British Columbia Geological Survey annual program review 2017-2018

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Recommended citation: Hickin, A.S., Jones, L.D., and Clarke, G., 2018. British Columbia Geological Survey annual program review 2017-2018. In: Geological Fieldwork 2017, Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2018-1, pp. 1-13.

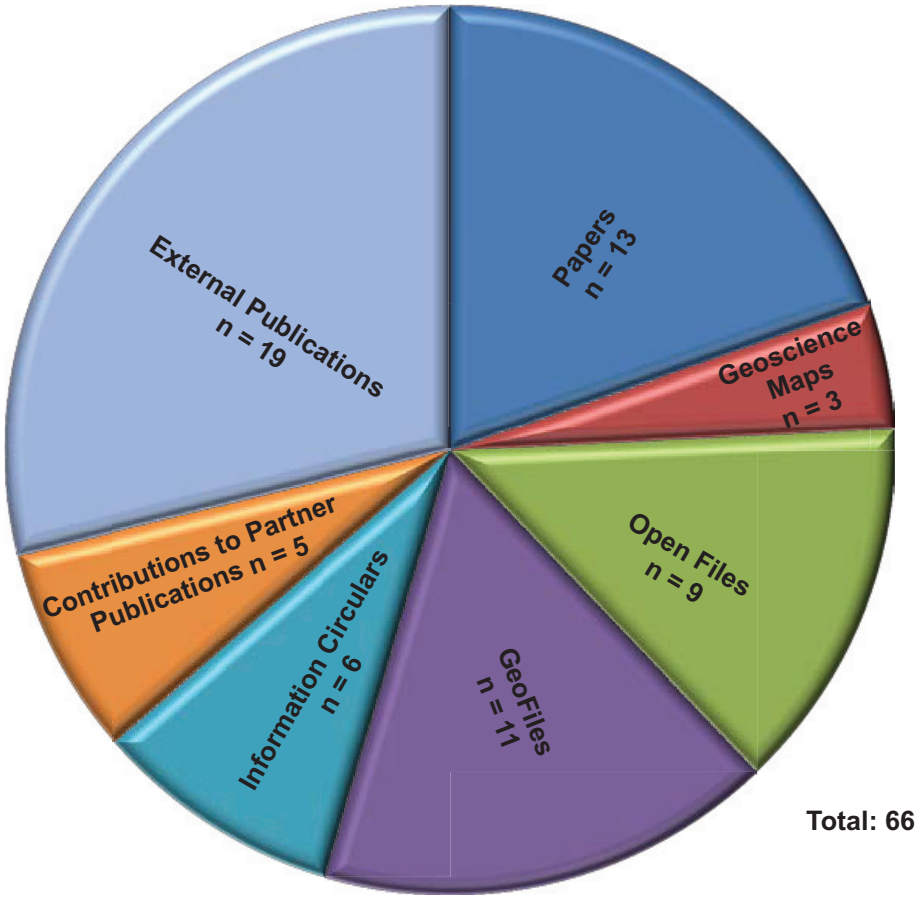
1. Introduction

The British Columbia Geological Survey (BCGS) annual program review highlights the activities of the Survey and provides a summary of the activities, events, and accomplishments. BCGS links government, the minerals industry, and communities to the province's geology and mineral resources. The BCGS generates, disseminates, and archives British Columbia's geoscience data to stimulate investment and provide knowledge to society's decision makers for responsible land and resource management. The Survey strives to be a leader in public government geoscience, providing geological and geomorphological information to all through traditional reports, maps, and databases (Fig. 1), which can be freely accessed online. The BCGS is part of the Mines and Mineral Resources Division of the Ministry of Energy, Mines and Petroleum Resources and operates from two offices, the headquarters in Victoria and the Mineral Development Office in Vancouver. The Survey has a permanent staff of 29 people (Fig. 2) in three sections: 1) Cordilleran Geoscience; 2) Resource Information; and 3) the Mineral Development Office (MDO). The Cordilleran Geoscience Section is responsible for generating new geoscience knowledge, largely through field-based studies and surveys. The Resource Information Section is responsible for maintaining and developing the provincial geoscience databases and disseminating geoscience data online through MapPlace 2. This section is also responsible for evaluating, approving, and archiving mineral and coal exploration assessment reports filed by the exploration and mining industry. The MDO links the province's mineral and coal resources to the investment community, distributes and promotes BCGS technical data, and coordinates the technical outputs of the Regional Geologists Program.

Although the mineral exploration sector continues to struggle against difficult market conditions, some relief may be forthcoming as highlighted in the 2017 British Columbia Mineral and Coal Exploration Survey, a joint initiative amongst EY (formerly Ernst & Young), the Government of British Columbia's Ministry of Energy, Mines and Petroleum Resources, and the Association for Mineral Exploration (AME). The survey, conducted in the fall of 2016, provides an overview of the mineral and coal exploration sector in British Columbia and examines a range of economic and sociopolitical topics that affect exploration and prospecting in British Columbia. Analysis presented in the 2017 report are based on data collected directly from 30 prospectors and 177 companies. This survey, which the BCGS helped coordinate, suggests that the outlook for the exploration sector in British Columbia will largely be influenced by the level of investment in grassroots and early-stage exploration that, in turn, will be determined by commodity prices and the ability of exploration companies to raise capital. Expenditure trends suggest that exploration in British Columbia may be experiencing an exploration lifecycle 'reset' as the province has benefitted from large-scale mine development projects that were approved and fully funded before the 2012 exploration downturn. Another survey was conducted in 2017, the results of which will be released in spring 2018.

BCGS staff received two significant acknowledgements from the geoscience community in 2017. We are proud to announce that geoscientist JoAnne Nelson was awarded the 2017 Provincial and Territorial Geologists Medal by the Committee of Provincial and Territorial Geologists (CPTG). The Medal is presented annually to an individual who has produced outstanding work at one of Canada's provincial or territorial geological surveys. The award recognizes major contributions in the areas of geoscience research and related developments or applications that serve to meet the mandates of Canada's geological surveys. JoAnne received her medal at the Energy and Mines Ministers Conference in St. John New Brunswick from the Federal Minister of Natural Resources Jim Carr and the New Brunswick Minister of Energy and Resource Development Rick Doucet (Fig. 3). The citation from JoAnne's nomination states:

> "JoAnne Nelson is an exceptional scientist, mentor, and teacher who synthesizes research at many scales. This has led to a career of innovative and insightful studies on the tectonics and metallogeny of the northern Cordillera, as related through more than 125 publications that include



Types of Publications by the British Columbia Geological Survey

Papers*: This series is reserved for reviews and final thematic or regional works. Geological Fieldwork, our annual review of field activities and current research, is released as the first Paper of each year.

