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ISSUES IN CANADIAN GEOSCIENCE

Report on Workshop on Canadian Participation in the International Continental Scientific Drilling Program
13-14 April 2002, Toronto

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INTRODUCTION

The International Continental Scientific Drilling Program (ICDP) facilitates and funds continental scientific drilling to address geoscience questions. One of the tenets of ICDP is that international co-operation is an essential component for responsible management of our natural resources and environment. The principal scientific themes include: processes related to earthquakes and volcanic eruptions and mitigation of their effects, climate change, impacts and mass extinctions, deep biosphere and the evolution of life, safe disposal of wastes, evolution of sedimentary basins, hydrocarbon and mineral resources, the physics of plate tectonics including heat and mass transfer, and constraints on interpretation of geophysical data.

The objectives of ICDP are: to obtain funding for planning and executing a strategic scientific continental drilling program to address significant socio-economic objectives, to identify drilling targets for international co-operation, ensure appropriate pre-drilling site surveys, and to provide technical support for drilling projects. The advantages of ICDP are in focussing efforts on world-class sites, cost-effectiveness through sharing of risk, the assembly of high-quality international research teams, and realizing the benefits of intellectual capital and knowledge by international co-operation

ICDP has nine nation members, including Canada. Several other nations are negotiating membership, or determining their intentions. Canada's membership is currently achieved and funded through a memorandum of understanding between the Geological Survey of Canada (GSC) and ICDP. It has enabled GSC to increase international participation in the Mallik Gas Hydrates project to more than 100 scientists and engineers, with 22 scientific activities added to the original concept. Although the GSC has clearly benefited from its partnership with ICDP, it is equally clear that these benefits need to extend beyond GSC to the Canadian geoscience community in general. As the GSC has focussed research goals, which are related to federal government priorities, Canadian geoscience participation in ICDP and the science questions to be addressed must be broader than these goals. To assess and develop this broader participation, a workshop was held at the University of Toronto, under the auspices of the Canadian Geoscience Council (CGC), 13-14 April 2002. Forty Canadian, United States, Mexican and German geoscientists and representatives from academia, government, industry, the Natural Sciences and Engineering Research Council (NSERC), and ICDP attended.

The workshop began with overviews of ICDP and some of its active projects, including those with Canadian involvement. Break-out sessions focussed on potential future Canadian projects that might be pursued within ICDP. In a concluding plenary session, participants recommended that CGC form a Standing Committee to build Canadian participation in ICDP, through dissemination, a search for further ideas, and specific project workshops on three potential "world-class" Canadian targets.

ICDP AND SOME OF ITS CURRENT PROJECTS

ICDP Overview

R. Emmermann GeoForschungsZentrum, Potsdam; Chair, Executive Committee, ICDP) provided historical background on ICDP, which was initiated after a conference in Potsdam in 1993, and a subsequent memorandum of understanding between GeoForschungsZentrum (GFZ) and the National Science Foundation (NSF) in the United States. ICDP has an organizational structure with low overhead, comprising a Scientific Advisory Group that focusses on selecting the most promising scientific ventures. The Executive Committee then assists with management, financial, and engineering support and an Assembly of Governors, representing the member nations, provides overview.

More than 100 drilling proposals have been received to date. As of April this year, ICDP had some 20 accepted drilling proposals in a dozen nations and in various stages of planning, execution, or completion. The process consists first of a pre-proposal that outlines the target and the overall vision. The criteria for consideration of such projects are global scientific significance, relevant societal needs, the calibre of the scientific team, effective leverage of financial and technical resources, quality of pre-site geoscience surveys, and realistic costs and engineering requirements. ICDP may then provide funds for an international workshop to discuss a strategy that will lead to a full proposal.

