



Canada Mining Innovation Council
Conseil canadien de l'innovation minière

Unlocking Canada's Mineral Wealth
Discovering Remote, Undercover, and Deep Mineral
Deposits

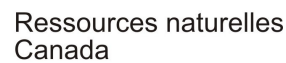
A CMIC Exploration Innovation Consortium

CANADA MINING INNOVATION COUNCIL

**IN SUPPORT OF ENHANCING THE COMPETITIVENESS
OF A RESPONSIBLE CANADIAN MINING INDUSTRY**

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Overview

Discovery is the first value added component of the mining industry as it is the discovery of a significant concentration of minerals in the Earth's crust that leads to a mine and the consequent derivative economic and strategic benefits. Across Canada, the financial impact of the mineral industry on the country's economy is considerable as it contributes on an annual basis about \$75.2 billion to exports and some \$40.3 billion to the GDP (Duke, 2010). Furthermore, some global commodity markets such as potash and uranium are dominated by Canadian production, thus ensuring an on-going role in the nation's economy, relevance in the global agriculture and energy sectors, and Canadian participation in offering global solutions to conflict commodity trade (e.g. diamonds, tantalum).

Discovery is the first critical step before any mineral and metal deposit is proved economic and can be mined in an environmentally and socially responsible manner. Most active mines were discovered many decades ago in areas lacking towns and other infrastructure, but they now form a vibrant core for industrial and sometimes urban development where none previously existed. Less than 20 years ago, there was not a single diamond mine in Canada. However, the country is now the third largest global producer of diamonds, largely from northern locations where the mines employ a significant number of First Nations individuals conferring financial and skill benefits to northern communities. Many of Canada's mines have either closed, thus contributing to the decreasing Canada base metal production (Drake, 2010), or have become mature and face closure as reserves are exhausted with consequent impact on the neighbour communities. Thus, new discoveries across the commodity spectrum are required for a sustainable and growing industrial economy for the country.

Discovery of new resources in Canada faces several challenges:

- Much of the country is remote from any societal infrastructure. Thus, exploration requires the ability to efficiently operate under varying climatic conditions with minimized costs, risk, and environmental impact in remote terranes across Canada where new mineral resource might be found.
- Basic geoscience knowledge of much of Canada is at a broad of scale. This renders the choice of where to target exploration for new resources more risky for explorers, and in turn for Canada's institutional and citizen investment community who in turn invest in lower technical risk foreign jurisdictions.
- Extensive vegetation, wetlands and lakes, glacial debris, and younger rocks mask terranes that may host significant mineral resources. Exploration thus needs the ability to rapidly and with minimal impact visualize the subsurface geology in order to explore efficiently.
- Many established mines in rural areas are nearing completion. However, some mines have been or can be extended with the discovery of new resources at depths or the recognition of nearby satellite bodies. Thus, techniques that efficiently and effectively explore at depths and in the near mine environment are important to the future of these operations.

Despite these challenges to success, Canada is an attractive destination for exploration; in 2009, some 16% of the global exploration spending of \$7.43 billion for nonferrous metals (excluding uranium) was focused in Canada (Metals Economic Group, 2010 World Exploration Highlights). However, much of the exploration expenditure is around existing operations in

efforts to extend mine lives or in known mineral prospects. Less effort is devoted to grass roots exploration in the vast tracts of unexplored territory across Canada or under in areas covered by vegetation or younger material that masks potentially mineralized terranes. The challenges and barriers to success in the grass roots programs are much greater, but where successful the potential outcome and contribution to the competitiveness of Canadian industry is immense. The success of growing a globally competitive diamond industry provides the most recent example. In essence, grass roots discoveries far from known infrastructure will play a major role in the future of the Canadian mining industry.

Despite the attractiveness of Canada as an exploration destination, the rate of discovery of new high-quality deposits has decreased over the past decade in Canada and around the world (Schodde, 2010). Many causes are proposed, ranging from technical to social to financial. Our foremost technical challenge is the Canadian environment. Firstly, there is a need to explore in covered terranes, at depths, in more and more remote areas such as the northern regions of the country, and under occasionally harsh climatic conditions. Many available exploration techniques have reached maturity in their ability to discover resources in these environments. They are thus in need of further refinement or the development of new technology and techniques, perhaps incorporating knowledge from non-geoscience disciplines. Secondly, much of the quality pre-competitive data so critical to the initial discovery stage is at a broad scale insufficient in many respects to the modern challenges for new discovery. There is thus a general barrier to the decision of where to explore for the commodity of interest.

