



Annual Report **2019**

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4 Chair & CEO Message

“ Our collaborative approach is generating more coordinated, relevant research projects and broadening the awareness of the fundamental value of public geoscience to everyone.

Sharing results publicly and developing understanding of Geoscience BC's research is stimulating innovation, informing investment and resource development decisions and catalyzing socio-economic opportunities in many regions of the province.



5 Geoscience BC Staff

In April 2019, Christa Pellett was promoted to Vice President, Minerals, and in May, Brady Clift joined the staff as Manager, Minerals.

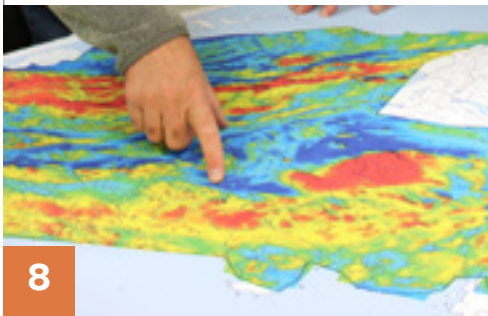


6 MINERALS



Identifying New Natural Resource Opportunities

We are helping to identify new natural resource opportunities in the province by investing in minerals projects that deliver new earth science research and baseline data for prospectors, explorers, mine developers, governments, community leaders and Indigenous groups.



8

Major New Regional Projects Announced

In 2019, we launched two new major minerals projects that are delivering new earth science information to focus the search for mineral deposits, increase discovery rates, encourage investment and promote responsible mineral development in our province.

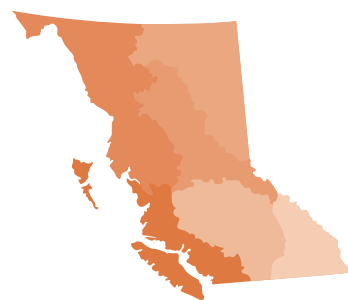
10 Preserving BC's Earth Science Legacy

In 2019, we launched a set of minerals curation projects to collect, store and share valuable earth science samples.



11 Tools for Mineral Discovery

To help find new mineral deposits across the province, we are advancing innovative new mineral exploration tools and methods.



12 OIL & GAS

We are collecting, interpreting and sharing new scientific data relating to natural gas development to guide clean, responsible energy development, minimize impacts, answer specific environmental and social questions and attract investment to BC.

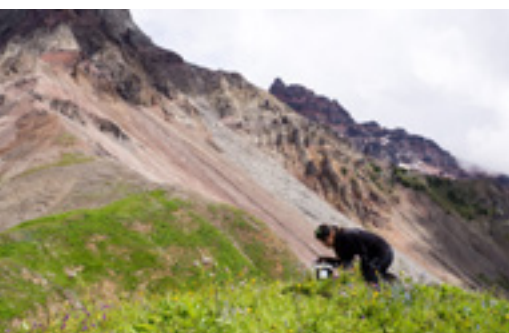
Facilitating Responsible Natural Resource Development

We have been supporting research that investigates the relationship between earthquakes and natural gas development since 2012. In 2019, we announced six new research projects to help to guide industry practice and regulation.

14 Innovation & Technology

Our research is developing new technologies and methods that improve the financial and environmental performance of natural gas development, with a focus on the Montney Play.

15 GEOTHERMAL



New Research into BC's Geothermal Potential

We are enabling clean energy in BC by providing geothermal explorers and developers, communities and decision-makers with unbiased data and information to answer questions related to the economic development of geothermal resources.

16 WATER

New Water Research Goals and Projects

In June 2019, we updated the *Geoscience BC Strategic Plan 2018–2022* to include four new water research goals to help understand water resources and use in relation to mineral and energy development in BC. We also launched three new water research projects.



18 Governance, Management & Finance

Since 2005, Geoscience BC has invested \$57.5 million in minerals, energy and water research and attracted an additional \$33.5 million in total direct and indirect partner funding and contributions, resulting in a total leveraged investment in public geoscience of \$91.0 million.

19 Board of Directors & Technical Advisory Committee

Thank you to our volunteer Board of Directors and members of the three Technical Advisory Committees who contribute more than 1,500 hours of their time every year.

20 Public Access & Data Management

In 2019, we began the process of rearranging GIS (Geographic Information Systems) data layers in the Earth Science Viewer (ESV) to better reflect the strategic focus areas set out in our *Strategic Plan 2018-2022*.

21 External Relations & Communications

In 2019, we focussed on strengthening relationships with government agencies and engaging with Indigenous groups, communities, academia, and industry to increase awareness and demonstrate the value of public geoscience.

22 2019 Geoscience BC Scholarships

We awarded \$50,000 in graduate research scholarships in 2019 to students working on projects in BC exploring each of our three research focus areas: Minerals, Energy and Water.

CHAIR & CEO MESSAGE

2019: A Year of Collaboration and New Research



Stephanie Killam
CHAIR OF THE BOARD



Gavin C. Dirom
PRESIDENT & CEO

Geoscience BC's fourteenth year delivering relevant and independent earth science research was filled with innovation and collaboration. This annual report highlights the minerals, energy and water research we undertook in 2019, and summarizes our progress implementing the *Strategic Plan 2018-2022*.

Geoscience BC completed 12 projects in 2019. Our Board of Directors committed funding to 22 new research projects recommended by our minerals, oil and gas and geothermal Technical Advisory Committees this year, increasing the number of ongoing projects to 46.

We gratefully acknowledge the steadfast support of the BC government and appreciate the bridge funding for Geoscience BC announced by Minister Michelle Mungall in May.

COLLABORATION

Our collaborative approach is generating more coordinated, relevant research projects and broadening the awareness of the fundamental value of public geoscience to everyone. Sharing results publicly and developing understanding of Geoscience BC's research is stimulating innovation, informing investment and resource development decisions, and catalyzing socio-economic opportunities in many regions of the province.

In July, we published new research data about the bedrock geology and mineral development potential of BC's Northwest Region. The project was the result of a partnership between Geoscience BC, the British Columbia Geological Survey and the University of British Columbia's Mineral Deposit Research Unit. In August, the mineral research outcomes were included in a public geoscience workshop with the Tahltan Nation as part of Geoscience BC's Collaboration Agreement with Tahltan Central Government.

Another example of widespread collaboration in 2019 was the launch of innovative research into sequestering carbon dioxide in ultramafic rocks. Geoscience BC is funding work to produce a carbon mineralization potential map for British Columbia as part of a wider research network that includes more than ten institutions and companies across Canada and beyond.

COORDINATING RESOURCES

Coordinating and leveraging resources between research teams is also at the core of a suite of new research projects investigating induced seismicity in BC's Northeast Region. Researchers involved in four new projects funded by Geoscience BC are sharing resources and collaborating to improve their collective efforts and increase the value of the research.

In June, our Board of Directors added specific goals to our water research focus area, and clarified that Geoscience BC's water research must support responsible mineral and energy resource development in the province. This has set a path for future research, including two projects that continue or expand water monitoring networks in BC's Northeast Region and, for the first time, a study looking at how science and Indigenous traditional knowledge can help us better understand changes to water flow in the region.

