Geoscience and Canada

Understanding our Earth: The vital role of Canada's geoscientists

CFES FCST
Canadian Federation of Earth Sciences | Fédération canadienne des sciences de la Terre

GEOSCIENTISTS GÉOSCIENTIFIQUES CANADA

This booklet explores the vital contributions of geoscientists to Canadian society.

It has been prepared for a wide audience, including the public, decision-makers, geoscientists, and all those who share an interest in Canada's land and resources, by

Geoscientists Canada (who represents the regulatory bodies that register and regulate Canada's geoscience professionals nationally and internationally)

and

Canadian Federation of Earth Scientists (the umbrella federation that represents earth science societies and associations across Canada).

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FOREWORD

Geoscience is the study of the structure and history of our planet and its natural systems. Human life and progress are underpinned by materials provided by the Earth and geoscience provides us with the knowledge and understanding to find resources and utilise the Earth sustainably, for the benefit of current and future generations.

The Earth is changing through natural processes and human actions. Geoscientists recognise, document, and interpret these processes and changes, particularly the gradual changes that take place over thousands to millions of years, and they help society find and manage Earth's resources for the present and future.

Canada is a resource-rich nation and knowledge of the land and its resources is fundamental to the nation's ability to provide environmentally sustainable services and resources for its people. Developing supplies of water, energy, minerals, and food are all critically dependent on the knowledge and skills of geoscientists. They have the expertise to determine where to construct important infrastructure, including buildings, roads, dams, and tunnels; how to keep people safe from natural hazards, such as earthquakes, landslides, and coastal erosion; how to deal with environmental problems, such as pollution; and how to help provide safe sustainable water to Canadians.

The quality of human life on Earth has changed immensely with the development of our natural resources. Fuel (mainly natural gas, oil, and coal) keeps billions of us warm, provides us with clean, hot (and cold) water, and helps us grow and transport our food and families. Plastics (petrochemicals) are needed in manufacturing, telecommunications, and construction. Metals are critical for vehicles, buildings, infrastructure, electronics, and equipment – including safe surgical instruments in our hospitals and virtually all of the devices that allow our modern technology to function. Geoscientists examine the Earth to find, and safely extract, our needed natural resources.

The wise use of our land's resources requires informed decision-making. Governments, who are charged with making these decisions, look to scientific knowledge, and the observations and interpretations of Canada's geoscientists, to guide decision-making and policy in all areas of land and resource use.

Canada is recognised globally for the expertise, skill, and ingenuity of its geoscience community. Its educational institutions provide geoscientific training and research that is world class. Our geoscientists are highly trained experts on the cutting edge of innovation and technology in their science. The knowledge and expertise of Canadian geoscientists is and will continue to be an important factor in the success and prosperity of the nation.

R. Fensome/NRCan

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GEOSCIENTISTS SERVE **THE NEEDS OF SOCIETY**

Geoscience has important impacts on many aspects of our lives: where we live; the materials used to make our homes, electronic devices, cities, and transportation; the crops we grow; how we communicate; and the water, energy, and material resources we use. Knowledge of the Earth's composition and how it functions is critical to most aspects of our society.

DID YOU KNOW

that Canada's highest mountain, Mount Logan in southwestern Yukon, is named after a geologist?

Sir William Edmond Logan was the first director of the Geological Survey of Canada, founded in 1842 to encourage a viable Canadian mining and energy industry. It is Canada's oldest scientific institution, older than the nation itself, and employs about 600 people.

W. Notman/Wikimedia Commons

DID YOU KNOW

that rocks dating from Earth's earliest history are found in the Acasta Gneiss Complex in Canada's Northwest Territories?

They were dated at 4.03 billion years old by examining the decay of minute amounts of uranium trapped in zircon crystals.

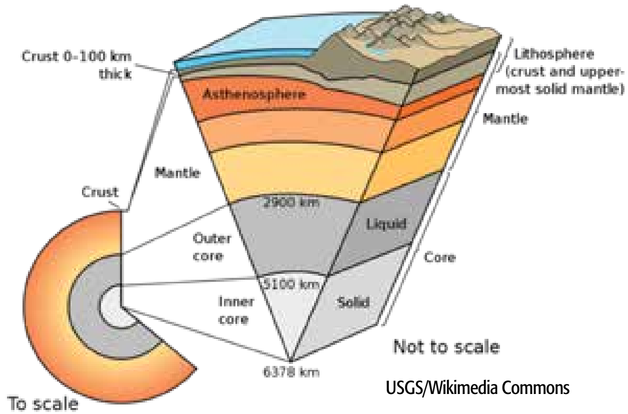
GEOSCIENTISTS ARE EXPLORERS

Geoscientists are geologists, geochemists, and geophysicists who work in the many sub-disciplines of geoscience. Examples include paleontologists, who study fossils to understand the history of life on Earth and determine geological ages; hydrogeologists, who search for and aid in managing water resources; mining and petroleum geologists, who lead the search for natural resources; geomorphologists, who study landforms and how air, water, and ice can mould the landscape; and geohazards experts, who study the causes of hazards, such as earthquakes and landslides, and are able to assess the risks involved. They explore the Earth and study the interrelated natural systems to arrive at an integrated understanding of how our planet functions.

Many geoscientists work closely with engineers to safeguard the development of our cities and towns by assessing water resources, soil stability, earthquake risk, groundwater contamination, and stone, sand and gravel (aggregate) supplies. Other geoscientists travel to remote locations around the world to collect field data and take rock, soil, water, and ice samples for study and analysis. Creating maps, interpretive sections, and three-dimensional models – based on field data and remote sensing – is a vital skill for geoscientists.

Geoscientists are not only interested in the surface but the entire Earth, which extends more than 6000 kilometres from the surface to the centre. As the deepest borehole reaches just 12 kilometres into the crust, geoscientists undertake geophysical surveys, such as seismic or gravity surveys which image the subsurface, and examine rocks presently at the surface that originally formed deep in the crust and upper mantle to interpret the structure of the Earth's interior. This information helps us to understand the formation and evolution of our home planet.

H. Falck



USGS/Wikimedia Commons

GEOSCIENTISTS WORK IN MANY WAYS TO IMPROVE OUR LIVES

Canada's geoscientists are part of a global network of geoscientists at universities, government geological surveys, research agencies, museums, consulting firms, and in industry. Geoscientists at universities provide high quality research that may be either fundamental (expanding the frontiers of geoscience knowledge), or applied (advancing the use of new knowledge in practical contexts). They are also training the next generation of researchers and workers. Geoscientists in government and industry and those working as consultants use their skills more directly to meet particular needs of society – whether they are working to improve bedrock maps, accurately delineate a mineral or energy resource, or finding a new long-term municipal water supply. Together, as an integrated community of science professionals, geoscientists work to address the needs of society by exploring and building a better understanding of the Earth.

CANADA'S RESOURCE ECONOMY

Canada celebrated 150 years as a nation in 2017 – a nation that has a modern, complex, globally integrated economy, in part through the wise use of its natural resources. The use of Canada's abundant mining and energy resources contribute strongly to our identity and to national, provincial, and territorial economies. In resource-reliant communities such as Yellowknife, Northwest Territories, or cities such as Calgary, Alberta, or Sudbury, Ontario, Canadians rely on incomes derived from employment in the natural resources sectors or in supporting industries.

THE EARTH IS CONSTANTLY CHANGING

Changes to the Earth occur at variable rates. Earthquakes and volcanic eruptions are sudden, but continents move on average at the same rate as our finger nails grow! Changes that are slow to human perception, such as the erosion of a mountain range by rivers or variations in global temperatures and precipitation levels, can fundamentally change the planet over time spans of thousands to millions of years.

Geoscientists identify, record, and interpret these changes to understand how the Earth has evolved and changed over the ages. Equipped with this information, decision-makers can develop informed policy to manage Earth's mineral, energy, and water resources in the face of a continually changing planet and to inform land-use planning to ensure environmental protection and mitigation of geological hazards, such as floods, landslides, volcanoes, and earthquakes.

DEEP TIME

The Earth's 4.6-billion-year history is recorded in the rocks – how continents and oceans have evolved and moved, the changing composition of the atmosphere, and when and where mountain ranges were formed and reshaped over billions of years.

Humans have only been present for a small fraction (<0.05%) of Earth's history. Geoscientists have a unique perspective, looking long before humans existed to observe the structure, sequence, and properties of rocks and sediments, as well as fossils, to reconstruct Earth's history.

Early geologists used the changing assemblages of fossils in rocks to determine the relative ages of the rocks. Fossils remain important for correlating rocks but for precise (or absolute) ages, geoscientists can measure the radioactive decay of elements, such as uranium, in specific minerals to determine the age of rocks formed millions, if not billions, of years ago.

H. Falck

THE CANADIAN ICE CORE ARCHIVE

An unassuming freezer at the University of Alberta in Edmonton contains tubes of ice drilled into Canadian ice caps. The ice cores are up to 200 metres long, drilled into ice sheets in the Canadian High Arctic, back as far as 1965[1].

The oldest ice is 80 000 years old. Geoscientists calculate the age of the ice by looking at its shape and texture, and inclusions such as sea salt, sulphates, trace metals, dust, sand, and even organic material like pollen. Just like the rings of a tree, these ice cores tell a story about past temperatures, past conditions, past atmosphere, recent changes, and recent pollution.

USGS/Wikimedia Commons

"We look at ice cores to see how climate has varied in the past, and what may have caused the variations. It's important for understanding the rhythm of climate change for the last 70 000 to 80 000 years and the forces that are involved in it."

Martin Sharp, Professor, Department of Earth and Atmospheric Sciences, University of Alberta

[1]Kylie Williams interview with Martin Sharp, 2017

GEOSCIENCE, **ENVIRONMENT,** AND **THE ECONOMY**

Geoscientists work across a range of disciplines to serve the needs of society. By working together with other scientists, geoscientists help to provide a complete picture of environmental issues to help decision-makers keep Canadian people, wildlife, culture, and landscapes safe and healthy, in balance with the strong economy needed to support a thriving society.

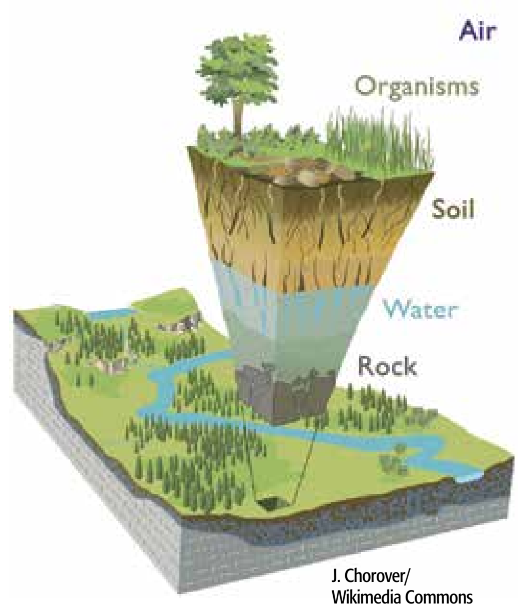
Most people think of environmental issues only in terms of their biological and chemical components. However, the interaction between humans and the environment also has an important geoscience component. Consider how processes such as weather systems, surface drainage, coastal erosion, and deposition, or even the location of natural geological features affect the environment – addressing all of these requires an understanding of the relationship between the underlying geology and ecosystems.

