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ISSUES IN CANADIAN GEOSCIENCE



Conference Report Geoscience Summit 2004 Ottawa, Ontario 16 - 17 October 2004

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SUMMARY

Over one hundred leaders of the Canadian earth science community met at *Geoscience Summit 2004* last October to discuss strategies for maximizing our contribution to society. The *Summit* was chaired by Canadian Geoscience Council (CGC) President Harvey Thorleifson and Geological Association of Canada (GAC) Advocacy Coordinator Simon Hanmer, while sponsors were CGC and Geological Survey of Canada (GSC).

Thirty-nine speakers prepared analyses, focusing on key points identified in discussions at CGC-sponsored Council of Presidents meetings in November 2003 and May 2004, which concluded that we need to establish a better sense of community, awareness of activity and priorities, and a more unified

voice which will allow us to take more effective collective action. Presentations reviewed earth science in the energy, mining, environment, survey, and research sectors. Representatives of associations described the progress of professional registration, and coordination of activities such as conferences and publishing, as well as communications activity such as outreach, advocacy, and student recruitment. Leaders of past, present and potential research programs outlined lessons learned and the opportunities ahead.

The energy and mineral industry representatives focused on the need for renewal of recruitment and training to provide a new generation of geoscientists, while the mining and environment sectors called for increased availability of public geoscience to support their work in fields such as mineral exploration and groundwater protection. The government sector focused on evolving mandates as well as redistribution and adjustment of geological survey capacity, while highlighting important initiatives such as formulation of a national consensus around the *Cooperative Geological Mapping Strategies* (CGMS) proposal. The *International Polar Year* (IYP) and the *International Year of Planet Earth* (IYPE) were reviewed by an invited expert panel, and discussions addressed the implications of the new Canadian Academy of Sciences. Speakers also reviewed the success of LITHO-PROBE, and new initiatives were presented, including NEPTUNE, POLARIS, proposals for deep drilling, as well as several others. The potential for broader and more aggressive marine programs was discussed, as were planet-scale approaches, our role in health issues such as toxic elements and groundwater protection, reducing our vulnerability to hazards, dealing with cli-

mate change, and ensuring sustainable groundwater supply.

Some participants felt that there should have been more presentations from industry and environmental earth sciences, while others expressed the view that there were too many presentations, at the expense of general discussion. The demographic and gender balance of the participants was seen by some as not reflecting the community. The *Summit* chairpersons responded to calls for maximization of time for discussion, which resulted in some speakers protesting that their ability to present their analysis was being curtailed. By adjournment time, however, the agenda had been completed on time, and there had been much lively and constructive discussion on successes to celebrate and promising opportunities to pursue.

Participants recognized that the earth sciences play a critical and extensive role in our society, so good coordination and communication within our community are critical to ensure that our contribution to society can be optimized. Fragmentation was seen as the principal challenge constraining our contribution. Therefore, the following priorities were identified:

- An effective Canadian earth science union that can better speak for the benefits of earth science, including a community-wide communication mechanism, pooling of community resources, and coordination of association functions
- More outreach and advocacy to enable Canadians to better utilize earth science knowledge, and to optimize the standing of the earth sciences in Canada
- Renewed agendas for geological surveys and university research, which will capture the imagination of our community, of the policymakers who

fund us, and of the public to whom the policymakers listen

- Recruit new geoscientists by providing opportunities for education and work experience; optimize the benefits of professional registration and facilitate professional mobility

The *Summit* revealed opportunities and frustrations. Fragmentation was seen as our principal challenge, and participants were anxious for follow-up steps to be taken quickly. The level of dissatisfaction with our progress, however, implies that a more efficient and effective model for community coordination is needed. The CGC, therefore, will host a June 2005 Planning Forum in Calgary to develop a Plan for the Earth Sciences in Canada. An autumn 2005 Town Hall in Ottawa will consolidate community views, and a document will result in June 2006. The participation of the entire Canadian earth science community will be required, as we have a responsibility to ensure that the \$7B that are spent each year on geoscience knowledge acquisition in Canada are spent effectively and efficiently, for the maximum benefit of all Canadians.

SUMMAIRE

Plus d'une centaine de leaders de la communauté géoscientifique sont réunis en octobre dernier au Sommet géoscientifique 2004, pour y discuter des stratégies permettant de maximiser la contribution de notre communauté à la société. Ce "sommet" était présidé par Harvey Thorleifson, président du Conseil géoscientifique canadien (CGC) et par Simon Hanmer, coordinateur à la promotion à l'Association géologique du Canada, et les commanditaires de l'événement ont été le CGC et la Commission géologique du Canada.

Les analyses préparées par les trente-neuf conférenciers portant sur des thèmes clés cernés discutés aux réunions de novembre 2003 et de mai 2004 du Conseil des présidents - commanditées par le CGC - ont permis de conclure qu'il nous faut renforcer notre sentiment de groupe, être plus conscient des événements en cours et de leur priorité, et aussi savoir nous faire entendre d'une voix mieux unifiée, ce qui nous permettra de décider d'un plan d'action collectif plus efficace. Les présentations soumises ont traité des sciences de la Terre dans les secteurs de l'énergie, des

mines, de l'environnement, de l'exploration, et de la recherche. Des représentants d'associations professionnels y ont discuté des progrès quant en l'enregistrement professionnel, et de la coordination des activités comme les congrès et les publications, ainsi que des activités de communications comme la sensibilisation, la défense des intérêts, et le recrutement des étudiants. Des dirigeants de programmes de recherches passés, actuels ou à venir ont décrit des leçons dont il faut tirer profit et les possibilités qui s'offrent à nous pour l'avenir.

Les représentants des secteurs de l'énergie et des minéraux ont surtout insisté sur la nécessité de recruter et de former une nouvelle génération de géoscientifiques, alors que ceux des secteurs de l'exploitation minière et de l'environnement ont mis l'accent sur la nécessité d'une meilleure sensibilisation du public aux connaissances géosciences afin que les besoins et les contraintes de l'exploration minérale et de la protection des eaux souterraines soit mieux compris. Les représentants des services gouvernementaux ont surtout traité de l'évolution des mandats ainsi que de la redistribution et de l'ajustement des outils des services de levé géologique, tout en montrant l'importance de grandes initiatives comme la formulation d'un consensus national sur la proposition de Stratégies coopératives de cartographie scientifique (SCCS). Un panel constitué d'experts invités ont traité de l'Année polaire internationale (API) et de l'Année internationale de la planète Terre (AIPT), et les discussions ont porté sur les engagements de la nouvelle Académie des sciences du Canada. Les conférenciers ont aussi passé en revue les réussites du programme LITHO-PROBE, et de nouvelles initiatives ont été décrites, dont les propositions de sondage à grandes profondeurs de NEPTUNE et de POLARIS, ainsi que plusieurs autres. Les mérites de programmes marins plus dynamiques et de plus grande envergure ont fait l'objet de discussions, et il en fut de même d'approches à l'échelle de la planète, de notre rôle à l'égard de grandes questions de santé comme les éléments toxiques et la protection des eaux souterraines, de la réduction de notre vulnérabilité face aux risques naturels, de la gestion des changements climatiques, et de l'assur-

ance d'un approvisionnement durable en eaux souterraines.

Certains des participants ont estimé qu'il aurait dû y avoir un plus grand nombre de présentations des secteurs de l'industrie et des sciences de la Terre en environnement, alors que d'autres pensaient qu'il y en avait trop par rapport aux discussions générales. Certains ont fait valoir que l'assistance n'était pas représentative de la diversité démographique et du profil homme-femme de la collectivité. Les présidents du "sommet" ont donc pris de mesures visant à maximiser le temps alloué à la discussion, ce qui leur a valu des protestations de certains conférenciers qui arguaient qu'ils n'avaient plus le temps de présenter correctement leur point de vue. Cependant, au moment de la clôture des travaux, tout le contenu de l'ordre du jour avait été traité, et on avait discuté vivement et efficacement des réussites et des possibilités de projets prometteurs.

Les sciences de la Terre jouent un rôle critique étendu dans notre collectivité, d'où l'importance critique d'une coordination et d'une communication efficace au sein de la communauté géoscientifique afin d'optimiser notre contribution à la société. L'absence d'unité de sa voix est le principal défi de la communauté géoscientifique. D'où la liste suivante de mesures prioritaires à mettre en œuvre :

- Une union véritable des sciences de la Terre au Canada dotée d'outils de communication lui permettant de porter efficacement les messages de la communauté, la mise en commun des ressources du groupe, et la coordination des fonctions des associations professionnelles.
- Davantage d'efforts de sensibilisation et de défense des intérêts des sciences de la Terre qui permettent aux contribuables canadiens de mieux tirer partie des connaissances géoscientifiques, et qui permettent d'optimiser la position des sciences de la Terre au Canada.
- Des programmes d'activités repensés pour les services géologiques et la recherche universitaire qui stimulent l'imaginaire de la communauté géoscientifique, celles des responsables des sources subventionnaires ainsi que celle du public en général, aux besoins duquel répondent les sources

subventionnaires.

- Le recrutement de géoscientifiques par la mise en place de mesures de formation et d'acquisition d'expérience; optimiser les avantages de l'inscription à une association professionnelle et faciliter la mobilité professionnelle.

Le "sommet" a permis de mettre au jour frustrations et perspectives d'avenir. La fragmentation a été perçue comme le principal problème confrontant la communauté géoscientifique, et les participants se sont montrés pressés de mettre les correctifs en place dans les meilleurs délais. Le niveau d'insatisfaction face à notre évolution appelle la mise en place d'un modèle de coordination de la communauté géoscientifique qui soit plus efficace. En conséquence, la CGC tiendra en juin 2005 à Calgary un forum de planification afin d'élaborer un plan pour les sciences de la Terre au Canada. À l'automne 2005, une assemblée publique à Ottawa permettra de consolider les points de vue de la communauté géoscientifique, et un document de synthèse sera produit en juin 2006. La participation de toute la communauté géoscientifique canadienne est essentielle, puisqu'il nous incombe de nous assurer que les 7 G\$ qui sont dépensés annuellement au Canada pour l'acquisition de connaissances géoscientifiques le soient de manière judicieuse et efficace, afin que les contribuables canadiens en aient le plus pour leur argent.

