

British Columbia Geological Survey annual program review 2022-2023



Neil Wildgust^{1, a}, Yao Cui¹, Gordon Clarke², and Adrian S. Hickin¹

¹ British Columbia Geological Survey, Ministry of Energy, Mines and Low Carbon Innovation, Victoria, BC, V8W 9N3

² British Columbia Geological Survey, Ministry of Energy, Mines and Low Carbon Innovation, Vancouver, BC, V6Z 2G3

^a corresponding author: Adrian.Hickin@gov.bc.ca

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Executive Summary

This paper provides an overview of current British Columbia Geological Survey (BCGS) geoscience activities, and highlights key findings from 2022 projects. Headquartered in Victoria, the Survey is part of the Mines Competitiveness and Authorizations Division in the British Columbia Ministry of Energy, Mines and Low Carbon Innovation. The Survey generates geoscience knowledge and data to inform land use and resource management decisions, and to support the growth of British Columbia as a competitive jurisdiction for mineral exploration.

The Cordilleran Geoscience Section of the Survey conducts field and office research including bedrock and surficial geology mapping programs, regional geochemical surveys, and targeted mineral deposit studies. The past year has seen further progress of multi-year mapping and applied research across the province. Highlights include detailed mapping in the Kitsault area in the northwest, reconnaissance work in the northern Toodoggone area and the south-central interior, and the deployment of remotely piloted aircraft systems (RPAS) to gather geophysical data in the central and southern parts of the province. Building on an international critical minerals workshop co-hosted by the BCGS in 2021, the Survey embarked on a multi-year study of critical minerals. The initial work of this project included compiling an inventory of critical minerals occurrences across the province. The Cordilleran team has also been kept busy with a major revamp of the provincial Sample Archive, prompted by forced relocation of the facility in late 2022.

Responsible for maintaining and developing provincial geoscience and mineral resource databases, the Resource Information Section disseminates data online through MapPlace geospatial web services. Information managed by the team includes traditional geological maps and reports, geochemical, geophysical, and geological databases, in addition to mineral resource inventory and exploration assessment reports. The databases and webservices are designed to update data, facilitate data mining, and support applications for mineral exploration (particularly for critical minerals), and land-use planning. The team has started projects to modernize information systems and build a geoscience Spatial Data Infrastructure (SDI).

The Mineral Development Office (MDO) is the Vancouver base of the Survey. It provides investment intelligence to government and global business and publishes the annual Provincial Overview of Exploration and Mining in British Columbia volume. The MDO is staffed by a group of Regional Geologists who, stationed in exploration centres across the province, track minerals activities and provide geoscience expertise in their jurisdictions.

1. Introduction

This paper provides an overview of current British Columbia Geological Survey (BCGS) applied geoscience activities and highlights key findings from 2022 projects. Headquartered in Victoria, the Survey is part of the Mines Competitiveness and Authorizations Division in the British Columbia Ministry of Energy, Mines and Low Carbon Innovation. As the steward of geoscience and mineral resource information in the province, the Survey has an important role in stimulating mineral exploration, attracting investment, informing decisions with technical information, and providing continuous research based on more than a century of corporate memory.

The province has significant endowments of metals, metallurgical coal, and industrial minerals. Many of the metals are considered ‘critical’ because they are essential for modern technologies and low-carbon emission energy as the world transitions to digital and green economies, and are included in the Canadian list of 31 critical minerals

(Natural Resources Canada, 2022). The provincial minerals endowment is intimately tied to the tectonic evolution of the Canadian Cordillera, which continued from protracted supercontinent breakup starting about 1600 million years ago to accretionary processes that operate today as Pacific Ocean crust slides beneath Vancouver Island. In the northeastern part of the province, the Western Canada Sedimentary Basin hosts significant petroleum hydrocarbon resources.