ICDP members include Germany, the United States, Japan, Canada, China, Mexico, Austria, and Iceland. Norway and the Czech Republic are presently negotiating terms, while France and the United Kingdom are considering membership. Membership allows Canadian scientists to propose and lead appropriate drilling ventures worldwide. ICDP does not pay the entire costs of a drilling project but serves in a role to provide financing that is intended to assist in leveraging other funding. The overall budget of the program falls in the range of US$3-4 million per year.

The GeoForschungsZentrum (GFZ), Potsdam maintains the operational office for the ICDP. The office offers technical and engineering support, access to a hybrid coring system developed by DOSECC, core logging equipment, geophysical logging tools, and the GLAD 800 portable drill platform for recovering soft sediment lake cores.

The following co-sponsored projects are currently under way:

- The Hawaiian deep drilling project is directed to the evolution of magma systems with time. This project began with a 1-km pilot hole, extended to 3.5 km in 1999, and is planned to go to 5 km in the next phase.
- Ultra-high metamorphic drilling, Donghai, China began in July 2001 with two 1-km pilot holes, and a 2-km hole, drilled with the DOSECC hybrid coring system, yielding 90% core recovery. A full 3-D seismic survey and a 5-km deep well are planned.
- The San Andreas fault zone drilling (SAFOD) project, seeks to study the state of stress on the fault in the vicinity of Parkfield, California, chosen for its history of moderate intensity and highly localized seismicity. A 2-km pilot well will be spudded on 1 June 2002 for stress and fluid recovery. This will be followed by a vertical well that would be deviated to intersect the seismically active region at depths near 4 km.
- The Unzen, Japan drilling project is to drill into a magma conduit with an inclined wellbore.
- The KTB project, Windisheschenbach, Germany. The 4-km pilot and 9.1-km main borehole from this project remain open for long-term studies.
- The Gulf of Corinth drilling project targets a rift zone characterized by shallow earthquakes. A multiborehole observatory will be created for long-term studies of seismicity and strain. Schlumberger has provided funds for an additional wellbore.

Projects that require drilling in shallow water may provide links between ICDP and ocean drilling programs. Examples include the well to a depth of 4-5 km in the Hellenic Arc and wells immediately offshore on the Chicxulub impact crater structure.

More information on the ICDP is available at http://icdp.gfz-potsdam.de.

Long Valley Caldera

J. Sass (United States Geological Survey, Flagstaff) explained that this project targeted hydrothermal resources within the caldera. A surprising result was that the temperature of the subsurface near the caldera is lower than expected because of the large flux of cold groundwater from the Sierra Nevada. A bonus from this project was an excellent set of stress measurements from borehole televiewer imaging and hydraulic fracturing.

Vital factors for successful scientific drilling include good working relations on-site, especially between drilling and science teams, continuous presence of scientists on site, and early setting of priorities that are called into play when the inevitable trade-offs arise during drilling.

Chicxulub Impact Crater Scientific Drilling Project

J. Urrutia-Fucugauchi (Universidad National Autónoma de México) reported that this ICDP project was completed in late March 2002. The Chicxulub site is one of the three largest craters on Earth, with a diameter of about 200 km, and may have been the cause of mass extinctions at the Cretaceous-Tertiary boundary. The DOSECC hybrid coring unit and other infrastructure was provided by ICDP. Cores yielded Tertiary limestones/siltstones to a depth of 794.4 m, with a zone of melt breccia at the K-T boundary about 100 m thick, underlain by Cretaceous limestones to the bottom at 1511 m. The breccia contained large fragments of basement.

The Mexican Continental Scientific Drilling Program aims to undertake additional drilling of the impact structure to better understand its character. Other projects being considered include one in the Mexico City basin, related to subduction beneath much of central Mexico, and the other a lake sediment drilling project for paleoclimatic records.

