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Atlantic Canada Glacier Ice Dynamics Workshop

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CONFERENCE REPORTS

Atlantic Canada Glacier Ice Dynamics Workshop

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Note: The workshop agenda and abstracts are available at www.dal.ca/~cnef/AcidWorkshop.html

Conceptual models for the glacial history of Atlantic Canada from interpretations of a variety of land and marine ice proxy records are in close agreement. This was revealed during a two and a half day workshop at Dalhousie University, May 22–24, 2002, where participants discussed evidence that constrains our picture of the nature of regional glacier ice cover over the last 115,000 years. Over the past decade, researchers have independently concluded that glacial cover over Atlantic Canada had three recurring characteristics: (1) complete ice coverage to the shelf edge (the eastern Grand Banks may have been an exception); (2) multiple zones of ice dispersal, envisaged as peripheral ice caps during the growth and decay of the Laurentide Ice Sheet; and (3) discrete zones of ice streaming and calving. Some disagreements persist at finer resolutions. Several areas were identified as having too few data to constrain the ice history (*e.g.*, north shore of Gulf of St. Lawrence estuary east of Sept Iles, and late ice surges in the Bay of Fundy). Some biological data suggest that ice-free zones may have persisted throughout glaciations along coastal highlands. The envisaged ice cover model can provide for isolated refugia on exposed cliffs below thin, non-erosive summit ice cover.

Motivation for the workshop was based on societal needs as well as the academic quest for understanding of this important part of Earth's history. In Atlantic Canada, glacial processes have affected three important industries: aggregate, mineral, and hydrocarbon exploration. For instance, a significant proportion of sand and gravel for construction in Atlantic Canada is derived from deposits left by glaciers. Mineral exploration companies seeking the source of ore-bearing, glacially transported boulders and sediments rely upon histories of regional ice flow to locate ore bodies. Oil and gas companies, hoping to learn more about the deformation of Mesozoic salt layers offshore, can benefit from knowledge of periodic sediment loading along a continental margin that has been glaciated many times over the past million years. The glaciation of petroleum development areas also presents unique challenges to the construction of pipelines and flowlines as well as platform stability.

This workshop was timely because no previous workshop of this nature had been organized for Atlantic Canada and because of several advances and landmarks of glacier research in Atlantic Canada that have occurred at the turn of the century (*e.g.*, Stea *et al.*, 2001; Shaw *et al.*, 2002). Furthermore, there is a mutual desire among the region's university, private, and government researchers to build a series of geologically constrained, numerical ice-cover simulations at different space and time scales to address questions, test hypotheses, and fill gaps in the glacial history of Atlantic Canada.

PARTICIPANTS

An attempt was made to involve any researchers who have studied the history of glacier ice dynamics in Atlantic Canada. A list of participants is shown in Table 1. Discussions will continue with other researchers who could not participate.

FORMAT

The participants took advantage of the opportunity of having sufficient time to present and defend data compiled from a wide range of spatial scales and long time ranges and answer questions from the audience. Presentations were organized by region, not by method of data acquisition, so marine and land records could be well integrated. Conceptual histories of deglaciation from the Wisconsinan glacial maximum in Atlantic Canada were presented by J. Shaw, D. Liverman, T. Bell, I. Spooner, G. Fader, H. Josenhans,

Table 1 Participants of the 2002 ACID Workshop

Ann Miller	Marine Geos
Brian MacLean	Geological Survey of Canada (Atlantic)
Dave Liverman	Newfoundland Geological Survey
David Scott	Dalhousie University
Doug Grant	GSC Emeritus Scientist
Gary Sonnichsen	Geological Survey of Canada (Atlantic)
Gordon Fader	Geological Survey of Canada (Atlantic)
Heiner Josenhans	Geological Survey of Canada (Atlantic)
Ian Spooner	Acadia University
James Gray	University of Montreal
Jane Willenbring	Dalhousie University
Jesse Johnson	University of Montana
Jim Fastook	University of Maine
John Gosse	Dalhousie University
John Shaw	Geological Survey of Canada (Atlantic)
Mike Lewis	GSC Emeritus Scientist
Ralph Stea	Nova Scotia Dept Natural Resources
Shirley McCuaig	Newfoundland Geological Survey
Thian Hundret	Dalhousie University
Tim Webster,	COGS and Dalhousie University
Trevor Bell	Memorial University of Newfoundland

