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University of Alberta, Edmonton March 29-30, 2003

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WORKSHOP REPORT

Report on Workshop on Canadian Participation in the International Continental Scientific Drilling Program: Themes in Arctic Science

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INTRODUCTION

Canada became a member of the International Continental Scientific Drilling Program (ICDP) in 2002. This program serves to facilitate scientific drilling globally with partial support for numerous projects ranging from drilling in the Chixilub impact crater in Mexico through environmental and paleoclimatic studies in undisturbed lake sediments to tectonic investigations of volcanism and fault mechanics. The 2002 Mallik gas hydrate research well program, drilled on Richardson Island in the Mackenzie Delta of the N.W.T. (Dallimore et al., 2002) represents an important and successful Canadian contribution to this program. This investment brought a wide variety of researchers from six countries and numerous scientific disciplines together to work on a topic that has great implications for both the economic development of Canada's North and the environmental understanding of greenhouse gas seepage to the atmosphere.

Motivated in part by the Mallik experience, a general workshop on scientific drilling was held in Toronto in April 2002 (Grieve et al, 2002) to discuss how Canada might play a part in the future of the ICDP. A number of significant problems of scientific interest to both the inter-national and Canadian communities were brought forward. Of these ideas, the themes of the Sudbury structure and of drilling in Canada's Arctic were considered to be of sufficient interest that more focussed follow-up workshops should be held. A workshop on scientific drilling in the Sudbury structure was held in Sudbury in September 2002 (Mungall and Milkreit, 2002). This 'local' workshop drew 80 participants primarily from Sudbury but also from as far away as Newfoundland and Alberta. This workshop led to the submission of a first-stage proposal for funding to the ICDP to support an international workshop that will be held in Sudbury in the fall of 2003.

Here we report on the workshop organized to address the broad theme of scientific drilling in the Arctic regions, a vast region comprising large segments of Greenland, Europe, Asia, and North America. This theme is, admittedly, less focused than that for the already long-studied Sudbury structure, where both impact and ore genesis motivate further research. However, the scientific issues that might be tackled by scientific drilling in the Arctic regions are perhaps even more compelling and of more immediate consequence given the recognition that the Arctic is an amplifier of the signals associated with global climatic change, a repository of nonconventional energy sources, and a possible analogue for extreme environments on other planets.

The workshop took place over two days. The first day's program consisted of a number of invited speakers representing different disciplines together with ongoing open discussion. The morning of the second day began with discussion of issues that face researchers hoping to carry out work in the Arctic and of some potential future research directions. In the report below, the presentations are first summarized and the principal points that arose in discussion are given. The PowerPoint presentations from this meeting are available at the http://www-geo.phys. ualberta.ca/arctic website.

OVERVIEW OF PRESENTATIONS AND DISCUSSIONS

Day 1

The meeting led off with an overview of the ICDP program and the goals of the workshop in order to set the stage. Doug Schmitt highlighted some of the unique attractions of the north and reviewed the cross-section of interest that had been received in response to advertisement of the workshop. In addition to the 22 participants at the workshop another 25 responded and provided written input.

Mallik 2002 Gas Hydrate Research Well

Scott Dallimore (GSC – Terrain Sciences Division, Sidney) followed with a presentation of the Mallik program that focused on the many different researchers associated with the project, on the logistics involved, and aspects of funding with an eye to the many additional resources that were brought to the project when the ICDP became a partner in the work. At present, the Mallik program involves more than 100 researchers from Canada, USA, Japan, Germany, China and India. One point brought out in the course of the related discussion focused on the compromises that had to be made when dealing with funding and logistical constraints (operational window, drilling technique etc.). For example, in order to focus on the deeper gas hydrates at Mallik the upper 700 m permafrost section of the well was not cored and no advanced geophysical logs were collected through this zone as a result of hole enlargement. A number of participants pointed out that the permafrost regime (ice bonding, engineering properties and intrapermafrost gas hydrates) remains poorly understood.

