments than their predecessors. Their adaptations to these environments, which probably included increased consumption of meat, set the stage for subsequent expansion into higher latitudes.

Stage 2: Colonization of Western Europe: Between at least 500,000 years ago and up to roughly 250,000 years ago, humans (most of whom may be assigned to the taxon Homo heidelbergensis) occupied the continent of Europe as far east as the Danube Basin. In Britain, sites in this time range are found as far as latitude 52o North. With the possible exception of controlled fire, obvious adaptations to cold are lacking in the human fossils and archaeological sites of this interval. The initial colonization of Europe may have been largely an opportunistic expansion into the warmest parts of northern Eurasia—previously blocked by factors other than cold climate. Alternatively, some cold adaptations may remain concealed by the poverty of Homo heidelbergensis fossils and their archaeological record.

Stage 3: The Neanderthals: The Neanderthals (Homo neanderthalensis) evolved gradually in Western Europe and expanded eastward into colder and drier parts of northern Eurasia by at least 130,000 years ago (OIS 5e). They became the first humans to occupy the central East European Plain and southwestern Siberia. Unlike their predecessors in Western Europe, the Neanderthals exhibit a suite of anatomical and behavioral adaptations to cold environments. A diet high in protein and fat—obtained from the hunting of large mammals—was of critical importance. Despite their special cold-adapted traits, the Neanderthal range of climate tolerance was limited compared to that of modern humans. They probably were unable to cope with average winter temperatures much below -10o C and were generally restricted to wooded terrain.
Stage 4: Dispersal of Modern Humans: Between 45,000 and 20,000 years ago, modern humans (Homo sapiens) derived from Africa expanded into habitats and regions never occupied by early humans. The regions included Eastern Europe Siberia as far as latitude 60o North (and even farther on at least a seasonal basis). Their success was due chiefly to an ability to develop complex and innovative technology (e.g., insulated clothing, artificial shelters), some of which was essential to survival at higher latitudes during the middle of the Last Glacial period — where mean winter temperatures probably fell below -20o C. However, flexible organization may have been an important factor in sustaining a population in very cold and dry habitats, where resources were widely scattered. Both novel technology and flexible organization were probably related to syntactical language and the use of symbols. The modern humans who invaded northern Eurasia 45,000 years ago retained the warm-climate anatomy of their recent African ancestors. This may have precluded sustained settlement of the Arctic and forced them to abandon the colder parts of northern Eurasia (including most of Siberia) as the Last Glacial reached its cold maximum about 24,000 cal BP.

Stage 5: Modern Humans in the Arctic: The final stage may be divided into two sub-stages. The initial occupation of arctic environments took place between roughly 19,000 and 7,000 cal BP, as modern humans reoccupied parts of northern Eurasia abandoned during the peak of the Last Glacial. Several factors—including postglacial warming and some anatomical cold adaptations—may have triggered this event. Milder climates opened the door to northeast Asia and the Bering Land Bridge, and humans crossed into the Americas for the first time. After 7,000 years ago, humans expanded into deglaciated areas of Canada and other previously uninhabited regions of the Arctic. Much of their success was based on technological innovation (e.g., large boats, toggle-head harpoons) that facilitated a robust maritime economy.

Fig 1. Major stages in the settlement of higher latitudes by representatives of Homo during the past two million years.
THE USE OF CHIRONOMIDS IN RECONSTRUCTING HOLOCENE PALAEOCLIMATE IN NORTHWEST ICELAND

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Little quantitative palaeoclimatic data exists for Iceland and, as yet there are no terrestrially derived full Holocene palaeoclimatic reconstructions for Iceland. The work presented on this poster is part of a wider project on Holocene climatic change in Iceland (Caseldine and Langdon, this conference), and is an initial attempt to develop the use of subfossil chironomids to produce precise and accurate palaeoclimatic (especially temperature) reconstructions for Northwest Iceland. A number of lakes from Northwest Iceland, both on the Snaefellsnes Peninsula and on the Northwest Peninsula, have been sampled, and data is presented from selected sites. The main aims of this work are to calibrate the chironomid signal against recent climatic change; to test the transfer function currently being developed (Langdon, this conference); and to evaluate the effects of within lake variability of subfossil chironomids on palaeoclimatic reconstructions.

Preliminary results suggest that while the effects of within lake variability of chironomids on predicted temperatures are not statistically significant, the level of the variation (c.1.5°C) between samples in one lake could prove problematic considering the relatively small magnitude of temperature changes experienced over the Holocene.
MARKED 20TH CENTURY STRATIGRAPHICAL CHANGES IN LAKE SEDIMENTS FROM WESTERN SPITSBERGEN

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Gravity cores from four lakes in western Spitsbergen, Svalbard, register marked stratigraphical changes in the 20th century. At Skardtjørna and Tjørnskardet on Nordenskiöldkysten, there is an apparent diatom floristic change coupled to increased diatom concentrations in the uppermost c. 10 cm of sediment, which at the former site corresponds to the last c. 40 years. At Istjørna and Istjørnelva, 25 km southwest of Longyearbyen, striking changes occur in siliceous algal assemblages contained in the uppermost c. 5 cm of sediment. At both sites, diatom and chrysophyte cyst concentrations increase dramatically in the most recent sediments. We hypothesize that algal production has increased in all four lakes in the 20th century, perhaps as a synergistic response to climate warming (longer growing seasons) and atmospheric nutrient deposition.

There is also evidence of increased inorganic sedimentation rates at all four sites, suggesting accelerated geomorphic activity in their catchments. We have observed dramatic dilutions of sediment 210Pb activities in the unsupported inventories from each lake. Marked and near-synchronous crashes in diatom concentrations and organic carbon content correspond with these 210Pb reversals, suggesting dilution of autochthonous sediment by inputs of predominantly inorganic material. Taken together, these data suggest that lakes of western Spitsbergen have entered new limnological and geomorphic states for which no adequate Holocene analogues exist.
SPATIAL TEMPORAL DISTRIBUTION OF GREENLAND MELT ANOMALIES

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Twenty five years of passive microwave observations from satellite allows melt on the Greenland ice sheet to be analyzed statistically. From a temporal standpoint, the peak variance in melt extent is now several weeks before peak melt as a result of statistically significant, increasing trends in daily melt of 5-8% per year since 1978. A method for identifying spatial and temporal melt anomalies is presented and applied to the 2002 and 2003 melt seasons. The results indicate that 2002 melted in a way that is unprecedented in the satellite record due to record melt extent and highly unlikely melt in the northeast. The 2003 melt season was also very irregular with extreme melt late in the season that resulted in 1.5 m of ice removed at the equilibrium line altitude on the west side of the ice sheet.
VARIABILITY IN SUMMER ARCTIC TEMPERATURE AND ARCTIC OSCILLATION OVER THE PAST 600 YEARS.

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Spatial arrays of high-resolution (annual-decadal) paleoclimate records from throughout the Arctic were used to distinguish different modes of variability and trace their behavior back in time. A previous compilation of primarily annual-resolution records provided a view of average Arctic summer temperature during the past 400 years, documenting dramatic 20th-century warming that ended the Little Ice Age in the Arctic and caused dramatic retreats of glaciers, melting of permafrost and sea-ice, and alteration of terrestrial ecosystems. Some evidence suggests that these recent changes may be linked to an increasing positive phase of the Arctic Oscillation (AO), and that this trend in the AO itself may theoretically be due to greenhouse warming. Multi-century records of temperature and AO behavior are needed to identify natural background variability and evaluate potential linkages. A new international collaboration has created a spatial array of high-resolution Arctic paleotemperature records for the past ~600 years. Annually resolved archives were used wherever possible (e.g., tree rings, varved lake sediments, and annual ice layers), but sub-decadal resolution records from ice cores and high deposition-rate lake and marine sediments were included as well. Empirical Orthogonal Function (EOF) analysis was used to characterize the spatial and temporal modes of variability contained in the proxy array. The three leading modes of proxy variability all have highly significant correlations to the three leading modes identified in NCEP-NCAR reanalysis data, and are associated with dynamically significant processes, including: 1) a circum-Arctic average temperature trend with rapid 20th-century warming; 2) the Arctic Oscillation; and 3) a Urals Trough wave number three circulation pattern. Our analyses demonstrate the ability to identify the major modern observed modes of Arctic SAT variability within an array of proxy data, and reconstruct these modes back in time. These results provide insight into the long-term natural background variability of the AO and its relation to average Arctic temperature, and place their recent positive co-variation into a pre-anthropogenic context.
CLIMATE AND TROPHIC CASCADES EXPLAIN INTRA- AND INTER-ANNUAL VARIATION IN WADER BREEDING PHENOLOGY IN HIGH ARCTIC GREENLAND

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Waders migrating to High Arctic breeding grounds have extraordinary energy demands during migration. Previous work has shown that High Arctic waders in Greenland are “income breeders”, that is, the energy source used for reproduction is almost solely based on biomass collected on the breeding grounds. Thus, waders arriving on the breeding grounds are strongly dependent on rich food supply, and their breeding phenology is expected to respond to food availability. At the same time, mean temperatures and the onset of snow melt may also influence timing of reproduction either directly or mediated through the food resources (trophic cascades).

Here, we report the intra- and inter-annual variation in nest initiation (1st egg dates) of three wader species breeding in High Arctic Greenland (dunlin, ruddy turnstone and sanderling). Systematic field work during eight complete breeding seasons in a geographically restricted area has enabled us to quantify the relative importance of abiotic and biotic factors on variation in breeding phenology. Dates of nest initiation have been recorded in parallel with food abundance (invertebrates), temperature, and snow cover within the study area. Since snow cover and temperature may both influence the abundance of invertebrates, we have modelled the direct effects of food abundance, snow cover and temperature along with the indirect effects of snow cover and temperature on nest initiation through their influence on food abundance. Food abundance had the strongest direct effect on date of nest initiation with important indirect added effects of snow cover through influence on food abundance for dunlin and ruddy turnstone. Likewise, food abundance was the most important direct factor for nest initiation in the sanderling. However, the indirect effect of snow was negligible in this species. The sanderling breeds later than dunlin and ruddy turnstone and prefers dry heath with early snow melt as breeding habitat, explaining this result. Thus, low food abundance and late snow melt may delay the onset of dunlin and ruddy turnstone breeding, whereas low food abundance may delay sanderling breeding. Our data also suggest that delayed breeding may in turn negatively affect mean clutch size, thus, contributing to reduced long-term reproductive output.
MIDDLE HOLOCENE PALEOCEANOGRAPHY IN THE DENMARK STRAIT REGION

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Large shifts in paleoceanographic parameters including IRD, biogenic carbonate, stable isotopes, and foraminiferal assemblages, occur in Holocene sediments from shelf troughs in the Denmark Strait area. These shifts are well documented in two cores, MD99-2269 from the northern Iceland shelf, and MD99-2322 from the southeast Greenland shelf. A combined age model for these two cores was constructed after paleomagnetic depth correlations were made, allowing for very well constrained age control in these cores. The carbonate records of the two cores are very similar, although the Iceland shelf core has higher carbonate contents. A striking aspect of the carbonate records is an interval of high carbonate content between 6,200 and 2000 cal yrs BP. Coccolith analyses on MD99-2269 (Giraudeau et al., submitted) have shown that production of Coccolithus pelagicus, a cold-water species, generated much of the carbonate in this interval of MD99-2269. The percentage distributions of Cassidulina neoteretis in MD99-2269, parallel the carbonate record of MD99-2269, supporting an interpretation of a stratified water column on the northern Iceland shelf, with Atlantic Water carried in the Irminger Current submerging beneath fresher Arctic or Polar waters as it rounded the Northwest Peninsula of Iceland. The closely parallel carbonate record of MD99-2322 suggests that the Kangerlussuaq Trough also was affected by Irminger Intermediate Water in the middle Holocene, and that this influence was strongest between 6200 and 2000 cal yrs BP. In MD99-2322, delta 18-O data on planktic foraminifers shows isotopic depletions generally associated with relative low carbonate intervals as well as IRD spikes. These depletions likely represent strong Polar Water outflows in the East Greenland Current. The IRD content of MD99-2322 shows frequent spikes after 3300 cal yrs BP. To the north of Denmark Strait, on the East Greenland Shelf, core MD99-2317 has an almost identical IRD record to MD99-2322, suggesting cooling and/or thickening of the surface Polar Water, finally leading to a decline in the carbonate production on the shelves after 2000 cal yrs BP. MD99-2317 has very low carbonate content. However, the Atlantic Intermediate Water indicator species, C. neoteretis, shows large, abrupt percentage variations beginning at 6200 cal yrs BP, coincident with the rise in carbonate in the other two cores. The large percentage spikes in C. neoteretis give way to an almost fully agglutinated fauna by 2800 cal yrs BP. We anticipate that the variations in carbonate content and foraminiferal faunas reflect hydrographic and climatic conditions that relate to intermediate convection in the Iceland and possibly the Greenland seas. To explore this idea we make preliminary comparisons between these parameters and the sortable silt (mean of the 10-63 micron size fraction) in core MD99-2246, which is interpreted to reflect the flow strength of the DSOW.

Giraudeau, J., Jennings, A.E., and Andrews, J.T., subm., Timing and mechanisms of surface and intermediate water circulation changes in the Nordic Seas over the last 10,000 cal. years: a view from the North Iceland Shelf. Quaternary Science Reviews.
INTRABASINAL VARIABILITY OF HOLOCENE TEPHRA IN A SMALL KETTLE LAKE, LORRAINE LAKE, UPPER COOK INLET, ALASKA

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The record of volcanic ash fall record preserved in Holocene lake sediments of Lorrane Lake was used to investigate the intrabasin variability of individual tephra units. Six sediment cores between 3.2 and 5.8 m long were recovered from Lorraine Lake, a small (0.53 km2) shallow (ca. 8 m) kettle located on the Elmendorf Moraine, of late Pleistocene age, 11 km northwest of Anchorage, Alaska. Situated in a region of low relief (49 m), the basin has a limited drainage basin (1.3 km2), no inflow and remains ice covered for approximately six months of the year.

Cores were recovered from the north, south, east, and west parts of the lake, which is divided into two (north and south) sub-basins. A total of 21 AMS 14C ages were obtained on terrestrial macrofossils. Radiocarbon ages from the base of three of the cores average ca. 12,300 14C yr BP, confirming that the cores contain the entire postglacial sedimentary record. Eleven tephra deposits, ranging from non-visual to several centimeters in thickness, have been identified and can be correlated among the cores based on their relative depths and spacing, color, texture, and thickness, high magnetic susceptibility (MS), low loss-on-ignition, X-ray gray scale value, and abundance of magnetic minerals. Although other less prominent tephra units may occur, these 11 clearly defined units are used to compare tephra deposition within the lake. Several physical characteristics were compared including: stratigraphic thickness, MS peak area, X-ray density stratigraphy and a numerical classification scheme ranking visual and stratigraphic prominence based on thickness, purity of ash and nature (sharpness and continuity) of stratigraphic contacts.

Despite sedimentation rate variations (0.75 to 0.32 mm/yr) the thickness of the tephra units does not appear to vary between cores recovered from different parts of the basin or different water depths. The stratigraphic prominence of the tephra layers and their similarity between core sites implies that probable depositional complexities (e.g., wind skimming, waves, lake ice, blowing snow) and post-depositional processes (e.g., bioturbation, bathymetric focusing) have a minimal impact on the preservation of tephra units. Open basins having larger runoff or higher relief areas, however, likely have more complex intra-basin stratigraphies.
Paleolimnological studies from the eastern High Arctic have shown that diatom species assemblages in small, alkaline ponds remained relatively constant for millennia, but began to change dramatically beginning in the 19th century, likely in response to climatic change. Less is known, however, about the variability of environmental change across the High Arctic. In order to accurately assess this information, regional data sets that encompass present-day limnological variability are needed. Here, we present the major trends in physical and chemical limnology across 46 lakes and ponds from Melville Island, NU/NWT, Canada. The large spatial, geological, and climatic gradients captured by the sites from Melville Island result in broad ranges of water chemistry variability. These data are part of ongoing research to develop a diatom calibration set for the western-central Canadian High Arctic.

In addition, a paleolimnological record of sedimentary diatom assemblages from a small pond on Melville Island is presented. Large diatom species shifts begin in the late 19th century. Although the species we see in this assemblage are different from those in other high arctic paleolimnological studies, the changes are consistent with a response to climatic change over the last 100 years, and suggest that, similar to ponds in the eastern High Arctic, this pond on Melville Island has also experienced dramatic environmental changes over the recent past.
Pinnipeds (seals, sea lions, and walruses) exhibit an unusual pattern of increasing species richness with increasing latitude that can be attributed, in part, to the critical role that sea ice has played in the group's evolution (Kelly 2001). The potential impact of climate change on ice-associated marine mammals has largely been discussed in terms of reductions in the thickness and areal extent of sea ice. We should look beyond ice thickness and extent, however, and consider the specific ecological relationships between individual species and the sea ice environment to predict likely impacts of climate change. Examples include Pacific walruses (Odobenus rosmarus divergens) and ringed seals (Phoca hispida).

Pacific walruses are benthic feeders that rest and bear their young on pack ice of the Bering and Chukchi seas. The reductions in the summer and fall ice cover observed in recent years effectively de-coupled the walruses' feeding and nursing habitats. In September 2002 and 2003, record retreats of the ice edge were observed in the Arctic Ocean. Female walruses and their young migrate in spring from the Bering Sea to the Chukchi Sea (Fay 1982) where they typically alternate resting on the ice edge with feeding on benthic prey below the ice. In recent years, however, the ice edge retreated to north of the shallow shelf so that the ice was over water too deep for walrus feeding (Kelly 2001).

Whereas the distribution and extent of sea ice relative to forage grounds is critical to walruses, the snow cover on top of the ice is the critical feature of ringed seal habitat. Ringed seals are regarded as the most ice adapted and the most numerous of the northern hemisphere pinnipeds (seals, sea lions, and walruses) (Chapskii 1940; McLaren 1958; Smith and Stirling 1975). They are found in all seasonally ice-covered seas and even some lakes in the northern hemisphere.

Ringed seals feed under heavy ice cover on fish and zooplankton and obtain air at breathing holes they maintain in the ice. Early in the winter, the breathing holes become snow covered. As snow accumulates on top of the ice, the seals continue to breathe under the snow. Where snow drifts to sufficient depths, the seals excavate lairs in the snow above their breathing holes. These subnivean lairs provide protection from extreme cold and decrease the seals' vulnerability to predation. Pups are born in the lairs in April and are nursed there for the first couple of months of their lives. The survival of pups depends on their remaining in lairs concealed from mammalian and avian predators. Ringed seals typically abandon lairs only in late spring and early summer, when the pups are weaned.

For the past 5 years, the abandonment of lairs has taken place increasingly early as spring temperature and snow melts have advanced. The transition from lair use to basking on the surface was especially early and abrupt in 2002, and by mid May all the seals had abandoned their lairs. Many pups in their natal coats were resting on the ice in the open instead of in subnivean lairs as is usual in mid May. The early snow melts we have observed are consistent with a general pattern observed in the Beaufort Sea. Premature lair abandonment by ringed seals, associated with early snow melts, likely will increase juvenile mortality rates via exposure to freeze-thaw conditions and predation.

The degree to which ringed seals can respond adaptively to earlier snowmelts will depend on several factors including the rate of climate change, the heritability of pupping dates, and the genetic variability within the population.
The area of breeding home ranges used by radio-tracked ringed seals averaged 2 km², and we have found adult seals returning to the same or nearly the same breeding home range in successive years. This high fidelity to breeding sites suggests that rather than forming a single, panmictic population, ringed seals may exist in a series of locally adapted demes. As such, they would be expected to have limited genetic diversity and scope for adaptive change in response to climate change.


ORIGIN OF THE EAST-WEST ASYMMETRY OF PALEO-GLACIERS IN THE SIERRA NEVADAS

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Maps of paleo-glaciers in the Sierra Nevada range indicate a strong east-west asymmetry in glacier lengths. West-side glaciers extended as much as ten times further than those on the east side of the range. Two hypotheses to explain this asymmetry involve differences in topography and differences in meteorology. Topography: there is a very strong asymmetry in the slope of the eastern and western flanks of the range. Much lower slopes and consequently longer valleys exist on the west side. The lower-sloped west side would have had much larger snow accumulation areas and proportionately larger ablation areas and glacier lengths. Climate: if most of the precipitation in the Sierra Nevadas was derived orographically as westerly storms rose up the western flanks, then these air masses would have been depleted of water creating a precipitation shadow on the eastern side and smaller glaciers.

We present a two-dimensional numerical model of glacier flow in which a realistic mass balance and DEM-derived topography can be specified. Finite difference methods are used to time step the continuity equation for the change in ice thickness, given fluxes in two horizontal dimensions by depth averaged ice deformation and basal sliding. Ice is added or removed each time-step in accord with the mass balance pattern. In addition, discrete transport processes, such as avalanching, have been implemented using cellular/stochastic methods to redistribute ice on steep slopes.