The Deep Biosphere

S. Haveman (University of Calgary) noted that the discovery of life at depth within the Earth has been a fascinating recent development in geoscience. Ninety percent of the prokaryotic cells on Earth reside either in oceanic sediments or the continental subsurface. Organisms are unlikely to exist at temperatures much in excess of 120°C (depths of a few kilometres). Most organisms can reproduce at pressures to 6 atmospheres but those that exist above this pressure need to be maintained at pressure in order to thrive. Water is an absolute requirement for growth but not for survival, and organisms can survive for millions of years in desiccated form. To be healthy at depth in the Earth, such organisms require pores with dimensions of a few microns and flow of a variety of nutrients (C, P, N, trace elements).

Ensuring that samples have not been contaminated is difficult. Usually the samples are maintained at low temperature and under anaerobic conditions. Contamination is avoided by sampling only interior portions of the core and by looking for fluorescent tracers within the sample that would indicate that the sample had been compromised.

Organisms are studied by counting total numbers of cells, by culturing, and by detection of biological molecules (*e.g.*, DNA/RNA and ATP). The results of two studies were presented. The first showed the exponential decrease in total number of cells with depth in an ocean sediment, the decreasing numbers indicative of the consumption of necessary nutrients with time. The second showed total counts with depth within continental rocks.

Lake Drilling

C. Scholz (University of Syracuse) described the drilling of soft sediments deposited in low-energy lake floors, which yield important clues as to climatic conditions over the past million years or so. Climate varies locally, so that a distribution of such studies at a variety of latitudes is necessary for the global signal to be discerned. A crucial development has been the construction of the modular GLAD-800 lake drilling barge. This carries a 30-tonne drill rig. It can work in waves of 1.5 m, and can be anchored in water up to 230 m deep, drill to depths of 800 m below lake floor, and may with future improvements reach 1200 m. The rig contains a hydraulic piston coring tool and has a high recovery success rate. The barge was developed by DOSECC in Salt Lake City, Utah. First engineering shake-down tests in Great Salt Lake and adjacent Bear Lake produced cores useful for climatic studies.

The first major project for the drill rig, however, has been in Lake Titicaca at an altitude of 3800 m in the Altiplano bordering Bolivia and Peru. This lake has a very delicate hydrological balance, with a very small total outflow and has a good record of sedimentation. Recovered materials are presently being studied.

The next major project will be in Lake Malawi, in the African rift system between Malawi and Tanzania and Mozambique. Wave heights on Lake Malawi can be too great for the GLAD-800 rig, so a larger barge will be modified, including the fitting of stabilization propellers. Drill siting relies on extensive sets of seismic profiles from the basin scale to very high resolution surveys. These surveys suggest that large shifts in lake levels occur with a frequency of about 100 ka, possibly suggestive of orbital precessional forcing.

Lake Baikal Drilling

V. Kravchinsky (University of Alberta) discussed measurements of rock magnetism and implications for paleoclimatic studies from scientific drilling in Lake Baikal, conducted by a consortium of Russian, United States, and Japanese scientists. The lake has a length of approximately 1000 km and widths up to 100 km; it is among the largest, deepest and oldest fresh water lakes on Earth. Drilling was done in winter from a barge frozen into the ice. Drilling over the Academician Ridge yielded a 280-m core covering 6 Ma of slow sedimentation.

Magnetic susceptibility and coercivity provide the magnetic mineralogy, indicative of temperatures at the time of deposition. A model of the magnetic inclination relative to age was developed and this allowed the novel use of magnetic inclination as a proxy for age.

Lake Bosumtwi, Ghana

B. Milkereit (University of Toronto) noted that the Lake Bosumtwi project is at the early proposal stage for ICDP. This site provides a record of sedimentation at the equator over the last approximately 1 Ma, and the 10-km diameter lake itself was produced by an impact. Much of the breccia sheet and original deformation around the lake remains, together with extensive tektite development. This project addresses two problems of global scientific interest: the paleoenvironment and impact structures.

An extensive series of geophysical pre-site surveys has been completed. These include gravity, magnetics, and both reflection and refraction seismic profiling. Serendipitous access to aeromagnetic services, while in transit over the area, has helped.

