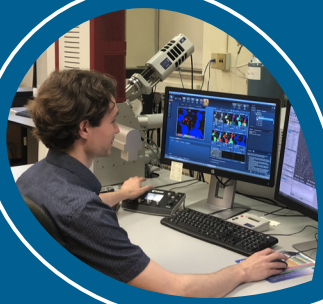
PAN-CANADIAN GEOSCIENCE STRATEGY

Enhancing geoscience data, knowledge and access for a stronger future



National Geological Surveys Committee of Canada, 2022. Pan-Canadian Geoscience Strategy: Enhancing geoscience data, knowledge and access for a stronger future; Natural Resources Canada, General Information Product 131e, 24 p. https://doi.org/10.4095/329347

ISBN: 978-0-660-40057-0

Catalogue Number: M4-211/2021E-PDF

Aussi disponible en français sous le titre :
Stratégie pancanadienne de géoscience : Accroître l'accès aux données et aux connaissances géoscientifiques pour bâtir un avenir meilleur

ACKNOWLEDGEMENT

The development of the Pan-Canadian Geoscience Strategy was made possible through the contributions of all geological survey organizations represented by the National Geological Surveys Committee:

- Alberta Geological Survey | Alberta Energy Regulator (Government of Alberta)
- British Columbia Geological Survey | Ministry of Energy, Mines and Low Carbon Innovation (Government of British Columbia)
- Canada-Nunavut Geoscience Office | Department of Economic Development and Transportation (Government of Nunavut), Natural Resources Canada (Government of Canada), Crown-Indigenous Relations and Northern Affairs Canada (Government of Canada), and Nunavut Tunngavik Incorporated
- Géologie Québec | Ministère de l'Énergie et des Ressources naturelles du Québec (Gouvernement du Québec)
- Geological Survey of Canada | Natural Resources Canada (Government of Canada)
- Geological Survey of Newfoundland and Labrador | Department of Industry, Energy and Technology (Government of Newfoundland and Labrador)
- Manitoba Geological Survey | Department of Agriculture and Resource Development (Government of Manitoba)
- New Brunswick Geological Surveys Branch | Department of Natural Resources and Energy Development (Government of New Brunswick)
- Northwest Territories Geological Survey | Department of Industry, Tourism and Investment (Government of the Northwest Territories) (contribution number 0144)
- Nova Scotia Geological Survey | Department of Energy and Mines (Government of Nova Scotia)
- Ontario Geological Survey Branch | Ministry of Northern Development, Mines, Natural Resources and Forestry (Government of Ontario)
- Saskatchewan Geological Survey | Ministry of Energy and Resources (Government of Saskatchewan)
- Yukon Geological Survey | Department of Energy, Mines and Resources (Government of Yukon) (contribution number 056)

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Message from the National Geological Surveys Committee (NGSC)

The Pan-Canadian Geoscience Strategy (PGS) builds on existing collaborations and represents a renewed commitment to strong relationships for delivering new accessible geoscience data and knowledge for all Canadians. The need for this Strategy was identified in the Canadian Minerals and Metals Plan (2019), and agreed upon by Canada's Mines Ministers under the related Action Plan 2020.

For over 178 years, Canadian Geological Survey Organizations (GSOs) have provided relevant geoscience to governments and industry to inform decision-making on topics such as responsible energy, mineral and groundwater resource exploration and development, natural resource infrastructure development, and public safety and security. The collaborative activities of all Canadian GSOs are coordinated through the NGSC under the terms of the Intergovernmental Geoscience Accord, first signed in 1996 and renewed four times by federal/provincial/territorial Mines Ministers.

Every year, GSOs contribute to Canada's economic success. According to an Ernst and Young study released in 2020, it is estimated that over the past decade GSO-led public geoscience programs have generated at least $1.22B in economic benefits — 7.3 times the amount of money originally spent by government. GSOs also support Canadian sovereignty, land management and public safety, and advance science leadership.

The rising demand for critical minerals used for clean and digital technologies presents an enormous opportunity for Canada to contribute to global supply chains. However, the long and steady decline of many Canadian mineral reserves shows that it is now more important than ever for GSOs to identify new prospective areas or new indicators of prospectivity, which is known to increase the success rate of private sector mineral exploration. It is also important for GSOs to provide geological information about environmental factors for safe and responsible resource development. Considering such factors is both ethically important and increasingly expected for operating and for marketing end products. To meet this challenge, Canadian GSOs aim to coordinate their efforts on shared priority areas while meeting other government and societal needs identified in each jurisdiction.

This PGS presents the opportunity for GSOs to cooperatively grow Canada's geoscience knowledge base, building on a foundation of expertise that resides in provinces and territories and is enhanced by the additional specialized capacities of the Geological Survey of Canada. This approach will enable the deep knowledge of a jurisdiction's geology and resources to continue developing under the resource managers in each province or territory while the federal government continues to invest in new areas of science and technology.

In developing this PGS, we have taken the first step towards the necessary closer collaboration among all Canadian GSOs to meet future challenges and take advantage of new opportunities. We look forward to the rest of this journey.

Daniel Lebel and Carolyn Relf, Co-chairs of NGSC, 2021

STRATEGIC OVERVIEW

The Pan-Canadian Geoscience Strategy (PGS) is a federal/provincial/territorial collaborative effort that is coordinated through the National Geological Surveys Committee (NGSC)[1] in alignment with the Intergovernmental Geoscience Accord (IGA).[2] The PGS helps achieve the targets set out under the Canadian Minerals and Metals Plan (CMMP)[3] and responds to calls from governments and stakeholders to explore options for improving public geoscience coordination and funding. The PGS supports the long-term **vision** to provide geoscience information that underpins the responsible development of Canada's geological resources (geo-resources) and serves the public good.

Under this vision, the PGS seeks to advance the following **mission statements:**

- Support a globally competitive mineral and energy exploration and development sector in Canada
- Provide accessible geoscience data and knowledge to inform sustainable development and land use decisions
- Reduce environmental and public safety risks associated with resource development and geological hazards (geo-hazards)
- Be responsive to society's evolving expectations for land and resource management

The PGS identifies five interdependent **priority areas** for action:

- Advancing framework geoscience
- Advancing mineral and energy potential modelling
- Facilitating access to online data
- Supporting the training of next generation geoscientists
- Enhancing public literacy in geoscience

These priorities support the PGS vision and mission statements by providing data and knowledge, ensuring that these data are sufficiently discoverable and understandable to maximize positive impacts, developing next generation geoscience expertise in Canada as current specialists leave the workforce for retirement, and enhancing the ability of the public to understand and benefit from geoscience. The PGS vision, mission statements and priority areas were all developed through discussion with a variety of geoscience users and are supported by an NGSC consensus.