The relative simplicity and speed of this numerical model permits an exploration of parameter space for the appropriate climate conditions to match both terminal moraine elevations and trimlines in each of many valleys simultaneously. We employ the model to determine a realistic climate scenario (mass balance pattern) for the south fork of Kings Canyon on the western side of the Sierra Nevadas at the last glacial maximum (LGM). Several climate scenarios were tested to determine how much east-west asymmetry in the climate is necessary to explain the difference between the lengths of east- and west-flowing paleo-glaciers at the LGM. Finally, we explore whether this climate scenario can be ascribed to the expected pattern of orographically-derived precipitation.
Discharge and sediment flux of the Po River, Italy, are simulated to determine the impact of climate change and sea-level fluctuations on the stratigraphy of the Northern Adriatic Sea. The drainage area of the Po River, one of the major alluvial systems of Europe, was 2.6 times larger during the Last Glacial Maximum (LGM), 21 kyr B.P. due to a 120m lower Adriatic sea-level (figure 1). The late-Würmian ice-sheet covered the Alps almost completely at that time. The Alpine glaciers did not add significant area to the Po basin as the glacier drainage divide at 21 kyr B.P. was roughly similar to the present-day basin divide (Baroni, 1996). Fifteen percent (29,000km2) of the total Po drainage basin was covered by glaciers.

Hydrotrend, a numerical climate-driven hydrological model, is used to simulate yearly discharge and sediment flux of the Po River outlet since the LGM. We used the global sea-level curve (Fairbanks, 1989) together with present day digital topography (Hydro1k) and bathymetry to determine changing drainage basin properties (river networks, hypsometry, relief and reservoirs) over time. Monthly climate statistics since the LGM are estimated based on the Community Climate Model1 (CCM1) modeled climate statistics for LGM combined with the present climate statistics and interpolated over time with a normalized δ18O curve. Using the CCM1 climate statistics is justified by the fact that Peyron et al. (1998) find cool steppe vegetations to be coherent with conditions predicted by CCM1. According to the CCM1 model the basin mean temperature is much lower (8.8°C vs. 2.4°C) and precipitation increases by 18% compared to present day values. The normalized δ18O curve also forces glacier equilibrium line altitude (ELA) changes. ELA values are based on global latitude-specific averages both for the LGM and present day. HydroTrend uses the ELA to determine the glacier volume, and ELA changes results in a glacier area change. Bahr et al. (1997) propose an exponential relationship for glacier area vs. volume. Based on this relation HydroTrend simulates glacier ablation or growth which influences the total discharge and sediment flux. A stochastic model of Morehead et al. (2003) is used to simulate the sediment fluxes at the river outlet (figure 2, equation 1 and 2). Bedload transport is simulated based on river slope and discharge relationship (Bagnold, 1966).

Climate studies in the Alpine region indicate that glaciers reached their maximum extend during the LGM and were approximately at their present position at the start of the Holocene. HydroTrend simulations reflect this trend (figure 3, grey line). Climate changed rapidly during the Bolling and the end of the Younger Dryas. The model shows two melting phases which have a significant impact on the total discharge for the Po (respectively up to 40% and 60% of the total discharge). Bedload is closely related to discharge and consequently shows the same trend. Suspended sediment changes due to climate affect small river basins more dramatically than large river basins like the Po River, due to the modulating ability of large rivers (Syvitski, 2003). Figure 4 indicates that high discharge values have more impact on the bedload than on suspended sediment load. We predict that these periods should be identified by layers with coarser grain sizes in the stratigraphic record. To analyze the significance of the glacier melt contribution we reran the model without glacier influence (ablation or growth). Suspended sediment flux at the river mouth tends to be less (on average 1.9MT/yr, approx. 5% over the period 21 – 10 kyr B.P.). This is most evident for the 2 melting phases when suspended sedimentation rates increases with 13MT/yr due to glacier melt. Apart from changing the grain size composition as discussed above, it is concluded that the glacial melting increases the sedimentation rates significantly as well.


Fig 1. Changes in the drainage basin of the Po river over time. Red and yellow combined indicates the basin during LGM; yellow indicates the present drainage basin.
\[ \left( \frac{Q_{si}}{Q_{sbar}} \right) = \Psi \left( \frac{Q_i}{Q_{bar}} \right)^C \]

Equation 1.

\[ Q_{sbar} = \alpha^3 Q_{bar}^{\alpha^4} R^{\alpha^5} e^{kT_{bar}} \]

Equation 2.

Fig 2. Equation 1. $Q_{si}$ is the daily suspended sediment discharge (kg/s), $Q_i$ the daily discharge (m³/s), $Q_{sbar}$ the long-term average of $Q_s$, $Q_{bar}$ the long-term average of $Q_i$, $\Psi$ a log-normal random variable and $c$ a normal random variable.

Equation 2. $Q_{bar}$ is the long-term average of $Q_i$ (m³/s), $R$ the maximum basin relief (m), $T_{bar}$ the basin-average temperature (degrees C), $\alpha_3$, $\alpha_4$, $\alpha_5$ and $k$ are dimensionless coefficients which depend on climatic zone (Syvitski et al., 2003).

Fig 3. Simulated glaciated area (grey line) and changing discharge ratio (Glacier discharge / total discharge) (blue line).
Fig 4. Black line is the yearly ratio of bedload over suspended sediment over time. The red line indicates the 50 years running average of this ratio over time. Bedload shows a more direct response to glacier melt than suspended load.
DEVELOPMENT OF SOLIFLUCTION LOBES, KLUANE RANGE, YUKON TERRITORY

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Solifluction lobes are abundant above treeline on an alpine plateau located near Kluane Lake, Yukon Territory. On a west slope (1800 m a.s.l.), lobes typically increase in size downslope, evolving from small sorted steps near the slope crest to extensive complexes with multiple fronts at the foot. In August 2001, 13 solifluction lobes were excavated to conduct stratigraphic observations and collect humus buried beneath the lobes (Figure 1). 25 humus samples were radiocarbon-dated to obtain long-term rates of lobe advance. In the spring of 2002, surface movement was monitored on five solifluction lobes using repetitive surveying of surface targets, while groundwater levels and thaw depths were measured on these lobes and along the entire slope. In addition, 250 lobes were mapped, and their morphometry measured.

These results were used to construct a simple model of lobe development, in which frontal advance results from the slow accumulation of material behind a comparatively rigid front, until a threshold of instability is reached and rapid advance occurs by shearing. Lobes across the study slope represent different stages of this cycle and inter-lobe comparison and climatic interpretation of changing rates must deal with the lag time of this episodic frontal movement.

The downslope increase in moisture availability is the primary cause for the spatial gradation of landforms observed on the slope: increased moisture during autumn freeze-back and spring thaw cause larger surface movements downslope while the vegetation cover, which is best developed in the moist areas downslope, causes an increase in slope resistance, allowing lobes to grow larger before collapse occurs. Spatial analysis of lobe dispersion suggest that the population of solifluction lobes represents an organized succession of wave-like benches, whose wavelength and amplitude are controlled by the downslope increase in solifluction activity.

Fig 1. Excavation of a solifluction lobe to uncover the buried humus horizon.
Fig 2. Downslope variation in lobe frequency. Some lobes from the upper slope (in grey) have been omitted from the analysis because mapping was inconsistent in that area, while three lobes on the lower slope and three lobes on the upper slope were omitted because they could not be included in the moving average.
VEGETATION TYPES OF NY-ALESUND, SVALBARD, AND THEIR HABITAT RELATIONSHIPS

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Vegetation development in recently deglaciated terrains in Ny-Alesund, Svalbard, was studied. Vegetation types were identified based on floristic structure of the plant communities. They were correlated with soil characteristics and key factors regulating vegetation differentiation were determined.

Ny-Alesund is located in the northwestern corner of Spitzbergen Island, Svalbard. Its latitude is approximately 78°55’N and longitude 11°52’E. Climate of the area is typically frigid and humid with mean annual temperature of −5.2°C, mean monthly temperature of the warmest month 5.4°C, and that of the coldest month −15.5°C. Annual total precipitation is approximately 400 mm. Such a climate may be classified as ET type (tundra climate) of Köppen’s classification. Geology of the area is dominated by Carboniferous and Permian sedimentary rocks predominantly of calcareous and dolomitic nature. Entire area was once covered by glaciers. There are some extant glaciers that have been receding quite rapidly in a rate of approximately 10 m/year on a low and gentle topography. Geomorphology of the area consists basically of a confluent glacial outwash plain of extant glaciers West Brogger and South Brogger Glaciers. In the forefront of those glaciers, there is a vast extent of recently deglaciated exposed terrains, where vegetation succession progresses. Therefore, most of the vegetation is in the early to intermediate stages with some in the stable stage of succession.

Throughout the study area, a total of sixty relevés of 2 m x 2 m size were established to represent various kinds of vegetation. For each relevé, all the vascular species were listed and their coverage was assessed. From each relevé, one soil sample representing top 10 cm of the solum was collected. The samples were later analyzed for physical and chemical properties.

Based on the floristic characteristics, seven vegetation types were distinguished. They were: 1. Draba nivalis type, 2. Dryas integrifolia type, 3. Cerastium arcticum type, 4. Cassiope tetragona type, 5. mesic moss type, 6. Saxifraga caespitosa type, and 7. Luzula arctica type. The Draba type develops in habitats of soils excessively well drained and over-saturated with basic cations but poor in organic matter; the Dryas type occurs where soils well-drained and high with basic cations with high soil pH; the Cerastium type in mesic habitats of soils rich in basic cations and high in electric conductivity; the Cassiope type in mesic habitats with low soil pH and base saturation; the mesic moss type in habitats moderately drained and low in base saturation and poor in calcium and magnesium; the Saxifraga type in habitats poorly drained and intermediate in amount of basic cations; and the Luzula type in water-saturated habitats and low in basic cations.

In terms of vegetation succession, the Draba type and the Luzula type both indicate early stage of succession, and the former represents extremely dry habitats while the latter very wet habitats. The Cassiope type and mesic moss type both represent more or less stable stage of the succession. The former indicates somewhat base-impoverished soil while the latter relatively base-rich soil conditions. Other types represent more or less intermediate stage of the succession. It was thought that vegetation of the area would eventually converge to and be represented by the Cassiope type or moss type, depending on chemical characters of soils, as the succession well advanced.
Peculiarity of the northern (tundra) ecosystems of the Siberian estuarine environment is in their development under severe natural conditions with snow cover existing for a long period, a short period of active life and a thin active soil layer over permafrost table. The latter determines formation of shallow soil containing weakly decomposed organic matter often saturated with water. Such conditions lead to conservation of air pollution in the top soil layers and its long-term retention and circulation in the local biogeochemical cycles, higher sensitivity of tundra ecosystems to contamination and their vulnerability. Flood plain areas in the tundra zone are characterized by better conditions due to river warming effect and accumulation of nutrient-enriched deposits. However river transports contaminants from the local sources (e.g. Krasnoyarsk Chemical and Mining Combine in the Yenisey river basin) that accumulate on flood plain and cause local contamination of soils and ecosystems in addition to the global fallout [4].

The main goal of the study was to evaluate modern contamination of the dominating plant groups of the lower Yenisey flood plain and watershed tundra landscapes caused the global fallout and local discharge, to compare it with the natural 40K background and to find possible relation between 40K and 137Cs transfer to plants.

Study sites were located in the Yenisey upper and middle delta and estuary on the island and right bank coastal flood plain and the adjacent high ancient terraces, characterizing typical and southern tundra landscapes. Vegetation was sampled at 1-3 m² plots (averaged sample per plot) located over the soil profiles. Air dried and homogenized soil and plant samples were analyzed for gamma-emitters with the help of CANBERRA spectrometer with HP Ge-detector (performed by A. Borisov, GEOKHI, and S. Kirov, SPA "Radon"). Determination error did not exceed 25%.

Vegetation cover in general consisted of mosses, lichens and rare grasses with dwarf birch and willow on watersheds, willow and alder shrubs on slopes of the ridges and gullies, wet meadows and mires on the low- and medium-level flood plains, grassy and shrubby communities on high ridges and cores of the high-level flood plain. Phytomass considerably varied in structure and amount (from 0.2 to 3.5 kg/m², dw) depending upon geomorphological position and the underlain rocks, and increased in southward direction.

Mean concentration of 137Cs in the main studied plant groups varied from 31 to 100 Bq/kg and increased in groups in the following order: grasses < alder, willow (leaves), lichens < mosses < mosses (lower part, litter) (Fig 1). Mosses and their lower part in particular appeared to be most enriched in radiocesium while lichens accumulate radionuclide to a lesser extent. These conforms with the data obtained for the Altai and Pur-Taz regions [5]. Compared to 40K 137Cs content in plants was 3-10 times lower and was more variable.

Our data proved lower moss parts to be relatively enriched in radiocesium. Therefore in case of forage deficiency the ration of grazing reindeers can be enrich in radiocesium. 40K accumulation in the studied plants was significantly higher compared to 137Cs and increased in plant groups in the other order being most variable in green mosses, willow leaves and horsetail.

137Cs TF were within the range of that obtained for the Chernobyl fallout for natural meadows [1-3], but mean values appeared to be relatively high (Fig. 1, TF values relative to the top 0-10 cm soil layer, they did not change much when calculated relative to the deeper layer except for the cases of buried deep contaminated horizons of the flood plain soils.).
corresponding more to the values for peaty swampy soils. These results conform to those obtained for peaty soils in the countries of the Arctic region and are comparable with TF obtained for mushrooms in temperate zones developing on the forest weakly decomposed litter [1]. In our opinion this has the following explanations: 1) conservation of contamination in plants and the top soil layer; 2) low radionuclide concentration in soil that usually leads to higher element transfer; 3) higher availability for plants growing on organic peaty weakly decomposed matter.

Although no statistically significant correlation was found for most groups between 137Cs and 40K content and their TF values (except for mosses, see below), for the boundary groups there is a tendency of lower radiocesium transfer to plants with higher potassium uptake and vice versa (e.g. horsetail and mosses) and for alder and willow. Horsetail and willow were noted for higher 40K accumulation and lower 137Cs TF compared to mosses and alder respectively. This means that mosses and alder are more sensitive indicators of 137Cs contamination compared to horsetail and willow despite relatively high concentration of radiocesium in the latter.

Cs137 concentration in green moss (Hylocomium splendens) collected in different landscape conditions varied from 19 to 96 Bq/kg (DM) and showed weak decreasing tendency in its level in seaward direction (Fig 2). Higher Cs-137 concentration was detected on watersheds and in their depressions and fissures with maximum value in the sample collected on the south-eastern slope to the watershed lake (KR2-3) covered by thick alder shrubs. Natural 40K concentration in mosses was 2-14 times that of technogenic 137Cs. Although moss cover is treated as a natural collector of atmospheric contamination there was inverse correlation between 137Cs concentration and 40K/137Cs ratio (r=-0.695, n=8) suggesting secondary uptake of radiocesium discriminated by potassium.

Radiocesium content in willow leaves was maximum in accumulative watershed landscapes and was not affected much by radiocesium buried in flood plain alluvium layers. Among sampled species Salix lanata showed maximum accumulation ability.

Calculation of 137Cs and 40K content in the main components of biomass per square meter confirmed the significant role of mosses (their litter in particular) in radiocesium accumulation by tundra vegetation. The tendency of inverse 137Cs and 40K accumulation by plant biomass per square was also found.

Conclusions

Concentration of 137Cs in plants growing the Yenisey estuarine zone is comparatively low and corresponds to the levels found earlier in the regions subjected to global and regional fallout due to distant aerial radionuclide migration. Mosses and their lower parts in particular appeared to be more enriched in radiocesium compared to lichens growing at the same plots.

Tundra plants have remarkably high TF values comparable to those obtained for peaty and swampy soils of the temperate zone and tundra areas contaminated after the Chernobyl fallout. This confirms vulnerability of tundra landscapes in case of radionuclide contamination.

Concentration of radionuclide in plants depends upon landscape conditions and plant species. Maximum 137Cs accumulation has been found in the lower parts of mosses grown on watersheds in accumulative elementary landscapes collecting surface run-off during melting period and incorporating perched water. 137Cs accumulation in shrubs (willow and alder leaves) especially growing on soils rich in organic and of coarse texture can considerably contribute to reindeer meat contamination in summer period. Salix lanata showed maximum accumulation ability among sampled species.

Local enhanced concentration of radiocesium in buried alluvium on flood plain area enriched in fine sediment may not lead to higher radionuclide accumulation in plants due to strong 137Cs fixation by fine particles.

Horsetail and willow accumulating 40K to a higher extent had lower 137Cs TF compared to mosses and alder. Therefore mosses and alder are believed to be most sensitive indicators of 137Cs contamination in tundra landscapes and more significant for the local food chains compared to lichens, horsetail, and willow.
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Fig 1. Cs 137 and K-40 transfer factors (TF, m2/kg) for different plant groups (x - mean value)

Fig 1. Cs-137 and K-40 transfer factors (TF, m2/kg) for different plant groups (x - mean value)
Fig 2. Cs-137 in green mosses (Bq/kg, dw) in different Yenisey estuary sections and landscapes. SK - gulf area, VR - inlet area, KR - delta area, UP - upper delta area. 1 - eluvial landscape (watershed); 2 - transitional landscape (slope); 3 - accumulative landscape (depression); 4 - super aqueous landscape (flood plain)
TESTING OF THREE NEW COOL-WATER CALIBRATIONS FOR THE MG/CA PALEOTHERMOMETER SUGGESTS REDUCED INFLOW OF ATLANTIC WATER ONTO THE N-ICELAND SHELF IN THE PAST 2000 YRS

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Calibrations of Mg/Ca ratio against temperature are reasonably well-constrained for temperatures >10°C but are poorly developed for cooler temperatures, thus limiting the method’s applicability to high-latitude and deep sea studies. This study focuses on strengthening the calibration at low temperatures by using a robust data set from the W, N Iceland and Greenland margins. The Iceland margin, near the northern limit of Atlantic Water, has a spatial temperature gradient of 0 to 9°C and is thus an ideal location to conduct cool water calibrations for Mg/Ca studies. Samples from the Greenland margin were then added to obtain the coldest endmember.

Previous studies have shown that the temperature-Mg/Ca relationship in benthic foraminifera is species-specific so that one common calibration cannot be obtained. Therefore we have chosen to develop calibrations for three common arctic, benthic species: Melonis barleeanus, Cassidulina neoteretis, and Islandiella norcrossi/helenae. All three species show Mg/Ca ratios comparable to published values for benthic foraminifera (0.6-2.2 mmol/mol). For both the calibration and downcore samples Mg/Ca was measured on an ICP-MS at the Univ. of California, Santa Barbara and isotope analysis was done at the Leibniz Laboratory at Kiel University, Germany.

The calibration samples were collected during cruises B997 and BS1191. They were stained with Rose Bengal upon collection and sieved at >63 µm. The three species of benthic foraminifera were picked from the >250, 150-250, and 106-150 µm fractions. Both stained and pristine, unstained individuals were picked due to a limited number of stained individuals in the samples. Furthermore, in order to get enough material for both Mg/Ca and 18O analysis the three size fractions had to be combined. Before analysis each sample (containing anywhere between 9 and 140 individuals) went through a rigorous cleaning procedure established by Boyle and Keigwin (1985/1986) as modified by Boyle and Rosenthal (1996). Because of the addition of pristine, unstained foraminifera (dead foraminifera) to the samples we have chosen to calibrate our thermometer against isotopic calcification temperature (calculated from the d18O measured in the same sample) rather than to use the CTD temperature obtained during the respective cruise. M. barleeanus shows the greatest temperature sensitivity, while both C. neoteretis and I. norcrossi/helenae show a slightly lower (but quite clear) sensitivity.

The downcore samples are from core MD99-2269. The core was collected in 1999 during the IMAGES V cruise aboard R/V Marion Dufresne. Site MD99-2269 is located in 365 m water depth in Reykjafjardaráll, N Iceland shelf (66°37.53´N, 20°51.16´W). The core is a 25 m long calypso piston core with basal radiocarbon date of ca. 12 ka cal BP and a modern coretop. Sample resolution is ca every 50 yrs. Samples were wet sieved at >63 µm and picked for foraminifera in the following size fractions: >250, 150-250, 106-150 µm. Where available all three arctic, benthic species were analyzed. Due to small sample size the three different size fractions had to be combined. Before trace-element analysis each sample went through the same cleaning procedure as the calibration samples. However, due to the small sample sizes (< 175 µg) sonication time and reagents were scaled down (not changing the concentration, just the amount) from normal procedure to maximize sample recovery. Only results with >10% recovery...
were used for data analysis, although some samples with less recovery were no different from the rest.

Applying our new calibrations to the downcore samples confirms that the new calibrations function well for this temperature range. Mg/Ca ratios during the last two millennia in core MD99-2269 show a clear species-specific effect where M. barleeanus ratios are consistently lower that those of C. neoteretis or I. norcrossi/helenae supporting the view that incorporation of Mg into foraminiferal calcite is species-specific. However, each species reconstructed a temperature record that was similar to the other two species and was within the expected range for this site. Cool conditions of <1°C are observed during the LIA; a warm spike of 4°C at 500 cal yr BP is seen in all three species; a second warm spike of 5°C is observed at 1500 cal yr BP, coincident with a peak in carbonate content in the core. Carbonate has a similar trend as the reconstructed temperature during the last two millennia suggesting that it could serve as an indicator of temperature on the N Iceland shelf. An overall cooling trend (and decrease in carbonate) from 2 ka cal BP to the present is interpreted as a decrease in inflow of warm Atlantic water in the Irminger Current to the site. We hypothesis that as the inflow decreased the Atlantic water changed from being a bottom water mass at the site and became an intermediate watermass as is observed in the area today.