Mallik Gas Hydrate Drilling

J.-S. Vincent (GSC, Ottawa) described Canada's first ICDP-supported drilling project. The Mallik wells were drilled to just over 1 km on Richardson Island, 170 km north of Inuvik, Northwest Territories, to acquire gas hydrate cores. Gas hydrate is an ice-like material that forms in the shallow subsurface below deep water margins around the world, and at shallower depths in cold climates. The reserves of natural gas locked into hydrates may far exceed those of conventional hydrocarbon reservoirs. The Mallik region alone may contain 3700 bcf of methane. Gas hydrates can also be hazardous. Methane is a greenhouse gas and large releases could be triggered by, and then amplify, global warming. Dissociation of gas hydrates may trigger slumping of marine slope sediments.

The main objectives of the Mallik well were to assess the response of the gas hydrates to production, and to attempt some stimulation of the dissociation process, within the framework of multidisciplinary science. The project was very successful in integrating the various scientific, engineering, and technical groups, from Germany, the United States, Japan, India, and Canada.

The ICDP support attracted valuable new science. Canadian universities contributed cross-well seismology, time-lapse seismic monitoring, and vertical seismic profiling studies. GFZ Potsdam carried out high-resolution fibre-optic temperature monitoring that will continue into the future. A compendium volume of data and interpretations will be published by 2004.

Timing of the Mallik project was logistically critical. The camp was mobilized on completion of the ice road in late November 2001. The first hole was spudded on December 25, drilling proceeded, and the camp demobilized by 15 March 2002. More than 300 m of very high-quality continuous core was obtained using a wireline system. The production results, confidential for the next 2 years, are reported to have exceeded expectations.

The Ocean Drilling Program (ODP) and Integrated Ocean Drilling Program (IODP)

M. Salisbury (GSC, Dartmouth) described the transition now going on in oceanic scientific drilling. The current ODP ends in 2003, and it will be supplanted by IODP.

ODP has been underway for 34

years, using the *Glomar Challenger* at first, and the *JOIDES Resolution* for the last 17 years. The program has drilled more than 1231 separate sites on 202 expeditions. ODP confirmed sea floor spreading and hot spot hypotheses, examined the K-T boundary and bacteria within sea floor sediments, and contributed to the discovery of marine gas hydrates and oceanic massive sulphides, and supplied cores that reveal information about orbital climate forcing.

The Resolution is a "non-riser" ship; the drill string is open to the water column, so the ship cannot circulate drilling fluids, and blowout prevention equipment cannot be used. The ship cannot drill in water less than 2 km deep, neither can it drill in hot rock, nor pack ice. Thus many important targets, in Arctic regions, in oceanic fracture zones, in thick sediment prisms on shelves and their edges, in very young oceanic crust, and lower oceanic crustal layer 3 cannot be accessed.

To overcome these problems, the Japanese are constructing a larger "riser" vessel, the *Chikyu.* This will include a 2500-m riser and carry 10 km of drill string. It will cost about US$ 500 million. Japanese drilling objectives are to understand the seismogenic zones above subducting plates. IODP would share use of the *Chikyu,* and a replacement for, or a refurbishing of, the *JOIDES Resolution.* Alternative platforms will be adapted for special needs, such as Arctic or shallow water land/ocean transition zones. The *Chikyu* will be tested and available by 2007, the new non-riser ship is expected to be operational by 2004.

There are currently 277 active proposals for ocean drilling. The IODP science plan includes studies of the deep biosphere, gas hydrates, extreme climates, and rapid climate changes, and attempts to access the upper mantle where the crust is thinnest. A high priority is to drill the Lomonosov Ridge in the Arctic Ocean, which may produce a record of 60 Ma of slow sedimentation. Two wells are planned for this project that would include a special Finnish ice-strengthened drill barge supported by a number of ice breakers.

A proposal has been submitted to the International Access Fund of the Canada Foundation for Innovation (CFI), to fund Canadian participation in IODP for 5 years. The funding would cover membership, secretariat, data centre, and post-cruise research support.