The mineral discovery process requires renewed and sustained public and private investment in geoscience and innovative advances to ensure continued success. The new investment also needs to be coordinated and focused to meet the needs of the exploration industry, and to open new avenues to facilitate exploration. To mitigate the challenges and facilitate discovery success, the Canada Mining Innovation Council (CMIC) Exploration Innovation Consortium seeks to encourage focused innovative and collaborative development, training, and education in mineral exploration through a partnership between the mineral exploration industry, the service industry, and the university- and government-based research community. Innovation in the exploration context is distinct from invention. Exploration innovation is a change in the exploration process through the coordinated and collaborative development of new concepts, technology and tools. It is a positive change leading to increased efficiency and effectiveness in the discovery of new resources to underpin the domestic economy of Canada.

Innovative changes are viewed as a series of incremental changes that collectively change the exploration process or a collaborative effort that creates a paradigm shift in the discovery process. Cross-disciplinary advances in understanding of the ore-forming environment and in the technology and tools utilized in the discovery and delineation process are just some of the routes to successful innovation. Incorporation and adaptation of technology, tools, and procedures from other industries to the discovery process should also contribute to the improved outcome.

The Exploration Initiative

The Canadian Mining Innovation Council Exploration Innovation Consortium (CMIC-EIC), consisting currently of a partnership of 15 major and junior mining companies, the Prospectors and Developers Association of Canada (PDAC), Natural Resources Canada (NRCan) in

collaboration with the Canadian Mining Innovation Council established the key collaborative research themes and challenges (Table 1). The 3 themes critical to the discovery process are: (1) Discovery Criteria; (2) Discovery and Delineation Technology; and (3) Data to Knowledge.

Table 1. Canadian Mining Innovation Council Exploration Initiative themes, questions, challenges, and paths.

Research Themes	Discovery Criteria	Discovery and Delineation Technology	Data to Knowledge
Key Question	<ul style="list-style-type: none"> • Where to look? • What to see? 	<ul style="list-style-type: none"> • How to detect? 	<ul style="list-style-type: none"> • What does the data mean?
Components to the Themes	<ul style="list-style-type: none"> • Deposit models • Key deposit attributes 	<ul style="list-style-type: none"> • Mapping and detection • Technology 	<ul style="list-style-type: none"> • Processing, Integration, Imaging • Computation • Ease of use
Challenges & Objectives for the Themes	<ul style="list-style-type: none"> • Select the right terrane • Select the right area within a terrane • Vector towards a deposit 	<ul style="list-style-type: none"> • Enable commercialization of technologies • More efficient tools • More effective detection 	<ul style="list-style-type: none"> • Make data accessible, standardized and integrated • Cost effectively improve visualization, interpretation, and integration of Geo-scientific data • Constrain physical property models
Research Paths toward the Desired Outcomes	<ul style="list-style-type: none"> • Exploration under cover • Definition of the entire ore deposit model • Mineralized terrane selection • Fundamental controls on ore deposit location and formation • Exploration geochemical technology 	<ul style="list-style-type: none"> • Surface or airborne technology and techniques in exploration • Instrumentation to extract drill hole information • Drilling technology • Field portable instruments to secure real-time automated data acquisition 	<ul style="list-style-type: none"> • Visualization tools for an integrate range of data sets • Methodology and programs to optimize technology transfer and train the next generation of geoscientists

The exploration-focused themes and challenges facing the industry are not mutually exclusive and need to be approached through integrated cross disciplinary collaborative research paths encompassing a stream of coordinated research projects across Canada, and not through disconnected and commonly overlapping projects, as is presently common in Canada. The goal on a 5-10 year time period is to harness the collective intellect of the mining community

(company, service provider and researcher) to solve or mitigate some of the challenges inhibiting the discovery and delineation of the next generation of mineral deposits and their potential economic impact on the domestic economy. The CMIC effort is not intended to infringe upon the competitive advantages of individual mining or service companies but rather is directed toward solving the common challenges that hinder successful discovery. It is also believed that the effort will foster a renewed commitment to the next generation of precompetitive public domain geoscience.

