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Letter of welcome from CANQUA 2015 committee

On behalf of the organizing committee of CANQUA2015, we’re delighted to welcome you to St. John’s for what we hope will be a rewarding and successful meeting. The committee has been working tirelessly over the past year to ensure that your experience is a positive one. We are proud to offer an interesting and varied technical program that highlights recent research in glacial lakes, climate change and extreme events, dating the Quaternary, fast-flowing ice and implications for dispersal and mineral exploration, environmental archaeology, applied Quaternary geology and evolution of the coastal zone. In addition, we are pleased to offer two special sessions in honour of two recently deceased eminent Canadian Quaternary scientists, Dr. Ian Brookes and Dr. Robert Gilbert. As a slight departure from recent CANQUA meetings, we have opted to have a combined session each morning, highlighted by a plenary talk. These presentations (by Roger Hooke, Michael Lewis, and Nicole Couture) will cover a range of topics that we hope will appeal to all, and we certainly encourage you to join us each morning for a continental breakfast prior to the talk.

On Tuesday afternoon we will be offering a choice of two field trips, one heading west to Conception Bay (led by Norm Catto) and the other heading east to Cape Spear (led by Carissa Brown). Both promise to be extremely interesting trips – fingers crossed for good weather, something which has been less than assured this summer!

Of course, almost as important as our technical program are the social events! We have planned a series of activities that will highlight the culture and rich heritage of the province, as well as providing you the opportunity to get to know each other better. Each event is hosted in a different venue (The Rooms for the Icebreaker; Quidi Vidi Brewing Company for the Kitchen Party; and the Geo Centre for the banquet). Each is a fascinating location and we’re confident that you’ll enjoy yourselves, although how much is up to you!

Of course, conferences do not organize themselves and numerous people have been involved in the organization of CANQUA2015. A big thank you to all those who helped make this event a success, but especially to Melanie Irvine, Jennifer Organ, Samantha Primmer and Denise Brushett who took on the lion’s share of the work.

We would also like to take the opportunity to thank the sponsors of the conference, Memorial University of Newfoundland, Geological Survey of Newfoundland and Labrador, and the City of St. John’s without whose assistance CANQUA2015 would not have been possible.

Have a great conference!

Trevor Bell (co-chair)  
Martin Batterson (co-chair)
## General Conference Program

<table>
<thead>
<tr>
<th>Day</th>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>Sunday</td>
<td>7:30-8:30</td>
<td>Ice Streams session</td>
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<tr>
<td></td>
<td>8:30-9:30</td>
<td>General Session in honour of Professor Robert Gilbert</td>
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<td></td>
<td>9:30-10:30</td>
<td>Lunch (on your own)</td>
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<tr>
<td></td>
<td>10:30-11:15</td>
<td>Refreshment break and posters</td>
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<tr>
<td></td>
<td>11:15-12:00</td>
<td>General Session in honour of Professor Ian Brookes</td>
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<td>12:00-12:30</td>
<td>Lunch (on your own)</td>
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<tr>
<td></td>
<td>12:30</td>
<td>Ice Streams session</td>
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<tr>
<td>Monday</td>
<td>1:20-2:00</td>
<td>Glacial Lakes session I</td>
</tr>
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<td></td>
<td>2:00-2:40</td>
<td>Climate Change session</td>
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<td></td>
<td>2:40</td>
<td>Refreshment break and posters</td>
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<tr>
<td></td>
<td>3:00-4:00</td>
<td>Glacial Lakes session II</td>
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<td></td>
<td>4:00-4:40</td>
<td>Dating session</td>
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<td></td>
<td>4:40</td>
<td>Refreshment break and posters</td>
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<td></td>
<td>5:00-6:00</td>
<td>Dinner on your own</td>
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<tr>
<td>Tuesday</td>
<td>5:00-6:00</td>
<td>Banquet (6:30 onwards)</td>
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<tr>
<td></td>
<td>6:00</td>
<td>Dinner on your own</td>
</tr>
<tr>
<td>Wednesday</td>
<td>7:30-8:30</td>
<td>Ice Streams session</td>
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<td></td>
<td>8:30-9:30</td>
<td>General Session in honour of Professor Ian Brookes</td>
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<td>9:30-10:30</td>
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<td>Quaternary Geology session</td>
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<td>12:00-12:30</td>
<td>Lunch (on your own)</td>
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<td></td>
<td>12:30-1:20</td>
<td>Quaternary Geology session</td>
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<tr>
<td></td>
<td>1:20-2:00</td>
<td>General Quaternary session</td>
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<td></td>
<td>2:00-2:40</td>
<td>Coastal session</td>
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<td>2:40</td>
<td>Refreshment break and posters</td>
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<td>3:00</td>
<td>General Quaternary session</td>
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<td>3:30-4:15</td>
<td>Beer and posters</td>
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<td>4:15</td>
<td>Banquet (6:30 onwards)</td>
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<td>6:30</td>
<td>Dinner on your own</td>
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</tbody>
</table>

**Note:** Times are approximate and subject to change.
Conference Schedule

Sunday, 16 August

9:00  Graduate Student Day (SN-2000)

19:00  Icebreaker and Registration (The Rooms, 9 Bonaventure Avenue)

Monday, 17 August

7:15  Registration, Coffee and Breakfast (Bruneau Centre Atrium)

8:30  Plenary Talk: Roger Hooke (IIC-2001)

WILL WE COLLAPSE?
THE CLASH BETWEEN GEOLOGY AND POPULATION

9:30  Refreshment Break and Posters (Bruneau Centre Atrium)

Quaternary Science Session in Honour of Professor Robert Gilbert
Chair: Alec Aitken (IIC-2001)

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker/Title</th>
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</thead>
<tbody>
<tr>
<td>10:00</td>
<td>Invited: Alec Aiken</td>
</tr>
<tr>
<td>10:20</td>
<td>Donald Forbes, B. Cowan, S. Hatcher, T. Bell and J.H. Clarke</td>
</tr>
<tr>
<td>10:40</td>
<td>Joseph Desloges</td>
</tr>
<tr>
<td>11:00</td>
<td>Tracy Brennand, A.J. Perkins, M.J. Burke and D.B. Sjogren</td>
</tr>
<tr>
<td>11:20</td>
<td>Vic Levson, A. Hickin, M. Best, C. Geloven and B. Ward</td>
</tr>
<tr>
<td>11:40</td>
<td>Duane Froese, B. Jensen, A. Reyes, B. Shapiro, H. Poinar and G. Zazula</td>
</tr>
</tbody>
</table>

12:00  Lunch (on your own)
## Concurrent Sessions

### Glacial Lakes: Environments, Dynamics and Drainage

*Co-chairs: Tracy Brennand and Jonathan Cripps (A-1045)*

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:00</td>
<td><strong>Invited:</strong> Stephen Livingstone, D. Utting, C.D. Clark, A. Ruffell, S. Pawley, N. Atkinson and G. Mallon</td>
<td>Reconstruction of a Paleo-Subglacial Lake Network in Alberta, Canada</td>
</tr>
<tr>
<td>13:40</td>
<td>Daniel Utting, N. Atkinson and S. Pawley</td>
<td>Reconstruction of Proglacial Lakes in Alberta</td>
</tr>
<tr>
<td>14:00</td>
<td>Jonathan Cripps and T. Brennand</td>
<td>Re-interpreting the Glacial Lake History of a Key Site for the Model of Cordilleran Ice Sheet Decay, Nicola Valley, Southern Interior, British Columbia</td>
</tr>
<tr>
<td>14:20</td>
<td>Tracy Brennand, A.J. Perkins and J. Cripps</td>
<td>Deglacial Style and Pattern of the Last Cordilleran Ice Sheet Near Its Geographic Centre: The Utility of Paleolake Reconstructions</td>
</tr>
</tbody>
</table>

### Climate Change and Extreme Events in the Quaternary

*Co-chairs: Jesse Vermaire and Joshua Thienpont (A-1043)*

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>13:00</td>
<td><strong>Invited:</strong> Johannes Koch</td>
<td>4300-Year Old ‘Glacier Forests’, Southern Coast Mountains, British Columbia and Their Global Context</td>
</tr>
<tr>
<td>13:40</td>
<td>Jessie Vincent and L.C. Cwynar</td>
<td>Recent Slow-Down in Global Warming Has Parallel in the Rapid Warming into the Present Interglacial</td>
</tr>
<tr>
<td>14:00</td>
<td>Elena Ponomarenko, D. Crossland and B. Gusott</td>
<td>Mapping the Wind: Citizen Science Project Aiming to Reconstruct Past Extreme Windstorms</td>
</tr>
</tbody>
</table>

**14:40 Refreshment Break and Posters** (Bruneau Centre Atrium)
## Concurrent Sessions

### Glacial Lakes: Environments, Dynamics and Drainage
*Co-chairs: Tracy Brennand and Jonathan Cripps (A-1045)*

<table>
<thead>
<tr>
<th>Time</th>
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<th>Title</th>
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<tbody>
<tr>
<td>15:00</td>
<td>Kenneth Lepper, T.G. Fisher and T.V. Lowell</td>
<td>WATER STORAGE CHANGES IN GLACIAL LAKE AGASSIZ: WHEN, WHERE, HOW; BUT MOSTLY WHEN</td>
</tr>
<tr>
<td>15:20</td>
<td>Rachel Patterson, H.M. Roe, S.A. Wolfe, R.T. Patterson and J.C. Vermaire</td>
<td>RECONSTRUCTING POSTGLACIAL LANDSCAPE EVOLUTION FOLLOWING THE DRAINAGE OF GLACIAL LAKE MCCONNELL, NORTHWEST TERRITORIES, CANADA: INSIGHTS FROM BIOLOGICAL PROXY DATA</td>
</tr>
<tr>
<td>16:00</td>
<td>Martin Roy, H. Dubé-Loubert and J.M. Schaefer</td>
<td>CONFIGURATION AND TIMING OF GLACIAL LAKE NASKAUPI IN THE SOUTH EASTERN UNGAVA BAY REGION</td>
</tr>
<tr>
<td>16:20</td>
<td>Brandon Curry, J. Thomason and A. Bruegger</td>
<td>LARGE DEGLACIAL FLOODS ASSOCIATED WITH RETREAT OF THE LAKE MICHIGAN LOBE, SOUTH-CENTRAL LAURENTIDE ICE SHEET</td>
</tr>
<tr>
<td>16:40</td>
<td>Jianguang Chen, A. Leitch and H. Rashid</td>
<td>USING GROUND PENETRATING RADAR TO INVESTIGATE LACUSTRINE SEDIMENTS FOR PALEOClimATIC RECONSTRUCTION</td>
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</table>

### Dating the Quaternary: Technological Advances and Applications
*Co-chairs: Olav Lian and Christina Neudorf (A-1043)*

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
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<tbody>
<tr>
<td>15:40</td>
<td>Martin Margold, J. Seguinot, J. Heyman and A.P. Stroeven</td>
<td>YOUNGER DRYAS GLACIER READVANCE IN THE CASSIAR MOUNTAINS, NORTHERN BRITISH COLUMBIA, CONSTRAINED BY Be-10 EXPOSURE DATING</td>
</tr>
<tr>
<td>16:00</td>
<td>Christina Neudorf, N. Smith, D. Lepofsky, G. Toniello and O.B. Lian</td>
<td>TOWARD A CHRONOLOGY FOR CLAM GARDEN CONSTRUCTION ON QUADRA ISLAND, BRITISH COLUMBIA, CANADA</td>
</tr>
<tr>
<td>16:20</td>
<td>Alice Telka</td>
<td>ACCELERATOR MASS SPECTROMETRY RADIOCARBON DATING: PROTOCOLS IN THE SELECTION OF CARBONACEOUS MATERIAL FOR DATING</td>
</tr>
<tr>
<td>16:40</td>
<td>Sarah Murseli, C.A. Crann, G. St. Jean and I.D. Clark</td>
<td>TECHNOLOGICAL ADVANCES AT THE LALONDE AMS RADIOCARBON SAMPLE PREPARATION LABORATORY, OTTAWA, ONTARIO</td>
</tr>
<tr>
<td>Time</td>
<td>Event</td>
<td>Authors</td>
</tr>
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</tr>
<tr>
<td>17:00</td>
<td>Drinks and Posters (Bruneau Centre Atrium)</td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td>Adrian Hickin, O.B. Lian, V.M. Levson and Y. Cui</td>
<td>Shorelines of Glacial Lake Peace: implications for isostasy and ice sheet configuration in northeastern British Columbia, Canada</td>
</tr>
<tr>
<td>#4</td>
<td>Jonathan Cripps and T. Brennand</td>
<td>The deglacial landforms of the Nicola Valley, Southern Interior, British Columbia</td>
</tr>
<tr>
<td>#5</td>
<td>Michael Lewis and B. Todd</td>
<td>Linking Hudson Bay subglacial meltwater at the time of the Atlantic Heinrich 1 event with a meltwater flood event in the Gulf of Mexico about 13.5 ka (16.2 cal ka)</td>
</tr>
<tr>
<td>#6</td>
<td>Larry Smith, O.B. Lian and M.R. Chambers</td>
<td>Cyclic lowering and filling of Glacial Lake Missoula, Montana, United States of America</td>
</tr>
</tbody>
</table>
Tuesday, 18 August

7:15  **Registration, Coffee and Breakfast** (Bruneau Centre Atrium)

8:30  **Plenary Talk: Michael Lewis** (IIC-2001)
UNDERSTANDING THE HOLOCENE CLOSED-BASIN PHASES (LOWSTANDS) OF THE LAURENTIAN GREAT LAKES AND THEIR SIGNIFICANCE

| Fast-Flowing Ice and Implications for Dispersal and Mineral Exploration  |
| Co-chairs: Denise Brushett and Roger Paulen (IIC-2001) |

| 9:30  | **Invited: David Evans**  |
SEDIMENT-LANDFORM ASSOCIATIONS OF TERRESTRIALLY-TERMINATING ICE STREAMS: CASE STUDIES FROM THE SOUTH-WEST LAURENTIDE AND BRITISH-IRISH ICE SHEETS

| 10:00  | **Samantha Primmer, T. Bell and M. Batterson**  |
THE ROLE OF ICE DYNAMICS ON DRIFT DISPERsal IN THE NEWFOUNDLAND ICE CAP

10:20  **Refreshment Break and Posters** (Bruneau Centre Atrium)

| Fast-Flowing Ice and Implications for Dispersal and Mineral Exploration  |
| Co-chairs: Denise Brushett and Roger Paulen (IIC-2001) |

| 10:40  | **Martin Margold** and C.R. Stokes  |
‘TRACTION RIBS’ ON THE PALEO-ICE STREAM TRACKS OF THE INTERIOR PLAINS

| 11:00  | **Jean Veillette, M. Ménard, G. St-Jacques, M. Roy, R.C. Paulen and S.J. Paradis**  |
THE BURIED COMPONENT OF THE JAMES BAY WINISK ICE STREAM

| 11:20  | **Chris Stokes, M. Margold, C.D. Clark and L. Tarasov**  |
ICE STREAM DYNAMICS DURING DEGLACIATION OF THE LAURENTIDE ICE SHEET

| 11:40  | Michelle Trommelen and **T. Hodder**  |
EXAMINING THE RELATIONSHIP BETWEEN DEGLACIAL STREAMLINED-LANDFORM FLOWSETS AND TILL COMPOSITION IN NORTHEASTERN MANITOBA: A TALE OF OVERPRINTING AND INHERITANCE

| 12:00  | **Roger Paulen, C.R. Stokes, J.M. Rice, H. Dubé-Loubert and M. McClenaghan**  |
DISPERsal TRAINS PRODUCED BY ICE STREAMS: AN EXAMPLE FROM STRANGE LAKE, QUÉBEC AND LABRADOR

12:45  **Field Trips** (buses depart from Macpherson College 1 pm sharp; lunch provided)
Wednesday, 19 August

7:15 Registration, Coffee and Breakfast (Bruneau Centre Atrium)

8:30 Plenary Talk: Nicole Couture (IIC-2001)
ARCTIC COASTAL ENVIRONMENTS AND PROCESSES

9:30 Refreshment Break and Posters (Bruneau Centre Atrium)

<table>
<thead>
<tr>
<th>Quaternary Studies in Newfoundland and Labrador in Honour of Professor Ian Brookes</th>
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<tbody>
<tr>
<td>Co-chairs: Ian Spooner and Norm Catto (IIC-2001)</td>
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<tr>
<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
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<tbody>
<tr>
<td>10:00</td>
<td>Invited: Ian Brookes, I. Spooner, M. Batterson, N. Catto, A.R. Berger, D. Liverman, G. Osborn and J. Gosse</td>
<td>ROCK-SLOPE FAILURES IN WESTERN NEWFOUNDLAND, CANADA</td>
</tr>
<tr>
<td>10:20</td>
<td>Norm Catto</td>
<td>1000 YEARS OF COASTAL QUATERNARY IN NEWFOUNDLAND: RAPID (BUT REVERSIBLE?) “LATE HOLOCENE-ANTROPOCENE” TRANSITIONS</td>
</tr>
<tr>
<td>10:40</td>
<td>Maureen McHenry, P. Dunlop, M. Batterson, T. Bell, N. Catto, D.M. Gheorghiu and P. Wilson</td>
<td>PALAEO-ICE SHEET RECONSTRUCTION OF THE FORMER NEWFOUNDLAND ICE SHEET, USING THE GLACIAL LANDFORM RECORD AND COSMOGENIC EXPOSURE DATING</td>
</tr>
<tr>
<td>11:00</td>
<td>Evan Edinger, C. Hillaire-Marcel, A. Blenet, S. Davin, B. de Moura Neves, G. Layne, J. Macali, L. Ménabréaz and O. Sherwood</td>
<td>NORTHWEST ATLANTIC QUATERNARY PALEOCEANOGRAPHY FROM DEEP-SEA CORALS: EXAMPLES, CHALLENGES, AND EMERGING QUESTIONS</td>
</tr>
<tr>
<td>11:20</td>
<td>Audrey M. Rémillard, G. St-Onge, P. Bernatchez, B. Hétu, J.P. Buylaert and A. Murray</td>
<td>GLACIAL HISTORY AND SEA LEVEL CHANGES ON THE MAGDALEN ISLANDS (QUÉBEC, CANADA) DURING THE LATE PLEISTOCENE</td>
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11:40 Lunch (bring your own) to the CANQUA AGM (SN-2018)
Concurrent Sessions

### Environmental Archaeology by the Sea
*Co-chairs: Frédéric Dussault and Trevor Bell (A-1045)*

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<th>Time</th>
<th>Speaker(s)</th>
<th>Title</th>
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<tbody>
<tr>
<td>13:00</td>
<td>Invited: Duane Froese, P.D. Heintzman, J. Ives, G. Zazula, R. Woywitka, M. Stiller, C. Jass and B. Shapiro</td>
<td>BISON DISPERSAL FROM BERINGIA INTO NORTH AMERICA VIA THE ICE-FREE CORRIDOR</td>
</tr>
<tr>
<td>13:20</td>
<td>Rolf Mathewes and E.F. Helmer</td>
<td>PALYNOLOGY AND PALEOECOLOGY AT KILGII GWAAY: AN EARLIEST HOLOCENE ARCHAEOLOGICAL SITE, SOUTHERN HAIDA GWAII</td>
</tr>
<tr>
<td>13:40</td>
<td>Elena Ponomarenko and D. Crossland</td>
<td>HUMAN VISIBILITY IN THE MARITIME LANDSCAPE: THE VIEW FROM THE SOIL</td>
</tr>
<tr>
<td>14:00</td>
<td>Kristen Coleman, N. Michelutti, T. Bell and J. Smol</td>
<td>ASSESSING THE IMPACTS OF DORSET PALEOESKIMO ON FRESHWATER ECOSYSTEMS FROM PHILLIPS GARDEN, NEWFOUNDLAND</td>
</tr>
<tr>
<td>14:20</td>
<td>Frédéric Dussault</td>
<td>AN ARCHAEOENTOMOLOGICAL PERSPECTIVE ON DORSET OCCUPATIONS IN NEWFOUNDLAND</td>
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### Quaternary Geology: 3D Technological Advances and Applied Engineering
*Co-chairs: Rodolphe Devillers, Michel Parent and Kevin Sheppard (A-1043)*

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<tbody>
<tr>
<td>13:00</td>
<td>Ben Bagnall, T. Bell and D. Forbes</td>
<td>CHARACTERIZING NEAR-SURFACE GROUND ICE AND PERMAFROST SALINITY; ARVIAT, NUNAVUT</td>
</tr>
<tr>
<td>13:20</td>
<td>Andrée Blais-Stevens and J.J. Clague</td>
<td>HOLOCENE EARTHQUAKES ON THE DENALI FAULT IN YUKON TERRITORY</td>
</tr>
<tr>
<td>14:00</td>
<td>Guillaume Légaré-Couture, M. Parent and R. Lefebvre</td>
<td>THE ST. LAWRENCE ICE STREAM – NEW EVIDENCE BASED ON LIDAR SURVEYS AND NEW FIELD WORK IN THE APPALACHIAN PIEDMONT AND UPLANDS</td>
</tr>
</tbody>
</table>

14:40 Refreshment Break and Posters (Bruneau Centre Atrium)
### Concurrent Sessions

**Evolution of the Coastal Zone: Recent Advances in Coastal Knowledge**  
*Co-chairs: Melanie Irvine, Chantel Nixon and Dominique St-Hilaire (A-1045)*

<table>
<thead>
<tr>
<th>Time</th>
<th>Session Title</th>
<th>Presenters</th>
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</thead>
<tbody>
<tr>
<td>15:00</td>
<td>Invited: Donald L. Forbes, M.R. Craymer and D.J.R. Whalen</td>
<td>SUBSIDENCE AND INUNDATION OF A LARGE ARCTIC PERMAFROST DELTA</td>
</tr>
<tr>
<td>15:20</td>
<td>Robert Deering, T. Bell, D. Forbes and C. Campbell</td>
<td>MORPHOLOGIES AND TRIGGERS OF SUBMARINE SLOPE FAILURES IN FROBISHER BAY,</td>
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<tr>
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<td></td>
<td>BAFFIN ISLAND, NUNAVUT</td>
</tr>
<tr>
<td>15:40</td>
<td>Kristie Duncan and N. Catto</td>
<td>GEOMORPHOLOGY, SEDIMENTOLOGY, AND SENSITIVITY TO PETROLEUM</td>
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<td></td>
<td>CONTAMINATION IN COASTAL SYSTEMS IN NEWFOUNDLAND</td>
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<tr>
<td>16:00</td>
<td>Adam Fenech</td>
<td>CLIVE: A TOOL FOR THE GEO-VISUALIZATION OF THE CHANGING COASTLINES OF</td>
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<td></td>
<td>PRINCE EDWARD ISLAND</td>
</tr>
<tr>
<td>16:20</td>
<td>Donald L. Forbes (Facilitator)</td>
<td>DISCUSSION ON THE STATE OF COASTAL RESEARCH IN CANADA</td>
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</table>

### General Session

*Chair: Evan Edinger (A-1043)*

<table>
<thead>
<tr>
<th>Time</th>
<th>Session Title</th>
<th>Presenters</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:00</td>
<td>Kathryn Hargan, K. Coleman, M. Mallory, J. Blais and J. Smol</td>
<td>UNTANGLING THE COMPOUNDING EFFECTS OF SEABIRD NUTRIENT SUBSIDIES AND</td>
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18:30 Banquet (Johnson Geo Centre, 175 Signal Hill Road)
Networking and Events

Icebreaker
Sunday, August 16th, 2015
19:00-23:00
The Rooms, 4th floor, 9 Bonaventure Avenue
Cost: Free (cash bar)
Come down to The Rooms where light snacks will be provided. Registration pick-up, and registration, will be available on site.