The Survey is the primary repository for provincial geoscience knowledge. Maps, reports, and databases are freely available online and are public resources for First Nations and stakeholder groups including local communities, the minerals industry, public safety agencies, environmental scientists, research organizations, and government agencies. Current research programs (Fig. 1) continue to define the geological evolution and natural resources of the province, generating knowledge and data to support land use and resource management decisions that balance economic,



Fig. 1. British Columbia Geological Survey projects in 2022.

environmental, and community interests. A particular focus is providing public geoscience to support the growth of British Columbia as a competitive jurisdiction for mineral exploration, boosted by the recent attention of policy makers and industry to critical minerals. Providing mineral resource information is essential for informed land-use decisions by government and, increasingly, from communities.

The BCGS consists of three sections: 1) Cordilleran Geoscience; 2) Resource Information; and 3) the Mineral Development Office. The Cordilleran Geoscience Section generates new knowledge through field, laboratory, and office-based research activities including bedrock and surficial geology mapping programs, regional geochemical surveys, and targeted mineral deposit studies. Section team members manage in-house laboratory facilities, curate the provincial sample

archive, and build capacity through contract employment and training of geoscience assistants, typically undergraduate and graduate students. The Resource Information Section is responsible for maintaining and developing provincial geoscience databases and disseminating data online through geospatial web services (MapPlace). 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. The Mineral Development Office (MDO) is the Vancouver base of the Survey and provides investment intelligence to government and global business. The MDO is staffed by a group of Regional Geologists who, stationed in exploration centres across the province, track minerals activities and provide geoscience expertise in their jurisdictions. The MDO publishes the annual

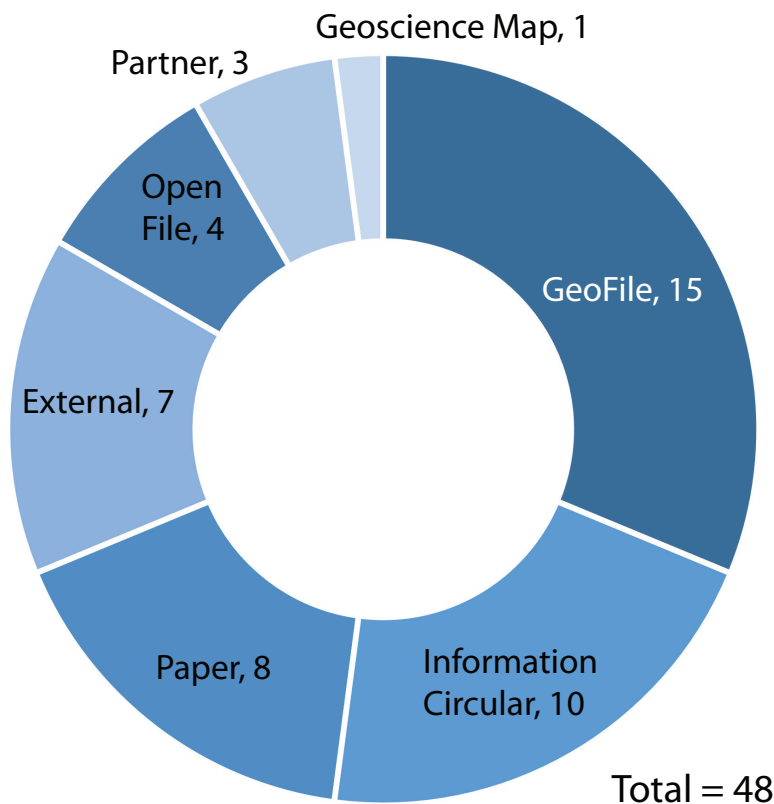
Provincial Overview of Exploration and Mining in British Columbia volume (Clarke et al., 2023).

The global Covid-19 pandemic again affected Survey operations in 2022, despite the relaxation of public health restrictions and resumption of normal working practices. External laboratory services continued to be affected in some cases, leading to delays in analytical testing and processing of

results. Despite these challenges, Survey staff maintained a full workload and publication output (Fig. 2).