FRESH FACES

It was also a pleasure this year to welcome fresh faces to our staff and volunteer teams. Following Bruce Madu's departure in April, Christa Pellett was promoted to the position of Vice President, Minerals. We then welcomed Brady Clift to the team as Manager, Minerals in May and Lana Eagle joined our Board of Directors in September. Lana's experience in economic development, mineral exploration and Indigenous relations make her a valuable addition to the Board. We also continued to encourage and develop geoscience talent through our scholarship program, and we look forward to seeing their research results.

On behalf of the Board, we wish to thank our professional staff and the many dedicated volunteers from industry, governments, communities, Indigenous groups and academia for their enthusiastic and valuable contributions to Geoscience BC's success in 2019.

GEOSCIENCE BC STAFF



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Rhonda Schultz
BFA
ACCOUNTANT &
CORPORATE SECRETARY



MINERALS

Research to Support Future Global Minerals Demand

British Columbia's competitive advantages include significant deposits of important metals such as copper, gold, molybdenum, silver and zinc as well as steel-making (metallurgical) coal and industrial minerals. Global demand for many of these commodities is set to grow in the coming years to meet the demands of an electrified economy¹.

Mineral exploration and mining play a vital role in BC's economy, with exploration expenditures of \$331 million² and gross mining revenue of \$12.3³ billion in 2018.

For BC to compete and thrive in the long term, relevant information and innovative public geoscience research are needed to solve challenges, attract investment, inform decisions and support the responsible development of our mineral resources.

This section highlights our new, ongoing and completed minerals research in 2019.



➤ Photo: Farhad Bouzari

Identifying New Natural Resource Opportunities

To help identify new natural resource opportunities in the province, Geoscience BC's goals are to: continue regional-scale surveys that deliver large data sets in support of identifying prospective targets and increasing discovery rates of deposits; and undertake research that adds value to existing or ongoing data sets through ground-truthing studies, data interpretation and mining camp compilations.

Minerals in the Kootenay Boundary Region

In January, we released a new geological map compilation covering 8,000 square kilometres of historic mining areas in BC's Kootenay Boundary Regional District. The new 1:150,000 scale *Geology of the Penticton Map Sheet (East Half)* updates our understanding of the relationships between different rock types and their ages in a large area north of Greenwood between Penticton and Trail in BC's Southeast Region.

Following on from this work, Geoscience BC launched a new geological mapping and rock age determination project in June to generate new information in the prospective area near Penticton. The isotopic dating of specific rock types and updated geological mapping over select areas will generate new ore deposit models to guide mineral exploration in an area that is currently experiencing renewed interest from industry.

Another Geoscience BC mineral development potential project continued in the East Kootenays in 2019. It is helping to reconstruct the geological evolution of the rocks in the Kootenay Arc and potentially direct mineral explorers to discover hidden ore deposits.

1. documents.worldbank.org/curated/en/207371500386458722/The-Growing-Role-of-Minerals-and-Metals-for-a-Low-Carbon-Future
2. amebc.ca/wp-content/uploads/2019/09/economic-impacts_web-small-FINAL.pdf
3. pwc.com/ca/en/mining/assets/p558049-bc_mine-2018_final.pdf

2019 MINERALS PROJECTS

The 2019 Geoscience BC Minerals Summary of Activities volume includes 20 new papers on minerals research. You can view it online at www.geosciencebc.com or request a print copy.

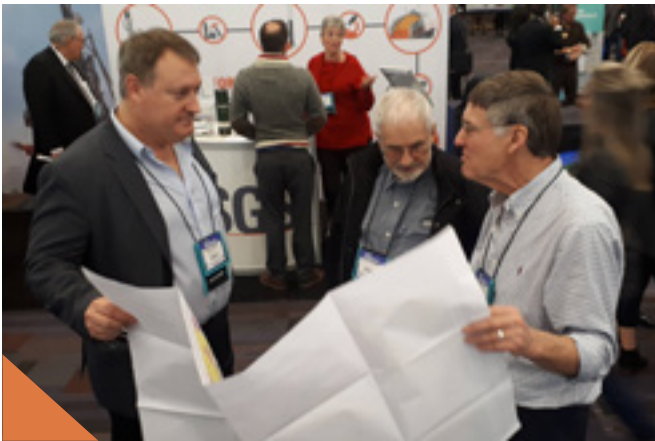
8 Completed Projects

15 Ongoing Projects

13 New Projects

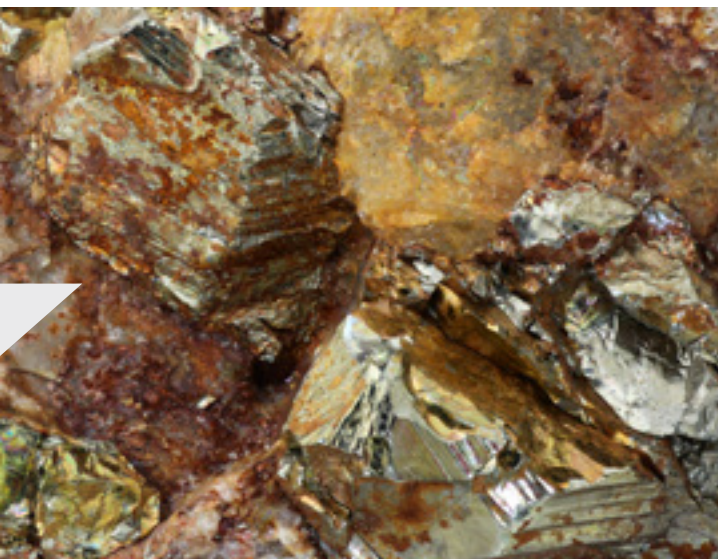
New Maps to Show Mineral Development Potential

Geoscience BC launched a new project in 2019 that is using machine learning and multivariate statistical methods to evaluate existing regional stream sediment data in BC's South Central Region, including samples analyzed as part of Geoscience BC QUEST-South project in 2011. This project will produce a series of mineral prospectivity maps for a range of mineral deposit types.



↑ New public data about mineral development potential in the Kootenays was a focus at the AME Roundup conference in January 2019. Photo: Richard Truman

↓ Photo: Jacob Moffat, Below BC



Are BC's East Kootenay Coalfields a Source of Valuable Rare Earth Elements?

Rare earth elements (REEs) are used in applications such as renewable energy generation, defense technologies and personal electronics. BC's coal deposits are potentially viable sources of REEs, and a new Geoscience BC project is characterizing and quantifying the potential REE content in select deposits.

“BC's coal deposits are potentially viable sources of rare earth elements (REE), and a new Geoscience BC project is characterizing and quantifying the potential REE content in select deposits.”



↑ This specimen of chalcopyrite and pyrite in quartz from Granisle Copper Mine resides at the Lakes District Museum Society in Burns Lake, BC, and was photographed for Below BC's Mining Heritage project in 2019. Photo: Jacob Moffat, Below BC

MINERALS

New Regional Projects

For more than ten years, Geoscience BC has undertaken regional-scale minerals surveys of large parts of the province. These deliver new earth science information that focuses the search for mineral deposits, increases discovery rates, encourages investment and promotes responsible mineral development.