Kitchen Party
Monday, August 17th, 2015
19:30-24:00
Location: Quidi Vidi Brewery, 35 Barrows Road
Cost: Regular $35, Student $20 Tickets are required for entry, and can be bought before the event, or at the door.
Come join us for an evening of live traditional music featuring local musician Fergus Brown-O'Byrne. Snacks of local cuisine will be provided as well as a range of local Quidi Vidi beers. Music will start at 8:00. Quidi Vidi Brewery is located in Quidi Vidi, or “The Gut”, a historic fishing village, and is a short drive (5 minutes) from downtown St. John’s and about 4.5 km from Memorial University. Parking is limited, so please walk, carpool, cab, or bus.

Banquet
Wednesday, August 19th, 2015
18:30-23:00
Cost: One ticket is included with each full conference registration. Additional tickets must be purchased before the event for $60.
The banquet will take place at the Johnson Geo Centre located on Signal Hill. The Geo Centre, a geological interpretation centre, is built primarily underground in a natural rock basin. The banquet will start at 18:30, and a three course meal will be served at 19:00.
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Abstracts

CONTRIBUTIONS OF ROBERT E. GILBERT TO THE STUDY OF GLACIOMARINE SEDIMENTS AND MARINE BENTHOS IN CANADIAN ARCTIC FJORDS

Aitken, Alec

Department of Geography and Planning, University of Saskatchewan, Saskatoon, SK, alec.aitken@usask.ca

This presentation will examine the pioneering field research undertaken by Bob Gilbert to investigate the physical processes that influence the delivery to, transport through, and deposition of sediments in fjord environments of the eastern Canadian Arctic. Work on fjord sedimentation began on Cumberland Peninsula, Baffin Island, Nunavut in the late 1970’s and early 1980’s. Working from inflatable Zodiaks and a Newfoundland dory, operating simple acoustic devices to examine fjord bathymetry, and deploying hand-operated sampling devices (e.g., gravity cores, temperature-salinity probes, Niskin bottles), Bob initiated a reconnaissance of physical sedimentary processes and patterns of sedimentation in Pangnirtung, North Pangnirtung, Coronation and Maktak fjords. A synthesis of this early research effort was presented in a paper titled “Sedimentary Processes of Canadian Arctic Fiords” (Sedimentary Geology, 36: 147-154). Building from this experience, Bob was invited to participate in the Sedimentology of Arctic Fjords Experiment organized by James Syvitski (GSC/Atlantic). Working with the enhanced coring and acoustic sampling capabilities of CSS Hudson, he made important research contributions to the study of the development of Broughton Trough, a glacial trough on the Baffin Island continental shelf, the acoustic stratigraphy and architecture of Quaternary glacial and glaciomarine sediments in 10 Baffin Island fjords, and the process of sea ice-rafting of coarse sediments and its contribution to both shallow and deep water sedimentation. An important contribution derived from the SAFE project is a paper titled “Quaternary Glaciomarine Sedimentation Interpreted from Seismic Surveys of Fiords on Baffin Island” (Arctic, 38: 271-280).

In the early 1990’s an opportunity arose to contribute to the study of land-sea correlations of Pleistocene-Holocene deglaciation of western Axel Heiberg Island organized by Don Lemmen (GSC/Calgary). Returning to the use of Zodiaks as work platforms, but with vastly improved coring and acoustic sampling capabilities, Bob engaged in the investigation of physical sedimentary processes and the acoustic stratigraphy and sedimentology of glaciomarine sediments in Expedition Fjord. This work was extended to include Cañon Fjord, Ellesmere Island. Important contributions from these research projects include “The glaciomarine sedimentary environment of Expedition Fiord, Canadian High Arctic” (Marine Geology, 110: 257-273) and “Preliminary Results on the Quaternary Sedimentary Environment and Benthos of Part of Canon Fjord, Fosheim Peninsula, Ellesmere Island” (GSC Bulletin 529: 197-205).

What is less well known perhaps is Bob’s encouragement of graduate students and colleagues who shared his fascination with fjord environments but who were interested in pursuing biological research. Working alongside Bob in a variety of watercraft Alec Aitken and
Janis Dale engaged in research projects investigating the species composition and community structure of marine benthos inhabiting arctic fjords. An important contribution from the research in Baffin Island fjords is a paper titled “Macrofauna of Canadian Arctic Fjords” (Marine Geology, 81: 331-358). He was ever mindful of the capacity of marine organisms to disrupt sedimentary archives. This presentation will provide examples of Bob’s research discoveries in glaciomarine sedimentation.

THE RECORD OF HOLOCENE ENVIRONMENTAL CHANGE AND CULTURAL OCCUPATIONS PRESERVED IN ALLUVIAL AND COLLUVIAL SEDIMENTS, OPIMIHAW CREEK, SASKATOON, SASKATCHEWAN

Aitken, Alec$^1$ and E. Walker$^2$

(1) Department of Geography and Planning, University of Saskatchewan, Saskatoon, SK, alec.aitken@usask.ca
(2) Department of Archaeology and Anthropology, University of Saskatchewan, Saskatoon, SK

The record of Holocene river terrace construction and incision within the Opimihaw Creek valley in central Saskatchewan is reconstructed based on the lithostratigraphy of alluvial and colluvial sediments. A period of persistent floodplain overbank aggradation ca. 6000 a BP to about 200 a BP was followed by a period of channel incision over the last 200 years. Five sedimentary facies are represented in the alluvial terrace sediments. Massive, fine-grained alluvium (Facies 1 and 2) containing multiple thin paleosols and Paleo-Indian occupations is interpreted as floodplain deposits. Massive, coarse-grained alluvium (facies 4 and 5) is interpreted as stream channel deposits. Massive, matrix-supported gravel (facies 3) is interpreted as colluvium derived from mass wasting of glacial till and glaciofluvial gravels on valley slopes. Alternating coarsening-upwards and fining-upwards sequences observed in the alluvial sediments record the lateral migration of Opimihaw Creek within its valley throughout the Holocene. Cultural artifacts preserved in the alluvial sediments record seasonal occupations by a variety of Paleo-Indian populations (i.e., based on diagnostic lithic tool production) of the river terraces over the past 6000 years. Variations in Holocene climates are interpreted as the principal driving mechanism influencing river terrace development and seasonal Paleo-Indian occupations of the river valley.

MULTIVARIATE ANALYSIS OF THE COMPOSITION OF TILLS FROM THE BURIN PENINSULA

Amor, Stephen

Terrain Sciences Section, Geological Survey of Newfoundland and Labrador, Department of Natural Resources, Government of Newfoundland and Labrador, St. John’s, NL, StevenAmor@gov.nl.ca
Analyses of 1245 till samples from the Burin Peninsula have been subjected to multivariate statistical techniques to investigate the relationship between till composition and various external factors, including local geology and type of surficial deposit. Prior to their application, the need for input variables to be normally distributed and equally scaled was addressed.

After experimentation using the “k-means” method of cluster analysis, a five-cluster model was adopted. Samples assigned to the clusters show good spatial correlation with each other, and in some cases with mapped geology. Two separate clusters seem to be represented by samples collected over granitic rocks; one more generally, and one more specifically over the St. Lawrence Granite; the element associations in the latter are more typically granitic than the former. Together, these clusters account for 35% of the samples.

Another cluster, characterized inter alia by enrichment in REE and siderophile elements and depletion in Br and LOI, is mainly made up of samples collected from coastal exposures, quarries and roadcuts. This may reflect the effects of weathering, which would be expected to be more intense than in samples collected from test pits and mudboils. This cluster accounts for 35% of the samples.

Discriminant analysis, using five major bedrock types to define training sets, resulted in only a 64% unbiased correct-classification rate. However, if the bedrock types are reduced to just two types – “plutonic felsic” and “other”, the rate increases to 81%. The most prominent concentrations of misclassified samples are of those whose composition suggests them to be derived from plutonic felsic rocks despite their sites being underlain by other rock types.

In the application of r-mode factor analysis, an 8-factor model, accounting for 80% of the total variance, appears most appropriate. A factor heavily loaded in siderophile elements accounts for 22% of the total variance. Samples over plutonic felsic rocks show factor scores significantly lower than the other principal rock types.

Two separate rare-earth element factors were extracted. One is heavily loaded in Ce, La, Sm, Dy, Y and Eu, as well as P, Mn and Zn, and the other in Lu, Yb, Zr, Y and Be; they account respectively for 15% and 10% of the variance. High scores of the first REE factor are concentrated over a variety of plutonic and supracrustal rock types. In general, felsic plutonic rocks show the highest overall values and mafic volcanics the lowest. The second REE factor displays a more focused response to the St. Lawrence Granite. Some other factors suggest association with content of carbonate, organics and sulphide.

While the usefulness of the till analyses in mineral exploration has been demonstrated previously, the results of this investigation suggest firstly that some subtle aspects of the till composition may provide indications of previously unmapped rock types, and secondly that composition may be subject to other controls, besides the composition of the source rocks.

CHARACTERIZING NEAR-SURFACE GROUND ICE AND PERMAFROST SALINITY; ARVIAT, NUNAVUT

Bagnall, Ben\textsuperscript{1}, T. Bell\textsuperscript{1} and D. Forbes\textsuperscript{1,2}

\textsuperscript{(1) Department of Geography, Memorial University of Newfoundland, St. John’s, NL, bab463@mun.ca}
Western Hudson Bay is currently experiencing a number of environmental changes, including warming ground temperatures and permafrost thaw. The isolated communities in this region are also expanding beyond their original footprints, to accommodate a young, rapidly growing population. The need for knowledge of suitable, stable building locations is acute, as available land is constrained by local landscape hazards. Permafrost, ground that remains at or below 0°C for at least two summers, is a defining feature of the northern building environment and presents unique challenges for northern community planners. This research project addresses a poorly understood yet integral component of northern landscape hazard mapping: the characterization and distribution of warm, saline, ice-rich permafrost at spatial scales suitable for community planning.

Permafrost, specifically permafrost rich in near-surface ground-ice, represents a hazard to community infrastructure. Near-surface ground ice development destabilizes infrastructure foundations through differential ground movement. This hazard is exacerbated in areas of glacial-isostatic uplift, which leaves a legacy of saline pore water in the permafrost. Saline pore-water within permafrost weakens inter-granular bonds, decreasing structural bearing capacity, and depressing ground thaw temperatures. Again, these two permafrost attributes are poorly understood at scales suitable for community planning. To respond to this knowledge gap, we present a model for characterizing near-surface ground-ice conditions and salinity in the underlying permafrost for the community of Arviat, Nunavut.

First, 1:10 000-scale aerial photographs and optical satellite imagery were used to map differences in ground morphology, tone and texture. These categorized surficial units were validated by active-layer soil samples, photographs, and sedimentological observations from 47 test sites (dug pits) with additional observations at seven sites. The product of these efforts is a community scale surficial geology map. Surficial units were classified based on the ratio of silt-clay content relative to sand-granule content. Silt content affects ground-ice accumulation and saline conditions, as unfrozen pore-water in the permafrost migrates upwards in silt-rich soils, concentrating ice in near-surface permafrost and saline conditions in the underlying permafrost. Second, a digital elevation model (2 m grid) was used to classify the local landscape according to ground wetness, using slope and surface drainage patterns. High moisture content in the seasonal active layer promotes near-surface ground-ice accumulation. Third, shallow permafrost cores from three drilling sites further constrains local ground-ice conditions and salinity changes with depth. Fourth, the risk of permafrost degradation in a warming climate is compounded for communities such as Arviat, underlain by warm permafrost already approaching 0°C. Degradation risk is defined by ground temperature measurements, collected by community members from a recently installed local permafrost monitoring station.

This is the first systematic attempt to model both near-surface ground-ice and salinity conditions in near-surface permafrost at the community scale. It is being conducted in partnership with the Government of Nunavut, Hamlet of Arviat, and 3VGeomatics and will inform ongoing community planning and adaptation efforts in the face of a changing environment.
HOLOCENE EARTHQUAKES ON THE DENALI FAULT IN YUKON TERRITORY

Blais-Stevens, Andrée¹ and J. J. Clague²

(1) Geological Survey of Canada, Ottawa, ON, ablais@nrcan.gc.ca
(2) Simon Fraser University, Burnaby, BC

Yukon Alaska Highway corridor (YAHC) in southern Yukon Territory is subject to several geohazards, including landslides and debris flows, floods, permafrost degradation, and earthquakes on faults in the St. Elias Mountains and Shakwak Valley. In Yukon Territory, the Denali Fault is located at the eastern front of the St. Elias Mountains and extends in a northwesterly direction parallel to the Alaska Highway for a distance of about 190 km. Holocene faulting is indicated by scarps and mounds on late Pleistocene drift, and by tectonically deformed Pleistocene and Holocene sediments exposed in a bluff on the north side of Duke River. We documented Holocene activity along the Denali Fault as part of Natural Resources Canada Program for Research and Development and its Environmental Geoscience Program. Trenches excavated across the Denali Fault scarp by the US Geological Survey and Yukon Geological Survey in 2008 and re-examined by SFU and GSC in 2013 reveal sediment disturbance related to several large earthquakes in the past 5000 years. A nearby pond (Crescent Lake) is ponded by the scarp; sediment cores recovered from the lake reveal water-level and sedimentation changes that are probably associated with these earthquakes. The fault also offsets sediments where it crosses Duke River, including the older White River tephras (ca. 1700 years old) and possibly the younger White River tephra (ca. 1200 old). Stratified Pleistocene outwash gravel beneath the tephras has been tilted to the east, and many stones within the outwash have been fractured and displaced by movement along the fault.

DECODING ICE SHEET HYDROLOGY FROM THE ESKER RECORD: THE UTILITY OF SHALLOW GEOPHYSICS

Brennand, Tracy¹, A.J. Perkins¹, M.J. Burke¹ and D.B. Sjogren²

(1) Department of Geography, Simon Fraser University, Burnaby, BC, tabrenna@sfu.ca
(2) Department of Geography, University of Calgary, Calgary, AB

Esker spacing has been used as a proxy for ice tunnel density in validations of paleo-ice sheet hydrological models. Changes in crest type (cross-sectional shape) along esker ridges have typically been attributed to the effect of changing subglacial topography on hydro- and ice-dynamics and hence subglacial ice-tunnel shape. These claims assume that all eskers formed in subglacial ice tunnels and that all major subglacial ice tunnels produced a remnant esker. Shallow geophysics, specifically electrical resistivity tomography combined with ground penetrating radar surveys, allow us to infer esker composition and sedimentary architecture
and show that esker sedimentation was dynamic, but that esker distribution and architecture were primarily governed by sediment supply. Where sediment supply is not limited, sedimentary architecture in combination with geomorphic context, sinuosity and cross-sectional shape suggest a morphogenetic classification of eskers which can encode differences in water source, flow magnitude and frequency, and conduit position. Reconstructions of ice sheet hydrology need to account for variation in esker morphogenesis because basing hydrodynamic inferences on the presence or absence of an esker alone ignores such differences.

DEGLACIAL STYLE AND PATTERN OF THE LAST CORDILLERAN ICE SHEET NEAR ITS GEOGRAPHIC CENTRE: THE UTILITY OF PALEOLAKE RECONSTRUCTIONS

Brennand, Tracy, A.J. Perkins and J. Cripps

Department of Geography, Simon Fraser University, Burnaby, BC, tabrenna@sfu.ca

Decay of the last Cordilleran Ice Sheet (CIS) near its geographic centre has been conceptualized as being dominated by stagnation (passive downwasting due to a rapid rise in equilibrium-line altitude), in part because of the lack of large recessional moraines. Yet multiple lines of evidence from interior British Columbia (BC), including trends in glacioisostatic adjustment, and recent inferences of the late glacial reconfiguration of the CIS based on the pattern of ice-marginal channels, suggest a more systematic pattern of ice margin retreat back toward the Coast Mountains. We integrate digital terrain and aerial photograph analysis, sediment logging and geophysical surveys to enhance late glacial reconstructions near the geographic centre of the last CIS: the southern Fraser and northern Thompson plateaus of BC. Here, we identify and map glaciotectonic and grounding-line moraines, glacial lake outburst flood (GLOF) eskers and ice-marginal channels, and reconstruct ice-marginal lake evolution. Together, these observations support contiguous, frequently lake-terminating, ice margin retreat northwestward, back toward the Coast Mountains, similar in style and pattern to that proposed for the late glacial Fennoscandian Ice Sheet. Ice-marginal lakes would have enhanced sliding and intensified thermo-mechanical melting of the ice front; they likely amplified melt rates beyond those expected based on climate warming alone. Glaciotectonic moraines suggest active retreat, and are consistent with enhanced sliding. Nested ice-marginal channels and flat-topped esker segments support downwasting (ice thinning), and GLOF eskers suggest the formation and drainage of supraglacial lakes, both consistent with rapid climate-induced melting. Patches of hummocky terrain record local stagnation. This deglacial style is analogous to parts of the Greenland Ice Sheet today.
ROCK-SLOPE FAILURES IN WESTERN NEWFOUNDLAND, CANADA

Brookes, Ian¹, ricel. Spooner², M. Batterson³, N. Catto⁴, A.R. Berger⁵, D. Liverman³, G. Osborn⁶ and J. Gosse⁷

(1) Deceased
(2) Department of Earth and Environmental Science, Acadia University, Wolfville, NS, ian.spooner@acadiau.ca
(3) Geological Survey of Newfoundland and Labrador, Department of Natural Resources, Government of Newfoundland and Labrador, St. John’s, NL
(4) Department of Geography, Memorial University of Newfoundland, St. John’s, NL
(5) 3 Prince Street, Wolfville, NS
(6) Department of Geology and Geophysics, University of Calgary, Calgary, AB
(7) Department of Earth Sciences, Dalhousie University, Halifax, NS

Rock-slope failure (RSF) is becoming recognized increasingly as an important contributor to landscape evolution in high-relief terrains. The term ‘sackung’ was coined for parts of slopes in the European Alps that had “sagged” at a high-angle, without breaking up leaving a diagnostic slope profile, featuring reverse scarps. More than 24 RSF examples have been identified in western Newfoundland, most examples occur in Lower Paleozoic mafic and ultramafic rocks (Cambrian oceanic crust and mantle) of the Humber Arm Allochthon. The largest example of a sackung in Newfoundland is at Norris Point in Bonne Bay where a rock mass estimated at 10 km³ has moved vertically by approximately 100 m. The head of the failure consists of a complex arrangement of scarps and fissures that align roughly parallel with regional jointing. Although the failure was initiated post-glacially, a more precise age of failure has not been determined. Visual examination from 1974 to 2003 suggested that no discernable movement was occurring during that time.

The causal mechanism for the Bonne Bay and other sackung throughout western Newfoundland remains uncertain. The locations of the sackungs do not coincide with fault escarpments, making tectonic disturbance unlikely. As the majority of sackungs are located adjacent to glacially over-steepened valleys, the failures appear to have developed in response to the removal of laterally supporting bedrock during glaciation, triggering lateral expansion when the ice ablated. Similar slope failures, albeit on smaller scales, are associated with valley down-cutting and “valley rebound” in other areas of the province.

RESOLVING THE FIRE REGIME OF LABRADOR: A COMPARISON OF HISTORIC AND RECENT FOREST FIRES

Brown, Carissa and J. Bowman

Department of Geography, Memorial University of Newfoundland, St. John’s, NL, carissa.brown@mun.ca
In the northern boreal forest ecosystems of Canada, climate change is resulting in higher temperatures leading to longer, warmer, and in some cases drier summers. These factors may lead to an increase in fire activity, with more frequent and larger fires. Changes from the historic fire regime could lead to decreased forest productivity or altered forest composition if the tree species present are not adapted to the new regime. Changing fire regimes have already been detected in the western boreal forest; however, scant research has been conducted on the effects of climate change on the fire regime of Labrador, and the subsequent effects on forest regeneration. Our research aims to i) characterize the historic fire regime of central to western Labrador; ii) assess changes in the fire return interval in the recent past; and iii) evaluate the impact of these changes on future forest composition. A combination of dendrochronological analysis and field surveys will be used in recently burned black spruce stands to determine the historic fire regime and pre-fire stand characteristics. We will compare pre-fire density and composition to recent post-fire regeneration to assess whether recent recruitment will match pre-fire stand characteristics. The results of this research will provide an extensive assessment of historic fire characteristics and an assessment of whether the fire regime of Labrador is changing with climate.

RADIOCARBON AND OPTICAL AGES OF ORGANIC DEPOSITS BURIED IN BEACHES ON CALVERT ISLAND, CENTRAL COAST, BRITISH COLUMBIA, AND THEIR IMPLICATION FOR THEIR GENESIS OF THE DEPOSITS

Bryce, Jordan1,4, L.C.M. Griffin1,2,4, C. Neudorf1,4, O.B. Lian1,4, I.J. Walker3,4, J.B.R. Eamer3,4 and D.H. Shugar3,4

(1) Department of Geography and the Environment, University of the Fraser Valley, Abbotsford, BC, jordan.bryce@student.ufv.ca
(2) Department of Earth Sciences, Simon Fraser University, Burnaby, BC
(3) Department of Geography, University of Victoria, Victoria, BC
(4) Hakai Institute, Calvert Island, BC

Organic-rich zones buried under modern beaches are sometimes used as indicators of past sea level position. Two such zones (organic mats), radiocarbon dated to ~6 and ~ 10 cal ka BP, respectively, have been exposed in the high intertidal zones of two beaches on Calvert Island, BC central coast. Multiple samples of wood and macrofossils from each mat yielded radiocarbon ages that suggest they may be composed of material reworked from sources of different age, opening the possibility that the organic mats did not form in situ when sea level was lower. These findings are consistent with a sea level curve recently constructed for Calvert Island (McLaren et al. 2014) which indicates that sea level in the region has remained stable for the last 15 ka. The organic mats may therefore have formed as a result of (i) erosion events at ~6 and ~10 cal ka BP that transported organic material to the beaches, or (ii) they may have resulted from more recent erosion of ancient organic deposits. Optical dating of beach sand directly below an organic mat closely approximates the time when the beach surface was last active, and provides a maximum age estimate for the time when the beach was stabilized by
organic material. Optical and radiocarbon ages from these sites converge and indicate stabilization times for these former beach surfaces at ~6 and ~10 cal ka BP, respectively.