2. Staffing

Currently staffed by 30 permanent and several term employees (Fig. 3), the Survey endured a challenging year with several retirements and people moving on to new opportunities.



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

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.

Fig. 2. Types and numbers of publications produced by the British Columbia Geological Survey in 2022.



Fig. 3. British Columbia Geological Survey staff.

Larry Diakow and George Simandl retired after long and successful careers with BCGS; their expertise will be greatly missed. Rebecca Hunter, Holly Arnold, and Neil Wildgust left the Cordilleran team in 2022 for opportunities elsewhere. Emily Miller joined as a permanent staff member, Evan Orovan transferred to the Cordilleran team from the Resource Information Section to lead the critical minerals inventory project, and Wyatt Bain started as a Economic Geologist. The Survey's geomatics team was bolstered by the recruitment of George Nyi, Paulina Marczak, and Kaitlyn McLaren. The Mineral Development Office welcomed Hassan Heidarian as Regional Geologist for the Northeast and North Central regions as Nate Corcoran moved from Prince George to Smithers to support the Northwest region.

Former Director of the Resources Information team Larry Jones, who retired from the Survey in 2021, has been acknowledged with a Special Tribute from the Association for Mineral Exploration (AME) for his leadership in assembling and distributing the British Columbia Geological Survey databases and geospatial datasets and for leading his team in the design, development, and marketing of MapPlace.

The Survey is an organization in transition. Faced with replacing retirements, departures, and the need to fill newly created positions, the Survey began an aggressive hiring program. Capacity building in areas such as critical minerals, field mapping, digital data delivery, geomatics, and mineral potential modelling will continue in 2023. Similarly, capacity building for enhancing engagement with First Nations before, during, and after future field seasons will remain a priority.

3. Partnerships

The Survey adopts a collaborative approach to extend the scope and content of public geoscience while minimizing the risk of duplicative work. The Geological Survey of Canada (GSC) is an established partner; 2022 saw multiple discussions between BCGS and the GSC for the Energy and Minerals (GEM)-GeoNorth program, to align research interests and ensure coordinated engagement with First Nations in northern

British Columbia. Active collaboration under GEM-GeoNorth during 2022 focussed on providing BCGS expertise to support assessing the distribution of metallic mineral systems in the northern part of the province.

The Survey signed an agreement with Newcrest Mining Limited in late 2021 to facilitate extensive lithochemical analysis of igneous rock samples collected in the northwestern part of British Columbia and stored in the BCGS Sample Archive. About 950 samples were re-analyzed using modern comprehensive and high-precision analytical methods (Van der Vlugt et al., 2022). This project underscores the value added to geoscience in the province by the archive facility and may provide a blueprint for future collaborative research and public-private partnerships using archived samples.

BCGS hosted a forum in November 2022 focussed on institutional research programs and primarily intended as a networking event, featuring activities at the British Columbia Geological Survey, the Geological Survey of Canada, British Columbia universities, and Geoscience BC. More than 70 participants explored shared, overlapping, and cross-disciplinary research.

4. Cordilleran Geoscience Section

Section geologists collect fundamental geoscience data through single and multi-year field-based programs complemented by laboratory and office studies. These programs include regional-scale mapping, mineral deposit studies, and new mineral exploration method development. Expertise encompasses tectonics, structural geology, stratigraphy, petrology, metallogeny, coal deposits, Quaternary and surficial geology, critical minerals, and geochemistry.

Engagement with First Nations communities is a priority for the Survey; as summer field projects are planned early each calendar year, liaison with First Nations is initiated as soon as possible. BCGS is committed to sharing geoscience information with all British Columbians and is expanding efforts to bring geological and mineral science to communities.