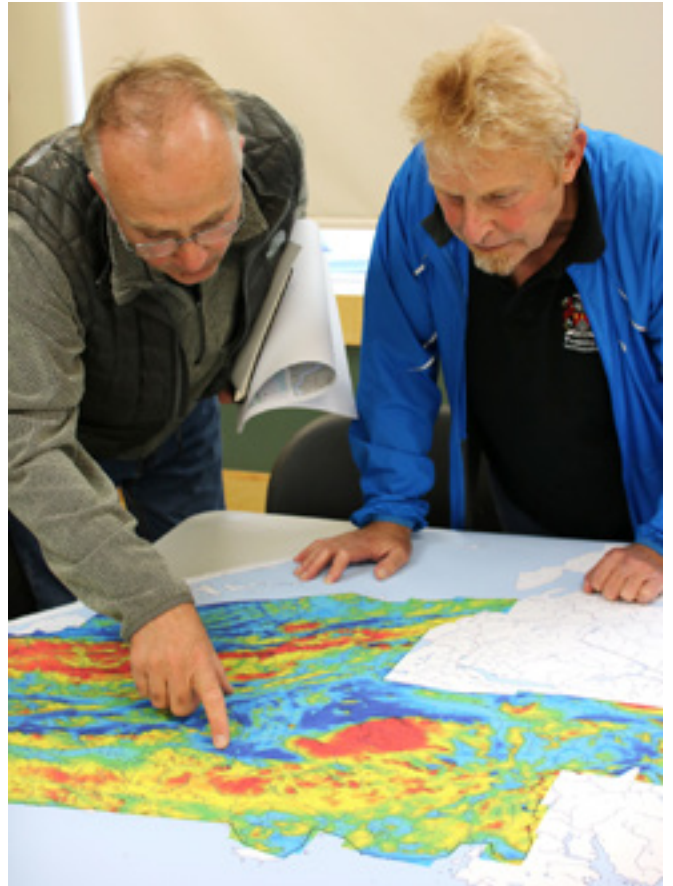
VANCOUVER ISLAND NORTH REGIONAL PROJECT

Airborne Survey Generates New Geophysical Data Over 20 percent of Vancouver Island

Announced in March, the *Vancouver Island North Regional Project* (VIN) collected new high-resolution geophysical data to help assess the geology and mineral development potential of northern Vancouver Island. The project's airborne geophysical survey was flown between July and October 2019.

Once published, the new data is expected to lead to new mineral claim staking and renewed exploration activity, and to inform discussions about mineral resource development in the area. This project abuts the Northern Vancouver Island geophysical survey released by Geoscience BC in 2012 and completes the next piece of the puzzle in an area that many consider to hold significant new mineral development potential.

The survey flew almost 27,000 line kilometres over a 6,100 square kilometre area that includes communities such as Port McNeill, Tahsis and Woss. The data collected during the survey will be publicly available in database and map form following an announcement at the AME Roundup conference in January 2020.



↕ Open house meetings in Campbell River and Port McNeill in September provided updates about the Vancouver Island North Regional Project to local industry, community, government and First Nation representatives.
Photo: Ingrid Thomas



↓ The Vancouver Island North Regional Project covers an area covering almost 20 percent of Vancouver Island. Photo: Precision GeoSurveys



CENTRAL INTERIOR COPPER-GOLD RESEARCH PROJECTS

Identifying Mineral Development Potential Beneath Glacial Sediments

In 2019, Geoscience BC launched *Central Interior Copper-Gold Research (CICGR)*, a major multi-year series of projects that are applying innovative research methods to unearth potential mineral deposits buried under glacial sediments, such as till. CICGR covers an area of approximately 50,000 square kilometres in BC's North Central Region between the Mount Milligan Mine near Mackenzie, and the Gibraltar Mine near Williams Lake.

One of the first projects in the series is the \$1.1 million *CICGR Surficial Exploration Project*. This research is characterizing the thickness and distribution of glacial deposits over a 9,000 square kilometre area using geological mapping, aerial photograph analysis, and till sample analysis to help 'see through' the deposits and improve our understanding of the rocks below.

A second CICGR project is using existing Geoscience BC and other publicly available geophysical data to identify, map and model prospective copper-gold deposits and related rocks in the area.

Both projects will assess the potential for the rocks in this area to host high-grade copper-gold deposits and the results of these projects will also inform future CICGR research projects.

MINERALS

Advancing Science & Innovative Geoscience Technologies

Geoscience BC is supporting continual environmental and economic performance improvement of the British Columbia minerals sector with projects that develop and apply innovative technologies and made-in-BC methods to provide next-generation public data.

CAPTURING CARBON DIOXIDE IN ROCKS

In July, Geoscience BC announced funding for new minerals research that is identifying, mapping and analyzing rocks to map their potential to absorb the greenhouse gas carbon dioxide (CO₂) in the province. The project is part of a major research collaboration to develop technology to capture CO₂ across Canada.

The research is being led by the University of British Columbia's (UBC) Bradshaw Research Initiative for Minerals and Mining (BRIMM) and MDRU-Mineral Deposit Research Unit. More than ten organizations, including industry, the British Columbia Geological Survey (BCGS) and the Geological Survey of Canada (GSC), are collaborating on this research.

A BC Earth Science Legacy

In 2019, we launched a set of minerals projects that address the challenges of collecting, storing and making earth science samples and information easily accessible and shareable.

The *Bringing Geological Collections to the Masses* project is creating a virtual museum of rock, mineral and fossil samples from sites and collections across the province. The project includes virtual 360° field trips at key locations across BC, making rare and delicate samples accessible to everyone for educational, research and general interest purposes.

The *Smithers Exploration Group (SEG) Restoration* project is promoting and preserving SEG's existing 2,000-piece 'Rock Room': a collection of samples from more than 20 ore deposits in the Northwest and North Central Regions of BC and beyond. During 2019 and into 2020, SEG is collecting new samples from additional locations and deposits; promoting the collection at conferences; and preserving it online and in a permanent physical location.

The *East Kootenay Chamber of Mines (EKCM) Core Library Project* salvaged drill core samples from important sites across the Southeast Region, such as the Sullivan Mine, and stored them in a custom-built facility at the EKCM Fort Steele Drill Core Library. The collection is protecting valuable information about mines, mineral exploration projects and mineral claims in the area and making it available to geoscientists, students and the public.

A fourth curation project is creating a database for mineral deposits and their locations that have an associated *National Instrument 43-101 – Standards of Disclosure for Mineral Projects* (NI 43-101) report filed with the Canadian Securities Administrators, making the information stored in NI 43-101 reports searchable and more easy to access.

“Preserving rare and delicate samples and making them accessible to everyone for educational, research and general interest purposes.”

Revolutionizing the Roben Jig

BC's steelmaking coal contains ash which must be removed to produce a washed sample for accurate coal and coke quality assessment. Geoscience BC has funded a series of 'Roben Jig' projects that revolutionize this vital step in the analysis process for accurately assessing the economic value of a steelmaking coal project.

In February, we released a new report that describes how the Roben Jig method eliminates dangerous organic chemicals and uses water and a simple shaking process to produce coal samples of comparable quality to traditional methods at reduced risk for laboratory operators and cost. We also announced funding for the next phase of research, which includes final pilot tests of samples in a larger scale coke oven to assess complete coke characteristics and quality.