1000 YEARS OF COASTAL QUATERNARY IN NEWFOUNDLAND: RAPID (BUT REVERSIBLE?) “LATE HOLOCENE-ANTROPOCENE” TRANSITIONS

Catto, Norm

Department of Geography, Memorial University of Newfoundland, St. John’s, NL, ncatto@mun.ca

Most coastlines in Newfoundland appear “untouched” in comparison to many around the world, suitable locations for the investigation of Quaternary phenomena, processes and change. However, combinations of rising sea level, changes in winter storm frequency and intensity, enhanced extratropical transition activity; reductions in offshore ice cover, ice foot formation, sediment flux, and both accentuated and reduced human activity have resulted in complex mosaics of geomorphic and biological processes and anthropogenic modifications.

Archaeological data and inundation of terrestrial peat deposits and trees indicate that sea level has risen throughout the past 1000 years. Enhanced erosion has accompanied recent rise of 1 mm/y to 3.3 mm/y over the past 50 years. Coastal dune development is related to destabilization of littoral areas initiated by marine transgression.

In many areas, anthropogenic pressure has diminished, with abandonment of many communities after 1955. Collapse of key marine stocks and socio-economic pressures led to partial “de-anthropoziation”. Modifications formerly undertaken by residents, including construction of wooden retaining walls and channels dredged by hand, continue to influence beach dynamics and storm surge modification. Interruptions in terrestrial sediment flux are evident in beaches which have undergone significant storm-induced activity. Many coasts have undergone successive anthropogenic modifications over time. Barrier beaches and tombolos were commonly fortified to provide protection and improve access to shorelines, resulting in simultaneous widening and lowering of these landforms despite rising sea level and increasing storm surge activity.

Vegetation assemblages and organic successions have also shown the combined impacts of changes in environment and human activity. Typical successions involve transitions from fibric peat accumulated in blanket bogs under krummholz (tuckamore) conifer assemblages, showing increased marine influences with rising sea level; to mixtures of windblown coastal loess, sand, and fine pebbles with disturbed fibric peat showing the impact of forest clearance and grazing; to recent aeolian deposits.

Gravitational-cryogenic features including gelification deposits, sorted and unsorted stone circles and stripes, and felsenmeer, accompanied by cryogenic sediment mounds and frost-wedged bedrock, have resulted from the removal of vegetation cover. Relict or active periglacial or frost-influenced features are not evident in areas where the vegetation is completely undisturbed or where introduced vegetation species are not present. In the vicinity of active or former human settlements, the distribution of these features largely reflects
anthropogenic activity.

Coastal landscapes, landforms, and Quaternary successions which at first glance may appear “untouched” have undergone fairly substantial modification by people, but not necessarily in a uniform, undeviating path. In the past 1000 years, the coasts have seen substantial changes in geomorphology, sedimentology, vegetation, and marine faunal assemblages. Our task as Quaternarists is to consider these parameters as proxies and analogues to study all manners of interlinked rapid Holocene change.

USING GROUND PENETRATING RADAR TO INVESTIGATE LACUSTRINE SEDIMENTS FOR PALEOCLIMATIC RECONSTRUCTION

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Lacustrine sediments can be good sources to investigate paleoclimatic studies since they may contain continuous and high-resolution records of environmental changes in the past, especially in the Quaternary period. Lacustrine sediments are generally easier to sample than other proxy sources such as ice cores and marine sediments. However, successful data collection of lacustrine sediments requires planning and preparation. Information about the distribution and thickness of sediments at the bottom of a lake is important for making decisions on the location and depth of coring. Ground Penetrating Radar (GPR) is an excellent tool in this application because it not only has the ability to profile the subsurface structures, but also determine some physical properties of the sediments. In our study, reflection GPR surveys were performed in a grid pattern over the ice on three small freshwater ponds locating about 18 km northwest of Clarenville, Eastern Newfoundland. The electrical conductivity of the water in these ponds was low enough to allow the radar to penetrate several metres downward to produce good subsurface images of the top and bottom interfaces of the sediment, and some interfaces within the sediment. A differential GPS attached to the GPR system provided accurate location information for the survey lines. When radar waves struck boulders at the bottom of the soft sediments hyperbolic reflection patterns were produced in the GPR profiles: the velocity of the EM waves in the sediments could be obtained by analyzing these hyperbolas and the depth of the sediments could then be calculated. Using geophysical software “Oasis Montaj”, 3-D lake sediments thickness and distribution maps were established to help make coring decisions.
ASSESSING THE IMPACTS OF DORSET PALEOEKSIMO ON FRESHWATER ECOSYSTEMS FROM PHILLIPS GARDEN, NEWFOUNDLAND

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The Northern Peninsula Archaeology and Landscape History Program is a unique collaboration between archaeologists and environmental scientists. A focus of this program is assessing the occupation and abandonment of the Dorset Palaeoeskimo at Phillip’s Garden (NL), one of the largest known Dorset settlements. Here we used a paleolimnological analysis of lakes in the Port au Choix area to reconstruct past environmental conditions, to determine possible environmental causes that might have led to site abandonment, and also to examine the ecological impacts of the Dorset people on nearby aquatic ecosystems. Increases in sedimentary stable isotope ratios of nitrogen ($\delta^{15}$N) were used here to detect human presence by tracking changes in marine-derived inputs related to Dorset activities. Increases in $\delta^{15}$N correspond to an increase in spectrally-inferred sedimentary chlorophyll-a (chl-a) concentrations indicating that human occupation is associated with increased primary production. These geochemical tracers are in agreement with archaeological analyses of Dorset Palaeoeskimo occupation. Corresponding shifts in subfossil diatom assemblages suggest that in addition to increases in primary production, aquatic ecology was also altered during this period. In contrast, these changes were not observed in a sediment core from a pond outside the influence of the Dorset settlement. It is hypothesized that the observed changes are a result of the processing of harp seals, the main basis for subsistence of this culture at Phillip’s Garden. This research suggests that ancient indigenous societies were capable of having measurable impacts on their surrounding landscape and that the sedimentary archives can be paired with archaeological investigations to determine the timing and extent of human impact on their environment.

ARCTIC COASTAL ENVIRONMENTS AND PROCESSES

Couture, Nicole

RE-INTERPRETING THE GLACIAL LAKE HISTORY OF A KEY SITE FOR THE MODEL OF CORDILLERAN ICE SHEET DECAY, NICOLA VALLEY, SOUTHERN INTERIOR, BC.

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Arctic coasts are dynamic regions at the interface of changing atmospheric, terrestrial, and marine systems. How do these coasts differ from their more temperate counterparts? What are the dominant processes occurring in northern environments and how are they changing?
This lecture will provide an overview of the physical characteristics of northern coasts, looking at how they vary at the circumpolar scale, as well as within Canada. The role of ice – both sea ice as well as ground ice in permafrost – will be explored in terms of how it shapes Arctic coasts above and below the waterline. A number of features and processes that are unique to these regions will be described, examining how they can be affected by past and projected changes in environmental forcings such as waves, storms, and temperatures of the air, ground and water. The implications of some of the changes in northern coastal environments at the local, regional, and global scale will also be discussed, from both a biophysical and a socio-economic perspective.

RE-INTERPRETING THE GLACIAL LAKE HISTORY OF A KEY SITE FOR THE MODEL OF CORDILLERAN ICE SHEET DECAY, NICOLA VALLEY, SOUTHERN INTERIOR, BC.

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The conceptual model applied to the retreat of the last Cordilleran Ice Sheet (CIS) of stagnation and vertical ablation is contrary to reconstructions of coeval ice sheets which generally show active, systematic retreat towards their centers. This stagnation hypothesis for the CIS therefore requires reappraisal to determine its applicability for anticipating future decay of modern ice masses. A reinvestigation of the glacial lakes and ice-marginal landforms in the Nicola Valley, south central BC, was undertaken to determine the ice retreat pattern and style. Current reconstructions of the area propose the ice margin disintegrated into dead ice lobes during deglaciation, a crucial observation within the stagnation hypothesis. A new reconstruction, presented here, identifies five ice-dammed lake levels; the damming ice margins reconstructed to account for these lakes, based on the extent of the landforms assigned to each distinct lake level and the order in which spillways would have opened, shows regional ice retreat to the northwest. Glacio-isostatic tilts reconstructed from each lake plane also show a strong gradient to the northwest of between 1.6 and 1.9 m/km, implying an ice surface slope in that direction during deglaciation. Several fields of ice-flow transverse ridges, with exposures revealing stacked, folded and sheared till, glacio-fluvial and glacio-lacustrine sediments, are interpreted as glacio-tectonic moraines, which imply active retreat. These lines of evidence support a reinterpretation of the south-central portion of the CIS as undergoing active retreat to the northwest, towards the Coast Mountains, along a contiguous ice margin. This suggests the vertical stagnation model of the CIS requires thorough reinvestigation across its extent.
THE DEGLACIAL LANDFORMS OF THE NICOLA VALLEY, SOUTHERN INTERIOR, BRITISH COLUMBIA

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Deglaciation of the Nicola Valley, south-central British Columbia (BC), has been proposed to have occurred through the disintegration of the ice margin into lobes of stagnant ice, damming a series of four lakes in the valley. This project has reinvestigated the ice-marginal and meltwater landforms in the Nicola Valley to test this local stagnation hypothesis. Presented here are the principle deglacial landforms mapped within the Nicola Valley. Several fields of ice flow-transverse ridges, trending approximately southwest to northeast are interpreted as glacio-tectonic moraines on the basis of folded and faulted glacio-lacustrine and glacio-fluvial sediment and till. An additional lake level has been identified within the basin, and new reconstructions of the ice-dammed lakes are proposed on the basis of the extent of glacio-lacustrine sediments and landforms. These reconstructed lakes expanded and lowered to the northwest as ice receded and opened progressively lower spillways. The glacio-isostatic tilts of these lake planes rise to the northwest at between 1.6 and 1.9 m/km. Within the spillways are potential outburst flood sediments and landforms including recessional cataracts, slack water sediments, chaotic gravels and coarse gravel bars. These lines of evidence imply active ice retreat in the Nicola Valley to the northwest along a contiguous ice margin, rather than stagnation and disintegration into dead ice lobes.

LARGE DEGLACIAL FLOODS ASSOCIATED WITH RETREAT OF THE LAKE MICHIGAN LOBE SOUTH-CENTRAL LAURENTIDE ICE SHEET

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Kankakee Torrent (KT), a large deglacial flood dating just prior to 18,930 ± 50 cal yr BP, has been associated temporally with the margin of the Lake Michigan lobe when it formed the Woodstock Moraine. Previous to this study, radiocarbon ages from landforms associated with, but not directly located on the Woodstock Moraine, suggested that the discharge predated or was intimately related to this ice advance at about 18,780 ± 50 cal yr BP. Recently obtained sediment cores from ice-walled lake plains located on the Woodstock Moraine (42.34533 N, -88.53690 W) have yielded well-preserved Dryas integrifolia leaves and stems in the rhythmically bedded silt and fine sand that form the lake plains. The minimum age of the Woodstock Moraine based on three AMS C-14 assays is 20,530 ± 80 cal yr BP (the calibrated pooled mean of 16,910 ± 70 C-14 yr BP (ISGS-A3497); 17,040 ± 80 C-14 yr BP (ISGS-A3498) and 17,130 ± 80 C-14 yr BP (ISGS-A3499)), about 1,500 years older than what the earlier work had indicated. These relationships indicate that sub-glacial water (slowly) built up prior to the KT
determining local rates of ice margin retreat is possible from fossils preserved in more than three bands of ice-walled lake plains revealed on shaded relief maps of LiDAR data. The new radiocarbon ages are statistically similar (σ1) to new Be-10 exposure ages of the southern Johnstown Moraine of the Green Bay lobe (Ullman et al., 2015), which forms an expansive interlobate area with the Lake Michigan lobe.

Other large floods occurred in the area at this time, but the existing dataset of landform ages precludes age estimates to the degree of accuracy of the KT. For example, the Fox River torrent, which formed high level depositional terraces along the “Algonquin reach” of the Fox River (e.g., 42.08417 N, -88.30209 W; Curry et al., 2014) is temporally bounded by the 20,530 cal yr BP Woodstock Moraine (which it cuts across) and older than 16,900 cal yr BP plant fossils found in slackwater lake deposits tucked behind the high-level terraces.

New radiocarbon ages from the middle Illinois River, and from deposits of the Glenwood Phase of Glacial Lake Chicago indicate catastrophic (?) discharge cut channels to bedrock just prior to 15,170 cal yr BP followed by slackwater conditions that persisted to about 13,000 cal yr BP. The depth of the channel indicates that initial discharge temporarily breached the Savanna Terrace sediment dam in the lower reaches of the Illinois River, but quickly healed to form a relatively long-lived lake. A possible trigger for the flood was added discharge from Glacial Lake Warren as it overflowed across the Grand River valley.

MORPHOLOGIES AND TRIGGERS OF SUBMARINE SLOPE FAILURES IN FROBISHER BAY, BAFFIN ISLAND, NUNAVUT

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With recent advances in seabed mapping technology and its application in the Canadian Arctic, a world of submarine features has been revealed. Notable among these are submarine slope failures (seabed slides, debris avalanches, debris flows, turbidity currents). These are common and widespread features of continental and island margins, ranging from small-scale features (<100 m³) to enormous failures, such as the 3000 km³ Storegga Slide on the Norwegian shelf, affecting a seabed area of 95 000 km², with a runout distance of 800 km. The largest submarine failures have received more attention, understandably, than smaller features in inshore environments. Nevertheless they present important hazards as sources of local tsunamis in fjords and as threats to seabed infrastructure such as communication cables. Similar features are found in abundance in the many fjords and bays along the east coast of Baffin Island. Of particular interest is Frobisher Bay, located on the southern end of Baffin Island, which is home
to Iqaluit, the capital of Nunavut. With the growth of this city, there is an increase in marine activity in the areas surrounding it. This includes proposals for a new deep-water port facility and a submarine fibre optic cable network to connect Iqaluit to southern Canada. However, in parts of Frobisher Bay submarine slope failures are ubiquitous, presenting a hazard to any coastal or seabed development. These submarine slope failures can be triggered in a number of ways, such as overloading by sediments (common on active delta fronts), seepage, excess pore pressure, undercutting of slopes, and seismic events. Of particular interest is the potential for triggering submarine slope failure by sea-level rise, both directly through increased overpressure and indirectly by induced seismicity. The easternmost coastal fringe of Baffin Island has experienced postglacial relative sea-level rise and is known to be a seismically active region. Through coring of sediments overlying submarine slope failure deposits, it may be possible to determine the ages of the failure events in relation to episodes of rapid relative sea-level rise. The collection of multibeam bathymetry and sediment cores throughout Frobisher Bay also allows for the study of glacial history in the area. The links between glacial history and submarine slope failures are unclear, with deglaciation being a potential triggering mechanism in this region. Methods include mapping and characterizing the morphology of mass movement landforms; investigating causes of failure through site characterization; establishing a chronology of failure events through coring.

CONTRIBUTIONS OF ROBERT E. GILBERT TO UNDERSTANDINGS OF GLACIAL PROCESSES VIA REMOTE SENSING AND SAMPLING OF LACUSTRINE AND MARINE ENVIRONMENTS

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Over a career of 45+ years Dr. Robert E. Gilbert made substantial and sustained contributions to the understanding of glaciolacustrine and glaciomarine processes via remote sensing and sampling of lacustrine and marine environments. This presentation highlights just two of these contributions. The first involves establishing the criteria for recognizing the rates and modes of transition from deglacial to interglacial environments including understanding the role of “extreme” events in the sedimentary record. Modern studies of outburst floods, the Mt. Polly mine tailings spill into Quesnel Lake, glacier surges in Greenland, and the collapse of the Larsen B ice-shelve have helped to establish analogues for interpreting the paleo-records from deep fiord, and fiord-like, settings using acoustic, multi-beam and lidar methodologies. The second involves work with John Shaw (University of Alberta) on the sculpted morphology of lake basins on the Frontenac Axis of the Canadian Shield. A recent, and not yet completed, paper examines ten lakes on or near the Frontenac Axis of the Canadian Shield for the morphology of large-scale s-forms in the bedrock beneath them. These landforms represent the upper range of
kilometres to tens of kilometres that form part of the seven orders of magnitude in the size of sculpted forms documented by Allen (1982). It is hypothesized that over this range, a single process, namely the action of sediment-laden, turbulent flow of water over a wide range of discharges, is sufficient to account for their formation. The nature of sedimentation on this landscape offers further support for this interpretation. Over much of the Kingston scablands glacial and glaciofluvial sediment is thin to absent, indicating that direct ice contact or the flow of water beneath the ice swept much of the sedimentary record from this region. The concentration of thick, mature fluvial sequences in several of the large reservoirs now occupied by lakes, and in a variety of smaller reservoirs on land including to the highest elevations of bedrock substrate, documents the waning stages of floods. As with deposition in eskers, flow patterns and the distribution of sediment was determined by the underlying morphology, and almost certainly more importantly, by the morphology of the glacial roof that confined and directed the flow. Competing hypotheses suggest landscape sculpting does not require the presence of large volumes of sub-glacial water. The key differences in these interpretations are presented.

GEOMORPHOLOGY, SEDIMENTOLOGY, AND SENSITIVITY TO PETROLEUM CONTAMINATION IN COASTAL SYSTEMS IN NEWFOUNDLAND

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With the projected increase in the expansion of offshore oil production in Newfoundland, the chance for accidental spills increases. Petroleum contamination can occur at various stages from extraction to storage, transportation and distribution leaving coastal areas vulnerable. Previous work assessed over 1400 beaches in Newfoundland and determined 27 locations as high-risk areas. The current project focuses on three sites: one coastal system on the east coast of Newfoundland (Witless Bay), and two sites on the west coast (Grand Bay West and Codroy). This study provides a critical look at how petroleum contamination relates to geomorphology and sedimentology, indicating how contamination could impact not only the sites but also the adjacent communities. Beach morphology and sedimentology, encompassing clast texture and characteristics, cusp shape, slope, vegetation, changing beach profile, and wave and current dynamics were some of the factors assessed. Coastal sedimentology processes, and dynamics largely influence sensitivity to petroleum contamination. Weather was a major factor in shaping the beaches’ morphology, and each site reacted differently under various weather conditions. Storm surge is a significant factor in beach geomorphology, coastal erosion, and dynamics. The coastal system at Witless Bay is dominated by high-energy and reflective conditions. Petroleum could seep through the gravel to bond geochemically with buried marine organic detritus. On the West coast, Grand Bay West is located near the town of Port-Aux-Basque. It consists of a medium sandy beach and has a reflective energy regime with shore-normal sediment transport. The coastal system in Codroy is organically productive consisting of a salt
marsh, fine sandy beach with a dissipative energy regime. Given the different physical characteristics, oil longevity will vary between the coastal systems.

**USING PRINCIPAL COMPONENT ANALYSIS ON REGIONAL SOIL GEOCHEMISTRY DATASETS TO UNRAVEL FORMER ICE SHEET HISTORY AND GOLD DISPERsal IN THE NORTH OF IRELAND**

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Till geochemistry is largely determined by its parent bedrock and soils developed on tills are known to inherit this geochemical signature. Soil geochemistry from areas of till can therefore be used to establish glacial sediment provenance, which in turn provides information on palaeo ice flow direction and former ice sheet history. Here we present results of the first regional statistical analysis of soils developed on tills in the northern sector of the last Irish Ice Sheet. The study uses the Geological Survey of Northern Ireland Tellus geochemical database, which covers all of Northern Ireland and the contiguous Geological Survey of Ireland Tellus Border geochemical database that covers the adjacent border counties. A total of 5729 soil samples that occurred on till were extracted from both surveys and Principal Component Analysis (PCA), which is a multivariate statistical technique used to study variability in large geochemical data sets, was used to establish sediment provenance. PCA identifies a number of principal components that allow identification of groups of related elements that together indicate a mineralogy, which in turn is used to locate the most likely bedrock source of the till. With reference to bedrock geology maps, the provenance of the sediment can then be determined and degree and direction of subglacial transport established. The results indicate that the upper surface of the majority of tills in the study area have a close relationship to local bedrock with rapid geochemical changes observed at lithological boundaries. This suggests that tills in this sector of the former Irish Ice Sheet are primarily local in origin, indicating rapid entrainment of bedrock and low rates of evacuation of debris to the ice margin. In addition to investigating ice flow history, soil geochemistry can also be used for mineral prospecting in areas of thick subglacial deposits. However, this approach has not been widely used for the glaciated terrain of Ireland. Here we present the first results of applying PCA to the Tellus and Tellus Border soil geochemical data to investigate gold dispersal in the Southern Uplands - Down-Longford terrain in the north of Ireland. Multivariate statistical analysis of the data proves effective in identifying potential gold mineralisation, correlating well with and expanding on sources that have already been identified in the region. The results also indicate there was no significant glacial dispersal of gold in the north of Ireland, in contrast to other glaciated terrains.
DECOUPLING NATURAL AND ANTHROPOGENIC CHANGE AT ALTA LAKE, WHISTLER, BRITISH COLUMBIA: IMPLICATIONS FOR MANAGEMENT

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Small, recreationally important lakes are economically critical to communities across Canada. Currently the development of management practices to prevent the deterioration of water quality in these lakes is based on 1-2 year limnological assessments that are only able to provide short-term characterizations of water quality variability. Using carbon-dated sediment cores from Alta Lake, Whistler, British Columbia, and this study reconstructed long-term changes in water quality using C/N stable isotopes, metals, and historical records. Evidence was found for large-scale landscape destabilization ca. AD 1650 and the rerouting of Twenty-one mile creek from Alta Lake to the Green Lake watershed by alluvial fan dynamics ca. AD 1770. Changes in productivity indicators (δ¹³C and δ¹⁵N) coincident with anthropogenic metal deposition (AD 1900 – present) were not similar to changes in productivity indicators associated with landscape destabilization and watershed dynamics, indicating human-induced nutrient loading and increased productivity. Limnological assessments of Alta Lake concluded that Alta Lake is an oligotrophic, clear-water lake with excellent water quality. This study confirmed these data but suggested that nutrient loading and increased productivity on Alta Lake is a result of human activity. These changes are subtle but indicate that a comprehensive assessment of nutrient input is necessary to prevent the further deterioration of water quality. The application of the paleolimnological method confirms that a long-term perspective on water quality variability facilitates effective management practices for Alta Lake and other small, recreationally important lakes across Canada.