Glaciologists, geochemists, hydrogeologists, geomorphologists, soil scientists, and inland water scientists (limnologists) all address environmental issues. Geoscience expertise and information are required by government departments, regulatory bodies, and industry to make sound, sustainable, and informed decisions with full knowledge of potential consequences to the natural environment.

Canada's wetlands, rivers, and coasts are changing because of natural processes and accelerated change resulting from human activity. Environmental geoscientists collect data about these changes, interpret the results, and communicate the likely environmental consequences.

GEOSCIENTISTS AND THE CRITICAL ZONE

The Critical Zone is the Earth's near-surface environment where soil, rock, water, air, and living organisms interact, influencing the availability of life-sustaining resources. In the Critical Zone, a series of physical, chemical, biological, and human processes and reactions occur including recirculation of chemicals, water storage, and the movement of contaminants. Geoscientists play an important role in the understanding and management of the Critical Zone, including conducting scientific research on the role of geochemical processes, developing plans to manage water



J. Chorover/
Wikimedia Commons

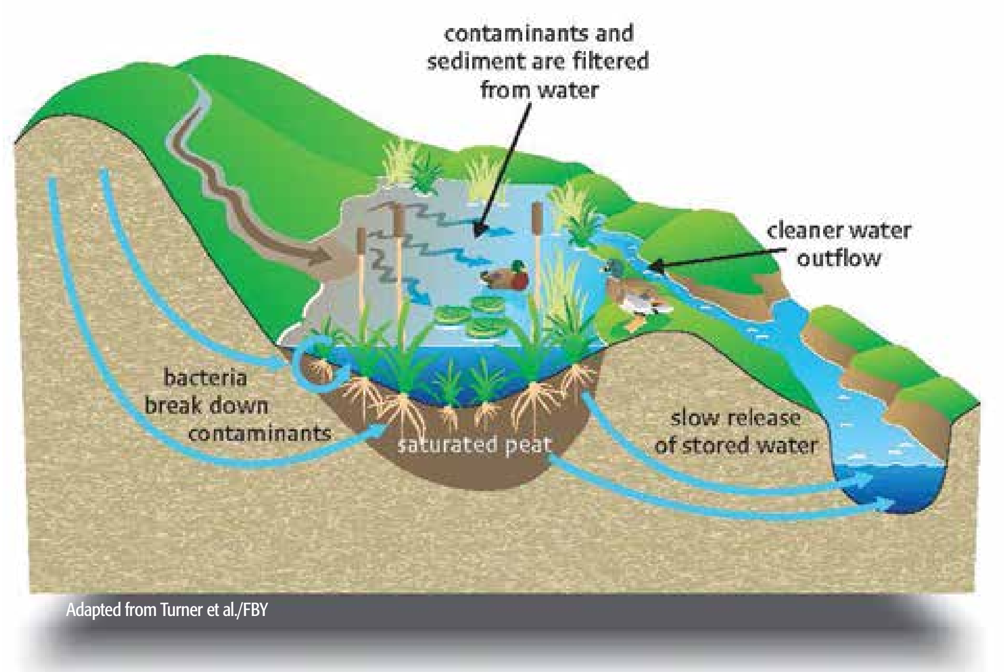
resources and mitigate groundwater pollution, and informing government policies that protect the natural cleansing capacity that this key zone provides.

CONTAMINATED SITES

Environmental geoscientists conduct environmental site assessments, remedial action planning, risk assessments, and monitoring and compliance testing of contaminated sites. They provide critical knowledge and advice to decision-makers and the public on the potential environmental impacts of a wide variety of commercial, industrial, and recreational activities in both urban and remote areas. Environmental geoscientists also have the challenging role of cleaning up sites where the soil, groundwater, and sub-surface have been contaminated by past commercial or industrial activities. Their role is to identify contaminated soil and water and ensure that it is all removed to be treated off-site, or that it is treated in situ by applying sub-surface treatment technologies to remove the contaminants.

DID YOU KNOW
that Canada's Earth observation satellites provide essential information on ocean, ice, land environments, and the atmosphere. Geoscientists interpret images captured by satellites to monitor and protect the environment, manage resources, and ensure the safety and security of Canadians.

NASA/Chris Hadfield/
Wikimedia Commons



Adapted from Turner et al./FBY

Remediation is defined as the removal of pollution or contaminants from soil, groundwater, sediment, or surface water for the protection of human health and the environment. The term **rehabilitation** is used in the aggregate and building stone sectors to describe the restoration of quarry or pit lands to their former use or condition, or another use or condition that is compatible with that of adjacent lands. The term **reclamation** is used in the mining sector to describe the restoration of soil, vegetation, and surface water features, modified during the life of a mine, to a quality, quantity, and appearance that represents pre-development conditions or the baseline environmental conditions measured and described during the beginning of mine development.

GEOTOURISM AND PROTECTING AREAS OF GEOLOGICAL SIGNIFICANCE

Geoscientists contribute to the protection, study, preservation, and display of sites and landscapes of geological significance. Many Canadian sites are recognised for their exceptional geological value and protected for educational and scientific purposes through the UNESCO World Heritage site program. These include Newfoundland's Gros Morne National Park – where remnants of ancient ocean crust are preserved at surface – as well as several internationally significant fossil sites, including the Joggins Fossil Cliffs in Nova Scotia, Mistaken Point in Newfoundland, Miguasha National Park in Quebec, and the Burgess Shale in Canadian Rocky Mountain Parks, British Columbia. Canada also participates in the UNESCO Global Geoparks program, sites that are managed with an emphasis on education, protection, and sustainable development. As of 2017, there were two designated Global Geoparks in Canada, the Stonehammer UNESCO Global Geopark in New Brunswick and Tumbler Ridge UNESCO Global Geopark in British Columbia. Preservation of these geologically interesting or significant sites can also provide an alternative economy, especially in rural areas, as millions of tourists are attracted to these strikingly beautiful geological landscapes.


T. Alt/Wikimedia Commons

R. Fensome/NRCan

CASE STUDY: MINING WASTEWATER MANAGEMENT THROUGH GENOMICS

Geoscientists are currently studying the ability of naturally occurring bacteria, present in mine wastewaters, to biodegrade and cleanse mine wastewater and materials (i.e., tailings). By studying these micro-organisms' genes and their functions (genomics), promising new adaptive and flexible solutions can be identified to better assess, monitor, and remediate mining waste.

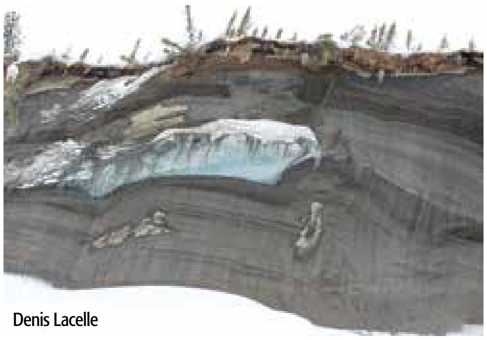
CLIMATE **CHANGE**

Geoscientists, using their understanding of climate variations throughout Earth's history, play a critical role in helping society understand present-day climate change, humanity's influences on these changes, and developing best strategies to adapt to climate change. Geoscientists will continue to serve a critical role in helping society monitor and adapt to these changes. Decision-makers need robust scientific information about the Earth's past and present climate to determine the potential range of future changes.

DID YOU KNOW

that one of the world's first projects to evaluate a commercial-scale carbon capture and storage (CCS) system was in Canada?

At Weyburn, Saskatchewan, a project was launched in 2000 and completed in 2012 to monitor and study carbon dioxide (CO_2) injection and storage in a depleted oilfield. Carbon dioxide injected into the Weyburn Oilfield enhanced oil recovery, increasing the field's oil production by an additional 10 000 barrels per day, and demonstrated the technical and economic feasibility of permanent capture and storage of carbon dioxide in geological formations.



Denis Lacelle

CLIMATE THROUGH GEOSCIENCE

Humans have only observed and recorded the climate directly using reliable measuring equipment for less than a century, but geoscientists can find evidence of dramatic past climate change on all time scales, ranging from hundreds to millions of years. Using evidence collected from lake-bottom sediments or ice tens of thousands of years old, geoscientists can reconstruct past climatic conditions to better understand the natural variability in the climate system. This background information is needed to properly assess the impact humans are having on the climate today.

PROTECTING THE MOST VULNERABLE: THE PERMAFROST PROBLEM

More than half of Canada is underlain by permafrost, a frozen subsurface layer that can range from a few metres to hundreds of metres thick. Many communities in northern Canada are built on permafrost and they are now on the front lines of climate change. Permafrost is thawing and what were previously stable landscapes have suddenly become waterlogged and unstable, and subject to slumping and failure. Geoscientists are observing these sensitive Arctic landscapes – measuring and mapping subtle changes, using satellite imagery as well as clues gained from subsurface drill cores – to help understand and inform our response to the changing landscape.

BEYOND OUR BORDERS

Canada has pledged its best efforts to understand and adapt to climate change. Geoscientists work to understand the potential effects of climate change on the land and help us adapt to its impacts. Through international collaboration, evidence gathered by Canadian geoscientists is fed into the global climate models, which help to predict future climate change and land system responses.

D. Forbes/FBY

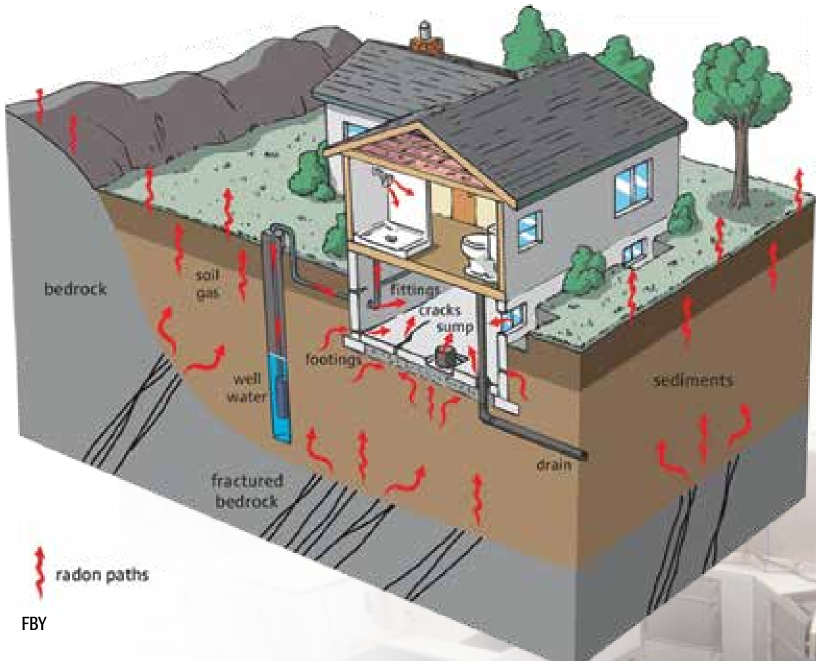
C. Bohm

GEOSCIENCE AND **PUBLIC HEALTH**

Medical geology is a multi-disciplinary field of research into the close relationship between human health and the naturally occurring elements, minerals, and organic compounds that are found in land, water, and air.