SUMMARY OF GEOSCIENCE SUMMIT 2004 PRESENTATIONS

The opening speaker was **Irwin Itzkovitch**, Assistant Deputy Minister for the Natural Resources Canada (NRCan) Earth Sciences Sector, which includes GSC and Geomatics Canada. He welcomed participants, and conveyed the full support of NRCan for this CGC initiative. He described important contributions that the earth sciences makes to society in provision of mineral, energy and water resources, as well as dealing with climate change and hazards. He also pointed to negative signs such as lack of success in NSERC re-allocation, reduction in industry employment, reduced survey budgets, lower enrolments, aging workforces, and lack of hiring. He attributed these trends to the failure of the community to come to grips with the end of the 1980s resource

and enrolment boom. Sustainable development and climate change are now dominant themes, and geoscientists have attempted to respond with multidisciplinary solutions such as earth system science. Itzkovitch called for reduced fragmentation, a common sense of purpose, and a unified voice among Canadian geoscientists. He noted that the IYPE and the IPY initiatives would provide many opportunities to raise the profile of Earth Sciences with decision-makers as well as the public at large. He stated that we will all fail if we are divided, so focussed discussion is needed during the *Summit* to develop a renewed sense of common purpose.

Harvey Thorleifson, President of CGC and Past President of GAC, described how Canadian geoscientists are responding to a widening array of societal needs - ensuring health by addressing toxic substances and waste disposal, securing our heritage by providing an understanding of land, oceans, life, and the planet as a whole, enhancing our wealth with a supply of energy and materials and guidance for construction, augmenting security by helping society prepare for, and cope with, climate change and hazards such as earthquakes and floods, and by making broad contributions regarding water, which influences our health, ecosystem viability, commerce, and security. He described our response to these needs and opportunities for new approaches in advocacy, consultation, consulting, coordination, education, exploration, management, mapping, monitoring, outreach, regulation, research, and synthesis. He outlined the Canadian earth science knowledge industry, driven by a \$6B annual investment in hydrocarbon exploration, \$500M in mineral exploration, \$300M in geotechnical and environmental earth science consulting, \$130M per year in geological surveys, and \$100M per year in basic earth science research in universities and museums - a sum of \$7B per year or ~1% of Canada's GDP. While the specialized scientific societies support the progress of knowledge in their fields, the GAC supports the progress of earth science as a whole, and the CGC facilitates coordination among the business, professional, and science sectors. Concurrently, the Canadian Geological Foundation and the foundations of specialist groups facilitate benevolence in

support of our science, and we play a role in international initiatives.

Gerry Reinson, CGC Director and former President of the Canadian Society of Petroleum Geologists (CSPG), described the cycle from exploration to drilling, production, processing, transportation, and use of oil and gas products, leading to reinvestment in exploration. Estimates for ultimate, discovered, undiscovered, produced and untapped hydrocarbons show that while significant gas resources remain in frontier basins, limited reserves are available in more accessible regions. Two decades ago, large companies generally were managed by geologists and employed over a hundred geoscientists in their Calgary offices; they traversed the country hiring new graduates, and provided intensive in-house training. More recently, they employ fewer than fifty geoscientists, hire selectively, limit in-house training, and few senior managers are geologists. About half of the ten thousand geoscientists presently in the industry will retire within a decade. Furthermore, employment in the oil sands and east coast is primarily in engineering; hence, student enrolment has shifted accordingly. Working geologists are expressing a need for development of new, applied technical prospecting skills.

Corporations are restructuring, downsizing, and cutting costs, technology is being leveraged to enhance production, few jobs are being created, but experienced geoscientists are in demand. While some believe that fossil fuel usage will soon peak, oil and gas will be required for many decades to come. Yet corporations are driven by short term thinking that results in intense exploitation of mature assets, and frontier exploration has suffered. Nevertheless, steadily increasing commodity prices will eventually drive corporations to explore, and there will be a need for well-rounded earth science graduates. Effective advocacy by the Canadian earth science community will smooth these transitions.

Richard Moore, representing the Prospectors and Developers Association of Canada, outlined three priority earth science issues in relation to mineral exploration - availability and mobility of geoscientists, new public earth science information, and funding for economic geology research. He stat-

ed that the current shortage of geoscientists reflects diminishing availability of long term employment by major mining companies, cutbacks in geological survey budgets, and declining summer student employment. Provinces and territories have enacted legislation to establish standards of practice, which do not adequately recognize the highly mobile nature of geoscientists, so multi-jurisdictional licensing and reciprocal agreements with other countries are needed. Efficient exploration requires comprehensive, web-accessible regional geoscience data. Funding to geological surveys is an investment that will stimulate much larger future economic gains in the form of exploration expenditures and the economic benefits of mining. Canada can remain competitive in exploration and mining because of a superior mineral endowment, stable governments, mature legislation, and availability of geoscience data. The exploration and mining community also needs continual updating of mineral deposit models, regional tectonic models, and exploration technique development to become more efficient.

John Gartner and speaker Steve Usher authored a presentation from the environmental and geotechnical industry. They indicated that site and regional water supply and other environmental investigations rely on earth science in the form of maps, reports, 3D models and databases to make up the framework that everything else hangs on. Concern was expressed that this needed regional geoscience is lacking over most of Canada, while geological survey activity is being curtailed. An abrupt influx of resources for geological mapping has followed the deaths and illnesses at Walkerton, and excellent results such as improved usage of water-well data and the Ontario Geological Survey seamless digital geology of southern Ontario have resulted. But this temporary flurry has been inadequately supported by field investigations, particularly in fast growing urbanized areas where environmental and geotechnical land-use issues are acute. Awareness has to increase, to ensure that collection of high-quality regional geoscience information will accelerate. It was suggested that the sector needs to mimic the mineral exploration community, which has been highly effective at convincing governments of

the economic benefits of the public geoscience that supports mineral development. A major constraint is our current inability to effectively demonstrate the benefit/cost ratio of environmental geoscience, although such analyses are now more readily available after the Walkerton experience. It was concluded that geoscientists in the environmental sector must take action to ensure that the needs of Canadians will be addressed.

Murray Duke, a GSC Director-General, described how the GSC is in the midst of a fundamental change in the way it develops and delivers its scientific programming, transforming itself from being activity-based and capacity-driven to a results-based, issues-driven organization. Scientific programs must now more clearly respond to explicit government priorities articulated in the Speech from the Throne and the Minister's mandate letter, through mechanisms no longer considered supplementary to the core program. While outputs remain important, they are no longer ends in themselves because achieving public policy objectives is now the focus. Outputs that have the highest probability of leading to desired outcomes are given priority, in particular multi-disciplinary applications to a broad range of societal issues. Produced knowledge must be accessible and usable by the non-geoscientist, through effective networks that go beyond the earth science community. Current priorities are in groundwater, climate change, metals in the environment, legislated environmental and resource assessments, hazards, mineral and energy geoscience, ocean management, information management, gas hydrates, and northern resource development. Energy is an increasing priority, as is the role of geoscience in public health. The transformation has resulted in an increased appreciation in government circles of the relevance of earth science, but whether this will translate into more robust budgets remains to be seen.

Mike Cherry, Nova Scotia Provincial Geologist and 2004 Chair of the Committee of Provincial Geologists (CPG), indicated that provincial and territorial geological surveys contribute half of Canadian government geoscience. Surveys tend to be located in economic development ministries, and

little geoscience is carried out in other fields. Funding has recently stabilized after a decade of decline, although fixed costs are rising. Staff rejuvenation has been constrained, some support has been short-term, the territorial surveys remain much too small, and some surveys have suffered deep cuts. Coming retirements will permit realignment with new mandates and technologies. The last 15 years have seen a remarkable improvement in cooperation and collaboration through the Committee of Provincial Geologists and the National Geological Surveys Committee (NGSC). The Intergovernmental Geoscience Accord, signed in 1996 and renewed in 2001, defines distinct roles for the two levels of government. NATMAP, EXTECH, Targeted Geoscience Initiative, and the developing Cooperative Geological Mapping Strategies are examples of successful cooperative programs. Most surveys operate liaison committees that provide industry and academic input into program priorities. Digital information management has been a major success, although meeting new expectations within constrained budgets and traditional bureaucracies remains a challenge. The Canadian Geoscience Knowledge Network (CGKN) will make survey data holdings interoperable and available digitally, although varying policy and regulatory environments are a hindrance. The surveys were established with a narrow mandate to support mineral and energy resources. However, the need to address issues such as land-use planning, water, contaminants, hazards, and climate change is growing, so institutional gaps need to be bridged through effective communication. The key challenge for the surveys in 2004, therefore, is the need to evolve from being focused on the minerals and hydrocarbons industries, into organizations that provide accurate and understandable responses to any earth science issue through application of the traditional strength of the surveys – the acquisition and interpretation of geological data.

Simon Hanmer of the GSC described Cooperative Geological Mapping Strategies Across Canada (CGMS), a proposal for renewal of government geoscience in Canada that will permit more effective land-use decisions and improved quality of life through

environmentally responsible development of energy and mineral resources. Canada's Mines Ministers agreed with industry that within the national innovation agenda, geoscience is a key to enhancing our competitive position for global exploration investment. In 2003, Ministers directed NGSC to complete the CGMS implementation plan. NGSC has identified common goals, assessed geoscience needs in each jurisdiction, and is now consulting with industry and academia about a 10-year, \$500M plan that will lead to a secure energy supply, prosperous mining communities, resource development in frontier areas, and environmentally responsible stewardship of geological resources. Funding allocations by provinces and territories will be determined after the level of federal investment is determined. A regional approach to public geoscience will reflect our geology, and will encourage sharing of expertise among geological surveys, universities, and industry. Priorities for partnerships with academia and industry include remote predictive mapping to map the vast North, and deep-search technologies needed for the detection of buried next-generation mineral deposits. Training of young Canadians will emphasize the capacity of Aboriginal people to ensure their full participation in the resource-based economy.