AN ARCHAEOENTOMOLOGICAL PERSPECTIVE ON DORSET OCCUPATIONS IN NEWFOUNDLAND

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The Dorset Palaeoeskimo occupied different regions of Newfoundland between 1920 and 1290 cal BP. Their hunter-gatherer way of life, which was focused on marine mammals, is generally regarded as having minimal impact on the landscape. Recent research, however, has demonstrated that the impact of hunter-gatherer populations on the landscape can be detected through environmental proxies. In this research project we use entomological remains to recognize and describe the impact of Dorset Palaeoeskimo on their environment at two important occupation sites in Newfoundland.
Archaeoentomology – the study of insect remains found in archaeological contexts – is a proven method for studying human occupations and their impacts on the local environment of archeological sites through time. Many insects, including ground beetles, are ecological specialists and can be linked to specific ecological conditions such as humidity, soil types and plant species. By examining their modern ecological requirements and applying them to identified insect specimens found in the archaeological record, it is possible to reconstruct past natural and human-influenced environments.

Soil samples taken from the Newfoundland Dorset sites of Phillip's Garden on the Northern Peninsula and Stock Cove in Trinity Bay were analyzed for taxonomically identifiable entomological remains, specifically ground beetles. Preliminary results show that the Dorset occupations had an impact on the environment of both archaeological sites. For example, in Phillip's Garden cultural layers Scolytidae or bark beetles indicate the presence of trees and the exploitation of forest resources. At Stock Cove, the remains of Syneta feruginea, the rusty leaf beetle, were identified. This species is typically found in the presence of oak and hazel, its reported food source. Neither tree species was found on the site or documented in the local vegetation; the nearest occurrence today is in the province of Quebec. The presence therefore of the rusty leaf beetle provides proxy evidence for the cultural use of non-native wood species by Dorset in Newfoundland.

NORTHWEST ATLANTIC QUATERNARY PALEOCEANOGRAPHY FROM DEEP-SEA CORALS: EXAMPLES, CHALLENGES, AND EMERGING QUESTIONS.

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Deep-sea corals are considered excellent paleoceanographic archives, and provide geographically widespread but discontinuous records of oceanographic change in the Northwest Atlantic. Deep-sea corals comprise a broad spectrum of cnidarians with hard skeletons or skeletal parts, including scleractinian (stony) corals, gorgonian (fan) corals, antipatharian (black) corals, and pennatulaceans (sea pens). All of these groups contain species that form annual growth increments in their skeletons, providing highly resolved oceanographic proxies. A few species of gorgonian corals in the NW Atlantic form carbonate-protein skeletons and live for hundreds of years. Similarly, antipatharian corals can live for hundreds to thousands of years, although the NW Atlantic species have century-scale lifespans. Most pennatulaceans contain a calcium carbonate axis with growth rings, and have much broader distributions than the other types of corals. Most sea pen species appear to live for several decades, and their high collagen content poses analytical challenges. Post-mortem skeletal
longevity of these corals varies among species and higher taxa, and ranges from years to centuries for gorgonians, to hundreds of millennia for scleractinians. Geochemical systems for measuring oceanographic change in the deep-sea corals include carbonate stable isotopes of carbon, oxygen and boron, carbonate elemental ratios such as Al–Ca, Mg/Ca, Sr/Ca, Ba/Ca and Na/Ca, carbonate and protein radiocarbon, and protein stable isotopes of nitrogen, carbon and sulphur.

Radiocarbon ventilation of the deep Northwest Atlantic, documented in gorgonian coral calcite and protein, varies geographically, with more rapid ventilation of bomb radiocarbon below the surface mixed layer off northern Labrador than off of Newfoundland, and least off of southern Nova Scotia. Deep-water ventilation of Baffin Bay has yet to be assessed, partly because the low carbonate saturation of waters of Baffin Bay make deep-sea corals with carbonate skeletons relatively rare there.

Paleoproductivity proxies such as nitrogen isotope ratios in subfossil gorgonian coral skeletons appear to track Labrador current strength. Comparing $\delta^{15}$N records from gorgonian protein to Ba/Ca ratios from gorgonian carbonate might reveal variations in the strength of benthic-pelagic coupling and biological transfer of primary productivity from surface waters to the deep sea.

Coral graveyards are time-averaged collections of coral skeletons, offering long-term records of paleoceanographic variation in one location. Coral graveyards of the solitary scleractinian Desmophyllum dianthus from Orphan Knoll and the southern Flemish Cap contain corals up to 181 ka in age, but show discontinuous accumulation. Corals at the Orphan Knoll graveyard grew intermittently, with coral ages corresponding to the Holocene, Bølling-Allerød, and marine isotope stages 5c and 7a. Coral growth at Orphan Knoll appears to have been limited by primary productivity, possibly linked to latitudinal shifting of the polar front. Boron isotope systematics in coral skeletons from Orphan Knoll has so far found no past pH variation at the depths in which the corals occurred. Strongly negative, continentally influenced Neodymium isotope ratios in the stage 5c and stage 7a Orphan Knoll corals may indicate stronger overflow of deep water from Baffin Bay, unlikely any deep-water formation in the Labrador Sea, during these interstadials, compared to Bølling-Allerød, Holocene and modern conditions.

SEDIMENT-LANDFORM ASSOCIATIONS OF TERRESTRIALLY-TERMINATING ICE STREAMS: CASE STUDIES FROM THE SW LAURENTIDE & BRITISH-IRISH ICE SHEETS

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The Canadian prairies and the Holderness lowlands of eastern England contain a record of complex glaciogenic sediment sequences arranged in large, arcuate ice-marginal subaqueous depo-centres and moraine assemblages. These prominent features demarcate the lobate, often overprinted, termini of fast ice flow corridors and thereby represent the terrestrial equivalents of trough-mouth fans. In the SW Laurentide Ice Sheet two depositional scenarios appear
appropriate; 1) glacier-marginal till thickening at occasionally stationary ice stream margins so that stacks of subglacial traction tills record annual sub-marginal incremental thickening; and 2) proglacial lakes and valleys infill with glacilacustrine deposits and mass flow diamictons associated with the advection of sub-marginal till into preglacial bedrock depressions, so that ice stream marginal oscillations are recorded by debris influx into subaqueous environments. In both scenarios, glacial overriding modifies the deposits to produce glacitectonites.

Greater stratigraphic complexity has been introduced to glacigenic sequences in southern Alberta, due to ice stream lobe oscillation and/or switching over single locations. This gives rise to stacked sequences of diamictons and associated deposits, whose changing lithologies/colours through time are reflected in the traditional nomenclature of the regional tills. Instead of till deposition being separated by interglacials or interstadials, the thick and complex glacigenic.

CLIVE: A TOOL FOR THE GEO-VISUALIZATION OF THE CHANGING COASTLINES OF PRINCE EDWARD ISLAND

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Previous studies have shown that Prince Edward Island has experienced significant coastal erosion with the most recent presenting an overall average rate from 1968 to 2010 of 0.28 metres per year. Erosion and accretion rates of particular regions of Prince Edward Island vary making it unclear as to what coastal infrastructure is at risk on Prince Edward Island. A quantitative risk assessment of Prince Edward Island’s coastal residences (homes, cottages), safety and security infrastructure (roads, bridges, water treatment plants, hospitals, fire departments, etc.) and heritage (churches, graveyards, lighthouses, archaeological sites, parks, etc.) was conducted by multiplying the current annual coastal change rates for every one metre from 1968-2010 by 30, 60 and 90 years to estimate possible future coastlines for Prince Edward Island. Using these future coastlines, the amount of coastal infrastructure that might be impacted by coastal erosion was then quantified. Over 1000 residences (houses and cottages), over 40 garages, 8 barns, and almost 450 outbuildings were shown to be vulnerable to coastal erosion. Such scientific results were significant but were threatened to sit on a shelf in a scientific report unless communicated sufficiently to the organizations and communities of Prince Edward Island. A geovisual interface, known as the CoastaL Impacts Visualization Environment (CLIVE), was developed by combining available coastal data, historical records and predictive climate change models and translating them into a 3D geovisual information tool that can be explored and queried by non-scientist stakeholders. CLIVE enables citizens to interactively navigate and view a 3-dimensional (3D) virtual environment of the province of Prince Edward Island (PEI) constructed from accurate historical spatial data and recent LiDAR surveys of topography. A public engagement tour was held across Prince Edward Island during the month of July 2014 at eight Prince Edward Island communities. Each session was preceded and concluded with a written survey to gauge attendee’s knowledge, concern and willingness
to adapt to coastal erosion and sea level rise. The concern for coastal erosion of each participant was high (presumably that was the motivation for attending the session), and increased after being introduced to CLIVE. CLIVE won an international competition at the Massachusetts Institute of Technology (MIT) for communicating coastal issues and the PEI Association of Planners awarded the Murray Pinchuk Community Builder Award based for efforts to develop a coastal erosion visualization tool. This presentation will introduce the results of the coastal erosion study, the development of the CLIVE tool, and the results of the public consultation.

IN GILBERT’S FOOTSTEPS: BOULDER FLATS AND BARRICADES ON THE EAST COAST OF BAFFIN ISLAND

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Bob Gilbert made seminal contributions to the understanding of high-latitude fjord-basin and margin sedimentation, with much of his work undertaken on the east coast of Baffin Island, including Pangnirtung and Qikiqtarjuaq (Broughton Island) on the Cumberland Peninsula. We have followed in his footsteps, employing new technology such as high-resolution digital satellite imagery, multibeam bathymetry, real-time kinematic GPS surveys, and underwater video, among other tools. This has enabled unprecedented morphosedimentary characterization of glaciomarine and deltaic environments, including submerged deltas and other coastal features, confirming early observations on the interpretive value of seabed morphology before the advent of multibeam bathymetry (R. Gilbert, 1978, Maritime Sediments, 14: 1-9). Here we focus on the fjord margins across a spectrum of relative sea-level trends and tidal ranges from submergent and 12 m (Iqaluit). Boulder accumulations shaped by ice push or rafting characterize intertidal environments on high-latitude coasts. These display a range of morphology, described by Gilbert and co-workers, from random distributions to patterns such as polygonal garlands, with or without marginal ridges known as boulder barricades. Slightly submerged boulder barricades and poorly developed active ridges are found in Patricia Bay near the community of Clyde River, confirming the observations of Gilbert and Aitken (1981) that boulder barricades can occur with a tidal range as low as 0.6 m. No boulder barricades are found on the modern coast of Broughton Channel near Qikiqtarjuaq, but a finely developed barricade and garlands are present at Pangnirtung (max tidal range >6 m) and boulder-strewn tidal flats with boulder clusters and a poorly developed barricade-like ridge are found at Iqaluit in Frobisher Bay (max tidal range 12 m).

Recent high-resolution mapping of uncharted coastal channels and fjords in the study region revealed a submerged boulder barricade in 16-18 m present water depth in Broughton Channel near Qikiqtarjuaq. The submerged boulder barricade represents a sea-level lowstand
at which Broughton Channel was cut off from Baffin Bay, becoming a semi-enclosed basin. The lack of a boulder barricade in the modern shore zone is attributed to the Broughton Channel tidal currents that developed when the subsequent transgression reconnected the basin with Baffin Bay. These high-velocity currents cause earlier ice breakup in Broughton Channel (Gilbert 1980), removing an important enabler of barricade formation. At Iqaluit, highly detailed imagery combined with a digital elevation model of the tidal flats in Koojesse Inlet enabled a hypsometric analysis relating the present tidal range to variations in the morphology of the flats and the distribution of boulders. This supported the attribution of a crude barricade in that setting to ice-breakup dynamics, but highlighted the ‘smearing’ effect of the large tidal range and high boulder mobility across the flats.

SUBSIDENCE AND INUNDATION OF A LARGE ARCTIC PERMAFROST DELTA

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The Mackenzie Delta is the second largest on the Arctic Ocean and comparable in size to the Mississippi Delta. Covering an area of 13 000 km² comprising a mosaic of branching channels and over 43 000 lakes, it is a locus of high aquatic productivity, hosts important waterfowl nesting habitat, and supports the subsistence economy of Gwich’in and Inuvialuit communities. The delta is over 200 km long (N-S) and 50-60 km wide with the northern third beyond the tree-line. Lying within the zone of continuous permafrost, the Holocene delta plain is underlain by sediments with temperatures <0 °C to depths of >60 m (except beneath deep lakes and channels), while parts of the outer delta onlapping adjacent Pleistocene deposits have permafrost extending to 500-700 m depth. Emptying into the Beaufort Sea, the spring freshet overflows nearshore ice and culminates in widespread flooding of the delta plain, which replenishes lakes and gradually builds up the surface as sea level rises. The outer delta is also flooded intermittently by storm surges, predominantly in late summer and fall. The region is affected by postglacial isostatic forebulge subsidence with some Cordilleran tectonic effects. The presence of frozen (ice-bonded) soils in the Mackenzie Delta was expected to limit compaction subsidence and rates of subsidence were unknown prior to this study. A network of monuments (stable deep pipes) for episodic GPS occupations was established in 2004 and gradually expanded through 2010 (with some stations occupied annually through 2014), while continuous GPS stations were located at Inuvik, Tuktoyaktuk, and one site in the northern delta. The results show rates of subsidence as high as 6.4±0.9 mm/a relative to Inuvik (subsiding at 0.48±0.58 mm/a; James et al., 2014, GSC OF7737), comparable to rates observed in non-permafrost deltas. This may involve seepage of water and methane through the numerous thaw taliks, associated deep compaction and possible fault reactivation, and/or shallow compaction in taliks. Some parts of the permafrost section are only weakly ice-bonded and may also be susceptible to compaction. These rates of subsidence add to relative sea-level rise in promoting gradual inundation of the outer delta, while delta-front erosion (>4 m/a in many
places) adds to the loss of nesting habitat. Measurements of sedimentation rates since 2010 have revealed very low rates of aggradation over a large part of the outer delta. Apart from rapid sand deposition on some levees, sedimentation is not keeping pace with subsidence, which is compounded by additional near-surface subsidence not captured in the GPS measurements. This is related to climate warming and thaw compaction through loss of excess ice as the seasonal thaw depth increases. There is evidence to suggest that the delta front has retreated tens of kilometres from its maximum Holocene extent 2000-3000 years ago (Hill, 1996, Can. J. Earth Sci. 33). This gradual loss of the delta will continue and may accelerate in the future.

**BISON DISPERSAL FROM BERINGIA INTO NORTH AMERICA VIA THE ICE-FREE CORRIDOR**

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The concept of an ‘ice free’ or ‘deglacial’ corridor has figured prominently in models of biogeographic exchange between Beringia and continental North America for much of the last century. Geological research during the last two decades has clarified that Laurentide and Cordilleran ice sheets coalesced during the height of the last glaciation, closing a longstanding pathway between Beringia and interior North America. Despite a greater clarity concerning coalescence, the timing and nature of deglaciation and the biotic habitability of the Corridor have remained in doubt, limiting a more refined understanding of faunal and human dispersals in terminal Pleistocene North America. Here we make use of one of the more readily available data sources from within the deglaciating Corridor region with a direct bearing on its biotic status: Quaternary vertebrate fossils. Bison are a well-represented species in Pleistocene and early Holocene assemblages in western North America, and previous research has revealed that genetically distinct northern or Beringian as opposed to southern bison clades can be identified through mitochondrial DNA (mtDNA) analyses of the fossils (Shapiro et al., 2004). Radiocarbon dating (using ultrafiltration) and mtDNA of more than 40 new bison from Edmonton, Alberta provide a new record of the dynamics of the Late Pleistocene-early Holocene dispersal of bison through the corridor. Vertebrate dates suggest that horses and bison from the south first occupied the corridor, but northerly bison quickly met these populations just prior to 13,000 cal yrs BP. And in contrast to models of bleak, unproductive post-glacial landscape, these bison were part of a diverse grazing community of herbivores and their predators that occupied the area during the early stages of deglaciation.
The direction of bison migration is overwhelmingly north to south during the Late Pleistocene, and only a single latest Pleistocene bison in northern Canada, dating to ca. 12,200 cal yrs BP, has been recovered. This early northerly dispersal likely took place prior to the development of significant ecological barriers, such as the development of the boreal forest, which may have limited subsequent northern dispersal of bison into Beringia. Our findings have significant implications for terminal Pleistocene faunal dispersals, including pathways for ancestral First Nations populations. Movement in both directions between eastern Beringia and regions south of the continental ice masses was feasible during the Clovis era (c.f. Waters and Stafford, 2007), and likely a few centuries before, but there is no clear evidence of this area as the prime route for initial settlement. However, the area likely played an important role for secondary movements of populations from the south, and potentially as a route for south-north migration of Clovis technology through western Canada.

DEEP PERMAFROST RECORDS AND DIVERSE CHRONOLOGIES

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Deep syngenetic permafrost of Beringia, or the deep Yedoma, hosts a reservoir of at least several hundred Pg of C that has survived through multiple interglaciations at least as warm or warmer than the present interglaciation. Relatively few sites are known across the northern hemisphere to estimate this reservoir, but based on known data, it appears that this reservoir is largely a feature of the Middle Pleistocene and may not pre-date the Early to Middle Pleistocene transition. Relict polygonal ice-wedge networks associated with syngenetic permafrost are present at four sites in the discontinuous permafrost zone of central Yukon and Alaska. They are stratigraphically associated with the Gold Run tephra (ca. 700 ka) and other Middle Pleistocene tephra beds, consistent with their normal magnetic polarity and vertebrate fossil assemblages. Soil organic matter content within these deposits is indistinguishable from Late Pleistocene and Holocene organic matter, with organic carbon ranging between 1 and 12% reflecting the depositional context. Plant and vertebrate communities indicate that the majority of this material accumulated in typical steppe-tundra ecosystems associated with Pleistocene cold stages, similar to late Pleistocene contexts. Where differences are more pronounced, however, is at the molecular scale. Ancient biomolecules show much greater rates of DNA damage reflected by decreases in the obtained plant and bacterial sequence diversity and elevated deamination of the 5' and 3' termini of DNA molecules, characteristic of ancient DNA
PAST PERMAFROST AND ITS ENVIRONMENTAL IMPLICATIONS IN EASTERN NORTH AMERICA DURING THE LATE WISCONSINAN

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Permafrost exists today in high-latitude regions and alpine mountains. In the James Bay Lowland of the far north of Ontario, discontinuous to sporadic permafrost occurs. During the last glaciation Late Wisconsinan Stage, extensive permafrost developed both outside and inside the southern limit of the ice sheets in the mid-latitude lowlands in North America, NW Europe and other parts of the world. However, unlike NW Europe, large-scale permafrost development in front of the Laurentide Ice Sheet in eastern North America has been questioned. This skepticism is because many of the reported relic periglacial features, e.g., ice-wedge casts, have remained unconfirmed. As well, the Laurentide Ice Sheet reached 40°N in North America, with an ice-marginal climate probably much warmer than that of the contemporaneous Scandinavian Ice Sheet of NW Europe, which only reached 50°N. In southern Ontario, the uncovered well-preserved ice-wedge casts and polygon relics provided unambiguous evidence for continuous permafrost at 15 000 to 13 000 years BP during the last deglaciation. Given a globally ameliorated climate at that time, the presence of extensive permafrost in southern Ontario, which is about 300 km inside the ice limit, implies that permafrost likely developed along the ice border during the height of Late Wisconsinan (LGM). Recent examination of Google Earth™ imagery has revealed orthogonal to hexagonal polygons, mostly 10–30 m in diameter, at more than 160 sites in sand and gravel deposits in southern New Jersey and the northern part of the Delmarva Peninsula, which have been previously considered permafrost-free during the LGM. The polygons were interpreted to be relic ice/sand-wedge polygons developed in a zone of continuous permafrost that extended to 38.5°N, with a width exceeding 250 km to the south of the ice limit during the LGM. Further south, discontinuous permafrost likely existed in a less-well defined zone that might have extended as far south as to 37°N. The development of the continuous permafrost indicates a mean annual air temperature (MAAT) of -6°C and lower for the mid-Atlantic Coastal Plain. To compare, the previous palynological studies and paleoclimate modelling all suggested an MAAT of 2 to 5°C and significantly underestimated the climatic severity of the LGM for this region.
TILL SAMPLING FOR INDICATOR MINERALS IN NORTHERN ONTARIO: A DECADAL REVIEW

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Subglacial till deposits are extensive in northern Ontario and they have been sampled for indicator minerals for gold, kimberlite (diamond) and base metals. During the last decade, several Quaternary geology mapping and till sampling projects were undertaken by the Ontario Geological Survey, mostly in the northeastern Ontario. The project areas each comprised 3 to 12 NTS sheets at a scale of 1:50 000. Physical constraints of the terrains, e.g., poor accessibility and lack of till exposures due to dense vegetation and a thick cover of Holocene deposits, usually resulted in irregular sample grids. Different types of till were sampled but their suitability for drift prospecting in relation to heavy mineral dispersals lacked quantitative assessments. There are two major types of till, regardless of age, in northern Ontario: a sandy and bouldery till often non-calcareous and a calcareous silty and clayey till with limited to moderate stone contents. They are closely related to the underlying bedrocks, with the former occurring in the Precambrian shield and the latter mainly in areas underlain by the Paleozoic carbonate bedrock, e.g., the James Bay Lowland. The sandy and bouldery till is, in general, thin and patchy and has a clast lithology dominated by the Precambrian crystalline rocks, whereas the silty and clayey till is thick and continuous and contains abundant carbonate clasts. Generally, the samples from the sandy and bouldery till showed higher counts of indicator mineral grains and most of the indicator mineral anomalies were found in this till, e.g., in the Cobalt-New Liskeard area where a Paleozoic bedrock inlier occurs. To compare, the adjacent samples obtained from the silty and clayey till in the same area contain lower counts of indicator minerals (KIMs) above the Paleozoic bedrock. This has been interpreted as a result of the dilution of heavy mineral grains by the carbonate rock fragments incorporated abundantly into the ice sheet from the easily erodible Paleozoic bedrock. However, in the James Bay Lowland where multiple calcareous silty and clayey tills occur, samples from such argillaceous deposits have produced anomalously high counts of indicator minerals at sites probably proximal to the source areas, suggesting their good suitability for sampling in drift prospecting. Future quantitative studies on the dispersal features in these tills are desired, which may help better determine the follow-up mineral exploration targets.