1 The **National Geological Surveys Committee (NGSC)** is responsible for the implementation of the Intergovernmental Geoscience Accord and reports annually to the Energy and Mines Ministers through the Intergovernmental Working Group on the Mineral Industry. The NGSC is an executive-level federal/provincial/territorial committee for Canada's GSOs. The NGSC is co-chaired by the Geological Survey of Canada's Director General and, in a rotational position, by one director among the provincial and territorial GSOs. This committee provides a forum for senior executives from Canada's GSOs to coordinate and integrate public geoscience activities across Canada. Members identify emerging geoscience issues, consult on best practices, pursue cooperation/collaboration opportunities and promote the value of public geoscience among Canadians.

2 The Ministerial-level **Intergovernmental Geoscience Accord (IGA)** outlines the framework for collaboration between federal/provincial/territorial GSOs in order to minimize overlap and duplication, enhance synergies among jurisdictions to resolve regional geoscience problems, and facilitate optimal utilization of resources. The IGA was first developed in 1996 and has been continuously renewed since then; the sixth iteration of the IGA is expected to be signed in 2022. The current IGA was signed in 2017 by most of Canada's Mines Ministers, with the exception of Quebec, which participated in the development of the IGA and agreed to act in accordance with its intent, and Prince Edward Island, which does not have a GSO.

3 The **Canadian Minerals and Metals Plan (CMMP)** is a co-developed policy framework that aims to build on Canada's position as a global mining leader and lay the foundation for a future looking industry that capitalizes on opportunities in an evolving global economy. On the date of its release (March 2019), the CMMP had been endorsed by all Mines Ministers of Canada, with the exception of the Ministers from Ontario and Saskatchewan. Action Plans are being released to operationalize the CMMP. The first in the series, Action Plan 2020, was released in March 2020 and introduced six pan-Canadian initiatives. Additional action plans will roll out in fall 2021, 2022 and every three years afterwards.

WHAT IS PUBLIC GEOSCIENCE?

Public geoscience refers to science that is geological, geophysical and geochemical in nature, and various types of data, maps and knowledge related to geology — openly available to the public. It serves the public good by providing information on economic opportunities, the environment, and geo-hazards, such as coastal erosion and earthquakes.

WHO PRODUCES PUBLIC GEOSCIENCE?

Federal/provincial/territorial governments have shared jurisdiction over public geoscience, and work together to conduct, coordinate and integrate public geoscience activities.

WHERE IS PUBLIC GEOSCIENCE INFORMATION COLLECTED?

Public geoscience takes place across the country, with certain areas targeted for research based on factors such as:

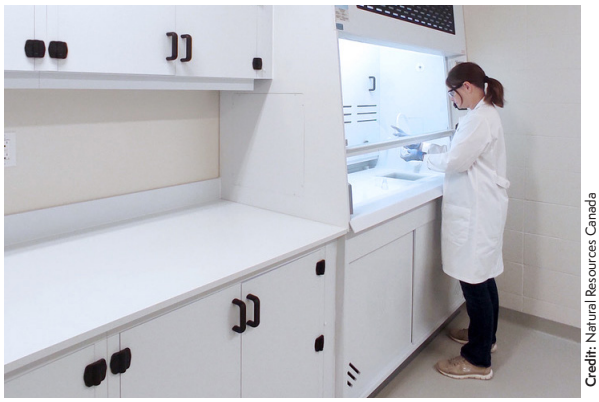
- How much data are currently available (i.e., a knowledge gap exists in that area)
- Whether the area is likely to hold economically important geo-resources (e.g., mineral commodities)
- Whether the area is at risk from geo-hazards (e.g., earthquakes) or climate-related geological changes (e.g., coastal erosion)

WHEN IS PUBLIC GEOSCIENCE INFORMATION COLLECTED?

Traditionally, geologists collect rock samples during the summer field season when there is no snow cover. Public geoscience information is also collected in many other ways throughout the year. For example, laboratory analyses of rock samples continue year-round and earthquake-prone areas are continuously monitored through on-the-ground sensors and satellites to assess risk.

Credit: British Columbia Geological Survey

Toting rock samples, British Columbia



Credit: Natural Resources Canada

Analyzing source rock organic matter, Alberta

WHY IS PUBLIC GEOSCIENCE REQUIRED TODAY?

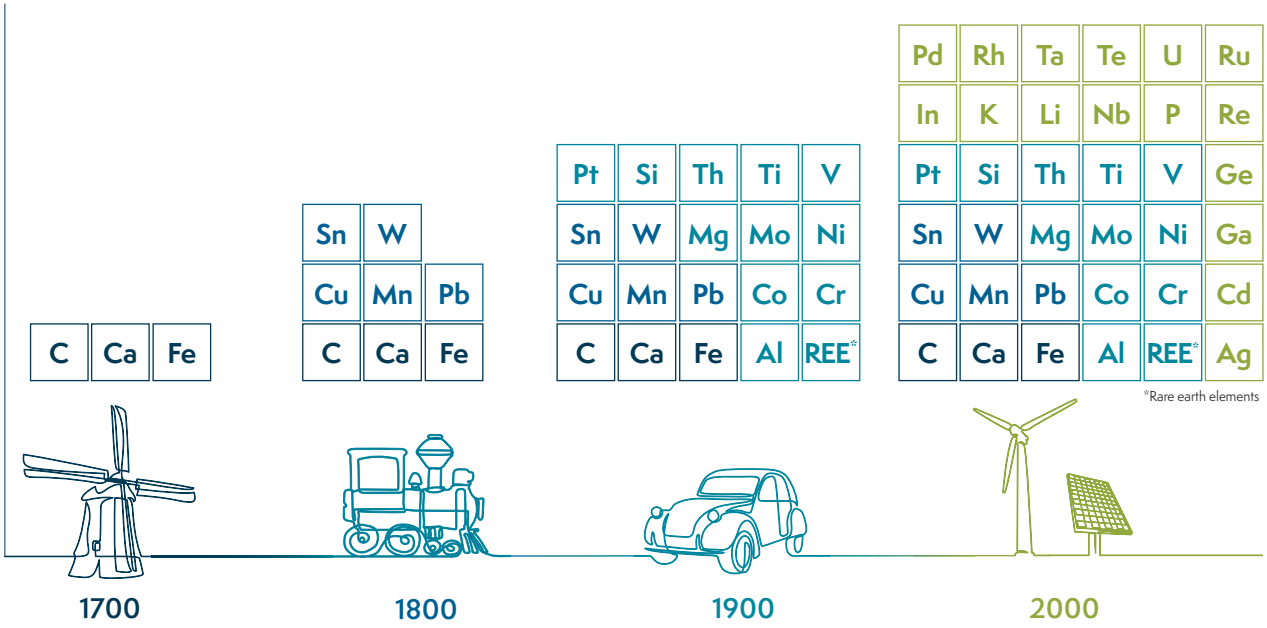
Our communication networks and transportation and energy infrastructure, and many other modern products, are built using minerals. As we endeavour to reduce our reliance on fossil fuels, we will require more minerals to enable the clean energy transition. This means geoscience information is needed to discover new resources and extend the life of existing mines.

Responding and adapting to the impacts of climate change require an ability to predict geo-hazards such as flooding, landslides and permafrost thaw slumps. Public geoscience helps to inform risk and ensure our safety.