Geoscience Maps: This series is the BCGS vehicle for publishing final maps.

Open Files: These maps and reports present the interim results of ongoing research, particularly mapping projects.

GeoFiles: These publications enable rapid release of extensive data tables from ongoing geochemical, geochronologic, and geophysical work. As such, they serve the same function as data repositories provided by many journals, providing immediate access to raw data from specific projects.

Information Circulars: These publications provide accessible geoscience information to a broad audience in government, industry, and the general public. Included in the Information Circular series are the annual Provincial Overview of Mining and Exploration, **Exploration and Mining in British Columbia, and the Coal Industry Overview.

Contributions to partner publications: This category includes reports, maps, and other products published by another agency such as the Geological Survey of Canada or Geoscience BC, but have received contributions from British Columbia Geological Survey staff.

External publications: These are contributions to the peer reviewed literature and published in a recognized national or international scientific journal.

*The count refers to the total number of articles authored by BCGS personnel in a volume.

**Although five articles are included in Exploration and Mining in British Columbia, it is counted as a single volume.

Fig. 1. British Columbia Geological Survey Publications in 2017.

Fig. 2. Members of the British Columbia Geological Survey at Mystic Beach, British Columbia.

Fig. 3. JoAnne Nelson receiving her Provincial and Territorial Geologists Medal from Federal Minister of Natural Resources Jim Carr (left) and New Brunswick Minister of Energy and Resource Development Rick Doucet (right) at the Energy and Mines Ministers Conference in St. John New Brunswick.

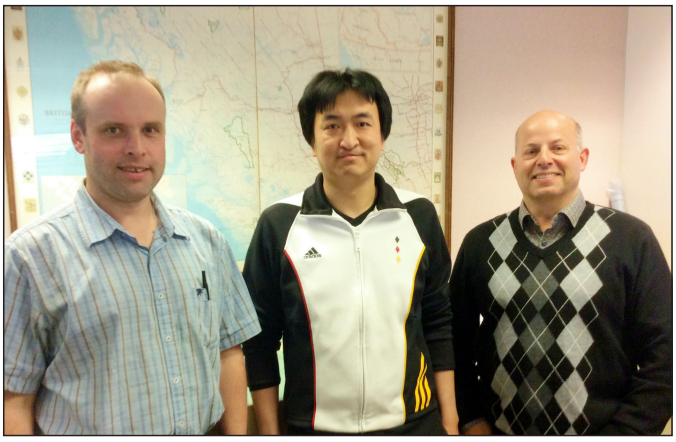


Fig. 4. Alexei Rukhlov (left), Mao Mao (centre), and Stephen Rowins (right) of the BCGS and colleagues at the University of Victoria received the 2017 Brian J. Skinner award from the Society of Economic Geologists for the best paper in the journal Economic Geology.

geological maps, bulletins, and peer-reviewed papers. In 1986, JoAnne joined the British Columbia Geological Survey where she undertook bedrock mapping and the study of mineral deposits in the northwestern part of the Province. In addition to her many scientific contributions maps, she is the co-author of a book aimed at the general public titled "The Geology of British Columbia: A Journey through Time".

JoAnne is embarking on a cross-country lecture tour in the New Year to tell her remarkable stories of mapping in the Canadian Cordillera.

We also recognize geoscientists Drs. Mao Mao, Alexei Rukhlov, and Stephen Rowins (Fig. 4), and University of Victoria colleagues Drs. Jody Spence and Laurence Coogan as recipients of the Brian J. Skinner award from the Society of Economic Geologists for their paper "Apatite Trace Element Compositions: A Robust New Tool for Mineral Exploration" (Mao et al., 2016). The Brian J. Skinner Award is presented annually to the authors of the most innovative and original paper appearing in the journal Economic Geology as selected by the editorial board. Papers are judged on technical excellence, innovation, and impact on the science of economic geology. Mao accepted the award on behalf of his colleagues at the Society of Economic Geologists annual meeting in Beijing, China.

BCGS is a technical partner for the Resources for Future Generations 2018 (RFG 2018) conference being held in Vancouver in June 2018 under the auspices of the International Union of Geological Sciences (IUGS). The Survey has been organizing sessions, preparing presentations, and planning two fieldtrips. More than 30 technical societies and geological surveys are partnering to mobilize industry, academia, and governments to address the availability and responsible use of Earth's finite resources. The RFG 2018 program will explore

six themes: the Earth, education and youth, energy, minerals, resources, and water. We invite the British Columbia geoscience community to participate in the conference.

2. Partnerships

The BCGS is a collaborative agency and partners with federal, provincial, and territorial governments, other national and international organizations, and the mineral exploration industry to develop and deliver geoscience projects. Based on a relationship that is embedded in the terms of British Columbia's entry into confederation, the Geological Survey of Canada (GSC) and the BCGS continue to benefit from strong partnerships. In 2017, this collaboration included two main programs, the Cordilleran Project in the second iteration of the Geo-mapping for Energy and Minerals (GEM 2) Program, and the fifth iteration of the Targeted Geoscience Initiative (TGI-5). The Survey is continuing its partnership with the Geological Survey of Japan to advance studies on critical and strategic material. Several projects are co-operations with the Department of Earth, Ocean, and Atmospheric Science at the University of British Columbia, supported by TGI-5 grants from the GSC. Since 2003, the Ministry has maintained a formal partnership with the University of Victoria that supports joint research projects and student training of benefit to the School of Earth and Ocean Science, the Ministry of Energy, Mines, and Petroleum Resources, and the mineral exploration sector.

3. Cordilleran Geoscience Section

Cordilleran Geoscience Section geologists have expertise in regional bedrock mapping, tectonics, mineral deposits, coal, Quaternary and surficial geology, geochemistry, petrology, mineral exploration methods, copper, gold, and nickel metallogeny, and geoscience data management. BCGS undertakes a variety of field-based, long-term initiatives and short-term projects that include mapping, mineral deposit studies, and developing exploration methods (Fig. 5). Many current projects are continuations of multi-year efforts, whereas others are new.

In addition to the typical projects executed in 2017, BCGS staff also contributed to, and edited a volume entitled "Indicator Minerals in Till and Stream Sediments of the Canadian Cordillera", a Special Paper of the Geological Association of Canada (GAC) and the inaugural contribution to the Mineralogical Association of Canada (MAC)'s new Topics in Mineral Sciences series (Fig. 6; Ferbey et al., 2017). The volume is the first joint publication of the GAC and the MAC and stems from a workshop given in 2016 at the annual GAC-MAC meeting in Whitehorse, Yukon. The workshop was led by the BCGS with support from the Yukon Geological Survey and the GSC. It was designed to address a subject of importance to the mineral exploration community: the use of indicator minerals in the Canadian Cordillera. With samples now routinely collected for mineral separations during regional till and stream-sediment surveys, indicator minerals are an efficient and cost-effective exploration tool. BCGS has delivered indicator mineral programs for many years and these approaches are becoming important as exploration is forced to consider covered terrain. The volume includes papers on the glacial history of the Cordillera Ice Sheet, drift prospecting methods, the evolution of survey sampling strategies, new analytical methods, and recent advances in applying indicator minerals to exploration in British Columbia.