LATE QUATERNARY VEGETATION HISTORY AND CLIMATE RECONSTRUCTION INFERRED FROM WESTERN ALASKA AND NORTHERN YUKON LAKES

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Late Quaternary Beringian ecological communities are unique, representing the totality of biotic response to large-scale fluctuations of environmental factors. In this study, three lake sediment records (Zagoskin Lake [western Alaska], Hanging Lake and Trout Lake [both northern Yukon]) believed to span approximately the last 30,000 (?) 14C yrs B.P. will be examined to elucidate fluctuations in regional climate and the response of the sub-arctic flora. The paleoclimatic reconstruction will consist of inferred mean July air temperatures from subfossil midge (Chironomidae, Chaoboridae, and Ceratopogonidae) assemblages (Walker et al., 2003). Sub-arctic vegetation change will be examined using detailed pollen, stomate, and aquatic plant macrofossil analyses. The pollen stratigraphy of a 15.2 m sediment core from Zagoskin Lake has been divided into five distinct zones with a basal age of >30,000 14C yrs B.P. (Ager, 2003). Preliminary analyses of 26 midge assemblages (0 – 4.35 m of sediment) from Zagoskin Lake suggests a dynamic midge response to Late Quaternary climate change with notable differences in midge stratigraphy throughout the last ~12,000 14C yrs B.P.. Late Holocene samples are dominated by the Tribe Pentaneurini, Stictochironomus, and Paracladius, suggesting a cool arctic-tundra environment. Early Holocene assemblages are mainly comprised of Mesocrictopus thienemanni, Chironomus, and Subtribe Tanytarsina. Midge diversity is highest during the early Holocene (3 – 4 m of sediment) with a greater abundance and diversity of Chironominae compared to Orthocladiinae.

A comprehensive watershed and lake monitoring program was initiated during the 2003 season at Cape Bounty, Melville Island, Nunavut (75dN, 108dW) to develop a field observation database for calibrating the paleoenvironmental record contained in varved sediments. The goal of the project is to collect hydrometeorological and limnological data for a six-year period at the site, to identify the key controls over inter- and intra-seasonal sediment delivery deposition in response to snow melt and summer rainfall events. A key element of the experimental design is the parallel study of two adjacent lakes with similar watershed conditions (bedrock, Quaternary deposits, relief, aspect, weather and vegetation) to determine the reproducibility of the varve record and to systematically identify signal and noise components. Additionally, the formation of the subfossil diatom record and related biogeochemical fluxes will be evaluated to identify the linkages between terrestrial and aquatic systems. The long term data derived from this work will be used to identify the comparative role of winter snow water equivalence (SWE) and melt season thermal conditions in the formation of varves. Previous research based on varve records has indicated both factors potentially act as primary controls over runoff and sediment delivery, but few studies have evaluated SWE directly.

The experimental design includes the following elements: a network of meteorological stations in both catchments, river stations for gauging and characterization of the suspended sediment load, and lake stations with traps and sensor arrays to measure deposition rates, bottom currents and sediment texture. Regular sampling of the rivers for particle size analysis will complement in situ measurement of particle size in the lake. Further analysis of the sedimentary environment will be carried out with a network of cores and acoustic characterization of the sedimentary fill in the lakes. Analysis of sediment cores will combine detailed microscopy and image analysis to determine sediment texture, mass accumulation rates, and composition to identify subannual sedimentary events of different origin.

Results from the first season of work indicate notable differences in SWE in the catchments that generated differences in the timing of sediment delivery between the two study watersheds. Despite these differences, both watersheds exhibit comparable responses to short-term hydrometeorological conditions, particularly rainfall events. For 2004, the sampling program will be substantially expanded to increase sample and trap recovery frequency.
Attempts to reconstruct the Holocene terrestrial climate of Iceland have utilised a range of proxies, although as yet little progress has been made on quantification of this record. Recent research has, however, shown that chironomid communities were sensitive to climate change throughout deglaciation and the early Holocene (Caseldine et al., 2003), and current research is assessing the potential of using them for reconstructing late Holocene climate (Holmes et al. 2004). Although chironomids have been identified as a key proxy for detecting past climate change, it is apparent that they are also influenced by a range of other environmental and limnological variables including food-web interactions as well as allogenic factors. This can be illustrated from the abundance of chironomid transfer functions for use with palaeolimnological data which have recently been developed. Depending on the environmental gradient of interest a range of factors have been shown to influence chironomid communities, notably air and water temperature, hypolimnetic dissolved oxygen, total phosphorus, total nitrogen, lake depth, treeline, and salinity.

Much depends on the subset of lakes chosen for environmental training sets as to which environmental variable will best explain the distribution of chironomid communities. In the Arctic, where the majority of lakes are relatively low in productivity, temperature can account for significant variation in chironomid communities (e.g. Larocque et al., 2001), although the organic content of lake sediment, substrate and certain nutrients can also affect chironomid distribution (e.g. Brodersen and Anderson, 2002). Lake type is thus important, coupled with catchment vegetation, sediment supply and food-web dynamics.

In NW Iceland 54 lakes have been sampled for surface sediments using a modified Kajak-gravity corer (Renberg, 1991). Water samples were also taken and a range of geochemical analyses undertaken. The lakes surveyed were mainly in the NW peninsula, but also extended west towards the Snæfellsnes peninsula, including the region around Stykkishólmur, and covered a mean July temperature gradient of 6.5-11.0°C. NW Iceland was initially chosen due to the relative lack of geothermal activity which could potentially compromise any thermal interpretations of chironomid distribution, although the training set will in the future be extended throughout Iceland increasing the temperature gradient.

A range of geochemical and lithological analyses have been undertaken on the water and sediment samples. The surface sediments from 32 of the lakes have been analysed for chironomid head capsules and some exploratory multivariate numerical techniques undertaken in order to assess the main factors affecting chironomid distribution. The species data comprised of 52 chironomid taxa, although this was based mainly on ‘splitting’ rather than ‘lumping’ taxa. As these data are based on subfossil larval head capsules, rather than the larvae themselves, key taxonomic issues will be discussed. The results from canonical correspondence analysis and two-way indicator species analysis (TWINSPLAN) will also be discussed, as well as the potential for this research within the context of Holocene climate reconstruction from Iceland.


EFFECTS OF INCREASED SNOW-COVER IN TWO NORTHERN SCANDINAVIAN ECOSYSTEMS

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Snow insulates the soil, reduces soil temperature fluctuations and increases minimum temperatures (Brooks et al. 1997). Therefore, the distribution of snow is perhaps the single most important factor controlling the cold season carbon dioxide emissions in high-latitude ecosystems (Walker et al. 1999). Since global warming is predicted to increase the snow-cover in some arctic regions (Kattenberg et al. 1996), we need detailed information on snow-plant-soil interactions and on effects of changes in the snow regime in order to predict possible ecosystem responses to climate changes.

I will present preliminary results from a snow-fence experiment carried out in a subarctic dwarf shrub heath and a subarctic birch forest, the two dominating vegetation types of Northern Scandinavia (Sjörs 1971). The aim of the study was to a) quantify winter/early spring carbon dioxide emissions, to b) quantify pools and flows of carbon, nitrogen and phosphorus in soil and soil microbes, and to c) investigate the short-term effects of artificially increased snow-cover.

In March, before the initiation of snowmelt, snow-fences increased the snow depths significantly in the treated plots at the heath but not at the birch. Still, ecosystem respiration was higher in fenced plots compared to controls in both ecosystem types, by 157% and 77% in the heath and birch, respectively. The latter increase was probably due to earlier snow built-up in fenced plots. During the snowmelt period in April-May, snow depths were significantly higher in fenced plots until completion of snowmelt. However, no consistent differences in either ecosystem respiration or net ecosystem exchange between fenced and control plots were found during this period. Gross ecosystem production rates in subnivean vegetation were much higher than expected and were for the April-May period on average 39% lower in fenced plots than in controls due to increased snow-cover in fenced plots. Microbial biomass C, N and P were generally high in subnivean soils and decreased only as snowmelt was ending. Soil inorganic nitrogen and phosphorus concentrations were low throughout the experimental period, indicating a plant sink for nutrients concurrent with release from the microbial biomass.

A TIME-TRANSGRESSIVE TILL ACCRETION AND BED DEFORMATION HYPOTHESIS

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Despite a concentrated effort over the last decades the formation of basal tills and the glacier dynamics involved are still controversial. This paper describes two basal tills of the last glaciation in Denmark and Poland (Larsen and Piotrowski, 2003, in prep; Larsen et al., 2004). It is shown that fabric orientation and -strength, grain-size distribution, clay mineralogy, clast roundness, crushing index and petrographic composition are highly uniform through the entire till thicknesses (Fig. 1 and 2). The boundary between the till and the underlying sediments is a mosaic of undeformed areas interspersed with areas exhibiting bed deformation (Fig. 3). Both tills are characterised by numerous inclusions of soft sediments and mm-to-cm thick sand lenses with microscale rip-up clasts. Small meltwater channels were observed at the base of the till in DK. Preliminary micromorphological studies reveal both depositional and deformational structures dispersed throughout the tills.

A time-transgressive model is suggested to explain the lack of vertical change in till properties and the preservation of soft sediment clasts, in which the debris released from the sole of an active glacier is sheared in a thin (<40 cm) zone moving upward as till accretion proceeds (Fig. 4). Small cumulative strain of the till allowed preservation of fragile clasts. The surprising lack of petrographical gradation in the tills is probably due to multiple reworking and homogenisation of different sediments over several glacial cycles. During deposition and deformation, pore-water pressures were high as indicated by the presence of small meltwater channels, the mosaic of deforming – non deforming areas and the sand lenses formed during multiple re-coupling events.

Fig 1. Lumped sedimentological data from Knud Strand, Denmark including mean till fabric eigenvectors (V1) from the same levels in three profiles. Note the uniform distribution of lithological components (modified from Larsen et al., 2004).

Fig 2. Sedimentary log and lumped sedimentological data from Kurzetnik, Poland including mean till fabric eigenvectors (V1) from the same levels in three profiles. Note that, except for the transition from sand to till on the grain-size scale, the distribution of lithological components in both sand and till units is consistent (from Larsen and Piotrowski, in prep.).
Fig 3. Glaciolacustrine sediment covered by Weichselian till at Knud Strand, Denmark. (A) Largely intact, layered fine-grained sand, silt and clay overlaid by till along a sharp contact with no apparent diffusive mixing of the two units. The till has very few local components indicating low degree of ice-bed interaction (Larsen et al., 2004). (B) Same outcrop (ca. 150 m from (A)) showing a deforming spot with mobilised and heavily disturbed top part of the glaciolacustrine sediment. Multiple transitions between (A) and (B) occur along the section. Ice movement to the right; coin for scale (from Piotrowski et al., in press).

Fig 4. Time-transgressive model of till deposition and deformation. Note that the depth of deformation at any time is relatively small but its time-transgressive nature results in deformation structures spread throughout the entire till thickness. Till accretion is mainly by lodgement (from Larsen et al., 2004).
CALIBRATION OF THE 14C TIMESCALE AND CONSTRAINTS OF THE GLACIAL CARBON CYCLE

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A new series of 14C measurements in Ocean Drilling Program cores from the tropical Cariaco Basin, which have been correlated previously to the annual-layer counted event chronology for the GISP2 ice core, provides a high resolution calibration of the radiocarbon timescale back to 50,000 years before present. Several lines of evidence, including independent radiometric dating of events correlated to GISP2, suggest that the calendar age model is accurate. Reconstructed 14C activities varied significantly during the last glacial period, including sharp peaks synchronous with cosmogenic nuclide peaks in ice cores and marine sediments, as well as the Laschamp and Mono Lake geomagnetic field intensity minima in marine sediments. Sensitivity tests performed using a geochemical box model indicate that much of the variability can be explained by geomagnetically modulated changes in 14C production rate, together with plausible changes in the global carbon cycle during glaciation.
POST LITTLE ICE AGE RECORD OF FINE AND COARSE CLASTIC SEDIMENTATION IN AN ALASKAN PROGLACIAL LAKE

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The coastal mountains of Southern Alaska are characterized by the highest glacial erosion rates in the world, but most quantitative assessments of glacial sediment yield (in Alaska and elsewhere) have traditionally focused on measurements of only the fine fraction carried in suspension by glacial rivers. Because bedload accounts for 30-70% of sediment discharge in proglacial streams, estimates of total yield based upon suspended sediment alone are subject to large errors; they also provide no insight into the relative contributions of glacial quarrying and abrasion. Here, we document coarse and fine-grained sediment yield over the past 200 years from Iceberg Lake, a proglacial lake in the Chugach Range of Alaska, using a well-dated suite of deltaic and lacustrine sediments. Iceberg Lake has an area of 4.4 km2 and is impounded by one tributary of the Tana Glacier, a large northward-flowing outlet of the Bagley Icefield in Wrangell-St. Elias National Park. It receives runoff and sediment from smaller alpine glaciers that cover 52% of the land surface in its 66 km2 watershed. While Iceberg Lake is glacier dammed, a spillway cut in a bedrock spur adjacent to the ice dam has controlled its level. The lake drained completely in a jökulhlaup in 1999, the only event of this kind evident in the record preserved in the lake sediments. Four discrete strandlines ring the lake above its 1999 shoreline. All but the oldest are associated with Gilbert deltas at the main inlet. The lake level dropped in discrete events associated with abandonment of one spillway for a new lower one, apparently in response to lowering of the ice dam. Varved lacustrine sediments record lake-lowering events as transient increases in the basin-wide deposition of unusually fine-grained sediments, and show that all events occurred within the last 200 years. Using a combination of subaerial sediment exposures, sediment cores, differential GPS surveys, and aerial photo interpretation, we calculated volumes of impounded deltaic and lacustrine sediments. These allow independent estimates of specific yield for the four time intervals bracketed by lowering events in 1825, 1834, 1867, and 1957 AD and the 1999 drainage event. The time-weighted average sediment yield is 4317 tons/km2/yr, and ranged from 14% above to 12% below this value. In each interval, 81-86% of the sediment is found in deltaic deposits, which we interpret to be derived from bedload. A wide range of evidence suggests a close coupling between sub-glacial source and lacustrine sink in this small, heavily glacierized basin. The time-averaged yields should therefore accurately reflect upstream glacial erosion. The average effective erosion rate of 1.6 mm/yr is well within the expected range for basins of comparable size. The texture of the deposits clearly attest to the long-term significance of bedload as a dominant component of glacial sediment output. Further, they provide a robust long-term estimate of the importance of quarrying in glacial erosion. Assuming that the silts and clays in the varved sedimentary record of Iceberg Lake are produced equally from abrasion of the bed and of quarried blocks embedded in the glacier sole, and that the sands and gravels in the deltas of Iceberg Lake are produced primarily by crushing of quarried blocks, then quarrying accounts for as much as 90% of the glacial erosion in this system.
Holocene concentrations of atmospheric methane reconstructed from the Greenland and Antarctic ice cores present puzzling patterns. First, there is a rapid increase of Northern Hemisphere derived methane at 12,000 Cal yrs BP (years before present) followed by a general decline between 10,000 and 5000 Cal yrs BP. The causes of the rapid increase to Holocene maximum levels is debated with some speculating this reflects the rapid release of marine methane by marine clathrates while others suggesting it reflects the establishment of methane producing peatlands in the high latitudes as these regions warmed at the close of the Pleistocene. Following 5000 Cal yrs BP there is another increase in methane that has persisted to present. The causes of this late Holocene increase in methane are again debated. Some have argued that it represents a new expansion of northern peatlands as high latitude summer insolation decreased and climate cooled from a thermal maximum. In contrast, it has also been suggested that anthropogenic activities, namely rice cultivation, drove much of the increase. We have sought to solve these puzzles by obtaining radiocarbon dates to document the history of the world’s largest high latitude peatland complex in west Siberia and combine these dates with a data base of over 1000 peat initiation dates from around the Northern Hemisphere. Peatland initiation in areas such as western Siberia coincides with the initiation of widespread warming in the early Holocene coincidental with boreal forest development and extension of treeline north of modern limits. There is evidence of limited new peatland development at the southern edges of the modern boreal zone in concert with neoglacial cooling. The preliminary results suggest caution in attributing all of the early and late Holocene increases in methane to high latitude peatlands and their response to Holocene warming and cooling.


Fig 1. Atmospheric methane and peatland history in west Siberia (from Smith et al. 2004)

Fig 2. Warming of northern Eurasia (after MacDonald et al. 2000)
SPATIAL ANALYSIS OF COASTAL EROSION OVER FIVE DECADES NEAR BARROW, ALASKA

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There has been increasing interest in recent years in processes affecting Arctic coastlines, including shoreline erosion and the release of both inorganic and organic sediment to the nearshore marine environment. Beyond scientific interest, the prospect of continued -- and possibly accelerated -- coastal erosion is a major concern for many Arctic communities. Documenting and understanding spatial variability in erosion rates are increasingly attainable as high-resolution imagery becomes available, and as GIS and remote-sensing tools are more widely accepted. This study presents such an analysis for a broad area near Barrow, Alaska (Fig. 1).

Shoreline erosion and accretion were quantified by comparison of co-registered datasets and imagery. Orthorectified Radar Imagery (ORRI) was acquired by Intermap Technologies in July, 2002 at 1.25 m horizontal resolution. Twenty frames of black and white aerial photos from August, 1955 were scanned and georectified to the ORRI using an image-to-image polynomial transformation in ArcGIS, with resulting resolution of about 1.4 m and an RMS error of 2.6 m. The 2002 and 1955 shorelines were digitized with points spaced every 20 m along the 250 km of mainland coastline. For barrier islands and the Barrow Spit, the 1955 coastline was digitized from DRG files depicting the USGS 15-minute topographic maps. Using a variety of vector ArcInfo commands, horizontal displacement of the mainland shoreline was converted to erosion and accretion rates for the intervening 47 years. (Note that time-averaged rates will underrepresent episodically high rates during storm events). Overall error considering georectification, digitizing, and transient waterline shifts due to microtidal fluctuation and wave-set up is approx. 3.1 m for the mainland coast, equating with 0.07 m/yr. For barrier features, where the DRG's are less accurate, error is about 28 m (0.6 m/yr).

Nearly all of the mainland coast (91%) has experienced erosion (Fig. 1). Highly variable across the study area, rates average -0.91 m/yr, with an average horizontal shoreline displacement of -42.5 m. (Rates and displacements are negative for erosion). Relatively low rates of about -0.3 m/yr occur along the Chukchi coast, where sand- and gravel-dominated beaches are backed by bluffs up to 15 m high. Rates are higher along the low coastal plain facing Elson Lagoon, exceeding -5 m/yr near Scott, Ross, and Christie Points (e.g., Fig. 2), before decreasing again in the sheltered waters of inner Admiralty Bay. Rates also decrease within small bays and inlets, on a local scale. Lateral accretion from 1955 to 2002 is uncommon, limited to short stretches of widening beach along the Chukchi coast, and isolated progradation or shifting of small nearshore spits and bars. Immediately adjacent to Barrow, the shoreline has eroded -0.2 to -0.8 m/yr, in agreement with a higher-resolution, related study, whereas the beach near the NARL/UIC complex has prograded on average +0.3 m/yr. The narrow offshore barrier islands have migrated considerably, with an average horizontal shift of 205 m.

Although erosion over five decades has been locally variable, a few patterns emerge. High bluffs and coarse beach sediment protect the Chukchi shoreline, whereas very low coastal bluffs exposing ice-rich, peaty soils are susceptible along the Beaufort mainland coast. Beyond bluff height and shoreface lithologies, fetch plays an important role, with the inner portions of bays and inlets protected at a variety of scales. It appears also that erosion is more pronounced where ice-wedge polygons are strongly developed within mature thaw-lake basins. Near Barrow, human activities in the nearshore zone may have played a role, and erosion is a concern -- even though it occurs there more slowly than the region as a whole. The importance of extreme weather events, and the possibility of accelerated change due to warming and decreasing summer sea ice, will be examined as other imagery improves the temporal resolution for analysis.
Fig 1. Orthorectified Radar Imagery from 2002 for the "Barrow Peninsula", also showing erosion rates calculated by comparison with 1955 aerial photographs. Along the mainland coast, coastal change is calculated as either erosion (blue to red) or accretion (white). For narrow offshore features that have commonly migrated farther than they are wide, results are presented in terms of distance of change per year. For color, please see the online figure or an available PDF file.
Fig 2. Close-up of Ross Point, showing: A) the black and white 1955 aerial photography, with the digitized 1955 shoreline in white, and the superimposed 2002 shoreline color-coded by coastal change; and B) the 2002 radar imagery, similarly showing the 1955 and 2002 shorelines. Numbers in panel A indicate rates of erosion or accretion in m/yr.
CYCLONE OCCURRENCE IN THE NORTH ATLANTIC: IMPACTS ON GREENLAND ICE SHEET MELT CYCLES 1979-2002

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Does a relationship exist between cyclone frequencies in the North Atlantic and melt extent on the Greenland ice sheet? This thesis work has explored this question through the analysis of NCEP/NCAR sea level pressure data spanning the period 1963-2002, passive microwave melt data spanning the period 1979-2002, and the derived NAO index for the respective time period. Through linear trend and correlation analysis it has been determined that there are regional differences in the relationship between cyclone frequency and melt extent on the Greenland ice sheet.
The Akshayuk Pass, Auyuittuq National Park in Cumberland Peninsula (Baffin Island – Canada), is a U-shape valley where numerous glaciers of all sizes are present. Modern glacier fluctuations in this valley have been previously analyzed using lichenometric studies, based on maximum thallus measurements (Innes, 1985; Locke and al., 1979). Various lichenometric studies in Cumberland Peninsula have (1) determined that the maximum extent of glaciers occurred during the Neoglacial period (Davis, 1985; Graham, 1997) and (2) established a growth curve for Rhizocarpon geographicum for the northeastern part of the Cumberland Peninsula (Andrews and Webber, 1964; 1969; Miller, 1973; Miller and Andrews, 1972).