R. Stea, J. Gray, J. Gosse, D. Scott, M. Lewis, C. Sonnichsen, and A. Miller. The latest map series depicting the deglacial history of the entire Laurentide Ice Sheet were provided by A. Dyke (GSC, unpub. data) prior to the meeting. G. Fader and coworkers presented a history of the research being done to determine ice positions in the offshore (till-tongue model) and concluded with examples of new marine glacial features discovered using multi-beam bathymetry. A. Miller and D. Scott reviewed micropaleontological records of ice margin positions and sea level. A short field trip to the West Lawrencetown Beach area led by R. Stea helped to illustrate how crosscutting indicators of glacier flow (*e.g.*, striae and drumlins) could be linked with land and offshore glacier sedimentary deposits. A three-hour short-course on the University of Maine Ice Simulation Model by J. Fastook and J. Johnson provided a summary of the types of questions that could be addressed by the model and what kinds of geological data could be used to constrain future simulations. The workshop concluded by devising a plan to compile maps and databases that will be used as boundary conditions for a series of numerical simulations over the next four years.

CONSTRAINTS ON THE GLACIAL HISTORY OF ATLANTIC CANADA

Marine and terrestrial geology, and isotope and biological data all contribute to the study of the glacial history of Atlantic Canada. The land record of the nature of glacier cover, processes, and flow includes databases of striae for Newfoundland, New Brunswick, and Nova Scotia, maps of large-scale landforms indicative of ice flow trends (*e.g.*, stoss-and-lee features, drumlins, flutes), maps of glacial sediment and associated stratigraphy, maps of distributions of landforms indicating non-erosive ice cover, soils, cosmogenic isotopes, and lake records of deglaciation and post-glacial climate. Marine records of ice cover, processes, and flow are derived from seismic reflection profiles of offshore Quaternary sediment, multi-beam bathymetry maps, core and grab samples of glacial and marine sediment, micropaleontology, and submarine observations of boulders, tunnel channels, and other indicative bedforms. High-resolution seismic reflection data and critically positioned cores remain a mainstay of unravelling the marine record of ice advance and retreat (*e.g.*, King and Fader, 1986). Relative sea-level histories of glacial isostasy have been derived from raised and submerged shoreline deposits and landforms, and micropaleontology.

It was agreed that some of the most important new advances in our understanding of the glacial history of Atlantic Canada have resulted from the development of high-resolution multi-beam bathymetry maps for the offshore (*e.g.*, Shaw *et al.*, 2000). The method has provided images of glacial deposits that are currently below sea level, enabling the various land records and marine seismic records of glaciation to be linked better than previously possible. The resolution of the multi-beam maps is sufficient to distinguish landforms characteristic of specific glacial processes, although cores and high-resolution seismic reflection data are necessary to discover buried features and determine the nature of the material below the surface. Another new approach involves the measurement of cosmogenic isotopes in rock to provide information about ice cover in areas where little or no evidence of erosion by glaciers is evident (Marquette *et al.*, work in progress).

Despite an abundance of physical and biological data constraining Atlantic Canada paleo-glacier ice dynamics, and an appreciation for the variation in the glacier cover with time, there is only rudimentary age control on the regional glacial history. Terrestrial and marine radiocarbon ages comprise nearly all constraints on the timing of glacial events. The remaining temporal constraints are derived from the following chronological techniques: U-series, amino acid racemization, optically stimulated luminescence, and cosmogenic isotopes. Many key areas lack chronological control (*e.g.*, Scotian Shelf and Grand Banks). In most cases where some chronology exists, only one age has been determined, and there are no continuous records with precise dating of glacial history. Several continuous records of paleoclimate for the Holocene and into the late glacial are known from the Scotian Shelf and slope and a few on the Newfoundland shelf. Sea-level data are abundant but not continuous for the entire 20 kyr since glaciation.