CHARACTERIZING LATE-GLACIAL READVANCES AND THE DRAINAGE OF LAKE OJIBWAY THROUGH COMPOSITIONAL AND PALEOMAGNETIC ANALYSES OF LONG SEDIMENT SEQUENCES

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Lake Ojibway invaded vast expanses of northeastern Ontario and northwestern Quebec during the last deglaciation. The evolution of this large ice-dammed lake was strongly influenced by the dynamics of the retreating ice margin, which readvanced into the Ojibway basin shortly before the end of the deglaciation and the final drainage of the lake into Hudson Bay around 8150-8450 cal yr BP. Although these so-called Cochrane readvances left a strong imprint on the regional geomorphology, their expression in sediment records remains poorly defined, giving rise to large uncertainties regarding their number and timing throughout the James Bay basin. Previous work have identified three readvances on the basis of marked compositional changes in varve sequences, but the low analytical resolution and lack of chronostratigraphic markers prevent any firm conclusions on their exact occurrences. Here we present compositional and paleomagnetic results from four long (7-14 m) sediment cores aligned on a NW-SE transect running across the eastern Ojibway basin. The Ojibway sequences were analyzed at high resolution to document their grain-size composition, detrital carbonate content, mineralogy (XRD), and geochemistry (XRF). The magnetic (magnetic susceptibility, inclination, declination and paleointensity) and other physical properties were measured with a Multi Sensor Core Logger (MSCL) and a u-channel cryogenic magnetometer. The sediment cores appear to record a significant fraction of the lake existence whereby they typically begin with massive sands that grade into thick rythmites, which turn into thinly bedded varves for most of the sequences. Preliminary results indicate that the sediment core located near the maximum extent of the Cochrane readvances show several minor compositional changes in its upper section. Of importance is the presence of two distinctive increases in detrital carbonate and concomitant changes in texture that reflect glacially-derived detrital (Cochrane) inputs from the Hudson Bay lowlands, with the latest interval occurring at the end of the Ojibway sequence. The sediment cores located further away in the basin are characterized by a rather homogenous composition, with the exception of the uppermost part of one core that shows a thick and massive coarse sand bed that lies on top of fine-grained Ojibway varves; a unit somewhat analogous to a well-defined regional marker bed that records the final drainage of the lake. These results indicate that these extensive Ojibway sedimentary sequences appear to record multiple minor fluctuations (or periods of intense melting) of the Cochrane ice margin, with at least two significant readvances, the latest being roughly synchronous with the termination of Ojibway deposition. This suggests that the late-glacial ice dynamics may have played an important role in the final drawdown of Lake Ojibway, possibly through destabilization of the disintegrating ice dam. Paleomagnetic investigations are currently underway and the upcoming results should allow the placement of these compositional changes within a chronostratigraphic template. This should clarify the timing of the events surrounding the final drainage of Lake Ojibway, an important contribution given the rarity of datable material in these glaciolacustrine sequences.
THE PLIOCENE-PLEISTOCENE TRANSITION IN THE CANADIAN WESTERN AND HIGH ARCTIC

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The rapid steepening of the latitude temperature gradient and incision of the Beaufort Formation and subsequent reopening of the Northwest Passages had first-order controls on the evolution of landscapes in the Canadian Arctic. Using cosmogenic nuclide burial dating approaches, combined with available paleomagnetic stratigraphy, we develop a chronostratigraphy in the Beaufort Formation and equivalent-aged high alluvial terraces on Ellesmere Island, and the White Channel Gravel in the Klondike gold fields, to examine the landscape response to this climate change. Based mainly on the burial dating (ages ranging from 3.5 to 3.8 Ma on Ellesmere and Meighen islands, and > 2.7 Ma on Banks Island) which is consistent with the majority of the extensive biostratigraphy, the Beaufort Formation appears Piacenzian. An angular unconformity separates it from the underlying Ballast Brook Formation, on Banks Is., but its age remains elusive and may only be obtained from the contemporaneous offshore Iperk Formation (currently being dated). The timing of Beaufort Formation incision remains unknown but must be after 3.5 Ma and is likely associated with a sea-level fall at the Pliocene-Pleistocene boundary. In contrast, in the Yukon, the Upper White Channel Gravel has been dated at 2.6 +/- 0.2 (1-sigma). The gold-bearing angular quartz-dominated alluvium thus appears to represent a landscape response in which a long period of chemical weathering of the Klondike schist was punctuated by a period of rapid erosion and aggradation of the placer sediments. Possible reasons for the contrasting landscape responses in the two Arctic systems will be proposed.

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POSTGLACIAL LANDSCAPE EVOLUTION OF AEOlIAN LANDFORMS, SAVARY ISLAND, BRITISH COLUMBIA

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Savary Island is the southernmost island of the Discovery Islands chain in the northern Strait of Georgia. It is situated between Vancouver Island and the mainland, approximately 145 km northwest of Vancouver, British Columbia. Savary Island supports a field of fossil parabolic sand
dunes, some up to 1 km long that contain palaeosols. The dunes rest on sediments deposited during the last glaciation. This study aims to understand the evolution of the dune field and identify periods of aeolian activity using LiDAR imagery, radiocarbon and optical dating, and palaeo-pedology. The two oldest palaeosols discovered so far developed during the early Holocene at 8,550 ± 40 and 7400 ± 25 14C years BP; each records a period of landscape stability separated by intervals of sand accumulation. Optical dating protocols for K-feldspar will be developed and tested using samples of aeolian sand associated with radiocarbon-dated palaeosols. The protocols will subsequently be applied to undated parts of the dune sequence to establish a chronology of aeolian activity on the island; preliminary optical ages will be reported in this presentation.

UNTANGLING THE COMPOUNDING EFFECTS OF SEABIRD NUTRIENT SUBSIDIES AND CLIMATE CHANGE ON COASTAL LAKES IN THE HUDSON STRAIT USING PALEOLIMNOLOGICAL APPROACHES

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Energy and nutrient fluxes across ecosystem boundaries can exert profound direct and indirect effects on the dynamics of the recipient systems, especially in nutrient-poor environments like the Arctic. Digges Sound, located in the Hudson Strait, provides nesting habitat to one of the largest Thick-billed Murre colonies in Canada (~400,000 pairs). Nutrient-rich wastes from the murre colony have fertilized the surrounding terrestrial and freshwater ecosystems. These birds are ingrained in the cultural fabric of Nunavik and Nunavut communities, yet murres have largely been understudied with respect to the important linkages that they may provide between marine and terrestrial ecosystems. Since the early 1990s, the region has undergone substantial climate-related changes including a reduction in sea ice thickness and extent, which is altering the distribution and abundances of keystone wildlife. Fundamental ecological knowledge from Digges Sound is pertinent to understanding the historical connection of seabirds to the landscape, as well as the unintended effects of climate change on coastal ecosystems. We have analyzed the water chemistry and diatom assemblages collected from rock substrates of 29 lakes located across a gradient of bird ‘impacted’ and pristine reference lakes. These bioindicators help track the main water chemistry variables (e.g., nutrients, conductivity) distinguishing lakes across the region, as well as identify key taxa associated with bird-impacted lake conditions. In addition to diatom assemblages, δ15N of surface sediments further differentiates sites receiving bird subsidies from reference sites. Paleolimnological research, including the analysis of four dated sediment cores (2 seabird impacted cores and 2 reference cores) for aquatic microfossils, sedimentary chlorophyll-a, and stable isotopes has
been completed to determine the long-term linkages between seabirds and aquatic food webs. Little is known about the historical connection of seabirds to the Arctic landscape, including the timing since colonization, transformation to a nutrient-rich landscape, and the potential interaction between seabird nutrient subsidies and climate change. This research aims to determine how nutrient contributions obtained from marine ecosystems alter lakes in the Arctic and may enhance production at these sites with longer growing seasons.

SHORELINES OF GLACIAL LAKE PEACE: IMPLICATIONS FOR ISOSTASY AND ICE SHEET CONFIGURATION IN NORTHEASTERN BRITISH COLUMBIA, CANADA

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The spectacular imagery that is generated from LiDAR based digital-elevation models (DEMs) reveal unprecedented geomorphic detail that can be used to establish the positions of former glacial lakes along the margin of continental ice sheets during deglaciation. When combined with geographic information systems, these tools have advanced considerably mapping and correlation of geomorphic features such as relict shorelines. Shorelines of glacial Lake Peace (GLP) developed between the Laurentide and Cordilleran ice sheets in northeastern British Columbia and northwestern Alberta. Shoreline mapping from high resolution DEMs produced more than 55,500 elevation data points from 3231 shorelines, enabling the identification of four major phases of GLP: Phase I (960 - 990 m a.s.l.); Phase II (890 - 915 m a.s.l.); Phase III (810 - 865 m a.s.l.); and Phase IV (724 - 733 m a.s.l.). The timing of Phase II of GLP is estimated by two optical ages of <16.0±2.5 and 14.2±0.5 ka BP. Extensive mapping of the shorelines allows for a measure of glacial isostatic adjustment since ice retreated. Shorelines currently dip to the northeast at approximately 0.4 - 0.5 m km⁻¹. This slope reflects the asynchronous retreat of the Cordilleran (CIS) and Laurentide (LIS) ice sheets. The relative uplift in the southwest of the study area within the Rocky Mountains and foothills suggests that the Late Wisconsinan (MIS 2) CIS persisted in the foothill after the LIS lost mass and retreated, or that the Late Wisconsinan CIS was very thick and caused added crustal loading which resulted in more uplift in the southwest before reaching equilibrium during, or shortly after deglaciation.

REVISITING THE TILL STRATIGRAPHY IN THE HUDSON BAY LOWLAND REGION OF MANITOBA

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The Hudson Bay Lowland (HBL) region of Manitoba, Canada, contains a depositional record of multiple glacial-interglacial cycles. The interglacial sediments have been studied in detail, but uncertainties persist regarding the till stratigraphy, which have implications for ice sheet reconstruction as well as drift prospecting in NE Manitoba. The region was affected by ice flows from the Keewatin and Quebec/Labrador sectors of the Laurentide Ice Sheet, from the north and east, respectively. Previous studies have documented a 4-till stratigraphy, but a compilation of existing literature has shown that the identifying characteristics are not unique, and descriptions of the named units are commonly contradictory. Furthermore, recent work has identified numerous new sections that provide opportunities to revisit the till stratigraphic framework.

WILL WE COLLAPSE? THE CLASH BETWEEN RESOURCES AND POPULATION

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Homo Erectus began moving earth 1.5 million years ago. On the banks of the Jordan River, he or she collected rounded pebbles and pressed them into muddy soil to make a firmer living surface. The resource was plentiful; and such pebbles were being made constantly by streams rattling them along their beds and by waves swishing them back and forth on the shore.

Fast forward to today. Homo (now of variety sapiens, but sometimes doubts creep in) now uses resources undreamt of by these long distant ancestors. Soil and water for growing grain, steel for tractors and combines. Oil to power them. Rare Earth elements in computers that tell the tractors where to go and that enable us to control them with a jab of a finger. All of these resources are renewable: some on times scales meaningful to homo, others only on geologic time scales. It doesn’t matter. We’re using all of them at rates faster than they are being renewed. Critically, for example, the Ogallala aquifer that waters the breadbasket of North America is being drawn down at rates, in many places, of decimeters per year, and the soil it nourishes is being washed down the Mississippi at rates ten times the rate at which it is being formed by weathering. Use of resources faster than they are replenished leads to overshoot, and eventually to collapse.

And we are discarding things faster than the environment can absorb them: CO₂, NOₓ, broken baby buggy bumpers, unfashionable kitchen sinks, rusty automobiles. Garbage, garbage, garbage. This, too, is unsustainable.

Resources nurture prosperity. But it’s a zero-sum game; above a certain population threshold the more people, the fewer resources per person. When resources per capita are low, comfort is elusive. Inadequate soil and water lead to food shortages. People lacking the basic necessities of life are easy prey for ideologues who, perhaps with some justification, think it is OK to take what they need from those who have it. Whereas a smaller population might be supported, a large one leads to famine, conflict, misery, and in some cases massive migrations.
Does Earth have the resources to support our present population, 7.3 billion, indefinitely and comfortably? Or the nearly 10 billion commonly projected for 2050? Or are we already in the initial stages of collapse?

Knight, R.D.¹, L.J. Valiquette² and H. Russell¹

PORTABLE X-RAY FLUORESCENCE ANALYSIS: AS AN ASSESSMENT OF THE SIGNIFICANCE OF SAMPLE THICKNESS

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Portable X-ray fluorescence (pXRF) spectrometry is increasing in popularity for the geochemical determination of unconsolidated sediments due to real time results and reduced analytical cost compared to traditional methods. This non-destructive surface technique is predicated on a programming assumption of infinite sample thickness as the depth of X-ray penetration and the ability of returning X-rays to encounter the detector are influenced by this parameter. Portable XRF analysis has been systematically completed on 1,045 core samples from 10 boreholes located in multiple glaciated basins across Canada (Champlain Sea, Oak Ridges Moraine, Spiritwood Valley, Nanaimo Lowlands). A grain size fraction of <63 µm is used to minimize nugget effect and to facilitate analytical comparisons between datasets. Situations may arise, however, where the <63 µm size fraction of coarse sand and gravel units result in samples of less than infinite thickness. To address the question of how much sample is required to obtain stable results, a comparative study on the analyses of variable sample thickness was undertaken using CanMet certified reference materials, Till-1 and Till-3. Analysis was completed on samples from 1 mm in thickness to 20 mm in thickness, incremented in 1 mm intervals. The pXRF was operated in Soil mode, which is optimized for elemental concentrations of <1%. A dwell time of 60 seconds each for the Low, Main and High filters was used. Sixteen of the 18 elements detected returned valid results (As, Ba, Ca, Cr, Cu, Fe, K, Mn, Ni, Pb, Rb, Sr, Ti, V, Zn, Zr).

Results indicate that detected elements fall into three categories that correlate with one of the three detectors, i) Elements detected using the Low filter for which concentrations remain fairly consistent with increasing sample thickness includes Ca, Cr, K, Ti and V. Of these elements Cr has the highest X-ray intensity and is determined using the Kα1 5.24 keV. ii) Elements detected using the Main filter for which concentration decreases significantly with increasing thickness until infinite thickness is achieved (generally >6 mm), include As, Cu, Fe, Mn, Ni, Pb, Rb, Sr, Zn, and Zr. Of this group Mn has the lowest X-ray intensity and is determined using the Kα1 6.10 keV while Zr has the highest X-ray intensity and is determined using the Kα1 15.98 keV. iii) Ba was the only element detected where concentrations continue to increase significantly over the full 20 mm of sample thickness indicating that infinite thickness has not been achieved. Barium is detected using the High filter and the Kα1 line of 32.70 keV.

Divergence from infinite sample thickness influences the analytical results depending upon the X-ray intensity used to detect a specific element. For elements determined at low
energy levels sample thickness is not a significant factor. Elements determined using the Main filter, the Compton normalization algorithms over report concentration for samples of <6 mm in thickness. For elements with high X-ray intensities, such as Ba, the Compton normalization algorithms under report concentrations until infinite thickness is obtained.

4300-YEAR OLD ‘GLACIER FORESTS’, SOUTHERN COAST MOUNTAINS, BRITISH COLUMBIA AND THEIR GLOBAL CONTEXT

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Dendrochronologic and radiocarbon dating of in situ and detrital wood have been utilized to date Holocene glacier fluctuations in Garibaldi Provincial Park and at Pemberton Icefield in the southern Coast Mountains of British Columbia. Fieldwork at over 30 glaciers has been carried out since 2002. The focus of this paper is on wood that has been radiocarbon dated between 4500 and 4000 years ago, which has been found at six glaciers. At four glaciers the wood was washing out from beneath present-day glacier snouts. At Helm Glacier in Garibaldi Park thirteen detrital branches and stumps were recovered, and at West Squamish Glacier at Pemberton Icefield seven detrital branches, stems, and stumps were sampled. Some of these samples had diameters of up to 40 cm and were up to 250 cm long, and thus are much larger than any living trees near the present treeline. Tree-ring analysis shows that these glaciers advanced into and over mature forests that had grown near present-day glacier margins for at least 135 years (Helm) and 357 years (W Squamish). Evidence for permanent snow and ice patches forming, as well as glaciers advancing beyond present-day extents at this time is found in the central Coast Mountains, Yukon Territory, Arctic Canada, Norway, and the Swiss Alps. Glacier advances of similar age have been reconstructed not only in western Canada, but also in Europe, Asia, South America, New Zealand, and Antarctica indicating the global nature of this event. A peak in ice-rafted debris in the North Atlantic about 4200 years ago may have been the result of reduced solar output, and based on Earth’s position in the obliquity cycle glaciers should have started to expand about 4000 years ago. Furthermore, the collapses of the Mesopotamian Empire, the Egyptian ‘Old Kingdom, and the Harrappan civilization were all partly caused by regional droughts, some of which likely linked to changes to the monsoonal system due to changes in insolation. These ‘glacier forests’ thus could provide a probable start date for Neoglaciation, which coincides with major changes in ancient civilizations.

ESTABLISHING A HISTORICAL CONTEXT FOR RECENT AND EXTENSIVE LAKE EXPANSION IN THE MACKENZIE BISON SANCTUARY (NORTHWEST TERRITORIES) USING PLANT BIOMARKERS PRESERVED IN LAKE SEDIMENTS

The Mackenzie Bison Sanctuary (MBS) near Fort Providence, Northwest Territories (Canada), has experienced rapid and dramatic increases in lake area since ~1990 for several large, shallow lake ecosystems. This has resulted in the flooding of large areas of terrestrial vegetation that is important habitat for the Mackenzie Bison herd. The causes of recent increases in lake size are unknown. In particular, because of a lack of long-term monitoring data in the region, it is unclear whether recent increases in lake size are unprecedented and linked to climate warming, or part of a natural cycle of lake expansion and shrinkage. The flooding of terrestrial vegetation that occurs following lake expansion transports soil organic matter to lake sediments. Therefore, terrestrial plant biomarkers preserved in lake sediments may prove effective for tracking the history of lake expansion/shrinkage. In particular, lignin-derived phenolic compounds are resistant to decomposition and exclusively produced by terrestrial plants. Consequently, they may be attributed unequivocally to allochthonous carbon sources in lakes. Similarly, long-chain aliphatic compounds such as n-alkanes are also useful biomarkers of terrestrial organic matter in lake sediments. We analyzed lignin-derived phenols and aliphatic compounds in a sediment core from Falaise Lake, the largest lake in the MBS, which experienced an 824% increase in lake area between 1986-2010. We observed large increases in the concentration of all lignin-derived phenols in the sediments after 1985, consistent with recent lake expansion. The greatest magnitude of increase was observed for cinnamyls, a group of lignin-phenols derived from non-woody tissues of gymnosperms and angiosperms. In addition, an increase in the proportion of n-alkanes derived from vascular terrestrial plants relative to semi-aquatic plants also occurred after ~1985. Collectively, changes in organic matter biomarkers indicate enhanced transport of terrestrial organic matter to the sediments following lake expansion and shoreline flooding. No notable changes in the biomarker record were observed prior to ~1985, suggesting that recent documented expansion in Falaise Lake is unprecedented over at least the last several hundred years represented by the sediment core. Shallow lake ecosystems in poorly-drained lowland areas of the northern boreal forest are susceptible to flooding events under future climate warming scenarios. Our results for Falaise Lake highlight the effectiveness of terrestrial plant biomarkers for tracking changes in lake size throughout the Holocene, providing important insights into the role climate warming may play in increasing the frequency of extreme lake expansion events.

THE ST. LAWRENCE ICE STREAM – NEW EVIDENCE BASED ON LIDAR SURVEYS AND NEW FIELD WORK IN THE APPALACHIAN PIEDMONT AND UPLANDS

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A new surficial geology mapping project was undertaken in the Appalachian piedmont and
The new Quaternary survey is primarily based on the interpretation of high resolution sub-metre accuracy ground elevation data obtained from an airborne LiDAR (light detection and ranging) survey. The laser survey offers an exceptional view of the ground surface, even under a thick vegetation cover. Digital terrain models (DTM) of various spatial resolutions were created in order to identify as many morphological elements as possible, from large to minute landforms, and hence to delineate distinct landform-sediment assemblages that characterize this region. Hillshade models were used to establish relationships between the texture and rugosity observed on the digital elevation model and the inferred surficial units. The highly detailed surficial geology map created this way will serve not only as the basis for a 3D geological model but also to identify and map subglacial bedforms associated with the St. Lawrence Ice Stream (SLIS).

Below marine limit, ranging from about 185 m ASL near Québec City to about 140 m ASL near RDL, a distance of 200 km, mega-scale glacial lineations (MGSL) produced by the northeast-trending SLIS are partly preserved in spite of strong erosion and reworking along the Goldthwait Sea paleoshorelines. Above marine limit, all types of lineations (MGSL, megaflutings and flutings) produced by the ice stream can be observed on the LiDAR images. Near Saint-André-Station, fast ice flow indicators including hundreds of NE and ENE oriented “crag and tail” features as well as curvilinear troughs winding between bedrock ridges and knobs can be observed. At Saint-Joseph-de-Kamouraska, river entrenchment through the MGSL terrain indicates that the till thickness reaches as much as 25 m in the uplands affected by the SLIS. The combination of LiDAR and SRTM (Shuttle Radar Topography Mission) data allows us to map features along the southeastern half of the SLIS as well as in the adjacent zone of ice-flow reversal in the Appalachian Uplands. While one of the most significant difficulties of the project remains to identify glacial landforms and sediments buried under the marine sediment cover, the LiDAR survey allows us to accurately delineate and identify Quaternary units in forested areas as well as in open fields. Below marine limit, a series of cone penetrometer tests (CPT) allows us to establish the depth of the marine sediment basins between the Kamouraska quartzite ridges and to characterize the main physical properties of these sediments.

WATER STORAGE CHANGES IN GLACIAL LAKE AGASSIZ, WHEN, WHERE, HOW; BUT MOSTLY WHEN

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The history of glacial Lake Agassiz and the deglaciation of the North American Midcontinent are closely intertwined. Lake Agassiz formed portions of the southern margin of the Laurentide Ice
Sheet from \textasciitilde14.1 to 8.2 ka as it trapped large volumes of meltwater. Drainage from Glacial Lake Agassiz has been implicated as a trigger of abrupt climate change during that time interval. However, the routing and timing of drainage from Lake Agassiz has been poorly constrained. Transitions between shoreline positions can indicate significant changes in water storage within the basin, but ultimately, the configuration of the southern margin of the Laurentide Ice Sheet over time will determine the timing and sequencing of active outflow pathways. However, storage volume changes could be influenced by factors other than drainage. This report will summarize a growing chronologic data set for beach ridge

**QUATERNARY STRATIGRAPHY, GEOPHYSICS AND HYDROGEOLOGY OF THE GROUNDBIRCH PALEOVALLEY, NORTHEAST BRITISH COLUMBIA**

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The Groundbirch paleovalley is a large buried valley system located in the foothills of northeast British Columbia west of Dawson Creek. Although only minor streams occur today in the area of the buried valley, a large preglacial river system flowing eastward from the Rocky Mountains was likely responsible for the original formation of the valley. Deeply buried aquifers within the paleovalley provide a significant source of drinking water for people living in the area as well as for livestock. Increasing pressure on the groundwater supply in the region has resulted from the widespread expansion of hydraulic fracturing operations to extract natural gas from the prolific Montney Formation. The Quaternary geology, hydrogeology and geophysical characteristics (in particular resistivity and gamma) of the paleovalley are investigated here using sonic and geotechnical drill data and time-domain electromagnetics (TEM). In the area investigated, the paleovalley is confined to the north and south by bedrock-controlled ridges. The Quaternary stratigraphy consists of a lowermost sand and gravel unit that is expected to be a potential major aquifer in the region. These old fluvial sediments are overlain by a thick package of glaciolacustrine sediments that were deposited in Glacial Lake Mathews when the valley was dammed by the Laurentide Ice Sheet advancing from the east in the Late Wisconsinan. These sediments generally coarsen upward and are locally overlain by glaciofluvial sand and gravel and a complex sequence of glacial diamicts that include ice-marginal debris flows and subglacial till. The glaciofluvial deposits host relatively shallow aquifers that are widely used as a potable water source by local ranchers. These aquifers were encountered in two of three sonic holes drilled during this study and are capable of producing significant volumes of fresh water. The capping Quaternary sediments in the paleovalley are a fining-up sequence of glaciolacustrine sand, silt and clay deposited in Glacial Lake Peace during the final retreat of the Laurentide Ice Sheet. By the time that Glacial Lake Peace drained, the paleovalley-fill was substantial and no
significant river system was re-established in the valley. Major rivers such as the Murray and Pine now flow northward into the Peace River leaving the Groundbirch valley without any large east-draining river system.

