British Columbia Geological Survey annual program review 2019-2020

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1. Introduction

Founded in 1895, the British Columbia Geological Survey (BCGS) is the oldest scientific agency in the province. Throughout its history, the BCGS has conducted research (Fig. 1) and published information (Fig. 2) defining the geological evolution and natural resources of the province. The BCGS generates, disseminates, and archives British Columbia's geoscience information to make the province a competitive jurisdiction for mineral exploration and provide knowledge to guide land use and resource management decisions that balance the economy, the environment, and community interests. Survey maps, reports, and databases are freely available online, connecting the public, First Nations, local communities, the minerals industry, public safety agencies, environmental scientists, other research organizations, and government to the provinces' geology and mineral resources.

The BCGS is part of the Mines and Minerals Resource Division in the British Columbia Ministry of Energy, Mines and Petroleum Resources. The Survey is headquartered in Victoria and operates the Mineral Development Office (MDO) as its representative in Vancouver. Staffed by 29 people (Fig. 3), the BCGS consists of three sections: 1) Cordilleran Geoscience; 2) Resource Information and 3) the Mineral Development Office. The Cordilleran Geoscience Section is responsible for generating new geoscience knowledge through field-based bedrock and surficial geology mapping programs, regional geochemical surveys, and targeted mineral deposit studies. It also manages the Survey's laboratory, curates the provincial sample archive, and trains the next generation of field geoscientists. The Resource Information Section is responsible for maintaining and developing provincial geoscience databases and disseminating data online through MapPlace, the BCGS geospatial web service. The Resource Information Section is also responsible for collecting, evaluating, approving, and archiving mineral and coal exploration assessment reports submitted by industry to maintain titles in good standing. As the steward of mineral and coal resources in the province, the Survey has an important role in stimulating activity, attracting investment, and providing continuous research based on a corporate memory that extends back more than 125 years. The Mineral Development Office provides investment intelligence to government and global business. It also produces the annual Provincial Overview of Exploration and Mining in British Columbia volume (e.g., Clarke et al., 2020).

We are proud to announce that Emeritus Scientist JoAnne Nelson (Fig. 4) was awarded the 2019-2020 Howard Street Robinson Medal by the Geological Association of Canada. Regarded as the leading expert on the tectonics and metallogeny of the Cordillera, JoAnne's career as a field geologist spans more than 30 years. JoAnne continues to be generous with her energies, supporting new and old colleagues, and nurturing the next generation of field geologists. In 2017, JoAnne was awarded the Provincial and Territorial Geologists Medal by the Committee of Provincial and Territorial Geologists. The Survey is delighted that she is receiving the recognition she rightfully deserves.

The BCGS continues to renew itself. In 2019, the Survey welcomed Rebecca Hunter as a Senior Minerals Geologist and Pierre Landry as a Mineral Assessment Geoscientist. At the end of January 2020, Fil Ferri will retire after 32 years with the Ministry of Energy, Mines and Petroleum Resources. His position as the Director of Cordilleran Geoscience will be filled by Neil Wildgust. Other key geoscientist positions will be filled in 2020 as the Survey celebrates its 125th anniversary.

2. Partnerships

The British Columbia Geological Survey works to optimize resources through collaborative projects, and partnerships are important. The BCGS and the Geological Survey of Canada (GSC) are traditional partners and continue to work together in delivering projects through the second iteration of the Geo-mapping for Energy and Minerals (GEM 2) program and through three Targeted Geoscience Initiative 5 (TGI-5) projects.

In 2013, the Government of Canada renewed support for the second phase of the GEM program aimed at advancing geological knowledge and further developing modern geological maps and datasets. The BCGS collaborated with the GSC and the Yukon Geological Survey (YGS) through the