The provincial Sample Archive is home to rock, mineral, and geochemical samples collected from across the province in the last several decades by BCGS staff and partner organizations. These collections represent a valuable resource for public geoscience, supporting quality control of published data, re-analysis using modern comprehensive and high-precision analytical methods, and new geoscience initiatives. Following a notice to vacate the historic BCGS storage facility at 254 Belleville Street in downtown Victoria (Fig. 4), systematic sorting, rationalizing, and cataloguing of archived samples was undertaken in anticipation of moving the collection to a new site at 1810 Blanshard Street, Victoria (Rukhlov et al., 2023). Work will continue to make the Archive a modern and reliable resource supporting Cordilleran geoscience with enhanced and accessible digital cataloging.

4.1. Mapping, regional synthesis and compilation

Mapping is a core element of Survey and Cordilleran Section



Fig. 4. Heritage 'Stores Building' (ca. 1912) at 254 Belleville Street, Victoria. See Rukhlov et al. (2023).

programs. The Survey delivers two key products: traditional published maps in the form of PDF files with accompanying research papers; and updates to the provincial digital geology database, which ultimately feeds into MapPlace as BC Digital Geology. The digital geology database is an instrumental component of modern mineral potential assessment methods being developed by the Survey to inform land-use planning policies in the provincial government (see section 5.6.).

4.1.1. Northwestern British Columbia

Northwestern British Columbia hosts significant base- and precious-metal mineral deposits, notably in a loosely defined area colloquially referred to as the 'Golden Triangle' between Iskut and Stewart. A multi-year program to expand regional bedrock mapping and better understand the stratigraphic, magmatic, structural, metallogenic, and tectonic framework of northwestern British Columbia is ongoing.

Nelson et al. (2022) continued long-term investigations into the evolution of Stikinia and adjacent terranes in northwestern British Columbia, presenting U-Pb detrital zircon data from the Stuhini and Hazelton groups to reconstruct the uppermost Triassic and Lower Jurassic pre-accretionary arc and early syn-accretionary back arc paleogeography and paleotectonics of the region. Nelson et al. (2022) also examined the relationships between Stikinia, Yukon-Tanana terrane, the Whitehorse trough, Quesnellia, and Cache Creek terrane. New bedrock geology maps were published for the western Skeena arch region (Angen et al., 2022), the Turtle Lake area (Mihalynuk et al., 2022), and a 5,000 km² area between the community of Dease Lake and the Stikine River (van Straaten et al. 2022a).

Hunter et al. (2022) reported U-Pb zircon geochronological data as part of a larger study to better establish the ages of the Stuhini and Hazelton groups in the Kitsault River area (Fig. 1). Because the Kitsault River area hosts Ag-rich volcanogenic massive sulphide, Au-rich epithermal, and Cu-Au porphyry systems, resolving the distribution, age, and affinity of prospective host rocks is key to understanding the metallogeny

and mineral potential of the area. Continuing this study, Miller et al. (2023) provide an update on work in the Kitsault River area, presenting a new preliminary map and extended legend for units (Fig. 5) in the northeastern part.

Working in the area of the Galore Creek porphyry Cu-Ag deposit (Fig.1), which is hosted in and broadly coeval with a multi-phase alkalic silica-undersaturated volcano-intrusive complex, van Straaten et al. (2023) examine the stratigraphy and depositional setting of the Stuhini Group (Upper Triassic) and provide initial geochronologic data. van Straaten et al. (2023) recognize a 'lower intermediate to mafic volcano-sedimentary succession' (Fig. 6; at least ~1.2 km thick) that is abruptly overlain by an 'upper alkalic volcanic succession' (at least ~0.8 km thick). Based on high-precision U-Pb zircon titanite geochronology, upper succession alkalic volcanism initiated at 210.26 ± 0.17 Ma, broadly coeval with published ages for mineralogically, texturally, and compositionally similar alkalic silica-undersaturated Galore intrusions. The Galore Creek deposit is bordered to the west near Butte ridge by a 2-3 km wide, >6 km long, poorly understood zone of foliated and folded Stuhini Group rocks that records anomalously high strain relative to elsewhere in the area. Based on preliminary



Fig. 5. Parallel- and cross-stratified sandstone and siltstone with a white-weathering tuff layer; upper part of Hazelton Group, unassigned unit (ImJHsv), Kitsault River area. View is to the east. See Miller et al. (2023).