Scientific Drilling in the North- USGS Experiences

Art Clark, a drilling manager for the USGS (Denver), detailed the numerous drilling projects he had been involved with in Alaska and elsewhere. The scale and rationale for the projects varied. The smallest project was the Sagwon Bluffs (North Slope, Alaska) in which a series of 20 m long sedimentary cores was taken at a number of locations down the slope of a hill in order to obtain a more complete core section without a large rig. The equipment for this project was hand portable down the hill and was helicoptered in. Other projects also allowed helicopters to deliver many of the rig components in remote locations for geotechnical drilling. The largest project was the 1994 Fort Yukon drilling project carried out primarily to acquire core for palynological studies related to detecting paleoclimatic changes. It is worthwhile noting that complementary drilling has been suggested for the Old Crow sedimentary basin in the Yukon.

There were a few points brought out in this talk for those considering such scientific work in the Arctic. The scientific work in the Fort Yukon project consisted solely of core description and palynological studies; geophysical logs that could have been added for only a modest cost were not included. This loss of information was regrettable and it highlighted the need to obtain a large base of researchers to be involved with any scientific drilling program. One problem here, however, is that workers often do not hear about the proposed drilling program until after the work has occurred and the opportunity has been lost; some kind of clearing house that maintains a list of accessible scientific projects may be valuable in this regard. A second issue focused on whether workers should use their own or contracted drilling. Based on Mr. Clark's experience, having one's own drilling equipment can be advantageous in some cases for two reasons: first, you have a knowledgeable "research oriented" drilling team that well understands the scientific purpose of the drilling and, second, there is overall flexibility in the project. The cost and flexibility issues are particularly acute if any unexpected conditions are encountered. A third problem focused on the environmental sensitivities of drilling in Arctic regions. This can be a significant problem as many of the drilling fluids and other wastes must be properly disposed of and this may be economically impossible in certain cases.

Lake Baikal- Scientific Drilling

Vadim Kravchinsky (Dept. of Physics, U of Alberta) addressed paleoclimatic studies arising from his participation in the Lake Baikal drilling program. Lake Baikal is one of the most ancient and deepest lakes on the planet and it has been subject to steady but slow sedimentation for long periods. Consequently, the cores from undisturbed lake sediments provide some indications of conditions over long periods of time in this region of the world. His own work focused on detailed studies of the magnetic susceptibility, this parameter being sensitive to the climatic temperatures via the chemistry of the magnetic minerals formed during deposition. Spectral analysis of the resulting susceptibility time series indicates that, for the most part, the Milankovich obliquity signal dominates. However, when the temporal evolution of the frequency content is investigated by studying sequences of time windows, a complex picture emerges in which eccentricity and precession power appears during some intervals. Furthermore, there is persistent evidence for significant power in a "non-Milankovich" band between 28 and 35 ka.

Geothermal Studies of Permafrost in Alaska

Vladimir Romanovsky (University of Alaska, Fairbanks) gave an overview of long-term geothermal studies of the permafrost in Alaska. A continuous monitoring program has been in place since the 1980s in which the temperature profiles are measured at least once a year in 20 shallow boreholes drilled to depths of 50 to 80 m. Surface temperatures, soil moisture, and snow depths are important parameters needed for proper modeling of thermal influences and these are recorded hourly using onsite data loggers. Some of the interesting observations are the increase in the near-surface temperatures of up to 2°C at the Deadhorse station over the 20 year monitoring period. It was noted that in many spots the upper part of the permafrost is near to thawing; some effects of this are evident in the noticeable settling of the surface without disturbance since the 1950s at one borehole location. Some issues that need to be better understood to improve the thermal gradient models within the surface layers and permafrost are the influences of salinity and 'non-frozen' water. Other related issues brought out in discussion relate to questions about the organic materials in various states of decay and what kind of greenhouse gases they might emit with continued warming. The talk showed that much of this material may not have been frozen very long, perhaps only since the last 'Little ice age', and in the longer term the thawing of this now frozen material could be problematic.