This presentation is to discuss results obtained at various sites during the fieldwork season of 2002 and 2003, including some moraines previously studied by Thompson (1954), Davis (1985) and Graham (1997). Specifically, these results focused on two time periods: (1) quantifying the actual glaciers snout retreat using aerial photographs and satellite images, and (2) analyzing the modern glaciers snout fluctuation using size-frequency distributions and percentage cover analyses of lichen populations.

Modern glaciers snout retreats are studied using the following three features. First, a comparison of maximum thallus measurements and size-frequency analysis is made to evaluate the former. Statistical analyses were executed to determine a good age surface index based on the size-frequency distribution analyses of lichen populations. Secondly, environmental variations between sampling sites were estimated with geomorphological and ecological indicators using population characteristics. Thirdly, relative dates supported by the lichen percentage cover were established within sampling sites. Also, absolute dates were recognized for the six glaciers studied, based on the age index resulting from the lichen size-frequency distributions and growth curves.

Graham, D., 1997, The Neoglacial history of Akshayuk Pass, Baffin Island, Canada, using lichenometry and rock weathering techniques: (Bachelor’s Thesis), Centre for Glaciology, University of Wales, Aberystwyth.
REPRESENTATIVENESS OF LONG-TERM COASTAL OCEAN OBSERVATIONS FROM THE FAEROE ISLANDS, ICELAND AND GREENLAND

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The subpolar North Atlantic and adjacent Arctic is a key region in the earth's ocean–ice–atmosphere system. Climate-system variability is unusually large in these regions, owing partly to interactions between the atmosphere, ocean and ice that lead to fluctuations across a range of time scales. The present understanding of interannual to multi-decadal variability comes primarily from analysis of instrumental, historical and multi-century records such as high-resolution paleo-environmental data. The number of long, high-quality observational records available from the Atlantic Arctic and adjacent areas is remarkably extensive for a high-latitude, predominantly marine environment.

The purpose here is to summarize the century-scale ocean temperature records that exist from the Faeroe Islands, Iceland and adjacent areas. The primary focus is on quantitatively establishing the reliability of the time series and the degree that these largely coastal observations may be representative of local, shelf and regional conditions. The secondary focus is to identify the linkages between sea-surface temperature in different locations and sea-ice variability evident in long time series from the Iceland–Greenland region. Resolving these issues is important for calibration and interpretation of high-resolution paleo-environmental proxy records such as from marine sediments. It is also important for documenting and understanding modes of variability, e.g., the early 20th century warming and cooling events and more recent changes observed in the Nordic Seas. Here, emphasis is placed on the winter season, when these records appear to be most representative for analyzing time scales of variability.
THE RAPIDLY DISAPPEARING PLATEAU ICE CAPS OF CENTRAL BAFFIN ISLAND: WHERE WILL IT ALL END?

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Instrumental records show that the Earth has warmed ca. 0.7 °C over the past century, with the most dramatic increase in the decades since the 1960s. The Arctic has experienced a similar pattern, but the magnitude is greater, with average annual temperature increases of 2 to 5 °C across much of the Arctic since the 1960s. Evidence of this warming includes decreases in arctic sea ice and snow cover, negative glacier mass balances, and increases in permafrost and ocean temperatures. The short time span of direct observations limits our ability to evaluate the roles of natural climate variability and greenhouse gas forcing in explaining these observations, but the pattern of change is consistent with GCM simulations of the consequences of increased greenhouse gases. Compelling questions that can be informed by the record of the past include “when the world was last as warm as present?”, “what is the range of natural climate variability relative to 20th century warming?” and “is present warmth unprecedented?”

The central plateau of northern Baffin Island Arctic Canada has long been considered one of the most sensitive areas for the Arctic in terms of snowline variations. Thin, cold-based ice caps dot the highest portions of the plateau at present. These ice caps have receded by 97% in area since their Little Ice Age maxima. The Tiger Ice Cap (7 km2) studied in the 1960s and early 1980s has now completely melted; multiple-year imagery of The Pleiades, a 17 km2 ice cap complex in 1958 shows that only 1 km2 remained in 2002, and complete disappearance is expected within 5 years. One of the largest ice cap complexes, Orion, diminished by 50% in the past 30 years; complete disappearance is projected by 2030.

We can begin to place constraints on the timing of growth and decay by radiocarbon dating vegetation that was entombed by the ice caps when they initially expanded. Polychritum moss collected beneath the receding margin of the Tiger Ice Cap in 1963 is 385±75 cal yr old, whereas moss beneath the 1981 ice margin is 510±10 cal yr old. Pronounced vegetation kill zones define the maximum extensions of the ice fields. For one of largest ice fields the maximum coverage was 3500 km2, whereas the current (2002) ice coverage is just 107 km2, a decrease in area of 97%.

Because the ice caps were always thin, cold-based, and lacking internal flow, their former lower limits define the maximum persistent snowline depression. In the case described above, the trimline lies at 500 m asl. The current snowline is above 1100 m asl. Using a lapse rate of 0.6 °C/100 m suggests a temperature increase since the late 1800s of >3.6 °C, or 5 to 7 times the global average. Even without additional global warming, all of the plateau ice caps are expected to disappear before 2050.
Fig 1. Present and past extent of plateau ice caps on a portion of northern Baffin Island
Loess (eolian silt) is geographically the most extensive surficial deposit in Alaska (Fig. 1). In central Alaska, near Fairbanks, loess is several tens of meters thick and the periods of deposition may span the entire Quaternary and extend into the Pliocene. Nevertheless, there have been few studies of loess origins in Alaska and it was not even until the mid-1950's that an eolian origin for these deposits was finally accepted, based on Péwé's (1955) pioneering study.

The source areas of loess in central Alaska (near Fairbanks and Nenana) are not immediately apparent. The loess is composed of quartz, plagioclase, K-feldspar and mica, as well as a suite of accessory minerals (e.g., magnetite, zircon, etc.). The high mica content suggests that local, schist-bedrock-derived particles, carried by first-order streams, is a possible source. However, Péwé (1955) showed that there are many accessory minerals in the loess that do not occur in the local bedrock. Immediately to the south of the main loess bodies near Fairbanks and Nenana, the Tanana River drains the glaciated Alaska Range. Although silt is abundant in this river even now (and likely was greater during glacial periods), other evidence suggests that dominant paleowinds were not from the south during the last glacial period. Orientations of sand dunes across much of Alaska indicate that last-glacial, or at least late-glacial, paleowinds were dominantly from the northeast (Lea and Waythomas, 1990). To the north of Fairbanks and Nenana, the Yukon River (which drains parts of the glaciated Brooks Range) provides an alternative source. Silt derived from the Yukon River would be consistent with the northeasterly dune-derived paleowind pattern. However, this river is 140-170 km from Fairbanks and Nenana. Fairbanks/Nenana-area loess has 50-70% coarse (53-20 microns) silt, which seems far too coarse to have traveled distances of over 100 km from a source, based on analogs with areas of active loess deposition in southern Alaska and past loess deposition in the North American midcontinent.

In this study, we investigated the origin of central Alaskan loess using trace element geochemistry as a provenance tool. We collected loess from three stratigraphic sections in the Fairbanks-Nenana area, Birch Hill, Gold Hill and Halfway House, from east to west, over a distance of ~ 45 km. Loess samples were taken from those portions of the section that are thought to date from the last glacial period, based on the stratigraphy and chronology reported by Muhs et al. (2003). We also sampled three potential loess sources: (1) local schist bedrock, (2) Tanana River silts and (3) Yukon River silts. Schist was analyzed as bulk rock after pulverization, but Tanana and Yukon River sediments were first fractionated into loess-sized (53-2 microns) material. Trace element abundances were determined by instrumental neutron activation analysis (INAA). We chose immobile elements Sc, Cr, Hf, Ta, and Th and a suite of rare earth elements (REE), including La, Ce, Sm, Eu, Tb, Yb and Lu to characterize the source rocks and sediments.

Results indicate that the three possible loess sources have very different compositions. Local schist bedrock has a highly variable composition, typical of schists in many other regions. Because the loess has a much more uniform composition, schist is unlikely to be the sole source of the loess, which supports Péwé's (1955) earlier mineralogical work. Tanana River and Yukon River silts have distinctly different compositions from each other. For example, Tanana River silts have higher La/Yb, Th/Ta and Th/U values, whereas Yukon River silts have higher Cr/Sc and Zr/Hf values as well as Eu/Eu*, a measure of the negative Eu anomaly in the REE suite. Simple bivariate plots indicate that central Alaskan loess has compositions that overlap closely the range of Tanana River silts for some element ratios (Th/Ta, Zr/Hf, and Eu/Eu*). However, a
measure of the full suite of REEs (La/Yb) and Cr/Sc ratios indicate that loess has compositions intermediate between Tanana and Yukon River sediments.

In order to provide a more quantitative analysis of the relative contributions of the three possible source materials, we also used a geochemical modeling approach that has been utilized in igneous petrology (Budahn and Schmitt, 1985). The approach uses a multiple regression method for the mean abundances of a suite of immobile elements for each source material compared to each loess sample. The calculations yield the estimated contribution of each source material (in percent) and chi-square analysis is used to assess the degree of explanation of the resultant regression equation. Results of the geochemical modeling approach indicate that central Alaskan loess is probably derived mostly from a mixture of Tanana River sediment and Yukon River sediment, with minor contributions from local schist bedrock.

Our interpretation of the results is that loess-generating winds in central Alaska were complex during the last glacial period. The orientations of dunes across the state suggest a dominance of northeasterly winds and the geochemical evidence for a Yukon River contribution to central Alaskan loess is consistent with this pattern. However, contributions from the Tanana River, also indicated by the geochemical data, require southerly winds. An explanation for this apparent dilemma may be the importance of katabatic winds during the last glacial period. Expanded, north-flowing glaciers from the Alaska Range (to the south of Fairbanks) during the last glacial period may have generated local, but strong southerly winds, a hypothesis proposed by Thorson and Bender (1985) and Muhs et al. (2003). These winds would have allowed transport of silt out of the Tanana River and into the Fairbanks-Nenana area. Alternation of regional-scale northeasterly winds and local, southerly, katabatic winds during the last glacial period can explain the mixture of sediment sources apparent in the geochemistry of central Alaskan loess. Multiple sources and paleowinds that could have as much as 180 degrees of directional variability demonstrate that loess deposition is a complex process. The results suggest that reconstruction of paleowinds or interpretation of loess-paleosol sequences in other regions first require an understanding of loess source sediments.

Fig 1. Map showing the distribution of loess in Alaska (shaded areas) and location of the Fairbanks area. Loess distribution from Péwé (1975) and additional sources cited in Muhs et al. (2003).
LOCAL ICE ON WESTERN MELVILLE ISLAND, NWT, CANADA

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Understanding the dynamics of former ice sheets and relative sea level in the western Canadian Arctic Archipelago is important for improving models of past climates and coastline stability, and for providing records of sediment transport to the adjacent Arctic Ocean Basin, whose depositional history is of growing international interest. At present, the late Quaternary glacial and sea level history of the Canadian High Arctic is best documented for the mountainous eastern Queen Elizabeth Islands (Dyke et al., 2002; England, et al., 2000) and the next stage of research has recently been initiated for the expansive lowlands of the western Canadian Arctic Archipelago. Western Melville Island has been selected because it supported a local ice cap (Hodgson, 1992), which flanked the adjacent Innuitian and Laurentide ice sheets during the Last Glacial Maximum (LGM). Research objectives for this study include determining the spatial and temporal relationship between these three ice masses during the LGM and also documenting the resulting magnitude and pattern of postglacial sea level change around the former Melville Island ice cap.

During the first season (2003) fieldwork concentrated on Inner Liddon Gulf, the largest marine embayment on SE Melville Island. This area was occupied by the SE margin of the local ice cap and during deglaciation, a marine corridor extended from southwest Hecla and Griper Bay to Liddon Gulf, splitting the island in two. A large ice-contact delta deposited by the ice cap marks marine limit (65 meters above sea level). Based on sea level curves constructed for inner Hecla and Griper Bay (Hanson, 2003; ~50 km to the northeast) the projected age of the 65 m shoreline could be greater than 11.5 ka BP. Shell samples relating to the 65m sea level and other lower, postglacial sea levels were collected and submitted for radiocarbon analysis.

Evidence for a recent transition from emergence to submergence along this coastline is recorded by coarse gravel onlapping vegetated coastal mudflats. Driftwood collected along the coast of Inner Liddon Gulf is also being dated and will help to test whether modern sea level is encroaching on beaches containing older wood (late Holocene) and mixing it with modern (anthropogenic) material. Driftwood at intermediate elevations will also be dated in order to construct postglacial relative sea level curves for this area.

Plans for 2004 fieldwork on western Melville Island include surveying and dating marine limits and postglacial shorelines throughout fiords flanking the western margin of the former local ice cap where both glacigenic and raised marine sediments have been cited. Currently, only three radiocarbon dates are available from the fiords of western Melville Island (Hodgson, 1992). These indicate that outlet glaciers from the local ice cap still occupied the fiords during the Younger Dryas Geochron (between 10 and 11 ka BP). This fieldwork will allow for further investigation of the response of the local ice cap on Melville Island to this climatic deterioration. The dynamics of the Melville Island ice cap will also contribute to a better understanding of the late glacial climate at high latitudes, and what role the ice played in the depositional record of the adjacent Arctic Ocean and its relationship to the NE extremity of Beringia.


Hanson, M. A., 2003, Late Quaternary Glaciation, Relative Sea Level History and Recent Coastal Submergence of Northeast Melville Island, Nunavut: Unpublished thesis, Department of Earth and Atmospheric Sciences, University of Alberta.
A FORCE BALANCE ANALYSIS OVER THE LOWER REACHES OF COLUMBIA GLACIER, ALASKA DURING ITS RAPID RETREAT

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Tidewater glaciers are known to undergo cycles of slow advance and rapid retreat (Post, 1975). A mass balance deficit may initiate the retreat, but observational and modeling evidence suggests that retreats are largely controlled by factors other than climate forcing (e.g. Vieli and others, 2001). This is nicely illustrated by the state of Alaskan tidewater glaciers today: many tidewater glaciers (i.e. Glacier Bay; Hunter, 1997) initiated rapid retreat phases around the turn of the 20th century, Columbia and LeConte Glaciers (Krimmel, 2001; O’Neel and others, 2001) are in the midst of rapid retreat today, while Taku and Hubbard Glaciers continue to undergo slow advance (Motyka and others, 2003). All these glaciers are located in south-central or southeast Alaska, thus experience roughly similar mass balance trends.

During retreat phase, a tidewater glacier may retreat on the order of 1-2 km yr\(^{-1}\), concurrent with dramatic increases in ice velocity (Krimmel, 2001). Mass loss is dominantly through calving, rather than ablation. Catastrophic retreats of this style are thought to be irreversible (e.g. Post, 1975; Meier and Post, 1987) until the terminus retreats to a position above local sea level. Understanding the dynamics of such systems is crucial to our comprehension of rapid retreats, applicable to modern tidewater glacier retreats as well as historical ice sheet collapse (e.g. van der Veen, 1997). Analysis of forces that both propel and restrain tidewater glaciers and the evolution of forces through a retreat provide insight into the processes governing retreats.

We present a top down force balance analysis performed over the lower reaches of Columbia Glacier following van der Veen and Whillans (1989) and making the assumption of depth-independent strain. The assumption is validated because the deformation component of flow at Columbia Glacier is known to be small (e.g. Meier and Post, 1987, Meier and others, 1994 [direct borehole observation]). In this analysis, total stress is partitioned into lithostatic and resistive components in the following way:

\[
\tau_{\delta\alpha} = \tau_{\delta\alpha} + \frac{\partial}{\partial x}(HR_{xx}) + \frac{\partial}{\partial y}(HR_{xy})
\]

where basal drag balances the sum of the driving stress, along flow stress gradients, and lateral drag. Stresses are related to surface strain rates via the constitutive law, and strain rates are calculated from surface velocities. Surface velocities are derived from aerial photogrammetry over a time interval spanning 1957 to 2000 (Krimmel, 2001); our analysis covers only the latter part of this record.

Also necessary is ice thickness at each measurement point. The intensely fracture glacier and temperate ice have prevented reliable ice thickness measurements using radar or seismic techniques. We present a new bed geometry estimation using a flux divergence analysis of surface velocity (Rasmussen, 1989) over the time interval 1988 to 2000. Forebay bathymetry performed in 1995, 1997 (Krimmel, 2001) and 2003 (D. Trabant, unpublished data) are used to constrain the bed estimate. The calculation suggests the glacier has eroded a large over deepening behind a constriction near the present location of the terminus. This constriction and overdeepened area create both large driving and resistive stresses as ice is squeezed through it.
Preliminary analysis suggests that longitudinal stress gradients are important to the dynamics of Columbia Glacier during this phase of the retreat. While important to the shape of the transverse velocity profile, lateral drag only accounts for ~ 25% of resistance to driving stress in the terminus region. The large surface area of the bed provides much greater resistance to ice flow. When performed over the entire interval, the analysis shows the time dependence of all stress components in the study area.


HUMAN ECOLOGY, LOCAL KNOWLEDGE, AND INTERDISCIPLINARY RESEARCH IN MYVATN, NORTHERN ICELAND

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This presentation focuses on past and present issues of environmental and socio-economic change in the Lake Myvatn region in northeast Iceland. This area, and indeed, Iceland as a whole, represents a striking case of dramatic landscape change. Since first settlement in the late ninth century, over 90% of the native forest has been lost, the productivity of the rangelands has been substantially degraded, and as much as 40% of the soil cover lost to catastrophic erosion. Whole districts that were densely settled in the tenth century have become abandoned, and in the seventeenth to early nineteenth centuries, the population was repeatedly devastated by disease, famine, and volcanic eruptions. Erosion control is a major goal of the modern Icelandic state, and the long term sustainability of agriculture in Iceland holds many lessons for other circumpolar cases. The causes of this disastrous interaction of human economy and northern ecosystems have long been debated, with different authors giving different weight to grazing pressure, volcanism, soil-nutrient depletion, climate fluctuation, and simple land management error, generally basing their arguments on one or two lines of evidence: a genuinely integrated systems science approach to this problem is only recently beginning to emerge (Arnalds et al. 1987; Fridriksson 1972; Ólafsdóttir and Gudmundsson 2002; Simpson et al., 2001, 2004; Thorsteinsson et al., 1971).

Current research suggests that broad-scale simplistic arguments (stocking versus climate) in fact obscure the complexities of the actual situation at the local level, where some farm sites seem to rapidly deplete local resources, suffer catastrophic soil loss and become abandoned, while other farms a few kilometers away seem to achieve millennial-scale sustainability and show little erosion impact. In discussions of landscape sensitivity human actions have generally been regarded as external forces contributing to landscape change. However, our studies have integrated physical and social systems in an historic context to explain the basis of human actions and their consequences in sensitive landscapes. Exploration of historical common land management in Iceland through integrated historical modeling approaches has demonstrated no “tragedy of the commons” in Icelandic grazing. Common lands have tightly defined regulations, including: definition of boundaries and membership; congruent rules; conflict-resolution mechanisms; and graduated sanctions from at least AD 1200 onwards. Furthermore, sufficient biomass was available across common land areas to support the numbers of livestock indicated by historical sources. We find that the scheduling of livestock management is more likely to contribute to landscape degradation than absolute numbers in common land areas grazed during the summer months. The significance of historical grazing management in shaping long-term land sustainability or degradation has also been demonstrated by assessment of land-degradation patterns in traditional winter grazing areas, with distinct and different landscape responses to winter grazing observed (Simpson et al., 2000). Volcanic tephra layers provide tight chronological control (tephra falls occur in the area most decades, with a major local eruption in 1982) allowing the correlation of distant sites and calculation of erosion/accumulation rates with high levels of precision (Dugmore et al., 1992). In the northern Iceland study areas considered, accelerated wind and water erosion is observed with colonization and settlement c. AD 874 through to c. AD 1477. Subsequently, in some locations, erosion rates decline through to the present day, while in other areas erosion rates continued to accelerate and create areas of arctic desert. Explanation of these research findings may lie, at least partially, in that adaptive grazing management was used where erosion rates are reduced, and, conversely, the failure to adopt sensitive grazing management regimes allowed erosion to accelerate. Our study combines integrated interdisciplinary millennium-deep investigations of long-term interactions with high
temporal resolution (decadal to annual scale) of environmental and landscape changes and present-day local and scientific knowledge. The presentation will include discussion of three major research components of our study: 1) Environment, climate, and landscape, both for wider North Atlantic teleconnections, and for the local Myvatn region; 2) The people who live and work in the Myvatn region (the Human Dimensions of the study); and 3) Integration of Human/Environment Interactions from global issues to local Myvatn perspectives.