Fig. 6. Cobble to boulder conglomerate and pebbly sandstone with light-toned intermediate volcanic clasts and green augite-phyric mafic volcanic clasts; well-developed foliation defined by aligned clasts. Lower succession of the Stuhini Group, conglomeratic unit (uTrSvc), northwest end of Butte ridge, Galore Creek area. See van Straaten et al. (2023).

work, Johnston et al. (2023) interpret that shortening in the Butte ridge area was accommodated by fold and foliation development (Fig. 7) rather than by discrete heterogeneous shear zones and that north-south changes reflect different structural levels.

van Straaten et al. (2022b) released whole rock litho-geochemical data from for 555 Devonian to Quaternary rock samples from northwestern British Columbia, predominantly from Triassic to Jurassic igneous rocks in Stikine terrane and, using modern high-precision techniques, Van der Vlugt, et al. (2022) re-analyzed almost 950 archived igneous samples. Lett et al. (2022) provided historical heavy mineral and geochemical data from stream-sediment, stream-water, and moss-mat sampling.

4.1.2. Central and southern British Columbia

Ootes (2023) examines regional stratigraphic relationships (Fig. 8) in the eastern part of central Stikinia to identify a major synclinorium-anticlinorium pair that extends along strike for more than 100 km into the northern Toodoggone region (Fig. 1) where the hinge zone of the anticlinorium coincides with the Black Lake intrusion (Early Jurassic). Epithermal mineralization (e.g., Baker, Lawyers, Shasta deposits) is distributed along the axial trace of the anticlinorium, which is apparently unique to this part of Stikinia, leading to the hypothesis of a causal relationship between folding, intrusion, and Au-Ag±Cu epithermal mineralization.

Jones et al. (2022) continued generating results from the northern Hogen batholith (Fig. 1) project, releasing in-situ zircon U-Pb, Lu-Hf, $\delta^{18}\text{O}$, and trace-element data from intrusive units. Ootes et al. (2022) presented igneous and detrital zircon U-Pb, Lu-Hf, and trace-element data and the first radiolarian ages from the Asitka Group (basement to eastern Stikinia).



Fig. 7. Decametre-scale isoclinal fold in southern part of the ‘Butte ridge deformation zone’ west of the Galore Creek deposit area. The light-toned unit(s) are tuffaceous beds. View to the south. See Johnston et al. (2023).



Fig. 8. Contact between orange-yellow weathering volcanosedimentary rocks of the Takla Group (Upper Triassic, at left) and grey volcanic rocks of the Hazelton Group (Toodoggone Formation; Lower Jurassic, at right). View is to the southwest from the road between the past-producing Baker and Lawyers mines. See Ootes (2023).

This work showed that, although an enigmatic older crustal fragment may have been nearby, eastern Stikinia formed on an ocean floor during the Carboniferous to early Permian from entirely juvenile magmatic sources.

Schiarizza (2022) released a 1:50,000 bedrock geology map of the Stump Lake-Salmon River area of the Thompson Plateau. Schiarizza and Friedman (2023) provide new U-Pb geochronologic data from rocks of the Cadwallader terrane that are exposed in a structural window beneath overthrust Cache Creek terrane along the Chilcotin River (Fig. 1). Rhyolites (Fig. 9) from near the top of the Wineglass assemblage returned a crystallization age of 260.8 ± 0.3 Ma, confirming that they are Late Permian. Detrital zircons from the lower part of the Tyaughton Formation, which unconformably overlies the Wineglass assemblage suggest a late Norian or Rhaetian maximum depositional age, and include a population of Late Permian to Middle Triassic grains, probably derived from the underlying Wineglass assemblage and/or related rocks. A second population of Late Triassic zircons are inferred to have been derived from Late Triassic volcanic and plutonic rocks exposed elsewhere in Cadwallader terrane. A sandstone from a higher stratigraphic level in the Tyaughton Formation contains only Late Triassic zircons and suggest a late Norian maximum depositional age. The Permian to Jurassic rocks of the Cadwallader terrane in the Chilcotin River window correlate with rocks in central and northern British Columbia, forming a fragmented belt that can be traced along the length of the province.