The two main goals of medical geology are to 1) quantify naturally occurring background variations of elements in the environment (including soil, water, sediments, and air) to provide a better understanding of the changes that pollution imposes, and 2) understand the risks and benefits of naturally occurring geological elements and minerals to people and organisms. For example, medical geology researchers study the occurrence of radon, which may infiltrate into homes from underlying uranium-rich rocks and glacial deposits. Others are concerned with inhalation of airborne mineral dusts, or drinking water from deep wells, which may be impacted by arsenic sulphides in the surrounding bedrock.

Advances in medical geology research rely on effective collaboration amongst earth and environmental scientists, geochemists, toxicologists, epidemiologists, and medical practitioners, including veterinarians. The success of these collaborative efforts ultimately depends on effective communication of risks and benefits to the Canadian public. The value of medical geology research in Canada is evidenced by the growing public awareness of the many influences of geology on the quality of indoor and outdoor environments.



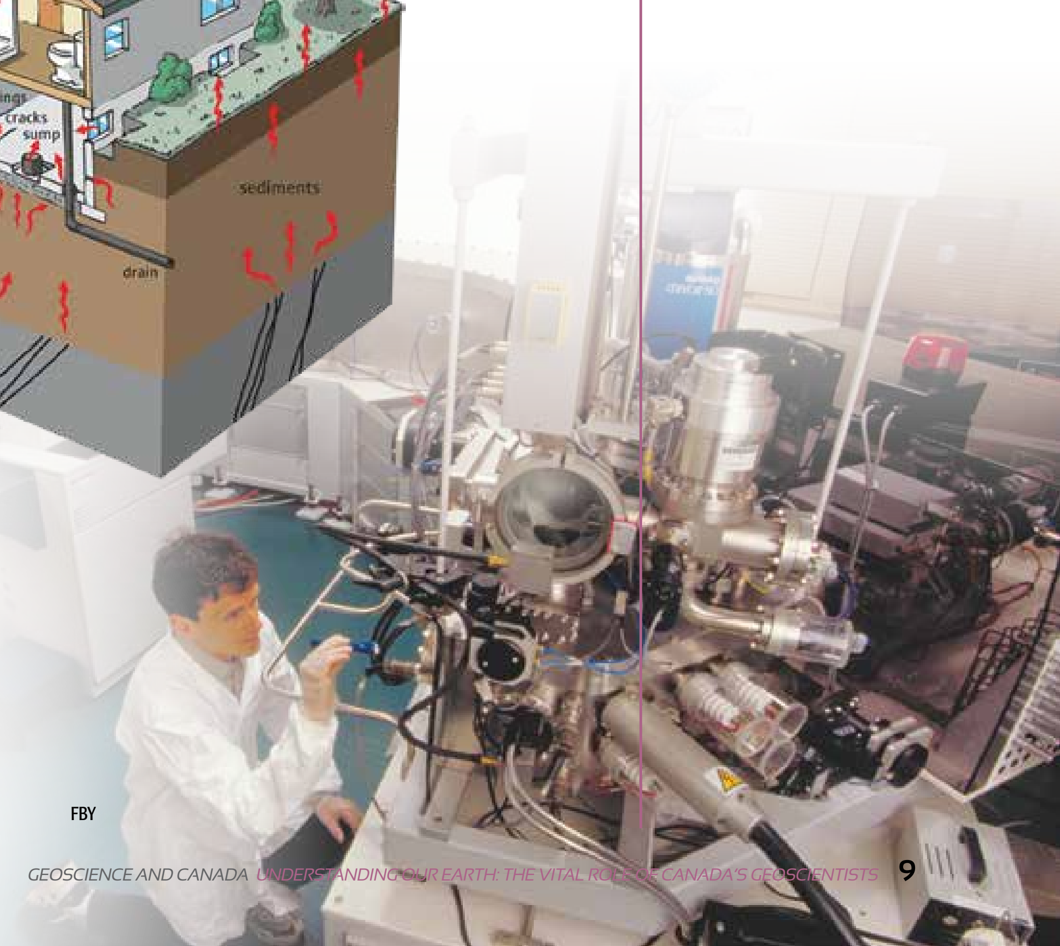
FBY

DID YOU KNOW

Some elements found naturally in geological sources, such as selenium, can be both essential and toxic to humans and animals depending on the concentration and the form of the element.

Selenium is particularly important to the health of grazing livestock. In some areas of Canada, selenium enters the food chain in high concentrations from geological sources, providing this much-needed nutrient. In other areas, selenium deficiencies occur and livestock may require dietary supplements.

For humans, selenium is an essential nutrient at low levels. However, at concentrations that are too high, selenium may result in damage to the nervous system; fatigue and irritability; and, when the exposure is long term, may cause more severe health issues.



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SAFEGUARDING CANADA'S WATER RESOURCES FOR FUTURE GENERATIONS

Water security is a growing global challenge. Poor water management can lead to potentially disastrous societal impacts ranging from deteriorating human health to food insecurity to broader environmental degradation. Geoscientists study the dynamic interplay between water, environment, landscape, subsurface sediments and rocks, and human society, to help Canadians monitor, access, and sustainably manage our precious water supplies.

DID YOU KNOW

that the oldest water on Earth was found in a Canadian mine?

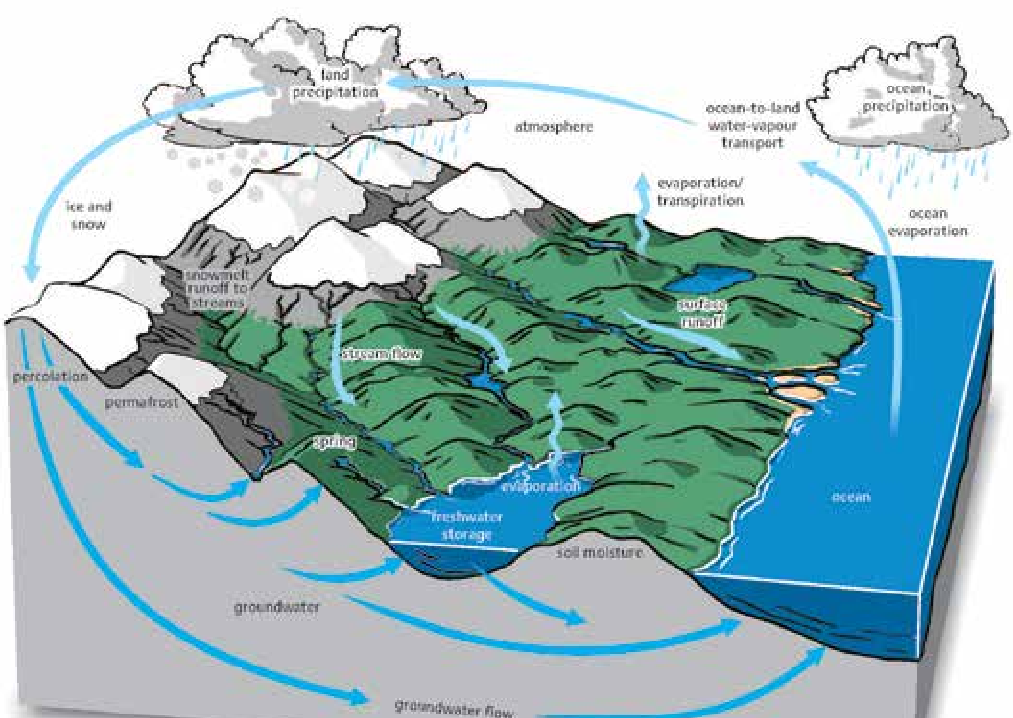
Geoscientists drilling into rock at a depth of between 2.4 and 2.9 kilometres in the Kidd Creek copper-zinc mine in Timmins, Ontario, discovered water 10 times saltier than seawater flowing through the ancient rock. The water is between 1.1 and 1.6 billion years old[2] and has been trapped in the rocks for eons, isolated from the surface. This water provides a time capsule of the Earth's environment at a very early stage of its development.

Approximately 30% of Canadians rely on groundwater as their primary source of drinking water. It is also used for agriculture, aquaculture, and is a necessary component in a wide variety of industrial activities, including manufacturing, mining, smelting and hydrocarbon production.

The Earth has abundant water, found in the oceans, in the atmosphere, on the land surface, and underneath the ground, including, in some cases, many kilometres beneath the surface. Of course, this water is not always in the right quality, quantity, form, or in the right place at the right time for human use. Understanding the location and limitations of this vital water supply is the role of hydrogeologists.

GROUNDWATER

Canada is well known for its millions of lakes. Less well known is the fact that much of the country's fresh water is stored below ground rather than on the surface. Aquifers are porous and permeable rock units that permit the storage and flow of water beneath the surface. They may be interconnected and are frequently connected to lakes, rivers, and springs on surface. Aquifers, which can be tapped by wells, can range in area from a few hectares to millions of hectares, and in thickness from a few metres to hundreds of



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2 https://agu.confex.com/agu/fm16/meetingapp.cgi/Paper/178092


M. Priddle

metres. Many communities in Canada rely on groundwater from aquifers for their supply of drinking water. Geoscientists provide critical scientific information to ensure that those groundwater resources are tested, mapped, and assessed for protection and conservation as a sustainable resource.


M. Priddle

WHO STUDIES CANADA'S WATER?

Hydrogeologists work to provide secure access to clean, sustainable water supplies. By understanding how water moves across the land surface and through the subsurface, hydrogeologists can calculate water budgets to help in evaluating the water needs of the natural environment and balance those with the water needs of society. They endeavour to understand where and how water flows in aquifers and where to seek new groundwater resources. Working with their colleagues in the various industrial sectors, hydrogeologists also help to monitor and minimise the release and migration of contaminants in groundwater, such as pesticides, fertiliser, or seepage from landfills and industrial waste. Hydrogeologists translate this information into knowledge for effective and wise groundwater governance by a wide range of decision-makers.