Credit: Natural Resources Canada

Landslide on Cecil Lake Rd, British Columbia

MINERAL REQUIREMENTS FOR EVOLVING ENERGY TECHNOLOGIES



Graphic adapted from Volker Zepf, John Simmons, Armin Reller, Morag Ashfield, and Cameron Rennie's 2014 handbook: *Materials critical to the energy industry — An introduction* (2nd edition)

THE IMPERATIVE FOR A PAN-CANADIAN GEOSCIENCE STRATEGY (PGS)

PUBLIC GEOSCIENCE FOR THE ECONOMY, THE ENVIRONMENT AND SOCIETY

The mineral and energy sectors are significant to Canada's economy. Geoscience plays an essential role in fostering strong mineral and energy investment in Canada. In particular, public geoscience produced by Canada's federal/provincial/territorial geological survey organizations (GSOs) underpins Canada's competitive advantages in attracting resource exploration and development.

Public geoscience also contributes to environmental protection and societal well-being. For example, there is a growing public demand for social consensus in resource development. Environmental and groundwater geoscience coupled with maps of mineral and energy potential can provide evidence required for land use planning and decision-making by public and Indigenous governments, Indigenous Peoples and stakeholders.[4] Geoscience can also support climate change mitigation, adaptation and disaster risk reduction from geo-hazards such as landslides. In the context of resource development, the documentation of these hazards can reduce development costs and help to minimize environmental impact.

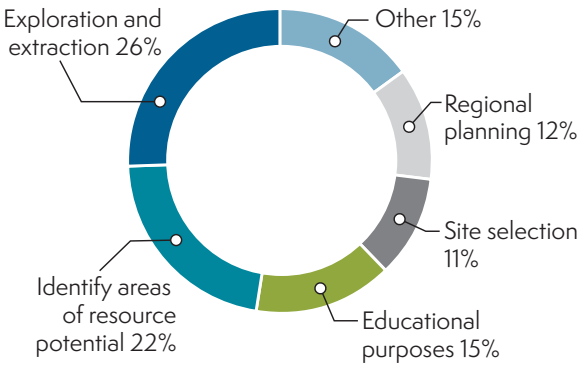
CASE STUDY
THE VALUE OF PUBLIC GEOSCIENCE FOR EXPLORATION — AND FOR OTHER PURPOSES

A 2020 Ernst and Young study on federal mineral geoscience programs found that over the past decade, spending related to public geoscience has yielded economic benefits of at least $7.30 on every $1 from the programs. These results demonstrate that immediate support of pre-competitive geoscience services can stimulate long-term economic gains.

The study also found that mineral geoscience often supported regional land use planning and educational purposes, in addition to development-focused goals such as site selection and exploration.

Data provided by Ernst and Young's 2020 Economic Assessment of Geoscience Information (GEM and TGI) for Natural Resources Canada

Program spending	Multiplier	Total economic benefits
$250M	**7.3**	**$1.22B**



4 A **stakeholder** is an individual or group with an interest in any decision or activity of an organization. Note that while Indigenous Peoples may have an interest in these decisions or activities, they are not referred to as 'stakeholders' in this document. Having more than an interest in decisions or activities, Indigenous Peoples also have special rights that must be respected.

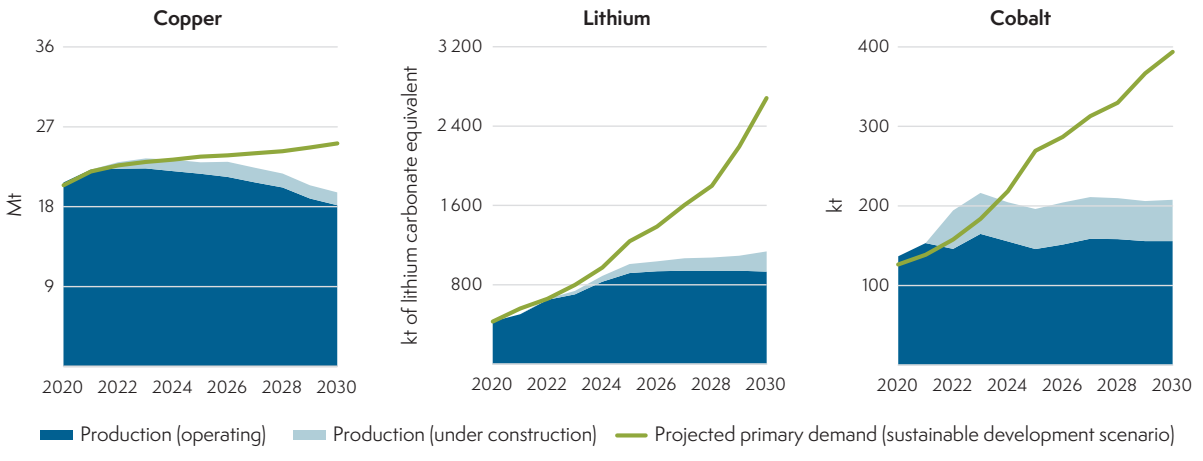
WHY DO WE NEED A PGS *NOW*?

Canada is richly endowed with natural resources and has always been a major contributor of minerals, metals and energy resources to international markets. One of our competitive advantages has been the high-quality geoscience knowledge base in Canada, which attracts investment and reduces exploration risk. Recently, this competitive advantage has been eroding: in some cases, challenges such as climate change mitigation and geo-hazard risks have led to a redirection of GSO resources; in other cases, funding for public geoscience has been reduced. This reduction in the collective capacity of GSOs comes at a time when Canada's mineral discovery rate is declining sharply and as demand for new commodities is growing, such as for certain critical minerals. It also coincides with a trend toward machine learning, artificial intelligence and harmonization of disparate data sources — areas where other countries have recently made significant investments. Further details on these challenges and opportunities are provided below.

MEETING DEMAND FOR NEW MINERALS

As the world is turning towards green energy, demand is quickly growing for critical minerals as the building blocks for a clean and digital economy. However, according to The Mining Association of Canada and statistics compiled by Canadian governments, the past 30 years have seen a marked decline in Canadian mineral reserves of all major base metals that are on the nation's critical minerals list. In addition, the distribution of less common critical minerals, such as rare earth elements, is not yet well known. This means that important challenges lie ahead in locating new critical mineral reserves and/or understanding prospectivity of existing mine sites for the hidden value of critical minerals. With its large landmass and varied and remarkable geology, Canada remains rich in these minerals but mineral exploration needs to be more strategic to lead to discoveries and development. Public geoscience is a proven tool to identify the most prospective areas and guide private sector investments in mineral exploration. Coordinating the work of Canada's GSOs to better focus on the country's inventory and potential for critical minerals, and to share critical minerals data, will increase efficiencies, build on collective expertise, and help Canada to successfully compete in the critical minerals and renewable energy sectors. It will also assist Canada in meeting bilateral commitments such as the Canada-US Joint Action Plan on Critical Minerals Collaboration.