A study to investigate the relationships between the Harper Ranch (Devonian-Carboniferous), Slocan Group (Triassic), and Nicola Group (Triassic) and potential affiliations with the Chase Formation (Devonian) started in the Trinity Valley area (Fig. 1). A number of past-producing mines are in the



Fig. 9. Quartz and plagioclase-phyric metarhyolite from near the top of the Wineglass assemblage, Cadwallader terrane with a new U-Pb zircon crystallization age of 260.8 ± 0.3 Ma. See Schiarizza and Friedman (2023).

area (mainly placer gold), and questions also remain about the connection between mineralization and bedrock. Mapping of the Lardeau Group in the Kaslo area (Fig. 1) continues, focussed on highly strained and well-metamorphosed rocks of the Index Formation, and its age, stratigraphic position, and tectonic significance. Within graphitic metapelites of the Index Formation are previously unmapped ultramafic layers and pods (now talc and chromian mica schist) with massive sulfide mineralization, the mineral potential of which is also being investigated.

4.2. Province-wide critical minerals assessment

Low-carbon energy technologies demand critical minerals, but the highly globalized supply chain of critical minerals and products is vulnerable to disruption. Furthermore, increased use of green technologies is increasing the demand for many metals, which could lead to shortages in the next few decades. British Columbia is Canada's largest producer of copper and metallurgical coal and only producer of molybdenum, and also produces zinc and manganese. The four metals are elements on Canada's critical minerals list (Natural Resources Canada, 2022), and metallurgical coal is required for high-quality steel. British Columbia has near-term potential to contribute significantly to the production of other critical metals required for a green economy including nickel, rare earth elements, niobium, tantalum, tungsten, and cobalt.

Following from an online international workshop co-hosted by BCGS, (British Columbia Geological Survey, 2021), the Survey has embarked on a multi-year project to assess critical mineral deposits and associated mineral systems across the province. The Survey is preparing an inventory of British Columbia's critical minerals, assessing geological settings most favourable to host deposits, and developing exploration techniques that would enhance discovery of new deposits.

4.3. Targeted deposit studies and exploration methods

Regional mapping programs are complemented by more specific or thematic studies, typically selected to develop public geoscience knowledge and datasets in key topics that support minerals exploration or government land-use policy. Survey geoscientists test new technologies that can support future regional mapping and mineral exploration activities.

This year the Survey finished data collection for its pilot study on the utility of RPAS (remotely piloted aircraft systems)-borne magnetometry and gamma-ray spectrometry to detect dispersal trains in subglacial tills, with test sites at the Mount Polley and Woodjam deposits and in the Guichon Creek batholith area (Fig. 1; Highland Valley deposit). In total, more than 300-line km were flown in 68 individual surveys designed to measure K, eU, eTh (using a Radiation Solutions Inc. RS-530; Fig. 10), and total field magnetics (using GEM Systems DRONEmag potassium magnetometer) over tills derived from contrasting bedrock rock types. Gridded autopilot surveys were flown in cutblocks at 5, 7.5 or 10 m above ground level. A radar altimeter instructed the RPAS flight control systems in



Fig. 10. Radiation Solutions Inc. RS-530 gamma-ray spectrometer, mounted to a DJI Matrice 600 Pro, completing a survey north of Merritt above tills derived from Bethsaida phase (Late Triassic) granodiorite, Guichon Creek batholith.