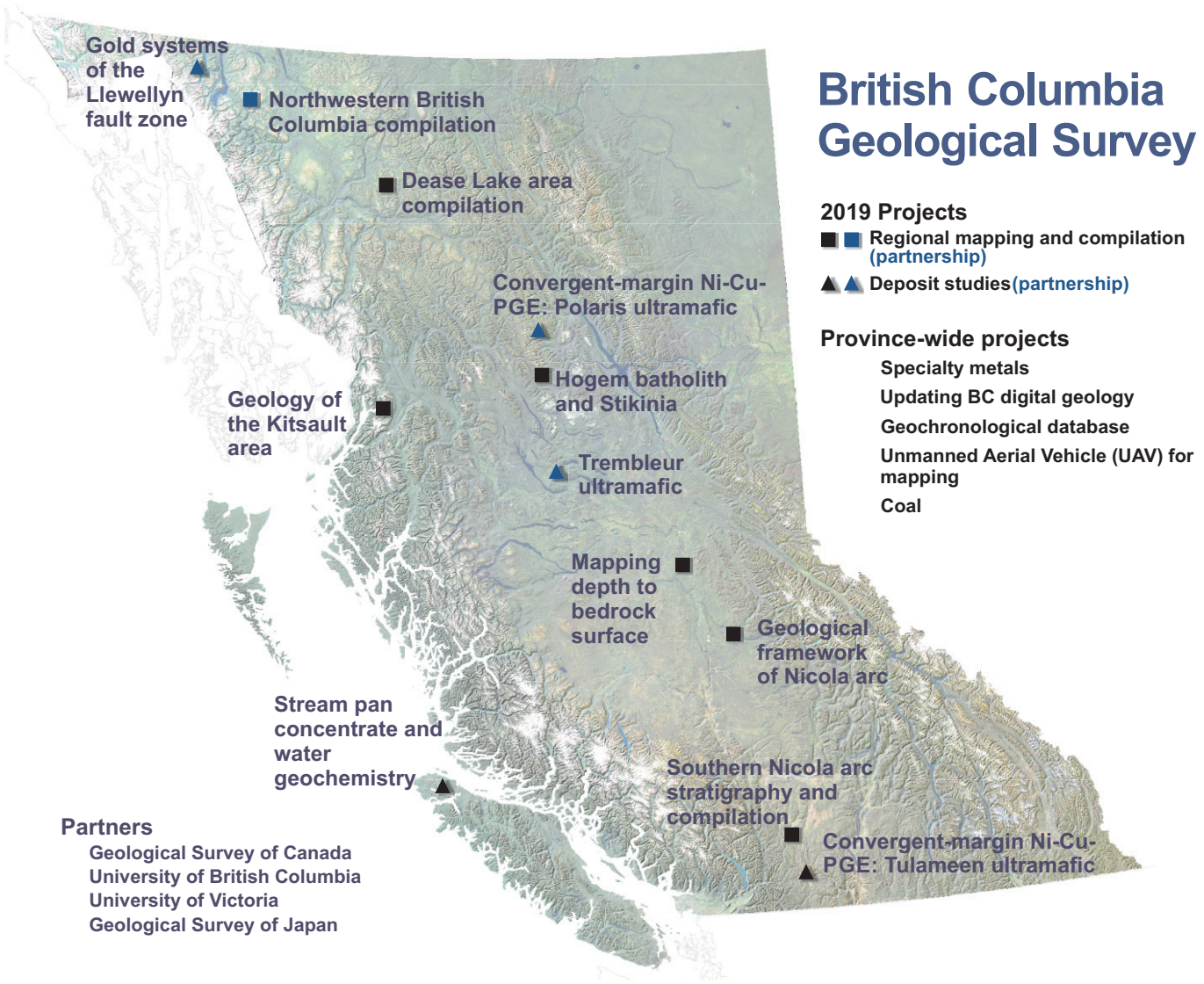


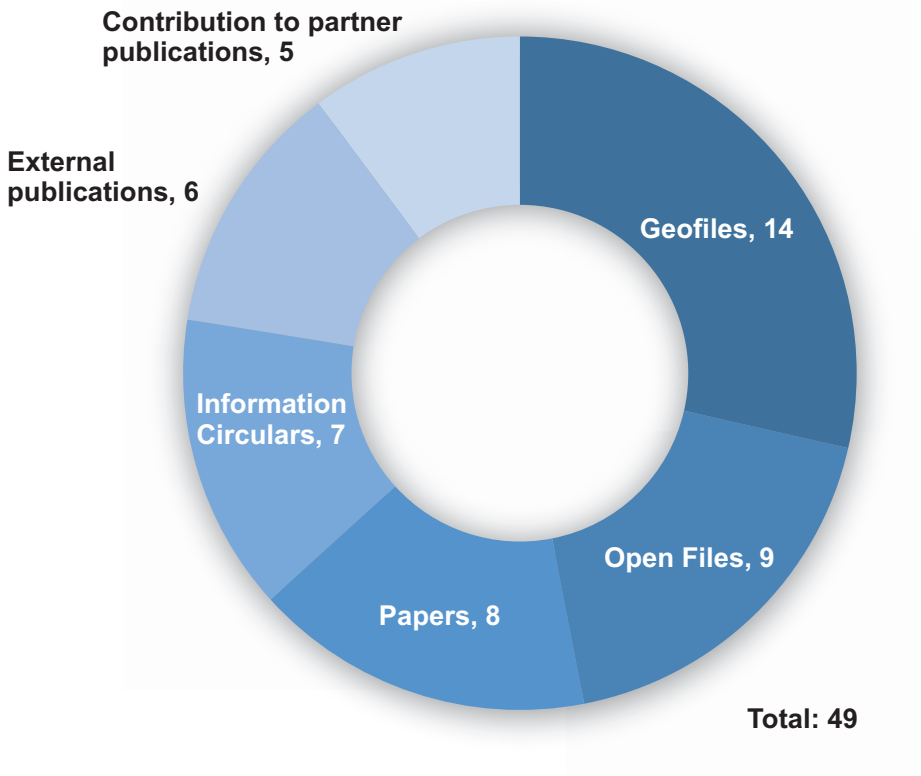
Fig. 1. British Columbia Geological Survey projects in 2019.

Cordilleran Activity, in which the British Columbia component focussed on the Cache Creek and Stikine terranes near Atlin. The GEM program will wrap up in 2020 and produce a summary volume and associated bedrock maps. In late March, the GSC, BCGS, and YGS, in conjunction with the Pacific Section of the Geological Association of Canada, will be holding a two-day workshop (Cordilleran Geoscience: A 2020 perspective) in Vancouver.

TGI-5 is directed at building knowledge and developing methods to more effectively target buried mineral deposits. The program aims to better understand the geological processes responsible for liberating ore metals from their source regions and to establish the controls on metals transport and deposition. The current iteration of TGI-5 is expected to conclude in 2020. BCGS projects include: 1) assessing gold deposits spatially related to the Llewellyn fault and Tally Ho shear zone in northwest British Columbia and southern Yukon; 2) examining specialty metal deposits that host rare earth elements, lithium, tantalum, and niobium (also in partnership with the Geological Survey of Japan); and 3) defining a new mineral deposit model for orogenic Ni-Cu-PGE mineralization in Alaskan-type ultramafic-mafic intrusions.

3. Cordilleran Geoscience Section

Geologists with the Cordilleran Geoscience Section collect fundamental geoscience data through single and multi-year field-based programs, including regional-scale mapping, mineral deposit studies, and developing new exploration methods. Collectively, these researchers provide a wide range of expertise that includes regional mapping, metallogeny, coal, tectonics, surficial and Quaternary geology, geochemistry, petrology, and mineral exploration methods.



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. 2. Types and numbers of publications produced by the British Columbia Geological Survey in 2019.

In addition to ongoing work, this volume presents results from a previous project in which Schiarizza et al. (2020) report new U-Pb detrital zircon ages from the Gun Lake unit (Noel Formation) in the Bridge River area of southwestern British Columbia. They show that certain sections previously considered to be equivalent to the lower Relay Mountain Group are correlative to the middle part of this group and the younger Paradise Formation. Elia and Ferbey (2020) describe the use of

Fig. 3. Members of the British Columbia Geological Survey, 2019.

Fig. 4. JoAnne Nelson mapping in the Iskut area.

remotely piloted aircraft systems to generate photogrammetric digital elevation models. These models are easy to acquire, affordable, and immediately accessible, providing field crews with geologic details in near real-time that otherwise might not have been gained.