GLOBAL DEMAND FOR MANY MINERALS MAY EXCEED GLOBAL SUPPLY IN THE COMING YEARS



Adapted from the International Energy Agency's 2021 analysis: The Role of Critical Minerals in Clean Energy Transitions

SUPPORTING ENVIRONMENTAL, SOCIAL AND GOVERNANCE GOALS

An increasingly important factor for competitiveness of geo-resource sectors is meeting and/or exceeding environmental, social and governance standards. Canada is already recognized as a global leader in this regard, but competition is fierce and expectations are continually evolving. Public geoscience can support Canadian competitiveness in this context. In particular, an improved understanding of mineral and energy potential and other geological features such as groundwater vulnerability and geo-hazard risks, can help to support evidence-based land use planning by decision-makers such as provincial, territorial, municipal and Indigenous governments, as well as responsible geo-resource development by industry. On a national scale, this geoscience can also support Canada in deciding how to best deliver on international environmental commitments (e.g., Sustainable Development Goals, United Nations Sendai Framework for Disaster Risk Reduction, Paris Agreement on Climate Change) and domestic land and marine conservation targets.

RISING TO NEW SCIENTIFIC AND TECHNICAL OPPORTUNITIES

Science and technology advancements have made it possible to collect and analyze more geoscience data than ever before, and have improved our understanding of mineral deposits evolution, tectonics and other foundational geoscience. These advancements are now beginning to support the use of new paradigms and development of predictive models for geological systems. They have also made sophisticated data collection technologies such as portable X-ray fluorescence, ultra-low trace element detection and ever-improving drones as well as other Earth observation technologies more available. New technologies can be combined with traditional boots-on-the-ground activities to enhance both data collection in the field and sample analysis in the lab, and emerging digital tools and methods for big data analysis are making data fusion and more complex analyses possible.

These scientific and technical developments present enormous opportunities to further advance geoscience, both for Canada and for its competitors. To keep up on the global stage, it is critical for Canada to leverage these new opportunities, to modernize its approaches for acquiring and managing data across the country, and to develop appropriate decision-support tools and solutions that are accessible to end-users on the range of issues related to GSO mandates.

TAKING ADVANTAGE OF EVOLVING GSOs

GSOs collect, analyze and interpret geological data, producing new knowledge that end-users can access to support many different applications. To enable the production and use of this geoscience, GSOs have also historically contributed to the professional development of geoscientists and to public literacy in Earth sciences.

The specific and complementary roles of Canada's GSOs have evolved significantly over the last few decades. Fifty years ago, the federal Geological Survey of Canada housed the bulk of Canada's geological mapping capacity as the main repository of public geoscience knowledge for Canada. Since then, provinces and territories have developed their own capacity and expertise for regional geoscience, including both regional mapping and detailed investigations of regional geological systems.

Senior scientists for most provincial and territorial surveys are now the primary knowledge holders for regional geology in their respective jurisdictions. As for the Geological Survey of Canada, it focuses more and more on:

- Producing complementary geoscience with relevance across multiple jurisdictions and at the national scale
- Developing new methods for data collection and analysis
- Making additional investments in sub-disciplines of Earth sciences such as geophysics, geochemistry, groundwater and geo-hazards
- Building innovative analytical infrastructure and laboratories

Scientists at the Geological Survey of Canada enrich Canada's public geoscience knowledge base by adding specialized "layers" to the foundational information generated by provinces and territories, and by producing new science and developing new techniques in the national interest. The Geological Survey of Canada is also the only GSO in Canada to conduct marine geoscience, since offshore matters are a federal responsibility. This complementary expertise between federal and provincial/territorial jurisdictions[5] is formalized in the IGA.

The PGS presents the opportunity for GSOs to cooperatively grow Canada's geoscience knowledge base — building on a foundation of expertise that resides in provinces and territories, and enhanced by the specialized capacities that the Geological Survey of Canada has developed. This approach will enable the deep knowledge of a jurisdiction's geology and resources to reside with the resource managers in each province and territory while the federal government continues to invest in complementary areas of science and technology in the national interest.

Moving forward, the GSOs of Canada, represented by the NGSC, are prepared to re-examine the status quo and work towards strengthening federal/provincial/territorial relationships to co-develop, co-deliver and co-resource the geoscience activities of the future. These discussions will take place as the PGS is implemented over the coming years and during the next renewal process of the IGA (scheduled for 2022).

5 In the PGS, the terms, **jurisdiction** and **jurisdictional**, are used to collectively refer to federal and provincial/territorial levels of government.

COMMITMENT TO DEVELOP A PGS

The Canadian Minerals and Metals Plan (2019) and follow-up Action Plan 2020 recognized the changing landscape and the importance of coordinated national action on public geoscience to support a strong and responsible minerals and metals sector (further described within the Plan's Strategic Direction on Economic Development and Competitiveness). At the Energy and Mines Ministers Conference (EMMC) in September 2019, Mines Ministers agreed to co-develop a PGS via the NGSC. The overall direction of the PGS — vision, mission statements and scope — was endorsed by Ministers at the 2020 EMMC. The final PGS, including priority areas and early action items, was endorsed by Ministers at the 2021 EMMC.

VISION AND MISSION OF THE PGS

The **vision** of the PGS is to provide geoscience information to underpin the responsible development of Canada's geo-resources and serve the public good.

The geo-resource value chain extends from land use planning to exploration, and safe infrastructure development to reclamation. Therefore, diverse geoscience is required to underpin responsible development. This includes but is not limited to, mineral, energy, public safety, environmental, climate change and groundwater geoscience. For example, information about mineral and energy potential can help communities and governments in making their land use planning decisions that set the context for the rest of the value chain, as well as companies in deciding where to target their exploration activities (pending appropriate permissions). Similarly, climate change geoscience on thawing permafrost can inform decisions on engineering requirements for building mine infrastructure, and for roads to transport ore to market, and bring materials to nearby communities and resources development sites.

Diverse geoscience can also serve the public good by supplying evidence to support geo-hazard risk management, land conservation decisions, and other important decisions related to land, water, and resources.

The intertwined **mission statements** of the PGS are to:

- Support globally competitive mineral and energy exploration and development sectors in Canada
- Provide accessible geoscience data and knowledge to inform sustainable development and land use decisions
- Reduce environmental and public safety risks associated with resource development and geo-hazards
- Respond to society's evolving expectations for land and resource management

PRINCIPLES FOR PGS IMPLEMENTATION

RESPONSIVENESS TO STAKEHOLDERS AND INDIGENOUS PEOPLES

The PGS must meet the needs of stakeholders and respect the rights of Indigenous Peoples.

Priority areas for action under the PGS are further outlined in the sections that follow. Developed by the NGSC and based on needs consistently identified by the minerals and mining industry, energy industry, academia and government producers/users of geoscience over the last several years, these priority areas are:

- Advancing **framework geoscience**
- Advancing **mineral and energy potential modelling**
- Facilitating **access to online data**
- Supporting the **training of next generation geoscientists**
- Enhancing **public literacy in geoscience**

These priority areas for action support multiple stages of the value chain for geo-resources (e.g., minerals and energy) and the mission statements of the PGS. They also align with some of the priorities raised in reports developed by Indigenous groups (e.g., the 2018 National Inuit Strategy on Research by the Inuit Tapiriit Kanatami).