CURRENTS AND CLIMATE ON THE NORTHWEST ICELAND SHELF IN THE LATE QUATERNARY (10-30 KA CAL BP): RECONSTRUCTION BASED ON FORAMINIFERAL AND SEDIMENTOLOGICAL RESEARCH

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The shelf area northwest off Iceland has gained a significant attention for oceanographic studies because of its unique location. The area is close to the boundary (the Polar Frontal zone) between the cold and fresh southward flowing East Greenland Current and the warm and saline northward flowing Irminger Current. A 38 m long core (MD99-2264) spanning the last ca. 30 cal kyrs BP was obtained at 230 m water depth in the Djúpáll trough on the Vestfirdir shelf. The core location is bathed in relatively warm waters today, but the boundary zone has migrated through time leading to exchange between warm and chilled water masses.

The aim of this research is to obtain a marine based deglaciation history for the northwest Iceland shelf. We focus on the following questions: 1) Did the LGM ice sheet extend beyond the modern shelf break, 2) when was the first incursion of warm and saline N-Atlantic water, 3) how do the environmental conditions changes during the deglaciation, and 4) are there marked changes between the bottom and surface flow during the deglaciation.

To approach these questions multiple proxy records were established; sedimentological properties (visual description, IRD (>2mm on X-radiographs), total carbon, and magnetic susceptibility), foraminiferal assemblages and foraminiferal stable isotopes studies. The chronological model is constrained by 13 14C AMS dates and two well dated tephra layers (Saksunarvatn and Vedde tephra).

The results indicate 6 main sediment and foraminiferal faunal units.

Unit 1 ~ Glacimarine diamict (>30,000 cal yr BP)
This unit is composed of stiff mud loaded with IRD and hardly any bivalves. The foraminiferal assemblages is composed of a mixture of fresh looking and reworked foraminiferal tests, and a mixture of boreal and arctic species. This unit indicates that the main ice stream from the Vestfirdir ice sheet was most likely calving out to the Djúpáll region, with its margin close to the MD99-2264 core location.

Unit 2 ~ Turbidites (>15,300 cal yr BP)
This unit is characterized by several rhythmic sequences, each showing a gradual decrease in grain size toward the top. The sedimentation accumulation rate is high and the foraminiferal assemblages look reworked. This can be interpreted as the break up of the main Vestfirdir ice sheet.

Unit 3 ~ Glacimarine diamict (15,300-14,000 cal yr BP)
This unit is composed of fine sediment, with occasional sulfide streaks and frequent IRD. The foraminiferal fauna is composed of arctic species (Cassidulina reniforme and Elphidium excavatum) with peak abundance of Nonion labradoricum. The bottom δ13C signal is very low at the same time which might indicate renewing of the bottom water flow with increased nutrient supplies and high productivity, possibly, in some relation to the relocation of the Polar Front zone or fluctuation of the local ice-front margin.

Unit 4 ~ Marine sedimentation (14,000-13,800 cal yr BP)
This unit is composed of sandy mud with no IRD and high content of total carbon. The foraminiferal fauna has higher diversity and an increase in boreal species is noticeable. The $\delta^{18}O$ value in the boreal benthic species Cassidulina laevigata and the planktic species Neogloboigerina pachyderma (sinistral) is light. This might indicate a fresh water spike or the first incursion of warm and saline Atlantic water after the LGM.

Unit 5 ~ Glacimarine (13,800-11,500 cal yr BP)

This unit shows high sedimentation rate, with frequent sandlayers (often with high content of bivalve fragments). IRD is abundant and total carbonate content is low. This unit includes the Vedde tephra layer. The foraminiferal fauna has low diversity and the most abundant species are C. reniforme and E. excavatum. The benthic and planktic $\delta^{18}O$ signal is high. This indicates that the fauna and sedimentation is influenced by cold conditions in front of a calving glacier, sea-ice and presumably saline conditions and stagnant bottom water.

Unit 6 ~ Marine sedimentation (11,500-10,000 cal yr BP)

This unit is composed of muddy sand, with no IRD, high total carbonate content, and frequent bivalves. The foraminiferal fauna is composed of a high percentage of boreal species. The benthic $\delta^{18}O$ signal decreases gradually reaching the lightest value (2.8 ‰) in the record, around 10,000 cal yr BP. The surface water isotope signal also shows lighter values (2.4 ‰). These data suggest that the shelf is ice free and that the Irminger Current has attained its modern path and strength.

Fig 1. Map of Iceland, red dot showing the MD99-2264 core location.
A 1000-YEAR VARVED SEDIMENT RECORD FROM THE BROOKS RANGE, ALASKA

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Geomorphologic evidence of late Holocene glacial advances shows the central Brooks Range is sensitive to changes in temperature and moisture balance. Proxy records from the region detailing the middle to late Holocene are sparse. Blue Lake is a small (<0.5 km^2), shallow (4.7 m) glacier-fed lake set on the crest of the Brooks Range (68º05.3’ N, 150º27.8’ W) in north-central Alaska at an altitude of 1265 m. The 4-km2 watershed contains a small cirque glacier set on the north face of the 1890 m high headwall on the north side of the continental divide. Field observations and air photos indicate that melt-water from the glacier contributes a substantial quantity of fine-grained sediment to the lake. Sediment cores recovered in August 1999 contain mm-scale laminations comprised of couplets of thick, light colored silt to fine sand laminae overlain by a thin, darker clay cap. Thin-sections were prepared to study the laminations using a shock-freeze (sublimation) technique and embedded with low viscosity epoxy resin under vacuum. Laminae counts and thickness measurements were made using digital image analysis techniques. Scanning electron microscopy coupled with energy dispersive spectroscopy were used to characterize mineralogy and grain-size. In thin-section, the laminae couplets appear as alternating light and dark bands and exhibit the classic mode of varve formation in a glacial basin consisting of a succession of fine sands to silts deposited during the summer months, followed by a well-defined winter clay cap. In addition to annual variability in varve thickness, long-term trends in thickness were observed and compared to the historical climate record. Overall, the varve measurements from Blue Lake correlate with regional cooling and warming trends described for the late Holocene. Blue Lake records the glacial response to late Holocene climate phenomena such as the Little Ice Age (cooling), Medieval Climatic Anomaly (warming), and the 20th century warming trend and provide a record for panarctic comparison.
Global Circulation Models predict that future climate change due to anthropogenic forcing will be amplified at high latitude and have important feedback on global climate (e.g. Dickson, 1999; PARCS, 1999). Sedimentary modeling studies indicate that climate change could have a profound impact on the sediment flux transported into the coastal zone (Svyitski and Andrews, 1994; Svyitski, 2002). Such model predictions are still uncertain. On the one hand this is because the present 2D sedimentary simulation models do not properly address sediment storage in the fluvial domain. On the other hand there is a strong component of temporal uncertainty, which is due to the short measurement records in the Arctic. Little is known of the natural environmental variability in Arctic fluvial-deltaic systems. Extreme events, e.g. peak floods or even glacial lake outbursts, are of low-frequency (and thus rarely monitored), but may have a high impact. We selected Clyde River on Northern Baffin Island to improve model concepts and test them against a real-world example.

Our numerical hydrological model, HydroTrend, requires drainage basin characteristics and climate data as input parameters to predict daily discharge (Q) and sediment load (Qs) records. Clyde River basin has been delineated from Canadian Topographic Survey DEM data and was found to comprise 2526 km2. Clyde River is about 66km long, drains the SE part of the Barnes Ice Cap and includes a large pro-glacial lake, Generator Lake. The maximum elevation in the drainage basin is 1450m and the estimated glacier equilibrium line is 1000m. Daily temperature (T) and precipitation (P) data have been measured at the town of Clyde River (Fig 1). Mean annual T is -12°C, average monthly temperatures are above 0°C in June, July and August and mean annual P is 21cm. Based on these data HydroTrend shows a typical short melting season of less than 100 days between end of June and the beginning of September. The bulk of the water and sediment load discharge occurs in on average 45 days of the year. The mean Q over the melt season is rather low at 28m3/sec. HydroTrend predicts a modest total sediment load of ~0.1 million ton per year. However, the simulated peak event over a 50 year run drains 484m3/sec and the sediment concentration for that event is estimated to be 38kg/m3, which means that most probably a hyperpycnal plume develops for a few hours at the river mouth. Sensitivity tests, mostly focused on varying melt water discharge from the Barnes Ice Cap, show a larger range of Q and Qs predictions. This will especially be relevant if increased melting of the Barnes Ice Cap due to global warming continues.

Field observations in the Clyde River indicate that the present-day main river probably does not exceed its incised channel system and floods only the lowermost terraces occasionally. In addition, we compared the mapped channel and bar geometry in the summer of 2003 and the 1967 aerial photo; the analysis revealed only moderate changes.

The system response of the near-coastal part of the modern Clyde River is apparently subdued by the incised nature of the river.

The deglaciation history of Clyde Fjord is known in detail based on mapped moraines, cosmogenic and radiocarbon dates (Briner et al., 2003). We collected additional shell samples for dating and related them to sedimentary section in the delta deposits close to the present fjord head. The dates are merged with the previously existing dates, and show that the withdrawal of the main ice flows from the fjordhead area occurred between roughly 8000 C14 yrs (very close to the fjord head) and 6600 C14 yrs more land inward. Sedimentation rates must have been very high: two shell samples in marine muds which are ~12m apart have ages of 7470 +/- 40 and 7620
+/-40 C14 yrs, a time span of only 150 years. Volumetric reconstructions in a GIS of the mapped terrace surfaces and available dates corroborate the rapid sedimentation. In addition, a terrace surface is observed 21.6m above m.s.l., of which 60% is covered with boulders ranging from ~30cm to 1m. We interpret these deposits to be deposited by a catastrophic event for example a glacial lake outburst, possibly related to a phase of ice-cap reorganization. System dynamics appear much more pronounced proximal to the ice stream. The comparison between the modern-day Clyde River and the deposition during ice retreat indicates that the proximity of the ice margin is a strong factor determining the sediment flux dynamics.

For ungauged basins numerical models form a tool to predict water and sediment fluxes under changing climatic conditions. However, models will still need to incorporate new concepts to capture glacio-fluvial system dynamics, which can vary a great deal over time.

MODELING LONGSHORE TRANSPORT AND COASTAL EROSION DUE TO STORMS AT BARROW, ALASKA

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Coastal erosion and the associated risk to homes and structures is a major concern for the residents of Barrow, Alaska. During two unusually large storms in August of 2000 and October of 1963, there was little or no sea ice for a distance of over 360 miles from shore. This large fetch, combined with winds of over 30 mph that were sustained for more than 16 continuous hours, resulted in observed wave heights of 10 feet and very high longshore sediment transport rates. These wave heights are in close agreement with what would be predicted for a fully-developed sea created by a 30 mph sustained wind. Using the equations that describe a fully-developed sea state, semi-empirical longshore transport equations can be recast in terms of sustained wind speed and breaker angle. This reformulation shows that the longshore sediment transport rate is highly nonlinear and varies as the sixth power of sustained wind speed. This helps to explain why there is such a large difference in sediment transport rates for wind speeds of say 20 mph vs. 30 mph and helps residents of Barrow to assess risk from wind speed data. It also shows that storms from the west, like the two under consideration, have breaker angles close to 45 degrees near the city of Barrow. This is the breaker angle that results in the maximum sediment transport rate. Theory predicts that a nodal point should occur in the immediate vicinity of Barrow, such that such storms will result in coastal erosion south of Barrow and deposition or little change for the coast just north of Barrow. Preliminary results for a coastal erosion model that incorporates these results will be presented.
Midge (Chironomidae, Chaoboridae, and Ceratopogonidae) distributions are highly sensitive to mean summer surface water temperatures (Walker et al. 1991). In fact, midge analysis is considered to be a key proxy method for inferring past climatic conditions (Battarbee 2000). In this study, midge analysis will be applied to a 5 m sediment record from Marcella Lake, southwest Yukon, to assess the timing and magnitude of temperature changes throughout the past 10,000 years. Marcella Lake was selected after observing the pollen record of the site, which suggests several shifts in regional vegetation. Approximately 6000 calendar years ago, the dominant tree species on the landscape shifted from Picea glauca to Picea mariana, indicating an increase in available moisture within the region (Cwynar 1988). This increase in moisture may have been due to greater precipitation, decreasing temperature (resulting in decreased evaporation), or perhaps both. Combining a historical temperature record with a detailed lake level history (L. Anderson, unpublished) may aid in separating the effects of evaporation from those of precipitation on the local paleohydrology.

Preliminary results indicate that lake levels were low between 6,000 and 4,000 cal. years ago, contradicting inferences made from Marcella’s vegetation history. This discrepancy has stimulated an attempt to develop a new proxy method for qualitatively inferring past lake levels involving the relationship between the abundance of certain midge taxa and lake depth. Forty random surface sediment samples have been collected at various water depths from Marcella Lake. The general distribution of each taxon within the lake basin has been mapped. Mean mental width of the most common taxon, Tanytarsina, has also been measured in order to determine whether it may be useful in documenting changes in lake depth. Should there be a relationship between the distribution of any particular taxa with respect to water depth, or should mental width vary with lake depth, an attempt will be made to reconstruct a qualitative lake level history for Marcella Lake.

Preliminary results suggest that, although most head capsules are distributed uniformly across the lake basin, taxa such as Chaoborus, Sergentia, and Chironomus are more abundant in deep water sediment (7-10 m) whereas head capsules of the tribe Pentaneurini and Cricotopus are concentrated in shallow water sediments (0-4 m). Initial data also demonstrate a trend in deposition with respect to head capsule size. Head capsules isolated from shallow water sediment tend to be larger than those found in deep water sediment.

HOLOCENE LAKE ONTOGENY IN RELATION TO CLIMATIC FORCING AND CATCHMENT DEVELOPMENT IN THE KANGERLUSSUAQ REGION, WEST GREENLAND

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The 170 km-wide, ice-free area of West Greenland near Kangerlussuaq (67°N, 51°W) contains thousands of lakes ranging from dilute sites on the coast to evaporatively-enriched closed basin systems that reflect the more continental climate of the ice sheet margin. Sediment cores from these lakes are being used to generate a detailed spatial network of multi-proxy records (isotopes, diatoms, macrofossils, pollen, zooplankton, chironomids, metals) of Holocene environmental change in West Greenland. In the present study, diatoms from four lakes along this strong climatic gradient are being analysed to assess the spatial and temporal variability of post-glacial lake ontogeny in the region with regard to changing Holocene climatic and catchment influences. Here, we present a preliminary, 14C-dated Holocene diatom stratigraphy from lake SS16, a small, dilute, dimictic lake in the ice-proximal region. Low lake productivity (inferred from LOI) and early colonizing diatom assemblages characterize the immediate postglacial environment of SS16 (approximately 8.5 ka BP). With the arrival of Betula nana and stabilization of the terrestrial environment after 7.5 ka BP, LOI-inferred lake productivity increased, aquatic macrophytes and invertebrates became abundant, and diatom assemblages changed to small, benthic Fragilaria-dominated communities. The stratigraphic record is then punctuated by long periods in which no diatoms are present (6.5-4 ka BP). As there is little visual indication of diatom dissolution, the absence of diatoms during the early- to mid- Holocene strongly suggests nutrient (Si) limitation. Effective moisture (precipitation-evaporation) was extremely negative in the early-mid Holocene in West Greenland (McGowan, et al., 2003). Catchment weathering and nutrient inputs were thus limited to levels below the minimum required to sustain siliceous algal production. A marked shift occurred in the lake approximately 4 ka BP, when a predominantly planktonic community of diatoms and chrysophytes reappeared in the lake. Increased nutrient flux resulting from aeolian activity or increased precipitation is a likely explanation for the shift from benthic to planktonic diatoms in the later Holocene. This interpretation is corroborated by records from the West Greenland saline lakes that show a shift to increased precipitation at that time. The late Holocene record from SS16 is characterized by century-scale variability, but does not show the historically unprecedented recent changes seen in other circumarctic paleolimnological records. The diatom history of SS16, a dilute freshwater system, demonstrates the importance of catchment and biotic factors in structuring the diatom community response to climatic variability in arctic lakes, particularly at millennial timescales.
COLUMBIA GLACIER, TIDEWATER INSTABILITY AND UPGLACIER PROPAGATION OF KINEMATIC WAVES

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In the long term, glacier changes are ultimately driven by climate changes through mass balance, but flow processes both in conditions of equilibrium and disequilibrium also control glacier changes. Under ‘ordinary’ conditions, glacier flow process act to establish a glacier geometry and flow pattern in equilibrium with mass balance, but circumstances exist where glacier flow processes act independently of mass balance, and dominate climate in the determination of the evolution of glacier geometry and volume. These ‘extraordinary’ circumstances include glacier surges and tidewater instability.

Tidewater glaciers, defined as outlet glaciers with termini grounded below sea-level, retreat cyclically, with retreat generally starting abruptly and proceeding irreversibly until the terminus retreats into shallow water. During retreat, the discharge flux greatly exceeds the mass balance flux, and climate plays a nearly negligible role in the rate of volume change. The phenomenon of tidewater glacier retreat is well-documented in coastal central and southeast Alaska, where tidewater glaciers occupying major coastal fjords, with the exception of Columbia Glacier, retreated from their fully extended positions during the 19th and early 20th centuries. Columbia Glacier, in Prince William Sound, has retreated approximately 13 km since the abrupt onset of retreat in 1982. During 2001, seasonal terminus velocities exceeded 10 km per year, and discharge flux of ice into the ocean was as great as 12 cubic km per year.

We review the ongoing retreat of Columbia Glacier, and examine the processes leading to a transition to abrupt and irreversible retreat by considering the behavior of a sliding law which depends inversely upon effective pressure (Pice – Pwater) in the context of classical kinematic wave theory as applied to glacier flow by John Nye. In that theory, kinematic waves are seen to propagate downstream if flux increases with increasing thickness and to propagate upstream if flux increases with decreasing thickness. For an effective pressure-dependent flow law, flux can increase with decreasing thickness if the loss of bed traction dominates the effect of loss of driving stress. A simple analysis shows the conditions for which this is true, and those conditions are seen to obtain for Columbia Glacier at the time of onset of rapid retreat in 1982. It is also shown that in contrast to down-stream propagating kinematic waves, diffusion does not eliminate the propagating effect under the conditions of interest, where surface slope and ice thickness are not small.
This work is a high-resolution analysis of an Icelandic shelf core, as part of an effort to resolve ocean climate and environmental changes in and around the North Atlantic over the last 2000 years. High-resolution data from Core MD99-2266, retrieved from NW Iceland’s inner continental shelf at the mouth of Isafjardardjup, were analyzed isotopically and sedimentologically to determine if the results can provide valid and substantial information about climatic and environmental variations during the past 2000 years, and to determine if settlement of Iceland may have caused marked changes in the record. Tests of Cibicides lobatulus, a calcareous, benthic foraminifera, were analyzed for d18O and d13C in carbonate, as possible indicators of changes in climate or environment. Five radiocarbon dates through the upper 265 cm of the core were used to correlate depth to calibrated year, which yielded a linear sedimentation rate of 7.6 years/cm.

The results of all sedimentological and isotopic analyses were cross-correlated to evaluate possible associations with one another. Features that may be associated with marine influence were higher total carbonate, higher d18O, and an increase in sand-size particles. Features that may have been associated with terrestrial influence were higher percent nitrogen, an increase in clay-size particles, and an increase in organic carbon and higher magnetic susceptibility. The interpretation of d13C remained inconclusive.

Although time-related shifts clustered around 300, 800, 1200, 1600, and 1800/1900BP, consistent with other studies that linked these periods to major climatic changes, no significant changes in the variables were found that might reflect the settlement of Iceland by humans.

This work is the preliminary study for more detailed research of Isafjardardjup. The ongoing research will be aimed at Cores B997-339, 441, and 442, which are more proxal to the fjord head and land/sea interaction. It is hoped that these cores will yield a more refined view of the Late Holocene climate and of the influence of terrestrial processes in the sedimentary record.
TILTED TREES AND LOST LAKES: DENDROGLACIOLOGICAL INSIGHTS INTO LITTLE ICE AGE GLACIER ACTIVITY IN THE NORTHEAST ST. ELIAS MOUNTAINS, YUKON TERRITORY

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Chronologies of regional Holocene glacier activity in the St. Elias Mountains can complement ongoing high-resolution paleoclimate investigations based on tree-ring records and high-altitude ice cores. Previous investigations of Little Ice Age (LIA) glacier activity in the northeast St. Elias Mountains, however, were limited by uncertain ecesis intervals and lichen age-growth relationships, as well as large error terms associated with calibrated radiocarbon ages at LIA time scales (Denton and Stuiver, 1966; Rampton, 1970; Denton and Karlén, 1977). Tree-ring dating of overridden trees and tilted snags, which has been extensively used in coastal Alaska (Calkin et al., 2001) and the Canadian Rocky Mountains (Luckman, 2000) to resolve LIA glacier advances at decadal timescales, has not been applied in the St. Elias Mountain because suitable dating material has not previously been located.