Research themes, questions, and paths in Table 1 are synthesized from discussions with the exploration industry across Canada, and reflect their needs. The CMIC Exploration Innovation Consortium provided the vision of the program and currently acts as the Technical Board for the program described herein. The partnership includes Barrick Gold, Vale, Kinross Gold, Goldfields, DeBeers, Cameco, Goldcorp, Teck Resources, Altius Minerals, Western Potash, Hudson Bay Mining, Ur Energy, Cliffs Natural Resources, Iamgold, and AngloAmerican representing major and junior mining companies exploring or mining the complete commodity spectrum across Canada including precious and base metals, uranium, diamonds, potash, and iron ore. The representative from Barrick Gold currently chairs the partnership.

Two additional research needs identified by the CMIC Exploration partnership form critical components to enhancing the competitive climate of the Canadian exploration industry. These are 1) calibration standards and locations for physical property instruments; and 2) establishment of a common access portal for precompetitive public domain geoscience data, maps, and information. Both avenues are the responsibility of federal and provincial governments, which are currently developing those initiatives. Nonetheless, CMIC Exploration recognizes the critical role pre-competitive information and calibration standards contribute to the discovery of new resources.

Research Themes

The CMIC Exploration Initiative presented herein is thus very broad in scope and addresses national issues that cross commodities but are also commodity specific. Because of the scale and intention of the program and the challenges it seeks to address, the CMIC initiative seeks to establish funding at levels adequate to meet the national level programs goals in the 5 to 10 year time frame. Whereas these levels have not yet been established and secured, the Initiative partnership envisions this level to be in excess of \$1M per annum. Development of the individual projects will involve the research providers (service and university), but will be coordinated by CMIC.

Theme 1: Discovery Criteria

A reliable set of discovery criteria for new resources is the first step in the process of wealth creation. Two overriding questions define the Discovery Criteria theme. Where does one go to look for a particular commodity? And, what does one see geologically, geophysically, or geochemically across the range of geologic environments in Canada that tells an explorer that the commodity of interest is potentially present? These questions generate several challenges to the research community, including the development of robust and encompassing regional terrane selection criteria. In other words, why are deposits located in specific geologic terranes and not elsewhere? More specifically, easily applied criteria are required to know where to explore within a selected terrane, how to recognize a deposit when one is there, and how does the

discovery process vector towards a potential resource concentration in area of extensive cover by vegetation or younger materials.

The partnership has identified 5 critical and interlinked project areas in need of innovation. These are:

1. Exploration under cover — *techniques, concepts, and technology to better image the subsurface geology and detect buried mineral concentrations from surface, airborne, or satellite platforms*
2. Definition of the entire ore deposit model — *1) define the full deposit scale to far field variations in mineralogy, geochemistry, physical properties of ore forming systems; 2) derive criteria for their recognition where partially eroded and dispersed or buried under cover*
3. Mineralized terrane selection — *characterization of terranes favourable for mineral deposits and what distinguishes mineralized terranes from mineral-poor but similar geologic environments*
4. Fundamental controls on ore deposit location and formation — *1) crustal and lithospheric architecture leading to ore formation; 2) tectonic controls and crustal controls or influences on recognition of potentially mineralized terranes*
5. Exploration geochemistry — *1) develop full understanding of the elemental dispersion halo of an ore forming system; 2) understand elemental variations in robust and refractory indicator minerals associated with the range of deposits, their dispersal during erosion and burial, and recognition in exploration geochemical surveys; and 3) utility of airborne gasses to detect deposits*

Theme 2: Discovery and Delineation Technology

Discovery requires the development of tools and technology to assist the process of finding resources using drill hole, surface, or airborne platforms. Once a resource is discovered, tools and technology utilizing surface and drill holes platforms are required to enhance the delineation process and transfer of a mineral resource to reserves, or to be dropped as a potential target. The overall goal is acquisition of a more accurate and reliable understanding of the deposits, and the resource / reserve potential while minimizing time and costs as well as mitigating any environmental impact.

To achieve the goals of the theme, both incremental changes to current technology but also the development of new technology and techniques based on other industries are required. Opportunities are available to incorporate and adapt new technology to facilitate the discovery and delineation processes.