The NGSC recognizes and respects the rights of Indigenous Peoples in Canada, and the important relationships they have with the land and water. When developing action items to implement the PGS, the GSOs will use jurisdictional mechanisms to engage and/or consult Indigenous groups in the spirit of reconciliation and will seek opportunities for project co-development wherever possible.

THE CONVERSATION SO FAR

ENERGY AND MINES MINISTERS' CONFERENCE 2019

Leveraging previous input on geoscience needs and future directions

- Existing records from the Canadian Minerals and Metals Plan engagement
- Existing external reports and letters on research priorities and geoscience needs
- Environmental scan of international trends
- Previously expressed opinions/input from GSO staff

PGS-specific engagement to identify priorities

- Provincial/territorial open houses — discussion, surveys
- Bilateral meetings with individuals and regional/national organizations
- Discussions within NGSC about jurisdictional mandates and capacity

ENERGY AND MINES MINISTERS' CONFERENCE 2020

Follow-up engagement on proposed PGS priority areas and associated activities

- Association for Mineral Exploration Roundup — presentation, polls
- Prospectors & Developers Association of Canada Convention — information at booth
- National Mining Week Mineral Outlook Dialogue — presentation, panel discussion, polls
- Presentations to other branches of government
- Presentations and discussions with GSO staff
- "People-focused" priority areas session — breakout groups with discussion, survey
- "Technical" priority areas session — breakout groups with discussion, survey
- Bilateral meetings with individuals and regional/national organizations

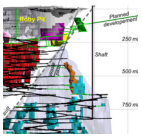
ENERGY AND MINES MINISTERS' CONFERENCE 2021

Reached groups included a cross-section of industry, professional geoscience associations, academia, Indigenous groups, and governmental producers/users of geoscience.

WHAT WE'VE HEARD

- General support for PGS vision, mission statements, and priority areas
- Appreciation for the fact that the PGS acknowledges the importance of both the science and the people who produce/use the science
- Appreciation that the NGSC is acting as national convener to discuss geoscience in the context of cross-cutting priorities such as critical minerals
- Recognition that PGS results will scale with inputs, and that the NGSC will need capacity and distributed, empowered co-leadership to succeed with the PGS in the long term
- Many ideas for future collaborations and action items

RELATIONSHIP BETWEEN PGS PRIORITY AREAS AND THE GEO-RESOURCE VALUE CHAIN

		Framework geoscience	Mineral and energy potential modelling	Access to online data	Training of next generation geoscientists	Public literacy in geoscience
Land use planning		✓	✓	✓	✓	✓
Licensing and permitting		✓	✓	✓	✓	✓
Exploration and prospecting		✓	✓	✓	✓	✓
Feasibility analysis		✓	✓	✓	✓	✓
Planning and construction		✓	✓	✓	✓	
Production						
Transportation		✓		✓	✓	
Markets						
Reclamation		✓		✓	✓	

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RESPECT FOR JURISDICTIONAL ROLES AND RESPONSIBILITIES

The goals outlined in the PGS can be delivered in a truly collaborative way as GSOs in Canada continue to grow into their different and complementary roles. Activities can be co-developed and co-delivered, thus respecting various mandates, addressing jurisdictional priorities, and establishing a process by which regional and national interests are considered. Leadership for delivering on different parts of the PGS will reflect the capacities of each GSO. The Geological Survey of Canada will support those jurisdictions that are still developing capacity. When developing specific action items, the NGSC will define GSO roles such that they can each contribute and benefit from their different strengths. As needed and at their discretion, GSOs may reach out to other agencies within their own governments or to knowledge holders outside of government, for further input.

Although it is challenging to work across jurisdictions and mandates, GSOs across Canada have a track record of delivering complementary and collaborative geoscience in alignment with the IGA. Focused on set areas for coordination, this PGS will enable GSOs across Canada to maximize complementary expertise for the achievement of common goals, while respecting the purview and data ownership of each jurisdiction and allowing them to take the lead on different priority areas and projects.

BALANCE BETWEEN ASPIRATIONAL GOALS AND PRACTICAL CONSIDERATIONS

The PGS cannot address all issues at once and must be grounded in the mandates of GSOs and adjusted to the availability of fiscal resources. However, it does provide some immediate opportunities to increase national collaboration on geoscience innovation, and offers a strong framework within which jurisdictions can co-develop future initiatives or position their own initiatives.

INCLUSIVITY

The NGSC is committed to the principles of equity and diversity in the implementation of the PGS. It will particularly strive to ensure that diverse perspectives are considered during the development of action items and that opportunities and resources associated with the PGS are made equally accessible to people who might otherwise be marginalized or excluded.

INTERSECTIONAL OPPORTUNITIES

Just as the PGS is meant to encompass all federal/provincial/territorial jurisdictions, action items under the PGS may cross-cut more than one mission statement or priority area. For simplicity, actions described below are grouped under the five priority areas. Many actions could in fact be linked to several priority areas and/or mission statements.

Credit: Saskatchewan Ministry of Energy and Resources

Geoscientists examining an outcrop as part of a regional geological mapping program in the Precambrian shield of northern Saskatchewan

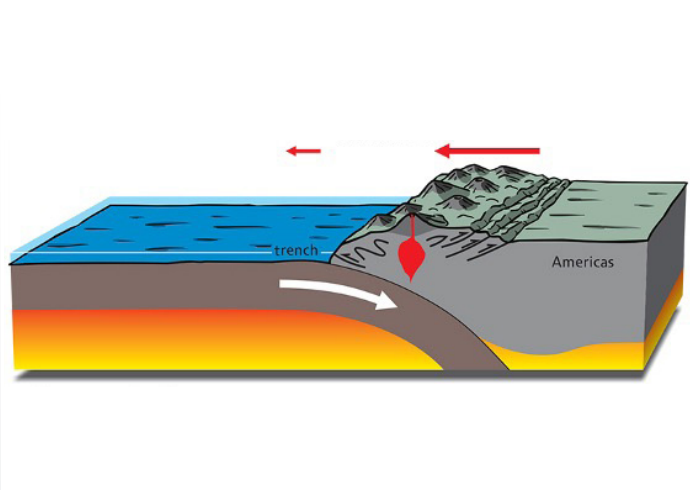
PRIORITY AREAS FOR ACTION

ADVANCING FRAMEWORK GEOSCIENCE

Robust geoscience is foundational to all other priority areas under the PGS. GSOs have collected high-quality geoscience data, produced geological maps, and conducted thematic studies for many decades. Such work has clear benefits — for example, industry can use data about mineral deposits and rock types in one location to draw inferences about what mineral deposits might be present in the same rock type at other locations. However, geoscience has historically been conducted through a series of individual projects. Even when these projects have been interlinked or built on each other, the resulting geological understanding at regional or national scales was not necessarily unified or comprehensive.