↑ Research published in 2019 proposes a new understanding of mineral deposit types in the North Central Region's Toadoggone district.
Photo: Farhad Bouzari

TOOLS FOR DISCOVERY

Developing Enhanced Exploration Tools

We are actively developing innovative exploration tools to help find new mineral deposits across the province. In 2019, Geoscience BC launched several projects and delivered new tools to inform mineral exploration in sometimes challenging terrains.

Clues in Clays

Certain types of clay minerals indicate that a porphyry copper mineral system is nearby. By studying the textures and geochemistry of the clay minerals found on the edges of three rich copper and gold deposits in BC, this Geoscience BC minerals project will establish exploration protocols that can be applied in the field to help locate new mineral deposits.

Exploration Framework for the Toodoggone District

In November, this project culminated in the publication of a final report from research in the Toodoggone district. It includes easy-to-access and illustrated descriptions of the mineralization and alteration styles present in the Toodoggone district. In the report, researchers suggest a new understanding of how mineral deposits formed in the area.

New Skeena Arch Data

In July, we published results of a partnership between the British Columbia Geological Survey (BCGS), Geoscience BC and the University of British Columbia's MDRU-Mineral Deposit Research Unit that includes new information about bedrock geology and potential mineral deposits in the North Central Region's Toodoggone district.

The project helps to understand how and why the known mineral deposits are where they are, and if similar deposits might be found in parts of the Skeena Arch – including an area covered by Geoscience BC's 2015 Search Phase I geophysical survey. A final report was published in December.

Characterization of Gold Compositions in BC

This project is helping to identify new mineral development opportunities in BC by building a comprehensive, open source database of information about the composition of gold grains collected from streams and mineral deposits around the province.

Using Soil-Gas to Detect Mineralization Beneath Thick Glacial Deposits

Using small, electronic gas sensors, this minerals research project is measuring the composition of gases in soil to assess the method as a potential tool to rapidly and economically identify bedrock mineralization and geological faults beneath thick glacial sediment deposits in the North Central Region.

Upgrading the BC Regional Geochemistry Survey Database

This new project is collecting bulk stream sediment samples from an area near Penticton to add to the existing Regional Geochemical Survey (RGS) database. Indicator minerals in these new samples will help identify geochemical anomalies that may be derived from undiscovered mineralized sources.

Halogens in Spruce Treetops

This Geoscience BC minerals project is analyzing the halogen elements (fluorine, chlorine, bromine and iodine) in spruce tree-top samples collected in central BC during our *Targeting Resources for Exploration and Knowledge (TREK)* regional biogeochemical survey in 2015. The analysis will help to focus mineral exploration activity in the area by creating the first database of halogen elements in spruce trees, and by applying the halogen analytical and sampling techniques developed in previous Geoscience BC-supported minerals projects at a regional scale.

OIL & GAS

Innovative Energy Research as a Competitive Advantage

British Columbia's energy sector supports thousands of jobs and supplies domestic and global markets. According to the Canadian Association of Petroleum Producers, oil and gas revenue and capital spending in BC was valued at \$3.9 billion in 2018 and forecasts indicate an increase in natural gas production in coming years. As Canada's second largest natural gas producer, 30 per cent of the country's natural gas is sourced from operations in our province.

Collecting, interpreting and sharing new scientific data about this sector helps to guide clean, responsible energy development, minimize impacts, answer specific environmental and social questions and attract investment to BC.

This section highlights new, ongoing and completed oil and gas research for 2019.

Facilitating Responsible Natural Resource Development

“The outcomes improve understanding of when, where and why induced seismicity occurs.”

Geoscience BC has been funding research investigating induced seismicity – earthquakes caused by human activity – and natural gas development in BC's Northeast Region, especially in areas close to communities and infrastructure, since 2012. It was also a focus in 2019, and the outcomes improve understanding of when, where and why induced seismicity occurs. The public research informs industry, government and community decisions to reduce the likelihood and impact of induced seismicity in the future.

Numerous factors influence the potential for hydraulic fracturing and wastewater disposal to cause earthquakes ('induced seismicity'). The main factors controlling induced

seismicity include the current state of stress within the earth; the presence, size, type and orientation of faults; the amount and rate at which fluid is injected; and the amount of sand being pumped into the open fractures. In rare cases, induced seismicity is strong enough to be felt at the surface. Research has shown that some areas are susceptible to induced seismic events whereas other areas are unaffected. Understanding the complex interplay between the controlling factors in induced seismicity is key to reduction and mitigation.

Northeast Focus

This research focuses on the Northeast Region's Montney Play – a gas-prone area within the Western Canadian Sedimentary Basin that contains some of North America's most significant natural gas deposits.

Our induced seismicity research is guided by subject matter experts and by reports such as:

- *Investigation of Observed Seismicity in the Horn River Basin* (BC Oil and Gas Commission (OGC), 2012)¹;
- *Investigation of Observed Seismicity in the Montney Trend* (BC Oil and Gas Commission, 2014)²;
- *Environmental Impacts of Shale Gas Extraction in Canada* (Council of Canadian Academies, 2014)³; and
- *Scientific Review of Hydraulic Fracturing in British Columbia* (Ministry of Energy, Mines and Petroleum Resources, 2019)⁴.

1. bcogc.ca/node/8046/download

2. bcogc.ca/sites/default/files/documentation/technical-reports/investigation-observed-seismicity-montney-trend.pdf

3. cca-reports.ca/reports/environmental-impacts-of-shale-gas-extraction-in-canada/

4. www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/natural-gas-oil/responsible-oil-gas-development/scientific_hydraulic_fracturing_review_panel_final_report.pdf

2019 OIL & GAS PROJECTS

The 2019 Geoscience BC Energy & Water Summary of Activities volume includes 10 new papers on oil and gas research. You can view it online at www.geosciencebc.com or request a print copy.

2 Completed Projects

5 Ongoing Projects

6 New Projects



← Natural gas sector representatives, residents and staff from local First Nations attended an open house in Dawson Creek in May 2019 to discuss induced seismicity research.

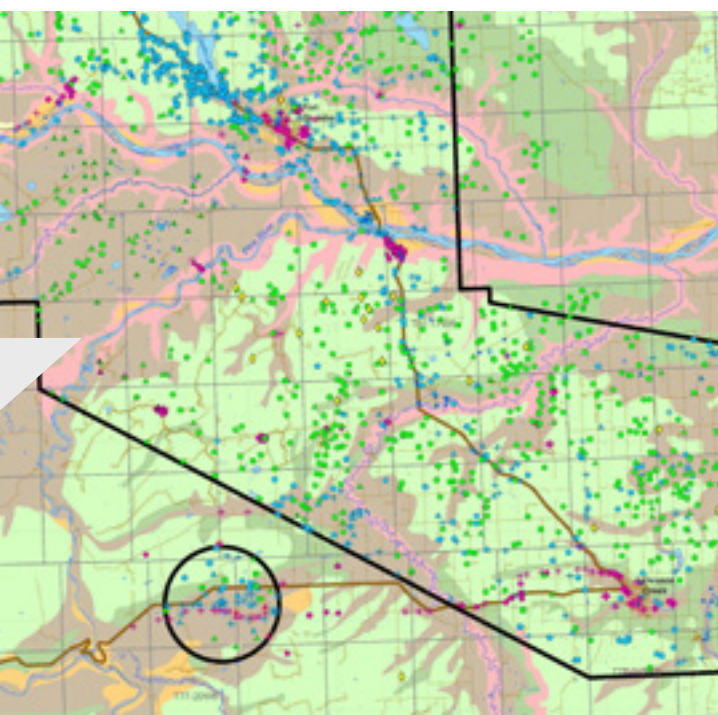
Photo: Darcy Shawchek

How Seismic Waves can be Amplified

In May 2019, we announced a new project to assess how seismic waves from earthquakes can potentially be amplified in specific shallow geological conditions, looking specifically at earthquakes induced by hydraulic fracturing in an area around Fort St. John and Dawson Creek in the Northeast Region.