Critical needs identified by the partnership are:

1. Surface or airborne technology and techniques in exploration — *develop and adopt techniques useable in the range of climatic, vegetation, and geologic conditions of the ore forming environment 1) 3-D seismic and ground electromagnetics from surface that can be deployed at mine site or in exploration environment; 2) biogeochemistry in vegetated terranes; 3) exploration geochemistry through till and glacial deposits; 4) water geochemistry; 5) radiometrics beyond K, Th, U and in the subsurface; 6) emerging technology using other energy sources to image subsurface; 7) combined airborne EM and gravity; 8) geophysical tools for mapping subsurface through permafrost*

2. Instrumentation to extract drill hole information — *1) automate acquisition of reliable geochemical and geophysical data including downhole chemical, mineralogic, physical property measurements; 2) downhole IP; 3) downhole 3-D seismic; 4) cross hole tomography and geoelectrochemical technology; 5) downhole seismic; 6) off-hole detection of geologic features; 6) inexpensive and disposal downhole instruments for use in environments where drill hole stability is minimal.*
3. Drilling technology — *1) develop lighter but still powerful drills for remote exploration; 2) directional drilling technology; 3) minimize environmental disturbance and water usage; 4) equipment (casing) to incorporate downhole geophysical, geochemical, and visualization instrumentation; 5) develop material and equipment for northern climates and permafrost*
4. Field portable instruments to secure real-time automated reliable mineralogical, geochemical, and physical property data — *automating current technology and improving detection levels of present instrumentation*

Theme 3. Data to Knowledge

Transferring and utilizing the vast amount of data being collected into knowledge that can be utilized in the discovery process is a major challenge not only to the exploration, but also to the geoscience community in general. Important to the process is assurance that excessive technological or computational knowledge and time is not required to utilize data and knowledge, and that transfer of knowledge and technology is rapid to the exploration team and to young geoscientists.

Critical areas to investigate:

1. Visualized and integrate the range of data sets — *facilitate on-going effort to develop standard format for geophysical, geologic, geochemical, geometallurgical, mineralogic information for rapid incorporation into computer software and platforms*
2. Methodology and programs to optimize technology transfer from the research community to the industry and to the young geoscientists

CMIC Exploration Management Structure

Research and development across Canada in the geosciences is traditionally fragmented, resulting in lack of coordination, a duplication of efforts, and also general lack of sustained progress due to multiple projects competing for the generally limited funds available to the basic research. Furthermore, the exploration industry has also been somewhat fragmented in expressing their needs to the research community as they have commonly developed knowledge and technology within the corporate structure. However, this in-house ability is no longer common across the corporate spectrum.

Recognizing the need to focus the mining research efforts to enhance the competitiveness of the Canadian mining industry, CMIC will establish coordinated and focused programs across the spectrum of mining activities, including exploration, energy, and tailings (Fig. 1). Constructing a coordinated effort is critical to the CMIC goal of enhancing the competitiveness of a responsible Canadian mining industry through excellence in research, innovation and commercialization in the next 5 to 10 years. Continued fragmentation of research and development will not address the immediate needs of new resource discovery and following mine development. In addition

due to the breadth of the industry partnership, CMIC can also contribute a unified voice of the mining industry on issues of geoscience research and development.

CMIC will be coordinated through the central Secretariat, which will maintain overall management and coordination responsibility for the program. Once fully established, each of the major research areas of CMIC will have a program manager responsible for coordinating projects in that area (Fig. 2). As a consequence of the management structure, CMIC program managers will also act as the industry representative in collaborative research projects. Industry representatives will constitute a technical advisory board to the project during development and operation. This management matrix simplifies project development and administration for research providers, but more importantly provides better management and assurance that the project goals and outcomes are directed toward the CMIC goals.