John Broome of GSC outlined the role of information management in enhancing earth science information usage. Existing clients will continue to demand static products that can only be understood by professionals, but targeted services in some cases delivered by the private sector will serve a broader client base with online, current information customized to needs. We have moved to digital cartography, but our online information services tend to contain only local information, use local standards, and deliver static products. Canadian Geoscience Knowledge Network (CGKN) is developing networked information services to permit discovery, access, and visualization of standardized geoscience information from multiple sources. The first priority is digital information nationwide to serve clients who prefer immediate access to non-standard data rather than delayed access to fully standardized data. But upgrading for consistency must fol-

low through restructuring and adoption of national terminology standards or mechanisms for translation from local to national standards. Cataloguing and visualization services are using widely accepted international standards to ensure compatibility with existing and future national and international services. Development of targeted services will require a large interdisciplinary effort to extract themes from geological maps that presently integrate many attributes. We will be constrained by varying licensing and pricing policies, and by the inconsistent and inadequate nature of our geoscience data, particularly in urban areas. But we must accelerate development of new information systems so that our wealth of presently available knowledge will be used. This will require a profound change in the culture of the geoscience community, combined with adoption of standards for information management and delivery.

Norman Marcotte of the Natural Sciences and Engineering Research Council of Canada (NSERC) described how Earth Science was one of the original 22 Grant Selection Committees (GSCs) when NSERC was created in 1978, and reviewed major NSERC support to initiatives such as Lithoprobe and ODP (Ocean Drilling Program). Total NSERC support to Earth Science in 2003-04 was \$56M, including Canada Research Chairs. Three Networks of Centres of Excellence (NCEs) that involve earth science, the Canadian Water Network, Geomatics for Informed Decisions Network, and ArcticNet, are funded at \$5.8M for 2003-04. NSERC support to Earth Science presently totals 9% of its budget, reflecting the importance of the discipline in fields such as resources, climate and the environment. Recent successes include the Research Networks MITE, Clivar, SOLAS, GEWEX, and CASES that pull together researchers. In Discovery Grant reallocations exercises, the Earth Sciences GSCs lost 4.2% of their budget in 1994, gained 8.2% in 1998 as the overall budget increased 10%, while the discipline lost 3.7% of its budget in 2002. No conclusions or decisions have been made on the nature of the next exercise. Among Discovery Grants, the earth science budget of \$17.1M made up 8.9% of the total in

1995, while the 2003 total of \$21.1M was 8.0% of the total. Earth Science has been more successful in partnership programs. Earth Science must become more cohesive in order to compete against rising disciplines such as Information Technology and Genomics while overcoming the perception that it is a mature discipline not linked to the human dimension. The 1990 separation of Solid Earth Sciences from Environmental Earth Sciences may have been a hindrance, and NSERC is willing to assist the discipline examine itself. However, NSERC has found that the community has difficulty in getting together to agree on a vision for the whole. With an increased focus on interdisciplinary research and integration of science, a divided discipline will have difficulty providing a common front. But there are tremendous opportunities for earth science research in topics such as climate change, energy, and sustainable development, while IPY, IYPE, and the US-led Global Earth Observatory System present exciting opportunities.

Joe White of the University of New Brunswick, current coordinator of the Council of Chairs of Canadian Earth Science Departments (CCCESD), described the state of earth science programs in Canadian universities. He described how the success of reorganizations, driven by perceived opportunities for efficiencies of scale, salary savings, and elimination of units, has been determined by timing relative to faculty turnover, initiatives, and hiring, as well as cultural differences between the units being combined. Faculty demographics are skewed and there is inadequate renewal, but staffing of many positions is not controlled at the departmental level. Competition to attract people is increasingly intense, candidates are not quick to accept offers, and negotiations have been much more intense than in the past. Roles and responsibilities are fragmented as too few are attempting to do too much. Demographics are shifting, and there is inadequate renewal, while universities do not answer to a single community. Enrolment fluctuations have been unpredictable, while enrolment cycles have been more out of phase with industry cycles than in previous years. Student attitudes and interests are similar to those of previous decades, while their range of opportunities has

changed, as has their tendency not to follow in the paths of their predecessors. Students need to be convinced of the value of certain options, based on compensation, stability, challenges, and opportunities. A smorgasbord approach rather than coherent programmes has resulted from the perception that core courses are not innovative. The goals of students are not in our control, so we need to demonstrate the range of opportunities available. If there is a shortage of geologists with mapping skills, for example, it is because they are choosing to do something else. Student choices are not necessarily incompatible with traditional requirements or new directions, if a sufficiently solid core curriculum is taught. There is a need to avoid inappropriate dilution of content without undue rigidity. We have leverage through student mentoring, alumni influence, and departmental interaction with the community.

Marc Boivin, President of the Canadian Council of Professional Geoscientists (CCPG), described how CCPG is a national coordinating body created in 1997 by the provincial and territorial geoscientist associations in Canada. Because professional registration falls under provincial or territorial legislation, the CCPG is not a licensing body, it cannot license individuals, it has no legal authority over the licensing associations, but rather is responsible to the constituent associations. Each provincial or territorial licensing associations sets admission requirements, admits members to licensure, disciplines licensed members, and enforces compliance with legislation. CCPG and the constituent associations develop consistent high standards for geoscience licensure and practice, facilitate national and international mobility, and promote the recognition of Canadian professional geoscientists. Geoscientists are licensed in all Canadian jurisdictions except Yukon and PEI. All of these jurisdictions have joint Engineer-Geoscientist licensing, except for three that have stand-alone geoscientists acts - Ontario, Québec, and Nova Scotia. Over 8500 Canadian geoscientists are registered - half of them in Alberta. The associations have legal responsibility to set admission, academic, qualification, experience and professional practice requirements. The CCPG Canadian Geoscience

Standards Board (CGSB) has provided Minimum Requirements for Qualifications (MRQ) of a four-year geoscience degree in geology, geophysics, or environmental geoscience, including 50% Geoscience, 25% Fundamental Sciences, and 25% options. Experience requirements are 48 months after fulfilling academic requirements, progressively increasing responsibility, partial credit for post-graduate work, partial credit for co-op internships, and one year of Canadian experience. While useful, these MRQ are the lowest common denominator for academic requirements. Inter-association mobility of geoscientists is a key priority for CCPG, although the lack of national standards for academic requirements is a constraint, as is the legal and legislative responsibility of each association, which cannot relinquish or transfer their legal responsibility to administer provincial or territorial law. An Inter-Association Mobility Agreement (IAMA) has been in place since 2001, although it is more an administrative agreement for accelerating registration than a mobility agreement. The Québec-Ontario model, however, provides for reciprocal recognition of Québec and Ontario geoscientists to facilitate incidental practice and temporary practice between the provinces. Multi-jurisdiction licensure is the ideal, although it would require modifications to regulations or legislation for most of the organizations.

Sandra Barr, President of the GAC, described the diverse roles of GAC and its regional Sections and topical Divisions in serving the Canadian earth science community in a manner that is supportive of, but not duplicating, the specialized societies or professional and policy-oriented geoscience organizations. Current individual membership stands at 2100, and GAC Council and executive members are drawn from government, academia, and industry. The core GAC functions are dissemination of scientific information, professional development, public awareness, and advocacy. To sustain membership sales, GAC communicates with members through Geolog and e-communications, with prospective members through membership drives, with University communities through campus representatives and student chapters, with constituent communities through lecture

tours, Sections, and Divisions, with the Canadian earth science community through the Awards program and Geoscience Canada, with policy-makers through advocacy, and with the general public through outreach. GAC facilitates earth science conferences that are a key factor in the progress of earth science as well as interaction within the earth science community. The broad GAC membership base and partnerships with MAC and other specialist groups ensure that the annual meeting will attract a wide cross-section of the Canadian earth science community. Annual meetings are planned through to 2010 in a range of attractive locations and partnered with Canadian specialist societies to maximize their scope and attractiveness; long lead times permit optimal planning and marketing, and the best possible timing relative to other meetings. GAC plays a key role in the progress of Canadian earth science by ensuring the publication of financially self-supporting books and periodicals that ensure the free flow of information on research and professional community activity. The GAC bookstore website is leading to easier management and more efficient and cheaper distribution. GAC seeks to enhance Geoscience Canada distribution to the widest possible community. Geolog, now distributed to members on-line, is an attractive source of news in the Canadian earth science community. Internally, GAC is streamlining costs, and keys to financial viability include corporate memberships, while fund-raising to the Canadian Geological Foundation is strongly supported. GAC welcomes enhanced cooperation and collaboration among earth science organizations in Canada.

Jennifer Bates, GAC

Publications Chair, described the essential role that printed and digital, formal and informal, public sector earth science publishing in Canada plays alongside the large role of commercial publishers. This includes publishing that scientific societies do for reasons of science, service to members and community, and for profit to support other operations, and institutional publishing by geological surveys, museums, and the National Research Council (NRC) done mostly to fulfil mandate. Most publications are author-driven, small-market relative to most commercial publications, and

directed at peers, although publishing directed at the public, students, teachers, policy-makers and decision-makers is expanding. Public sector geoscience publishing in Canada could probably be improved for the good of Canadian earth scientists and our clients, to increase effectiveness and financial viability, and to prepare for increased digital publishing. Increased cooperation could perhaps be achieved while identity is maintained. GAC and GSC have recently co-published, while GAC and MAC are teaming up on marketing, and the potential for wider distribution of Geoscience Canada is being investigated. Digital initiatives such as GeoScience World are examples of co-operation elsewhere. Ideally, public sector publishing will fill a needed niche not adequately served by commercial publishers. Consolidation, which may become essential, could increase critical mass, efficiency and clout on the national and international scene, while ensuring quality publications, healthy finance, and a national and international presence that will serve the Canadian earth science community well.