A developing picture of Atlantic Canada paleo-glacier dynamics reveals a complex interaction between peripheral ice caps and the Laurentide Ice sheet, ice streams and multiple secular dispersal zones, frozen- and wet-based ice conditions, and glacial responses to sea-level variations. It is also clear that these interactions varied temporally throughout each glaciation, with variations in paleoclimate (including moisture sources and ocean circulation), glacier geometry and flow, lithology and bed character, and sea level.

BOUNDARY CONDITIONS AND PLAN FOR NUMERICAL SIMULATIONS OF PALEO-GLACIER DYNAMICS IN ATLANTIC CANADA

Numerical models that simulate the growth and decay of ice sheets, cirque glaciers, and ice caps, such as MAP5 and the University of Maine Ice Sheet Model (UMISM), can be used to predict ice thickness and surface gradients, ice flow directions, flow velocities, ice marginal positions, ice streaming within a glacier, the effects of topography and basal hydrology, and the interactions between paleo-glaciers. The models are based on physical laws (conservation of mass, energy, and momentum) and relationships (*e.g.*, ice strain), as well as fitted parameters (*e.g.*, lapse rates). The models are also thermo-mechanical in the sense that heat flow values from geothermal heat, atmosphere, and ice movement are incorporated. Upcoming improvements to the UMISM include: 1) better modeling of heat and ice advection; 2) development of independent modules such as calving; 3) increasing the spatial resolution for regional simulations; and 4) incorporating better GCM simulations of paleoclimate, that will be iteratively adjusted to ice sheet geometry. However, in addition to paleoclimate data, the models can also be controlled by a variety of geological constraints that are being compiled into a suitable format (Table 2). The workshop participants discussed uncertainties in the data sets, including the dating of particular glacial events. A number of tests have been proposed to determine how well the simulations fit other observed data that are not part of the initial boundary conditions (*e.g.*, ice-free cliffs in areas of refugia, frozen-based ice zones, measured lateral moraine gradients).

The workshop participants agreed upon a tentative schedule for generating the boundary conditions, improving the model, running the model to test its sensitivity to certain conditions and the validity of certain outputs, and applying the model to address specific questions (Table 3). Not only does the schedule require interaction between different research groups (*e.g.*, glacial geomorphologists and marine stratigraphers) but it also requires sharing across political boundaries (*e.g.*, provincial surveys will need to compare and reconcile map contacts).

Table 2 Ice sheet modeling boundary conditions that are currently available

DEM	During late Pleistocene glaciations, present continental shelves were exposed due to a lowered sea level. The ice models are sensitive to basal topography at various scales. Therefore, medium resolution (~700-m or better) DEM of the topography and bathymetry will be assembled, building from one that was constructed by J. Shaw and others at the Geological Survey of Canada (Atlantic). Higher resolution DEMs for more detailed simulations at local scales will be constructed as needed.
Ice Cover	In the six months following the workshop, representatives of provincial surveys and the Geological Survey of Canada (Atlantic) have agreed to compile their conceptual models of ice cover history for at least the past 22,000 years, in 1000-yr increments. Two levels of certainty in the map features will be represented by solid and dashed lines.
Ice Flow	Databases already exist of hundreds of striation and other micro-scale landforms used to indicate ice-flow trends at 1:50,000 scale. In some databases, a level of confidence in the actual flow direction is indicated, and relative chronologies are recorded. Maps depicting the larger landforms indicating ice flow have also been compiled at 1:250,000 scale.
Sea Level	Submergence and emergence histories for parts of Atlantic Canada are known to some degree and are being summarized.
Geothermal heat	Although precipitation and solar energy will be input through different paleo-climate models, it is also necessary to include an estimate of the magnitude and spatial variation of geothermal flux to the base of the glaciers.
Shear strength of the bed materials	The bedrock geology of the region is already available in digital form, and a map summarizing the thickness of glacial drift can be added to the GIS. A goal will be to provide an indication of the softness and permeability of the underlying glacier bed.