In this paper we compare the paleovalley stratigraphy determined from a sonic drilling program with the results of the ground-based TEM (Geonics EM-47) survey. In general, inversions using Interpex 1D inversion software agree well with the drilling results and suggest that TEM can be a very useful tool for regional aquifer mapping. In addition, a high resolution reflection seismic survey was recently carried out over the same area and is presently being integrated with the TEM and borehole data.

Special instructions / comments: I left this abstract in a general session, but it could potentially be considered for the 3D modelling or geophysical techniques sessions.

UNDERSTANDING THE HOLOCENE CLOSED-BASIN PHASES (LOWSTANDS) OF THE LAURENTIAN GREAT LAKES AND THEIR SIGNIFICANCE

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The Laurentian Great Lakes are a chain of five large water bodies and connecting rivers that constitute the headwaters of the St. Lawrence River. Collectively they form one of the largest reservoirs of surface freshwater on the planet with an aggregate volume of >22,000 km$^3$. The predecessor Late Wisconsinan glacial lakes formed with retreat of the Laurentide Ice Sheet and have been intensively studied and reconstructed since the late 1800s and during the first half of the 20$^{th}$ century. Shore features of the reconstructed lakes were traced over long distances to reveal moraines of similar age, and so the shorelines were a significant element in mapping ice margins and deciphering the pattern of deglaciation before the advent of radiocarbon dating. Quaternary studies of geomorphology and surficial geology during the second half of the century have placed glacial retreat and glacial lake history into a consistent and absolute time frame.

Early efforts to extend the lake history through the Holocene used a paradigm of interpretation that all lakes overflowed their outlet sills, just as the Great Lakes do today. The few indicators of past water levels lower than present were either ignored or explained by previously lower lake outlets owing to differential depression of Earth’s crust by the load of the previous ice sheet. In the 1990s, a major study of coastal and offshore Lake Winnipeg led to the conclusion that that lake had dried up for millennia during the Early to Mid-Holocene because of a lack of water supply in a dry climate. This finding led to re-evaluation of the Great Lakes water-level history. Using elements of the Lake Winnipeg synthesis and the empirical information of glacioisostatic rebound derived from $^{14}$C-dated and upilted Great Lake paleo-shorelines, a method of computation was developed to test and disprove the paradigm of continuous lake overflow.
With this tool which evaluated site and outlet uplift independently, many indicators of low-water levels such as submerged tree stumps rooted beneath the present Great Lakes were found to be lower than the lowest possible corresponding basin outlet.

Sedimentary investigations and comparison of the original elevations of water level indicators and basin outlet sills during the last decade confirmed the low-level, closed-basin hydrological status of the early Great Lakes. This status was consistent with paleoclimatic inferences of aridity during the Early Holocene before establishment of the present patterns of atmospheric circulation which now bring adequate precipitation to maintain the overflowing lakes. In a sense, the Early to Mid-Holocene phase of dry climate and low water levels, is a natural experiment to illustrate the sensitivity of the Great Lakes to climate change in this era of global warming, should their climate shift to one much drier than present.

LINKING HUDSON BAY SUBGLACIAL MELTWATER AT THE TIME OF THE ATLANTIC HEINRICH 1 EVENT WITH A MELTWATER FLOOD EVENT IN THE GULF OF MEXICO ABOUT 13.5 ka (16.2 cal ka)

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The Heinrich 1 event about 14–13 ka (~17-15 cal ka) which discharged meltwater plumes with detrital carbonate from Hudson Strait to Labrador Sea and icebergs throughout the North Atlantic Ocean led to instability in the Laurentide Ice Sheet with accelerated movements of ice and subglacial meltwater. Sediments deposited between 14.4 and 13.6 ka in the Finger Lakes area of New York State from meltwater moving southward from Hudson Bay beneath the ice across the Lake Ontario basin have been related to this event by Mullins et al. (1996, Geological Society of America Special Paper 311: 1–35). N-S drumlins inferred to be associated with the southward flows are truncated along a WSW trend south of Lake Ontario, suggesting diversion of the ice and meltwater flows WSW along the deep lake axis as the moving ice cover thinned.

Lakebed relief in deep eastern Lake Ontario is dominated by WSW-trending ridges. Interpretation of multibeam sonar and seismic reflection surveys showed that individual ridge features were drumlins. Incoherent internal reflections characterize the drumlin material, and a piston core which recovered stony, sandy diamicton (till) confirmed the glacial origin of the relief-forming ridges, not faulted or glacially-scoured bedrock as in some previous interpretations. The till is absent in places between ridges, suggesting the drumlins were formed by erosion from a former till sheet. Erosion of drumlins by horizontal vortices in turbulent meltwater flow is suggested by narrow furrows that wrap around their upstream (ENE) ends and sides.

South of central Lake Ontario, a land-based digital elevation model revealed drumlins in the same orientation, suggesting the erosive ice and meltwater flows continued WSW into the northern part of the eastern Lake Erie basin where seismic profiles and a borehole at the tip of
Long Point, Ontario revealed an absence of till, unusual for the region, except for thin remnants, with glaciolacustrine sediments resting directly on bedrock. We suggest removal of the till by the WSW ice and meltwater flows. The till removal appears to extend to the cross-lake Norfolk Moraine between the base of Long Point and Erie, Pennsylvania, the LIS margin at 13.5 ka (Dyke et al. 2003, GSC Open File 1574). Borehole sediment ages indicate the glaciolacustrine sedimentation following till removal began prior to 13 ka. An extensive cover of till remains atop a 45m-high bedrock escarpment in the southern part of the eastern Erie basin, suggesting an ice cover was pinned there, protecting it from the erosive subglacial flows.

Excess meltwater would have continued westward from the ice margin into the Maumee or Arkona glacial lakes which existed between approximately 13.8 and 13.4 ka in central and western Erie and southern Huron basins. These lakes with the excess meltwater discharged to the Mississippi drainage and the Gulf of Mexico where a meltwater spike had been detected as ‘MeltWater Flood 2’ dated between 13.6 and 13.4 ka with a flux of 4600 km3.yr-1, nearly twice the Mississippi baseline discharge at the time (Aharon 2003, Paleoceanography 18: 1079).

TRIGGER MECHANISMS FOR RE-ADVANCE OF THE NEWFOUNDLAND ICE CAP DURING THE YOUNGER DRYAS

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The Ten Mile Lake Moraine is the only known re-advance moraine of Younger Dryas age in Newfoundland. It is a continuous end moraine, 10-30 m high, 60-70 miles long, located on the Great Northern Peninsula of Newfoundland. It is a bifurcate moraine, with the main segment being a semicircular embankment. A pair and triplet of ridges extend from this to the southwest and northeast, respectively. Yet, the trigger mechanism of the formation is not clear.

D.R. Grant argued that Ten Mile Lake Moraine was the result of re-advance of the Newfoundland Ice Cap in response to climate cooling during the Younger Dryas. This hypothesis was based on two main pieces of evidence. Radiocarbon dating of shells from the moraine yielded ages of 11,000 +/- 160 BP (GSC-1324) and 10,900 +/- 160 BP (GSC-1277), taken to be the earliest time the ice sheet could have re-advanced. A complete shell found on the tip of the moraine, dated as 10,100 +/- 160 BP (GSC-1270), was believed formed after the re-advance. This evidence places the time of moraine formation around the Younger Dryas. Pollen records and lake sediments from Atlantic Canada place the Younger Dryas as being from 10,830 BP to 10,000 BP. Grant’s sea level curve, reconstructed from the discontinues marine limit, indicates a “stillstand” contemporaneous with the Newfoundland Ice Cap re-advance. This was taken to be the geoidal response of the sea surface to the enhanced gravitational attraction of the ice sheet.
However, if the ice cap re-advance was indeed a response to climate cooling we might expect to find other re-advance moraines in Newfoundland. New shell samples from glacial diamicton positioned in front of the moraine date to 11,710+/-25 BP (ULA-1388) and 11335+/-25 BP (ULA-1389), while another from diamicton behind the moraine dates to 11,335+/-25 BP (ULA-1389). Together these provide an estimate of the earliest date of moraine formation. The latest estimate for its time of formation comes from a shell taken from undisturbed marine unit atop the moraine, dated to 9835+/-25 BP (ULA-1386). Furthermore, other sea level reconstructions from nearby areas disagree with Grant’s sea level curve. Relative sea level curves reconstructed from Pinware in Labrador, Bellburns, Bay of Islands, St. George’s Bay, and Port au Choix indicate a continuous falling sea level during the ice cap re-advance. This might because that a mechanical adjustment of the ice cap to over steepening because of rapid calving was not able to balance the crust rebound during deglaciation, instead of gaining extra mass result from climate cooling re-advance.

RECONSTRUCTION OF A PALEO-SUBGLACIAL LAKE NETWORK IN ALBERTA, CANADA

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There are hundreds of reported and thousands of predicted subglacial lakes beneath the Antarctic and Greenland ice sheets, and they comprise a significant component of the subglacial hydrological system (Wright & Siegert, 2011). However, their investigation is largely limited to contemporary ice masses despite critical information that could be gleaned from palaeo-subglacial lake studies, including: (i) their influence on meltwater drainage, ice flow and ice streams; (ii) details about how they relate to palaeo-floods, ice dynamics and sub-Milankovitch-scale climate events; and (iii) as archives of long-term Quaternary climate change. They are also readily available, we can sample the sediments and map the landforms with ease and we have comprehensive information on the lake-bed properties.

Palaeo-subglacial lakes are widely predicted beneath the former Laurentide Ice Sheet (Livingstone et al., 2013), but investigation of their geological signature and drainage pathways are rare. Here we present the discovery of a spatially extensive network of palaeo-subglacial lakes and their drainage channels in the foothills of central Alberta, western Canada, at the suture zone of the former Cordilleran and Laurentide ice sheets. Our observations, from geophysical, geomorphological and sediment data, have allowed us to determine the mode and style of lake drainage events and to characterise the sedimentary archive left by the lakes. The palaeo-subglacial lakes comprised shallow (< 10 m) lenses of water perched behind ridges orientated transverse to ice flow. We show that they repeatedly drained through 200-300 m wide by 4-10 m deep channels incised into sediment. The channels are typically < 2 km long or trend into eskers, indicating a downstream evolution into channels cut up into the overlying ice.
The network of subglacial lakes and channels are formed on top of glacial lineations, which implies that shut-down of fast ice-flow was linked to a significant hydrological re-organisation.

YOUNGER DRYAS GLACIER READVANCE IN THE CASSIAR MOUNTAINS, NORTHERN BRITISH COLUMBIA, CONSTRAINED BY Be-10 EXPOSURE DATING

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The Tuya volcanic field in the Cassiar Mountains preserves a record of a Middle Pleistocene Cordilleran Ice Sheet (CIS) glaciation. During the last glaciation, the ice divides, separating ice flow to the SW, NW, and NE, converged over the Cassiar Mountains and this area is thus important for understanding the history of CIS growth and retreat over the Pleistocene. The glacial geomorphological record indicates a complex deglaciation history for the Cassiar Mountains. The pattern of glacial meltwater landforms records a gradual ice retreat across the mountain plateaux to the west, towards the northern Coast Mountains. In contrast, moraines evidence large trunk glaciers, but also a readvance of small valley glaciers and an outlet glacier draining a local icefield in the Cassiar Mountains.

We have applied Be-10 exposure dating of glacial boulders in the Tuya-Teslin area to constrain its glacial history and specifically to determine the timing of glacier readvances recorded in the landform record. Two moraines have been sampled: one at Aconitum Lake formed by a large trunk glacier in the broad Jennings River valley that blocked a tributary valley. The other moraine is located southeast of Tuya Lake, and it consists of two sharp-crested ridges and documents a glacier lobe emanating from the Cassiar Mountains. We have further sampled two glacial erratics at the summit above the Tuya Lake moraine. These two erratics date to 43 ka with tightly overlapping ages. We interpret these as having been deposited during an earlier glaciation and having been preserved under, and shielded from cosmic rays by, non-erosive ice cover during the last glaciation. In contrast, twelve samples collected from the moraines (3 from Aconitum, 4 from inner Tuya and 5 from outer Tuya) all yield younger ages. On the Aconitum moraine, two ages date to 10 and 11 ka, and one, which we interpret as an outlier due to prior exposure, to 17 ka. The two crests of the Tuya Lake moraine do not display any apparent age difference. Whereas apparent exposure ages of six samples cluster tightly at 10-11 ka, only three show inheritance. While the ages might be subject to some change when corrected for the effects of snow cover and erosion, we are confident that the sampled moraines originate from the Late Glacial and are probably a record of colder climates during the Younger Dryas chronozone. Our results therefore indicate that the readvance of mountain glaciers, which has been reported also from other areas of British Columbia, and which occurred while some trunk valleys were still occupied by the retreating CIS, most likely dates to the Younger Dryas. Locally, even larger ice bodies, such as the icefield in the Cassiar Mountains, appear to have been rejuvenated at this time. Our results from the Cassiar Mountains thus help
to paint a coherent picture across southern and northern British Columbia with reconstructed last readvance of Cordilleran ice dated to the Younger Dryas.

‘TRACTION RIBS’ ON THE PALEO-ICE STREAM TRACKS OF THE INTERIOR PLAINS

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Spatially distinct pattern of basal shear stress beneath a number of Antarctic and Greenlandic ice streams has recently been discovered by inverse methods using high resolution data of ice velocity, elevation and thickness. Surrounded by regions of near-zero basal shear stress, these areas of high basal shear stress have been termed ‘traction ribs’ and hold important implications for the force balance of ice streams. The cause of the traction ribs is unknown (i.e. whether they have a topographic expression), but their horizontal dimensions and pattern lie somewhere between typical ribbed (Rogen) moraines and recently described mega-scale ribbed moraines identified on palaeo-ice sheet beds. However, whilst both of these landform types form with their long axis transverse to the ice flow direction, the traction ribs are most commonly oriented oblique to the ice flow at angles of 30-60 degrees. Here, we report new findings from the beds of palaeo-ice streams on the Interior Plains in Alberta and Saskatchewan where landform assemblages, similar to traction ribs, occur at several sites. Individual landforms at the mapped sites have typical lengths (transverse to flow) of 5-10 km, width of ~2 km, and their spacing is ~2-3 km. As such, they appear to represent an intermediate scale of ribbed landform that overlaps with the more extreme (larger) values of classic ribbed moraine and the smaller values of mega-ribs. Unlike mega-ribs and ribbed moraines, we also note that many of the ribbed features we mapped are aligned obliquely to ice flow direction at angles and mimic the arcuate patterns of traction ribs seen under modern ice streams. Profiles across the ridges indicate that they have amplitudes of 10-15 m, which is comparable, but slightly lower than the mean value for ribbed moraines. The resemblance of our newly mapped features to the traction ribs of modern ice streams is close not only in the size and shape but also in the overall pattern of the whole landform assemblage. We therefore suggest that traction ribs have a topographic expression that sits on a continuum between ribbed moraine and mega-ribs. However, it is not clear which mechanisms lead to their formation or how widespread they are on other palaeo-ice stream beds. Future work might search for these landforms and their assemblages using higher resolution DEMs and fieldwork would allow sedimentological investigation of till properties and characteristics.
UPDATED QUATERNARY GEOLOGY MAPPING AND LANDSCAPE INTERPRETATION OF THE LINDSAY AND PETERBOROUGH AREAS OF SOUTHERN ONTARIO

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Ongoing urban development in southern Ontario has led to the increased need for high quality geological mapping for land-use planning, groundwater resource management and other geological applications. In order to fill this data gap, the Ontario Geological Survey undertook a two year, detailed Quaternary geology mapping project of the Lindsay (NTS 31 D/7) and Peterborough (NTS 31 D/8) 1:50 000 map areas; an area previously mapped in the late 1950’s at a scale of 1:126 720. New, higher resolution aerial photography, digital elevation models (DEMs), and increased access to natural and man-made exposures of surficial sediments has enabled the production of more detailed Quaternary geology maps.

The landscape of the Lindsay and Peterborough areas was shaped primarily during the last glaciation beginning approximately 20 000 to 25 000 years ago. Glacial ice, originating from the north to northeast, extended south of the current study area and generated a suite of landforms within the map area. The final stage of deglaciation was marked by widespread ice stagnation and subsequent modification of landforms by meltwater and glaciolacustrine processes.

The study area contains world-class examples of landforms representing the various stages of glaciation. These include the drumlins of the Peterborough drumlin field, large esker systems, tunnel valleys, ice-marginal and hummocky moraines, and shoreline features. Examples of these landforms, including a discussion of their morphology, internal composition, and genesis will be presented.

Drumlins are the dominant landform type in the study area and exhibit various morphologies, from asymmetrical mounds, to the classic streamlined form, to very thin, highly elongated spindle-like features. In addition, some drumlins appear to be superimposed on top of one another, or may be conglomerations of several features. The drumlins are composed primarily of Newmarket Till, a stone-poor silty to sandy diamicton, containing pockets of sorted sands and gravels. The surfaces of the drumlins are commonly draped by several centimeters of fine-textured glaciofluvial sand.

Several large esker systems were identified, and they commonly occupy tunnel valleys. An excellent example is the Omemee esker, whose branches range from 8-13 km in length, and extend up to 23 m higher than the surrounding landscape. The predominant orientation of these esker systems suggests southwestward meltwater flow. The tunnel valley dimensions range from several metres to multiple kilometres in length.

The final stages of glaciation are recorded by a large area of hummocky moraine in the northeast as well as discontinuous glaciolacustrine deposits throughout the study area. The hummocks are composed primarily of stony, silty to sandy Dummer Till. Clasts within the till are highly angular, and are dominated by local bedrock lithologies, indicating short transport distance, followed by in situ melt-out. Both Newmarket and Dummer tills were identified in recessional and terminal moraines in the northern part of the study area.
Meltwater discharge from Glacial Lake Algonquin traversed the study area generating fluvial and wave-cut terraces. These landforms provide insight into late-glacial water levels and drainage within the study area.

CONFIGURATION AND TIMING OF GLACIAL LAKE NASKAUPI IN THE SOUTHEASTERN UNGAVA BAY REGION

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Deglaciation of the Labrador sector of the Laurentide ice sheet was complex and led to the development of large ice-dammed lakes that were confined within river valleys draining northward into Ungava Bay. The evolution of these lakes was strongly influenced by the late-glacial dynamic, but some uncertainties regarding the ice retreat pattern currently limit paleogeographic reconstructions. In the southeastern Ungava lowlands, glacial lake Naskaupi invaded the George River valley, leaving extensive boulder beaches and raised deltas. Previous studies carried out in the 1950-60s have focused on the most developed shorelines present in two key sectors separated by more than 150 km, the Pyramids Hills and Indian House lake areas. These discontinuous shorelines were associated with a single water plane that extended across the main George River valley and into its tributaries. In spite of limited means, 1 to 5 Naskaupi lake levels (N1-N5) were identified. These long-held reconstructions, however, do not integrate the influence (and position) of the retreating ice margin, which likely played a significant role on the configuration of the lake. Here we present 120 elevation measurements of boulder beaches from 75 sites covering a 175 km-long segment along the George River and its surroundings. The results indicate that the so-called N2 Naskaupi shoreline, which supposedly marks the most extensive lake phase, cannot be correlated across the George River valley. Our measurements point towards a lake invasion consisting of two main basins that were separated by about 30 km. Our shoreline elevation data further indicate that most tributary basins located to the east of the George River hosted independent meltwater bodies during a significant part of the deglaciation. Recent field investigations and systematic mapping of Quaternary deposits further show significant variations in the spatial distribution of the main deglacial landform assemblages across the region. Several sectors along the George River and the region to the east are characterized by extensive felsenmeer and thick (local) ground moraine that likely reflect the presence of residual ice masses or the persistence of cold-based ice conditions during the deglaciation. Elsewhere, the terrains show numerous ice-marginal meltwater channels that typically mark the ice retreat in the region. This regional pattern of ice
retreat undoubtedly played a key control on the configuration of Lake Naskaupi, notably through relict ice masses isolating sub-basins in the George River valley and damming the main tributary river valleys. The presence of spillway channels, deeply incised gorges in bedrock and areas of scoured (sediment-stripped) bedrock surfaces suggest that the main and tributary basins interacted closely at various moments during the deglaciation. Furthermore, one sector shows jökulhlaup-type deposits consisting of a thick (25 m) accumulation of imbricated meter-size boulders and mega-size sand ripples that record a sudden and massive meltwater discharge that is likely related to the drainage of the main Naskaupi basin. Cosmogenic dating (10Be) was also applied to Naskaupi deposits to constrain the glacial lake invasion and to provide insights on the chronology of the ice retreat of the Labrador sector eastern margin.

PALYNOLOGY AND PALEOECOLOGY AT KILGII GWAAY: AN EARLIEST HOLOCENE ARCHAEOLOGICAL SITE, SOUTHERN HAIDA GWAI I

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Buried pond sediments at the intertidal Kilgii Gwaay archaeological site on Ellen Island in Gwaii Haanas National Park were analyzed palynologically to produce a high-resolution record of postglacial vegetation changes during late glacial and early Holocene time. The time of human occupation around 10,700 cal yr BP makes Kilgii Gwaay, interpreted as a summer hunting and fishing camp, one of the oldest sites on the BC coast with demonstrably strong maritime adaptations.

Seven AMS radiocarbon dates on plant macrofossils from the peaty sediment core were used to generate a chronology spanning the period 14,470-10,870 cal yr BP. Four local pollen zones are defined, showing transitions from early herb-shrub tundra beginning at 14,510 cal yr BP to a pine-dominated forest by 14,000 cal yr BP. Taxa such as Salix, Cyperaceae, Ericales, and Poaceae dominate the tundra zone, along with a variety of rarer herbaceous taxa including Abronia latifolia, Asteraceae, Campanula, and Polygonum bistorta. The presence of planktonic Pediastrum algae indicates fresh water conditions.