Kevin Ansdell, GAC Program Chair, described the essential role that conferences play for all of us, whether academic, industry, or government, professional or student. Keys to success include venue, program, partnership, marketing, timing, critical mass, field trips and short courses. Meetings permit exchange of ideas and knowledge, professional development, and networking, while financially sustaining sponsors. Conferences serve academic, government, hydrocarbons, minerals, or environment, or a combination. Retreats such as GAC NUNA meetings are best for advancing specific topics. Large, multi-society conferences are most successful in impact and profit. The calendar tends to be Roundup in January, PDAC in March, CIM, GAC-MAC, CGU, and CSEG in May, and CSPG in June or so. Most provinces and territories hold lively mining open houses in the fall, and interspersed among these dates are specialist meetings such as CANQUA, nearby US-based meetings, and international conferences. GAC-MAC with their partners typically attract 500 to 1000, CSPG with partners attract up to 5000, while PDAC attendance now exceeds 9000. We all struggle to choose

which meetings to attend, and funds for travel compete with professional registration fees and other expenses. Meeting choice is driven by technical program, interest, location, cost, and loyalty, and the ability and willingness to attend multiple meetings seems to be diminishing. An astonishing number of conferences is planned for 2005, and it is hoped that they all attract the desired attendance. Whether this activity is sustainable remains to be seen, or even whether it is desirable, in view of widespread recognition that fragmentation is our principal handicap. A permanent office staff organizing larger, multi-society meetings would probably be ideal, and the practices of Canadian chemists may be a model. GAC will be co-sponsor of meetings in Halifax in 2005, Montreal in 2006, Yellowknife in 2007, a mining theme for Quebec City in 2008, a water theme for Toronto in 2009, and GeoCanada 2010 in Calgary.

Canadian Geological Foundation (CGF) activity was included in *Summit* discussion in the form of an abstract describing the role that CGF plays in carrying out the wishes of benefactors whose objective is to support Canadian earth science, thus complementing the foundations that serve a sector of the community. Since 1968, CGF has awarded over 300 grants with a value exceeding \$1M. The Foundation is led by 14 members from which an Executive and Board of Directors are elected. Membership is specified in the Foundation's by-laws to be representative of the Canadian geoscience community. The fund was launched by a gift of \$0.25M from Thayer Lindsley in 1969, and Jérôme H. Remick III has given \$0.5M to support grants to support development and awareness of geosciences in Canada. The Logan Legacy Fund receives donations toward the conservation of the Sir William Logan Collection of rare books, maps and papers. The GAC Endowment Trust Fund is designed to support regular GAC activities that qualify for foundation support. The W.W. Hutchison Medal Endowment Trust Fund was established in 2004 with monies donated to support an annual lecture tour. The Foundation holds annual meetings at GAC-MAC to conduct business and act on the reviews by the Grants Selection Committee of proposals received by

March 31. Available annual funding ranges from \$25K to \$50K, depending on the performance of investments. A call for applications is made in Geolog and on the CGF website. Grants support activities of national interest and broad significance, such as geoscience outreach, teacher-training, career booklets, publications, meetings, and special cooperative projects of national and long-term significance. CGF is actively soliciting new contributions and bequests.

Simon Hanmer, Chair of the Partnership Group for Science and Engineering (PAGSE), prepared an abstract that described Parliament Hill advocacy in support of earth science. While business-based groups and those responsible for professional registration tend to their own advocacy, activity in support of science is primarily carried out through PAGSE, a cooperative of more than 20 national Science and Engineering (S&E) organisations who speak for fifty thousand individuals. PAGSE communicates the economic benefits of research in Canada, sponsors analyses, addresses intellectual property issues, showcases the international dimensions of research initiatives, and supports decision makers with information on the importance of S&E to Canada. PAGSE meets regularly with the Presidents of the principal S&E funding agencies, as well as senior officials in federal science-based departments, and with the National Science Advisor. PAGSE holds an annual fall symposium in Ottawa, and submits a brief to the House of Commons Standing Committee on Finance each fall. PAGSE strongly supported the creation of the Canada Foundation for Innovation (CFI), the Canada Research Chairs, and Canada Graduate Scholarships. Since 2000, PAGSE briefs have made recommendations on governance gaps in S&E research in Canada, support for university-based S&E research, support for S&E students and young scientists, and support for S&E research in industry. This has been in tune with recent federal actions on funding for indirect costs of university research (2002), increased funding to granting councils (2003), creation of the position of Science Advisor to the Prime Minister (2004), and recognition of the need for support for the commercialisation of university-based

research (2004). The 2004 PAGSE brief recommends support for the office of the National Science Advisor, creation of the Canadian Academies of Science, optimization of government science, strengthening the capacity of the granting agencies, capacity for research in remote areas, coordination of Arctic logistics, commercialisation, and support for young scientists and engineers. In partnership with NSERC, PAGSE sponsors the widely acclaimed Bacon and Eggheads breakfast lectures held monthly since 1998 on Parliament Hill while parliamentarians are in session. Earth Science has been well represented at Bacon and Eggheads by Harvey Thorleifson, John Clague, Verena Tunnicliffe, John Smol, Alfonso Rivera, Robin Riddihough, and Kirk Osadetz.

Alan Morgan of the University of Waterloo and President of the Canadian Geoscience Education Network (CGEN), suggested that although our science is world class, and regardless of low funding and department closures, our outlook is bleak due to inadequate recognition by the educational system and general public, an aging geoscientist population, and a worsening replacement rate. This will lead to a human resources crisis in 2015 to 2020, just as the world is grappling with a population in excess of 7.5 billion, diminishing easily accessible natural resources, increasing water problems and more impact from hazards and climate change. We therefore must accelerate our recruitment immediately, as seven to ten years are required to train a geoscientist. Promotion of our discipline has been made through disbursement of 54,000 CGC "Careers in Geoscience" booklets and an additional 5,000 CD-ROMs. New promotional activities are being undertaken and more are needed. Our outreach must demonstrate relevance to the public such as in provision of energy and mineral resources, we must ensure earth science instruction at all levels of education by qualified teachers, and our research must address societal interests and needs. The public is keenly interested in volcanic eruptions, earthquakes, palaeontology, mineralogy, and water, and a select group of geoscientists are addressing this demand, but employers commonly do not reward outreach. Nevertheless, tremendous success has been achieved in Canadian earth

science outreach, such as the GeoSciEd IV Congress in Calgary in 2003. CGEN currently is focusing on EdGEO workshops for teachers, the EarthNet web site, Geoscape and Waterscape posters, and the What On Earth newsletter. Canada will play an important part in the outreach activities associated with the proposed International Year of Planet Earth, and CGC and CGEN have a meaningful liaison role in this activity.

Jeff Packard of the CSPG described the results of two surveys conducted by the society in 2004 on the make-up of the Canadian petroleum geoscience community, focusing on career choice influences, early career pathways, and the matching of tasks and skills. Replies were received from 345 members, about 10% of the membership. A strong mode was seen at 20 to 24 years experience, a group that largely will retire within 5 to 20 years, presenting staffing challenges. Half of current recruitment is female, while the overall proportion is 18%, reflecting past scarcity of female graduates, maternity and career decisions, and past bias in hiring. Retention of women geoscientists may be a key factor in alleviating upcoming staffing shortfalls. A bachelor's degree is held by 31% of the respondents, in contrast to the US where there is a tendency to require an M.Sc. Higher degrees are most abundant in the 10-19 year experience level, reflecting the late 1980s oil price collapse when hiring was limited to specialists. Recent graduates are widely thought to be more mercenary and pecuniary, but the survey indicates that less than 5% of the youngest respondents were drawn to geology by employment opportunities, while over 60% followed their interests into the subject. Most attended Alberta universities, live in Calgary, and work on Alberta geology. The tendency to be trained in Alberta and not to have worked in other sectors is increasing. The industry is known for employment volatility, but the data show that current and anticipated job changes are no more prevalent than in other sectors. The tasks of a petroleum geologist have changed little, but methods have changed enormously. Technology has caused an exponential increase in productivity, but as a result we now have an identity as processors of information and database managers, causing concern for our observation skills.

John Clague, Past President of CGEN, stated that there currently is no organized effort to recruit students to Canadian university geoscience programs. Earth science either is not taught in schools or is taught by underqualified teachers, so students have little awareness of geoscience or jobs in the field, and we lose bright students to biology, chemistry, and physics. Therefore, we must institute a nationwide program of earth science education and recruitment consisting of teacher training, web-based resources, increased summer student employment in all sectors, and public education. A CGEN Careers in Earth Science website, now in prototype, will be aimed at the Grade 9 level, to encourage students to consider the geosciences, and will provide basic information about qualifications, job prospects, and salary expectations. A printed flyer advertising the website will be widely distributed. The website will be visual in style, will emphasize adventure, travel, and linkage to broader interests, skills, and hobbies. Grants and content are needed to complete the website and its promotion, and we must all contribute to increased summer employment, promotion of earth science school curricula, and outreach.

Ron Clowes, Director of Lithoprobe, described the immense success of the 20-year, \$110M Lithoprobe project that mapped deep geology along transects, influenced thinking in the mineral, energy, and hazards sectors, and generated spin-offs in research, training, and technology transfer. Keys to success were grassroots involvement, widespread support, multidisciplinary research, collaborative studies, clear communications, and an effective management structure. Benefits included regional information for industry, technological innovation and transfer of science and technology to the private sector, new resources and mitigation of hazards, training of the next generation of earth scientists, and public awareness of science and technology. Grassroots initiation began in academia and the GSC with recognition of the need for a flagship project to bring cohesion to the discipline. A 1981 NSERC meeting on earth sciences in the 80s along with discussions at GSC resulted in a steering committee with representation from academia, GSC and industry. A successful Phase I on

Vancouver Island and the Kapuskasing Zone resulted in a Phase II proposal and 1985 national workshop. Widespread support throughout the community was a key, as were mechanisms such as University Supporting Geoscience Projects grants to NSERC-eligible scientists, and a cross-Canada lecture tour by the Director to show the value of the project for the community at large and to respond to concerns and criticisms. Multidisciplinary research was another factor, as a broad range of techniques was applied, as was collaboration among academia, GSC, provincial/territorial geological surveys, and both the petroleum and mining industries. Both direct and in-kind support from all sectors was crucial to the success of the project, but scientific involvement of representatives of industry was difficult to achieve. Communication and interaction among scientists and the public maintained enthusiasm and support, and workshops provided a key forum for interaction. As the first national centre of excellence or research network, Lithoprobe established an efficient and effective management structure now emulated broadly. Lithoprobe defined a new approach to collaborative science, redefined much of earth science, fostered an unprecedented degree of cooperation, spawned a healthy atmosphere of scientific cooperation, and enhanced the international renown of Canadian earth science, through quality scientific results derived from a unique combination of collaborative research and multidisciplinary studies. While earth sciences are essential for Canada's economic and environmental health, our science is in a state of crisis. We must make every effort to ensure the health, vitality and vision of our discipline, and Lithoprobe showed we can do this much better and more efficiently through collaborative, multidisciplinary approaches that are developed by the community and that energize the community as a whole.