3.1. Mapping, regional synthesis, and compilation

3.1.1. Porphyry transitions (BCGS-GSC-GEM 2)

The Porphyry Environment Transitions project is in collaboration with the GSC through the GEM 2 program and includes both topical studies and focused mapping. The project addresses the continuity of the prospective Triassic-Jurassic magmatic belt and assess porphyry potential in northern Stikinia and other prospective deposits in adjacent terranes. In 2015, BCGS activities focused in the Sinwa Creek area (Mihalynuk et al., 2017), and in 2016 mapping was completed in the Turtle Lake map area. The field mapping component of the project is now complete and activities in 2017 focused on synthesising data and updating the provincial geology compilation.

3.1.2. Stikinia magmatism

This program is an ongoing multi-year 1:50,000-scale mapping project aimed at late Early to Middle Jurassic rocks in the Dease Lake region (Fig. 7). Mapping, which incorporates the interpretation of regional airborne geophysical data (Aeroquest Airborne, 2012), is accompanied by geochronological studies that constrain key magmatic and mineralizing events, and lithogeochemical analyses for evaluating magma sources, melt evolution, and tectonic setting. The 2017 program was the second full field season and a third year of fieldwork is planned. These regional studies will help develop northern Stikinia-wide tectonic and metallogenic models and provide insight into the accretion of the Cache Creek and Stikine terranes. The project will also provide a much-needed regional update of the geology east of the Hotailuh batholith.

3.1.3. SeArch (BCGS-MDRU-GBC)

Building on mapping completed by the BCGS between 2005 and 2009 (Nelson et al., 2006, 2007, 2008), this mapping project, north of Smithers and Terrace, was led by Mineral Deposits Research Unit (University of British Columbia), and completed in collaboration with BCGS, with funding from Geoscience BC. Economically significant porphyry and related mineralization is genetically related to Late Cretaceous and Eocene intrusions in a northeast-trending paleotopographic high (Skeena arch). Angen et al. (2017) provided an update of the project; final maps will be released in 2018, along with an update to the provincial geology compilation.

3.1.4. Trembleur Ultramafic Complex

The Trembleur ultramafic unit, host to the Decar awaurite prospect (Britten, 2017), was the focus of a one-year mapping

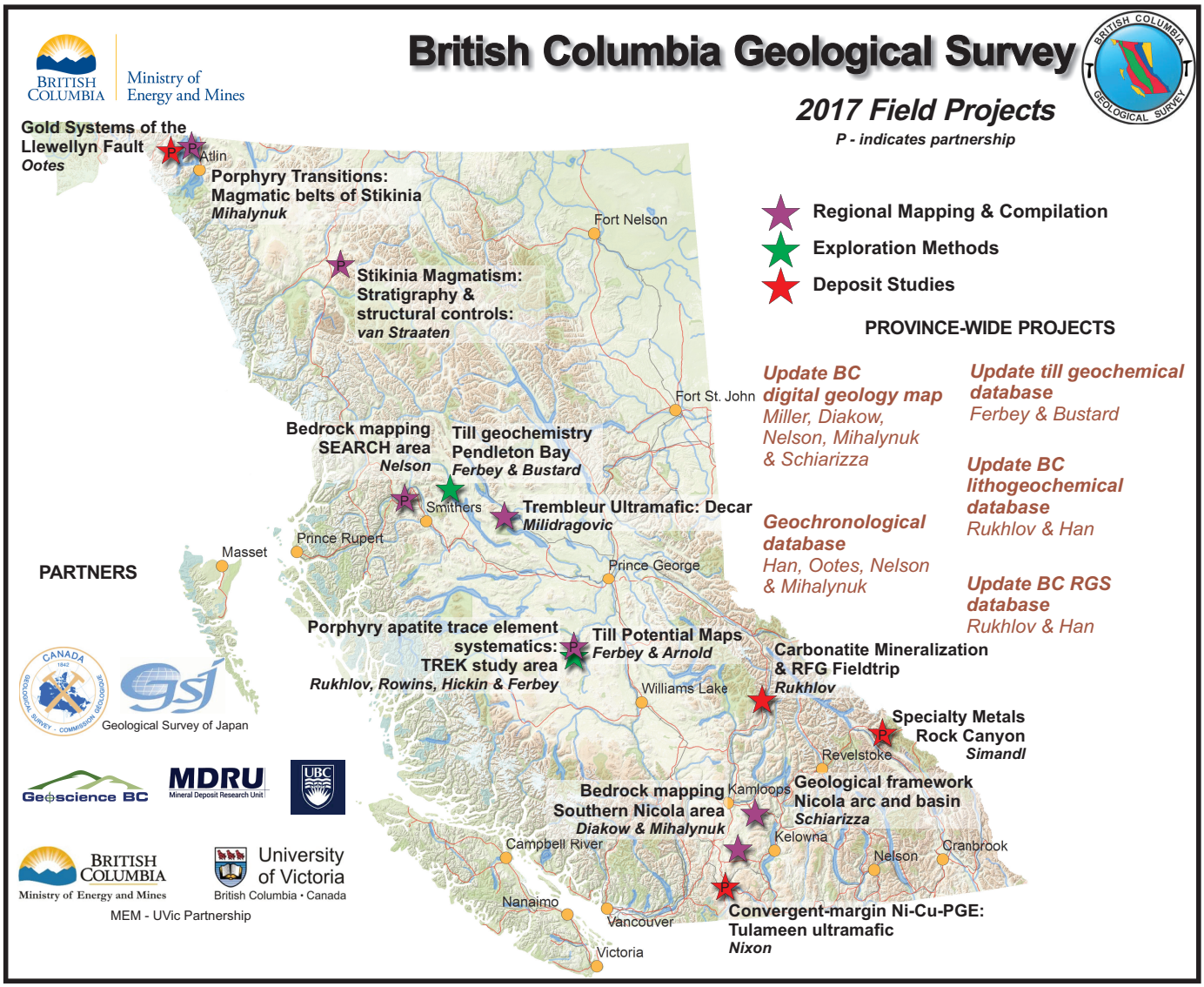


Fig. 5. British Columbia Geological Survey field projects in 2017.

project in 2017 (Fig. 8). The unit, forming a series of tectonic panels in the Cache Creek complex, is interpreted as obducted mantle that is overlain by massive to pillowed basalt flows, and intruded by sheeted diabase dikes. Formation of awaruite is intimately linked to hydrothermal alteration (serpentinization) of Ni-bearing Fe-Mg silicate minerals (olivine+pyroxene), and is therefore critically dependent on fluid chemistry and deformation history. At present, both the age and geochemical affinity of the unit are poorly constrained. Geochemical and isotopic characterization of the Trembleur ultramafic unit and overlying successions will be used to improve the petrological and tectonic framework of the Cache Creek complex and provide a better understanding of its Ni potential.