Table 3 Proposed schedule for building a numerical model of Atlantic Canada ice cover

Date Completed	Milestone
May, 2002	Initial workshop
October, 2002	Medium resolution DEM
October, 2002	Ice flow databases compiled
October, 2002	Ice cover map series for regions
March, 2003	Compiled maps of boundary conditions
March, 2003	Refinements in the UMISM
March, 2003	Paleo-climate models attained
April, 2003	Boundary conditions maps distributed to researchers for verification
June, 2003	Second workshop at CANQUA
June, 2004	Medium-resolution UMISM model of geology consistent Atlantic Canada ice cover history distributed
June, 2005	Specific questions related to the glacier history, paleoclimate, and society addressed

STATE OF KNOWLEDGE AND FUTURE TASKS

There seems to be consensus on a multi-dome, time variant, complete cover glacial history for Atlantic Canada. The recurring theme resembles the maximum ice models of Denton and Hughes (1981) and Grant (1989) except that there is a perception of much thinner ice cover (to explain geomorphological, biological, and isotopic data). The close proximity of land, ocean, high summits, fjords, the Laurentide Ice Sheet, and broad shelf regions has created a platform for studying glacier history that will continue to challenge researchers as we focus on higher resolution issues in the paleo-ice dynamics of Atlantic Canada.

Meanwhile, progress is being made in deciphering the offshore and onshore geologic record of glaciation throughout Atlantic Canada. For example, Shaw (work in progress) will present data from coastal areas of Newfoundland in the context of glaciation that reached the shelf edge. Positions of former ice streams and their catchments will be shown. The proposed conceptual model will be integrated with data from onshore (*e.g.*, Bell *et al.*, 2001) through collaboration with a team of researchers at the Newfoundland and Labrador Geological Survey and Memorial University of Newfoundland.

It is clear that three future endeavours will have immediate and profound implications on the development of the regional glacial history. First, more chronological data is needed to determine the precise timing of glacial events recorded in land and marine records. Although relative order of events exists in many cases, these events are not yet fixed in time. Radiocarbon, U-series, optically stimulated luminescence (OSL), and cosmogenic nuclide exposure histories are examples of techniques that can provide this chronology. The numerical simulations of ice cover could also provide estimates of the timing of specific ice flow directions, the timing of growth of ice caps and encroachment of Laurentide Ice into Atlantic Canada, and perhaps fill in gaps in the ice marginal retreat history. Second, the value of multi-beam bathymetry cannot be overstated, and we should strive for complete coverage of the shelf on which lies an important portion of the evidence of Atlantic Canada paleo-glacier dynamics. Third, in keeping with the spirit of this workshop, we need to continue to share compilations and data sets of various scales and type from geological surveys, universities, and private companies. The current perceptions of ice history in Atlantic Canada could not have been formulated without the large body of geological, geophysical, and paleontological research and compilation that has resulted from decades of effort and was shared by the provincial and federal geological surveys.

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International Symposium on Vanadium - Conference of Metallurgists

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Vanadium by E.R. Rose (1973)
Vanadium from Vanadis,
Goddess of Norse folk-lore,
Strengthen the steel that serves us,
Toughen our iron ore.
Go—get the fumes that exhaust us,
Muffle the mighty jets' roar,
Crack up the compounds that plague us,
Help us to find more ore.

An International Symposium on Vanadium was held in conjunction with the Conference of Metallurgists in Montreal, Canada, on 11–14 August 2002. Vanadium is a strategic metal having many important industrial applications. It is widely used to toughen and strengthen steels. Vanadium foil is used as a bonding agent in cladding titanium to steel and generally by the aerospace industry. Medical implants often contain vanadium alloys because of their excellent stability. Some vanadium compounds have catalytic properties that make them useful in many industrial applications, such as the production of sulfuric acid. The vanadium redox battery is an exciting new development, which has found uses in load leveling, back-up power, and for storage of electricity from wind and solar power.