Chris Barnes of the University of Victoria described how the NEPTUNE Project will revolutionize ocean sciences through installation of fibre-optic-cable-linked observatories across the Juan de Fuca Plate of the northeast Pacific. Instruments on the seafloor, in boreholes, and in the water column, as well as autonomous vehicles recharged at observatories, will send near-real-time

measurements to shore stations in BC and Oregon (www.neptunecanada.ca; www.neptune.washington.edu). Research will address structure and seismic behaviour of the ocean crust, dynamics of hot and cold fluids and gas hydrates in the upper ocean crust and overlying sediments, ocean circulation and climate change and their effects on the ocean biota, as well as deep-sea ecosystem dynamics and biodiversity. All involve interacting processes, long term changes, and non-linear, chaotic, episodic events that currently are hard to study. The 70/30, US/Canada partnership will cost \$250M, and \$50M has already been spent on design. NEPTUNE Canada funding of \$73M from CFI and BC Knowledge Development Fund (BCKDF) was announced in October 2003. New science and technology will address seismic hazard assessment, resource development, pollution, and fish stock management in a changing climate. The marine industry will develop new technologies, market new systems and services, and mine resulting data. US funding is anticipated in FY 2006, so a northern loop will first be installed by the 12-university NEPTUNE Canada consortium. At the University of Victoria headquarters, a dozen staff members have been hired, and the former Teleglobe TPC4 Shore Station at Port Alberni has been purchased. Cable and nodes are presently being acquired for deployment in 2007 and 2008. Three workshops in 2004 chose community experiments, observing systems, use-case scenarios, and node locations. Planning for data management and development of agreements with partner agencies are underway. The work is coordinated with the VENUS Project, a shallow-water, coastal observatory in southern BC whose installation has been funded for 2002-06 and also lead by UVic (www.venus.uvic.ca). The project has huge potential for public education and outreach, with real-time images and video transmitted through science centres, schools/universities, and TV programs, and it provides challenges for current earth science curricula and professional registration syllabi.

David Snyder of GSC described how the unique, national-scale, university-government-industry POLARIS geophysical consortium is investigating lithospheric structure and

dynamics as well as earthquake ground motion prediction. The current 84 broad-band, photovoltaic-powered seismological and magnetotelluric (MT) observatories installed in Ontario, BC, Nunavut, and NWT are transmitting over a VSAT satellite network to London and Ottawa, which receive data and control the stations. All data are rapidly made available, and seismograms from large earthquakes are posted within minutes of occurrence. Five MT field systems are semi-permanently co-installed at Polaris observatories, and a mobile array of 20 MT systems will be co-located at each station for a few weeks. Extensions in development include GPS sensors to measure crustal deformation and portable sensors. Polaris is similar to the portable array of the much larger USArray of the US EarthScope program. Purchase and installation were funded by \$10M from CFI, with additional funds from Ontario Innovation Trust, Ontario Challenge Fund, Ontario Power Generation, BCKDF, BC Hydro, BHP Billiton, De Beers Canada, the Department of Indian Affairs and Northern Development, the Manitoba government, NRCan and other sources. Over the next two years, maintenance of the system will be funded by the NSERC Major Facilities Access program, along with NRCan, the Ontario Research and Development Challenge Fund, and USGS. Recoverable costs include redeployment of the equipment for later studies, and user fees borne by researchers, based on submission of proposals to the Polaris steering committee. Educational applications and outreach are active, and First Nation communities are monitoring seismic activity within their communities. Growing interest from researchers in the mineral exploration industry, academia, government and other organizations have established Polaris as a leading new initiative in Solid Earth Sciences in Canada.

Jim Mungall of University of Toronto described the International Continental Drilling Program (ICDP), which helps worthy drilling projects secure funding, facilitates international cooperation, and provides technical and organizational support. Canada currently pays \$US 200K per annum to ICDP, allowing Canadian scientists to participate in ICDP projects worldwide.

Proposals selected for scientific merit, global significance, cost-effectiveness, leverage, and societal benefits have addressed volcanism, earthquakes, climate change, impacts, sedimentary basins, and mineral deposits. In Canada, ICDP supported the Mallik gas hydrate drilling north of Inuvik, NWT, a broadly-funded government-industry-university partnership that attracted \$2M in ICDP support toward a \$17M field budget. The Sudbury Integrated Geoscience Network (SIGNet) has proposed a \$10M, 5-year study of the Sudbury Structure, a feature of extraordinary scientific and economic significance, based on two 4-km boreholes along with fluid and gas sampling to investigate biological activity, and down-hole geophysical surveys to assess temperature, stress, and potential fields. Ongoing monitoring will address fluid flow, temperature, and seismic activity, and an ambitious program of surface-based geology, geochemistry, and geochronology will utilize 4-D visualization and modeling facilities to place the borehole studies in context. NSERC has indicated that it will entertain a full proposal to the Research Networks Program in June 2005, and discussions are underway among industry, NSERC, ICDP, NRCan, Ontario Geological Survey, and SIGNet to seek a viable funding formula. The SIGNet experience is an example of the challenges and possible rewards of attempting to fund partnered and complex earth science initiatives in the Canadian research establishment.

Wouter Bleeker of the GSC placed his comments in the context of a trend toward increasing hydrosphere-atmosphere research, the end of Lithoprobe, an increasingly competitive environment in which projects must show societal, environmental, and economic benefits, the difficulty in communicating the importance of earth science funding in NSERC reallocation exercises, and the trend toward funding of large, Lithoprobe-style research groups working around common themes. He reported on an informal Spring 2004 meeting in Montreal that discussed potential earth science projects that could reinvigorate the solid earth sciences in Canada. As most first-order problems are global in nature, he stressed the increasing need for a global

research scope and the critical need for full integration of different disciplines, e.g. earth and ocean sciences, geophysics, and planetary science, perhaps even astronomy. A “portfolio” of promising flagship projects was identified, among them IODP, NEPTUNE, POLARIS, and ideas for partnership with the planetary science community. A promising new project, called “Taking the pulse of planet Earth”, would address earth systems through time by undertaking a multi-parameter analysis of global magmatism, including spatial distribution, ages, periodicities, rates, volume estimates, geochemical fluxes to atmosphere and hydrosphere, tectonic and geodynamic settings, sequence stratigraphic framework, structural trends, evolving major- and trace-element compositions, evolving isotopic ratios, paleomagnetic data, paleo-intensity data, paleogeography, and ore deposits. In principle, such an analysis is the most direct route to a complete paleogeographic evolution of planet Earth back to ca. 2.5 Ga, thus providing critical feedback to numerous earth science questions. A complete record of mafic magmatism provides critical constraints, not only on such questions as the nature of flood volcanism or the supercontinent cycle through time, but also on geochemical fluxes, geodynamics, core and mantle evolution, global climate evolution, major extinction events, major impact events, the evolution of sedimentary basins, and strategic mineral resources. At its core, the project would provide several hundred new high-precision ages of magmatic events across Canada and adjacent regions, and would encourage development of new dating methods (e.g., dating of sedimentary rocks) at Canada’s highly regarded labs. A sizable supporting geoscience grant system, modeled after Lithoprobe, would ensure participation and integration across numerous traditional and emerging disciplines. The project would make optimum use of the next generation of analytical equipment now being acquired through CFI and other programs, and would be closely integrated with research in the marine and mantle realms. Proposal development, perhaps linked to planning for the next NSERC reallocation, is underway and will involve a NUNA conference to flesh out many of the details.

Tom Skulski of the GSC

described a vision for research on evolution of earth surface environments. He described the potential for climate change to revolutionize our world, and how the earth science community needs to understand how the solid Earth and its atmosphere, hydrosphere and biosphere have evolved with time. He outlined how a grasp is needed of the long-term history of water in the mantle, mantle dynamics, magmas and fluids, degassing of the Earth, early life, extreme environments, oxygen/water cycles, Proterozoic oxygenation, paleo-environment, climate, glaciation, orogeny, continental reconstructions, volcanism, earth resources, and fluids. This long-term perspective allows comprehension of current climate, erosion, crust/mantle dynamics, glaciation, ice extent, permafrost. This broad knowledge is required to manage future topics such as northern development, carbon dioxide sequestration, and water resources.

Jeremy Hall of Memorial University of Newfoundland described the follow-up to a BC request to the federal government for the moratorium on oil and gas activities in offshore BC to be lifted. The federal government has responded with a three-phase review involving a science review, public consultations, and discussions with First Nations. The six-month science review, undertaken by a Royal Society of Canada panel consisting of a geophysicist, structural engineer, marine biologist, and toxicologist, identified science gaps to be filled before a decision is made, provided a path forward on the science requirements relative to exploration or development, identified who should fill the gaps, evaluated risks associated with not filling a gap, evaluated sensitive environments and previously recommended exclusion zones, and identified additional areas requiring special management measures. At the three workshops, attended by several hundred people, over 90 expert technical presentations were given and discussed. The review assessed the risks and rewards of oil and gas development in the Queen Charlotte Basin (QCB) only. GSC estimates of the volume of producible hydrocarbons indicate a potential value of around \$100B, broadly comparable with the Jeanne d’Arc Basin off Newfoundland. Physical environment science gaps

include bathymetry, winter ocean currents, local wind fields, and seismicity. Quantitative risk assessment assessed the safety of offshore structures, although risks to biota are not readily quantifiable where basic data on temporal and spatial distributions of key species are poorly known. Canada's Species at Risk Act (SARA) will define permitted activity relative to threatened and endangered species. The report concluded that much science is needed prior to the oil and gas development approval processes, including that required by the Canadian Environmental Assessment Act, although it was recognized that there is no science-based reason to maintain the moratorium. The 15 years required to go from exploration to production will allow time for adequate assessment of the environmental impact of oil and gas activities set against natural change. A response from the federal government is anticipated in 2006, but in the meantime there is ample opportunity for scientists to plan for possible lifting of the moratorium, and to continue to indicate to policy makers the value of science to Canadians.