In the last decade, advancements in geospatial and database software have made it possible to adopt a new, framework-oriented approach to geoscience. This approach aims to integrate our understanding of geological systems, processes, and indicators into a collective "framework" of core geoscience knowledge. This four-dimensional framework (of the three-dimensional Earth and its development over time) enables important predictions. For example, understanding the overall geological processes and indicators associated with gold deposit formation makes it far easier to predict where gold may be extracted across Canada, especially in locations where limited geoscience data are available. A framework approach to geoscience can also have public good applications, such as the evaluation of relative geo-hazard risk in different areas.

Framework geoscience applies two broad investigative methods to unravel the geology of a region: it acquires new geoscience data sets (e.g., geological, geophysical and geochemical information) and it concurrently carries out targeted thematic geoscience research to understand geological processes and indicators of these processes. It then works to integrate the results of these investigations to yield a comprehensive and unified understanding of geological features and processes at large spatial scales.



Credit: Marilyn Garnett / Airscapes.ca

Geological features, such as mountain belts and mineral deposits, result from many dynamic processes. Framework geoscience integrates concepts and data through space and time to better understand these features and the processes that create them.

Some steps towards framework geoscience are already underway in individual jurisdictions. For example, as noted earlier, the Geological Survey of Canada has developed considerable expertise related to geophysics and geochemistry, and carries out thematic research of national interest by drawing on data collected either by its own staff or by provinces/territories or industry. Some provinces have also collected detailed information on regional geology and have begun conducting thematic studies within their own jurisdictions. As the scale and detail of mapping and the availability of thematic data layers vary significantly across Canada, considerable effort is necessary to complete the adoption of this new scientific paradigm. For example, along many provincial and territorial borders, datasets intersect at different scales and/or in different formats, requiring work to ensure seamless knowledge across these jurisdictional boundaries.

ACTIONS

A comprehensive, four-dimensional geoscience framework for Canada is a long-term goal. To get there, Canada's GSOs will use their expertise and connections to strategically target gaps in the framework and work together to enhance inter-jurisdictional collaboration under existing national geoscience programs, such as GEM-GeoNorth and the Targeted Geoscience Initiative (TGI).[6] This approach will vary based on scale, vintage, format and availability of data but may focus on foundational mapping to fill gaps in geological, geophysical, and geochemical coverage, and targeted studies based on regional resource endowment and emerging opportunities. GSOs will collaborate to develop shared methodologies for producing geological compilations at national and regional scales, building on existing efforts such as the Atlas 2027[7] and Canada-3D.[8] As specific actions are planned and implemented, jurisdictions will leverage Indigenous engagement activities already taking place at federal/provincial/territorial levels to better understand the geoscience research priorities of Indigenous Peoples across Canada.

6 **Geo-mapping for Energy and Minerals** (most recently renewed as GEM-GeoNorth) and the **Targeted Geoscience Initiative** (TGI) are long-standing mineral geoscience programs run by the Geological Survey of Canada that include collaboration with provinces and territories, and were most recently renewed in 2020 for a total of $135 million over seven years. GEM-GeoNorth provides geoscientific knowledge of the immense untapped resources in Canada's North and informs mineral resource opportunities in the context of a changing climate. TGI provides next-generation geological knowledge and innovative techniques to target deeply buried mineral deposits. Both programs align with the Geological Survey of Canada's responsibility under the IGA and the PGS to deliver broad-scale geoscience for the Canadian landmass, and provide opportunities for federal/provincial/territorial collaboration on geoscience under the PGS.

7 The **Atlas 2027** project, by the Canadian Society of Petroleum Geologists and partners, including GSOs, is designed to give geologists a comprehensive perspective on all aspects of the vast Western Canada Sedimentary Basin, which is renowned for its mineral and energy wealth. It aims to update a previous Atlas (developed in 1994) by 2027.

8 The **Canada-3D** project, led by the Geological Survey of Canada in partnership with the rest of the NGSC, aims to develop an ongoing national synthesis of the geology of Canada and deliver it via an online portal. This synthesis can be used by government, industry, and others to inform various geoscience activities, with applications including but not limited to nuclear waste management, national water modelling, and management of minerals, hazards and energy. Phase 1 of this online portal is expected to be publicly launched in the near future.

ADVANCING MINERAL AND ENERGY POTENTIAL MODELLING

Mineral and energy potential modelling is essential for understanding economic opportunities (and avoiding missed opportunities), understanding future exploration and development trends, developing emerging commodities inventories (e.g., critical minerals and non-carbon energy sources such as geothermal), encouraging investment where natural resource assets are underused, and providing factual information to public and Indigenous governments for supporting land and water management choices in a time of increasing competing interests.

While Canadian jurisdictions already use geoscience data to produce mineral and energy potential models and associated maps, challenges remain. For example, when a jurisdiction creates a new potential map, it must use the best (usually newest) available data to keep this map from quickly becoming obsolete. It can be logistically challenging to access data from external sources (including from other jurisdictions) as many data are not published immediately and some that are older but useful have not been digitized. Additionally, decision-makers often require information from multiple sources to make sound, evidence-based choices. This also represents a challenge. Comparing different maps — even when they overlap the same region — can be a difficult or impossible task as existing potential maps are commonly fragmented and of different vintages, and produced using different methods. This lack of consistency also hinders the development of national estimates of mineral and energy potential.

This means that Canadian investment is needed to develop updated and coordinated mineral and energy potential models, from regional to national scales. The timing is right since the emergence of geoscientific concepts, such as ore systems models, combined with recent developments in artificial intelligence technologies, currently stands to revolutionize mineral and energy potential modelling.

ACTIONS

With their vast collections of geoscience data, GSOs are well positioned to coordinate the next generation of mineral and energy potential modelling that can enable sound land use planning and attract investment in emerging geo-resource opportunities.

As a first step, the GSOs will examine current best practices for mineral and energy potential modelling across jurisdictions and at the international level. When creating new models and associated maps, GSOs will seek out opportunities for collaboration and data-sharing between jurisdictions.

FACILITATING ACCESS TO ONLINE DATA

"Easy access to new geoscience data and knowledge sustains the junior sector."

—Collaborative Public Geoscience Report for EMMC, 2017

Geoscience data and knowledge can only have meaningful impacts if they are accessible (i.e., available, discoverable and understandable) to end users.

On a global scale, the last two decades have seen the development and adoption of open and international standards and web services to distribute and exchange geospatial data over interoperable web applications. For geoscience, a major driver is the recent proliferation of machine learning in predictive modelling, including applications in mineral resource assessments for exploration and land use decisions.

Outside of Canada, competing nations are coordinating their approaches for data collection and management to enhance their global positions. Many nations offer interactive maps with geoscience data for the entire landmass. Others have taken this a step further to create expansive geoscience portals with centralized datasets and online services. Two examples are geo.fi by the Geological Survey of Finland and the Australia Geoscience Information Network by Australia's federal, state and territorial geological surveys.