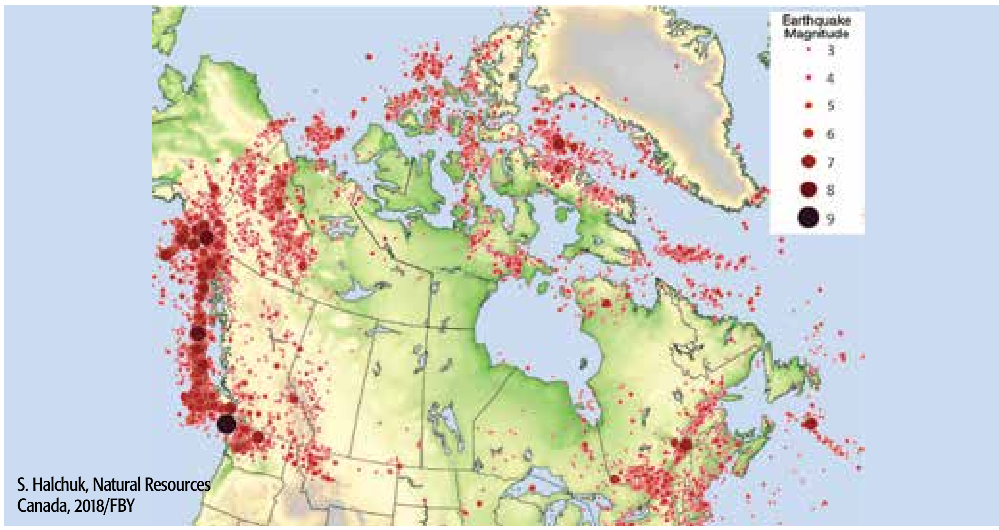
FROZEN WATER

About 70% of the world's fresh water is frozen, tied up and inaccessible in glaciers, permanent snow, ground ice, and permafrost. Glaciologists study snow and ice and their physical properties – sampling, monitoring, and using remote sensing techniques to observe how ice sheets, shelves, fields, and ice caps, as well as alpine and arctic glaciers and snow, move and change under different conditions. The ice trapped in glaciers has preserved comprehensive records of changes in the climate over time, particularly the variability of atmospheric pollution, allowing climate scientists to understand past changes in climate.


A.Morgan/FBY

GEOHAZARDS, ENGINEERING, AND INFRASTRUCTURE

Earthquakes, landslides, floods, tsunamis, and volcanoes cost lives and billions of dollars. Geoscientists seek to understand the processes responsible for these geohazards to assist in disaster preparedness. Geoscientists also provide critical knowledge about the land and availability of local earth materials to ensure the wise location and safe development of infrastructure.



S. Halchuk, Natural Resources Canada, 2018/FBY

DID YOU KNOW
that a layer of clay can be 'sensitive'?

Underlying parts of Ontario and Quebec is a 15 to 100 metre-thick layer of clay deposited in the ancient Champlain Sea. Geoscientists have studied this clay and determined that because of its distinctive physical and chemical characteristics, it is 'sensitive' to river erosion, earthquakes, and human disturbance, and subject to sudden failure, which can cause catastrophic landslides. More than 250 collapses related to this clay have been identified; the most catastrophic was in 1908 at Notre-Dame-de-la-Salette, Quebec, where 33 lives were lost.

The Earth is a dynamic planet and we must understand the behaviour of the ground beneath our feet in order to live and build on it safely. Geoscientists help ensure the safety of communities by studying the Earth processes linked to natural hazards. Mapping, remote sensing, geophysical surveying, and modelling are all used to identify areas susceptible to natural hazards. Findings are shared with engineers, policy-makers, public safety and emergency responders, and others to prepare and build safer communities.

Geoscientists, particularly engineering geologists and geomorphologists, study both the structure of the earth where infrastructure is built and the earth materials from which it is constructed. These geoscientists collect the data and build an understanding of the Earth and its materials that engineers and others rely upon to build a wide variety of infrastructure (including roads and railways; mines, quarries, and petroleum wells; dams, pipelines, bridges, and buildings) safely and with minimal public and financial risk.

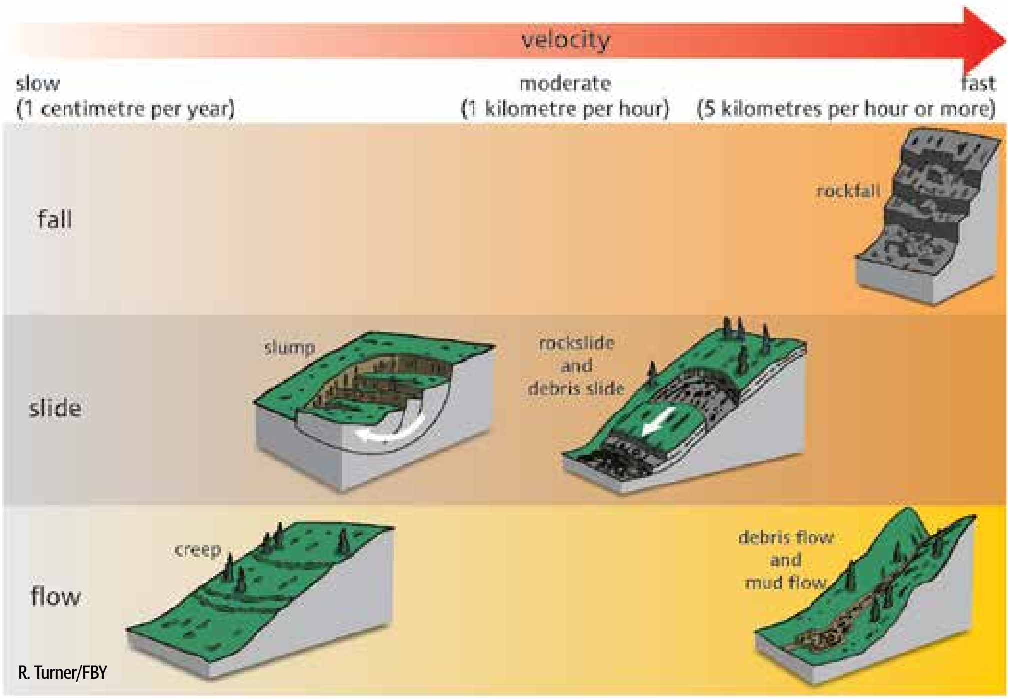

R. Couture, Natural Resources Canada

LIVING IN EARTHQUAKE ZONES

Geoscientists, including seismologists, geophysicists, and structural geologists, continuously assess the seismic hazards for all parts of Canada. They are developing a better understanding of earthquakes and the hazards they pose, but are still a long way from accurately predicting exactly when and where an earthquake will strike. Although earthquakes can happen almost anywhere, the west coast of Canada is particularly vulnerable because of the movement along faults related to the ongoing collision of the Pacific and North American tectonic plates. Geological evidence suggests that strain between these plates is building again. Geoscientists continuously monitor earth movements in this region and gather evidence of the historical movements on these faults and their impacts. Structural engineers and construction experts are using this information to update building codes and ensure that structures are built safely and are sufficiently robust to withstand the potentially strong earthquakes that strike this coast every 200 to 850 years.

where erosion is most likely to occur, how earth material will be transported, and predict where it is most likely to be re-deposited. This work is another example of the contributions geoscientists make towards ensuring resilience of our infrastructure and communities.

Sudden events, such as tornadoes, hurricanes, and intense rainfalls or snowfalls, as well as major flooding may pose a threat to life and infrastructure. Geoscientists measure the impact of past events, understand the processes by which these events can affect the land and provide advice on where to build and what potential impacts need to be mitigated when doing so, helping to protect lives and property.



R. Turner/FBY

ROCKS IN MOTION

In the Canadian Cordillera, steep terrain coupled with abundant precipitation results in many rock and soil slides and rock and debris flows. These pose a hazard to people, infrastructure, and homes downslope. Geoscientists study slopes susceptible to such hazards to determine how and under what conditions they might fail and to predict the location and severity of the hazard. Working with engineers, they develop measures to mitigate the risk and working with municipalities, they inform land-use planning decisions.

EROSION, DEPOSITION, AND COASTLINE LOSS

Sudden weather events or the steady daily action of water, wind, and freeze/thaw over prolonged periods of time can cause significant erosion, movement, and the re-depositing of rocks and soils. Geoscientists study the behaviour of both sudden and gradual natural earth systems and predict

Rising sea level worldwide is causing added coastal erosion and coastline loss. This is a particular concern along low-lying coastal areas such as Canada's Arctic and Atlantic shorelines. The loss of permafrost in the North is an added concern because land stability is suddenly reduced and increased amounts of sediment and water are being released into the ocean over huge areas, adding to erosion and deposition, and overall sea-level rise. Geoscientists are examining evidence of past erosion and monitoring current erosion in order to best advise coastline communities.

DID YOU KNOW

that geoscientists are keeping their eyes on the coastline on which the northern community of Tuktoyaktuk, Northwest Territories, is built?

It is rapidly eroding as a result of a combination of sea-level rise and thawing of permafrost. Some buildings have already been lost and the community may eventually have to move to escape the sea's encroachment.

RED RIVER FLOOD MANAGEMENT, MANITOBA

The Red River in Manitoba flows through a shallow valley surrounded by a relatively flat clay plain. When river levels rise during the spring thaw, floodwater can spread some 40 kilometres across the surrounding plain. This has resulted in the flooding of numerous rural communities and, in some years, even the city of Winnipeg, where approximately 800 000 people reside.

Geoscientists scoured the landscape for evidence of previous floods and collected geological evidence indicative of their frequency and magnitude and the capacity of the river to contain them. This information informed a $665 million expansion of the Red River Floodway, completed in 2010, that now safely diverts floodwater around the city.[3]

[3]https://www.gov.mb.ca/flooding/fighting/floodway.html


G.R. Brooks, Natural Resources Canada/FBY

GEOSCIENTISTS ACROSS CANADA

In Canada, geoscientists are typically employed by

- mineral exploration, mining, energy, and environmental companies,
- federal, provincial, and territorial governments (and increasingly local government agencies),
- consulting companies or are independent consultants,
- universities, research agencies, and museums.

GENDER AND GEOSCIENCE

Geoscience was, for many years, a male-dominated field. Ontario's former Mining Act, for example, prohibited women from working in underground mines until 1978. Today, university geology classes have reached gender parity in most of Canada, and initiatives to welcome women into geoscience and retain them as part of the workforce are well advanced.

MATTHIAS JAKOB, PH.D., P.GEO.
Principal Geoscientist at BGC Engineering Inc.