Technology of Drilling, Coring, and Downhole Measurements

A. King (INCO) and L. Pascoli (Longyear Drilling) discussed the "slimhole" drilling technology employed in the hardrock mining industry. Hundreds of thousands of such wells have been drilled; INCO alone has about 100,000 fully-cored wells of which approximately one-third are drilled from the surface and remain open to depths up to 3 km. Currently, at Sudbury, mining is taking place at depths of 2.5 km and there are plans to go deeper, possibly using remote robotic equipment.

Minimum drill hole size is 75.7 mm (NQ) with a 60.3-mm diameter drill string taking a 50.8-mm diameter core. Drilling takes place by wireline retrieval of core and as a result a continuous core is obtained. The strength of the rock must be high enough to keep the hole open. Drilling beyond 2.5 km requires special equipment, including a thicker and heavier walled drill string that can support a greater weight. However, for an NQ size drill string, this restricts the final core diameter to 36.5 mm (BQ). Geophysical logging tools for such wells are currently limited to pressures of around 140 MPa (20,000 psi or 1400 bars) and temperatures of 175°C, although there are some tools that can survive up to 260°C. Tools available include sonic, natural gamma, induction resistivity, galvanic resistivity, density, magnetic susceptibility, and temperature.

The longest drill hole in the Sudbury structure is 3.5 km, drilled 20 years ago, although the world record for this technology is around 5.4 km from a South African mining camp. The cost for a 3-km deep well would be ~$450 thousand, for a 4.5-km well ~$1.5 million, while a 5.5-km well would exceed $2 million. Drilling could progress at rates near 60 m/day at higher levels and as low as 40 m/day at 3 km.

Discussion

Prior to the break-out sessions, A. Cruden (University of Toronto) commented on the value of drilling granitic plutons, to understand their construction, to ground-truth some of the geophysical features, to extend our understanding of fracture density and hydrological conductivity, and to carry out deep biospheric research in what should be pristine and ancient continental crust. G. Lodha (Atomic Energy Canada Ltd.) reviewed the status of research on radioactive waste disposal that had been carried out primarily in a granitic pluton. J. Sass mentioned a borehole drilled into a pluton near Flin Flon, Manitoba that may still be accessible.

POTENTIAL THEMES FOR FUTURE CANADIAN PARTICIPATION IN ICDP

Three break-out sessions were organized for discussions of potential themes and targets for future Canadian participation in ICDP. Facilitators summarized the conclusions of those discussions as follows.

Potential Projects on Crustal Anatomy, Impact Structures, and Volcanics

M. Salisbury (GSC, Dartmouth) summarized this group discussion under seven topics. Drilling active faults (*e.g.*, North Anatolian, Main Boundary in the Himalaya, the Queen Charlotte transform) might yield new understanding of relationships among stress, strain, fluids, and seismic precursors. Drilling ancient faults associated with Proterozoic suturing of the Canadian shield, and now exhumed, might help distinguish deeper crustal shearing processes. The Sudbury complex and the New Quebec crater are world-class structures for studying extraterrestrial impacts, and the latter also would have a valuable paleoclimate record. The origins of deep crustal conductivity anomalies are widely debated: drilling the Mid-Continent Conductivity anomaly would help resolve these arguments. The anatomy of Canadian kimberlites would have industry interest, and also global interest in the peculiarities of Canadian dyke-like examples. The internal structure of batholiths in the Andes and the Precambrian shield could be drilled to assess heterogeneity, geophysical structure, microbiology (free of Ni catalysis), stress, strain. There are LITHOPROBE and

Canadian radioactive waste studies available as background. This group also suggested drilling to ground truth LITHOPROBE seismic reflectors. Special interest was also expressed in drilling Darnley Bay, the Temagami Anomaly, and markers in gold deposits (*e.g.*, in Red Lake).