Accessible information produced by Canadian GSOs has contributed to revealing the country's natural resource wealth and reducing investment risk. As a result, jurisdictions across Canada have been recognized for world-class geological data, including by the Fraser Institute Annual Surveys of Mining Companies.

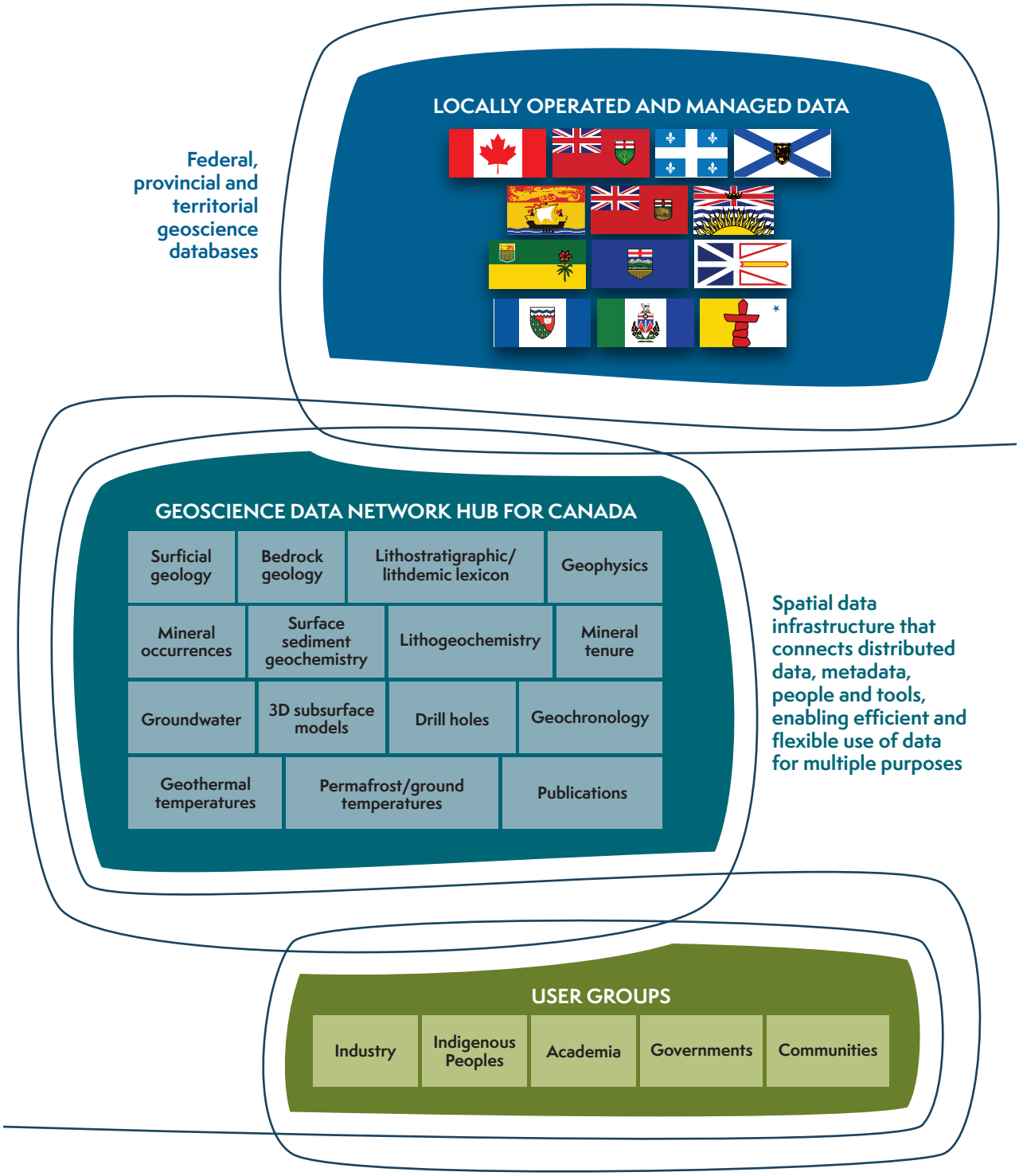
Despite this, current approaches to collecting, archiving and presenting geoscience data in Canada are generally not coordinated, standardized or seamless from one jurisdiction to another, which requires users to seek out data from multiple sources and in various formats. Data may be disregarded entirely if data compatibility impedes governments, stakeholders, Indigenous Peoples and other decision-makers from easily integrating information. As other competing nations rapidly coordinate their data and its accessibility, Canada must catch up to them to retain or capture investment market share.

ACTIONS

All GSOs have identified this priority area as compatible with their mandates and essential to supporting other priority areas of the PGS and crucial to keeping up with global competitors. Detailed planning for a cross-jurisdictional coordinated approach to online delivery, discoverability and access to consistent, analysis-ready data is currently taking place under the NGSC Information and Data Management Working Group. This effort provides the foundation for adopting data standards and promoting compatibility, advancing geoscience data networks, developing data sharing and management best practices, and coordinating the interoperable digital transformation of Canadian geoscience data. Some funding for an external contractor to assess the state of readiness of jurisdictional data has already been provided by the Geological Survey of Canada's TGI.

Building on this work, GSOs plan to coordinate the development of common data standards and build data source transformation connections between jurisdiction-managed data assets. This work will act as a foundation toward the eventual development of an online portal or a similar tool that will connect existing data sources owned and managed by jurisdictions to improve accessibility and interoperability for end-users.

HOW PUBLIC GEOSCIENCE DATA FROM MULTIPLE JURISDICTIONS COULD CONNECT THROUGH AN ONLINE PORTAL

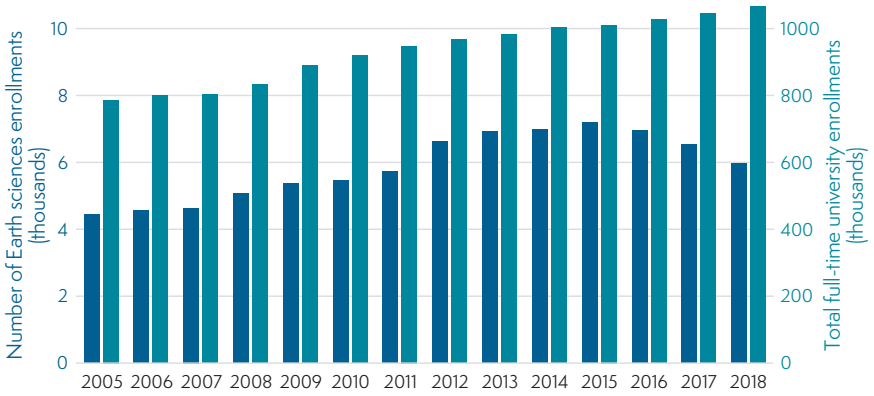


SUPPORTING THE TRAINING OF NEXT GENERATION GEOSCIENTISTS

One of Canada's competitive advantages in terms of global geo-resources is the strong and experienced geoscience community working in industry, GSOs, academia and other organizations across the country. The geo-resource industry has strongly indicated that a pool of highly skilled personnel is critical to its success. This is currently at risk because many experienced and skilled geoscience workers are nearing retirement, and there is an increasing shortage of new skilled workers at all stages of the value chain resulting from an enrolment decline in post-secondary Earth sciences programs. In parallel, an increased demand for geo-resources is also anticipated as Canada and the rest of the world transition to a green economy, with more focus on securing domestic supplies of critical minerals and metals that require innovation for discovery, production and use. This in turn will likely create a growing demand for geoscientists. Furthermore, the geo-resource industry is becoming more technical and technology-dependent, so the geoscience workforce required to support the sector, both now and into the future, will not be the same as the workforce of the past. The next generation of geoscientists will need to be equipped with the appropriate skills and training to be effective.