Here we present initial results of several investigations that are broadly targeted at elucidating the Little Ice Age behaviour of glaciers in the northeast St. Elias Mountains. Dendrochronological techniques were used to refine the history of Neoglacial Lake Alsek (Clague and Rampton, 1982), which formed at least three times since the early 17th century when Lowell Glacier blocked drainage of the south-flowing Alsek River. Crossdated driftwood associated with three phases of Lake Alsek constrains the timing of advanced positions of Lowell Glacier, including its LIA maximum position, which was probably attained in the 17th century. Similar methods are being used to develop a high-resolution chronology of ice-dammed Lake Donjek (Perchanok, 1980) which potentially threatens the Alaska Highway transportation corridor north of Kluane Lake. We dated two distinct driftwood strandlines that suggest Donjek Glacier was at its maximum LIA position in the early-mid 19th century. At Kaskawulsh Glacier, white spruce stems were sheared and tilted when terminal moraines were deposited during the culmination of its most extensive Little Ice Age advance. The ages of seven such stems, which we dated by comparing their ring-width patterns to a ~900 year tree-ring chronology from nearby south Kluane Lake, suggest that Kaskawulsh Glacier was at its most extensive Holocene position in the early-mid 18th century. Our results highlight the potential for long tree-ring records to provide decadal-scale dating of geomorphic events in the northern St. Elias Mountains.
SEISMIC NETWORK ENABLES ASSESSMENT OF FLOOD DYNAMICS BENEATH AN ICELANDIC GLACIER

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Sensor-based observations of glacier floods (jökulhlaups) have given impetus to an emerging paradigm shift in glaciology. Formerly, the predominant view was that floodwater travelled within a single conduit eroded into the underside of a glacier; but the latest hypotheses unite empirical and theoretical evidence to show that floodwater permeates large zones of the glacier bed, before draining from isolated vents. Despite resurgent interest in jökulhlaup hydraulics, the capricious timing and intensity of jökulhlaups continues to put human activity at risk. We report here about a regional network of digital, three-component seismometers that communicate distinct seismicity immediately before and during jökulhlaups that propagate beneath the glacier Skeiðarárjökull, Iceland. We exploit this unique circumstance to enable (i) an empirical assessment of jökulhlaup dynamics beneath Skeiðarárjökull; and (ii) an evaluation of the utility of glacier seismicity as a basis for short-term forecasts about jökulhlaup probability.
INTERNET-BASED PLATFORM FOR REAL-TIME GEOSCIENCE DURING TECTONIC CRISES IN ICELAND

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Iceland straddles the spreading, tectonic boundaries of the northeast Atlantic plate and the Eurasian plate. This situation promotes frequent earthquakes and volcanic eruptions due to elevated crustal stresses imposed by magma pressure. Hazardous earthquakes occur in two geographic regions: the south Iceland seismic zone and the Tjornes fracture zone. Twenty active volcanoes reside on land and a further 10 exist in offshore regions; collectively, 229 observed eruptions have occurred since the ninth century. Although Iceland has a population density of just three persons per square kilometre, the direct effects of earthquakes and volcanic eruptions have caused at least 193 fatalities. Sensor-based measurements of seismicity and ground deformation are fundamental to real-time monitoring and assessment strategies for nascent tectonic hazards. To enable accurate, short- and long-term factual statements about tectonic hazards, the Icelandic Meteorological Office (IMO) has developed an Internet-based early warning and information system (EWIS) for visualizing results from its national seismic network. Here we (i) outline the design of EWIS; and (ii) explain how EWIS facilitates real-time geoscience for hazard identification and risk reduction.

Telemetric methods deliver data from 41 seismometers to IMO in Reykjavik. Basic seismological parameters are computed at each seismic station before automated waveform analysis takes place at IMO. Earthquake magnitude and hypocentre data are available routinely a few minutes after an earthquake has occurred. We use GIS and Internet technology in tandem to unite seismological data with geological information in a Website environment. This approach allows synoptic views of past and present seismicity levels, thus providing a forecasting basis for earthquakes and volcanic eruptions. The EWIS Website also hosts a database, which comprises scientific publications, customised hazard summaries, pre-processed information for civil defence purposes, and annotated map and image resources. Although EWIS is utilised primarily by IMO, it also serves as a heuristic tool for scientific and public communication of geophysical information. Through Internet-based analyses of earthquake data, distinct, time-dependent changes in tectonic activity are apparent. For example, we observe that comparatively large earthquakes on bedrock faults can transmit stress changes to several fault-lengths distance, thereby mechanically triggering secondary earthquakes. By calculating the stress changes resulting from individual earthquakes, we are progressing toward a national map of expected earthquake intensities. The main strength of EWIS is the ease and speed at which multi-parameter historic and real-time seismic data can be visualized via the Internet. This synergy of information is fundamental to timely identification and assessment of tectonic hazards in Iceland.
POTENTIAL CLIMATE CHANGE IMPACTS AND ADAPTATION FOR INFRASTRUCTURE IN NORTHERN COMMUNITIES UNDERLAIN BY PERMAFROST

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Regional studies in the Arctic (Maxwell, 1997) and in the Mackenzie Valley (Cohen, 1997; Dyke and Brooks, 2000) suggest that permafrost will partially or completely disappear over large areas of the Canadian north in the event of predicted climate warming. Warm (>−2°C) and thin (<50 m thick) permafrost is at greatest risk of thaw (Smith et al., 2000). There has already been significant research examining the potential impacts of climate change upon natural systems, yet the impacts upon communities and infrastructure are generally poorly known or little studied, as are possible strategies for adaptation. As much of the infrastructure in northern communities relies on the properties of frozen materials for stability, warming of the ground could degrade the performance of many existing and future structures including roads, building foundations, utilities, and embankments (Etkin, 1998; Nelson et al., 2001).

Infrastructure problems have already been experienced in the Mackenzie valley and delta regions owing to both natural and anthropogenic changes and difficulties of building on permafrost. Even under current climate conditions, the clearing of a vegetated surface imposes changes upon the thermal regime of underlying permafrost, in many instances initiating near-surface thaw and ground subsidence in ice-rich material. Over time, engineers working in northern environments have incorporated the impacts of moderate thaw into infrastructure design. However, it appears likely that these structural integrity problems will be enhanced under a warmer climate, in which near-surface thaw will become deeper, ground subsidence more pronounced, and in which the complete loss of permafrost will occur in some regions.

It appears likely that communities in the north, including both communities in this case study, will experience some negative impacts upon infrastructure owing to a warming of the ground and thaw of permafrost. There will be a need to adapt to these impacts. Some possible adaptations are reactive; that is they can be initiated after the impact has occurred, whereas others are proactive, requiring an ability to anticipate and forecast climate and impact magnitude.

This presentation discusses the potential impacts of climate change-induced permafrost thaw upon infrastructure in northern permafrost-affected communities, using case studies from the communities of Norman Wells and Tuktoyaktuk, Northwest Territories, Canada. Although this presentation focuses on the Mackenzie Valley region, in many cases the impacts and adaptation mechanisms may be applicable in other communities with similar permafrost conditions.
LONG DISTANCE POLLEN TRANSPORT TO SOUTHERN GREENLAND: IS THERE A REGULAR PATTERN?

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The on going EPILOBE project, monitoring the pollen transport to the Greenland coast, is based on several stations where filters are trapping all year long the pollen grains present in the air. A previous record of long distance pollen transport to southern Greenland, at Narsarsuaq, have been observed in 2002 through the capture of pollen grains from trees, hickory and hemlock, oak, beech, hornbeam, walnut, growing in North America. This transport was in agreement with the dates of pollen production measured in southern Canada in the Toronto area, at the northern range of the common distribution of these trees (Fig. 1). The pattern of the transport had been described by using the HYSPLIT application from NOAA, which allows determining backward trajectories.

A new transport to Narsarsuaq has been observed in the filters exposed in Narsarsuaq at about the same timing than in 2003. The filters exposed during weeks 21 (20 - 26 May) and 22 (27 May - 2 June) indicate the occurrence in the Greenland air of pollen grains from trees, which again are better growing in eastern North America (Fig. 2). Despite the plants already observed in 2002, which absolutely indicate North America as a potential source of the pollen, other trees, also growing in eastern North America have been noticed. These are poplar, yew, ash, plane tree, and spruce. The backward air trajectories, computed by the HYSPLIT application for the concerned weeks, show mostly a similar pattern for most of the transport over the Great Lakes area.

Conversely, the total number of pollen grains present in the atmosphere in southern Greenland (total number per cubic meter of air, computed with the available Danish Meteorological Institute) was higher in 2002 than in 2003. It appears then that a regular pattern of air masses responsible for the transport of pollen grains from North America to Greenland should be constant, as already described for anthropogenic pollutants.


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Fig 1. Long distance transport to Narsarsuaq in 2002 (from Rousseau et al. 2002 modified)A) Backward trajectories provided by the HYSPLIT model [HYSPLIT4Model, 1997] of air masses reaching Narsarsuaq (61.15° N, 45.43° W, 1 m asl) at different altitudes: ground level (red), 1000 m (blue) and 3000 m (green) on June 4th of 2002. The grey area in eastern USA and southeastern Canada represents the zone where "exoctic" trees are all growing [from Thompson et al., 1999a; Thompson et al., 1999b]. The 3000m? air mass passed over this area. L: London, P: Peterborough, S: Sudbury, T: Toronto. B) Altitude variation of the three air masses used in the backward trajectories analysis. The "3000 m" air mass over Narsarsuaq on June 4th, 2002, was at a lower elevation on June 1st, when it passed over the area where "exoctic" trees are growing.
Fig 2. Long distance transport to Narsarsuaq in 2003. A) Backward trajectories provided by the HYSPLIT model [HYSPLIT4Model, 1997] of air masses reaching Narsarsuaq (61.15° N, 45.43° W, 1 m asl) at different altitudes: ground level (red), 1000 m (blue) and 3000 m (green) on May 20th of 2003. The grey area in eastern USA and south-eastern Canada represents the zone where "exoctic" trees are all growing [from Thompson et al., 1999a; Thompson et al., 1999b]. B) Altitude variation of the three air masses used in the backward trajectories analysis. The "3000 m" air mass over Narsarsuaq on May 20th, 2003, was at a lower elevation on May 14 to 16st, when it passed over the area where the "exoctic" trees are growing.
A HIGH RESOLUTION CLIMATE RECORD FROM THE NORTHGRIP DEEP ICE CORE

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The North Greenland Icecore Project (NorthGRIP) deep drilling operation reached bedrock at 3085 m in July 2003, making the NorthGRIP core the longest ice core ever drilled in Greenland. The drill site is located at 75.10°N, 42.32°W, which is 324 km NNW of the summit of Greenland where the Greenland Icecore Project (GRIP) and Greenland Ice Sheet Project 2 (GISP2) deep ice cores were drilled. NorthGRIP was initiated in 1995 as a joint international programme involving Denmark, Germany, Japan, Belgium, Sweden, Iceland, the U.S.A., France and Switzerland. The main goal was to obtain undisturbed high-resolution information about the Eemian climate period (115-130 kyr BP). The records from GRIP and GISP2 are different and disturbed in the ice covering this period. Internal radio-echo sounding layers showed that NorthGRIP is located on a gently sloping ice ridge with very flat bedrock and has a lower annual accumulation than central Greenland, resulting in a higher age of the basal ice. In the Eemian the climate was several degrees warmer than present conditions, making it an important period to study for evaluation of possible future climate scenarios with an anthropogenic global warming.

The NorthGRIP camp was established in 1996, where shallow drilling, casing and construction of the deep drill setup was accomplished. In 1997, the drill got stuck at 1371 m depth and could not be recovered. This core is referred to as the NGRIP1 ice core. In 1998 a new bore hole was prepared and casing was made. During the 1999 and 2000 field seasons, a depth of 2930 m was reached, before the drill got stuck. This time, though, the drill was successfully recovered. In the 2001 season the drill was repeatedly stuck and recovered 4 times due to increased bore hole temperature near the base of the ice sheet. In 2003 bedrock was reached at a depth of 3085 m.

The NorthGRIP core contains the first continuous record of the end of the Eemian and the start of the last glacial period recorded in a deep Greenland ice core. The bottom of NorthGRIP is essentially undisturbed and annual layers are relatively thick, a situation caused by basal melting which results from an unexpectedly high geothermal heat flow along the NorthGRIP flow line. The ice from the NorthGRIP ice core contains about 1 cm thick annual layers in the period of the transition from the Eemian to the last ice age, making the NorthGRIP records the best resolved climate series from this period ever recorded in Greenland. The NorthGRIP core will make it possible to investigate the duration of the onset of the ice age and how the atmospheric circulation changed from year to year and thereby get valuable insight of the dynamics of the climate system at the onset of an ice age. The precise dating will also provide the opportunity for using it as an important link between the northern and the southern hemisphere. The detailed measurements have been initiated and we hope to have significant results within a year.

The NorthGRIP isotopic record covers the Holocene, the entire last glacial period, and part of the last interglacial, the Eemian. The NorthGRIP core can be cross dated with the GRIP core down to 105 kyr BP using the isotope curves together with the methane concentrations and the oxygen isotopic composition of air in the air bubbles. Older ice can be dated using these gas concentrations and comparing them to the corresponding Vostok profile. Below Dansgaard-Oeschger event 24 the NorthGRIP record is compared to the planktonic oxygen isotope record from marine core MD95-2045 drilled at the Iberian coast. Based on similarities between the two records and 1D ice modelling, the basal part of the NorthGRIP record is dated to 123 kyr BP.
The lower 60 m of ice core contains ice from 115 kyr BP to 123 kyr BP, corresponding to the end of the Eemian. The results from the isotope measurements imply significantly warmer (approx. 5°C) climate in the Eemian compared to the present and that the temperatures slowly decreased during a 5000 yr period before suddenly dropping to ice age conditions.

Using the continuous flow analysis (CFA) it is possible to measure the concentration of trace materials in ice cores at a very high depth resolution. During the field season of 2000 the ice core from the depth interval 1400-2930 m was analysed for its contents of Ca2+, Na+, NH4+, NO3-, SO42-, H2O2, HCHO, and insoluble microparticles (mainly mineral dust). Also, the electrical conductivity of the melted ice sample was measured continuously. In addition, the visual stratigraphy of the ice was recorded continuously with sub-millimeter resolution using a dedicated line scanner. The depth resolution of the CFA equipment is approx. 1–2 cm, making it possible to detect changes in concentration and timing of the trace substances on a sub-annual scale in the last part of the glacial period and during the Bølling-Allerød – Younger Dryas – Preboreal oscillation. This part of the ice core can thus be dated by identification and counting individual annual layers in the ice core based on a multi-parameter approach. It is believed that the timescale produced for this part of the core will have an uncertainty of a few percent or less. For the deeper parts of the core, annual layers will be detectable from the CFA data in the relatively warm interstadials due to the increased accumulation, and with improved CFA measuring techniques it should be possible to detect annual layers during the stadials as well.

In the field many additional measurements were made. The electrical properties of the ice were recorded with Dielectric Profiling (DEP) and Electrical Conductivity Measurements (ECM), and the borehole was logged using several independent methods. In the laboratory the physical properties of the ice are studied and deformation experiments performed.

When bedrock was reached at NorthGRIP, basal water flooded the lower 45 m of the hole. From the measured temperature profiles it was known that the base of the ice sheet was at or very near the pressure melting point, but the sudden and rapid flooding was unexpected. A distinct layer of liquid water was not observed in the radar profiles taken during site selection, so the water is apparently contained in a sediment layer under the ice. The drill came up covered with refrozen basal melt water and a 2 kg reddish colored piece of ice was attached to the end of the drill head. The recovered basal ice had a high contents of gases. The hydrological system under the ice cap may have been isolated from the surface for 2 million years. At this time, we know little about the basal water ice at NorthGRIP, including why it is pink, what the gas is, and if it contains signs of bacterial life. Samples are examined at the moment.

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Fig 1. Picture from the NorthGRIP camp just after bedrock was reached. Basal water had entered the bore hole and the drill was brought to the surface. Under the drill a piece of reddish refrozen basal water can be seen.
A NEW METHOD TO RECONSTRUCT BARK BEETLE OUTBREAKS: RECURRENCE INTERVALS AND HISTORY OF SPRUCE BARK BEETLE (DENDROCTONUS RUFIPENNIS) INFESTATION IN SOUTHWEST YUKON, CANADA

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It is widely accepted today that disturbance is a major force structuring vegetation mosaics (De Grandre et al. 1993) by altering vegetation composition and processes of the system. Spruce bark beetles (Dendroctonus rufipennis) are considered a major force of disturbance in boreal forest ecosystems as they have the potential to remove large proportions of the forest canopy. Outbreaks of these pests are of great concern because it appears that the patterns of beetle attacks are changing. Evidence suggests that the size, level of tree mortality, and frequency of outbreaks may be increasing as of the last few decades (Ross et al. 2001). Garbutt (2000, pers comm.) observed that the current outbreaks in the Yukon Territory and Alaska have already outlasted all of the known historic spruce bark beetle attacks that have occurred in British Columbia. Yet we know surprisingly little about the influence of these outbreaks on forest dynamics (Veblen et al. 1991), and the historical record of spruce beetle activity is presently limited to tree ring data (dating back two to three centuries in the Yukon and up to five centuries in the Rockies) and written records that only reach back to the 1800s in North America. Bark beetles will typically attack and kill all mature spruce trees within the infested area. Subsequently, all of the needles on these trees will fall off about one year after being attacked. If an infested spruce stand occupies the land within a lake’s basin, many of these needles will presumably be transported into the lake waters where the needles will break down. The stomata from conifer needles are very resistant to decomposition and are typically reworked from shallow into deep regions of lakes and preserved in these sediments. The massive influx of needles from an infested stand around lakes should produce a long-term proxy record of spruce bark beetle outbreaks in the area. A sediment core was extracted from a small lake within the Kluane Lake region of the southwest Yukon in order to determine the historic occurrences, recurrence intervals, and levels of past spruce bark beetle outbreaks in this currently infested area. The core was sectioned at 3 mm intervals to provide high temporal resolution over the past 900 years. A 1 cc sub-sample from each sample was processed to extract fossil stomata using standard pollen extraction techniques (Faegri et al., 1989). Fossil stomata will then be identified and counted on slides under light microscope. A select fewer samples will be analysed for beetle remains as per the kerosene flotation method (Elias, 1994) and hand picked bark beetle fragments from the samples will be identified. Bark beetle remains, found in the sediments which stomata concentrations have indicated outbreaks, would confirm the presence of an outbreak. The concentration of conifer stomata of each sample will be extrapolated from slide counts and plotted over time. I expect a large rise in stomata concentrations, over that of the immediately previous years, will indicate the occurrence of spruce defoliation and thus bark beetle infestation. This research is needed to establish the recurrence intervals of bark beetles and, to not only relate these data to other proxy indicators (e.g. pollen and charcoal and dendrochronology) of vegetation, fire history, and climate, but to also shed light onto the possible effects of climate change on insect pests and forest disturbance dynamics.
PALEOLIMNOLOGICAL RECORDS OF NUTRIENT DYNAMICS ASSOCIATED WITH SOCKEYE SALMON (ONCORHYNCHUS NERKA) PRODUCTION IN SUB-ARCTIC AND ALPINE NURSERY LAKE ENVIRONMENTS

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Pacific salmon (Oncorhynchus spp.) represent a keystone ecological resource in sensitive arctic and alpine environments throughout the coastal North Pacific. In many systems, returning spawners import critical nutrients to inland, nutrient-limited aquatic ecosystems and associated riparian areas. The past 150 years, however, have witnessed significant declines in salmon populations coast-wide, associated with anthropogenic stressors such as harvest pressures, habitat destruction, hydroelectric development and hatchery production. These changes have occurred in the broader context of climatic change, a large-scale forcing mechanism of Pacific salmon through time.

Recently, novel application of established methods in the field of paleolimnology, the study of lake histories, has provided a means to reconstruct long-term sockeye salmon productivity. By exploiting the “counter-current” nutrient flow created by sockeye moving inland to oligotrophic nursery lakes to spawn, we use information archived in lake sediment cores to track salmon-derived nutrients and infer records of salmon abundance through time.