Pine is largely replaced by spruce 13,290 cal yr BP, followed by establishment of Western Hemlock 12,420 cal yr BP. Changes in vegetation assemblages and stratigraphy may indicate cooling associated with the Younger Dryas event. Presence of foraminiferal linings as well as macroscopic shell fragments in the upper portion of the core confirm marine transgression of the site around 10,630 cal yr BP due to postglacially rising eustatic sea level combined with crustal forebulge collapse.

Analysis of fossil charcoal (particles greater than 100 micrometres) in the pond sediments reveals peak abundances during the century-long known occupation of Kilgii Gwaay (ca 10,680–10,780 cal yr BP). Artifacts are common along the pond edge adjacent to the coring site, confirming human presence and local use of fires during this time. Charcoal presence at this site is thus interpreted as a proxy for human presence in this hypermaritime environment where natural fires are very rare or absent. Charcoal is continuously present below the known
Kilgii Gwaay occupation horizon, indicating probable human presence at the pond as early as 11,500 cal yr BP, approximately 800 years earlier than previously documented. Charcoal was not identified in basal core samples below 11,500 cal yr BP.

PALAEO-ICE SHEET RECONSTRUCTION OF THE FORMER NEWFOUNDLAND ICE SHEET, USING THE GLACIAL LANDFORM RECORD AND COSMOGENIC EXPOSURE DATING.

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The former Newfoundland Ice Sheet was situated on the fringes of the northwest Atlantic Ocean and the Laurentide Ice Sheet (LIS) during the last glaciation. This location suggests Newfoundland is a key location for examining ice sheet response to a number of internal and external forcing mechanisms, including configuration changes in the LIS, ice stream activity, changes in oceanic and atmospheric circulation and fluctuating sea levels. An established approach used to reconstruct former ice sheets is to use a remote sensing approach to map the glacial geomorphology. Analysis of this record can be used to decipher the dynamics, extent, retreat patterns and configuration changes of the ice sheet throughout its evolution. Here we present new mapping based on our interpretation of SPOT satellite imagery and digital elevation models across Newfoundland as well as swath bathymetry from several locations offshore. Our new database consisting of ~150,000 individually mapped subglacial bedforms which includes glacial lineations and ribbed moraines significantly increases the known landform record in this region. We illustrate how this data is being used to reconstruct this ice sheet using flowset analysis to separate discrete ice flow patterns into snapshots of ice sheet behaviour through time. Although this technique provides a relative chronology of ice sheet events, if we are to accurately explore former ice sheet variability and investigate links between ice-sheet fluctuations established by this mapping programme greater radiometric control of ice-sheet events is required. To facilitate this we report forty new cosmogenic exposure ages (10Be and 36Cl) from several sites around southeast Newfoundland. We aim to combine these new exposure ages, allowing direct dating of ice retreat, with any existing and available cosmogenic records to help temporally constrain the ice sheet reconstruction using this newly mapped landform record.
A PALEOENVIRONMENTAL AND PALEOGEOGRAPHIC RECONSTRUCTION OF THE TERMINAL ARCHAIC - WOODLAND BOSWELL SITE, KINGSTON, NOVA SCOTIA

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The Boswell archaeological site is located near Kingston, Nova Scotia on farmland next to the Annapolis River. Despite being the area of earliest European occupation in Canada, very little is known about Pre-Contact occupation along the Annapolis River drainage system. This has long puzzled local archaeologists, as the Annapolis River is an obvious travel route to the interior, and a large (2130 km²) watershed rich in plant and animal resources. However, in 2009 artifacts were found at the location that has subsequently revealed a complex history of site development. Excavations at the site have uncovered potsherds, lithics and ecofacts which collectively indicate Terminal Archaic to Late Woodland occupation. Ecofacts from the site suggest that beaver hunting and fishing took place, along with the collection of various edible berries and nuts. Although the site was likely intermittently occupied from the Terminal Archaic to the Late Woodland (ca. 3800 -1000 BP), the environmental and ecological conditions which made this location appealing for native occupants are unknown.

High resolution paleoenvironmental data from wetland and lake records in southwestern Nova Scotia indicate that at about 3000 BP forest composition changed rapidly as cooler and moister conditions developed. At this time hemlock became a more significant component of the forest cover in the region. From 3000 BP till 1000 BP, cool and moist conditions were punctuated by occasional droughts. The Boswell site is located on one of the few reaches of the Annapolis River that experienced little lateral migration in the last 3000 years, a condition which facilitated site preservation. The river terrace at the excavation site was formed by 3000 BP in response to both an increase in river discharge and a prominent bedrock sill which aided sediment aggradation. A prominent depression in the sill about 20 m upriver from the site has created one of the few large, deep (>3m) pools along the stable reach of the river and may have been a harvesting site for migrating fish species including shad, alewife, brook trout and smelt all of which were thought to be important resources.

Collectively, forest composition, which aided in bank stability, increased river flow which facilitated fish occupation and migration, bank stability and the presence of a harvesting site nearby may have made this site desirable for continued seasonal use over a long period of time. Recent erosion at the site appears related to development both upstream and downstream from the Boswell site.
TECHNOLOGICAL ADVANCES AT THE LALONDE AMS RADIOCARBON SAMPLE PREPARATION LABORATORY, OTTAWA, ON

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The Lalonde AMS system was commissioned in early 2014 at the Advanced Research Complex, University of Ottawa and includes a new radiocarbon laboratory with state-of-the-art equipment designed to streamline sample processing, handle smaller samples, reduce the potential for operator error and maximize throughput. Here we present a description of this equipment, highlighting some of the fully-automated systems designed and built in-house for sample combustion/hydrolysis, CO₂ cleanup and graphitization. Pressure/temperature monitoring and automation make the sample preparation process operator-insensitive, allowing us to provide involvement and training for students who wish to prepare their own samples. Since its inauguration, the radiocarbon sample preparation laboratory has successfully completed a quality control program and has been routinely analyzing collagen containing material (bone, antler, tusk), cellulose (wood), carbonates, and organic materials (sediment, peat). A review of standard, blank, IAEA, and international radiocarbon comparison (SIRI) samples is discussed, as well as an overview of the ongoing projects and other techniques in development, such as extraction of CO₂ from waters and gases. Future work includes pushing conventional limits to analyze smaller samples, including the implementation of a direct CO₂ gas source for ultra-small (low microgram-level) samples.

COMPARISONS BETWEEN MACRO- AND MICROFABRICS IN A PEBBLE-RICH, SANDY TILL DEPOSITED BY THE CORDILLERAN ICE SHEET

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It is standard practice to measure particle fabrics in glacial studies to infer palaeo-ice flow directions and processes of till formation but few studies examine the relationships between particle fabrics at different (i.e. the macro- and micro-) scales. This knowledge is critical to inform the utility of the methods and limitations of the associated interpretations. Micro- (sand grain) and macro- (pebble) fabrics of pebble-rich, sandy subglacial till (Kamloops Lake till) deposited by the Cordilleran Ice Sheet, south-central British Columbia, were compared to assess their similarities and differences, and therefore their utility for understanding subglacial processes. Before comparisons were made, the data were tested for robustness by assessing various controls (e.g. sampling face orientation, number of particles measured, statistical
variation resulting from sampling effects, particle shape, size and concentration) on particle fabrics. A new method of microfabric analysis was applied that involves the identification and delineation of distinct clusters of similarly orientated sand grains in order to compare them with macrofabrics and inferred ice-flow directions. The results show that microfabrics, on their own, are an unreliable indicator of ice-flow direction in Kamloops Lake till in the study area and should not be used as a substitute for macrofabric data, as they probably record late-stage microscale strain patterns and pore-water flow in addition to till deposition and deformation by overriding ice. We suspect that this would also be the case for coarse-grained till elsewhere. Our findings suggest that till microfabric interpretations should always be made after assessing corresponding macrofabric data alongside sedimentological and structural observations.

TOWARD A CHRONOLOGY FOR CLAM GARDEN CONSTRUCTION ON QUADRA ISLAND, BRITISH COLUMBIA, CANADA

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This study explores the feasibility of constraining the time of clam garden construction on Quadra Island, British Columbia using optical dating. Clam gardens are walled intertidal terraces that were constructed by First Nations communities to increase bivalve habitat and productivity. These features are evidence of ancient shellfish mariculture on the Northwest Coast of North America, dating back to at least 1000 years ago. Optical dating exploits the luminescence signals of quartz or feldspar minerals, as sand grains or in cobbles, to determine the last time they were exposed to sunlight (i.e., their burial age). In the summers of 2014 and 2015, samples were collected from below three clam garden walls in Small Inlet. Vertically-oriented ~1 m core samples were also obtained from the sediment infill behind the walls in order to see if fluctuations in sedimentation rates are recorded in down-core trends in luminescence signal brightness. Optical age information from these samples, as well as radiocarbon ages from clams and barnacles at the same sites will be used to develop a new protocol to constrain the time of clam wall construction.

RECONSTRUCTING POSTGLACIAL LANDSCAPE EVOLUTION FOLLOWING THE DRAINAGE OF GLACIAL LAKE MCCONNELL, NWT, CANADA: INSIGHTS FROM BIOLOGICAL PROXY DATA

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Reconstructions of meltwater routing following the retreat of the Laurentide Ice Sheet, 10,000-8,000 cal BP, include a significant northwest drainage outlet for glacial Lake Agassiz, via glacial Lake McConnell, into the Arctic Ocean. In the Great Slave Lowlands of the central Northwest Territories, clay-rich sediments from glacial Lake McConnell are widespread and commonly overlain by silty and sandy sediments derived from ancestral Great Slave Lake and its inflow streams. Despite the regional significance of this proglacial lake, limited palaeoecological knowledge exists, and few studies extend back to the early postglacial period. Knowledge of the timing and character of the final phases of proglacial lakes and the impact of sudden changes in lake discharge on regional vegetation dynamics thus remain poorly understood. To address these issues, a series of peat and lake sediment cores were collected from the Great Slave region. High-resolution analysis of pollen and sub-fossil chironomids, combined with radiocarbon dating, constrain the timing and nature of palaeoenvironmental changes associated with the later stages of lake sedimentation, vegetation colonisation and peatland initiation.

In this paper, we present palynological data from two peatland sites and chironomid data from one small lake. White Truck bog (informal name) and Cameron River bog are both situated within the maximum extent of glacial Lake McConnell, and Matthew’s Lake is located ca. 200 km beyond the former glacial lake limits. The peat cores show an abrupt transition from fine grained minerogenic sediments at White Truck bog and sandy facies at Cameron River bog to organic sediments. Peat initiation at White Truck bog and Cameron River bog are dated to 7738-7943 cal BP and 6990 – 7134 cal BP, respectively. Betula pollen dominates the base of the pollen record at each site, (60% of the Total Land Pollen), suggesting that dense birch shrub cover prevailed in the earliest phases of peat formation. Both peatland records exhibit evidence of a fen-bog transition with early peaks in Cyperaceae pollen (20-40%) followed by a sharp decline. The palaeoecological record from the two sites also show a number of differences, which likely relate to local variation in hydrological conditions.

The chironomid record from Matthew’s Lake shows that oligotrophic and cold stenothermic taxa prevailed during the earliest phases of clastic sediment deposition with a high species diversity. A transition from fine grained clay to gyttja is dated to 8423-8585 cal BP and correlates with a decline in cold-adapted species and the dominance of Corynocera ambigua. This study aids in understanding the landscape evolution in the Great Slave region, whilst constraining the timing of vegetation colonisation and peatland development following proglacial lake inundation.

DISPERAL TRAINS PRODUCED BY ICE STREAMS: AN EXAMPLE FROM STRANGE LAKE, QUEBEC AND LABRADOR

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Large tracts of northern Canada were impacted by a large number of land-terminating and coastal-terminating palaeo-ice streams during deglaciation of the Laurentide Ice Sheet. In soft-bedded areas, subglacial landforms can be used to map the spatial extent of ice stream tracks (e.g., mega-scale glacial lineations, ice stream shear margin moraines). Over hard-bed areas, the bedform imprint of ice streams is, perhaps, less obvious. However, sediment dispersal trains, coupled with erosive corridors of streamlined terrain, provide a potentially powerful means of identifying ‘hard-bedded’ ice streams. The Strange Lake dispersal train, in northern Quebec and Labrador, has a remarkably linear ribbon-like dispersal pattern trending 40 km down ice (northeast) from a mineralized rare earth element (REE) peralkaline intrusion. The train was originally attributed as a product of a consistent late-Wisconsin regional flow regime. Recent mapping of Laurentide Ice Sheet streams by Margold and others (2015), places the Strange Lake train directly within the Kogaluk River ice stream (IS #187), one of a number of ice streams that operated near the centre of the Labrador dome and drained into the Atlantic Ocean. There are numerous mega-scale glacial lineations (up to 5000 m long, with length:width ratios exceeding 12 and higher) within the mapped dispersal train. The dispersal train shows a remarkable linear consistency with REE element concentrations in till tens of kilometres down ice from the mineral source, a phenomenon similarly observed with the carbonate dispersal trains formed by streaming ice in Nunavut. Thus, whilst drift prospecting methods have traditionally considered long term steady-state ice flow as the primary method for transport of glacial debris from a mineralized source, we argue that changes in glacial erosion, transport distances and diffusion rates are factors that should be considered when mapping and interpreting glacial dispersal trains in palaeo-ice stream corridors.

HUMAN VISIBILITY IN THE MARITIME LANDSCAPE: THE VIEW FROM THE SOIL

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Our research aimed to reconstruct pre-historic fire regimes in three coastal areas of Canadian Maritimes: Kouchibouguac National Park (New Brunswick), Prince Edward Island National Park (PEI), and Kejimkujik National Park (Nova Scotia). The three study areas have a similar forest, but differ drastically in the general geomorphology and soil texture, which could entail differences in the fire frequencies. Reconstruction of past fire regimes was based on radiocarbon dating of the soil charcoal incorporated in uprooting structures. Mass tree
uprooting caused by hurricane-speed winds creates in the soil a specific signature that enables a site-specific reconstruction of past windstorms. Trace fossil analysis of soils in three Maritime National parks revealed the presence of several generations of hurricane-caused tree uprooting structures in each of our 105 study sites. As the hurricanes created an immense amount of woody debris, the debris could be ignited: many paleo-hurricanes were followed by fires. Timing of the past hurricane events was determined by the radiocarbon dating of charcoal associated with coupled hurricane-fire events. In each of our study areas, traces of 13 to 14 coupled hurricane-fire events were recorded for the time period from 300 to 10,000 years ago, with the average frequency of the events peaking in the last millennium. Some of the events occurred simultaneously in all three areas, whereas the others occurred simultaneously in two of the three areas. Simultaneous events occurred in the New Brunswick and PEI lowlands approximately 5000 BC and 2300 BC, in eastern PEI and south-eastern Nova Scotia ~AD 920 and AD 1350. Finally, all three areas were affected by large-scale fires in approximately 2000 BC, AD 1100, AD 1550, and late 1700s. Only one of the peaks coincided with the warm climatic phase. The windstorms were not always followed by fires: prolonged breaks in fires were documented in Kejimkujik and PEI NP areas (e.g., between 2000 BC and 300 BC, and 300 BC and AD 500), whereas in Kouchibouguac the fire occurrence was more regular. In contrast to the peak fire frequencies, the breaks were mainly asynchronous for the three areas, which could be attributed to the absence of human occupation. The synchronous ignition of debris in the areas distanced for hundreds of kilometers most likely reflected the colonization of the area by newcomers: the migration waves of the Early, Middle, and Late Woodland cultures and, later, the Europeans. After AD 900-1000, the fire frequencies increased drastically, reaching an average of 200yrs. In coastal areas, traces of even more frequent fires (every 40-60yrs), not associated with windstorms were recorded. The spread of agriculturalism during the Medieval Warming is well known for more southern areas, but was not confirmed archaeologically in the Canadian Maritimes. The unprecedented synchronous occurrence of fires in all study areas in AD 900-1000, the drastic increase in the fire frequencies after AD 1000, and new finds of specific charcoal-cored concretions (indicators of deforestation) in deposits accumulated during this period can be interpreted as new evidence for the adoption of agriculture in Canadian Maritimes from AD 900-1100 onwards.

MAPPING THE WIND: CITIZEN SCIENCE PROJECT AIMING TO RECONSTRUCT PAST EXTREME WINDSTORMS

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The past extent of extreme windstorms and characteristics of their spatial distribution are poorly understood. The only systematic method of reconstructing paleo-windstorms that is currently utilized for a systematic study is the analysis of sedimentation dynamics in coastal
lakes. This method is not applicable to any inland areas; precise dating of the windstorm events is problematic due to mixing of debris from unrelated sources prior to sedimentation and determination of wind direction/hurricane tracks is impossible. Several auxiliary methods of windstorm reconstruction (markers in corals, speleothems, and tree rings) can be applied either within a short time span, or to a very small set of objects. We developed a protocol of recording traces of the past windstorms by documenting certain parameters of pit-and-mound topography of the forest floor. In forested areas, extreme windstorms cause mass tree uprootings. As the uprooted structures decay and the soil settles down, the displaced soil forms a “pit-and-mound” topography on the forest floor. Thanks to such “wind imprints”, we can read traces of past windstorms by looking at the soil surface, and map past windstorm tracks by plotting the spatial distribution of the uprooting structures. Each tree uprooting structure (TUS) has parameters that allow for determining the direction of tree fall and, hence, prevailing wind direction. Observations on the recent tree uprooting complexes with in situ trunks showed that the TUS shortest dimension was aligned with the wind during the windstorm. Once the trunk is decomposed and the uprooted earth clot has settled down, an asymmetric mound is formed. Its shortest dimension has two unequal sides: the low-angled side has been facing the wind during the tree fall, whereas the higher-angled (steeper and shorter) side has been pointing in the direction of wind. Mapping such “wind vectors” for groups of uprooting structures provides information on the spatial pattern of the tree fall that reflects certain types of wind disturbances (e.g., ‘aligned’ direction of tree fall during hurricanes and extratropical storms, and ‘fan-shaped’ distribution during downbursts). Finally, the lack of pattern (random distribution of tree fall) provides information on post-fire tree uprootings that are caused by low-energy winds. The protocols of the microtopographic analysis are simple and can be accessed by a wide range of participants. The method can be applied to any site that is or has been forested/treed in the past. The approach has been tested in a number of sites in Ontario, Quebec, and the Maritimes where the direction of windstorm tracks was known from historical accounts. Applying the method to a large number of sites would allow for delineation of past windstorm tracks, reconstruction of shifts in their boundaries related to changes in patterns of air circulation, and identification of the windstorm-proneness or susceptibility of sites/landscapes. Mapping past windstorms requires a large number of spatial records, therefore we see Mapping the Wind as a citizen science project, open to and participated by as many interested researchers, citizens, and naturalists as possible.

THE ROLE OF ICE DYNAMICS ON DRIFT DISPERSAL IN THE NEWFOUNDLAND ICE CAP

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Ice streams represent a major uncertainty in our understanding of ice-sheet dynamics and their role in sediment dispersal. Traditionally, approaches used in drift prospecting have considered
normal ice-sheet flow as the primary method for transporting glacial sediment from its source region. Recent research has highlighted, however, that ice streams are linked to well-defined tracks of far-travelled debris. As a result, increased glacial erosion and transportation of glacial sediment must be considered when drift prospecting in areas influenced by ice streaming. To understand how former ice streams affected the dispersal of glacial sediment, down-ice element concentrations in adjacent areas influenced by normal ice-sheet flow and ice stream flow in the Newfoundland Ice Cap (NIC) were compared using till geochemical data.

Models focused on the dispersal of glacial sediment in areas influenced by normal ice-sheet flow demonstrate a negative exponential decay in down-ice element concentration. A large portion (roughly 50%) of the glacial sediment is deposited close to the source region. In areas influenced by ice stream flow, however, conceptual models and limited field evidence suggest that a linear decay in down-ice element concentration would be more appropriate. A higher concentration of glacial sediment can remain in the ice over longer distances due to a combination of englacially entrained sediment and rapid ice flow. Distance-decay curves produced within ice stream footprints in the NIC display a distinct linear decay in down-ice element concentrations. Higher element concentrations persisted 5-10 times longer in ice stream footprints when compared with adjacent areas that experienced normal ice-sheet flow.

A comparative study was conducted to determine whether ice streams in the NIC were capable of eroding and entraining higher concentrations of glacial sediment close to the source region. A bedrock outcrop overlapping both the onset zone of the ice stream footprint and an adjacent area influenced by normal ice-sheet flow was isolated. Higher element concentrations were observed in distance-decay curves produced within the ice stream footprint.

Finally, a wider range of elevated element concentrations should exist within the trunk zone of ice stream footprints due to their convergent onset zones. To investigate, an ice stream footprint with varied bedrock lithology in its onset zone was targeted. At a corresponding distance down-ice, a broader range of elevated element concentrations exists within the trunk zone of the ice stream footprint when compared with an area influenced by normal ice-sheet flow in the NIC.

The occurrence of ice streams in the NIC does not alter the traditional drift prospecting techniques used in areas of normal ice-sheet flow. Results from this study indicate, however, that alternate interpretations of till geochemical data must be made in order to account for modified drift dispersion in areas influenced by ice streaming.

THE HOLOCENE CLIMATIC EVENTS IN THE LABRADOR SEA AND GRAND BANKS

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The retreat and eventual demise of the Laurentide Ice-Sheet paved the way for resumption of the coastal Labrador Current (LC) and formation of the Labrador Sea Water (LSW). It has been hypothesized that the numerous meltwater and sediment discharge events during the Holocene might have curtailed or decelerated both LC and LSW formation. Here we present data that sheds light on the strength of the LC covering the past 11,000 years for the first time from the Labrador Sea and Grand Banks. In addition, we present data about the past strength of LSW formation. The sediment dynamics sortable silt size proxy, in addition to geophysical, marine sedimentological and geochemical data, were used to assess changes in the strength of the LC and LSW formation and source of sediments in three sediment cores on the eastern Canadian continental margin.

Data suggest that the LC abruptly decelerated at 9 ka, 8.4 ka, and 7.7 ka ago, in which the latter two events were tied to the Hudson Strait sediment and meltwater discharges. The connection between the LC deceleration events and LSW formation is not clear due simply to lack of data. However, weakening of the North Atlantic Deep Water (NADW) formation inferred from the central Labrador Sea *Cibicidoides wuellerstorfi* δ¹³C data were associated with the 8.4 ka and 7.7 ka events. We hypothesize, following Thornalley et al. (2009), that an increase in the meltwater discharge in the Labrador Sea oriented the subpolar gyre (SPG) more toward a North-South direction, resulting in weakening of the SPG. The weakening of the SPG reduces the upper limb of the NADW and by extension slows down the Atlantic meridional overturning circulation as inferred from carbon isotopic data from benthic foraminifera in the Labrador Sea and northeast Atlantic Ocean.