The project addresses public concerns relating to seismicity and natural gas industry development in areas close to communities and infrastructure. The new research builds on findings from research over a larger area that we published in February 2019.

The information generated from both projects is particularly useful for regulators and natural gas operators to identify areas which may have an increased likelihood of felt events due to local surface conditions.



Four New Induced Seismicity Projects Launched in 2019

We launched a series of four new joint research projects in December 2019 to further investigate how and why, in certain circumstances, earthquakes can be caused by hydraulic fracturing during natural gas development.

Two of the projects are using seismograph stations to record the motion of the ground during an earthquake. The real-time, public data generated by these instruments will be used by researchers to help generate models to help predict when, where and why earthquakes associated with natural gas development activities occur.

The other two projects are taking innovative, data-driven approaches to further develop understanding of relationship between natural gas operations, geology and seismic activity in BC Northeast Region. The projects are producing maps, models and increased understanding of where, why and how induced seismicity occurs and how to regulate activities and further reduce risk.

← A 'traffic light' map helps to illustrate areas where seismic waves are more or less likely to be amplified in the Peace region.

OIL & GAS

Advancing Science & Innovative
Geoscience Technologies

Geoscience BC supports research that fosters made-in-British Columbia innovation and the development of new technologies and methods to improve the fiscal and environmental performance of the natural gas sector in the Montney Play.

Wastewater Disposal in the Montney Play

Suitable locations for the disposal of wastewater – fluids used or recovered by an operator during natural gas production or completion operations – are essential to efficient and environmentally responsible natural gas development. In December 2019, we announced a new project to identify and characterize suitable disposal zones in BC's Northeast Region.

In consultation with operators and the BC Oil and Gas Commission, researchers are compiling and interpreting public well test and production data, reservoir pressure data and well logs. The data will pinpoint suitable locations in the Montney Play for wastewater disposal.

Identifying New Natural Resource Opportunities

Our goal is to support collaboration to encourage investment in responsible development in BC through joint research and partnerships.

Hitting the Right Spot

A new report released in April 2019 summarized the results of a multi-year research project that examined the complex network of tiny fractures and pores that store and transport gas and liquid hydrocarbons in fine-grained sediments.

The project applied advanced research methods to samples and data from oil and gas production areas in northeastern BC. The results will help the sector more accurately target hydrocarbons and to improve production rates by improving methods to characterize reservoirs.

SOUR GAS MAPPING IN NORTHEASTERN BC

Announced in September 2018, Geoscience BC funded researchers continued a project to map sources of 'sour gas' – natural gas which can contain hydrogen sulphide (H_2S) – to reduce the cost of natural gas operations in 2019. The project is mapping and predicting the distribution of sour gas and hydrocarbon liquids in the Western Canadian Sedimentary Basin in BC's Northeast Region. It includes work in the Montney and Doig formations that have significant natural gas activity.



↑ GHGMap is a groundbreaking greenhouse gas detection project which uses a miniature, cutting-edge optical instrument developed by NASA's Jet Propulsion Laboratory (JPL) mounted on a drone to detect and analyze greenhouse gas emissions. Launched in 2017, development and testing continued in 2019.

GEOTHERMAL

Exploring BC's Geothermal Potential

Geothermal energy may play a significant role as we transition to alternative sources for electricity and heat. Our geothermal research reduces investment risk and cost at high-potential sites in British Columbia to encourage long term geothermal investment. This includes the potential for geothermal power to be used to electrify natural gas production in Montney Play in BC's Northeast Region.

The public geoscience we generate is providing geothermal explorers and developers, communities and decision-makers with unbiased data and information to answer questions related to the economic development of geothermal resources.

This section highlights our new, ongoing and completed geothermal research in 2019.

Enabling Clean Energy

Geoscience BC's goal is to continue geothermal resource mapping and research focussing on economically viable projects and sites with high geothermal energy potential.

Reenergizing a Natural Gas Field for Geothermal

In September, we published a pre-feasibility study that examined the potential for a geothermal power and heat pilot plant to repurpose the Clarke Lake natural gas field south of Fort Nelson to generate geothermal energy and heat. The report details potential costs and revenues as well as technology recommendations and permitting requirements as a next step to understanding economic viability.

The report concludes that there is the potential for a combined geothermal power and heat plant, with a payback period varying from 12 to 24 years depending on input parameters. The report also identifies potential customers for power and uses for heat, including public buildings and industrial customers.

Garibaldi Volcanic Belt Geothermal Potential

In collaboration with the Geological Survey of Canada (GSC), Geoscience BC launched a new project to assess the geothermal resource prospectivity of the Garibaldi Volcanic Belt, one of the highest resource potential



↑ The Garibaldi Volcanic Belt project uses a variety of sensors installed in remote locations to verify geothermal potential at Mount Meager.

Photo: Carlos Salas, Geoscience BC

geothermal regions in Canada. The first phase of the project is using a variety of geophysical methods and geological techniques to understand the geothermal resource potential of Mount Meager thereby reducing geothermal exploration risk at the site. Information collected will also be used to further understand the geohazard potential from landslides on Mount Meager.

This multi-year, multidisciplinary project is examining the major controls such as permeability, geological structures, and the earth's current stress condition at each site or 'hot spot' along the Garibaldi Volcanic Belt. In 2019, fieldwork involved 34 project participants from the GSC and five BC universities, with the helicopter pilot and a wildlife monitor from the Lílwat First Nation. In planning the field portion of the project, input from the three local First Nations – Lílwat, Squamish, St'át'imc – was sought and included in the final field program.

“Fort Nelson First Nation is grateful for the studies by Geoscience BC that have highlighted geothermal resource opportunities immediately adjacent to our home community and located in our territory where our people have lived for thousands of years.”

CHIEF SHARLEEN GALE, FORT NELSON FIRST NATION

2019 GEOTHERMAL PROJECTS

The 2019 Geoscience BC Energy & Water Summary of Activities volume includes three new papers on geothermal research. You can view it online at www.geosciencebc.com or request a print copy.

1 Completed Projects

1 Ongoing Projects

0 New Projects

WATER

Focus on Water Research

Geoscience BC water research is related to energy and mineral development in British Columbia. We have been funding water research since 2008, and water became a separate Geoscience BC strategic focus area in 2018 in response to feedback during the development of our *Strategic Plan 2018-2022*.

This section highlights our new, ongoing and completed water research in 2019.

Understanding Water

In June 2019, we updated the Geoscience BC *Strategic Plan 2018-2022* to include four new water research goals. The goals were recommended by our *Strategic Task Force on Water* formed in late 2018 and were approved by our Board of Directors in early 2019. They are:

- improving baseline surficial geology, including regional soil characterization;
- assessing watershed dynamics in relation to climate change;
- characterizing groundwater and aquifers throughout British Columbia; and
- measuring local and regional water balance.



