

# British Columbia Geological Survey annual program review 2013

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## Chief Geologist's Message

Why support public geoscience? In short, public geoscience reduces exploration costs and risk, thereby improving returns on private investment and increasing revenues accruing to governments as royalties and taxes.



*“Most mineral resources in Canada are public assets and governments have determined that the responsible development of these resources is in the public interest. Moreover, because much of the geoscience information that underpins exploration has the economic characteristics of a public good, the provision of public geoscience to stimulate exploration is a key element of federal, provincial and territorial mining strategies”.*

*J.M. Duke 2010 (former Director General of the Geological Survey of Canada)*

Public geoscience is undertaken on behalf of the public through open and transparent processes, and its results are freely available to all. It traditionally consists of geological mapping, data custodianship and delivery, mineral deposit studies, geochemical and geophysical surveys, and resource studies. Duke (2010) points out that it is important to subsurface resource exploration and development because: it attracts exploration investment by allowing industry to identify areas of favourable mineral and oil and gas potential; increases exploration efficiency by making it unnecessary for individual companies

to spend money on non-prospective ground or to duplicate common information; and increases exploration effectiveness by providing key information for risk-based decisions.

Geological surveys in Canada cooperate under the terms and conditions formally set out in the Intergovernmental Geoscience Accord (IGA). The agreement was first signed by Energy and Mines Ministers in 1996 and has been renewed three times, most recently in Charlottetown, 2012. The roles and responsibilities as defined by the IGA are as follows:

*2.1. The Geological Survey of Canada (GSC) carries out national geoscience programs to define the geology and resources of Canada. These programs are typically thematically based, and national or broadly regional in scope and significance. They are implemented across Canada, and include aspects of fundamental research, technology development, and information transfer not contained in the programs of all of the provincial and territorial survey organizations.*

*2.2. The provincial and territorial geological surveys carry out programs specific to the economic development and resource management of their own jurisdictions. These programs are carried out at a scale appropriate to addressing provincial or territorial responsibilities, and are geographically limited to the jurisdiction over resources, environment, and land of the province or territory. They contribute to a systematic description of the geology of the provinces and territories, including their mineral and energy endowment. Provincial and territorial programs are largely directed toward sustainable economic development and are closely linked to the needs of clients. They are also related to provincial and territorial land use and social issues.*

The IGA also sets out principles and mechanisms of cooperation. It establishes a framework for jointly setting priorities and planning programs. Although precipitated by a federal policy decision, the IGA has gained broad acceptance, indicating the appetite for collaboration among the geological surveys. The BCGS and the GSC share an especially close professional relationship due to commitments made in the British North America (BNA) Act, 1867, and the Terms of Union, 1871. Specifically, Canada agreed to assume and defray the charges for a Geological Survey in British Columbia. In response, the GSC maintains two national geoscience offices in British Columbia, the Pacific Geoscience Centre (PGC) in Sidney, and the Cordilleran Geoscience Office in Vancouver.

This spirit of cooperation extends well beyond the geological surveys to other public geoscience groups. Since 2003, a geoscience partnership agreement between the University of Victoria, the Ministry of Energy and Mines, and the Ministry of Natural Gas Development has provided over \$2.6 million in funding for 33 applied geoscience projects to teams of researchers at the University of Victoria and the Ministry. The Survey has participated in numerous collaborative projects with Geoscience BC, a non-profit society established in 2005 to generate new applied geoscience information that will attract global investment to the BC mining and energy sector. Geoscience BC has no in-house capacity to undertake geoscience projects, but awards grants to consultants, contractors, and other geoscience providers to do the work. The Province has supported Geoscience BC through a series of unrestricted grants totaling \$48.7 million since 2005. The strength of Geoscience BC has been successful completion of large, multi-million dollar regional geophysical and geochemical surveys in relatively short periods of time. These high-profile projects were selected to have an immediate impact, and they complement the longer term applied geoscience activities of the British Columbia Geological Survey and the Tenure and Geoscience Branch in the Ministry of Natural Gas Development.

The Mineral Deposit Research Unit (MDRU) in the Department of Earth, Ocean and Atmospheric Sciences (EOAS) at the University of British Columbia has been another long-term research partner. Geological surveys play a central role in training and mentoring the next generation of geoscientists in regional geological mapping, mineral deposit studies, database management and development, and the use of analytical instruments in modern research laboratories. Hence, particularly rewarding projects have included working with energetic students and post-doctoral fellows.

The Survey also collaborates with the minerals industry. British Columbia's mineral exploration community provides critical logistical and financial support (both in-kind and direct) for many of our geoscience projects. These professional interactions keep the Survey in touch with the needs of the minerals industry and facilitate the transfer of knowledge generated by government geoscientists to the exploration community. It is said that you are judged by the company that you keep. The British Columbia Geological Survey is fortunate to be in the company of the British Columbia mineral exploration and mining community, the members of which we are proud to call friends.