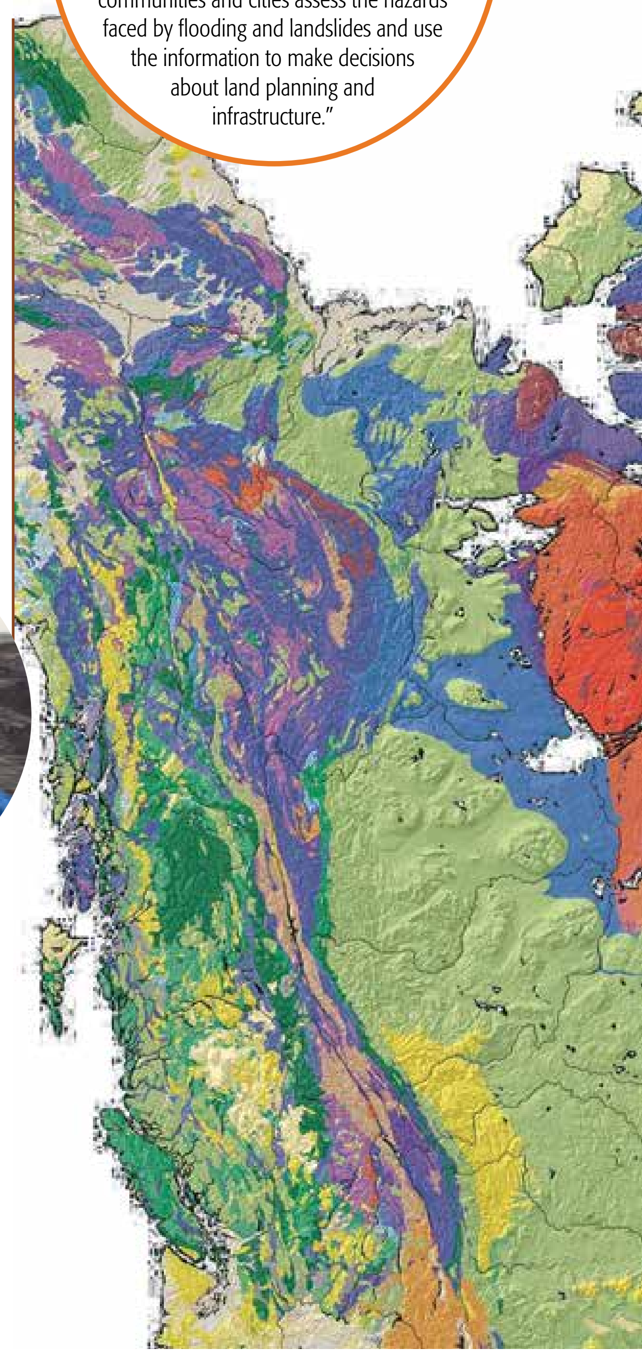
"My love of the outdoors attracted me to study geoscience and now I'm a specialist in debris flow hazard and risk analysis. My work helps communities and cities assess the hazards faced by flooding and landslides and use the information to make decisions about land planning and infrastructure."

JOANNE NELSON, M.SC.
Senior Project Geologist and Northern BC Manager at British Columbia Geological Survey

"As a field geologist, I have been mapping rocks in British Columbia for over 30 years. By understanding the nature and ages of the rocks, we can figure out where mineral deposits might be found. I interact regularly with exploration geologists, to help them understand the 'big picture' around their mineral claims."

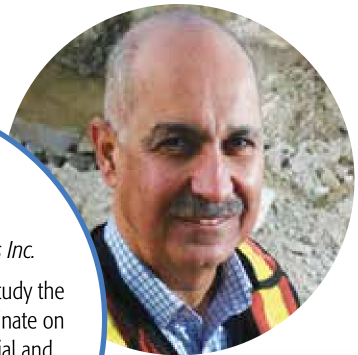
KRISTA ROSS, M.SC., P.GEO.
Senior Operations Geologist at Imperial Oil Resources

"I plan and execute drill programs, from selecting optimal well locations to regulatory applications, through the actual drilling of the wells and subsequent data collection. We are constantly working to balance our respect for the environment and the cultures of the Indigenous people, with the exploration, development, and production of new assets."



ALI RASOUL,
PH.D., E.P., P.GEO., Q.P.
President at
A&A Environmental Consultants Inc.

"As a consulting hydrogeologist, I study the impact of different types of contaminate on soil and groundwater at commercial and industrial sites, and design plans to protect groundwater resources and rehabilitate contaminated sites."



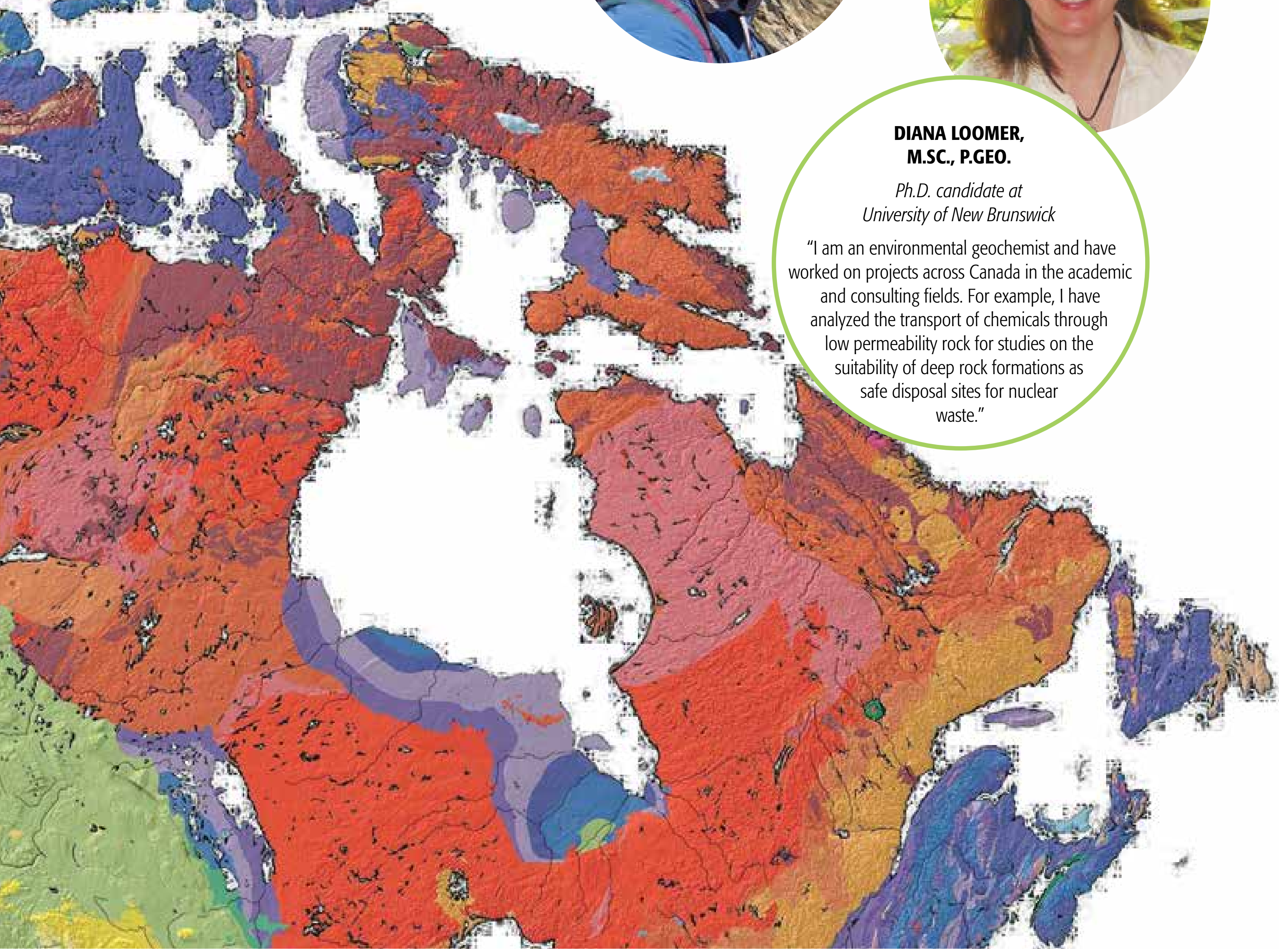
JOHN THOMPSON,
PH.D., P.GEO.
Cornell University & PetraScience
Consultants Inc.

"Discovering earth science was an accident, and joining the mining industry was initially a way to travel and see more rocks. Both became my passions – understanding the Earth and delivering vital resources in the best way possible."

DIANA LOOMER,
M.SC., P.GEO.

Ph.D. candidate at
University of New Brunswick

"I am an environmental geochemist and have worked on projects across Canada in the academic and consulting fields. For example, I have analyzed the transport of chemicals through low permeability rock for studies on the suitability of deep rock formations as safe disposal sites for nuclear waste."



GEOSCIENCE AND **MINERAL RESOURCES**

Canada is recognised as a global leader in mineral exploration and mining. Canadian geoscientists and institutions are known worldwide as experts and innovators when it comes to finding and developing new mineral resources.

DID YOU KNOW

that records of Martin Frobisher's explorations of the New World in about 1577 refer to gold (now thought to have been iron pyrite) in the area now called Baffin Island? Not long after, Samuel de Champlain's explorations in 1604 revealed the presence of copper around what is now the Bay of Fundy.

DID YOU KNOW

that Canada is consistently ranked as one of the top mineral exploration destinations in the world?

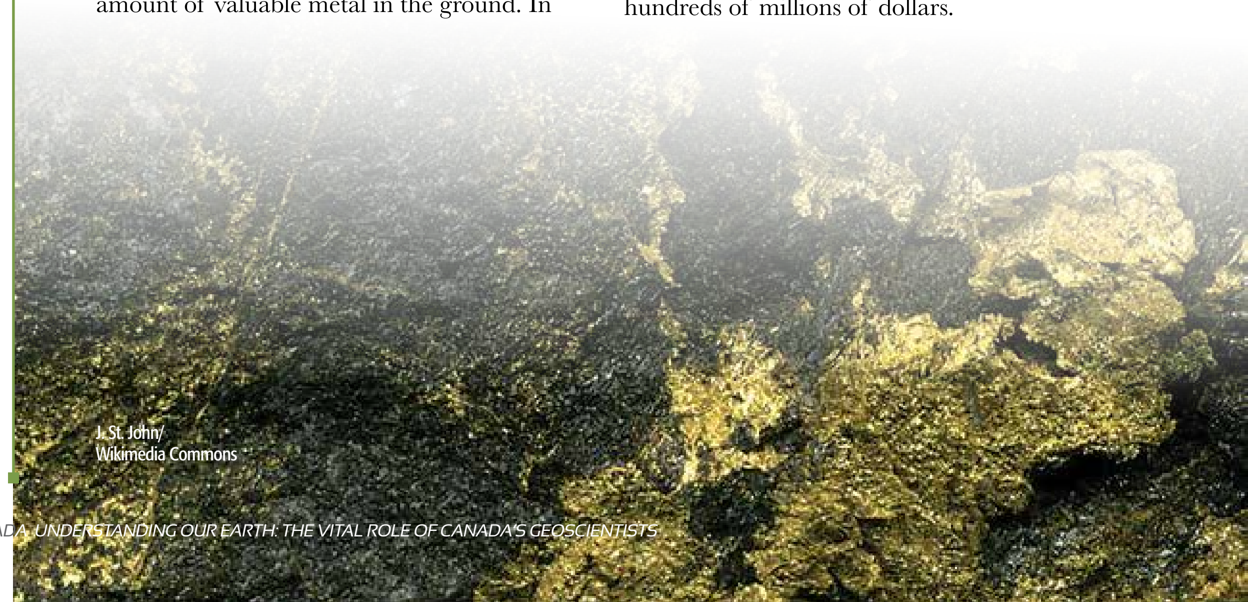
Canada has a wealth of identified deposits and the potential for new discoveries. It is politically stable and is a world leader in environmental and operating practices. Extensive publicly available geoscience information from government, research agencies, exploration companies, and prospectors is also a contributing factor to its ranking.