Resources on the Rebound- Discussion of the Deep Biosphere

Brian Horsfield (GeoForschungs Zentrum Potsdam, Germany) gave a talk entitled 'Resources on the Rebound' that addressed a wide range of issues stemming from the changes in chemistry and saturation state induced by removal of large ice loads and isostatic rebound. That is, the PVT properties of the fluids and hydrates at depth can have an important influence on their motion and how they might provide feedstock for the deep biosphere. He indicated that much is already known about mature and overmature hydrocarbons source rocks and of overmature reservoirs. What is not so well understood is the deep

microbial systems and how they interact with the 'diagenesis' of buried sediments at shallower levels. There is abundant evidence from ODP and elsewhere that bacteria exist at depths greater than 1 km. In Italy, drilling in the Po River Valley suggests bacterial activity to as much as 3 km.
Dr. Horsfield showed some recent geochemical results from the Mallik well that highlighted the existence of phospholipids, which can only be present in living cells and disappear rapidly once the cell dies; their presence is a strong indicator of microbial life. These organic compounds were detected to depths of 1050 m in the Mallik well. The question is what the source of nutrients for these bacteria might be. One solution is that these bacteria, likely simple methanogens, may be fed by low-molecular-weight substances (e.g., CO_2, H_2, acetate) generated abiotically at greater depth. As such, these organisms may effectively be 'decoupled' from the surface.

Glacial Coring

Martin Sharp (Department of Earth and Atmospheric Sciences, U of Alberta) described some proposed glacier coring projects that he and his colleagues are working towards. These could contribute to an international initiative to retrieve ice cores along a transect from 'Pole to Patagonia', which is driven by U.S. and Japanese workers. It is desirable to have strong Canadian involvement in the collection and analysis of cores from Canadian sites. Some Canadian targets include the Barnes Ice Cap, which is likely the last remnant of the Laurentide Ice Sheet, and the ice caps of the Queen Elizabeth Islands. These ice caps are relatively shallow but contain high-resolution information on the more recent past. One motivation for coring them is to gain some indication of the inter-annual to centennial scale variability in sea ice in the Arctic Ocean, inter-island channels and Baffin Bay. It would be useful to have complementary core records from nearby lakes that may be connected to these ice fields. Another initiative being developed in conjunction with NASA involves use of a thermal drill with sterile pumps that will allow on-site geochemical analyses of the fluids returned during ice coring and collection of water samples on sterile filters for analysis of the distribution of microbial populations within and at the base of the Devon ice cap.

Permafrost Microbiology

The biosphere was addressed a second time by Mark Skidmore (UC Riverside, California) who discussed issues related to microbiology in the permafrost. Microbes impact on a number of themes such as gas hydrates, carbon cycling, the overall nature of the permafrost biosphere, and permafrost as a potential exobiological analogue. Microbes have been found to depths of at least 300 m in permafrost and microbes have been resuscitated from ancient Russian permafrost, which is estimated to be 3 Ma old. The permafrost is an important store of carbon, with estimates of up to 500 Gtonne, and as such it is important to understand what happens to this carbon in situ at present and if temperatures warm, allowing increased microbial activity. Potential research questions highlighted were a) how is carbon cycled in the permafrost and how this might influence the production of gas,
b) whether permafrost environments may harbour unique organisms,
c) whether there are similarities of these organisms to those found in cold marine and terrestrial environments, and
d) what are the viability (depth–age) relationships of organisms within the permafrost.

Permafrost Geophysics

Bernd Milkreit (Physics Dept., U of Toronto) presented some unique geophysical observations within the permafrost. In particular, he noted that permafrost areas are often considered poor places to acquire surface seismic data and one motivation for better understanding this is to improve our capabilities to produce seismic images in this regard. The permafrost in particular is complex when the zones of free gas and non-frozen water are considered. One question relates to the scale and distribution of physical property variations within the permafrost.