Dick Pickrill of GSC described how coastal and ocean environments are coming under increasing pressure from resource development throughout the world, as competition for use of the seabed is often unresolved, hazards are overlooked, unique habitats are not protected, and fisheries collapse is common. We lack the knowledge base required for development of a management framework comparable to that established on land because mapping of the offshore is not sufficiently detailed. In previous decades, surveys of narrow swaths of sea floor and limited ground truth provided only sketchy knowledge of our sea floor, but we now have new GPS and multibeam sonar technologies that permit us to construct detailed images and geological interpretations of the sea floor. On the southwestern Scotian Shelf which supports a \$100M scallop fishery, government and industry used multibeam surveys and benthic species mapping to produce charts of bathymetry, backscatter strength, surficial geology and benthic habitat that immediately permitted reduction of effort by as much as 75%, reduction of benthic disturbance by scallop rakes, avoidance of sensitive habitat, reduction of by-catch,

and avoidance of lobster and groundfish habitat. Multibeam mapping of marine protected areas has provided the capability to identify and map habitats and their associated unique communities at a scale of one to ten metres, providing a basis for sustainable management plans. In coastal management, new understanding of water circulation and sediment transport have guided planning decisions such as sewage outfall design, cable routes, and spoil grounds. Seamless terrain models across the land-water interface result in integrated management of both onshore and offshore resources. In engineering, for example, new mapping is allowing offshore Nova Scotia gas fields to be brought into production in an area where bedform migration rates and the maximum depth of sediment disturbance are key considerations in pipeline design and routing. On the continental slope, submarine landslides and slope stability may require avoidance rather than engineering. For example, a government-industry survey mapped a spectrum of landslides that was only recognized because of the regional scale of the survey. Minimum survey requirements, standards and map products are now being defined, and experience dictates that nearly all seabed resource decisions can be addressed by mapping sea floor depth and shape, texture and composition of sea floor sediments, and the composition of the benthic community. The SeaMap proposal has developed plans for far more extensive application of these new mapping technologies to Canada's marine and large lake environments. Our challenge in the next decade will be to secure the political support and resources to deliver these new mapping strategies that clearly are so effective and needed.

Kathy Gillis of the University of Victoria gave an overview of the Integrated Ocean Drilling Program (IODP), a multi-year, \$1B, multi-disciplinary international program aimed at understanding the Earth systems that make up our planet, which is funded by the US, Japan, and a European consortium (ECORD) that includes 14 European nations and Canada. Extension of ocean drilling to multiple platforms will include improvements to the JOIDES Resolution, a riser-equipped drill-ship under construction in Japan that will operate in deeper

waters, continental margins, and gas-prone regions, as well as mission-specific platforms such as jack-up rigs and ice-breakers. Canadians have played leadership roles in IODP, and Canada has significant expertise in all aspects of earth system science research. Within the IODP deep biosphere, environmental change, and solid earth cycle themes, Canadian researchers are active in the preparation of drilling proposals related to climate dynamics, gas hydrates, seismic hazards, sedimentary basin formation, deep biosphere, formation and evolution of oceanic lithosphere, hydrothermal ore deposits, and mantle dynamics. Coordination of IODP and Neptune will revolutionize our understanding of linkages between plate deformation, earthquake generation and fluid flow. Canadian participation in IODP is currently limited to 2004/2005, and our financial contribution through ECORD is \$200K, about 1% of the ECORD participation fee. A proposal to NSERC for the same level of funding has been submitted by the Canadian Consortium for Ocean Drilling (CCOD). A critical issue for the Canadian earth science community is to find a reliable mechanism for Canadian researchers to contribute to international research programs at credible levels of participation, with stable long-term funding. The option favoured by the CCOD is for Canada to participate in IODP as an Associate Member, which requires an annual financial commitment of \$750K in 2004-06 and \$1.2M annually thereafter. This will allow four to six scientists to sail annually, ensure representation on the IODP science advisory board, and provide training of students on the most sophisticated sea-going facilities in the world.

Dick Peltier of University of Toronto described developments at the interface between solid earth science and environmental earth science, which are addressing natural surface climate variations to provide a context for understanding current human induced climate change. Deep-sea sediments, lake sediments, coastal deposits, tropical corals and polar ice can yield climate proxies for paleoclimate based on isotopes, pollen, and geomorphology; late Quaternary data are highest quality and most relevant for this purpose. The 100 kyr quasi-periodic variation of northern

hemisphere continental glaciation that has dominated the late Quaternary will be better understood with enhanced information on space-time evolution of the North American Ice Sheet complex, because ~60% of excess continental ice volume at the last glacial maximum 21 kyr ago was in Canada. Canada's apparent extreme sensitivity to climate change is the focus for the ongoing Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). Canadian scientists are providing input to policy development, and a \$5M, 5-year Polar Climate Stability Network initiative supported by the Canadian Foundation for Climate and Atmospheric Science will assemble the team needed to make meaningful predictions of the impact of global change in Canada as a whole, with emphasis on high latitudes. The Network will address mechanisms of rapid climate change, polar land and sea ice, the Arctic/North Atlantic oscillation and the role of the Arctic Ocean in the climate system, and low latitude-high latitude teleconnections. A recently completed \$20M, 8-year project examined glaciological, hydrological and oceanographic interactions that occurred during the last deglaciation, such as the Younger Dryas event that abruptly interrupted warming at the end of the most recent 100 kyr ice-age cycle. This network approach is needed to overcome the extreme diversity of our interests in the context of NSERC reallocation.

Dave Kroetsch of Agriculture and Agri-Food Canada (AAFC) described highly functional national and regional soil information systems being developed to support agricultural environmental policy and Kyoto Protocol commitments. An updated national 1:1M scale Soil Landscapes of Canada (SLCv3) soil map and database, and standardised 1:100K soil mapping of the Prairie agricultural region are now available. New applications bring together soil data with land use, climate, surficial geology and farm management information. Statistics Canada Census of Agriculture information is now allocated to individual SLC map polygons, enabling information about land use, farm management and crop cover to be linked to soil type, climate conditions and watersheds. The National Agri-Environmental Health and Reporting

Program is using soil degradation risk models, greenhouse gas emission models, and nutrient contamination of water risk models to produce indicators of environmental performance. While these applications were developed to run against the 1:1M SLC maps and databases, recent analyses have used the Prairie 1:100K mapping with excellent results. Models currently in development deal with a wider range of water quality impacts, biodiversity issues, citing of intensive livestock operations, and refined estimation of soil crop suitability. The National Carbon and Greenhouse Gas Accounting and Verification System for Agriculture, including new SLCv3 information, is a component of Canada's greenhouse gas accounting system. Most soil mapping staff are eligible to retire within 10 years, human resources have become fragmented, and resources have recently not been available to conduct new surveys, ground truth model output, or upgrade Canadian Soil Information System (CanSIS) detailed 1:20K to 1:75K soil mapping, now only 10% digital. The new \$100M National Land and Water Information Service (NLWIS) will, however, not only implement web-accessible soil mapping applications required to protect surface and groundwater supplies, it will also provide the opportunity to train the next generation of pedologists needed to ensure a future federal soil survey in Canada.

Bob Garrett of GSC addressed the role of earth science in understanding the toxic and essential substances that we ingest, drink, breathe and contact. Globally, ~2 billion people are affected by iodine, selenium or zinc micronutrient deficiency, while ~4.5 billion are deficient in iron. Formation of methyl-mercury in aquatic environments leads to biomagnification and neurotoxicity in consuming mammals. Lead is particularly neurotoxic in children, cadmium is a nephrotoxin, and excess fluoride affects teeth and bone, while selenium causes Enshi disease in the case of excess or Keshan syndrome and Kaschin-Beck disease in the case of deficiency. A key issue is speciation and bio-availability, as only some forms are harmful, and only those that cross biological boundaries are relevant. Agencies such as US-EPA, Health Canada and Environment Canada, which manage

exposure are requesting information on nationwide mapping of natural background levels in soil and other media from geological survey agencies with long-term mapping and monitoring roles. Research is being coordinated with, and between, universities through existing and proposed research networks.

John Cherry of University of Waterloo, who spoke on groundwater protection and remediation in Canada, indicated that adverse health effects are resulting from widespread neglect and contamination of this resource that supplies drinking water to over a quarter of all Canadians. This is because groundwater-reliant citizens tend to live in small towns and rural areas, while harmful groundwater contaminants tend to be tasteless and odourless, commonly date to previous years and decades, and are difficult and expensive to locate. Laws, regulations, and guidelines typically are weak, un-enforced, inconsistent province to province, and scientifically ill-informed. Contaminating groundwater beneath private property continues to be legal, even though on-property contamination eventually becomes off-property contamination. Current fiscal prudence is short-sighted, as remediation of contaminated groundwater is much more expensive than measures to prevent contamination. In fact, current spending levels on groundwater probably are adequate, but most of the effort is wasted on hasty responses to political crises rather than science-based problem solving and prevention. We thus rank far behind the US and northern Europe in efforts toward groundwater protection, apparently because of a governmental system that has resulted in an inadequate framework for groundwater monitoring, management and protection. But the Walkerton tragedy has presented a rare opportunity for the research community to become more proactive, and for governments to develop mechanisms that will lead to increased awareness, enhanced information, and more effective assessment and remediation. There is a great need for the government role in geological mapping, monitoring, and regulation to be augmented, including clarification of the necessarily overlapping roles of several federal departments. This regional work should not be done by consultants, because of inade-

quate expertise for some tasks, lack of continuity in personnel and information storage, transience of funding, and the need for linkage to enforcement.

Hydrogeological research in Canada is, however, well staffed and well funded, but an improved framework for identifying and funding research at Canadian universities is needed as the present system directs university researchers to conduct world class research, not necessarily research relevant to Canada. The question before us is whether Walkerton will result in permanent progress, or whether the response will be temporary, reflecting the low public profile of this critically important resource.