3.1. Mapping, regional synthesis and compilation

3.1.1. Porphyry transitions (BCGS–GSC)

This project, a collaboration with the Geological Survey of Canada through the Geo-mapping for Energy and Minerals (GEM 2), was initiated in 2016 to test the continuity of prospective Triassic-Jurassic magmatic rocks into northern Stikinia and assess their porphyry potential. With the GEM 2 wrap up in 2020, the project will produce a final report and map compilations.

3.1.2. Stratigraphic architecture of the Nicola arc

Although the field component of the Nicola arc project was completed (Schiarizza, 2019), the project continued with synthesis of earlier mapping (Schiarizza, 2016, 2017, 2018) and compilation of work in the Merritt and Princeton areas (Mihalynuk et al., 2014, 2015, 2016) to produce a coherent stratigraphic framework for this important metallotect. This compilation will be incorporated into the British Columbia digital geological database.

3.1.3. Regional mapping in the Dease Lake area

Major field activities for this project finished in 2018. This

mapping program focussed on Upper Triassic to Middle Jurassic arc-related volcanic and sedimentary rocks encircling the Hotailuh batholith in order to refine the tectonic and metallogenic history of northern Stikinia (van Straaten et al., 2012, 2017; van Straaten and Bichlmaier, 2018; van Straaten and Wearmouth, 2019). A very limited field program took place in 2019 to further refine unconformable relationships between the Stuhini Group (Upper Triassic) and the Horn Mountain Formation (Lower Jurassic). Field data from 2019 will be incorporated with work from previous years, compiled into a 1:100,000 Geoscience Map, and incorporated into the British Columbia digital geology database. In addition, all geochronology, paleontology, petrography, lithogeochemistry, structural, and petrophysical data will be released in a GeoFile publication.

3.1.4. Northern Hogem batholith, Stikine and Cache Creek terranes

A multi-year bedrock and surficial mapping project was initiated in 2018 targeting northern Hogem batholith and adjacent intrusive, volcanic and sedimentary rocks of the Stikine and Cache Creek terranes (Ootes et al., 2019 a, b; Fig. 5). The main objectives of this project are to update the bedrock and surficial maps of the area and incorporate new geochronological and lithogeochemical data to better understand the timing of intrusive events and relationship to mineralization.

Mapping in 2019 (Ootes et al., 2020a, b) further refined the distribution and relationships of plutonic rocks in northern Hogem batholith. The Hogem batholith is a composite body consisting of: ca. 197 Ma hornblendite and diorite of the Thane Creek suite; 182 to 178 Ma biotite pyroxenite and syenite of the Duckling Creek suite; ca.160 Ma granite of the Osilinka suite; and ca. 174 Ma tonalite and 140 to 135 Ma granodiorite and granite of the Mesilinka suite. All units contain a penetrative foliation, and $^{40}Ar/^{39}Ar$ biotite ages indicate post-deformation cooling and uplift after ca. 124 Ma. Mafic to ultramafic intrusions (Abraham Creek and Dortatelle Creek complexes) were also mapped in the Quesnel terrane. The Hogem batholith is bounded to the north and east by volcanic and sedimentary rocks of the Nicola Group (Triassic) along fault and intrusive contacts. To the west, Hogem batholith and Nicola Group are separated from the Cache Creek and Stikine terranes along the Pinchi-Ingenika dextral strike-slip fault system; farther west, an unexposed thrust fault juxtaposes Cache Creek rocks above Stikine terrane rocks. The Stikine terrane in the study area includes the Asitka Group (Carboniferous to Permian) volcano-sedimentary basement that is overlain by immature siliciclastic sedimentary rocks of the Dewar Formation (Takla Group; Triassic), and which is overlain by the Telkwa Formation (Hazelton Group; Jurassic). Uppermost Hazelton Group rocks pass upwards into Jurassic and Cretaceous siliciclastic rocks of the Bowser and Sustut groups, which constitute overlap assemblages deposited after the terranes amalgamated. Cache Creek terrane encompasses metamorphic rocks of the Sitlika assemblage (Lower Jurassic), which have sedimentary and volcanic protoliths, serpentinites of the Trembleur ultramafic complex (Permian to Upper Triassic), mixed volcanic and metasedimentary rocks of the Sowchea succession (Upper Pennsylvanian to Lower Jurassic), and Cretaceous intrusive rocks of the Axelgold layered mafic intrusion. About 88 mineral occurrences in the area are documented in MINFILE. Seven new occurrences were discovered in 2019. When combined with results of 2018 mapping, 24 new mineral occurrences have been documented in the study area. Porphyry Cu±Mo, Au in Hogem batholith is the predominant type followed by quartz-carbonate vein-hosted base and precious metals in Quesnel and Stikine terranes, and volcanic/sediment-hosted Cu in the Telkwa Formation of the Stikine terrane.

Fig. 5. Looking north at the rugged terrane of northern Hogem batholith; see Ootes et al. (2020a).

3.1.5. Hazelton Group stratigraphy and associated mineralization in the Kitsault area

In 2019, the BCGS initiated a new regional mapping program in the Kitsault area of northwestern British Columbia, in the southern part of a region popularly referred to as the Golden Triangle (Hunter and van Straaten, 2020; Fig. 6). This region is well known for its significant porphyry Cu-Au, epithermal Au, and volcanogenic massive sulphide (VMS), and precious and base metal deposits. Although this area was mapped by Alldrick et al. (1986), it lacked modern geochronology and lithogeochemistry. In addition, our knowledge of Stuhini Group (Triassic) and Hazelton Group (latest Triassic to Middle Jurassic) stratigraphy has significantly advanced since this original work (e.g., Nelson et al., 2018). This project builds on concurrent research nearby at Kinskuch Lake by Miller et al. (2020; see below).