Fort Nelson First Nation Water Monitoring Agreement Extended

In 2019, we extended our agreement with the Fort Nelson First Nation to continue managing hydrometric monitoring stations in the Horn River Basin. The stations, installed in 2008, are collecting information about surface water flow data in one of the most significant natural gas basins in North America.

Fugitive Gas and Groundwater

In 2019, Geoscience BC continued to support two water projects in northeast BC's Peace Region that are investigating the behaviour of fugitive methane gas on groundwater and its impacts.

As part of the *Assessment of Fugitive Natural Gas on Near-Surface Groundwater Quality* project, 15 new sampling intervals were added to six boreholes to expand the groundwater monitoring network at the Hudson's Hope Field Research Station in September 2019. Additional drilling and geophysical surveys were also completed at the site.

In the fall of 2019, the *Peace Region Scientific Groundwater Monitoring Network Installation Study* completed installation of a regional groundwater monitoring well network in the Peace Region. Of the 29 new monitoring stations, nine will measure baseline groundwater characteristics and the remaining 20 stations will monitor groundwater close to areas of natural gas production.

2019 WATER PROJECTS

The 2019 Geoscience BC Energy and Water Summary of Activities volume includes two new papers on water research. You can view it online at www.geosciencebc.com or request a print copy.

1 Completed Projects

4 Ongoing Projects

3 New Projects



← The University of British Columbia's (UBC) Energy and Environment Research Initiative expanded its Hudson's Hope Field Research Station in 2019.
Photo: Tom Balke, UBC

New Projects

Two new water projects were started in 2019. The new *Northeast BC Hydrometric Monitoring Network Improvements* project involves close collaboration with government scientists and BC Oil and Gas Commission (OGC) to increase the number of hydrometric stations in northeastern BC to provide better coverage for surface water monitoring. The data generated by this project will support surface water studies and surface water-groundwater interaction studies, and will monitor watershed water balances.

In the related *Matching Science with Traditional Knowledge* project, researchers will bring together water scientists and Indigenous groups in northeastern BC to compare water quality and quantity observations from scientific and Traditional Knowledge perspectives. This project will be supported by surface water data generated by the *Northeast BC Hydrometric Monitoring Network Improvements* Project. The findings from this research will be used to inform robust and transparent water resource management decisions.

In 2020, we expect to publish details of further water research projects as a result of a request for project proposals issued in November 2019.

Scientific Review of Hydraulic Fracturing

In March 2019, BC's Ministry of Energy, Mines and Petroleum Resources released the *Scientific Review of Hydraulic Fracturing in British Columbia* report. The report emphasized the need to monitor, record and share baseline surface water and groundwater quality and quantity data, to assist with regulation and transparency. Geoscience BC's new and future research projects are being guided by the report's findings and recommendations.

“The findings... will be used to inform robust and transparent...decisions.”

GOVERNANCE, MANAGEMENT & FINANCE

Geoscience BC employs nine staff and is supported by over 70 volunteers who contribute more than 1,500 hours annually. Our volunteer Board of Directors is responsible for overall governance and strategic direction, including research project budget decisions based on recommendations from the Board's three standing Technical Advisory Committees (TACs). Our organizational structure maximizes applied research investment and minimizes administrative-related expenditures.

Ensuring Transparency, Accountability & Responsibility

At our 14th Annual General Meeting in September, we welcomed Lana Eagle to the Board as recommended by Geoscience BC's Nominating Committee.

Geoscience BC's standing Finance Committee met regularly through the year and the activity-based cost centre budget system that was developed in fiscal 2018 was fully implemented in 2019. Part of the Finance Committee's role is to review and recommend the approval and adoption of Geoscience BC's interim and annual financial statements to the Board of Directors. In 2019, it recommended approval of the fiscal 2018/19 financial statements that were independently audited by Beauchamp & Company LLP Chartered Professional Accountants.

All interim and annual Geoscience BC Society financial statements are available to download at www.geosciencebc.com/updates/financial-statements.

Building Future Opportunities

In May 2019, Minister of Energy, Mines and Petroleum Resources Michelle Mungall granted Geoscience BC \$5 million in one-year bridge funding to support earth science research in BC. This allowed Geoscience BC to continue its minerals, energy and water related public earth science for an additional year. New projects launched in 2019 support the objectives in our *Strategic Plan 2018-2022*. These objectives inform our *Scientific Project Plan*, a working document guided by independent expert technical advice to ensure our research is credible, responsive and relevant.

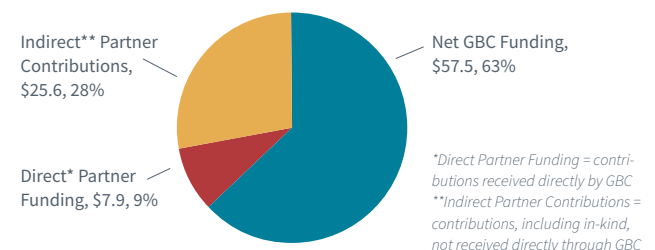
Since our inception in 2005, Geoscience BC has invested \$57.5 million in minerals, energy and water research. We have attracted an additional \$7.9 million in direct partner funding and \$25.6 million in indirect partner contributions (for total partner contributions of \$33.5 million), resulting in a total leveraged investment in public geoscience of \$91.0 million.* We continue to build strategic alliances that add value to our research.

*As at December 31st, 2019.

STRATEGIC RESEARCH AREA	COMPLETED RESEARCH PROJECTS	CURRENT RESEARCH PROJECTS
Minerals	129	27
Energy: Oil & Gas	24	11
Energy: Geothermal	11	1
Water	25	7
TOTAL	189	46

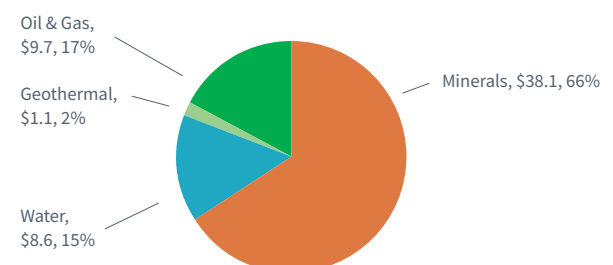
Total Leveraged Research Investment

Geoscience BC \$ + Partner Contributions (\$ + In-Kind)
Net to December 31, 2019 (CDN\$ Millions)



Geoscience BC Project Investments by Strategic Research Area

Net to December 31, 2019 (CDN\$ Millions)



GEOSCIENCE BC Board of Directors

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Craig Hart Mineral Deposits Research Unit,
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Julie Hunt Mineral Deposits Research Unit,
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OIL & GAS

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Brad Hayes Petrel Robertson Consulting Ltd.

Randy Hughes Painted Pony

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Jeff Johnson BC Oil and Gas Commission

Carlos Salas Geoscience BC

Clint Tippet Canadian Society
of Petroleum Geologists

Laura Wytrykush Geoscience BC
(Staff Support)

GEOTHERMAL

Technical Advisory Committee

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Canada, Natural Resources Canada

Cathie Hickson Geothermal Canada

Sarah Kimball BGC Engineering Inc.