3.1.5. Till potential (BCGS-GBC)

Basal till potential maps are derived from surficial geology, terrain, or soils and landform data. The purpose of the basal till potential map series is to assist designing surface-sediment exploration programs by identifying areas where basal till is most likely to occur. Basal till is ideal for assessing bedrock-hosted mineral potential in areas covered by Quaternary sediments because it is commonly a first derivative of bedrock (Shilts, 1993), has a relatively simple and predictable transport history, and produces a geochemical and mineralogical signature that is more extensive than its bedrock source (Levson, 2001). Glacial transport and deposition of basal till produces a dispersal train elongated down ice from its bedrock source. In 2017, the BCGS and Geoscience BC released six new maps for the Targeting Resources for Exploration and Knowledge (TREK) project area of central British Columbia, complementing the 12 that were published in 2014.

3.1.6. Geological framework of the Nicola arc

Quesnel terrane is an important metallogenic belt that hosts

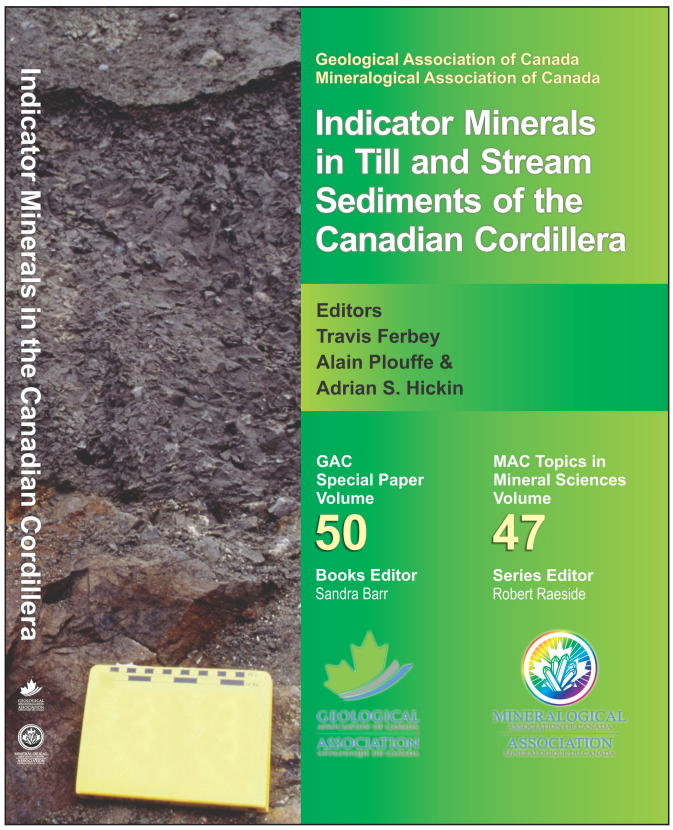


Fig. 6. Cover of the first joint GAC-MAC publication. The Minerals in Till and Stream Sediments of the Canadian Cordillera volume was coordinated by the BCGS with support from GSC.

Fig. 7. Horn Mountain Formation (Lower to Middle Jurassic) from the Dease Lake area.

most of British Columbia's producing porphyry Cu-Au-Mo mines. This Mesozoic arc complex includes Triassic to Jurassic volcanic and sedimentary rocks and related calc-alkaline and alkalic intrusions. In south-central British Columbia, the Nicola Group represents the supracrustal part of the arc and was originally named for exposures of volcanic rock and limestone on the south side of Nicola Lake. The Nicola Group

Fig. 8. Trembleur ultramafic rocks at the top of Mount Sidney-Williams, central British Columbia.

has not been formally defined or subdivided on a regional scale. Ages, typically Carnian or Norian, are known only locally, and syndepositional faults are known to control the distribution of some facies.

In 2015, the BCGS started a multi-year field-based program to establish a regional stratigraphic framework for the Nicola Group. The study aims to define the characteristics and ages of individual volcano-sedimentary facies, and establish their stratigraphic and structural relationships. Initial investigations were carried out in the Bridge Lake-Quesnel River area in 2015. The preliminary results included separation of Triassic rocks into the Nicola and Slocan groups, and dividing Nicola Group rocks into four stratigraphic assemblages (Schiarizza, 2016). The 2016 mapping covered the eastern part of the Nicola belt in the Stump Lake-Salmon River area, southeast of Kamloops (Schiarizza, 2017). The youngest Nicola rocks in this area correlate to assemblage four of the Bridge Lake-Quesnel River area, and older Nicola rocks were tentatively assigned to assemblages two and three, suggesting that the stratigraphic scheme may have general applicability. Easternmost exposures of Triassic rocks, along the Salmon River, were assigned to the Slocan Group, which highlighted the need for a better understanding of the relationships between the Slocan basin and the coeval Nicola arc to the west. Fieldwork in 2017, near the town of Likely, focused on an eastern siltstone-rich component of the Nicola Group and its relationship to the main part of the Nicola arc to the west, and the Slocan Group to the east.

3.1.7. Southern Nicola arc

The Southern Nicola Arc Project (SNAP), between Merritt and Princeton was a mapping project conducted from 2012 to 2015 (Mihalynuk et al., 2016). Ongoing work complements the Nicola arc project described above, refining stratigraphic subdivisions along a segment of the Late Triassic Nicola magmatic arc axis in southern Quesnel terrane. Recent results provide time-space relationships in three northerly trending

stratigraphic belts that were originally proposed to subdivide stratigraphy of the Nicola Group (Preto, 1979). Nicola arc magmatism occurred during a 37 million year interval, spanning the Middle Triassic to end of the Late Triassic. Stratigraphic ties, supported by conodont-biostratigraphy and radiometric ages, suggest the western and central belts evolved as a solitary block between 238 and 224 Ma, and that the central and eastern belts were stratigraphically linked before 202 Ma. The southern Nicola magmatic arc segment evolved during two major constructional stages, the first between 238 to 223 Ma, the second between 212 to 202 Ma. The economically significant calc-alkaline and alkalic intrusions spatially associated with the Nicola Group apparently coincide in age with the younger stage in southern Quesnellia. A 1:50,000-scale geoscience-series map that revises the stratigraphic and structural framework will be released and incorporated into the provincial geology compilation. Brief follow-up fieldwork in 2017 was aimed at: 1) infill mapping for selected areas; 2) targeted assessment of intra-arc stratigraphic relationships; and 3) geochronologic sampling to validate and constrain late-arc incision and erosion. These data will be incorporated into a depositional and tectonic reconstruction for the basin east of the Nicola arc.