Mapping focussed on facies analysis of Hazleton Group volcanosedimentary rocks. New U-Pb geochronology from detrital zircons indicates a maximum depositional age of ca. 206 Ma (Rhaetian) for the onset of Hazelton Group volcanism. A monzonite dike near the Homestake Ridge deposit yielded a U-Pb age of ca. 191 Ma suggesting that this Cu-Au

Fig. 6. Maroon volcanic breccia in the lower part of the Hazelton Group in the Kitsault area; see Hunter et al. (2020).

mineralization is Early Jurassic. Felsic lapilli tuff in underlying the Wolf deposit contain zircons with crystallization ages of ca. 178 Ma indicating that this VMS related mineralization is in the upper part of the Hazelton Group, and a volcanic-derived sandstone sample from the southern shore of Kitsault Lake returned a detrital zircon maximum depositional age of ca. 169 Ma. These upper Hazelton Group units differ from those in the Eskay rift and at the Anyox deposit, which contain abundant bimodal felsic and mafic volcanic rocks. Nonetheless, these coeval syngenetic mineralizing systems are likely related and VMS mineralization in the Kitsault River area may reflect hydro-magmatic fluids flowing along syndepositional faults to near-surface levels. Extensional processes that operated at Eskay may have extended into in the Kitsault River area but without producing a large rift basin.

3.1.6. Geology of the Kinskuch Lake area

Mapping by Miller et al. (2020) in the Kinskuch Lake area during the last two summers has focussed on the depositional and structural history of the Stuhini and Hazleton groups and related Cu mineralization at the Big Bulk prospect. This work indicates that syndepositional faulting in the Rhaetian (latest Triassic) strongly influenced the transition from Stuhini Group to Hazelton Group deposition. Conglomerates, informally referred as the Kinskuch conglomerates, containing Stuhini Group-derived megaclasts (up to 120 m) at the base of the Hazelton Group (Fig. 7) signify a high-relief, fault-generated paleotopography and mark a fundamental break in the tectonic history of the region. This tectonism also appears to be related to emplacement of Cu mineralization in the Big Bulk porphyry system, which returned a U-Pb zircon age of 204.61 ±0.18 Ma. Like other areas in northwestern Stikinia, latest Triassic to Early Jurassic sedimentation, magmatism, and porphyry mineralization appear to have had a strong structural control.

Fig. 7. Dark grey-weathered Stuhini Group-derived megaclast in Kinskuch conglomerate, basal Hazelton Group near Kinskuch Lake; see Miller et al. (2020).

3.2. Deposit studies and exploration methods

3.2.1. Late Neogene porphyry Cu-Mo(±Au-Ag) mineralization, northern Vancouver Island

In northern Vancouver Island, recent high-precision dating (U-Pb zircon and Re-Os molybdenite) of mineralized stocks of the Klaskish Plutonic Suite (ca. 7 to 4.6 Ma) show that porphyry Cu-Mo magmatic-hydrothermal systems are genetically linked to pluton emplacement and crystallization. This dating also confirms that the emplacement of these plutons was coeval with older phases of Alert Bay volcanism (8-2.5 Ma). Nixon et al. (2020) formally name the Klaskish Plutonic Suite and show that these plutons, which are in the forearc of the Cascadia subduction zone, define the northeast trending late Neogene Brooks-Haddington tract that extends for 65 km across the island, from the Pacific Coast to Queen Charlotte Strait. Previous to this work, Neogene Mo/Cu-Mo mineralization elsewhere in British Columbia was thought to have been restricted to the Pemberton arc along the southeastern Coast Mountains. Dating is key in distinguishing these Neogene plutons from Early to Middle Jurassic intrusions of the Island Plutonic Suite which host major porphyry Cu-Mo-Au-Ag deposits on the island. These young plutons in northern Vancouver Island define an extensive and underexplored Cu-Mo porphyry metallotect.

3.2.2. Specialty metals

Part of the TGI-5 program, the specialty metals project is a BCGS collaboration with the GSC and Geological Survey of Japan. Specialty metals are elements that are essential to the growth of the electronics and green-energy sector, and critical or strategic for technologically advanced devices and industrial processes. They include rare earth elements (REE), Li, Ta, Nb, Ga, Ge, In, Co, W, Mg, Cs, Rb, Rh, Be, Zr, Hf, V, Sb and Sc.

Work in 2019 focussed on laboratory analyses of carbonatite samples collected in the last six years, compilation, and publication. Akam et al. (2019) published a paper about selecting analytical procedures and reference materials for evaluating REE-bearing deposits and a paper documenting mineral control on chemical zoning in the main mineralized zone at the Rock Canyon Creek REE-Ba-F deposit is in progress. In addition, rare earth element concentrations were acquired from dolomite and calcite hosted by various deposits and deposit-types, including: 1) Mississippi Valley-type deposits; 2) the Rock Canyon Creek deposit (Paradis and Simandl, 2019); 3) the Mount Brussilof magnesite deposit (Simandl et al., 2019) and 4) carbonatites in general. The concentration and pattern of these elements will be described in external papers that focus on each deposit or deposit-type.

3.2.3. Polaris: towards a new mineral deposit model for convergent margin Ni-Cu-PGE (BCGS–TGI-5)

This is the second year of a TGI-5 project that builds on our current understanding of high-tenor Ni-Cu-PGE-bearing Alaskan-type ultramafic-mafic intrusions. The primary objective of this project is to establish the temporal and magmatic evolution of the Polaris intrusion that will have implications on the nature and timing of sulphide mineralization. This new work will ultimately feed into the development of a new mineral deposit model encompassing the temporal evolution and ore system processes involved in the genesis of Ni-Cu-PGE-rich sulphides in Alaskan-type ultramafic bodies in the Cordillera.

Work in 2019 (Nott et al., 2020) focussed on delineating the main phases of the Polaris ultramafite, showing it to be an elongate, 14 km long, sill-like body with rock types distributed asymmetrically. Dunite is predominant in the east, wehrlite, clinopyroxenite, and mixed zones in the central parts, and gabbro-diorite to hornblende clinopyroxenite in the west. Chromitite layers, hosted primarily by dunite, occur as schlieren and Ni-Cu-platinum group element sulphides are mainly hosted by clinopyroxenite. Future work will focus on the emplacement history of the various phases based on detailed geochronological analyses.

3.2.4. Serpentinized ultramafic rocks and CO_2 sequestration

The BCGS continues to work on projects aimed at a low-carbon economy. This is primarily through a partnership with the University of British Columbia under Natural Resources Canada Clean Growth Program that will determine the feasibility of ultramafic rock tailings to sequester CO_2 from the atmosphere. BCGS researchers will also compile the distribution of serpentinized ultramafic rocks in the province that have the potential to sequester CO_2.