The symposium covered various aspects of vanadium and its industry, including the production of vanadium oxides and ferrovanadium, and the latest discoveries, developments and emerging markets. Keynote lectures were given by internationally known experts in the areas of interest to the vanadium industry. Original papers were presented in four sessions.

SESSION I: HISTORY, GEOLOGY AND MINERALOGY

Session I contained six talks: 1. "Two Hundred Years of Vanadium" by F. Habashi, explained the historical development of vanadium metal since its discovery in 1801; 2. "The Vanadium Industry: A Review" by L. Perron, provided a detailed analysis of the vanadium industry in the world, including production, price, marketing, and new applications 3. "Roof Rock Assimilation in the Doré Lake Complex and its Influence on Vanadium Concentration" by G.O. Allard, who gave an excellent talk about the geological environment of the Chibougamau vanadium deposits in Quebec and the role of roof rock assimilation in magma chambers in the formation of vanadium deposits 4. "Mineralogy of the Matagami and Chibougamau Vanadium Deposits, Abitibi, Québec, Canada" by M.F. Taner, T.S. Ercit and R.A. Gault, who talked about the mineralogy of Matagami and Chibougamau vanadium deposits from the Abitibi greenstone belt, Québec and discussed where the vanadium is located in the vanadium ore structure; 5. "Titanium – Vanadium Resources in Southern Québec: The Anorthosite Link" by S. Perreault, who explained the existing relationship between titanium and vanadium resources in the Grenville Province, Québec; and 6. "Vanadium Resource Potential At Matagami, Québec" by G. Arnold and M. Allard, who gave detailed geological and geophysical information on recently discovered vanadium deposits at Matagami Québec owned by Noranda Inc.

SESSION II: PROCESSING

Session II contained the following three talks: 1. "The Production of Vanadium Pentoxide" by S. Bradbury, who explained the flow sheet for the classic (over 30 years old) Sodium Salt roasting process for the production of vanadium pentoxide from vanadiferous magnetite as used by the main South African producing plants; 2. "Beneficiation of Vanadium-Bearing Magnetite from the Sinarsuk Deposit, West Greenland" by T. Grammatikopoulos, A. McKen, R. Molnar, and O. Christiansen, who gave the results of pilot testing on the vanadium-bearing magnetite from West Greenland; and 3. "The Recovery and Assimilation Kinetics of Ferrovanadium

Alloys in Liquid Steel" by *S.A. Argyropoulos*, who explained the assimilation kinetics of various grades of ferrovanadium alloy additions in liquid steel.

SESSION III: ELECTROCHEMICAL APPLICATIONS

Session III contained the following four talks: 1. "An Historical Overview of the Vanadium Redox Flow Battery, Development at the University of New South Wales" by M. Skyllas-Kazacos, who gave an excellent overview on the important features and advantages of the Vanadium Redox Flow Battery (VRB). She provided a historical overview of the VRB development since 1984, as well as an update on the commercial installations that have been recently commissioned and are being planned around the world; 2. "The Impact of Low Temperature on Vanadium Redox Battery (VRB) Performance" by M. Gattrell, J. Park, B. MacDougall, S. McCarthy and J. MacDonald, who discussed the effect of temperature on the rates of the vanadium redox reactions underlying the VRB, and the implications of low temperature for VRB system design for remote off grid applications in Canada; 3. "Development and Applications of the Vanadium Redox-Flow Battery" by S. Miyake and N. Tokuda, who presented successful applications of VRBs installed by his company at various locations for reliable power, load leveling, and wind power stabilization. Long-term tests with the VRB systems connected to actual electrical networks have been carried out, verifying their performance and VRBs are now available commercially. Thus the VRB, which use large volumes of vanadium in sulphuric acid solution as the electrolyte, represents a new energy storage system for large-scale energy storage applications; and 4. "The Lac Doré Vanadium Project: Current and Future Trends" by J. Sawarin explained the success to date of McKenzie Bay International Ltd in developing the Lac Doré vanadium/titanium deposit at Chibougamau, Quebec. This deposit is considered to represent the world's second largest with the deposit having good quality, size and consistency along with a highly favourable infrastructure and tariff advantages. As well, McKenzie Bay's future role in the newly evolving vanadium markets was discussed.