Ground Thermal Studies in Northern Canada

Geothermal variations in relation to local changes at the surface were addressed again by Jacek Majorowicz (Edmonton). He noted that the geothermal profiles that he and other workers have obtained could be improved by thermal measurements in a deeper well. Deeper wells have been drilled for exploration purposes but these could not be properly logged for a variety of reasons. Obtaining a record that begins beyond the depth of the gas hydrate stability zone would be desirable to obtain the proper signal; these records would be needed to carry out the inversion for the temperature forcing at the surface. Such inversions have been done for the wells with temperature logs obtained some 20 to 30 years ago and surface temperature histories derived for previous 1000 years. These show significant rebound of surface temperatures from the colder era some 200 years ago and an average temperature warming of 1.3C (PAGEOPH paper, in press). The possibility of obtaining new precise temperature-depth measurements in additional deep wells 20 to 30 years after the last logs were acqured in the northern areas would significantly constrain surface-temperature histories to date.

Scientific Drilling Hudson Bay

Wouter Bleeker (GSC, Ottawa) gave a new perspective on some work in the Canadian Shield and in particular related to Hudson Bay. Many large-scale tectonic and geodynamic questions come together underneath Hudson Bay and further study in this area is necessary to advance the overall understanding of the largest shield in the world. Hudson Bay is one of the largest, if not the largest intracontinental basin on the planet, it is a part of the largest craton, and overlies what appears to be the largest seismically fast mantle root that may be indicative of mantle downwelling. The Hudson Bay lowlands are showing good potential for diamond production. As well, the current thinking in the petroleum industry with regards to the lack of maturity of the basin may not be correct and is in need of additional testing. Further, although yet unproved, the semicircular (215 km radius) section of coastline along the eastern side of the bay (Nastapoka Arc) may be evidence of a large impact scar. If so, it would be by far the largest preserved terrestrial impact basin. Geological relationships suggest it must be ca. 2.6–2.0 Ga in age, leaving a cryptic imprint in Superior craton crust. Scientific drilling may be able to address a number of these issues; a properly designed program might be able to include other studies mentioned earlier.

High Resolution Climate Studies in Arctic Islands Area and Hudson Bay/Hudson Straight

Scott Dallimore mentioned the interest of John England and GSC co-workers in scientific drilling in the channels separating the Arctic Islands. Sharp and Dallimore broadened this discussion to consider the positive linkages of the glaciology work and paleoclimatic studies of companion marine and lake cores. John Shaw provided a number of comments on the late glacial erosion history of Hudson Bay and the companion depositional history in the Hudson Straight area.

Day 2

The second day began with an overview talk by David Malcolm of the Circumpolar Institute on activities in northern communities that might impact such research. He first mentioned the development of the 'Mid Canada Research Institute' that is being formed to be a clearinghouse for research issues related to all of the Boreal areas. This institute would mainly focus on assisting northern communities to address their local research concerns. Communities are anxious for close collaboration with researchers but often they do not see how the research applies to them.

Some discussion of licensing procedures in the various jurisdictions ensued. Levels of organization are evolving at different rates but the overall situation is likely to improve. At the present time, aside from issues related to climate change, there does not seem to be a unified view to research across the Arctic although there may be political movement on this issue. One concern voiced at the meeting is that the involvement at the community level may have swung too far and that northern communities, by failing to transfer some of their interest to structures able to look at the broader perspective, may be crippling some of their own long-term development.

Kirk Osadetz (GSC, Calgary) discussed potential research 'horizons' in light of possible directions for the GSC. Development of the North will depend on development of its energy resources, both for indigenous use and for export. One area of particular interest for northern development will be additional gas hydrate development studies with a longer term view towards local use and northern energy development. Such research will likely be carried forward independent of the mainstream of ICDP Arctic Drilling, but the ICDP should be offered an opportunity to participate if another drilling experiment proceeds. There are some areas where tapping other, more conventional local supplies could be highly beneficial to the local community. Indeed, this is the motivation for much of the USGS scientific drilling in Alaska. A Canadian example could be found near Resolute, where an Upper Cretaceous graben on Cornwallis Island may contain significant amounts of coal. Coal-bed methane in this deposit may have some potential for developing a supply proximate to Resolute. Art Clark noted that this is the direction that the USGS will be going as it is determined that North America must turn to the North for additional resources to fill the longer term gap that will appear in gas supply.