Fieldwork in the Trembleur Lake area (Steinthorsdottir et al., 2020) focussed on serpentinized ultramafic rocks in the Cache Creek terrane that are part of the Decar Ni prospect. Here, Ni-bearing awaruite is associated with brucite, which can sequester CO_2 from the atmosphere. Work in 2019 focussed on the protoliths and alteration of the Trembleur ultramafite and resulted in recognizing that the primary ultramafite composition likely controlled fluid pathways and the extent of serpentinizing fluids and the abundance and distribution of awaruite and brucite. The heterogeneity in the Trembleur ultramafite protolith, together with the extent of alteration will have implications on the abundance and distribution of brucite and awaruite and, ultimately, the nickel and carbon sequestration potential of this occurrence.

3.2.5. Rapid, inexpensive and effective drainage geochemical surveys for mineral exploration

Typically, heavy mineral surveys use extensive laboratory processing of bulk samples to recover heavy mineral concentrates and indicator minerals. This process is expensive and beyond the affordability for most prospectors. In this volume, Rukhlov et al. (2020), describe a method for collecting heavy mineral separates in the field using a portable sluice, and panning, that is both effective and inexpensive (Fig. 8). This pilot study was undertaken in northern Vancouver Island where it confidently identified known mineralization in stream drainages that conventional stream and moss-captured sediments commonly failed to detect, even where close to known mineralization. In addition, Rukhlov et al. (2020) describe the use of Pb isotopic data and show that they are effective at fingerprinting different mineralizing systems. They propose a three-stage survey consisting of reconnaissance, exploration and detailed steps. Reconnaissance-level work targets 3rd order and higher drainages leading to exploration-level sampling at the mouths of tributaries within basins identified as being anomalous. This part of the survey will identify the single drainage containing the anomaly leading to focussed prospecting and detailed geochemical and geophysical surveys.

Fig. 8. Photomicrographs of panned sluice heavy mineral concentrate with abundant pink euhedral Mn-rich almandine in 1-2 mm fraction; see Rukhlov et al. (2020).

3.2.6. Exploration in drift-covered areas of the Interior Plateau

Abundances of major oxides and pathfinder elements are

not typically used in drift prospecting. Using analytical data from subglacial till samples collected in the Highland Valley mine area by Ferbey et al. (2016) and principal component analysis, Shewchuk et al. (2020) demonstrate that major oxide concentrations can detect drift-covered porphyry Cu-Mo mineralization. Furthermore, the pathfinder elements Pb, Zn, As and Sb also delineate local dispersal fields. This analysis can also outline specific rock types in the area. This method offers a potentially new exploration and mapping tool in heavily drift covered areas.

To help steer future exploration efforts, the BCGS is currently undertaking a regional depth-to-bedrock study in the drift-covered area of the Quesnel terrane between the Mount Polley and Mount Milligan Cu-Au porphyry deposits. This project will use publically available data, including drill hole, bedrock, and surficial maps to establish the geometry of the bedrock-drift interface.

3.3. Geochemical and geochronological databases

BCGS field activities generate voluminous geochemical data, primarily in the form of rock, till, stream-sediment, and coal analyses. This information is currently contained in individual representative databases. A current project is developing a skeleton data model (Han et al., 2019) capable of capturing and representing the commonalities of these different data sets. Establishing a reliable method for managing BCGS geochemical data, this skeleton data model will update current databases and streamline data handling. In addition, an effort is underway to update and modernize the current geochronological database for the province.

4. Resource Information Section

The British Columbia Geological Survey is the custodian of all provincial public geoscience data. Since its inception, the main activities of the BCGS have been targeted at enhancing the province's geological knowledge base and making it a competitive jurisdiction for mineral exploration. This entails constantly upgrading databases and making this information, and its derivatives, easily accessible through web portals. BCGS geoscientists collect fundamental geoscience information that is funneled into these online databases and used by industry to develop projects and assist with the search for new discoveries. This information includes traditional geological maps together with thematic studies and reports, geochemical, geophysical, and geological databases, plus archived information such as MINFILE, COALFILE, and Property File.

4.1. MapPlace

MapPlace is the BCGS geospatial web service to efficiently visualize, search, report, and generate custom results and maps from all province-wide geoscience databases (Fig. 9). Some of the advanced applications and user interfaces are specifically designed to enable research and analysis in mineral exploration and prospecting. Easy access to, and analysis of, geoscience data and maps are fundamental for informing decisions about mineral exploration, mining, environmental protection, and land use management. MapPlace 2 provides a platform to facilitate the discovery, display, search, and analysis of geoscience in the context of all other relevant data such as mineral titles, assessment reports, linear infrastructure, aquifers, topography and satellite imagery. After 25 years of webservice, the original MapPlace will be retired this year.

4.2. ARIS reports and database

ARIS (Assessment Report Index System) is a database linking to a collection of mineral exploration assessment reports submitted in compliance with the Mineral Tenure Act Regulation. The ARIS library of more than 37,600 PDF reports dating from 1947 describes exploration work valued at more $2.8 billion. After a one-year confidentiality period, the reports become an open resource for planning mineral exploration, investment, research, land use, and resource management. All reports are available online as PDF documents through the Survey website. Digital data from 545 assessment reports are available for download through the ARIS search application and monthly tables. The ARIS database records metadata about the location, mineral occurrences, commodities, claims, general and specific work types, and expenditures in the reports. A version of the ARIS database is available in Microsoft Access format (.mdb) from the BCGS digital geoscience data webpage.

Extracting data in assessment reports from the Interior Plateau, Norris and Fortin (2019) generated a surface sediment geochemical database with a total of more than 1.45 million determinations from about 34,000 samples. This work has continued, and more data have been added to the database and incorporated into MapPlace 2. In another project that harvests data from assessment reports, the BCGS has begun to develop a drill hole database.

4.2.1. ARIS digital data submission

Traditionally, data in assessment reports have been embedded in paper or non-digital electronic files, such as PDF, making them difficult to extract and use. To resolve this problem, the Survey has embarked on a program to encourage digital data submission. Explorationists will benefit because digital data can be easily retrieved, integrated, processed, recalculated, and recast for specific needs. Digital submission will also enable the Survey to better maintain province-wide databases and create derivative products that use past results to guide future exploration.