3.2. Deposit studies

3.2.1. Gold and the Llewellyn fault (BCGS-GSC-TGI-5)

The Llewellyn Fault gold project is a collaboration between the GSC and BCGS, under the TGI-5 program (Ootes et al., 2017). The Llewellyn fault is a southeast-striking, steeply dipping brittle dextral strike-slip structure that overprints 'early' ductile deformation (Fig. 9). The Tally-Ho shear zone, Yukon, shares similar early ductile deformation and is overprinted by the Llewellyn fault. Previous work and this study demonstrate that brittle strike-slip deformation along the Llewellyn fault occurred between ca. 56 and 50 Ma (Love et al., 1998; Millonig et al., 2017). Results suggest that the early ductile fabrics formed before ca. 75 Ma and, potentially, after ca. 120 Ma. This study demonstrates that, although the early ductile and late brittle deformation share the same space, they developed at least ca. 20 Ma apart and are not part of a structural continuum. The various styles of gold mineralization developed during temporally distinct tectonic events.

Fig. 9. Investigating the Tally-Ho shear zone and Llewellyn fault at Mount Hodnett, Yukon.

3.2.2. Blue River Carbonatite

Carbonatites, such as those in the Blue River area of east-central British Columbia, continue to be of interest as potential sources of REE, Ta, Nb and other commodities. The area is in the Omineca belt, at the northeastern margin of the Shuswap metamorphic complex in the Monashee Mountains. Much of the area is underlain by Neoproterozoic supracrustal rocks and mafic intrusions that formed during rifting of western Laurentia. Several alkaline-ultramafic and carbonatite complexes were emplaced into these rocks during the Cambrian and Late Devonian-Mississippian (mostly ca. 330 Ma; Pell, 1994; Rukhlov and Bell, 2010; Millonig and Groat, 2013). The origin of carbonatite magmas, their mantle sources, and controls of their mineralization are not well understood. For example, the origin of the unusual Nb-Ta and Mo mineralization of the Blue River carbonatites remains ambiguous. This project examines the petrography, mineral chemistry, and isotope geochemistry of the Blue River carbonatites to better understand their petrogenesis and mineralization, and will be featured in a RFG 2018 conference fieldtrip to the Upper Fir deposit.

3.2.3. Specialty metals (BCGS-GSC-TGI-5)

Building on the collaborative work completed under the joint BCGS-GSC TGI-4 Specialty Metals project, the BCGS and GSC are advancing a multi-year partnership under the TGI-5 program. The continued availability of 'specialty metals', also referred to as high-technology metals or rare metals, is essential to the growth of the electronics and green-energy sectors. Specialty metals are informally defined as a group of materials considered critical or strategic for technologically advance devices and industrial processes but are produced in quantities of less than 150,000 tonnes/year. Examples include rare earth elements (REE), Li, Ta, Nb, Ga, Ge, In, Co, W, Mg, Cs, Rb, Rh, Be, Zr, Hf, V, Sb and Sc. Canada has a specialty metals resource potential to support domestic use, but remains underexplored. To help with the efficient search for, and extraction of, specialty metals, this project investigates the ore-forming mineralizing systems and geological conditions.

3.2.4. Convergent margin Ni-Cu-PGE

This project will advance the understanding of the metallogeny and potential of Ni-Cu-PGE deposits at convergent margins by investigating precious metal-enriched magmatic sulphide mineralization in late-stage differentiates of an Alaskan-type ultramafic-mafic intrusion. High-tenor Cu-PGE magmatic sulphides have recently been discovered in the Tulameen ultramafic-mafic intrusion, a classically zoned Alaskan-type complex. These discoveries led to establishing a new subclass of magmatic Ni-Cu-PGE deposit formed at convergent margins, and prompted re-evaluating the mineral potential

of ultramafic-mafic intrusions in the Cordillera and possible genetic links to porphyry Cu-Au systems (Fig. 10). This study complements a BCGS-University of British Columbia-TGI-5-funded project of broader scope that investigates the physical and chemical controls on the emplacement and contrasting metallogenic evolution of two Alaskan-type ultramafic-mafic intrusions in British Columbia: the Turnagain intrusion with its unusual endowment of Ni-Cu-PGE mineralization; and the Tulameen intrusion with early chromitite-PGE mineralization. Fieldwork in 2017 defined the mineralogical and geochemical characteristics of high-tenor Cu-PGE mineralization in late-stage differentiates of the Tulameen intrusion.

Fig. 10. Sampling pyroxenite and dunite exposed in bed of Tulameen River.

3.3. Exploration methods

3.3.1. Till geochemistry of the Pendleton Bay map area (93K/12)

Subglacial till geochemical surveys conducted in British Columbia have been effective at identifying covered mineralized bedrock sources, including both known and new mineral occurrences (Bustard and Ferbey, 2016). The Pendleton Bay map area (93K/12) is relatively underexplored compared to other areas of the Interior Plateau. In 1998, as part of the NATMAP Nechako Project, 182 subglacial till samples were collected and analyzed to assess the area's mineral potential. Geochemical results will be released in 2018 and preliminary interpretation shows that the most pronounced anomaly in the area is related to the Fort porphyry Cu±Mo±Au showing (MINFILE 093K 093). Here, elevated concentrations of Cu, Mo, Ni, Cr, As, and Zn occur in subglacial tills for up to 2 km to the southeast. This dispersal direction is consistent with the predominant ice-flow direction through the area during the Late Wisconsinan glacial maximum. Three new areas of geochemical interest were also identified from this data set, possibly related to porphyry-style mineralized systems.