We present paleolimnological records of salmon-derived nutrient (SDN) dynamics and related trophic changes using stable nitrogen isotope ($\delta^{15}$N) and biological (diatoms, zooplankton) proxies, from sockeye salmon (Oncorhynchus nerka) nursery lake sediment cores. Our data represent both natural variability and human-induced changes in a ~2000 yr record from Redfish Lake, ID, an alpine nursery environment, and a ~5000 yr record from Tahlto Lake, BC a remote sub-arctic nursery lake.
RECENT CHANGES IN THE ICE CAPS AND GLACIERS OF CANADA'S ARCTIC ISLANDS

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The Queen Elizabeth Islands in Arctic Canada contain over 110,000 km² of ice caps and glaciers, the largest area of land ice in the world outside Antarctica and Greenland (Williams and Ferrigno, 2002). These ice masses are located in a region that is projected to experience large climate warming over the next century due to the build-up of greenhouse gases in the atmosphere (IPCC, 2001). These small ice masses are likely to respond more rapidly to respond more rapidly to the projected warming than the larger Greenland ice sheet, and may contribute appreciably to sea level changes over the next century.

To provide a baseline against which future changes can be assessed, and to determine whether changes in glacier area and volume are already underway, we compared the extent of ice cover in the Queen Elizabeth Islands in 1959/60 with that in 1999/2000. 1959/60 ice extent was derived from Digital NTDB (National Topographic Database) ice outlines provided by Geomatics Canada. These outlines are available as a commercial product, and were derived from the digitization of 1:250,000 topographic maps, which in turn were plotted from 1:60,000 stereo aerial photography flown in 1959/60. The ice outlines were provided in ArcView shapefile format in both latitude/longitude and projected UTM formats. The 1999/2000 ice outlines were derived from automatic (unsupervised) classification of orthorectified Landsat 7 imagery. It was not possible to measure the present-day ice extent in the far northern part of Ellesmere Island due to the lack of Landsat imagery above ~82°N. The vast majority of the ice in N. Ellesmere Island (93.1%) was, however, imaged. The total ice area in N. Ellesmere in 1959/60 was 28,062 km², of which 26,131 km² could be seen in the Landsat 7 imagery.

This paper will present the results of the change analysis, and discuss the observed regional patterns in rates of change. It will also discuss relationships between patterns of change and ice dynamics. Volume-area scaling methods (Bahr and others, 1997) will be used to make an initial estimate of the changes in ice volume since 1960. An estimate of the contribution of these changes to global sea level will also be presented.

A VALIDATION OF THE MODIS CLOUD MASK OVER GREENLAND

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The results of a validation study of the Moderate-resolution Imaging Spectroradiometer (MODIS) Cloud Mask (MOD_35) data product will be presented. The goal of this work is to determine the range of errors to be expected in using this data set to develop a cloud cover climatology over Greenland’s high plateau. It is expected that there will be shortcomings in the MOD_35 product because of the inherent difficulties of high latitude cloud detection. This validation will investigate systematic errors in order to understand biases in MOD_35 as well as to provide feedback to the authors of the algorithm. MOD_35 is used as an input for a suite of other data products in the NASA’s Earth Observing System (EOS) family. It is important to understand how errors in the MOD_35 will propagate through other data sets. Results indicate that MOD_35 performs very well during daylight hours and reasonably well during nighttime hours. There is a clear sky detection bias in data from all months. With the exception of midwinter cloud detection, most shortcomings can be improved with careful filtering. This validation is a single point analysis that will be extrapolated over Greenland’s dry snow region. This analysis is a first step towards achieving a robust cloud climatology over all of Greenland with MODIS.

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Petermann Gletscher is the largest and most influential outlet glacier in central northern Greenland. Located at 81 N, 60 W, it drains an area of 71,580 km², with a discharge of 12 cubic km of ice per year into the Arctic Ocean. The dominant form of mass loss (55%) at the Petermann Gletscher floating ice tongue has been attributed to basal melting, with the never before measured surface ablation thought to account for about 2-3 m/yr. The extensive field campaign during 2002 and 2003 allows surface ablation to be described for the first time.

A MALÅ GeoScience RAMAC/GPR unit was used to measure the thickness of the floating glacier tongue along profiles of several hundred meters. The control unit (32-bit processor) keeps track of current position and time, connected to transmitter and receiver with fiber optic cable. The unit was installed on a sledge with 25 MHz and 50 MHz antennas. We used a sampling frequency of 1 sec with 8 stacks and a 4100 ns time window. Geolocation of the measured profile was obtained with differential GPS measurements (Trimble Pathfinder), with reference stations at the Camp, and at Thule AFB. Large sub-glacial melt channels on the floating ice tongue were discovered running along the flow direction. Some of these melt channels are up to 200 m deep.

A step frequency radar based on a vector network analyzer (VNA) with a center frequency of 305 MHz at 1260 MHz bandwidth was used to measure the bottom melt of the floating Petermann glacier tongue with resolution of 2.3 mm in thickness change over only a couple of hours to days. Maximum bottom melt values of up to 50 m/y were measured. These multi-phase radar point measurements revealed interesting results of bottom melt rates, which exceed all previous estimates. It is worth mentioned that the largest bottom melt rates were not found at the grounding line, which is common on ice shelves in the Antarctica. In addition, GPS tidal motion has been measured over one lunar cycle at the flex zone and on the free floating ice tongue and the result will be compared to historic measurements made at the beginning of last century.

A peculiar surface feature resembling an “ice worm” was found some 5-km from the orographic left margin of the floating ice tongue. The vertical extension of this “ice worm” is approximately 50 m and it can be identified on Landsat imagery running for several tens of kilometers.
Fig 1. Ground Penetration Radar (MALÅ GeoScience RAMAC/GPR) on Petermann Gletscher with 100 MHz antenna.
Fig 2. Base Camp on Petermann Gletscher with Step Frequency Radar based on a Vector Network Analyzer (VNA). Transmitting and receiving antennae are shown separated by approximately 10 m.
SEASONAL CHARACTERIZATION OF DIATOMS IN THE LORD LINDSAY RIVER, BOOTHIA PENINSULA, NUNAVUT

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The purpose of this study was to characterize the diatom assemblage of a large middle arctic river in order to examine the potential for enhancing interpretations of the lake sedimentary record. The ability to isolate species that show a strong affinity for the lotic environment presents an opportunity to interpret stratigraphic changes in these species in terms of past hydrological change. Significantly higher relative abundances of Achnanthes minutissima Kützing, Fragilaria capucina Lange-Bertalot, Diatoma tenuis Agardh, and Cymbella arctica (Lagerstedt) Schmidt, C. minuta Hilse, C. silesiaca Bleisch and C. fogedii Håkansson in the lotic environment throughout the 2001 growing season compared to the sedimentary record suggest that these species characterize the Lord Lindsay River diatom assemblage. Comparison of seasonal abundances of these taxa to hydrological parameters including river discharge, electrical conductivity, and water temperature reveal key information about the character of this community. The fact that the lotic assemblage changes very little throughout the sampling period, despite major changes in hydrological conditions, suggests a high degree of resiliency and inherent structure in the community. However, a decrease in diatom productivity in response to rapid and dramatic changes in hydrological conditions following a major rain event suggests that a threshold tolerance may exist, with potentially important implications for interpreting changes in the palaeoenvironmental record. Stratigraphic changes of the lotic assemblage in the sedimentary record track changes in mean varve thickness and suggest that these species may be used to infer past hydrological and ecological conditions in the Lord Lindsay River.
LATE HOLOCENE PALEOMAGNETIC SECULAR VARIATION (PSV) FROM NUNAVUT, CANADA: DEVELOPMENT OF A DATING CURVE

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Historical observations and Pleistocene paleomagnetic data indicate the rather unique properties of the geomagnetic field in the polar regions. To examine the Holocene paleomagnetic record from the Arctic, we have undertaken a u-channel paleomagnetic study of late Holocene sediments from multiple cores taken from two lakes on Ellesmere Island (Nunavut, Canada). Sawtooth Lake (79 21 N, 83 56 W) is an oligotrophic lake located in the southwestern part of the Forsheim peninsula. Murray Lake (81 34 N, 69 54 W) is also oligotrophic and is located on the eastern coast of Ellesmere Island, near the Archer Fjord. Both lakes contain annual clastic laminations, providing varve chronologies that document a sedimentation rate of ~200 cm /kyr for the last ca 2600 yrs at Sawtooth Lake, and ~50 cm/kyr for the last ca 4000 yrs at Murray Lake. U-channel paleomagnetic data using progressive alternating field (AF) demagnetization show that the sediments of both lakes preserve a strong, stable, single component magnetization that can be tied to the historical record. A late Holocene PSV record for Ellesmere Island can now be established for the last 2600 yrs based the agreement between multiple cores from each lake and similarities of inclination, declination and relative paleointensity between lakes. This record documents high amplitude geomagnetic field changes that are significantly larger than anything in the historical record including the ~1000 km migration of the North Magnetic Pole during the last century. These records are compared with initial results from Devon Island (Cape Hurd Lake & Cape Eardley Wilmont Lake), Cornwallis Island (Depot Point Lake) and Bathurst Island (Danielle Point Lake) that support the idea that under the correct conditions PSV can be used as a tool for dating Arctic sediments.
OCEANOGRAPHIC CHANGES AROUND 8 KYR. BP ON THE NORTHERN ICELANDIC SHELF INTERPRETED FROM SEDIMENTOLOGICAL AND FORAMINIFERAL FAUNAL ANALYSES IN CORE MD992275

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During the past few years the North Icelandic shelf area has been subject to several studies. Many of these investigations deal with oceanographic changes from the Late Glacial and throughout the Holocene. This talk will concentrate on changes, which have been observed in a short time interval around 8 kyr. BP in a core a high sedimentation rate area off North Iceland.

The investigated core MD992275 is located at app. 440 m water depth in the Tjörnes Fracture Zone east of the Kolbeinsey Ridge in the oceanographically sensitive area of the Northern Icelandic shelf. Here the warm Irminger Current, running clockwise along the southern and western part of Iceland, meets a modified branch of the cold East Greenland Current, the East Icelandic Current. The easternmost part of the shelf is possibly also affected by the Jan Mayen Gyre carrying cooled Atlantic water. The core contains sediment deposited during approximately the last 14 kyr. with a mean sedimentation rate of 2.6 m/kyr. The high sedimentation rate enables a high time resolution, and the identification of known tephra layers e.g. the Vedde Ash, the Saksunarvatn ash, the Hekla 5 and the Hekla 3, combined with radiocarbon datings provide a robust fundament for construction of an age model and for correlation to other localities.

A series of sedimentological analyses have been performed on the early Holocene part of core MD992275. They include water content, solid density, organic and inorganic carbon content as well as grain size analyses and mineralogical counts. A prominent change in the grain size distribution and total inorganic carbon content of the sediment is observed around 8 kyr BP. The same interval is characterized by major changes in the foraminiferal faunal composition of both the benthic and the planktonic assemblages. For instance, the benthic species Cibicides lobatulus shows major oscillations and the planktonic Neogloboquadrina pachyderma sinistral also varies in abundance.

Investigations by Knudsen et al. (in press) of other cores from the North Icelandic shelf area west of the Kolbeinsey Ridge also clearly show an oceanographic event. This is seen by increased amounts of Neogloboquadrina pachyderma (sinistral), lighter δ18O stable isotope values and changes in the grain size distribution occurring at approximately the same time. This oceanographic event, which has been found in several North Icelandic cores probably correlates with the well-known, so-called “8.2 kyr event”.

Evidence of the contemporaneous climatic event at approximately 8.2 kyr BP has been observed in many different records throughout the North Atlantic Ocean and the surrounding landmasses. It is seen as a notable change in δ18O stable isotope values compared to the otherwise relatively stable Holocene values in the Greenland ice cores (e.g. Johnsen et al., 1992) as well as in a number of proxies in marine sediment cores e.g. changes in foraminiferal and coccolithic assemblage compositions, δ18O stable isotope values and sediment grain size distribution (e.g. Andrews and Giraudeau, 2003; Klitgaard-Kristensen et al., 1998) and in European terrestrial records such at tree-ring width (Klitgaard-Kristensen et al., 1998). Different suggestions of the forcing mechanism behind this event have been put forward. Among those is affection of the North Atlantic thermohaline circulation by changes in the freshwater flux to the area (e.g. Clark et al., 2001; Klitgaard-Kristensen et al., 1998).


Fig 1. Present day oceanic surface circulation pattern in the North Atlantic. Light grey arrows mark cold water mass currents and dark grey arrows mark warm water mass currents. The Polar Front is the boundary zone between the warm and the cold water masses.
Fig 2. Bathymetric map of the shelf and upper slope area around Iceland. Location of the studied sediment core MD992275 is marked with a black dot. Modified after Knudsen et al. (in press).
DECADAL HYDROCLIMATIC VARIABILITY AS EVIDENCED BY THE SEDIMENTARY RECORD OF MIRROR LAKE, NORTHWEST TERRITORIES, CANADA

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Mirror Lake, Northwest Territories (62 ° N, 128 °W), is a weakly stratified, oligotrophic lake that receives meltwater and suspended sediment on a seasonal basis primarily from the partially glacierized southern portion of its catchment. This seasonal delivery of sediment, in addition to 137Cs measurements, suggests that the sedimentary record has an annual resolution (i.e., varved). Through image and microscopic analysis of thin sections, a varve chronology was developed and the resulting varve thickness record was compared to local meteorological data (Tungsten, 7 km from site) to determine hydrometeorological influences on varve formation during the past 35 years.

Analysis of the varve thickness and meteorological records indicates that the hydrological regime of the Mirror Lake catchment fluctuates on a decadal time scale between two recognizable modes. July temperature was the most influential climatic control over varve formation throughout the sedimentary record, although precipitation also played a role through the negative effect of thick snowpacks on glacier ablation during certain periods of the record. Varves formed in the 1970s reflect one mode of the hydrological system, where July mean temperature was the main control ($r^2 = 0.890$, $n = 11$, $p < 0.01$) on varve thickness due to its positive influence on glacier ablation and average to below average snowpacks during this period. By contrast, varves formed in the 1980s reflect the second mode, whereby both summer temperature and snowfall were both significant influences on varve thickness. Observed mean July temperature increased 0.7 °C between the 1970s and 1980s, while no other months showed substantial changes. Despite this temperature increase, above average snowfall during the 1980s weakened the July temperature signal in the sedimentary record. Thicker snowpacks are inferred to have delayed glacial melt, resulting in a stronger precipitation signal in the sedimentary record.

The decadal climatic variability determined at Mirror Lake was also evident through varve structure. Varves formed under the first hydroclimatic mode had only one silt unit while varves formed under the second mode had two prominent silt units. The lower silt unit of the second mode varves likely formed from spring nival melt or the first peak in glacial meltwater discharge in July, while the upper silt unit likely formed during peak melt in August. This upper unit was largely absent in years under the first hydrological regime mode. Therefore, varve structure in the Mirror Lake record reflected the dominant hydroclimatic processes operating to transport sediment to the lake to form varves, in addition to demonstrating an annual record of climatic variability.
LATE QUATERNARY VEGETATION HISTORY OF SOUTHWESTERN YUKON TERRITORY

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Late Quaternary vegetation and climate history of the southwestern Yukon is of interest to paleoecologists as this region remained unglaciated during the last glacial period and formed the southeastern corner of the Bering land bridge (Beringia). Rampton (1971) cored Antifreeze Pond (AP), southwestern Yukon Territory, Canada, from which he obtained 7 14C bulk sediment dates and analysed the pollen. The basal dates indicate that the AP sediment record spans 30,000 14C yr. B.P.. If this chronology is correct, AP is one of only two known lakes in the Yukon Territory with a sediment record extending into the middle Wisconsinan, a period poorly understood in southeastern Beringia. This chronology has been questioned due to a date reversal near the base of the core and the possibility of old carbon within the lake. A new core from AP has been obtained and 23 samples of terrestrial plant macrofossils have been submitted for AMS 14C dating.

Pollen, stomates, and plant macrofossil analyses of a 5 m long sediment core from AP provides a vegetation history of southwestern Yukon Territory. The use of a multi-proxy approach will provide both a regional and local signal of past vegetation. Preliminary evidence suggests that during the late Quaternary southwestern Yukon Territory underwent five major environmental shifts. The early vegetation history was dominated by sedges (Cyperaceae) and grasses (Gramineae) along with Artemisia, Thalictrum, and Pediastrum. This period is interrupted by an interstadial inferred by an increase in Picea, Alnus, and Salix pollen along with macrofossils of Ranunculus aquatilis, Potamogeton, Chara, Sphagnum, and statoblasts of the bryozoan Cristatella mucedo. Also, conifer stomates are present during this period suggesting that southeastern Beringia may have been lightly forested. This may represent an eastern expansion of Picea woodland into southwestern Yukon Territory during the middle Wisconsinan. Although this has been previously hypothesized, the pollen data from this region have been inconclusive. Following the interstadial is an environment again dominated by Cyperaceae and Gramineae. Few plant macrofossils, diatoms, and chironomids were recovered during this period, which may represent a hiatus in the lacustrine record. Approximately 13,000 yr. B.P., Salix pollen increases coeval to a rise in Hippuris, Eleocharis, Ranunculus aquatilis and Potamogeton macrofossils. This period is also marked by a rapid sedimentation rate. The characteristic boreal forest vegetation, with increased Picea, Betula, Alnus, and Salix and a decrease in herbaceous pollen, developed approximately 9,000 yr. B. P. in southeastern Beringia.

A POTENTIAL MODEL FOR PEDAGOGICAL TECHNIQUES IN UNDERGRADUATE FIELD GEOLOGY: AN EXAMPLE FROM SOUTH-CENTRAL ALASKA

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Recent research studies sponsored by the National Science Foundation, the American Association for the Advancement of Science, and other science educators have shown that the most effective learning environment is experiential, or “hands-on,” and steeped in investigation throughout all four years of undergraduate learning. The proper study of geology involves extensive field study to supplement material obtained from textbooks and received in lecture. The field study approach gives students a chance to acquire and apply knowledge and skills in a relevant setting. Field study should include sites where certain facies, formations, and features can be seen, as well as localities where there is an active, or “direct encounter” with the processes of formation/deposition of similar material. However, many colleges and universities do not have access to adequate field locations, they lack funding, or are simply lacking a developed program to take advantage of the sites they may already have.

The St. Lawrence Valley of New York and Ontario, Canada has a dynamic glacial history and is therefore an integral part of the undergraduate Geology and Geography departments at St. Lawrence and Queen’s Universities, respectively. Students are frequently exposed to numerous glacial features and deposits dating to the late Wisconsinan. However, faculty have found that many students are unable to fully comprehend the link between glaciers and glacial deposits because all local field expeditions are in areas where glaciers do not currently exist. Additionally, courses in geomorphology at universities in eastern North America suffer from a general lack of highly active contemporary geomorphic processes such as slope processes and braided river development.

In order to better understand the nature of the paleoglacial environment in Pleistocene New York and Ontario, a two week trip (August 14-27, 2003) to South-Central Alaska was undertaken by students and advisors from St. Lawrence and Queen’s Universities to study both contemporary and Pleistocene glaciations, as well as active geomorphic processes. The field trip for students at St. Lawrence University required a half credit semester course in the spring of 2003 in order to become familiar glacial geology and geomorphology of the region. In addition to lectures, students were required to prepare a paper on a related topic to be assembled into a field guide (Robinson, 2003) for the trip. Some sample research paper topics included the Quaternary geology of South-Central Alaska, braided river dynamics in the Knik River, glacial hydrology of the Chugach Mountains, and dendrochronology of Western Prince William Sound.

The route chosen for the trip (Figure 1) was designed to expose the students to a variety of different processes active in the glacial and periglacial environment with stops in Portage, Valdez, Worthington Glacier, the Copper River Basin, and Matanuska Glacier. Once in the field, students were taken to numerous road cuts in the region around Valdez and the Copper River Basin, and after a period of individual study, were given supervised lectures on the formation/deposition of each. Students were then asked to relate the road cuts to episodes in glacial deposition. Later stops included an extensive examination of a lahar deposit, peat formation in a permafrost-affected bog, and active permafrost melting. Students were also required to initiate and lead group discussion at the field site relating to their chapter of the field guide.
A major focus of the trip was to provide students with opportunities to develop independent projects that they would research during supervised group stops and on their own time. These projects were meant to teach students the investigative skills needed for field study, including how to make quantitative measurements, examine spatial and temporal variations in data, look for patterns in variation, and investigate the relationships among these various factors. Therefore, the students were also required to learn how to operate field equipment such as a GPS receiver, a conductivity meter, a dissolved oxygen meter, a tree corer, and a current meter. The projects that were pursued included a comparison of contemporary glaciers of South-Central Alaska, Quaternary geology of the Copper River Basin, intertidal environments of the Valdez Arm, proglacial lake sedimentation, stream gauging, and dendrochronology studies to reconstruct climate. Project results were presented in a mini-conference two months after the trip.

The entire trip proved to be a valuable teaching tool in helping students better understand the glacial environment. The projects proved to be the cornerstone of the trip, and have encouraged the development of several senior theses and other independent research projects to be carried out during the summer of 2004. The preparation done by the students of St. Lawrence University during the spring of 2003 helped them immensely in the field, as they seemed to be more engaged and cognizant of the area under study. This experiment of study in the field has proven to be an effective model for other research disciplines at other colleges and universities, whether it is as large a logistical task as a two week trip to Alaska or the study of a local site of geologic interest during the semester. This trip shows how a successful combination of proper planning, supervised lectures, and independent field work can lead to a significantly greater understanding of the subject matter by the student. We believe that by making the students personally responsible for much of their own learning, especially the development of a field guide, responsibility for group discussions, and research projects in the field, made the field trip a much more engaging experience.