The BCGS requests the submission of digital data files such as spreadsheets, databases, maps, grids describing technical work in an assessment report. Data can be uploaded through the ARIS data submission page (http://ardata.bcgeologicalsurvey.ca), submitted by CD/DVD/USB when a report is filed, or e-mailed to ARIS.digital@gov.bc.ca.

4.3. Other databases

COALFILE includes a collection of 1020 coal assessment reports dating from 1900. Associated data include

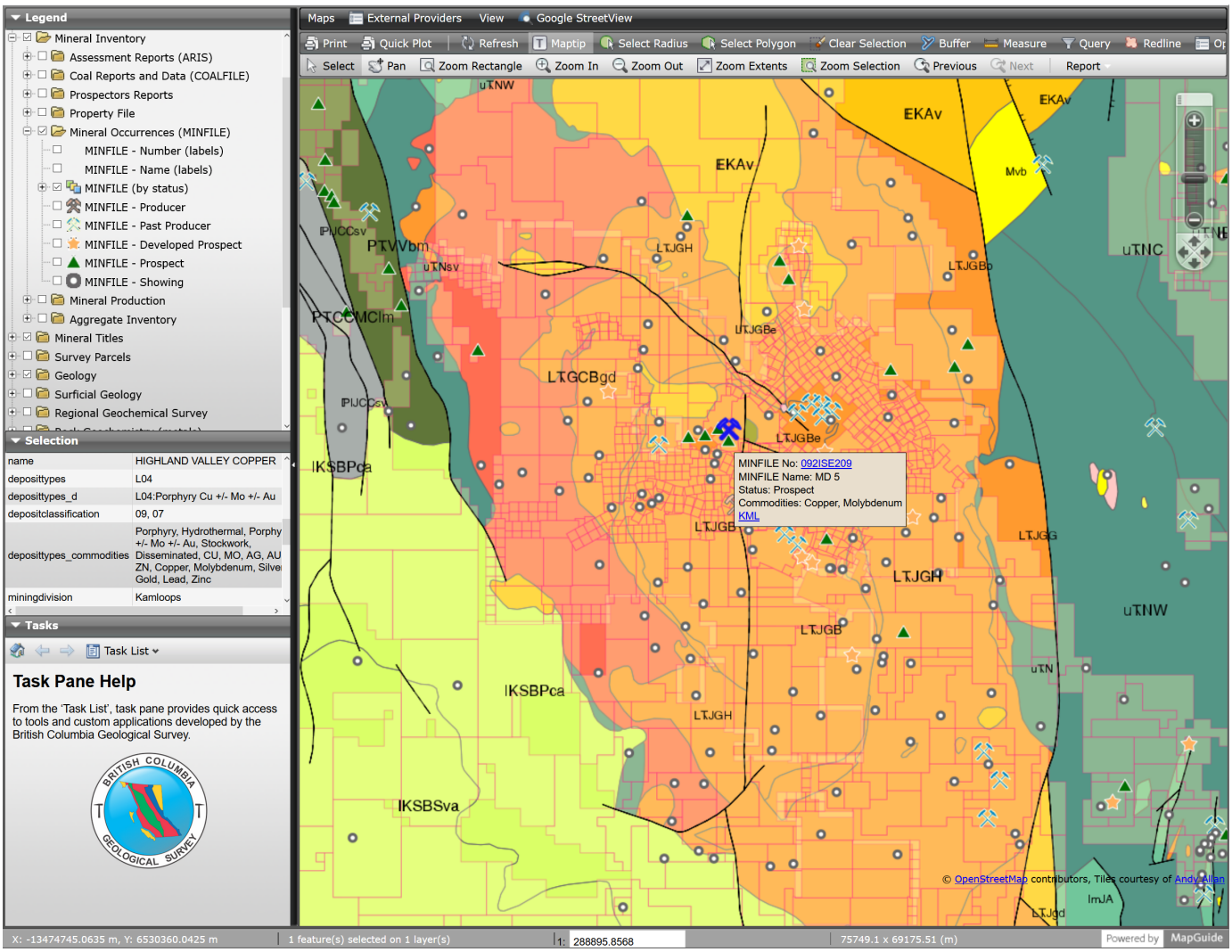


Fig. 9. MapPlace interface with the geology of the Highland Valley mine area and data from MINFILE, and Mineral Titles Online.

15,900 boreholes, 550 bulk samples, 5500 maps, 3650 trenches, 484 coal ash chemistry analyses and links to MINFILE. COALFILE data are integrated with MapPlace.

MINFILE is a database for mineral, coal, and industrial mineral occurrences and associated details on geology and economic information for more than 15,000 records. In the last year, more than 200 new occurrences and 480 updates were added to the database. The web-enabled MINFILE search application interacts with MapPlace, ARIS and Property File. The BCGS implemented the open geoscience standard EarthResourceML and developed interoperable connections of the Survey's mineral inventory databases for the OneGeology portal.

Property File is a collection of more than 82,400 archived reports, maps, photos, and technical notes documenting mineral exploration activities in British Columbia from the late 1800s. These documents are accessible in a full-text, searchable, online database. Recent additions include 1400 documents from Albert Reeves, 1900 documents from Gerry Carlson, and the complete collection of George Cross Newsletters. The records are spatially linked to MINFILE. The Survey accepts donations to Property File.

The provincial geochemical databases hold field and geochemical data from multi-media surveys by the Geological Survey of Canada, the BCGS, and Geoscience BC. The databases are updated regularly and contain results from: 1) the Regional Geochemical Survey program (RGS) including analyses from more than 65,000 stream-sediment, lake-sediment, moss, and water samples; 2) 10,500 till surveys; and 3) 11,000 lithogeochemical samples.