real-time to maintain a constant height above ground, ensuring measured data variation was not related to changes in distance between the geophysical sensors and ground. As part of this final field season, ground radiometrics (using a Radiation Solutions Inc. RS-230BGO) and magnetic susceptibility measurements (using a KT-20 with 3F-32 sensor) were also collected within the survey areas to further validate the RPAS data. In early 2023, processed data from all surveys will be released as a GeoFile (Elia et al., 2023). Interpretations and assessments of the individual datasets will follow in a series of Open File publications (e.g., Ferbey et al., 2023).

5. Resource Information Section

The Survey collects, compiles, and disseminates provincial public geoscience information that supports effective mineral exploration, sound land use management, and responsible governance. This public geoscience includes traditional geological maps, reports, and thematic studies, province-wide digital coverage of bedrock geology (BC Digital Geology), and databases including mineral assessment reports (ARIS), mineral inventory (MINFILE), coal information (COALFILE), geochemical and geophysical surveys, and collections of documents donated to the British Columbia Geological Survey since the late 1880s by government, universities, industry, and individuals (Property File). The Survey operates numerous information systems to update these databases and deliver them through web portals and MapPlace, the BCGS geospatial web service.

As part of the Survey's digital transformation efforts, information systems are being re-engineered to build a geoscience Spatial Data Infrastructure (SDI). The Survey carried out a system review with recommendations for an SDI architecture to improve efficiency in operating and updating databases, to further digitalization and analytical-ready geoscience, and to enable interoperable data sharing.

5.1. Geoscience Spatial Data Infrastructure

Geoscience data are inherently related in the data lifecycle and need to be managed coherently. However, the Survey currently operates geoscience databases and applications built in the last two decades, mostly in discrete systems of varying legacy or obsolete technologies. Thus, the Survey is now developing a geoscience Spatial Data Infrastructure (SDI) to manage all geological and mineral resource data together as sub-systems in the same environment, using common data and system components and well-defined interface across service boundaries. In early 2022, we commissioned a consultant to conduct a system review of all geoscience databases and applications in the Survey. The review recommended a containerized microservices architecture using Cloud-native technologies and opensource software for our SDI. As a first step on our path to SDI the Survey, completed an upgrade of ARIS (Assessment Report Indexing System) from obsolete technologies with multiple manual steps to a modern and standard-based environment with streamlined and automated processes.

5.2. MapPlace

MapPlace is the BCGS geospatial web service to discover, visualize, search, and generate summary reports and maps from province-wide geoscience databases. Easy access to, and analysis of, geoscience maps and data are fundamental to inform decisions on mineral exploration, mining, environmental protection, and land use management. MapPlace provides a platform to facilitate data mining and analysis of geoscience information in the context of all other relevant data such as mineral titles, assessment reports, land ownership, public infrastructure, aquifers, and topographic base maps. Some of the data layers and applications are specifically developed to enable research and analytics for mineral exploration and prospecting.

5.3. ARIS assessment reports and database

Results of mineral exploration are submitted by industry as assessment reports to the government in compliance with the Mineral Tenure Act regulations. After a one-year confidentiality period, the assessment reports become freely available to the public. The Survey manages these reports in the Assessment Report Indexing System (ARIS) database with metadata to search the locations, mineral occurrences, commodities, claims, work types, and expenditures as documented in the reports. ARIS contains more than 39,100 reports dating from 1947. All the assessment reports are available online as PDF documents through the ARIS website, and nearly 800 of them contain data (e.g., geochemical analyses and geophysical surveys) in common digital formats that can be readily used. In addition to the search interface on the ARIS website and MapPlace, a copy of the ARIS metadata is available to download in Microsoft Access, with locations in Microsoft Excel and ESRI shapefile format.