Jasmin Raymond Institut National
de la Recherche Scientifique – Eau Terre
Environnement

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Sadlier-Brown Consulting Ltd.

Carlos Salas Geoscience BC

Alex Tu BC Hydro

Nathalie Vigouroux-Caillibot
Douglas College / Simon Fraser
University (adjunct)

Warren Walsh BC Ministry of Energy,
Mines and Petroleum Resources

Jeff Witter Innovate Geothermal Ltd.

Laura Wytrykush Geoscience BC
(Staff Support)

PUBLIC ACCESS & DATA MANAGEMENT

Providing Public Access to Data

In 2019, we began the process of rearranging GIS data layers in the Earth Science Viewer (ESV) to better reflect the strategic focus areas set out in our *Strategic Plan 2018–2022*. Our GIS Specialist, Ron Prasad, conducted an audit of Geoscience BC's research project and report databases to ensure project information for more than 200 completed and current projects can be found more efficiently internally, on the website and ESV, and through external partners who access our data, such as the Ministry of Jobs, Trade and Technology's *BC Economic Atlas*.

Earth Science Viewer

The ESV is Geoscience BC's custom, web-based map and data delivery service. It is a single access point to view all of our research projects, reports and data. Using ESRI's ArcGIS platform and accessed via www.geosciencebc.com, the ESV is an easy way to view information and add context with extra GIS data layers.

Using the ESV, data generated by Geoscience BC research projects can be viewed over different base maps, including BC mineral tenures, satellite imagery, geology layers, or BC Geological Survey datasets such as MINFILE. For example, a user interested in seeing the location of individual stream sediment samples collected and analyzed for geochemistry over a certain area can create a custom map that includes the geochemistry data, locations of known mineral occurrences, as well as adding their own GIS data layers.

For those with technical expertise and their own software, the ESV links to our data, organized by project, on the Geoscience BC website where it can be downloaded for use offline or in a different GIS application.

GIS Practicum Student Adds to Earth Science Viewer

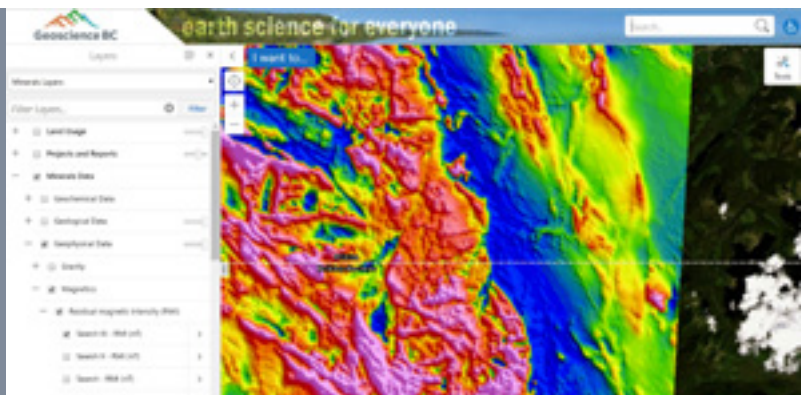


Each year, one student from BCIT's Geographic Information Systems Advanced Diploma Program completes their industry practicum at Geoscience BC. In 2019, Matrika Koirala joined us to assist with auditing more than 3,000 square kilometres of geophysical data generated by Geoscience BC since 2005 to make sure data available in reports is also accessible through our ESV online mapping application.

Maintaining Secure Digital Data

We continued to work towards our goal to maintain safe and secure databases, digital data project libraries, information technology infrastructure and management controls to professional standards and practices in 2019. An information technology (IT) lifecycle plan was completed, in part to ensure the servers that store Geoscience BC reports and research data remain efficient, secure and reliable.

In 2019, we placed a particular focus on our goal to use proven, high-quality technology and ensure advanced hardware is seamlessly integrated with reliable software and adaptable to next generation systems as technology evolves. This included planning and preparing for IT infrastructure upgrades and migration in 2020 as Geoscience BC prepares to move to newer versions of the ESRI ArcGIS software used for the ESV.



“Research project information for more than 200 completed and current projects can be more found more efficiently... through our website and Earth Science Viewer, and through external partners.”

EXTERNAL RELATIONS & COMMUNICATIONS

Increasing Awareness & Expanding Collaborative Network of Partners

In 2019, Geoscience BC strengthened relationships with government agencies, such as the British Columbia Geological Survey and the BC Oil & Gas Commission, and built connections with the new industry representatives leading the Association for Mineral Exploration (AME), the BC Liquified Natural Gas Alliance, Clean Energy BC and the Mining Association of British Columbia.

Sharing Geoscience BC's research and data with natural resource industries and across all governments and political parties played a key role in building awareness, understanding and support for the importance of fundamental public geoscience in the province. We continued to meet regularly and collaborate with provincial government ministries and local governments. This included attending local government association conventions throughout BC in 2019, and in September we hosted a series of well-attended regional update sessions about our geoscience research at the Union of BC Municipalities Convention in Vancouver.

A new Geoscience BC website, including a faster and more effective search function, was launched in April that makes accessing our research information more efficient and effective. Also, Geoscience BC's first logo and branding refresh since 2005 more accurately reflects our minerals, energy and water research focus areas.

Demonstrating Research Value & Building Broader Support

Preparing for and beginning external relations and communications programs for ongoing and new Geoscience BC research projects was a focus in 2019. Community meetings for projects such as the *Garibaldi Geothermal Volcanic Belt Assessment Project*, *Amplification of Seismic Ground Motion Hazard Mapping for the Fort St. John - Dawson Creek Area* and the *Vancouver Island North Regional Project* attracted many representatives from industry, communities, academia and Indigenous groups. These meetings were an ideal opportunity to share information about Geoscience BC's strategic objectives and the specific outcomes anticipated from our new research projects, as well as incorporate feedback and answer questions from community members.

Geoscience BC continued to work with Indigenous communities in active research areas throughout the province. As well, the success of our relationship with Fort Nelson First Nation (FNFN) was underlined by the extension and expansion of our Memorandum of Understanding with FNFN, which is managing a series of hydrometric monitoring stations in BC's Northeast Region.

In May 2019, Geoscience BC and the Tahltan Central Government announced a Collaboration Agreement that sets out how the organizations will work together on completed, ongoing and potential future Geoscience BC earth science research in northwestern BC.

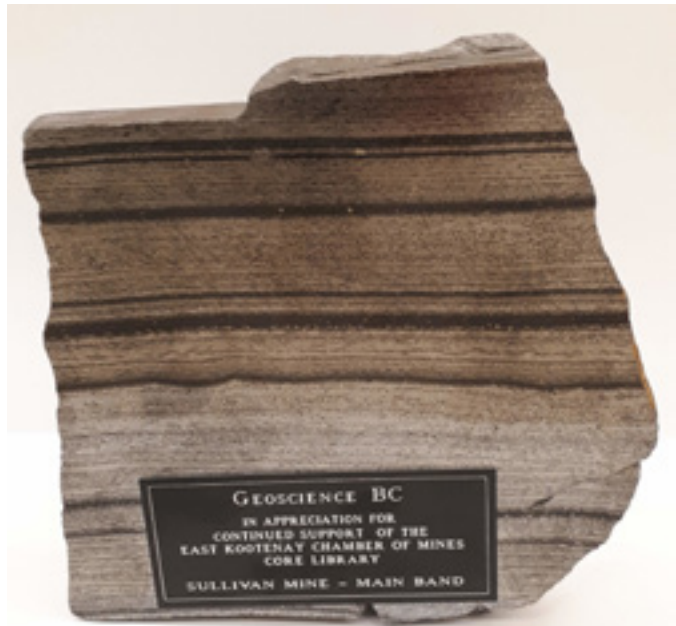


← Tahltan Central Government President Chad Day (l) with Geoscience BC Director, External Relations Richard Truman at the Smithers Exploration Group 2019 Mining Month lunch

Serving Technical and Academic Partners

Technical summaries for the majority of Geoscience BC's active minerals, energy and water research projects in 2019 have been published in our Minerals and Energy & Water Summary of Activities volumes, which are available in print and digital formats.