4.4. British Columbia digital geology map

The BCGS offers province-wide integrated digital coverage of bedrock geology, including details from compilation of field mapping at scales from 1:50,000 to 1:250,000. The British Columbia digital geology continuously integrates new regional compilations. The bedrock geology is standardized with consistent stratigraphic coding, ages, and rock types to enable computations. The digital geology is available for download in GeoPackage and Esri shapefile formats. Customized

bedrock geological maps and legends can be explored and data downloaded as KML by spatial and non-spatial queries via MapPlace. The Survey is using vocabularies adopted by the Commission for the Management and Application of Geoscience Information, which enables the access to the digital geology on the OneGeology portal and allows interoperable connections of Survey databases to the exploration and mining industry.

5. Mineral Development Office

The Mineral Development Office is the Vancouver base of the British Columbia Geological Survey. It links the more than 800 exploration and mining companies headquartered in Vancouver to provincial mineral and coal information. The MDO distributes Survey data and provides technical information and expertise about mineral opportunities to the domestic and international investment community. The MDO monitors the activities of the mining and exploration sectors and co-ordinates production of the 'Provincial Overview of Exploration and Mining in British Columbia', an annual volume that summarizes activities in the different regions of the province and written by the Regional Geologists and the MDO (see e.g., Clarke et al., 2020).

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. We welcome Sean Tombe as the new Regional Geologist for the Northwest Region.

Table 1. British Columbia Regional Geologists.

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

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References cited

Akam, C., Simandl, G.J., Let, R., Paradis, P., Hoshino, M., Kon,Y., Araoka, D., Green, C., Kodama, S., Takagi, T., and Chaudhry, M., 2019. Comparison of methods for the geochemical determination of rare earth elements: Rock Canyon Creek REE–F–Ba deposit case study, SE British Columbia, Canada. Geochemistry: Exploration, Environment, Analysis 19, 414-430. https://doi.org/10.1144/geochem2018-044.

Alldrick, D.J., Dawson, G.L., Bosher, J.A., and Webster, I.C.L., 1986. Geology of the Kitsault River Area (NTS 103P), British Columbia British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Open File 1986-02, scale 1:50,000.

Clarke, G., Northcote, B., Katay, F., and Tombe, S.P., 2020. Exploration and Mining in British Columbia, 2019: A summary. In: Provincial Overview of Exploration and Mining in British Columbia, 2019. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Information Circular 2020-01, in press.

Elia, E.A., and Ferbey, T., 2020. Generating photogrammetric DEMs in the field from remotely piloted aircraft systems. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-01, pp. 189-200.

Ferbey, T., Plouffe, A., and Bustard, A.L., 2016. Geochemical, mineralogical, and textural data from tills in the Highland Valley Copper mine area, south-central British Columbia. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey GeoFile 2016-11, 15 p.

Han, T., Rukhlov, A.S., Riddell, J.M., and Ferbey, T., 2019. A skeleton data model for geochemical databases at the British Columbia Geological Survey. In: Geological Fieldwork 2018, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2019-01, pp. 125-135.

Hunter, R.C., and van Straaten, B.I., 2020. Preliminary stratigraphy and geochronology of the Hazelton Group, Kitsault River area, Stikine terrane, northwest British Columbia. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-01, pp. 101-118.

Mihalynuk, M.G., Logan, J.M., Diakow, L.J., Henderson, M.A., Jacob, J., and Watson, A.K.G., 2014. Allison Creek area preliminary geology (NTS 92H/9W and 10E) (and parts of adjacent sheets north and south), British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2014-05, scale 1:50,000.

Mihalynuk, M.G., Diakow, L.J., Logan, J.M, and Friedman, R.M., 2015. Preliminary geology of the Shrimpton Creek area (NTS 092H/15E, 16W) Southern Nicola Arc Project. In: Geological Fieldwork 2014, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2015-1, pp. 129-163.

Mihalynuk, M.G., Diakow, L.J., Friedman, R.M., and Logan, J.M., 2016. Chronology of southern Nicola arc stratigraphy and deformation. In: Geological Fieldwork 2015, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2016-1, pp. 31-63.

Miller, E.A., Kennedy, L.A., and van Straaten, B.I., 2020. Geology of the Kinskuch Lake area and Big Bulk porphyry prospect, northwestern British Columbia: Syndepositional faulting and basin formation during the Rhaetian (latest Triassic) transition from the Stuhini to the Hazelton Group. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-01, pp. 77-99.

Nelson, J., Waldron, J., van Straaten, B., Zagorevski, A., and Rees, C., 2018. Revised stratigraphy of the Hazelton Group in the Iskut River region, northwestern British Columbia. In: Geological Fieldwork 2017, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2018-1, pp. 15-38.

Nixon, G.T., Friedman, R.M., and Creaser, R.A., 2020. Late Neogene porphyry Cu-Mo(±Au-Ag) mineralization in British Columbia: the Klaskish Plutonic Suite, northern Vancouver Island. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and

Petroleum Resources, British Columbia Geological Survey Paper 2020-01, pp. 119-132.

Norris, J., and Fortin, G., 2019. Assessment report-sourced surface sediment geochemical database: Development and initial data release from the Interior Plateau. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey GeoFile 2019-04, 10 p.

Nott, J., Milidragovic, D., Nixon, G., and Scoates, J., 2020. New geological investigations of the Polaris ultramafic-mafic Alaskan-type intrusion (Early Jurassic), north-central British Columbia. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-01, pp. 59-76.

Ootes, L., Bergen, A., Milidragovic, D., Graham, B., and Simmonds, R., 2019a. Preliminary geology of northern Hogem batholith, Quesnel terrane, north-central British Columbia. In: Geological Fieldwork 2018, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2019-01, pp. 31-53.

Ootes, L., Bergen, A.L., Milidragovic, D., and Graham, B., 2019b. Preliminary bedrock geology of Notch Peak and Ogden Creek (parts of NT S 094C/04 and 093N/13), northern Hogem batholith, Quesnel terrane, north-central British Columbia, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2019-02, scale 1:50,000.

Ootes, L., Bergen, A.L., Milidragovic, D., Jones, G.O., Camacho, A., and Friedman, R., 2020a. An update on the geology of northern Hogem batholith and its surroundings, north-central British Columbia. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-01, pp. 25-47.

Ootes, L., Bergen, A.L., Milidragovic, D., and Jones, G.O., 2020b. Preliminary geology of the northern Hogem batholith and its surroundings, north-central British Columbia. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2020-02, scale 1:50,000.