SESSION IV: EXTRACTIVE METALLURGY

C.K. Gupta was unable to attend the symposium because of illness, but he submitted two papers to the proceedings volume. "The Vanadium Metallurgy Scenario – Then, Now and Future" reviews vanadium metallurgy, with particular emphasis on the extraction, refining and processing of this important and versatile metal, as well as a few applications of vanadium, such as steel additives, vanadium-titanium alloys for the aircraft industry and potential uses such as gallium/vanadium alloys as a semiconductor material. "The Aluminothermic Process for Vanadium Production" discusses the basic principles and the practice of aluminothermic technology, both in general terms and as they apply to the recovery of vanadium;

The session had four other presentations: 1. "Recovery of Vanadium from Fly Ash and Spent Catalysts" by G.V.K. Puvvada, R. Sridhar and V.I. Lakshmanan, who gave the results of their investigations for the recovery of vanadium from spent catalysts and fly ash obtained from processing tar sands. Processes used included flotation, leaching and finally ion exchange. They also described the recovery of vanadium from spent catalysts, which was attempted through sulphidizing roasting followed by acid leaching; 2. "The Behaviour of Vanadium (III) during Jarosite Precipitation" by J.E Dutrizac and T.T. Chen, discussed the synthesis of V(III) analogue of potassium jarosite at 100°C from VCl3 solutions containing an excess of K2SO4; 3. "Recovery of Vanadium from Oil Sands Fly Ash" by P. Holloway and T.H. Etsell, presented the results of the most recent studies into vanadium recovery from oil sands fly ash in northern Alberta, Canada, produced by Suncor and Syncrude, and proposed strategies to improve vanadium extractions; and 4. "Vanadium Extraction from a Mexican Power Plant Residue" by J.A. Barrera-Godínez and T. Campos-González, who gave the results of their studies for the recovery of vanadium from the slags from heavy oil-burning plants in Mexico, which generate about 1,000 tonnes of slag per year containing 29% vanadium. They indicated that this slag can be considered as a viable vanadium resource in Mexico.

In conjunction with the symposium, Prof. M. Skyllas-Kazacos, from School of Chemical Engineering and Industrial Chemistry, University of New South Wales, Sydney, Australia, gave a very successful short course on "Electrochemical Energy Storage Systems and Applications". The one-day short course described the principles of electrochemical energy systems and the fundamentals of electrochemistry, secondary batteries and fuel cells. Advanced batteries for stationary and mobile applications were described, including the features and characteristics of the Vanadium Redox Flow Battery, the Sodium Sulphur, Zinc-Bromine, Sodium-Metal Chloride, Sulphur-Bromine and Lead-Acid battery systems. The criteria used in the assessment of different battery storage technologies were covered together with practical calculations of capacity, theoretical and practical energy density, coulombic efficiency and overall energy efficiency. Important design considerations for maximizing battery energy efficiencies were also discussed.

All papers presented at the International Symposium on Vanadium were published as a Proceedings volume (**Vanadium - Geology, Processing and Applications**, edited by M.F. Taner, P.A. Riveros, J.E. Dutriziac, M.A. Gattrell and L.M. Perron, ISBN 1-894475-26-7, 265 pages, COM2002). This book is available via the Metallurgical Society of CIM at a cost of $CAN50.00 (to order, contact: Mrs. Ronona Saunders, MetSoc, 1210-3400 de Maisonneuve Blvd, West, Montreal, Quebec Canada H3Z 3B8, tel.:(514) 939-2710, ext.1327; fax.: (514) 939-9160; e-mail: rsaunders@cim.org or metsoc@cim.org; website: www.metsoc.org).