GLACIAL HISTORY AND SEA LEVEL CHANGES ON THE MAGDALEN ISLANDS (QUÉBEC, CANADA) DURING THE LATE PLEISTOCENE

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The effects of global sea level rise are exacerbated throughout the maritime provinces of eastern Canada due to subsidence which has followed since deglaciation. Consequently, many coastlines are at risk of submersion and erosion. In order to generate accurate predictions of relative sea level (RSL), it is imperative to understand former glaciation patterns and consequent RSL variations. The Magdalen Islands, located in the centre of the Gulf of St. Lawrence, are likely to have experienced and recorded these phenomena, and to provide an
overview of the glacial history and RSL changes for the Maritime area. This study presents a lithostratigraphic analysis of the Magdalen Islands based on over 50 outcrops. Approximately 70 optically stimulated luminescence (OSL) and 20 14C ages provide a chronostratigraphic framework for the islands for the last ~ 100 ka. Along with sedimentological analyses (clast fabrics, particle size, etc.), the new chronology reveals that at least the southern part of the Magdalen Islands was affected by marine transgressions during Marine Isotopic Stages (MIS) 5 (~current level) and 3 (+ 40 m). During the Last Glacial Maximum (LGM), the archipelago was affected by two ice flows originating from the Escuminac ice cap located in the western Gulf of St. Lawrence, and from Newfoundland. The islands experienced another marine transgression (+ 25 m) from ~18 to ~10 ka following the LGM. These new data also suggest that periglacial conditions and the occurrence of permafrost persisted from MIS 3 through to the Younger Dryas. Finally, 10 infrared stimulated luminescence (IRSL) ages derived from deposits that are partly composed of Precambrian sediments in the northern sector of the archipelago reveal evidence of a marine transgression around 300 ka. This is the only terrestrial evidence for the passage of the Laurentide Ice Sheet in this part of the Gulf of St Lawrence. While terrestrial evidence of the Escuminac and Newfoundland ice caps were observed, no younger evidence of the LIS has been found on the archipelago.

TOWARD A 3-D FRAMEWORK OF SURFICIAL GEOLOGY FOR CANADA

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Increasing pressures on natural resources in the 21st century require reassessment of the geological framework necessary to successfully manage land use planning issues and economic development. In formerly glaciated terrains, surficial sediments commonly host much of the groundwater resources that sustain agriculture, industry, potable water, shallow, low-temperature geothermal systems, and, groundwater is also critical to ecosystem health. There is increasing concern about contamination of shallow potable water from alternative energy developments (e.g. shale gas) and how climate change may impact the availability and quality of groundwater. To address these issues, there is a need to develop a data-driven, 3D framework for surficial geology in Canada, which captures, develops, manages, and disseminates related data and knowledge, including 3D geological models. Notably, to address various jurisdictional responsibilities and to optimize scarce financial and human resources, progress can be most efficiently advanced through inter-governmental and inter-disciplinary collaboration.

The surficial geology of Canada is diverse and has complex stratigraphy. There is variable, intense, land use pressure on surface sediment. It is thus reasonable to assume that no single methodology should be used for mapping surficial geology in 3D, even though
some materials exist across diverse geological settings. Approaches might vary across settings; however, common data and methodological frameworks can be utilized. A common data framework includes a data model covering the breadth of input data and output models, a well-structured science language aligned with national and international standards, development of an appropriate metadata structure, and, the capture of key stratigraphic and ancillary legacy data. A common science framework then includes development of conceptual geological models that are supported by an understanding of the geological processes responsible for the development of individual geological terrains. This will provide the necessary insight to support stratigraphic classifications, which will further facilitate integration of disparate (e.g. geophysical) data, legacy data (e.g., geotechnical logs) and low quality archival data (e.g. water well records).

An approach is presented that builds on parsing the Canadian landscape into distinct geological domains, (e.g., Precambrian Shield, Phanerozoic basins, orogenic belts) each of which is supported by an idealized stratigraphic succession. A workflow is reviewed for 3D mapping with two different approaches to model development based on: i) stratigraphic complexity, ii) sediment thickness, and iii) availability of subsurface data. For large areas of the Canadian Shield with limited subsurface data, a knowledge-driven approach, relying primarily on landforms and surficial mapping, is employed. The approach taken for a 32,000 km² area of the Slave Province in NWT will be previewed. For areas of thicker sediment (i.e., up to 200 m) that have more abundant subsurface information, a data-driven approach is taken. A number of work flows have been employed in mapping areas ranging up to 240,000 km² in southern Canada by academic, private sector, and government agencies. Several of these methods will be reviewed and assessed based on their operational functionality for mapping large areas and multi-jurisdictional operability.

QUATERNARY STRATIGRAPHY AND TILL PROVENANCE ACROSS THE DRUMLINIZED TERRAIN OF THE MCARTHUR RIVER URANIUM MINE AREA IN THE EASTERN ATHABASCA BASIN: PRELIMINARY RESULTS

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The McArthur River uranium mine is located in northern Saskatchewan within a corridor of elongated drumlins and long dispersal trains that have been associated to a major ice stream of the Laurentide Ice Sheet. The high-grade uranium deposit is associated with the intersection of reactivated basement faults and the unconformity between sandstones of the Athabasca Group and the underlying basement rocks. It is located at an approximate depth of 500 m. The alteration footprint extends above the deposit but the depth of the deposit, combined with the complex Quaternary geology, makes it challenging to apply drift prospecting successfully. A new study aims at describing and analyzing the Quaternary stratigraphy and till composition in the vicinity of the mine. One of the main goals is to develop an understanding of till provenance
and production in the study area and to get insights into the potential role of fast-flowing ice, which could have implications for drift prospecting in that and other similar prospective regions.

Erosional ice flow indicators were measured at the few sandstone outcrops and compared to the orientation of drumlins. In addition, more than 70 till samples have been collected to date at several sites across the study area. One section through the side of a large drumlin was studied in detail for stratigraphy. So far, grain size analysis involving dry sieving and laser diffraction, and pebble lithological counts on both the 4-8mm and the >8mm size fractions have been completed. Preliminary results show that the study area contains at least one sub-till fluvial unit consisting of medium to coarse sand with abundant iron and manganese oxides, and the presence of diamicotic clastic dykes provides evidence of subglacial hydro-fracturing. This distinctive unit has also been identified in geotechnical boreholes in another nearby drumlin. Overlying this unit there is a stiff till with a relatively high silt content and proportion of basement clasts. Higher up the stratigraphy, the till sheets become more sandy and increasingly rich in local sandstone lithologies. These hybrid and more ‘local’ tills are widespread at the surface throughout the study area. The basement-rich till and the underlying oxidized sand unit could possibly form the core of many drumlins, but this will need further investigation. From these preliminary results, the sequence of events include 1) a till production event that first brought distal lithologies to the study area, 2) partial erosion and re-entrainment of that till and mixing with local lithologies. Interestingly, the most ‘local’ till is found at the top of the sequence suggesting that the glacier had access, probably in the drumlin swales, to fresh and altered sandstone bedrock. This local till could thus be related to the drumlinization phase and possibly to fast-flowing ice despite its ‘local’ signature in the coarse fractions. CMIC-NSERC Exploration Footprints Network Contribution 049.

CYCLIC LOWERING AND FILLING OF GLACIAL LAKE MISSOULA, MONTANA, USA

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Lowering and filling cycles of late-glacial Pleistocene glacial lakes are mostly understood through stratigraphic and chronologic studies of shorelines in the lake basins, documentation of exposure surfaces on lake sediments, and the study of outflow deposits. The lake-level record of glacial Lake Missoula in western Montana, USA is poorly known because shorelines are typically weakly developed and not amenable to correlation and that few transgressive or exposure surfaces in the basin have been dated; most interpretations are from distant flood features in the Channeled Scabland. Surfaces below or within glaciolacustrine sediments in the Clark Fork River valley have been dated at a few sites in central to upper positions in the lake.
The basal transgressive surface at the upper site, near the Garden Gulch tributary to the Clark Fork River, is represented by sandy alluvial sediment and gravelly colluvium that interlayers with laminated glaciolacustrine silt. Ten cycles of fining-upward glaciolacustrine sequences are capped by coarsening-upward beds, exhibiting downward tapering wedges of sandy and gravelly silt. The cycles are interpreted to represent lake transgression, deepening, and subsequent regression with the coarsening-upward units interpreted as periglacial soil wedges and ice-wedge casts.

Optical ages of quartz sand were obtained from two samples, one in the sandy alluvial sediment below the lowermost lake-bottom sediments, and one above the glaciolacustrine section. An optical age of 20.1 ± 1.5 ka for the basal sediment suggests the preserved transgression is ~2 to 5 ka older than at Missoula, Montana, about 100 km downvalley along the Clark Fork River. The optical age of 10.5 ± 0.6 ka from above glaciolacustrine sediments is consistent with other ages in the lake basin for final drainage prior to deposition of the Glacier Peak tephra (13.7-13.4 cal. ka B.P.).

These data show that glacial Lake Missoula reached ≥70% of its maximum capacity around 17-22 ka B.P. and either partially or completely drained about 10 times from this position. One or more catastrophic drainage events would have eroded glaciolacustrine silt and clay lower portions of the lake basin, explaining the younger ages at those sections. Lake-level lowerings are commonly attributed to catastrophic failure of the ice dam. Preservation of easily erodible glaciolacustrine sediment during some lake lowering suggests only low water velocities and that the levels may be due to fluctuations and not lake drainage. These fluctuations could be due to climatic variations affecting summer water supply to the lake combined with year-round groundwater leakage beneath the ice dam. A constant head difference groundwater flow model, with 600 m of potentiometric head in the sublacustrine alluvial aquifer across the dam, gave preliminary estimation of lowering on the mm scale. Modeling of yearly or decadal changes in glacial meltwater and groundwater leakage may ultimately provide reasonable estimations of lake-level fluctuations.

USING METAL CONCENTRATIONS IN LAKE SEDIMENTS TO GENERATE ZONES FOR POTENTIAL MINERAL DEPOSITS AND ESTABLISH RESTORATION TARGETS FOR LEGACY MINE CONTAMINATION

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In 2004 a lake sediment survey conducted by the Ontario Geological Survey (OGS) sampled 2441 lakes in the North Bay-Temagami area (Superior and Grenville geologic provinces). Using this dataset we analyzed metal concentrations in the lake sediments to establish natural background metal concentrations and metal “hotspots” for the region. Watersheds were
derived for each lake using a GIS software and the metal content observed was corrected for percent coverage of lithology. Multiple regression techniques were applied to predict zones of increased mineral potential using variables such as glacial till type, bedrock type, fault structures and indicator elements associated with silver within the watershed of the lake. Background metal signatures were examined and a strong association between the bedrock type in the watersheds and metal content observed in the lake sediments was noted. For some lakes the observed metal concentration exceeded the predicted background value. These anomalous metal signatures were related to 1 of 2 scenarios. The first related the anomalies to past-producing mines and historical contamination. The second scenario is attributed to natural metal contributions from bedrock enriched in these metals within the watershed, likely from a concealed ore deposit. In many cases in the Superior province the strong metal signatures were associated with watersheds having contact relationships between Nippissing Diabase, Gowganda conglomerate and Archean metavolcanics and structures predating the intrusive diabase (2.4 Ga). This observation agrees with literature describing the high grade silver ore, Cobalt-type, and indicates that there may still be substantial deposits within these watersheds. A number of these anomalies can be verified through the Ontario mineral deposit index where prospects and occurrences were located close to the anomalies. In the Grenville province significant anomalies were also found, and the deposit model is at this stage unknown due to the lack of geological knowledge in areas where the anomalies occurred. Nonetheless these areas still represent target zones for exploration. These datasets represent a powerful tool to generate environmental quality guidelines (for legacy contaminant sites and future development) and to generate target zones for mineral exploration, especially in lake rich regions of Canada.

ICE STREAM DYNAMICS DURING DEGLACIATION OF THE LAURENTIDE ICE SHEET

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Observations of ice sheets in Greenland and Antarctica reveal that their contribution to sea level has accelerated in recent decades, largely as a result of the thinning and retreat of ice streams. This ‘dynamic’ contribution to mass loss is a serious concern, with some studies suggesting that irreversible collapse may already be underway in one catchment in West Antarctica. However, these observations typically span just a few decades and, at the ice sheet scale, it is unclear how ice streams might evolve over longer time-scales. This represents one of the largest sources of uncertainty in future predictions of ice sheet mass balance and sea level rise. Do ice streams arise and evolve to merely regulate climatically-driven changes in ice sheet volume, or can they induce major instabilities beyond that which might be expected from climatic forcing alone? Here we reconstruct a complete population of ice streams (>100) during deglaciation of the Laurentide Ice Sheet (~22,000 to ~7,000 years ago). Our results show that
Ice streams switched on and off in different locations during deglaciation, but there were no episodes when several ice streams switched-on together. Rather, their overall number decreases, and we identify several episodes when ice streams switched-off near-synchronously, linked to the loss of marine margins and a ‘soft’ sedimentary bed. The number of ice streams is remarkably stable when normalized by ice sheet volume, but they occupied a progressively smaller percentage of the ice sheet perimeter and likely discharged a decreasing proportion of the ice sheet volume. Thus, whilst underlying geology and topography clearly influence their location, ice stream activity over millennial time-scales was closely linked to ice sheet volume. This implies that deglaciation was largely driven by surface melt and hints at a more regulatory role for ice streams than previously recognized.

ACCELERATOR MASS SPECTROMETRY RADIOCARBON DATING: PROTOCOLS IN THE SELECTION OF CARBONACEOUS MATERIAL FOR DATING

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AMS 14C radiocarbon dating has become the most widely applied chronostratigraphic tool in studying late Quaternary deposits. The ability to date small carbon samples (milligrams in size) has reduced many of the errors/uncertainties connected with conventional 14C radiocarbon dating. Plant macrofossils and insect fossils have become the most desirable source of carbon for AMS radiocarbon dating since they are more likely to be contemporaneous with sediment deposition. Plant macrofossils and insect fossils are preserved remains large enough to be visible by the naked eye. Macroscopic remains of terrestrial plants (macrofossils) include seeds, leaves, twigs, bracts, needles and cones. Insect fossil remains typically found in Quaternary deposits refer mostly to beetles (Coleoptera) and include heavily sclerotized exoskeletal parts of heads, pronota and elytra. Macrofossils for dating should be chosen based on their habitat requirements that are consistent with the paleoenvironment as interpreted from the analysis of the combined floral and faunal assemblages. This avoids the problem of dating reworked material especially wood, which can withstand erosion and may have undergone several depositional cycles prior to final deposition. When considering macrofossils for dating from lacustrine environments, terrestrial fossils that derive their carbon supply from the atmosphere should be selected. The dating of aquatic macrofossils may show a reservoir or hard-water effect associated with photosynthesis/respiration of dissolved carbonates derived from ground water and ancient carbonate rocks. When a series of dates are required for good chronological control, AMS radiocarbon measurements can be costly. Carbonaceous samples for dating need to be carefully scrutinized from field collection to final preparation and submission to a dating facility. Among the many factors to consider are nature of the deposit/sediment, choice of sample material, storage after field collection, sample processing, macrofossil isolation and identification. Contamination by younger or older carbon including modern root penetration, recrystallization of secondary carbonate in shells, and the presence of biological contamination (modern mold and fungi in association with mycorrhizal root systems) must be avoided. This
presentation will be appealing to anyone submitting samples for dating especially students that are new to dating. Protocols required in the selection of suitable material for AMS dating will be discussed. Carbonaceous material including plant macrofossils, fossil insects, wood, charcoal, bones, and shells will be reviewed.

EXAMINING THE RELATIONSHIP BETWEEN DEGLACIAL STREAMLINED-LANDFORM FLOWSETS AND TILL COMPOSITION IN NORTHEASTERN MANITOBA: A TALE OF OVERPRINTING AND INHERITANCE

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We discuss four different field areas in northern Manitoba, where ‘fast-flow’ streamlined-landform flowsets at surface overlie thin and thick glacial sediments that drape the Precambrian Shield. Two of these areas have been interpreted as deglacial paleo-ice streams. These field areas in northern Manitoba, Canada, have been subject to a complex glacial history, with multiple competing ice-flow phases from the Keewatin and Quebec/Labrador sectors of the Laurentide Ice Sheet over at least three glacial cycles.

We use a multi-proxy approach to determine the relationship between this surface ‘fast-flow’ and the underlying till composition. Data collected includes remotely-sensed maps (surficial geology and landform), stratigraphy, sedimentology, field-based ice-flow, clast-fabric analyses and till samples – analyses of which includes till-matrix texture, carbonate content, geochemistry, and till-clast lithology counts.

Results show that two of the streamlined-landform flowsets, including the Quinn Lake ice stream, directly impacted the underlying glacial dispersal. In these areas, there has been considerable overprint (reworking to complete removal) of pre-existing till, and the resultant till composition displays a strong correlation with the streamlined ‘up-ice’ direction bedrock lithologies. Inherited detritus from the pre-existing till sheet is still present. Contrastingly, two of the streamlined-landform flowsets, including the Hayes Lobe ice stream, did not impact the underlying glacial dispersal. In these areas, streamlined flowsets were generated through erosion, or subglacial modification/cannibalization of pre-existing sediment with little overprint (till reworking and dilution) from the streamlined ‘up-ice’ direction. Tills in these latter cases correlate to the inherited pre-existing till sheet, and have no relationship to the fast-flow event.

The resultant surface till, in all four field areas, is a spatial mosaic of till composition, interpreted to reflect variable intensities in modification (overprinting) and preservation (inheritance) of a predominately pre-existing till sheet. Hence, a multi-proxy approach is necessary to determine how, and if, the surface ‘fast-flow’ events affect composition of the underlying till in areas of complex ice-flow history such as northern Manitoba.
RECONSTRUCTION OF PROGLACIAL LAKES IN ALBERTA

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As the Laurentide Ice Sheet retreated down gradient across the Albertan portion of the southern Canadian Interior Plains, it blocked regional drainage, resulting in formation of an extensive succession of proglacial lakes across the province. Recent compilation mapping by the Alberta Geological Survey shows that approximately one-fifth of the province is overlain by glaciolacustrine sediment. An understanding of the distribution, volume and drainage history of these proglacial lakes is important due to their role in deglacial ice sheet dynamics and paleoclimate. For example, ice flux within outlets of the southwest Laurentide Ice Sheet that terminated in proglacial lakes was likely higher than those that terminated along land-based margins, due to increased sliding due to higher basal water pressures, calving and thermo-mechanical erosion. Proglacial lakes may have also played a significant role in local and regional paleoclimate. Nevertheless, despite their significance, few studies have addressed the distribution, extent and chronology of proglacial lakes across Alberta.

The aim of this study is to map and reconstruct the sequential evolution of proglacial lakes in Alberta. Their occurrence was determined primarily based the distribution of glaciolacustrine sediments and associated overflow channels and basins, as well as littoral features. We also incorporate previous studies, particularly for naming conventions, and where the overflow channels are outside of the province (e.g. Glacial Lake McConnell). Data sources also include recent compilations documenting the distribution of glacial sediments and landforms across Alberta, as well as digital elevation models. This reconstruction does not incorporate glacioisostatic adjustment that would potentially alter the extent of larger proglacial lakes. Further work incorporating isostasy could improve the delineation of lake margins; however, there is limited information on rebound in the area, and experimentation with different isostatic rates suggests the lake extents would vary, but their pattern does not.

The reconstructions can contribute towards deciphering the deglacial configuration of the southwestern Laurentide Ice Sheet, including the relative timing of retreating ice lobes. Areas previously mapped as glaciolacustrine deposits, but without a glacial lake require further investigation. This reconstruction can also act as an aid to locate potential sources of aggregate, particularly in locations where meltwater entered proglacial lakes.

THE BURIED COMPONENT OF THE JAMES BAY WINISK ICE STREAM

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The Glacial Map of Canada shows an enigmatic ice-flow anomaly (Area A) covering about 10,000 km² in the Hearst/Kapuskasing area of northern Ontario. It consists of streamlined landforms and striations indicating ice movement toward 130° oriented at right angle to another ice flow toward 220°. Both are late glacial flows but Quaternary geologists disagree on their relative age, some argue that the east-southeast (130°) flow is the youngest and others that it is the oldest. The analysis of aerial photographs, satellite images and a detailed survey and analysis of cross-striated surfaces over an area of about 30,000 km² within and around Area A indicates clearly that the 130° flow preceded the 220° flow. The conflicting interpretations on the relative age of the two flows within Area A are attributed mainly to the sporadic occurrence of relict striated surfaces formed by former southwestward (220°- 240°) Wisconsinan ice flows that have escaped destruction by late glacial flows with the result that the southwestward flows are older (Wisconsinan) at some sites and younger (late glacial 220°) at others relative to the 130° flow. This constraint considered with other factors like the maximum elevation reached by the youngest late glacial flow show that Area A is simply the outcropping portion of a much larger, east-southeast ice-flow system which is the southern and distal part of the Winisk ice stream (Ekwan River ice stream) located to the north, west of James Bay. The distal part of the ice stream, except for Area A, escaped detection by remote sensing methods because depositional and erosional features associated with it are masked by deposits laid down by the younger (220°) Cochrane ice flow and/or by postglacial marine and organic deposits (or were destroyed by it). Relict striations indicating ice movement toward the east-southeast crossed by striations toward the southwest are the only reliable indicators of the passage of the ice stream in this "buried" section of its extent. While the east-southeast striations indicate that the advancing ice stream preceded the late Cochrane 220° flow, the mapping of several thousand iceberg furrows in Quebec and Ontario, directed toward the east and overprinted on Cochrane flutes, indicates that the ice stream also outlasted the Cochrane episode. It calved in Lake Ojibway from a position to the northwest of Hearst, Ontario until final drainage as indicated by ice-rafted debris found at the surface and in the upper part of cores from sub bottom lake sediment. The removal of large volumes of ice in the marginal part of the retreating ice sheet by the eastward progression of the ice stream accelerated deglaciation, and eventually triggered the Cochrane surges. The encroachment of the ice stream in Lake Ojibway is correlated with varve 1528 of Antevs’ series (500 to 600 years before final lake drainage) shortly before the onset of the Cochrane surges. With this southern component the Winisk ice stream becomes the largest terrestrial ice stream in the Hudson Bay basin. These new results clarify the sequence of events associated with the chronology of Cochrane surges.

RECENT SLOW-DOWN IN GLOBAL WARMING HAS PARALLEL IN THE RAPID WARMING INTO THE PRESENT INTERGLACIAL

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The recent slow-down in the rate of global surface warming, with cooling in the North Atlantic, has fuelled debate about the validity of global warming projections. Although the excess heat predicted by climate models is being stored in the deeper oceans, many are left wondering if this slow-down is unique or a typical feature of rapid rising temperatures. We looked to the Younger Dryas-Holocene transition in lake sediment records from Nova Scotia as an analogue for rapid warming and found a decadal scale temperature reversal in the warming trend leading into the Holocene. This transition has been previously viewed as uninterrupted. We then examined marine, ice core and terrestrial records from throughout the North Atlantic and found that the slowdown leading into the Holocene was widespread, indicating that, similar to the recent slow-down, it too was the result of major ocean and atmospheric reorganization.
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