Paradis, S., and Simandl, G.J., 2019. Preliminary carbon and oxygen isotope analyses of hydrothermal carbonates from Mississippi Valley-type and REE-F-Ba deposits of the southern Canadian Rocky Mountains–a comparison. In: Rogers, N., (Ed.), Targeted Geoscience Initiative: 2018 Report of Activities, Geological Survey of Canada Open File 8549, pp. 205-216. https://doi.org/10.4095/313652.

Rukhlov, A.S., Fortin, G., Kaplenkov, G.N., Lett, R.E., Lai, V. W.-M., and Weis, D., 2020. Multi-media geochemical and Pb isotopic evaluation of modern drainages on Vancouver Island. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-01, pp. 133-167.

Schiarizza, P., 2016. Toward a regional stratigraphic framework for the Nicola Group: Preliminary results from the Bridge Lake-Quesnel River area. In: Geological Fieldwork 2015, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2016-1, pp. 13-30.

Schiarizza, P., 2017. Ongoing stratigraphic studies in the Nicola Group: Stump Lake-Salmon River area, southcentral British Columbia. In: Geological Fieldwork 2016, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2017-1, pp. 17-33.

Schiarizza, P., 2018. Geology of the Spanish Lake area, south-central British Columbia. In: Geological Fieldwork 2017, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2018-1, pp. 143-156.

Schiarizza, P., 2019. Geology of the Nicola Group in the Bridge Lake-Quesnel River area, south-central British Columbia. In: Geological Fieldwork 2018, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2019-01, pp. 15-30.

Schiarizza, P., Monger, J.W.H., Friedman, R.M., and Northcote, B., 2020. Detrital zircons from the Gun Lake unit, Gold Bridge area, southwestern British Columbia. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-01, pp. 13-24.

Shewchuk, C., Ferbey, T., and Lian, O.B., 2020. Detecting porphyry Cu-Mo mineralization using major oxides and pathfinder elements in subglacial till, Highland Valley mine area, south-central British Columbia. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-01, pp. 169-187.

Steinthorsdottir, K., Cutts, J., Dipple, G., Milidragovic, D., and Jones, F., 2020. Origin and serpentinization of ultramafic rocks in dismembered ophiolite north of Trembleur Lake, central British Columbia. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-01, pp. 49-58.

Simandl, G.J., Petrus, J.A., Leybourne, M.I., Paradis, S., and Akam, C., 2019. Characterization of primary fersmite from the Mount Brussilof magnesite deposit, southeastern British Columbia. In: Geological Fieldwork 2018, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2019-01, pp. 113-123.

van Straaten, B.I., Logan, J.M., and Diakow, L.J., 2012. Mesozoic magmatism and metallogeny of the Hotailuh batholith, northwestern British Columbia. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2012-06, 58 p.

van Straaten, B.I., and Bichlmaier, S.J., 2018. Preliminary bedrock geology of the McBride River area, British Columbia, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2018-03, scale 1:50,000.

van Straaten, B.I., Gibson, R., and Nelson, J., 2017. Preliminary bedrock geology of the Tanzilla and McBride area, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-09, scale 1:50,000.

van Straaten, B.I., and Wearmouth, C.D., 2019. Preliminary bedrock geology of the Latham and Pallen Creek area, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2019-05, scale 1:50,000.

In memoriam
Dr. Victor M. Levson (1956-2019)

Victor M. Levson passed away on 31 March 2019, at the age of 62. Vic was a Quaternary geologist and spent most of his professional career at the British Columbia Ministry of Energy, Mines and Petroleum Resources in Victoria. He first worked as a Quaternary geologist with the British Columbia Geological Survey (1989 to 2002) and then moved to the Oil and Gas Division where he started as a Quaternary geologist, moved to Director of Petroleum Geoscience and then went on to head the Resource Development and Geoscience Branch (2002 to 2009).

Vic was a pioneer of drift prospecting in the Canadian Cordillera. He made significant contributions to the discipline and provided important insights into the Quaternary history of British Columbia, and the effect of complex ice-flow histories (including ice-flow reversals) on the clastic dispersal of mineralized bedrock in subglacial tills. Vic also wrote important papers on the stratigraphy and geologic settings of gold placers in the Cariboo and Atlin regions of British Columbia.

Vic's M.Sc. and Ph.D. work focussed on the Quaternary sedimentology, stratigraphy, and history of the Jasper area under the supervision of Nat Rutter at the University of Alberta. He joined the British Columbia Geological Survey in 1989 and completed his Ph.D. in 1995. Upon leaving government in 2009, he formed his own consultancy, Quaternary Geosciences Inc. Throughout his career Vic was keenly interested in applied aspects of Quaternary geology, across a diverse range of research topics. He is best known for his contributions to Canadian Quaternary stratigraphy, sedimentology, and ice-flow histories, seismic hazard maps for parts of southwest British Columbia, and drift prospecting method development for the Canadian Cordillera. Vic authored or co-authored more than 150 scientific papers, reports and maps, and wrote countless conference abstracts and presentations. Known for his astute observations and attention to detail, his till geochemical datasets continue to guide mineral exploration in central British Columbia.

Vic was also an Adjunct Professor in the School of Earth and Ocean Sciences, University of Victoria, where he supervised 10 graduate students. He served as an external examiner for many theses at University of Victoria and other Canadian schools. For 18 years Vic taught a fourth-year applied Quaternary geology course at the University of Victoria. A highlight of the undergraduate program, this course inspired many students to pursue careers in Quaternary geology. His annual four-day field trip through Washington State, with stops at the Channeled Scablands and Mount Baker, became legend. Vic also lectured in the Department of Geography (University of Victoria) and the Department of Chemistry and Geoscience (Camosun College).

Perhaps Vic's greatest contribution was how he treated people. Not only was Vic a respected geoscientist and gifted teacher, he was a selfless mentor and friend. Vic taught all of us fortunate to have worked with him how 'to do the right thing', a legacy that will endure. He led by example and passed on a set of core values that have continued to guide us well.

Cherished by his family, Vic squeezed the most out of every day. We will miss his infectious laugh, ingenious practical jokes, and unwavering friendship.