Throughout 2019, we delivered technical presentations and project updates at industry hosted conferences. These included AME Roundup, Canadian Society for Unconventional Resources events, Geoconvention, Kamloops Exploration Group, Minerals North and Minerals South. In addition, Geoscience BC continued to contribute to technical groups and innovative scientific forums, such as the BC Oil & Gas Methane Emissions Research Collaborative.



↑ At the Minerals South conference, the East Kootenay Chamber of Mines presented a sample from the Sullivan Mine to recognize Geoscience BC's support for its Core Library

2019 SCHOLARSHIPS

Increasing Geoscience Literacy & Capacity

Geoscience BC awards scholarships to graduate students working on British Columbia-based projects each year in a program designed to inspire the next generation of earth scientists. In 2019, we funded 10 student projects that covered subjects ranging from the formation of mineral deposits, to geothermal assessments, to characterizing hydrocarbon deposits.

Geophysical Prospecting for Antimony and Chromite



↑ M.Sc. student **Drew Branson** is evaluating geophysical techniques to indirectly locate antimony and chromite deposits by detecting the altered rocks that host them. Branson is testing geophysical methods over known antimony and chromite deposits in an area near Kelowna, BC.

Supervisors: Alexander Braun & Georgia Fotopoulos, Queen's University

How Soils Age

← M.Sc. student **Chantalle Gervan** is using DNA meta barcoding to investigate how soils age, particularly soils set aside for mine site reclamation. She is examining the invertebrate assemblages in soils under various soil amendments, include biosolids, fertilizer and wood mulch, near four active mines in BC.

Supervisor: Dr Lauchlan Fraser, Thompson Rivers University

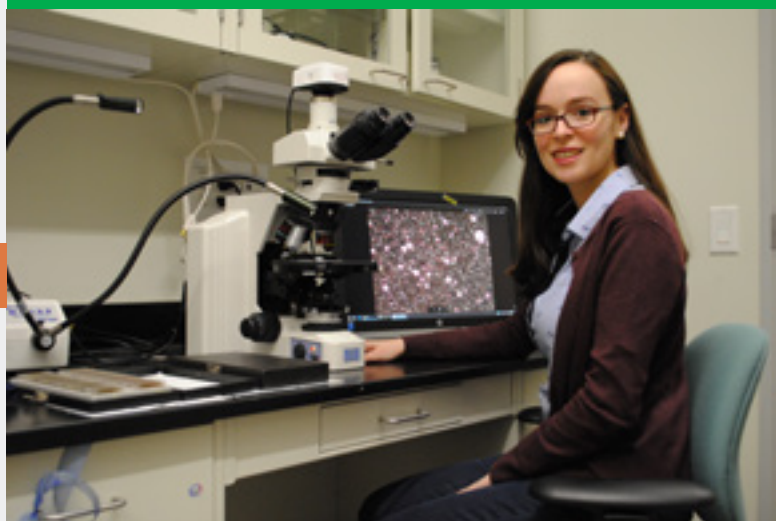
Understanding Geothermal Energy Resources



↑ M.Sc. student **Theron Finley** is examining the characteristics of fault zones at thermal springs in the Columbia Mountains of BC's Southeast Region to better understand why hydrothermal systems occur where they do. His research will provide valuable information for assessing the geothermal energy potential of BC.

Supervisors: Martyn Unsworth and Stephen Johnston, University of Alberta

Architecture of the Montney Formation



↑ Ph.D. candidate **Patricia Gonzalez Hernandez** is studying the fossil-bearing rock layers in the Montney Formation, a gas-prone area within the Western Canadian Sedimentary Basin in BC's Northeast Region. Her research will analyse drill core samples to establish the depositional model and stratigraphic architecture of the formation.

Supervisor: John-Paul Zonneveld, University of Alberta

Analysis of the Doig Formation



↑ Ph.D. candidate **Pablo Lacerda Silva** will map and characterise the properties of rocks in the Doig Formation, a generous oil-bearing rock in northeast BC, to reconstruct and determine the timing of thermogenic hydrocarbon generation, migration, expulsion and retention.

Supervisor: Marc Bustin, University of British Columbia

Skarn Mineralization on Vancouver Island



↑ Ph.D. candidate **Rebecca Morris** is examining skarn deposits that were historically mined for copper, gold and other metals. Her research will examine the characteristics of the skarn mineralization at pluton-carbonate contacts in two contrasting magma systems and generate 3D models.

Supervisor: Dr. Dante Canil, University of Victoria

Formation of the Brucejack Deposit

← M.Sc. student **Cameron Peddle** is using structural field mapping and age dating of rocks to unravel the complex formation and deformation events that resulted in the rich Brucejack deposit in BC's Northwest Region.

Supervisor: Dr Stephen Johnston, University of Alberta



Fluid Injection and Earthquakes

↓ Ph.D. candidate **Marco Roth** is creating a catalogue of earthquakes that have occurred in the Dawson-Septimus area in northeast BC to examine the relationships between fluid injection and earthquakes. He will investigate the characteristics of induced earthquakes and the rocks they occur in to better understand how operation parameters affect earthquakes.

Supervisor: Rebecca Harrington, Ruhr University Bochum, and Yajing Liu, McGill University



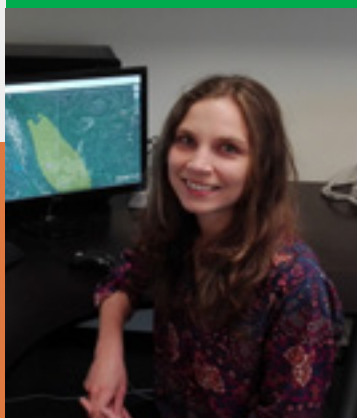
Sloquet Thermal Springs



← M.Sc. student **Ashley Van Acken** is examining the hydro-geothermal setting of the Sloquet Thermal Springs near Garibaldi Provincial Park in BC's Southwest region. Ashley will use field mapping and groundwater investigations to generate a model of the depth, source and temperature of the geothermal fluids at the site.

Supervisor: Dr. Tom Gleeson, University of Victoria

Induced Seismicity in the Montney Formation



← Ph.D. candidate **Paulina Wozniakowska** is developing a tool to assess seismic potential in northeast BC's Montney Formation using machine learning. The project puts emphasis on the determination of seismogenic potential and the discrepancy between the seismicity rates in particular oil and gas fields.

Supervisor: David Eaton, University of Calgary



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