5.3.1. Assessment report digital submission

Traditionally, assessment reports from mineral exploration have been submitted in hardcopy or as files such as scanned PDF, which render data within the files difficult to extract and use. The BCGS has set up a digital data submission portal to encourage inclusion of digital files such as spreadsheets, databases, GIS maps, and grids. Explorationists will benefit because digital data can be easily retrieved, integrated, 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. Both assessment reports and digital data can be uploaded through the ARIS data submission page. The Survey continues to digitally extract information for our assessment report-sourced surface sediment geochemical database (ARSSG). In 2022, digital extraction was expanded to include drillhole collar and core geochemical data.

5.4. Other databases

MINFILE is a database for mineral, coal, and industrial mineral occurrences that includes information for more than 15,800 records. In 2022, more than 400 new occurrences and 2,100 updates were added to the database. COALFILE includes a collection of assessment reports, dating from 1900. Property File is a collection of archived reports, maps, photos, and technical notes documenting mineral exploration activities in British Columbia from the late 1800s. 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 the Regional Geochemical Survey program, till surveys, and lithochemical samples. Accompanying the physical relocation and rationalization of the BCGS Sample Archive in 2022 a modern digital inventory was created for integration with other provincial datasets (Rukhlov et al, 2023).

5.5. British Columbia Digital Geology

The BCGS offers province-wide digital coverage of bedrock geology including details from field mapping, with a typical regional compilation at a scale of 1:50,000. A geospatial frame data (GFD) model is used to simplify the compilation and integration of new regional mapping into the BCDigital Geology database (Cui, 2021). Bedrock geology is standardized with consistent stratigraphic coding, ages, and rock types to enable computations, and 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 BCGS has transformed the digital geology to the GeoSciML Lite schema

and mapped the contents using the vocabularies adopted by the IUGS Commission for the Management and Application of Geoscience Information (CGI). The GeoSciML Lite-compliant digital geology is accessible via the OneGeology portal and open standard-based interface such as Web Mapping Service (WMS) and Web Feature Service (WFS) specification, to enable interoperable data sharing and analytics.

5.6. Mineral potential modelling

Modernized mineral potential modelling identifies areas of high prospectivity for key mineral systems. Mineral potential assessment continues as a renewed focus for the Survey, with an emphasis on supporting government, First Nations, and stakeholders in land-use planning and policy development. A pilot study, which produced data-driven mineral potential maps for three mineral systems (VMS, porphyry copper, magmatic nickel), now continues into new areas and will be applied to the Survey's province-wide critical minerals assessment.

6. Mineral Development Office

The mining industry contributes greatly to the economy of British Columbia. Particularly important for northern communities and First Nations, the mineral exploration, mining, and related sectors employ more than 30,000 people. For 2022, the forecast value of mine production in British Columbia is \$18.2 billion (Clarke et al., 2023).

Mineral exploration is the backbone of mining and an estimated \$740.4 million was spent on exploration in 2022. More than 200 companies have projects in British Columbia and these projects are monitored by the Mineral Development Office (MDO) and its Regional Geologists. The MDO is the Vancouver base of the British Columbia Geological Survey. It links the more than 1100 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 produces the Provincial Overview of Exploration and Mining in British Columbia, an annual volume that summarizes activities in the different regions of the province (see e.g., Clarke et al., 2023).

The British Columbia Regional Geologists (Table 1) represent the provincial government on geological matters at a regional level, capture information on industry activity in their jurisdictions, and produce reports such as a province-wide review of volcanogenic massive sulphide deposits by Northcote (2022). Within their communities, the Regional Geologists provide information on exploration trends, possible investment opportunities, land use processes, First Nation capacity building, and public outreach.

Table 1. British Columbia Regional Geologists.

Regional Geologist	Office	Region
Nate Corcoran	Smithers	Northwest
Hassan Heidarian	Prince George	Northeast and North Central
Vacant	Kamloops	South Central
Fiona Katay	Cranbrook	Southeast
Bruce Northcote	Vancouver	Southwest

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