Almost **25%** of Canada's mineral exploration workforce is **over age 65**.

University enrollment is steadily increasing in Canada, but enrollment in Earth sciences has been declining since 2015.



Pie chart data provided by the Mining Industry Human Resources Report: Canadian Mineral Exploration HR Outlook 2020

Bar graph data provided by the Canadian Council of Chairs of Earth Science Departments' Enrolment Report for 2019, and by Statistics Canada's Table 37-10-0011-01: Postsecondary enrolments, by field of study, registration status, program type, credential type and gender.

GSOs in Canada have a long history of training post-secondary students in the Earth sciences and equipping them with practical skills to be successful. This can take the form of hiring and training summer students, supporting graduate and post-doctoral researchers, and collaborating with post-secondary institutions on projects. Universities in Canada have noted that their Earth sciences departments benefit strongly from collaboration with GSOs. In addition, budding geoscientists with practical experience (e.g., through working with GSOs) are highly sought-after by industry.

ACTIONS

To help meet the need for next generation geoscience supporting industry competitiveness and sustainability, GSOs aim to play an active role in attracting and training newcomers to geoscience in Canada. GSOs will continue to offer "traditional" geoscience training, such as hands-on field and laboratory-based experience, to develop mapping and analytical skills. Furthermore, as GSOs continue to modernize their own approaches to research, they will also create opportunities for students to develop next generation skill sets, including new technological skills and machine learning. When developing and sharing these opportunities, GSOs will work to be inclusive of under-represented groups (e.g., Indigenous Peoples, visible minorities, women, gender diverse individuals and LGBTQ2SI persons) in an effort to increase equity and diversity in the pool of skilled geoscience workers in Canada.

As a first concrete step towards these goals, over the next five years the NGSC plans to compile a list of hands-on training best practices and leverage ongoing work under the CMMP regarding local procurement (particularly Indigenous procurement) to inform GSO hiring practices wherever possible. The NGSC will also develop an online national repository of geoscience training opportunities with GSOs to make it easier for potential applicants to find opportunities.

ENHANCING PUBLIC LITERACY IN GEOSCIENCE

Science illiteracy among the general public is a serious issue that has become a fundamental barrier to social progress. Recent surveys have found that among Canadians almost half think science is a matter of opinion, and that approximately one-third consider themselves "science illiterate." Furthermore, there is a general decline of robust science reporting in the media in the midst of a major transformation in traditional media outlets. This allows vested interests groups and lobbyists to sway public opinion through sophisticated special interest campaigns or social media.

SCIENCE LITERACY IN CANADA

37% of Canadians consider themselves science illiterate.

43% of Canadians believe that science is a matter of opinion.

83% of Canadians want to know more about science and how it affects our world.

Data provided by the Ontario Science Centre's Science Literacy Survey, 2018

Credit: Dan Anthon

Children from a local community visit a Coast Guard ship to learn about geoscience in British Columbia.

Authorities, communities and individuals require authoritative, trusted and accessible information, including geoscience knowledge, to make informed choices that impact economic opportunities, the environment, and health and safety. For example, authorities such as regulatory boards, public governments and Indigenous governments may use public geoscience as an unbiased source of information to inform decisions related to terms and conditions for permitting exploration and development opportunities or balancing habitat and biodiversity protection with economic opportunities. While the public does not have a direct role in making these decisions, it expects authorities to make decisions for the public good based on sound, unbiased information. Broadening the target audience for public geoscience information will provide more transparency in decision-making processes and in the information on which private sector and public interest decisions are made.

Beyond ensuring transparency in decision-making, making geoscience information accessible, discoverable and comprehensible to the public provides many benefits. When presented in plain language, geoscience information can inform the public of geo-hazard risks, economic opportunities and environmental impacts or simply provide information that links geological processes to landscapes of interest. It can also help to counter negative perceptions that geoscience is used exclusively to support the mining and energy industries, or that these industries have solely negative impacts (e.g., on Indigenous Peoples and the environment). Accurately portraying geoscience is particularly important now since new sources of critical minerals and related jobs created (directly and indirectly) will contribute to the green economy and Canada's recovery from the COVID-19 pandemic that started in early 2020.

ACTIONS

To increase geoscience interest, understanding and support among the public, the NGSC will work with member GSOs to:

- Enhance their public engagement activities
- Build partnerships with existing science outreach organizations for gaining an understanding of their lessons learned
- Identify opportunities for complementary work and/or collaboration

GSOs will continue to develop plain-language materials about geoscience projects for communities on a case-by-case basis — supporting each other when appropriate and sharing capacity on joint projects. Jurisdictions will work with Indigenous Peoples and communities to develop best practices for geoscience engagement and to build local capacity in using geoscience information. GSOs will explore opportunities to coordinate public geoscience outreach, to share and develop best practices, and to develop innovative new ways to connect, including virtual solutions.

NEXT STEPS: FROM STRATEGY TO ACTION

The PGS is an evergreen framework intended to guide public geoscience in Canada for years to come. As a next step, and in compliance with PGS principles, the NGSC will:

- Initiate actions described above for each priority area
- Identify further opportunities to advance the five priority areas, in collaboration with Indigenous Peoples where possible
- Explore potential funding options
- Develop key performance indicators

This will be carried out through expert working groups that will be established for each priority area with GSO representation from across Canada.

The NGSC will also use the renewal of the IGA as a means to further facilitate and underscore PGS implementation through collaborative federal/provincial/territorial effort, recognizing the unique roles and mandates of Canada's GSOs.

The NGSC will include PGS updates and proposed next steps in its regular reporting schedule to the Intergovernmental Working Group on the Mineral Industry and to Mines Ministers at the annual EMMC.

ANNEX — LIST OF ACRONYMS

CMMP: Canadian Minerals and Metals Plan

EMMC: Energy and Mines Ministers' Conference

GEM or GEM-GeoNorth: Geo-mapping for Energy and Minerals program

GSO: Geological Survey Organization

IGA: Intergovernmental Geoscience Accord

NGSC: National Geological Surveys Committee

PGS: Pan-Canadian Geoscience Strategy

TGI: Targeted Geoscience Initiative