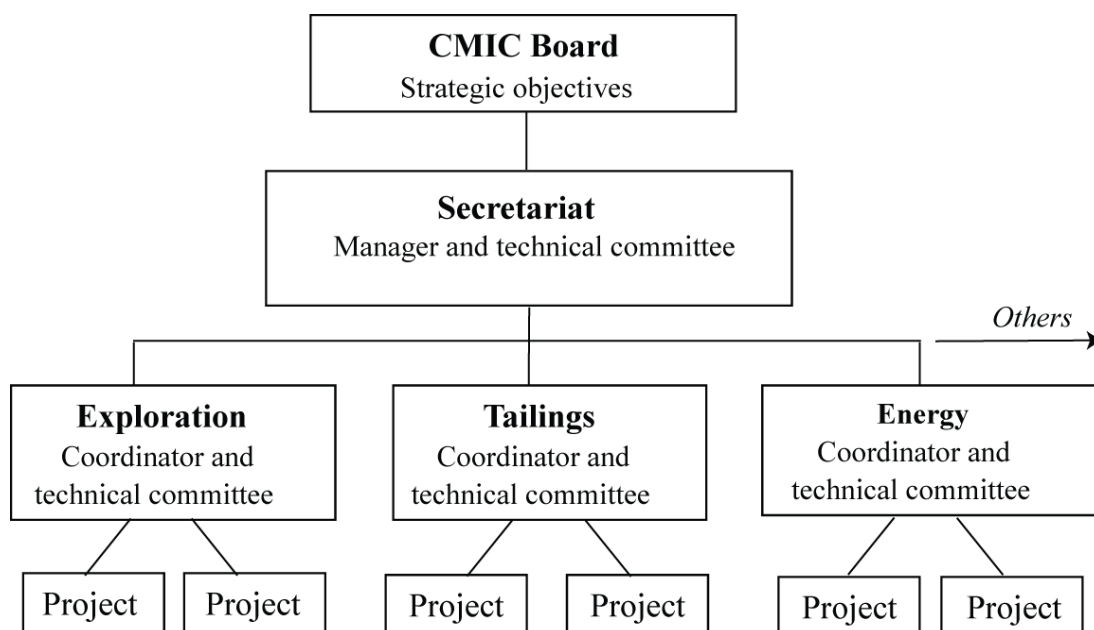


Figure 1. Administrative structure of the Canada Mining Innovation Council

In addition to a CMIC program manager responsible for project management and administration, a technical advisory committee composed of senior industry managers from the exploration divisions of the mining industry will be established (Fig. 2). The Exploration Technical committee is different from the industry advisory groups associated with each of the projects. The Exploration Technical Advisory Committee is responsible for the overall Exploration program's research goals on an annual basis and the selection of project areas to be initiated by the CMIC Exploration Program. The Board will meet several times a year, at a schedule to be determined. In addition, the Technical Board will host a meeting where partners and providers discuss research ideas, and outline project areas to be addressed in forthcoming years.

Project development

Project ideas will be submitted to the CMIC Exploration Program through a call for proposals once the Exploration Technical Board establishes the research targets. Following approval by the Board, individual projects can be developed along two routes. CMIC

exploration projects can be single or multi-institutional that address all or a significant component of the research paths outlined in Table 1. Technology development projects may be established with a single partner or an industrial consortium. Single or multi-institutional projects eligible for matching funds from governmental sources will be based at a university. CMIC will act as the industry representatives for projects where a governmental agency matches the industry cash and in-kind contributions toward particular project.