Potential Projects on Stress, Strain, Fluid Flow, and Drilling Technology

R. Bailey (University of Toronto), on behalf of this group, noted that Canadian sites did not have a clear advantage over others for this set of themes. There are many geothermal areas much more easily accessible than Canadian sites, such as Meagher Mountain. There are poorly understood bands of intraplate seismicity in Canada (*e.g.*, under the St. Lawrence), but other areas such as the New Madrid zone in the United States would provide more scientifically compelling sites. A subduction deformation observatory over the descending Juan de Fuca plate would be interesting, but this might be better carried out in the Pacific Northwest of the United States where the plate is closer to the surface or in places such as the Mexico basin. A handful of possibilities was discussed more fully. Drilling the Kapuskasing uplift would ground truth seismic reflectors and electrical conductors imaged by LITHOPROBE, and build on prior work in the early 1990s. Stress studies could complement drilling in this location. Drilling the Sudbury impact structure could focus on testing the impact hypothesis for its formation. There is a wealth of existing geophysical and geological information at Sudbury, and understanding the state of stress, especially at increasing depths, is of very great interest to the mining companies. This site could highlight the innovation of the Canadian slim-hole drilling industry in reaching depths of about 5.5 km with continuous core at a relatively low cost relative to other drilling methods. Drilling a granite pluton could address science issues relating to batholith form and heterogeneity, but also include inserting instrumentation for long-term stress/strain and fluid monitoring, perhaps at significantly greater depths than have previously been attempted. The Queen Charlotte transform fault could be a target to complement the San Andreas, which appears to be a particularly low friction fault: is this also? A disadvantage is that the fault itself is far enough offshore to pose a problem of lateral reach from a terrestrial site.

Potential Projects on Deep Biosphere, Paleoenvironment, and Paleoclimate

J.-S. Vincent (GSC, Ottawa), in a summary of the group discussion, suggested that Canada might play a leadership role in scientific drilling focussed on the deep biosphere. By bringing various disciplines together, we could focus on geological sequences with steep chemical gradients. These might be add-ons to other targets, such as the Canadian Shield (with links to radioactive waste disposal, perhaps by drilling in existing mines); life signatures in banded iron formations; rift systems to establish how they influence the growth of microbes in the subsurface; the Western Canadian sedimentary basin (with links to the hydrocarbon industry and groundwater dynamics); and permafrost areas. For the latter, in areas like the Mackenzie delta, there is linkage with gas fluxing, and with analog studies of subsurface water on Mars.

For climate change, there is a need for high-quality continuous sequences in key areas, to allow for high-resolution paleoenvironmental reconstructions. Paleomagnetic methods could play a key role in such studies, to provide links to orbital controls on the environment. Some potential Canadian drilling targets with undisturbed sediments are the New Quebec crater; the Old Crow basin (an unglaciated section of the Yukon in which long-term continuous lake sediment records may occur); the Mackenzie River delta (for records of the permafrost history); Great Lakes; the mouth of the Saguenay River; the Beaufort sea shelf; lakes in British Columbia; and West Hawk Lake, Manitoba (already being considered as a ICDP drilling site) (proposed by J. Teller, University of Manitoba, and colleagues).

CONCLUSIONS AND RECOMMENDATIONS

In the concluding plenary session, participants deliberated on connections with the national LITHOPROBE research project, promotion of Canadian participation in ICDP to the broader geoscience community, selection of a small number of highly rated Canadian drilling targets, and potential funding sources.

J. Hall noted that LITHOPROBE's seismic images of the continental crust show either whole crustal structures (*e.g.*, dipping reflectors that descend from the surface to the lower crust) or structures that sole, or disappear, in mid-crust from above or below. Drilling to lower crustal structures detached from surface geology would be prohibitively expensive, though of crucial importance to understanding crustal evolution. Shallow structures imaged to the surface appear to correlate with mapped geology, so that the geological value of drilling them is questionable. However, the seismic image responds to variations in elastic properties and, in the near subsurface, these are as much a function of porosity as of lithology. This situation changes downwards so that the image of a dipping structure will not represent the same combination of physical properties at the surface as it does at depth. The interplay of factors affecting seismic reflectivity is worthy of further geophysical study, because it is the main reason why in early deep-drill sites (such as the German KTB), the correlation between seismic reflections and lithologies cored was not as expected.