Canadians use mineral resources in almost every aspect of their daily lives. Mineral deposits are unevenly distributed in the crust and most of the easy-to-access, near-surface mineral and energy deposits around the world have already been found. To keep ahead of growing global demand, geoscientists are knowledgeable and innovative in both exploration and development of mineral resources.

Canada has been endowed with abundant and varied mineral resources because of its complex and long-lived geological evolution and vast landmass. It is one of the world's largest producers of minerals and metals. Canadian geoscientists have made a significant contribution to the development of the nation through discovery and development of its mineral resources, and today they work around the world on exploration projects, developing and managing mines, and sharing knowledge about mineral exploration and sustainable development.

Estimating the size, composition, and volume of a mineral deposit buried deep below the surface is challenging. Geoscientists are trained to use sophisticated geological, geophysical, and geochemical knowledge and techniques to accurately estimate the amount of valuable metal in the ground. In Canada, this information is presented to the public in documents that must conform to National Instrument 43-101, which requires that reports be prepared by a 'qualified person', who must be a registered Professional Geoscientist. The accuracy and completeness of these reports are critical as investors use them to make financial decisions worth hundreds of millions of dollars.

H. Falck



J. St. John/
Wikimedia Commons


C. Jefferson/FBY

INDUSTRIAL MINERALS

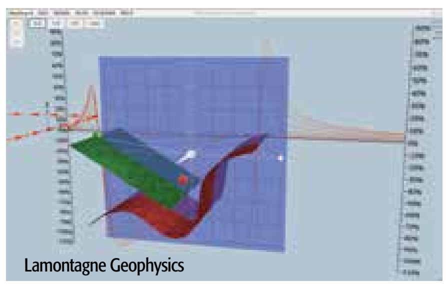
In contrast to metal commodities (like copper, zinc, or gold), industrial minerals include those rock materials used every day in countless ways in the construction industry and in chemical and manufacturing processes. Examples include aggregate for construction and road-building, building and dimension stone for construction, salt for de-icing, potash for fertiliser, limestone for ceramics and pharmaceuticals, and gypsum for wallboard. Geoscientists identify areas where industrial minerals can be found, evaluate their quality and characteristics, and help identify markets where these materials can be utilised.

EXPLORER'S TOOLS

Maps and sections: Mapping is a core skill for exploration and mining geologists. Geological maps show the distribution of rock units at the surface, as well as measurements of the orientation of beds and structures. Geologists also map underground in mines, tracing the distribution of orebodies and their associated geological characteristics. A two-dimensional slice of the subsurface between two points on a map is called a cross-section. Today, software can create a three-dimensional model of the rocks in the subsurface from data measured at surface and in drillholes.


H. Falck

Geophysics: Geophysicists collect data about the physical properties of rocks and minerals using high-tech tools and equipment, and process the data using mathematical analysis and complex modelling. By measuring properties, such as density and the magnetic, seismic, and conductive responses of rocks, they are able to detect features that may signal hidden resources deep below the surface.


Lamontagne Geophysics

Geochemistry: Traces of elements can be found in a range of earth materials and these may help to find mineral deposits. Geochemists systematically collect soil and rock samples via surface surveys or shallow drilling. They sample stream and lake sediments, water, and vegetation to detect geochemical indications of the presence of a hidden deposit.


Overburden Drilling Management Limited

Kimberlite indicator minerals (KIM) Certain specific mineral particles in surficial materials can signal the presence of kimberlites - the rock-type that typically hosts diamonds. By mapping the distribution of these KIMs, Canadian prospectors and geoscientists have found many kimberlites, some of which have been developed as diamond mines.

MINING IN CANADA[4]

- In 2016, more than 350 000 people were directly employed in mineral extraction, smelting, fabrication, and manufacturing.
- Mining is the largest private sector employer of Indigenous people in Canada.
- Mining's contribution to Canada's Gross Domestic Product (GDP) in 2016 was between 2.7% and 4.5%.
- Mining contributes around 20% to the value of Canadian goods exported each year.
- In 2016, more than half of the world's publicly listed mining companies (more than 1100 mining and junior exploration companies) were listed on Canada's stock exchanges – the Toronto Stock Exchange (TSX) and TSX Venture Exchange (TSXV).
- The mining industry is the largest customer group in Canada's transportation sector.
- Tens of billions of dollars were collected from mining companies in taxes and royalties in the last decade.

[4] http://mining.ca/sites/default/files/documents/Facts-and-Figures-2016.pdf

POWERING THE NATION THROUGH GEOSCIENCE

Canada has abundant and diverse energy resources, including crude oil, natural gas, coal, nuclear, and renewable energy, and is recognised as a global leader in energy production. Canadian geoscientists make major contributions to finding, interpreting, and developing these resources.

DID YOU KNOW
that Canada has the third largest crude oil reserves and is the second largest uranium producer in the world? Alberta has the world's largest oil sand deposit.

A LONG TRADITION

Canada is an energy powerhouse with a long history of energy production. Coal was first mined in Canada in New Brunswick in 1639. The first commercial oil well in Canada was drilled near Sarnia, Ontario, in 1858. Then, in 1947, Imperial Oil drilled "one more hole" to discover incredible volumes of crude oil near Leduc, Alberta. Uranium was first produced in Canada near Great Bear Lake, Northwest Territories, in the 1930's.


B. Hayes

Today, Calgary is a global energy hub and an energy research and development centre. It is home to more than 1400 energy businesses, including large multi-national corporations, small exploration companies, and oilfield supply and service companies. The Calgary geoscience community is one of the biggest in Canada, including several thousand experienced and highly trained petroleum geologists, geophysicists, and petrophysicists who work with data collected from within Canada and around the world.

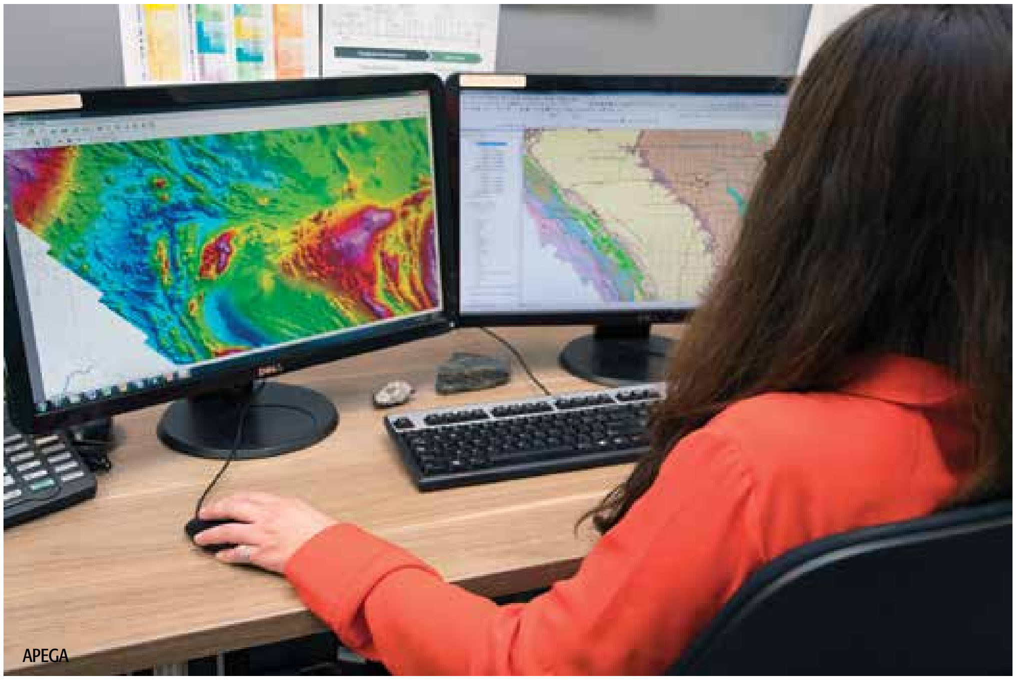
GEOSCIENTISTS IN THE PETROLEUM INDUSTRIES

Canada's 'conventional' petroleum (oil and natural gas) resources (conventional refers to those resources held in porous sedimentary rocks where the petroleum flows naturally and can be pumped to surface), are hosted in vast sedimentary basins – such as the Western Canada Sedimentary Basin that lies underneath parts of Northwest Territories,


ExxonMobil Canada Properties

British Columbia, Alberta, Saskatchewan, and Manitoba, or the more fragmented offshore Scotian Shelf and Grand Banks sedimentary basins on Canada's east coast. Geoscientists are involved in all aspects of conventional petroleum discovery and production. They identify reservoir-quality rocks and interpret the location of structural or stratigraphic traps where migrating fluids (e.g., oil) may have accumulated. For any given prospect, geoscientists advise management on the chances of success and estimate the size of the 'prize'. Once a petroleum resource is discovered, geoscientists are an integral part of the team that works to maximise production from the reservoir.


APEGA



A large portion of Canada's petroleum reserves are contained in the Athabasca oil sands of Alberta and Saskatchewan. Although known for hundreds of years, these deposits have been developed only since the mid 1960's. Geoscientists provide the appraisals of the resource from field and geophysical surveys and work in multi-disciplinary teams to efficiently and safely recover the petroleum and plan for the reclamation of the land when mining has been completed.

Development of new technologies now allows petroleum to be produced from 'unconventional' oil and natural gas resources. These sources, unlike conventional resources, are hosted by rocks of very low permeability (often shale), which do not allow the petroleum to flow freely. These resources cannot be extracted via a vertical well, but are released by hydraulic fracturing of the host rock and then recovered via horizontal wells. Geoscientists appraise the potential of sedimentary basins to host unconventional petroleum deposits, and work in multi-disciplinary teams to bring these resources into production.

URANIUM

Canada is the second largest global producer of uranium, and nuclear energy fuels about 17% of Canada's electricity generation. The richest deposits in the world are found in northern Saskatchewan. As these deposits are mostly buried under younger sedimentary rocks, geoscientists discovered them using sophisticated geological studies combined with data from geophysical surveys and shallow drill-holes. Geoscientists also play a critical role as part of government regulatory bodies that set rules for the safe exploration and mining of uranium.

DID YOU KNOW

that Canada mines two types of coal?

Thermal coal is burned to produce heat or electricity. Metallurgical coal contains fewer impurities and is a vital ingredient in the manufacture of steel. In 2016, Canadian coal production was about half thermal (mainly used domestically) and half metallurgical (mainly exported).