John Clague of Simon Fraser University indicated that as population and vulnerable infrastructure increase, geoscientists are increasingly being called upon to help defend Canadians from natural hazards that cause injury, suffering, and damage. Catastrophic threats include earthquakes, tsunamis, landslides, floods, volcanoes, windstorms, extreme precipitation, magnetic storms, avalanches, and impacts, while chronic hazards include shoreline erosion, wind erosion, and permafrost degradation. Damage from a large earthquake near Vancouver or an eruption of Mount Baker could reach tens if not hundreds of billions of dollars. Landslide damage to highways and railways costs Canada \$100-200M every year, while underwater landslides off the coast of Newfoundland and BC have inflicted loss of life and damage along shorelines. Floods are the most damaging natural hazard in Canada, destroying bridges, inundating land, contaminating drinking water, and disrupting economic activity. A flood on the Fraser River in 1948 caused hundreds of millions of dollars in damage and forced thousands of people from their homes, while Winnipeg suffered major losses during 1993 basement flooding and the major 1997 flood. Earth scientists augment local knowledge on how these processes work, we outline events prior to recorded observations, and we assess changing risk. But much more could be done in earth science research, training, and awareness, resulting in lives being saved and billions of dollars in economic losses being prevented, through wiser land-use decisions and early warning. Indirect economic benefits would also include stimulation of innovative engi-

neering design and services to the public such as seismic retrofitting of unsafe buildings, innovative construction methods, and earthquake preparedness kits. The results of the research must be appropriately transferred to the public, land-use planners, and government agencies who will limit development, improve protection, and strengthen emergency preparedness. An expanded network of regional centres of excellence is needed to increase partnership between universities, utilities, NRCan, Environment Canada, provincial governments, and the Insurance Bureau of Canada. University-based research centres are needed to combine science, public policy research, innovative technology, and education. Socio-economic research is needed on societal vulnerability, resilience, preparedness, risk perception, disaster management systems, disaster planning and training, disaster forecasting, psychological and social impacts of natural disasters, community response to natural disasters, and integration of scientific information into the decision-making process. Consultation with stakeholders such as emergency planners, government agencies, and the public is essential, and public policy research is needed on how to effectively apply scientific information.

Don Lemmen of the NRCan Climate Change Impacts and Adaptation Directorate indicated that earth science is a key to defining the scientific basis of climate change as well as informing the two policy options available, mitigation and adaptation, to reduce social, economic and environmental impacts. To bolster the science, a priority is the collection and analysis of >400 year high-resolution climate records to better document variability and natural drivers. High resolution records also document frequency and magnitude of extreme climate events, while lower resolution records can be important in understanding regional impacts. Improved understanding of earth system linkages, climate processes, as well as natural sources and sinks for greenhouse gases (GHG) will improve model projections. Current mitigation efforts (reduction of net greenhouse gas emissions) focus on the short term, but long term solutions will require less GHG-intensive technologies as well as GHG capture and storage. Successful long term sequestra-

tion will require better understanding of earth systems, and Canada is a leader through work such as the Weyburn project. Adaptation, actions that reduce negative impacts or take advantage of new opportunities, is a necessary complement to mitigation. Earth science will help guide issues such as coastal zone dynamics, sea level change, permafrost degradation, impact of reduced glacier cover on water resources, groundwater quality and quantity, and occurrence of climate-related natural hazards such as flooding, dust storms and landslides, with a goal of identifying critical thresholds or key vulnerabilities to current and future climate. Policy relevant science will be better achieved through partnerships with social and economic researchers and decision makers to provide a consistent, integrated analysis of risks associated with climate change and the capacity of systems to adapt. While it is critical for research to continue to refine and assess the scientific foundation of climate change, it is also important that the scientific community recognize and respond to the need to develop mitigation and adaptation policy responses, leading to a more scientifically-informed decision making process.

Alfonso Rivera of the GSC addressed groundwater supply in Canada in a summary presented by Dave Sharpe. It was acknowledged at the outset that we simply do not know what the sustainable capacity of our groundwater systems is, especially at the national scale, despite being a strategic source of clean, abundant and cheap freshwater for over a quarter of Canadians. While steadily shifting to reliance on groundwater, we take this out-of-sight, out-of-mind resource for granted, and neglect its mapping, monitoring and management. Hydrogeology is now a relatively mature science in which we understand much about the physics and chemistry of groundwater flow. Comprehensive assessment of Canada's regional aquifer systems is required, but current efforts toward this goal are modest. The most recent national assessment of Canada's groundwater resources was published in 1967, and current tentative steps are being guided by a Framework for Collaboration on Groundwater developed in 2003. Challenges include combined surface water-groundwater models, indicators of groundwater condi-

tions, grappling with flow and storage, quantification of pumping, and outreach. Opportunities include new techniques, remote sensing in support of recharge assessments, new methods for large fractured aquifers, airborne geophysical surveys of large bedrock aquifers, new techniques to measure water stored in porous media, and use of temperature for calculating surface water-groundwater interactions.

Integrated models will be a major priority, as will work related to climate change, better measurements of recharge, and enhanced information systems.

Groundwater scientists in Canada are world leaders in research, especially on point-source contamination, but we have been unwilling to commit the resources required to map and therefore, manage our aquifers. New programs focusing on sustainability of regional groundwater resources and better public understanding are needed, and we must prepare a new generation of scientists for this task.

Peter Harrison, Senior

Research Fellow at National Research Council Canada and former NRCan and Fisheries and Oceans Deputy Minister, gave the introductory remarks for a Panel Discussion on International Geoscience. He encouraged *Summit* participants to be attentive to signs of increasing needs that we as a community are best positioned to respond to. The Speech from the Throne (SFT) is a key indication of upcoming priorities, and the forthcoming establishment of the Canadian Academies of Science will create a demand for our role. The SFT, a mandate to government departments and a clarification of policy objectives, has affirmed an emphasis on science in the North, sustainable development, climate change, and ocean management within a broader knowledge strategy. While responding to these challenges, we must ensure that senior policy makers are aware of our broader contributions, and upcoming International programs such as IPY and IYPE present excellent opportunities to do so. The focus will be on the legacy that the programs will leave, and a balance between basic science and issue-oriented work will be needed. Fundamentally, governments need the right scientific information at the right time to govern effectively. Also, there is an opportunity to change the

way we do business, and we are facing a real challenge in the need for partnerships along and across the spectrum of our sciences from industry to academia to government. Attitudes toward partnership need to become more open and positive. We also have large capacity and talent challenges and opportunities, not only with respect to age, but also gender and inclusion of traditional knowledge. This issue will be particularly prominent with respect to IPY, as we all seek to establish human resources in the North, for the North, by the North.

Bryan Schreiner of University of Saskatchewan and CGC International Director, gave an overview of Canada's extensive involvement in international earth science programs. Three Canadians have been Presidents of the International Union for Geological Sciences (IUGS), while Peter Bobrowsky is now IUGS Secretary-General and Godfrey Nowlan the Publications Chair. Several specialist international associations have been led by Canadians, and we have been similarly prominent on editorial boards, conference organizing committees and scientific committees, to our far-reaching benefit.

Charles Gower of the Newfoundland and Labrador Geological Survey described how the International Geological Correlation Programme (IGCP), has been active for over 30 years as a long-term, interdisciplinary, co-operative venture in the geological sciences between the International Union of Geological Sciences (IUGS) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). IGCP enjoys a reputation for being among the most successful international scientific programmes and it provides a grass-roots global platform by which geoscientific information may be gathered, exchanged and made available to all, regardless of various political, economic, ethnic, religious, or language barriers. The programme operates through topical 5-year, multi-national and multidisciplinary thematic projects. These are initially approved, and then evaluated annually and funded through a 20-member International Scientific Board, appointed jointly by IUGS and UNESCO. Projects approved range broadly in content and include both fundamental and applied earth science. On average, about 40 projects are active

worldwide in any given year. Canada has a proud tradition of involvement in IGCP, participating in about 45% of projects and providing many of the projects' international leaders. On a per capita basis, Canada has the highest participation rate in the world. Canadians have also played a prominent role as members of the International Scientific Board. In addition to the undoubted high respect that Canadian earth science commands is the role that government funding has played in facilitating Canadian involvement. Although modest in absolute terms, this financial support has been a key element in sustaining Canadian activities. Financial support for IGCP activities in Canada has been severely eroded in recent years, however. If this trend is not reversed, it can be anticipated that Canadian participation in IGCP will be drastically curtailed.

Jim Teller of University of Manitoba and IYPE Senior Advisor described how the UN International Year of Planet Earth (IYPE) will be the most ambitious scientific and outreach program ever designed in the earth sciences. This new international multidisciplinary earth science initiative was conceived by the International Union of Geological Sciences (IUGS), which represents about 250,000 geoscientists from 117 countries, and has been endorsed by UNESCO's Earth Sciences Division as well as by participants at the International Geological Congress in Florence. Planning began in 2000 with seed money from IUGS, UNESCO, and Shell Exploration & Production BV. It now has the support of all IUGS sister unions in related disciplines, and to date has won the full political backing of Russia, China, India, Argentina, Brazil, South Africa, Pakistan, Mexico, Lithuania, Jordan, Romania, and Italy, and the scientific and ministerial backing of many more countries, including Canada. Activities for the Year will be coordinated with plans for the International Polar Year and the new International Geophysical Year+50, which begin in 2007. Proclamation of the International Year of Planet Earth by the United Nations General Assembly is anticipated in 2005. The aim of the Year is to increase public understanding of the relationship between people and Planet Earth, and to demonstrate that geoscientists are key players in

creating a balanced, sustainable future for both. Recent declines in funding for the earth sciences, and in student enrolment, mean that we must make public and political awareness a top priority. Although 2007 will be the officially designated Year, activities will begin in 2005, and efforts are underway to raise 20 million Euros to be divided equally between research and outreach that will bring the message of the Year home to billions of people world wide. A web site has been developed at www.esfs.org, and a prospectus and flier, Planet Earth in our Hands, has been published. Selected themes provide the Year with an initial focus, and planning will respond to the demands of the community. Outreach is especially important, as the public, policy makers, and politicians commonly make decisions about our changing environment without adequate knowledge and understanding of Earth history, materials, and processes. Themes have been chosen for their societal impact, potential for outreach, multidisciplinary nature, and high scientific potential. Fliers for each of the priority themes have been or will be published, including groundwater sustainability, hazards, public health, climate, resources, urban geology, Earth systems, oceans, soils, and life.