Participants agreed that there was great potential for exciting new science with Canadian involvement in ICDP. Building the case for Canadian participation in ICDP would require the momentum developed during the workshop to be amplified. A two-pronged approach was recommended: promotion of ICDP to the wider geoscience community in Canada and, in parallel, the pursuit of three potentially world-class drilling projects through individual workshops.

Promotion to the wider community should be effected through publication of this report, and holding further workshops in Canada on the general objectives of ICDP (*e.g.*, at regular meetings of learned societies). These activities, the project-specific workshops, and movement towards proposals and funding, should be co-ordinated by a

Standing Committee of CGC. This committee could be in place by 1 May 2002.

Participants deliberated on Canadian targets that might be of sufficient global interest to draw support from ICDP, and hence justify Canadian membership in the program. Three targets were defined and participants recommended that workshops on each be held in the fall of this year.

Sudbury Impact Drilling

The Sudbury impact structure is world renowned for its intraplate layered igneous bodies, and its global significance as a nickel producer. Yet, features of it origin remain enigmatic for lack of deeper borehole information to distinguish between interpretations of modern seismic reflection images. Testing these models with one or more deep boreholes would not only help resolve genetic issues, but could also be useful as a guide to further mineral exploration in the structure, and to the stress conditions that affect deep mining. The Canadian mineral industry development of slim-hole drilling might also be promoted through a deep drilling program using in comparison with the more conventional drilling systems used by ICDP to date. There is a wealth of shallow drill hole information available to set the context for deep drilling, as well as high-resolution geophysical data sets, including seismic images from LITHOPROBE and others.

Drilling in the North

Canada's first ICDP project was drilled early this year to test gas hydrates at Mallik in the Mackenzie delta of the Northwest Territories. Further drilling on land in Canada's north could extend the gas hydrate project to somewhat different temperature-depth regimes, so testing the model phase relationships of the hydrates. Perhaps more significantly, such drilling could also target high-latitude paleoclimate data (to complement Siberian data), major permafrost issues, and the peculiarities of the deep biosphere below a cold Earth surface in a low geothermal gradient.

Kimberlite Drilling

There has been an explosion of interest in kimberlites in Canada, because of the diamond finds. Canadian kimberlites include variations from the standard central vent familiar from well-studied, and deeply-mined, South African examples. Drilling through one of the unusual Canadian dyke-like kimberlite bodies could yield first-order understanding of the variation in the form of kimberlite bodies and the relationship between from and lithologies. Such a project could have global impact from a genetic viewpoint and national value in terms of diamond exploration strategies.

DISCUSSION

If, as anticipated, the CGC Standing Committee on the International Continental Scientific Drilling Program materializes quickly, it will charge subcommittees, including volunteers from this workshop, to organize open workshops devoted to these specific drilling targets this fall. Interested readers may check with the authors of this report regarding progress on these workshops, or check the CGC Web page for further information.

Participants discussed a number of potential opportunities for funding participation by Canada in ICDP. The Canada Foundation for Innovation has a one-off program (the International Access Fund) that assists Canadians with access to international projects. However there has been no announcement of an extension to the program. NSERC offers several research funding programs that might help: the International Opportunities Fund (supported this meeting); the Collaborative Research Opportunities program (which assists Canadian researchers participate in timely major international or interdisciplinary research projects); the Major Facilities Access program (for access to ICDP specialized laboratories); and the Research Networks Program (which funds LITHOPROBE and Canada ODP). There may also be other components of Industry Canada's support for research and development that could be approached, especially in the light of the government's Innovation Strategy.

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