3.3.2. Porphyry apatite

As a contribution to the GAC-MAC volume 'Indicator Minerals in Till and Stream Sediments of the Canadian Cordillera', this project applies the step-wise discrimination approach developed by Mao et al. (2016) that enables the subdivision of apatites by origin. Detrital apatite grains recovered from till in ten glaciated and underexplored study areas of the Nechako Plateau in central British Columbia were analyzed by electron probe microanalysis and laser ablation-inductively coupled plasma mass spectrometry. Based in previous BCGS-UVic work, the apatite grain trace element chemistry discriminated the major types of mainly magmatic-hydrothermal mineral deposits. Aided by till geochemistry, detrital chalcopyrite and gold grain counts, and airborne geophysics, the interpretation of these apatite data, enabled 342 apatite grains (344 analyses) to be classified as associated with mineralization, whereas 41 apatite grains were classified as derived from barren rocks. Mineralization-related apatite grains were classified as alkalic porphyry Cu-Au (80), porphyry Cu-Mo-Au (28), porphyry Mo (72), porphyry-related Cu-Au breccia (16), W skarn (112), orogenic Au (26), orogenic Ni-Cu (7), and Kiruna–type IOA (3) deposit-types. Detrital apatite grains in till down-ice from developed mineral prospects in brownfield areas were correctly identified by the discriminant method. Detrital apatites also helped to generate several new exploration targets in greenfield areas lacking known mineralization or hosting only minor mineral occurrences, demonstrating that the method is beneficial for exploring covered terrain.

3.3.3. Single grain XRF

Qualitative portable X-ray fluorescence (pXRF) offers a novel method of rapid, non-destructive identification of sand-size, single mineral grains. Using a (pXRF) instrument on 60 single-grain (0.5-1.0 mm) samples comprising 17 different rock-forming and accessory minerals, results of this study show that the essential constituents can be detected and used to identify ambiguous grains recovered from concentrates (e.g., Ca-P for apatite, Ca-Ti-Si for titanite, Ca-Nb-Ta for pyrochlore). Thus real-time readings (30-150 s) from a factory-calibrated instrument can cost effectively help identify separated sand-sized single mineral grains in the field or laboratory.

4. Resource Information Section

The BCGS creates, delivers, and archives geoscience data to help the mineral industry, resource planners, public safety agencies, communities, First Nations, government, research organizations, and the general public make decisions related to the Earth sciences. In particular, the data and derived products increase exploration effectiveness by enabling users to efficiently gather regional information for property-scale evaluation, and help explorers advance projects without duplicating previous work. To accomplish this mandate, the Resource Information Section continues to update databases and disseminate information through MapPlace 2.

4.1. MapPlace 2

Since 1995, MapPlace has provided web map services to help clients browse, visualize, and analyze geoscience and

mineral resource data, such as geology, mineral occurrences, regional geochemical survey, assessment reports, surficial geology, geophysical survey, and mineral tenures. Building on its predecessor, MapPlace 2 available on the BCGS website, continues to offer tools to query and generate custom results from data connected to many sources (Cui et al., 2017a, 2018).

MapPlace 2 works in commonly available web browsers, requires no plug-ins, and has a quicker, simpler, more intuitive interface that accesses third-party base maps and imagery from sources such as Google Maps and OpenStreetMap. MapPlace 2 is designed for anyone who wants to reduce the costs of accessing and analyzing geoscience data in British Columbia, including the mineral industry, resource planners, public safety agencies, communities, First Nations groups, government, research organizations, and the general public. Based on the MapPlace 2 (beta) Workshop notes (Cui et al., 2017a), the BCGS offers workshops on how to use MapPlace 2. BCGS will continue to improve MapPlace 2 with advanced applications and access to more databases.

4.2. Databases

ARIS is the searchable database of over 35,800 assessment reports submitted to the Ministry of Energy, Mines and Petroleum Resources, in compliance with Mineral Tenure Act Regulations. These reports summarize results from exploration programs on mineral claims. After a one-year confidentiality period, the reports become an open resource for planning mineral exploration, investment, research, land use, and resource management. Between 1967 and 2017, ARIS stored work representing expenditures of about $2.8 billion. Digital data are available for download from 480 assessment reports through the ARIS search application and monthly tables. The BCGS has been digitally capturing surface-sediment geochemistry data from reports in the Interior Plateau (Fig. 11). In early 2018, MapPlace will display more than 30,000 sample sites with over 1 million analyses from over 100 assessment reports dating between 2000 and 2015.

COALFILE is a library of 1000 Coal Assessment Reports submitted by exploration companies since 1900. It includes data from more than 15,400 boreholes, 540 bulk samples, 5500 maps, and 3600 trenches. MINFILE is an inventory documenting metallic mineral, industrial mineral, and coal occurrences in the province. With more than 14,650 entries, the database is being updated continuously. Users can query MINFILE by location, identification number, mineralogy, commodity, host rock, deposit type, geological setting, age, production, and references. Property File is a collection of more than 66,500 documents donated by people from government, universities, and industry dating from the late 1800s. Previously available only in hard copy, these documents can now be searched for, and downloaded from, the Property File database. Property File contains: unpublished reports; theses; field notes; company prospectuses; correspondence; hand-drawn maps; claim maps; mine plans; photographs; and geological, geochemical,

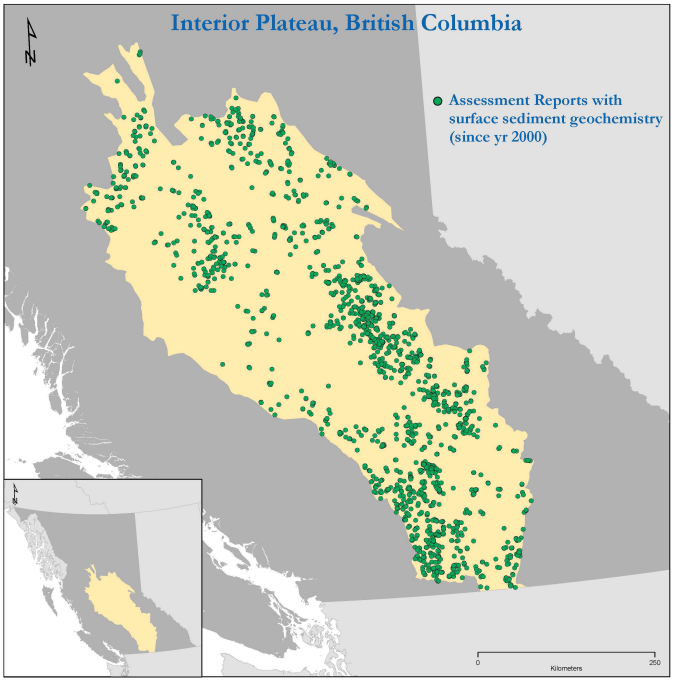


Fig. 11. Location of ARIS reports with surface-sediment geochemical sampling from the Interior Plateau since 2000.

geophysical, and drill data. The BCGS accepts donations to Property File.