Fig 1. Map of South-Central Alaska showing the field trip route. (Robinson, 2003)
TOWARDS A TEPHROCHRONOLOGY FRAMEWORK FOR THE LAST GLACIAL/INTERGLACIAL TRANSITION IN SCANDINAVIA AND THE FAROE ISLANDS

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The Last Glacial/Interglacial transition (LGIT; ca 15-8 cal. ka BP) was a period of rapid climatic transitions around the North Atlantic. Although close similarities are evident in the palaeoclimatic reconstructions obtained from terrestrial, marine and ice-core records for the LGIT, uncertainties exist as to the degree of synchronicity (or asynchronicity) between them, largely due to the limitations of the radiocarbon dating method (radiocarbon plateaux, reservoir effects) and the lack of suitable dating methods for the time period before ca 40 ka BP. Therefore, new approaches are required for geochronology models and correlation of sequences and events. One method that holds much promise of effecting more precise regional correlations is tephrochronology.

Ten years ago, only three tephra horizons were described from this time period in Scandinavia and the Faroes: the Saksunarvatn Tephra (ca 10.2 cal. ka BP), the Vedde Ash (ca 12.0 cal. ka BP) and the Laacher See Tephra (LST, ca 12.9 cal. ka BP). The first two of these are of Icelandic origin while the LST has its origin in the Eifel volcanic field in SW Germany.

A technique for extracting cryptotephra (a tephra horizon invisible to the naked eye) has revolutionised the application of tephrochronology in minerogenic deposits from the LGIT (Turney, 1998). This technique relies upon the difference between the specific gravity of the tephra shards and the host sediment matrix and has led to the first discovery of the Vedde Ash on the British mainland as well as the previously unrecorded Borrobol Tephra, dated to ca. 14.4 cal. ka BP (Fig. 1; e.g. Turney et al., 1997). In Sweden, this technique led to the first discovery of the Vedde Ash, as well as a previously unrecorded rhyolitic tephra dated to ca 10.2 cal. ka BP (the Högstorpsmossen Tephra; Björck et al., 2002). The rhyolitic component of the Vedde Ash was also found in two sites on the Karelian Isthmus in NW Russia, greatly extending the distribution of this important marker horizon (Fig. 1; Wastegård et al., 2000). Recently, the Borrobol Tephra and two new tephra horizons, the Hässeldalen Tephra (ca 11.5 cal. ka BP) and the Askja 10-ka Tephra (ca 11.2 cal. ka BP) were discovered in LGIT deposits from Blekinge, SE Sweden, (Fig. 1; Davies et al., 2003). An effort to date the Borrobol Tephra in Sweden using wiggle-matching of AMS-dates to the Cariaco basin chronology (Hughen et al., 2004) yielded an age of ca 13.9 cal. ka BP, indicating that the Borrobol Tephra in Sweden and Scotland either represents two separate eruptions from the same volcanic system, or that the British age estimate is slightly too old (Davies et al., 2004). Lacustrine records from Andøya, north Norway (Fig. 1) extending back to ca 20 cal. ka BP are also under investigation as well as the classic Vallengaard mose site on Bornholm, Denmark (Fig. 1) that contains a visible occurrence of the Laacher See Tephra (ca 12.9 cal. ka BP).

Sediments from the Lateglacial seem to be missing on the Faroe Islands in the North Atlantic, probably due to an extensive ice cover during the Younger Dryas which may have removed older deposits. The Saksunarvatn Tephra is visible in several sections and in lake sediments and is an important marker horizon for the Early Holocene. Silicic tephra horizons below the Saksunarvatn Tephra have been found at two sites, the L3574 Tephra (Dugmore and
Newton, 1998) from Lake Saksunarvatn (the type site for the Saksunarvatn Tephra) and the Hovsdalur Tephra dated to ca 10.5 cal. ka BP (Wastegård, 2002). The highly silicic Hovsdalur Tephra has an identical geochemistry to the Hässeldalen Tephra (Fig. 2), but is ca 1000 years younger. A rhyolitic tephra called the Suduroy Tephra, dated to 8 cal. ka BP was also found in the Hovsdalur site on the southern island of Suduroy. This tephra has a geochemistry similar to the rhyolitic component of the Vedde Ash and the IA2 tephra from the Rockall Trough, west of Ireland (ca 13.5-13.0 cal. ka BP; Bond et al., 2001). This indicates that “Vedde-like” rhyolitic eruptions of the Katla volcano may have persisted during the Lateglacial into the Early Holocene. After the Holmsá event (ca 7.6 cal. ka BP; Larsen, 2000) the composition of the silicic magma below the Katla volcano seems to have changed to a more dacitic composition. This is indicated by the fairly homogeneous composition of the so called SILK tephras erupted between the Holmsá and Eldgjá (AD 930s) events (Larsen et al., 2001).


Fig 1. Map showing investigated sites in Sweden, Denmark (black diamonds) and the Faroe Islands. The type sites for the Vedde Ash, the Borrobol Tephra and the Saksunarvatn Tephras are also marked as well as volcanic centres on Iceland.

Fig 2. Biplot of SiO2 and K2O concentrations in tephras from the LGIT in Scandinavia and the Faroe Islands. The envelopes show the composition in tephra from some of the main European volcanic provinces (modified after Mangerud et al., 1984 and Davies et al., 2002).
<table>
<thead>
<tr>
<th>Name</th>
<th>Age BP (ca)</th>
<th>Source volcano</th>
<th>Composition</th>
<th>Reference</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suðuroy</td>
<td>8000</td>
<td>Katla</td>
<td>Rhyolitic</td>
<td>Wastegård (2002)</td>
<td>Faroe Islands</td>
</tr>
<tr>
<td>Saksunarvatn</td>
<td>10,240</td>
<td>Grimsvötn</td>
<td>Basaltic</td>
<td>Mangerud et al. (1986)</td>
<td>Faroes, W Nor way</td>
</tr>
<tr>
<td>Askja 10-ka</td>
<td>11,200</td>
<td>Askja</td>
<td>Rhyolitic</td>
<td>Davies et al. (2003)</td>
<td>SE Sweden</td>
</tr>
<tr>
<td>Hässeldalen</td>
<td>11,500</td>
<td>Snaefellsjökull?</td>
<td>Rhyolitic</td>
<td>Davies et al. (2003)</td>
<td>SE Sweden</td>
</tr>
<tr>
<td>Vedde</td>
<td>12,000</td>
<td>Katla</td>
<td>Rhyol./Bas.</td>
<td>Mangerud et al. (1984)</td>
<td>Norway, Sweden</td>
</tr>
<tr>
<td>Laacher See</td>
<td>12,900</td>
<td>Laacher See</td>
<td>Phonolitic</td>
<td>Usinger (1977)</td>
<td>Bornholm, Denmark</td>
</tr>
<tr>
<td>Borrobol</td>
<td>13,900</td>
<td>?</td>
<td>Rhyolitic</td>
<td>Davies et al. (2003)</td>
<td>SE Sweden</td>
</tr>
</tbody>
</table>

Fig 3. Table 1. Tephra horizons from the LGIT (ca 15-8 cal. ka BP) found in terrestrial deposits in Scandinavia and the Faroe Islands. Ages are given as cal yr. BP
CALIBRATING THE SEDIMENT RECORD OF LINNÉVATNET, SVALBARD, NORWAY: PRELIMINARY RESULTS OF A MODERN PROCESS STUDY

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The Svalbard archipelago (between 74° and 81° N latitude) in the North Atlantic lies at the northern end of the warm Gulf Stream current and therefore is sensitive to subtle climate and oceanographic changes. On Svalbard, the 20th century has been associated with profound reductions in sea ice and the retreat of glaciers in association with measured warming. Proxy records of Holocene climate indicate that Svalbard experienced even greater climatic fluctuations during the late Holocene culminating with the Little Ice Age at the end of the 19th century. The Linné Glacier and several small cirque glaciers exist in the headwaters of the Linné Valley and contribute meltwater to Lake Linné located 5 km down-valley. Prominent moraines fronting these glaciers testify to late Holocene glacier advances and well-laminated sediment cores recovered from Lake Linné have been used to date the onset of Neoglaciation and to infer subsequent glacier fluctuations.

As part of a three year Research Experiences for Undergraduates (REU) project, we have initiated a monitoring and modern process study of the glacier-fed lake system located in Linné Valley on the west coast of Spitsbergen. We are studying the modern climatological, glaciological, hydrological, and sedimentological processes operating in the Linné Valley, in order to better interpret sediment cores recovered from Lake Linné. An automated weather station and three temperature stations are being used to document local weather conditions, glacier mass balance (and ablation rate) is being studied using ablation stakes, and the meltwater stream is monitored for river stage and routinely sampled to determine sediment load. Five moorings (sediment traps and data logging thermisters) have been deployed at varying depths and distances from the inflow stream to document the amount (and nature) of sediment deposition in the basin and to monitor the seasonal changes in the lake’s water mass. Our ultimate objective is to provide a more accurate means for calibrating the paleoclimatic signal in the lake sediments. Future plans will expand the REU to glaciology and late Holocene marine sediments.
ALASKAN TEMPERATURE CHANGE OVER THE PAST MILLENNIUM: SOLAR FORCING MODULATED BY THE ARCTIC AND PACIFIC DECADAL OSCILLATIONS

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Well-dated histories from 130 land-terminating glaciers spanning the Little Ice Age (AD 1200-1900) are compiled from three climatically distinct regions: 1. The Arctic Brooks Range (94 glaciers), 2. The southern transitional interior to near-coastal region straddled by the Wrangell and St. Elias mountain ranges (9 glaciers), and 3. An 800-km transect along the coastal ranges of the Kenai, Chugach and St. Elias mountains (27 glaciers) bordering the Gulf of Alaska. The primary data are dendrochronologically-derived calendar dates from forests overrun by advancing ice and age estimates of moraines based on botanical methods using tree-rings and lichens.

For each of the three regions, we have generated a Glacier Expansion Index (GEI) in order to distill the glacial geologic record into time series that reflects as accurately as possible the actual intervals of glacier advance. This index is compiled from the glacial chronology and corrected for maximum (tree-ring) and minimum (moraine) age estimates of ice expansions. We have also created a composite GEI that is an average of each of the normalized GEI series from the three regions.

Correlation of GEIs with a record of solar irradiance (14C record preserved in tree rings) suggests that multi-decadal to century-scale temperature variations in the North Pacific and Arctic sectors have been influenced by solar forcing. A Blackman-Tukey (BT) spectral analysis of the normalized composite series shows peaks at 65, 104, and 170 - 210 years. The peaks in the composite GEI occur shortly after AD 1050, and are centered on ~1250, 1450, 1650 and 1850. The 210-year peak is coherent with the deVries mode of solar variability recognized in the solar irradiance series and suggests that solar forcing was instrumental in cooling inferred from the GEI.

However, solar irradiance changes alone are not likely to be sufficient to force significant temperature change for glacier advance. We suggest that one means of enhancing the solar-induced cooling and, in part, may explain regional differences in the glacial record, is to take into account the effects of two key modes of atmosphere-ocean circulation known to impact the three regions. These are the Pacific Decadal Oscillation (PDO), in southern Alaska, and the influence of the Arctic Oscillation (AO) in the Brooks Range.

The normalized composite glacier record is compared with the solar record and a tree-ring-based reconstruction of the Pacific Decadal Oscillation (PDO) for the spring and summer months. The PDO reconstruction spans AD 1479-1977 and is based on tree-ring data from Mexico to Alaska (Cook 2003). The comparison shows that sustained intervals of low PDO indices and cold temperatures during the AD1600s and 1800s are coupled with the Maunder and Dalton solar minima and perhaps the earlier Spörer minimum as well. We postulate that a sustained negative phase of the PDO, when combined with decreased solar output, can result in the large-scale glacial advances and inferred cooling we observe in Alaska.

The decadal modes of the AO may also impact temperature, particularly at high latitudes in Alaska. In a sustained negative phase of the AO, the frigid air at high latitudes, spills southward across Alaska favoring glaciation there. Based on these relationships we suggest that during the
Spörer minimum (~AD 1450) a negative phase of the AO may have had a role in the cooling to favor more intense glaciation in the Brooks Range than in the southern regions. Work underway to extend dendroclimatic reconstructions of the AO and PDO (i.e. Cook, 2002, D’Arrigo et al., 2003) will allow us to more fully compare the interaction of decadal and century-scale climate variability in the Arctic and North Pacific Sectors.

ARE CURRENT RATES OF ATMOSPHERIC NITROGEN DEPOSITION INDUCING BIOGEOCHEMICAL SHIFTS IN LAKES OF THE EASTERN CANADIAN ARCTIC?

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Although arctic lakes rank among the most pristine ecosystems remaining on Earth, widespread paleoecological analyses have revealed rapid recent changes in lake ecology that largely surpass Holocene natural variability, and are generally attributed to climate warming since the end of the Little Ice Age. However, the possibility that climate is only one dimension of these ecological shifts has not yet been explored, even though current warming is unlikely to exceed maximum naturally-mediated postglacial warmth. Here, we explore whether the increased availability of fixed nitrogen (N) from distant anthropogenic sources has contributed to directional changes in the biogeochemistry and ecology of two remote lakes on Baffin Island in the eastern Canadian Arctic. Paleoecological analyses, including diatom assemblages and a suite of biogeochemical proxies (organic matter, biogenic silica, organic nitrogen content and stable isotopic ratios) reveal a complex suite of progressive shifts in both lakes. Diatom assemblages began to shift as early as the mid-19th century, but major inflections in the biogeochemical proxies occurred significantly later, after 1950 A.D. Climate warming, subsequently coupled to a release from N limitation, may be acting synergistically in driving these ecosystems towards states for which no prior natural analogues exist.
Climate change during the 20th and 21st centuries has resulted in extensive modification of polar regions; this trend is expected to continue as predicted temperature increases in these regions exceed those elsewhere on the globe (IPCC, 2001). Consequently, the Arctic is a key region to investigate and monitor in order to assess both past and present climatic variability. However, because the instrumental record in the Canadian High Arctic extends back only ~50 years, it is essential to investigate other proxy records to determine variability over longer time scales, in order to provide a more meaningful measure of natural variability, and to function as reference against which modern and future conditions may be compared.

The Queen Elizabeth Islands (QEI), Arctic Canada, represents an area of ~410,000 km2 and contains ~5% of the terrestrial ice found in the Northern Hemisphere (Koerner, 1989). Evidence for a substantial reduction in terrestrial ice cover in the QEI following the Little Ice Age (LIA) (~1600 – 1900 AD), is in many cases indicated by lighter-toned zones that display an abrupt ice-distal margin, extending back to the modern ice mass. These trimlines or so-called “lichen-free zones” also record the former position and maximum extent of perennial snowfields, which mark the position of the former equilibrium-line altitude (ELA). Supervised classification methods were used with orthorectified multispectral imagery (ASTER, 2000-2002; Landsat 5 and 7, 1993-2002) to map trimlines throughout the QEI. Modern ice margins were derived through supervised and unsupervised classification processes of the same imagery, and 1959/60 ice outlines were acquired from the National Topographic Database (NTDB) (provided by Geomatics Canada). Differences revealed between modern and former ELAs, as well as the removal and rapid retreat of former ice masses, serves to substantiate the impact of 20th century warming in the QEI.

TREE-RINGS AS A HYDROMETEOROLOGICAL PROXY IN THE CARCROSS DESERT, YUKON TERRITORY, CANADA

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The sensitivity of tree growth to temperature conditions at high elevation environments from northern North America has been well documented. However, few tree-ring chronologies have been developed from this region with a response to moisture availability. In order to understand the potential consequences of environmental changes to particularly sensitive high latitude locations, it is vital to have an understanding of the variability in both temperature and precipitation patterns in these regions in the past.

The Coastal-St.Elias Mountains act as a barrier to moist maritime air creating a rainshadow effect over portions of southwestern Yukon. Annual precipitation in the Carcross area is <250mm, suggesting tree growth in this region might be limited by moisture availability. The Carcross Desert is actually a series of remnant sand dunes from when the area was covered by a large glacial lake, with the desert-like appearance maintained by strong winds blowing in from Lake Bennett and low annual precipitation levels. Reconnaissance sampling of lodgepole pine (Pinus contorta Dougl.) at this site found trees older than 350 years. The sandy and dry conditions at the site were ideal for the preservation of dead wood, with this material used to develop an annual ring-width chronology back to 1546 AD (Figure 1). Patterns of ring-width variability in the chronology differ from regional ring-width records that display cohesive patterns of variability in response to temperature conditions during the growing season.

Preliminary assessment of the climate-tree growth relationship in this chronology suggests high frequency variability in the chronology is driven by a response to moisture availability during the growing season. The strongest relationships (p<0.05) are found between annual tree growth and proximal hydrometeorological records (streamflow from Wheaton River and lake level from Bennet Lake, Figure 2). Significant, albeit weaker relationships are also found with local and gridded precipitation records using an annualisation period of July-June. Cumulatively, these relationships indicate the importance of moisture availability to tree growth as water moves through the hydrological cycle (i.e., from precipitation to streamflow to lake level) during the growing season.

The ability to use paleoclimatic data can be limited by the availability and quality of the instrumental climate record. The paucity of high quality and lengthy instrumental data in the Carcross region necessitated a flexible approach in this study. When possible, the missing or low quality portions of instrumental records were estimated or verified using other records in the region. The results presented here have used the best available instrumental data and highlight the limitations of data availability for paleoclimatic research in remote areas.

Cursory analysis also indicates the presence of a ring-width signal unique to lodgepole pine in the region. These results suggest some dendroclimatic utility in exploring the response of lodgepole pine to moisture availability in this arid region of Yukon. Further sampling will target the retrieval of well-preserved snag material from this unique site.
Fig 1. Carcross standardised ring-width chronology. Vertical line denotes portion of chronology maintaining high signal strength (1683 A.D.). Chronology has been rescaled to have a mean of zero.
Fig 2. Scatterplots between ring-width and Bennett Lake level (n=50) and Wheaton River streamflow (n=35). Values shown are anomalies over the common period between each record, r values significant at p<0.05.
“PACKRATS” OF BERINGIA: PALEOECOLOGY OF SMALL MAMMAL MIDDENS IN CENTRAL YUKON.

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Perennially frozen loess exposures in the Klondike goldfields of west-central Yukon (Fig. 1) are important archives of Pleistocene terrestrial environments (Kotler and Burn, 2000; Zazula et al., 2003; Schweger, 2003). Ages from distal tephra beds (Westgate et al. 2001; Froese et al., 2002) mark accelerated loess deposition at multiple sites during Marine Isotope Stage (MIS) 2 (ca. 25,000 to 14,000 yr BP) and 6 (ca. 190,000 – 130,000 yr BP). Burrows and hibernacula containing nests and seed caches from Arctic ground squirrels (Spermophilus parryi) and microtine rodents are common within these frozen loess sequences (Fig. 2, 3). The middens provide a site-specific record of local full-glacial vegetation in valley-bottom and valley margin settings in eastern Beringia. Preliminary macrofossil analyses indicate a locally diverse, herb-dominated flora during MIS 2 including Poa sp., Elymus sp., Festuca sp., Deschampsia caespitosa, Hierochloë hirta ssp. arctica, Carex spp., Allium schoenoprasum, Astragalus sp., Ranunculus sp., Potentilla sp., Draba sp., Cardamine sp., Lepidium cf. densiflorum, Papaver cf. mcconnellii, Androsace septentrionalis, Cerastium sp., Minuartia sp., Silene cf. taimyrensis, Penstemon gormani, Erigeron sp., Artemisia frigida and Taraxacum ceratophorum (Fig. 4). This assemblage suggests open, pioneer-type vegetation that grew on well-drained, actively accreting loess and colluvial substrates subjected to continuous disturbance from cryo- and bioturbation. The presence of burrow systems and nesting sites indicates that active layers were thicker during Pleistocene glacials than at present, especially on north-facing slopes. Although these paleoecological records are biased by small mammal behavior (e.g., McLean, 1985), they represent important paleobotanical archives of vegetation which may have also been available to Beringian megaherbivores as forage.

Fig 1. Map of Eastern Beringia with Klondike goldfields inset.

Fig 2. Arctic ground squirrel nest in Dawson Tephra (24,000 14C yr BP) at Quartz Creek (after Froese et al., 2002 QSR).
Fig 3. Nest in MIS 6 loess at Dominion Creek.
Fig 4. Selected plant macrofossils from MIS 2 aged small mammal middens associated with Dawson Tephra: a) Elymus sp. floret; b) Hierochloë hirta ssp. arctica spikelet; c) Carex sp. achene; d) Deschampsia caespitosa floret; e) Cardamine sp. siliqua; f) Draba sp. siliqua; g) Lepidium densiflorum siliqua; h) Ranunculus sp. seed; i) Potentilla sp. achene; j) Cerastium sp. seed; k) Papaver cf. mcconnelli capsula; l) Silene cf. taimyrensis capsula; m) fossil Silene cf. taimyrensis seed (left) and modern Silene taimyrensis seed (right); n) Androsace septentrionalis seed; o) Artemisia frigida leaves.
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