COAL

Canada has a long history of coal mining for energy generation and steel-making. About 9.5% of Canada's current electricity supply comes from coal, mainly in Saskatchewan, Alberta, New Brunswick, and Nova Scotia. The Government of Canada has announced the phasing out of coal-fired electricity by 2030. However, coal will continue to be used for metallurgical processes and geoscientists will be responsible for assessing the quality of coal reserves to ensure it meets the needs of end users.

[5] www.nrcan.gc.ca/energy/facts/energy-economy/20062
[6] www.capp.ca/publications-and-statistics/statistics/basic-statistics

CANADA'S ENERGY INDUSTRY[5,6]

- Canada is the sixth largest energy producer, the fifth largest net exporter, and the eighth largest consumer.
- In 2016, Canada's energy sector directly employed more than 270 000 people and indirectly supported over 600 000 jobs.
- Canada's energy sector accounts for almost 7% of the Gross Domestic Product (GDP).
- Oil and natural gas industry listings currently comprise about 10% of the Toronto Stock Exchange.
- Government revenues from energy were $12.9 billion in 2015.
- Almost $900 million was spent on energy research, development, and deployment by governments in 2015–2016.
- In 2016, Canada produced
  - 1.2 million barrels per day of conventional oil,
  - 2.4 million barrels per day of oil sands petroleum,
  - 15.2 billion cubic feet per day of natural gas.
- In 2016, capital spending in the oil and gas industry was $38 billion.

CANADA'S **NORTH**

Canada is a northern country; and much of Canada is arctic country. 'The North' includes all of Yukon, Northwest Territories, and Nunavut, and the northern areas of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, and Newfoundland and Labrador. Canada's geoscientists are particularly knowledgeable and experienced in dealing with northern issues and opportunities, including climate change, arctic science, water management, sustainable mineral and energy development, and protection of the North's unique and fragile polar environment. Geoscientific studies help us understand how northern landscapes function and contribute to Canada's assertion of sovereignty over this vast and important area.

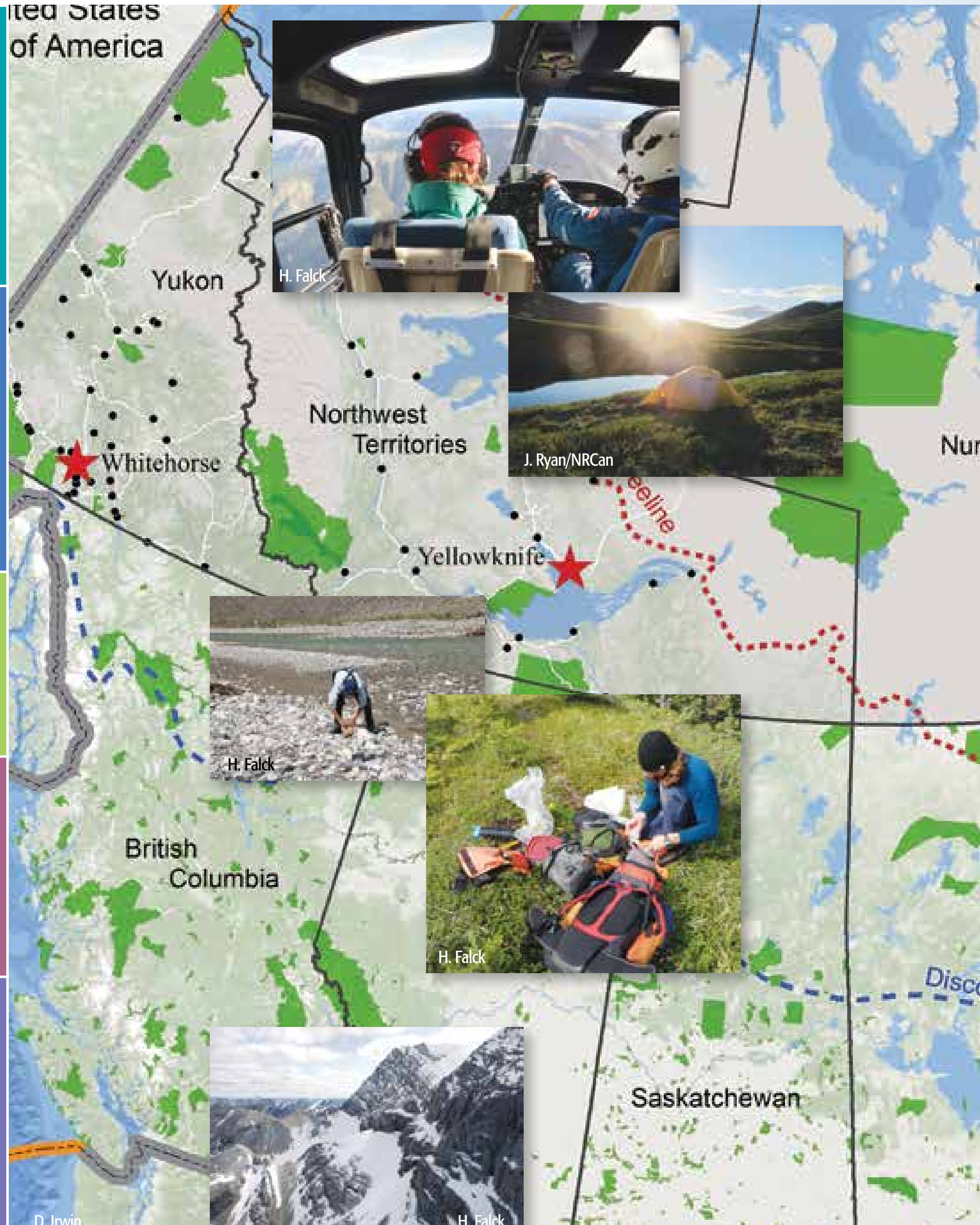
The North, defined by the southern edge of the zone of discontinuous permanently frozen ground (permafrost), is a vast area of land, lakes, sea, and ice in varied landscapes. Ice caps on Arctic islands are vestiges of the continent-covering ice age glaciers. The position of Canada's treeline, where boreal forest meets the treeless tundra, is largely controlled by the arctic front – the boundary between dry–cold arctic air and warm–moist southern air.

Canada has 162 000 km of Arctic coastline and geoscientists are responsible for mapping and establishing an understanding of surficial and bedrock geology along that coastline. They gather scientific evidence needed to manage Canada's polar continental shelf, an underwater landmass that extends from the continent, for environmental management, pollution protection, and preservation of the marine environment, as well as resource identification and development.

Building infrastructure in the North is challenging because of permafrost, a harsh climate, and vast distances between settlements and from resources. Geoscientists assess construction risks associated with building on permafrost and provide mitigation advice on northern infrastructure development.

Incorporating the traditional knowledge of Indigenous people into geoscientific studies, resources development, and environmental management decisions across the North is important. Community engagement, education, and outreach with First Nations, Inuit, and Metis benefits from geoscientists as key participants.

In the Northwest Territories, mining contributes (directly and indirectly) more than 40% of the Gross Domestic Product. The North contains iron ore, nickel, gold, and diamond mines. Canada is the third-largest diamond producer in the world, with four mines, all located in the North. Relatively under-mapped and under-explored, the North offers opportunities for new discoveries coupled with responsible development.



[1] L.J.S. TSUJI et al ARCTIC VOL. 62, NO. 4 (DECEMBER 2009) P. 458–467

The Beaufort-Mackenzie Basin hosts immense petroleum resources and significant potential for the discovery of natural gas and gas hydrates. In order to meet Canada's future energy requirements, geoscientists are needed not only to find the resources, but also to identify safe transportation corridors to bring these energy supplies from production sites to their users.

Isostatic rebound is a significant geological phenomenon of the North. While most of the world is contemplating rising sea level, much of the land mass in the North is still rising in adjustment to the loss of the weight of glaciers from the last ice age. The most rapid land uplift is at Hudson Bay, at an average of about 10 cm per decade. Geoscientists ensure adaptation to this uplift is appropriate for communities and developments in these areas.

Canada's North is home to a vast network of national parks, shown in green on the map, and protected areas. These parks seek to protect the ecosystems of outstanding natural landscapes and manage them for visitors. Many of the largest Canadian parks, including the largest, Wood Buffalo National Park, were established in the North and are being augmented by the three candidate marine protected areas. Geoscientists are integral to the parks' establishment process, helping to define their extents and interpreting the landscape for the appreciation of visitors.

As we consider adaptation to the changing modern climate, it is important to understand climate change in the past. Lush forests existed well north of the Arctic Circle 45 million years ago. Geological reconstructions of the region show a warm, ice-free environment, with high humidity. Research by geoscientists provides a basis for understanding the history of natural climate change.

The North Magnetic Pole (used for compass navigation) moves or "wanders" over time. Changes to the position of the magnetic north pole and other polar phenomena, like the aurora borealis (or northern lights) and magnetic storms, are studied by geophysicists. Magnetic storms can disrupt power grids and damage electronic infrastructure.

The Northwest Passage is one of very few sea routes through the Arctic islands, connecting the Atlantic and Pacific oceans. The melting of Arctic sea ice raises the possibility of new trade routes, energy production, and tourism, as well as the potential for geopolitical conflicts and environmental damage. Geoscientists continue to work closely with hydrographers and other specialists to chart, map, and understand both the landforms and the seafloor in our northern regions.

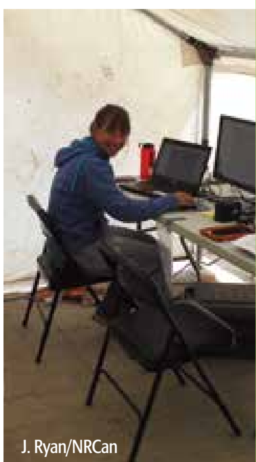

J. Ryan/NRCan

GEOSCIENCE COMMUNITY – SHARING THE KNOWLEDGE

Society needs geoscience information to make informed decisions about local and global issues. Geoscience information is critical to environmental protection, climate change adaptation, and ensuring resilient communities and infrastructure as well as the provision of mineral commodities and energy resources (both fossil fuels and renewable energy). Our well-being relies on a robust geoscience knowledge base and the expert interpretation and advice of geoscientists.

DID YOU KNOW
that there are about 15 000 geoscientists[7] in Canada?

They work across the country, in cities, remote locations, kilometres underground and in the air, offshore on rigs and ships, in the field, and in laboratories and offices.



J. Ryan/NRCan

In Canada, geoscience is a regulated profession and all geoscientists must demonstrate that they are able to apply the principles of geological science safely, effectively, and ethically, by registering as a Professional Geoscientist (P.Geo.). Geoscientists Canada is the national organization of the professional geoscientists associations in Canada's provinces and territories. It co-ordinates the development of national admission standards, and professional practice requirements to ensure that Canada is served by a skilled, versatile, reputable, and accountable geoscience profession.