The provincial geochemical databases hold field and geochemical data from multi-media surveys by the GSC, the BCGS, and Geoscience BC. The databases are updated regularly and contain results from: 1) the Regional Geochemical Survey program (RGS), including analyses from stream-sediment, lake-sediment, moss, and water samples; 2) till surveys; and 3) rock samples. The current version of the RGS database of about 65,000 samples is compiled from 111 original sources (Han and Rukhlov, 2017) and is delivered in flat tabular XLS format for ease of use and consistency with previously published data. The till index and till database were updated in 2017. The till index is available in various formats and links to 56 regional-scale and 78 property-scale subglacial till geochemical and mineralogical surveys (Bustard and Ferbey, 2016). The till database, a compilation from 39 reports released between 1992 and 2017, includes geochemical data from 10,450 samples and is released in XLS format (Bustard, et al., 2017). Han et al. (2016) published an update to the provincial lithogeochemical database, which includes a new data model and rigorous quality control. This database includes data from about 2000 papers and reports published by the BCGS, GSC, and universities between 1986 and 2015. The data set consists of about 11,000 samples, including a quarter million determinations analyzed by 26 different methods in 21 laboratories. New in 2017, is a coal ash chemistry database that will be of value to those seeking information on coal quality and coke strength (Riddell and Han, 2017).

Ice-flow indicator data were compiled from published and

unpublished surficial geology, terrain, and glacial feature maps. New data were generated using digital stereo airphotos, digital derived-stereo orthophoto mosaics, and digital derived-stereo SPOT imagery (Arnold et al., 2016). Using the geochemical database with ice-flow indicator data helps to target the location of mineral deposits. The geochemical databases and ice-flow indicators are available on MapPlace 2.

4.3. British Columbia digital geology map

BCGS provides digital coverage of British Columbia's bedrock geology, integrating details from compilations of field mapping at scales from 1:50,000 to 1:250,000. The bedrock geology of the entire province is held in a database, and people can download shapefiles to conduct computations and generate customized products. People can work in GIS software or MapPlace 2 (Fig. 12). A new 'geospatial frame data' model simplifies integration and reduces the time needed to move from field mapping to data delivery. The current edition (Cui et al., 2017b) includes updates to the Chilcotin-Bonaparte, northern Vancouver Island, North Coast, Kutcho, QUEST, and Terrace areas; updates to Nicola South and Bowser-Sustut basins are coming soon.

4.4. Three-dimension geological modelling

The BCGS conducted two 3D modeling exercises using GOCAD, one on the Turnagain intrusion and the other in the Ootsa Lake area. The Turnagain intrusion is an ultramafic-mafic Alaskan-type body that was emplaced in four discrete stages during a period of at least 3 million years (ca. 188-185 Ma). Nixon et al. (2017) generated a model (Fig. 13) based on field mapping aided by drill and structural data provided by Giga Metals Corporation (formerly Hard Creek Nickel Corporation). At Ootsa Lake, digital datasets were used to build a three-dimensional (3D) GOCAD model that estimated the thickness of unconsolidated sediments covering bedrock. The area hosts several porphyry Cu±Mo±Au deposits and the past-producing Huckleberry Cu-Mo mine. Estimates of drift thickness in the depth-to-bedrock model were based on bedrock surfaces identified in diamond drill holes, bedrock outcrop, and surface topography derived from aerial Light Detection and Ranging survey (LiDAR) data. Where combined with geophysical data, structural data, and geochemical anomalies identified in sediment from Regional Geochemical Survey (RGS) data, the depth-to-bedrock model is a useful aid in ranking exploration targets.

5. Mineral Development Office

The British Columbia Mineral Development Office (MDO) in Vancouver provides mineral and coal resource information and is a point of contact on issues affecting the exploration and mining industries. Through formal and informal activities including conferences, business meetings, investment missions, and over the counter contacts, the MDO promotes the province's mineral and coal industries both domestically and abroad.

A primary output is the delivery of a technical marketing campaign that highlights the province's mineral and coal potential, geoscience resources, global expertise, and attractive

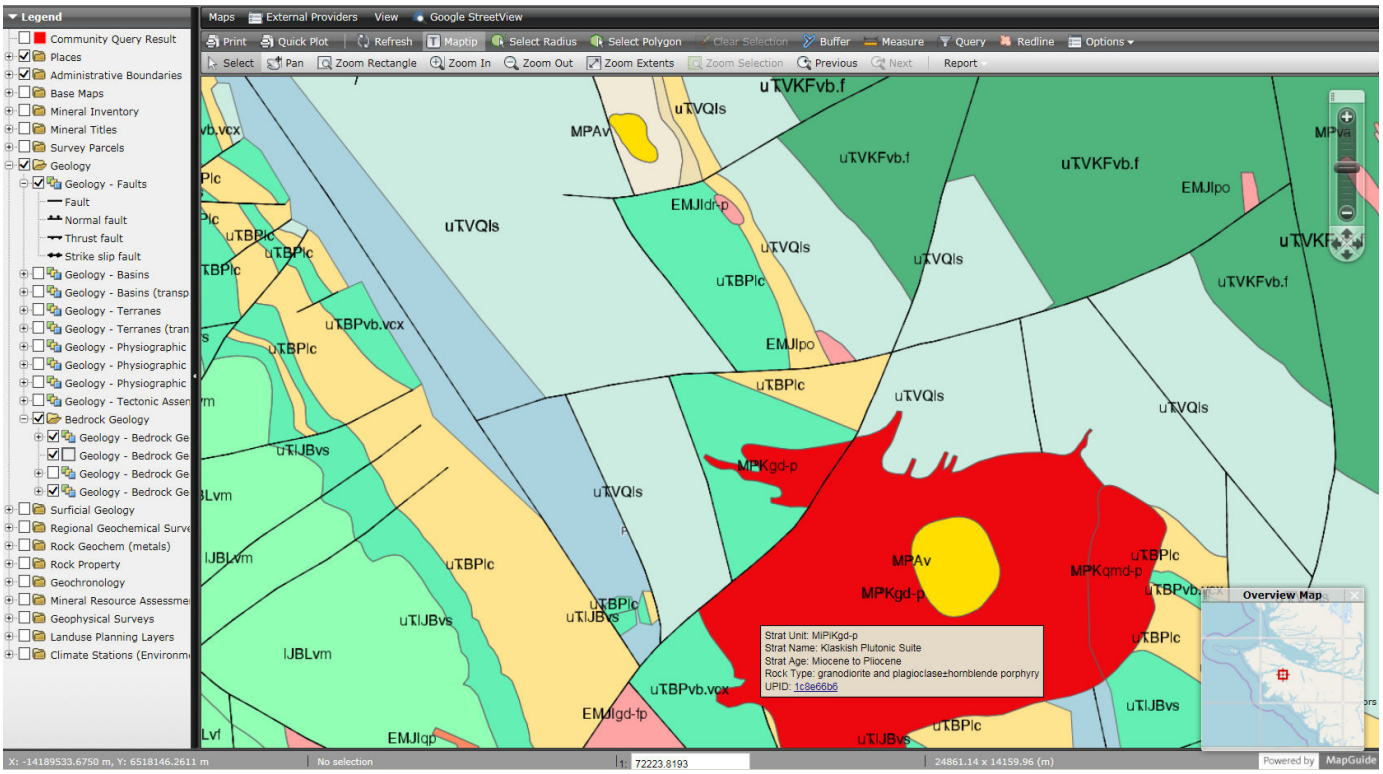


Fig. 12. Screen capture from MapPlace 2.