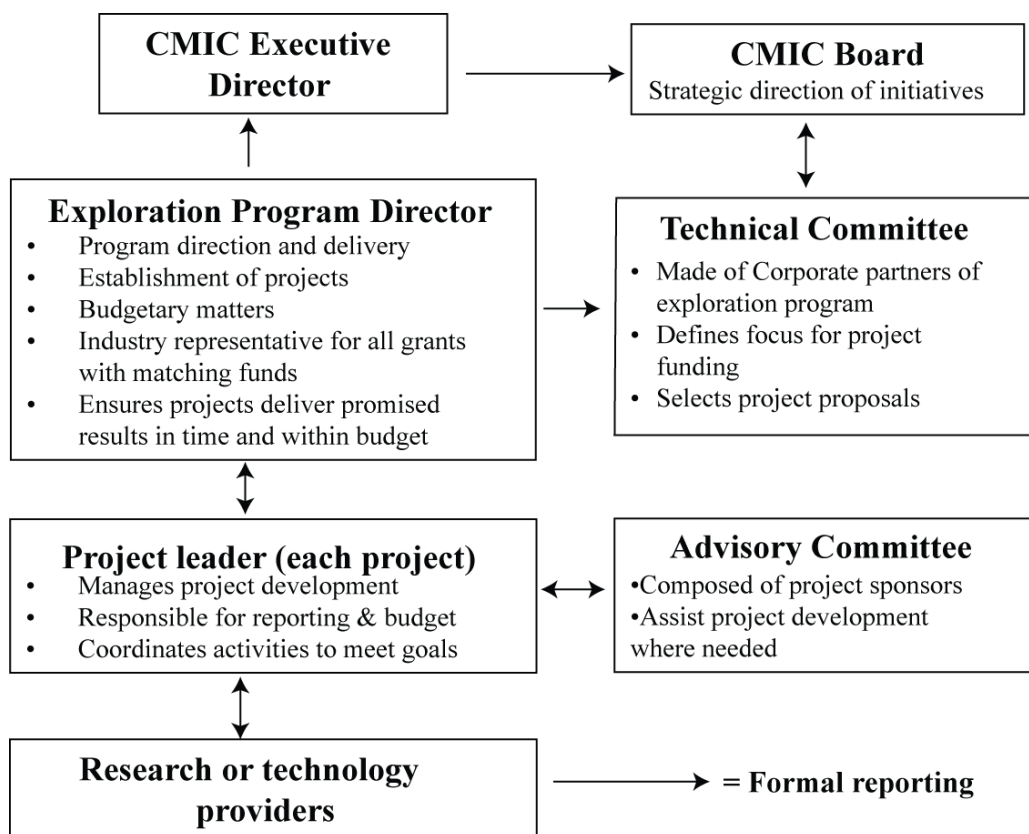


Figure 2. Internal structure and responsibilities of the CMIC Exploration Program Manager

CMIC will not be a single funding source for any projects, but it will act on behalf of the industry partners sponsoring a particular project. Industry funds to support projects will flow through CMIC to the respective research providers. Technology being developed for commercialization by private industry will require matching contributions from the industry developers.

Budgets will depend upon the scale of the project. Time durations will be appropriate for the project to achieve the promised results. Projects may be for 1 year to 4 or 5 years duration. Annual or more frequent technical review meetings will ensure a level of successful technical transfer and exchange between research providers and the industrial sponsors. The exchanges also provide the opportunity for the project sponsors to evaluate progress toward the stated goals.

Individual CMIC Exploration projects may be organized in several manners. As the Research Themes are interlinked, the inclusion of research paths that cross the Exploration

Initiative themes is encouraged. CMIC is a national collaborative initiative, and funded projects will be collaborative in theme, scale, and focus unless otherwise required for success.

1. Collaborative Research and Development Projects – Projects should be multidimensional and multi-institutional that seeks to address interlinked aspects of research that crosses paths and themes of the Exploration Initiative. These projects will also be eligible for matching funds from the NSERC Collaborative Research and Development program. CMIC will represent the industry partners as a single industry champion for the project development and management. A university based principal investigator acts as a lead proponent in the application for matching funds, and manager of the project, as well as represents the collaborating academic institutions. CMIC industry partners sponsoring the project act as a technical advisory board for project development and project progress but CMIC acts as the industry sponsor responsible for managing the industry funding, project “oversight” and assurance that goals and directions are being followed.
2. Technology Development Projects – Industry partners via CMIC engage in co-funding with a service provider or consortium of providers to develop technology that will be commercialized upon completion by the providers or be available from the providers for licensing by the sponsors.
3. CMIC facilitated collaboration between interested partners and research providers whereby individual research providers (university or service industry) develop project separate but aligned with stated CMIC Exploration goals.

Note that small projects addressing a component of a research theme will be considered if they address a critical missing component of a larger research path or theme. They may also provide a missing incremental step required to complete an innovative development.

Intellectual property and commercialization

CMIC intends to enhance the competitiveness of the Canadian mining industry. To this end, ownership of intellectual property as well as commercialization and licensing opportunity will generally reside with research and technology providers under the guidelines being established by the CMIC Board. There will also be the opportunity for university researchers to publish results.

Technology transfer

A critical challenge to the CMIC Exploration Initiative is the transfer of technology, understanding, and training from the providers to the sponsoring company or consortia. Furthermore, there is a need to transfer new knowledge into the education system and provide training opportunities such that young geoscientists are better prepared to meet the challenges of the work place.

To address this challenge, each CMIC exploration project must devote effort to technology transfer to sponsoring partners beyond simple report submission. The uptake of research results by the exploration community and the training of the next generation of young geoscientists are of paramount concern and goal of the CMIC initiative.

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