Peter Johnson of University of Ottawa and Chair of the Canadian Polar Commission outlined plans for the International Polar Year (IPY) 2007-2008, envisioned as an intense, internationally coordinated campaign that will initiate the dawn of a new era in polar science. The IPY will be multi- and interdisciplinary in scope and truly international in participation. It will educate and excite the public, and help train the next generation of engineers, scientists, and leaders. It will include elements from a wide range of scientific disciplines. International themes include:

1. determination of the present polar environmental status,
2. quantification and understanding of past and present environmental and human change in the polar regions in order to improve projections of future changes,
3. advancement of our understanding on all scales of the links and interactions between polar regions and the rest of the globe and of the process-

es controlling these,

4. investigation of the frontiers of science in the polar regions,

5. use of the unique vantage point of the polar regions to develop and enhance observatories from the interior of the Earth to the Sun and the cosmos beyond,

6. investigation of the cultural, historical, and social processes that shape the sustainability of circumpolar human societies, and identification of their unique contributions to global cultural diversity and citizenship.

Canada intends to promote emphasis on the human dimension of the IPY. Leadership in northern communities is being sought, and the emphasis will be on the legacy left by the program, including capacity building, infrastructure, education, traditional knowledge, monitoring, information dissemination, and archiving.

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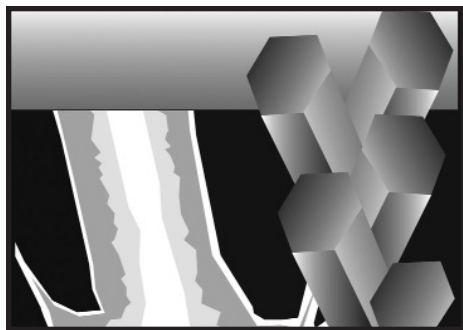
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ARTICLE



Emerald and Aquamarine Mineralization in Canada

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SUMMARY

This paper reviews the geology, mineralogy, and origin of the gem varieties of beryl, including emerald (green) and aquamarine (blue); it focuses on western Canada, especially the Yukon Territory, because this is where most of the recent discoveries have been made. However, emerald occurrences in Ontario are also considered, including Canada's first reported discovery in 1940. Beryl ($\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$) is relatively common and spatially associated with granites and granitic pegmatites, but emerald is rare because trace amounts of Cr and/or V are required (to replace Al in the crystal structure) and these elements generally do not occur in sufficient concentrations in granitic rocks. The geological conditions needed to bring Be into contact

with Cr and/or V are briefly discussed, as are the factors to consider and techniques to use in exploring for gem-quality beryl.

SUMMAIRE

Le présent article traite de la géologie, de la minéralogie et de l'origine de variétés gemmifères de béryl (vert), dont l'émeraude et l'aigue-marine (bleue). Il traite principalement de l'Ouest canadien, particulièrement du Territoire du Yukon, région où la plupart des découvertes ont eu lieu. Toutefois, des découvertes faites en Ontario sont aussi considérées, incluant la première au Canada, en 1940. Le Béryl ($\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$) est relativement commun et associé aux granites et aux pegmatites granitiques, mais l'émeraude est rare parce qu'elle nécessite le remplacement de l'Al dans la structure cristalline du béryl par du Cr et/ou du V, et ces éléments ne se retrouvent généralement pas dans des concentrations suffisantes dans les roches granitiques. Les facteurs géologiques nécessaires pour que le Be et le Cr et/ou le V soient mis en contact font l'objet de discussion, tout comme les facteurs à considérer et les techniques à employer dans l'exploration de gisements de béryls gemmifères.

INTRODUCTION

Beryl, $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$, is a common, rock-forming cyclosilicate mineral, generally occurring within granites and granitic pegmatites. Gem varieties of beryl include emerald (green), aquamarine (blue), red beryl, goshenite (colourless), heliodor (yellow), and morganite (pink or peach). Of these, emerald is the most prized, and can be worth more than US\$100,000 per carat. The colour of emerald reflects the trace amounts of Cr and/or V replacing Al in the crystal structure; it may be diminished by the

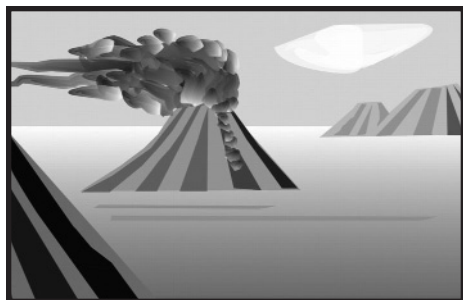
presence of Fe which can add a greyish tint (Walton, 2004). Emerald is rare because Be and Cr are generally insoluble, and the geological conditions needed to bring Be into contact with Cr and/or V are, typically, incongruous.

There is debate over the difference between emerald and green beryl (see Conklin, 2002, and Schwarz and Schmetzer, 2002). However, a definition that appears to be attaining broad acceptance is that of Schwarz and Schmetzer (2002): "emeralds are yellowish green, green or bluish green, natural or synthetic beryls, which reveal distinct Cr and/or V absorption bands in the red and blue-violet ranges of their absorption spectra."

There are many classification schemes for emerald deposits. Most recently, Schwarz et al. (2002) and Grundmann (2002) divided emerald deposits into the following categories: pegmatites without schist, pegmatite and greisen with schist, schists without pegmatites, and black shales with veins and breccias. Most emerald deposits, and all of those described in this paper (with the possible exception of the Lened property) belong to the first three classes. The "black shale" category is typified by the Colombian deposits where emerald occurs in calcite + dolomite + pyrite ± albite veins in black shales and related rocks. In this type of deposit, the emerald is considered to have formed because of the thermochemical reduction of mesothermal brines by organic-rich black shales, which is effective at releasing Be, V, and Cr into solution. This model has most recently been espoused by Giuliani et al. (2000).

Recent discoveries of emerald in northwestern Canada have led to increased exploration expenditures; for example, in 2003, approximately 30% of exploration expenditures (>\$3.5M) in

SERIES



Igneous Rock Associations 5. Oceanic Island Volcanism II: Mantle Processes

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SUMMARY

Oceanic island basalts (OIBs) have been central to understanding evolution of the Earth and mantle because their isolated positions in ocean basins limit the potential for magma contamination by continental crust. Melting processes (e.g., percentage melting) affect OIB chemistry but isotopic and trace-element ratios provide information on mantle-source compositions. They indicate that OIB mantle sources represent mixtures between mid-ocean ridge basalt (MORB)

and four other mantle components: EM1 (enriched mantle 1), EM2, HIMU (High U/Pb = Hi μ) and FOZO (FOcal ZOne). Mass-balance and noble-gas arguments indicate that most of the mantle is depleted but He and Ne isotopes, and convergence of Sr-Nd-Pb isotopic arrays suggest that FOZO is a somewhat primitive (unmelted) component common to all oceanic basalt sources. The other components contain "materials" such as basaltic ocean floor (HIMU), pelagic sediments (EM1), oceanic plateaus (EM1), subcontinental lithosphere (EM1, EM2), terrigenous sediments or subducted continental crust (EM2), which have been recycled by subduction processes, and mixed back into the depleted mantle. How these components cycle through the mantle is debated but heterogeneities occur on all length-scales. One school argues that oceanic islands develop above mantle plume convection cells that deliver recycled components and FOZO (lower mantle?) for mixing with depleted upper mantle. Others contend that propagating cracks in the lithosphere create oceanic islands, that plumes do not exist, that the upper and lower mantle are isolated and depleted, and that MORB and OIB form from the same upper-mantle reservoir. Small-scale melting allows OIB to sample local, low-melting-point heterogeneities that are averaged-out by the large-scale melting that forms MORB. These radically different views of mantle structure and composition indicate that OIB will continue to be a focal point in studies of Earth's evolution.

SUMMAIRE

L'étude des basaltes d'îles océaniques (BÎOs, ou OIBs en anglais) s'est avérée essentielle pour la compréhension de l'évolution de la Terre et de son man-

teau, et cela, de par l'isolement de ces îles dans les bassins océaniques, ce qui limite les possibilités de contamination par des matériaux de la croûte continentale. Les mécanismes de fusion (le pourcentage de fusion par ex.) délimitent la composition chimique des BÎOs, mais les ratios isotopiques et des éléments traces permettent d'obtenir des indications sur la composition des sources mantelliques. Ils indiquent que les sources mantelliques des BÎOs sont des mélanges de basaltes de dorsales océaniques (BDOs ou MORBs en anglais) de quatre autres composantes du manteau, soit des EM1 (enriched mantle), EM2, HIMU (ratio élevé de U/Pb = Hi μ), et FOZO (FOcal ZOne). Les études des bilans massiques et des gaz nobles indiquent que la plus grande partie du manteau a subi un appauvrissement, mais les isotopes He et Ne, ainsi que la convergence des ensembles isotopiques Sr-Nd-Pb portent à penser que la composante FOZO serait de composition à peu près primitive (n'aurait pas subi de fusion) qui serait commune à toutes les sources de basaltes océaniques. Les autres composantes renferment des "matériaux" issus de plancher océanique basaltique (HIMU), de sédiments pélagiques (EM1), de plateaux océaniques (EM1), de lithosphère sous-continente (EM1 et EM2), de sédiments terrigènes ou de croûtes continentales enfouies (EM2) et qui ont été recyclés par des mécanismes de subduction et réinjectés dans les matériaux appauvris du manteau. La façon dont ces composantes sont recyclées dans le manteau fait l'objet de discussions serrées et on observe la présence d'hétérogénéité à toute échelle. Une des écoles de pensée soutient que les îles océaniques se forment au-dessus de cellules de convection de panaches mantelliques qui apportent des composantes recyclées et de la