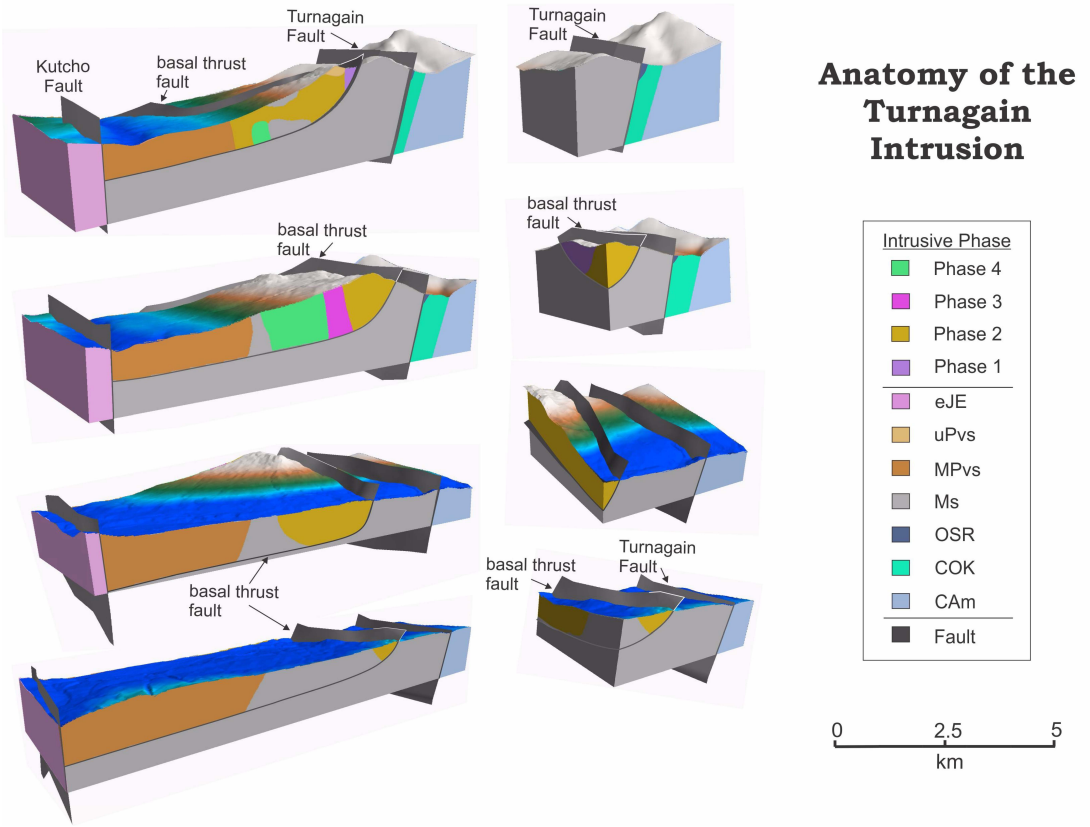


Fig. 13. 3D model of the geology in the Turnagain area from Nixon et al. (2017).

business climate. This includes developing publications aimed at audiences from large foreign investors through to independent domestic entrepreneurs. These publications are distributed widely at conferences, business meetings, over the counter, and online.

In September of 2017, the MDO supported the Ministry of Jobs, Trade and Technology at events in Asia. The MDO provided materials to raise British Columbia's profile at the Canada Mineral Investment Forum in Beijing and the Canada Mineral Investment Forum in Tokyo.

The MDO oversees publication of the 'Provincial Overview of Exploration and Mining in British Columbia' a document containing an overview of mineral exploration and mining activities in the different regions of BC written by the Regional Geologists and the MDO. The most recent annual summaries can be found in Clarke et al. (2018) and BCGS (2018).

6. Regional geologists

The British Columbia Regional Geologists (Table 1) represent the provincial government on geological matters at a regional level and capture information on industry activity in their jurisdictions. Within their communities, they provide information on exploration trends, possible investment opportunities, land use processes, First Nation capacity building, and public outreach.

7. Staff

After more than 30 years with the BCGS, JoAnne Nelson (Fig. 14), Senior Project Geologist and Northwestern British Columbia Manager, retired at the close of 2017. JoAnne's insightful scientific contributions and commitment to public service have made her a role model and leader in Cordilleran geoscience. JoAnne has influenced several generations of Cordilleran geologists and has published in national and international journals on topics that have strongly shaped our current understanding of Cordilleran tectonics. In addition to her research excellence, JoAnne has remained extremely active and enthusiastic member of the BCGS, organizing conferences, special sessions, and fieldtrips. JoAnne's accomplishments were formally recognized in 2013 when she was listed in the top '100 Global Inspirational Women in Mining' by the United Kingdom's Standard Bank. In 2015, she was awarded the 'Gold Pick' award by the Kamloops Exploration Group (KEG) in recognition of "outstanding services and contributions to the minerals industry". In 2017, she was given a 'Special tribute' by the Association of Mineral Exploration (AME) at the 2017 Mineral Exploration Roundup conference in recognition of her distinguished career in geoscience focused on the tectonics and metallogeny of the Northern Cordillera. JoAnne's decades of outstanding work in Canadian Earth science was recognized with the 2017 Provincial and Territorial Geologists Medal.

Table 1. British Columbia's regional geologists.

Regional Geologist	Office	Region
Vacant	Smithers	Northwest
John De Grace	Prince George	Northeast and North Central
Vacant	Kamloops	South Central
Fiona Katay	Cranbrook	Southeast
Bruce Northcote	Vancouver	Southwest

Fig. 14. JoAnne Nelson at her poster at Cordilleran Roundup in 1990 (top) and Joanne Nelson near Johnny Mountain, 2014 (bottom).

JoAnne remains active and will continue to contribute the Cordilleran Geology as an Emeritus Geoscientist with the Survey.

Acknowledgment

We thank George Owsiacki of Total Earth Science Services (Victoria) for the desktop publishing of this volume.

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