Most geoscientists are also members of several technical and learned scientific societies. The Canadian Federation of Earth Sciences (CFES) is the national umbrella organization of Canada's geoscientific societies. With 13 member societies, CFES is the co-ordinated voice of Canada's earth science community, and represents its Canadian member societies in the International Union of Geological Sciences (IUGS) and at UNESCO. Geoscientists Canada in turn is the Canadian representative in the IUGS's Task Group on Global Geoscience Professionalism.

COLLABORATION

Collaboration is fundamental to science and is a cornerstone of geoscience. Regardless of the type of work a geoscientist does, collaboration and the sharing of data and knowledge across all stages of research and application is essential. This takes place by publishing scientific papers

J. Nelson


H. Falck

in peer-reviewed journals, government maps, and reports; disseminating results and findings through talks and posters at conferences; and by leading and participating in seminars, workshops, and fieldtrips.

New findings arising from basic research are optimised through applied research and capitalised upon by geoscientists in industry and in consulting. Conversely field discoveries by industry and consulting geoscientists offer important new opportunities for the commencement of new basic and applied research.

GLOBAL INTEGRATION

Geoscience is a global field, and geoscientists from around the world come to study and work in Canada. Similarly, Canadian geoscientists, renowned throughout the world, are sought to address items of a geoscience nature globally.

HOW IS GEOSCIENCE RESEARCH FUNDED?

Federal, provincial, and territorial governments in Canada provide direct funding to geoscience through their geological surveys, and the activities of geoscientists who work in other departments, such as environment, transportation, and municipal affairs. In research agencies, universities, and museums, individual geoscientists and groups of researchers often rely on grants from governments, international research funding agencies, and private industry to fund scientific research.

NSERC

In Canada, university-based geoscience research is primarily funded through the Natural Sciences and Engineering Research Council of Canada (NSERC). NSERC was created by the federal government in 1978 and has grown from a budget of $112 million to a budget of $1.1 billion, to cover the annual funding needs of science and engineering, including the earth sciences. NSERC covers funding for fundamental research by independent investigators or teams of researchers; it also funds targeted research through partnerships with other funding sources.

CLOSE TIES TO INDUSTRY

Mining and energy companies often fund and support research through university- and government-based research groups. Companies also directly support students who work on projects tied to their properties or on geoscience-related topics or challenges important to the company.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SHARING GEOSCIENCE WITH SOCIETY

Geoscientists like to share their knowledge and enthusiasm, to help society understand the impact of geoscience on our daily lives. In classrooms and public venues, geoscientists support the education of students, teachers, and the public. Classroom visits, museum programs, and field trips delivered by geoscience experts and educators provide enriching experiences that highlight the many aspects of geoscience and its application. Outreach also provides opportunities to expose young people to geoscience career opportunities. In Canada, much of this work is co-ordinated by the Canadian Geoscience Education Network.

Geoscientists play a critical role in developing the scientific literacy of the general public and serve as informed and knowledgeable voices in public discussions. Their voices promote an awareness of the role that geoscience and geoscientists play in daily life. This provides a deeper understanding of the ways in which our planet has evolved, and empowers people to make informed and evidence-based decisions.

PUBLISHING

Canadian earth science societies publish a number of scientific journals of world renown, including

- *The Canadian Mineralogist*, published by the Mineralogical Association of Canada, is one of the world's leading scholarly publications on mineral science, including mineralogy, crystallography, and petrology;
- The *Canadian Journal of Earth Sciences*, published by NRC Research Press in collaboration with the Geological Association of Canada, covers all aspects of the geosciences and attracts papers from all across Canada and from around the world;
- *Bulletin of Canadian Petroleum Geology*, published by the Canadian Society of Petroleum Geologists, has been publishing articles dealing with the broad scope of petroleum geology for more than 60 years; and
- The *Canadian Geotechnical Journal*, considered one of the best journals in the geotechnical field, began as a publication of The Canadian Geotechnical Society in 1963, and since 2010 has been published by NRC Research Press.

[7] https://www.cfes-fcst.ca/aboutcfes

GEOSCIENCE AT THE **CUTTING EDGE OF INNOVATION**

Geoscientists need more than boots and a hammer to provide the knowledge needed to discover, extract, manage, and protect Canada's resources and to provide decision-makers with the tools to make informed decisions about land use and protection from natural hazards. Using sophisticated techniques and tools, geoscientists collect gigabytes of information about the Earth to generate high-level science that helps plan for the wise use of finite resources and the social and environmental well-being of society.

DATA

A single rock sample can provide a trove of information, such as its location, density, and mineral and chemical composition, and its ability to conduct electricity, transmit a seismic wave, or to contain water or permit its flow.

Geoscientists collect data at every scale, from the composition of tiny bubbles of fluid trapped inside a single mineral crystal or pollen grain that fell to the sea floor during the age of the dinosaurs, to the dimensions of mountain ranges and continental margins. They are specialists at data collection, management, and interpretation. Historical paper archives of reports and geological maps are becoming increasingly rare. Old maps, photographs, and reports are digitised and archived on modern digital media for safekeeping and easy access by modern day geoscientists.

THE GEOSCIENTISTS' TOOLKIT

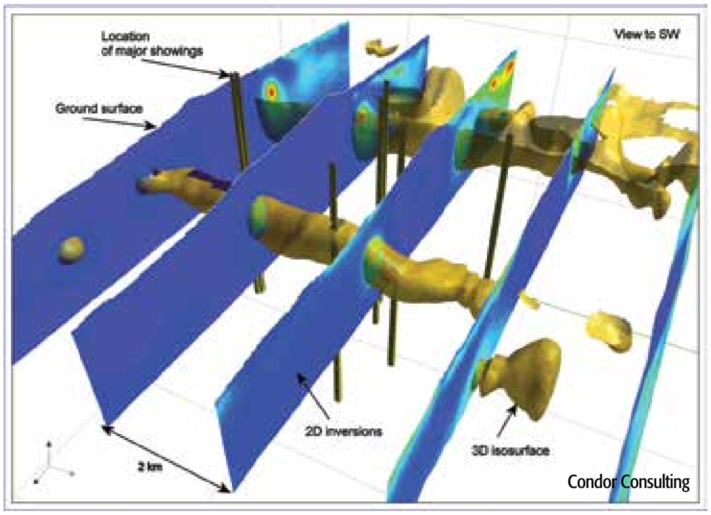
Today, geoscientists are highly skilled professionals with an extensive knowledge of rocks, strong logistical and operational skills, and the ability to work in multi-disciplinary teams. They are also able to work with the latest in modern technology and information. For example, recent breakthroughs in analytical technology allow geoscientists to quickly and accurately measure the chemical composition and mineralogy of rocks in the field, observe the chemistry within single mineral crystals, or date long-term physical changes in the Earth using isotopes produced by cosmic rays. Global Positioning Systems allow geoscientists to know precisely where they are located at all times, vastly improving their ability to record and map their observations, and Virtual Reality technologies provide exciting new ways to visualise the Earth in three dimensions (3D). Society's needs for geoscientific information are increasingly sophisticated, and the scientists who provide answers are meeting the challenge. Geoscientists are on the cutting edge of innovation when it comes to finding new ways to use many of these developing technologies.


H. Falck

CYCLICITY, FLEXIBILITY, AND NEW DEMANDS

The mining and energy industries tend to be cyclic, reflecting the economic expansion and contraction of different commodity markets over time. Notwithstanding this cyclicity, the work of geoscientists in industry continues to meet evolving needs, supporting the economy with innovative search techniques, new discoveries, and productivity improvements. Geoscientists' basic understanding of earth processes is key to their ability to meet these challenges.


Precision Geophysics



Condor Consulting

Rapidly developing technology implies increasingly sophisticated use of natural materials in our personal lives, in our industrial processes, and in environmental protection. This is particularly evident in emerging high technologies and renewable energy applications. Computers, cell phones, electric and hybrid automobiles, wind turbines, solar panels, and a wide range of personal and industrial high-technology devices require new sources of specialty metals, such as rare earth elements, cobalt, and lithium, which a few short years ago were little in demand. This, in turn, requires broadening in the requirements for geoscientific expertise and ever-evolving geoscientific skill sets needed to find and develop these resources. Geoscientists are in the forefront of changes in materials science, and in developing techniques to explore for and recover these critical materials.

3D MODELS OF THE GROUND BELOW OUR FEET

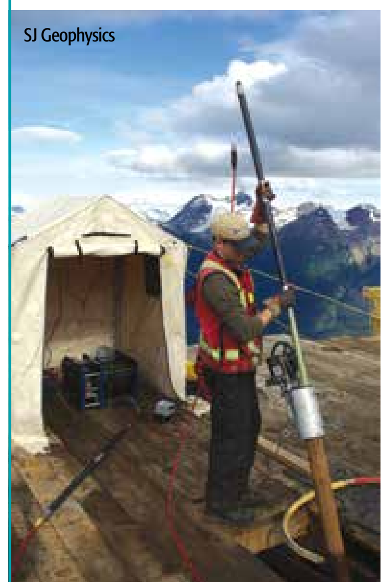
Although direct access to the subsurface is limited, geoscientists have developed remote sensing techniques that are integrated with surface observations of rocks types and structures to create 3D models of underground geology. Geophysical surveys at site, local, and regional scales can now produce precise models of the geological layers and structures in the subsurface. In the same way as an X-ray or MRI scan allows us to 'see' inside the human body, geophysical measurements coupled with knowledge of rock properties can be used to visualise the interior of the Earth. These subsurface models help geoscientists to predict the location of resources and assess the risks from natural hazards.

CANADIAN GEOSCIENTISTS IN A CHANGING WORLD

Developing our natural resources, while protecting the environment that sustains life on Earth, is key to the continued advancement and indeed survival of civilization in the 21st century. Global populations are steadily growing, and their increasing demands on the resource base are supplemented by those of emerging economies that rightfully aspire to the high living standards that are experienced in the developed world. The challenge for Earth's people is to locate and utilise the necessary natural resources, and to do it in such a way that we do not compromise the health of the planet and its environments. Living sustainably, within the limits of our resources, increasingly requires the knowledge and skills of geoscientists who understand how the Earth works and have the knowledge and skills to address the problems that are posed by increasing numbers of people and their demands on the resource base of the planet. Canadian geoscientists are in the forefront of learning and application of geoscience and will continue to play a key role in our quest to live well and sustainably on planet Earth.

D. Whalen

SJ Geophysics



TECH DEVICES

Geoscientists are at the forefront in adopting new devices as work aids and tools: drones (aerial surveys of field areas), supercomputers (data storage and modelling), wearables (GPS location devices), satellites (remote sensing and geophysics), driverless vehicles (isolated mine sites and radioactive uranium mines), virtual reality (3D modelling of petroleum reservoirs, mineral deposits, and aquifers).

NOTES

Geoscience and Canada

Understanding our Earth: The vital role of Canada's geoscientists

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