A number of questions were raised by these discussions. Some of the thoughts captured centered on:

- Logistics of carrying out such drilling. Who would be responsible for liabilities? What are some legal issues (i.e., who owns the rights to the gas hydrates)?
- Structure of industrial collaborations. It is beneficial to share the risk and the cost but how willing might industrial partners be to tolerate scientific investigations in light of their more immediate, and often proprietary, goals. Often, the science will be subordinated to the industrial needs but if workers start early enough there may be ways to make some scientific goals compatible (e.g., understanding permafrost). However, in many cases researchers are probably on their own as industrial programs are unable to factor in the potential of nonconventional resources such as gas hydrates.
- Incompatibility of goals. For example, obtaining a continuous permafrost core with adequate study of non-frozen zones, for example, may require different drilling techniques. As such, a hole drilled to optimize core recovery could be unacceptable for production studies in hydrate zones. Drilling a horizontal hole might not allow for good core recovery.
- Engineering and scientific linkages. Given some of the problems that would be encountered, one sentiment expressed the hope that there could be better linkages between engineering development and the more fundamental scientific studies. It was asked whether engineering could not be more of a goal in such drilling.
- Long-term observatories. Given the cost of drilling, it is important that the wells be available as long-term observatories. Indeed, this is a major motivation for the holes drilled for the San Andreas Fault project near Parkfield, California and for the potential scientific drilling in the Sudbury basin.

SCIENTIFIC DRILLING OPPORTUNITIES

A summary of the themes that might be of interest for international participation in scientific drilling was set down.

- Permafrost. There are a large number of questions here. Aside from the direct interest in being able to observe changes in the thermal regime with the obvious climatic connections, other issues focus around studies of the unfrozen water content and the free gas zones, the variability of physical properties, and geochemical and deep biospheric activity. Dave Sego (Civil Engineering, U of Alberta) noted that the permafrost is poorly understood from a geotechnical perspective and this lack of knowledge is likely to lead to costly failures in future exploration if past experience is any guide. Such studies could likely be carried out at relatively low cost and would be of interest to a wide variety of researchers. Wells could also be completed so that they are accessible as long-term observatories of changes in the permafrost. This issue raised the greatest amount of interest and will be taken to the International Permafrost Conference held in Europe this summer.

- Climate Studies. This was also an important theme and not at all unrelated to the permafrost discussions. Drilling studies that would be important here include acquisition of more lake and shallow-marine cores, geothermal gradient studies, and glacier studies as indicators of open sea corridors. Both ice and lake cores could provide the millennial record of climate change in the Arctic. Canadian lake cores could not provide long-term undisturbed records because of the extensive glaciation but could yield information about the last 5 ka in many locations.
- Gas Hydrates. There remain a number of studies here and the hydrates, aside from the more direct potential as a resource, are a concern as a source of additional greenhouse gases. One aspect would be to carry out longer term production tests. Whether existing wells could, or should, be entered is currently a topic of discussion.
- Hudson Bay. Targets within this zone have a great deal of appeal. A deep hole drilled near the center of the possible impact structure might also be employed for the biospheric and permafrost studies if appropriately situated. As well, a deep hole might be an ideal long-term observatory. It would intersect not only Hudson Bay Basin stratigraphy, but also important Paleoproterozoic cover stratigraphy of the Superior craton, before entering the leading edge of the Superior craton and testing for relict structures from the putative impact.

The meeting concluded with some consensus that drilling of the permafrost may be one type of study that would have broad international appeal and be able to address a wide variety of differing scientific questions.

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