### 1. British Columbia Geological Survey overview

The BCGS was established in 1895 and is the oldest science agency in the British Columbia government. The BCGS links government, the minerals industry, and British Columbians to the province's geology and mineral resources. The key roles of the Survey are to

- create, maintain, and deliver geoscience knowledge to lead informed decision making
- attract companies and individuals to explore British Columbia for new mineral and coal resources
- act as the public steward of mineral and coal resources for current and future generations
- guide public policy by providing assessments on the nature and economic health of mineral exploration and mining activities

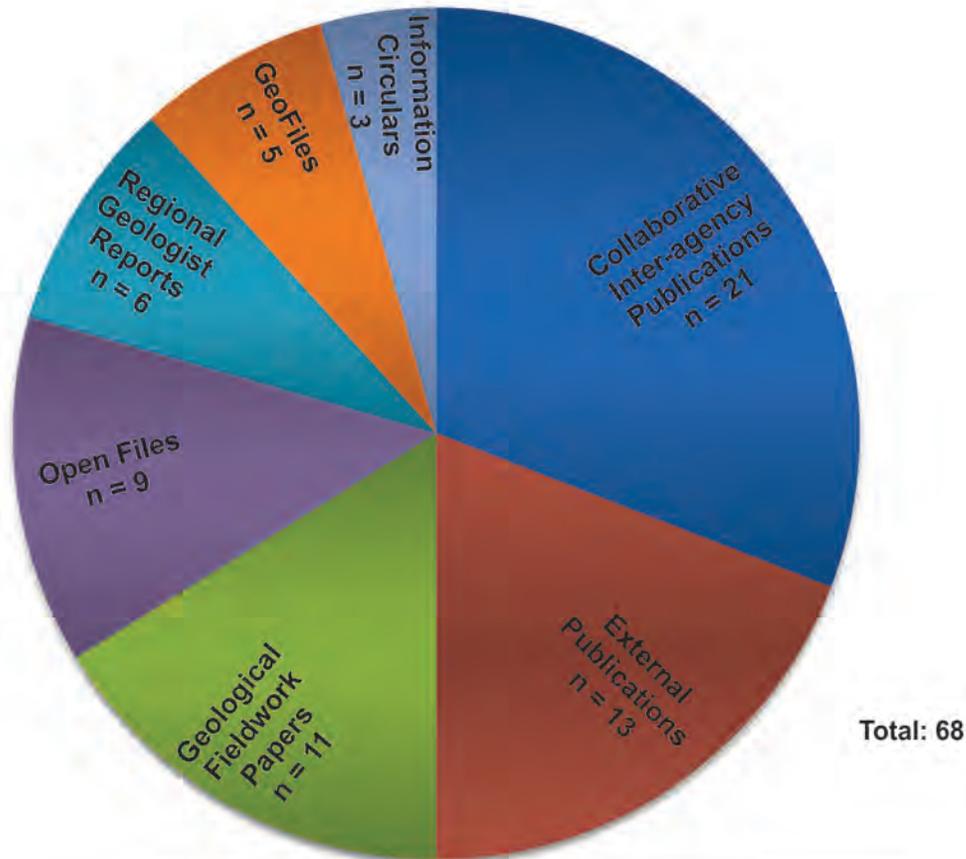
The BCGS is a branch in the Mines and Mineral Resources Division of the Ministry of Energy and Mines (Fig. 1). It is headquartered in Victoria, the capital city of British Columbia, on south Vancouver Island. The Survey is lead by Stephen Rowins, the Chief Geologist and Executive Director, and consists of three sections, each lead by a Director. These sections include: 1) Cordilleran Geoscience; 2) Resource Information; and 3) the Mineral Development Office (MDO). The Cordilleran Geoscience Section, lead by Adrian Hickin, is responsible for generating new geoscience knowledge largely through field-based studies and surveys. Larry Jones directs the Resource Information Section, which is responsible for maintaining and developing the provincial geoscience databases and disseminating geoscience data online. The Resource Information Section is the statutory authority for evaluating, accepting, and archiving mineral exploration assessment reports filed by the exploration and mining industry since 1947. These reports provide information on geological, geophysical, geochemical, drilling, and other exploration-related activities



Fig. 1. Staff of the British Columbia Geological Survey in 2013.

in BC. Most are available online from the ARIS (Assessment Report Indexing System) website. The Mineral Development Office (MDO), in Vancouver, is lead by Bruce Madu. It serves as the government's point of contact for the mineral exploration and mining industry. The MDO provides mineral and coal resources information and technical marketing to industry, governments, and the investment community. In addition, the MDO coordinates British Columbia's Regional Geologists Program.

Publications are the primary means by which the BCGS delivers on its mission to attract exploration to British Columbia. In 2013, the Survey produced 68 publications (Fig. 2) the results of which were also presented at regional, national, and international scientific meetings. Industry is the main client of the BCGS and our efforts are largely directed at providing new geoscience products to the minerals industry. All publications, data releases, conference presentations, web



**Types of Publications by the British Columbia Geological Survey**

**Collaborative Inter-agency publications** include reports, maps, and other products published jointly by the British Columbia Geological Survey and another agency such as the Geological Survey of Canada or Geoscience BC.

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

**Geological Fieldwork** papers are published in British Columbia Geological Survey's annual Geological Fieldwork volume. Papers typically report the preliminary results of field activities.

**Open Files** include geoscience reports, maps, and databases that receive internal review and usually represent the interim products of ongoing research.

**Regional Geologists reports** include overviews of exploration and mining activities. The contributing articles are prepared by the Regional Geologists and provide an annual report of activities in each jurisdiction.

**GeoFiles** are designed for rapid information release over the internet. They are not subject to the same editorial standards as other publications.

**Information circulars** provide government, industry, and the general public with non-technical geoscience information.

**Fig. 2.** British Columbia Geological Survey and Regional Geologists publications in 2013.

updates and new databases on MapPlace (MINFILE, ARIS, Coalfile, Property File) are profiled annually at the Association for Mineral Exploration in BC (AMEBC) Mineral Exploration Roundup in Vancouver, Canada.

In recent years the Survey has expended considerable time and resources on developing new mineral exploration methodologies and technologies. Development of these practical products is now possible with the refurbishment of the

Survey's geochemical laboratory and the renewal (in 2011) of the Ministry of Energy and Mines - University of Victoria (MEM-UVic) Geoscience Partnership Agreement. New exploration methodologies and technologies under development include: 1) using Pb isotopes to establish an inexpensive technique for targeting volcanogenic massive sulphide (VMS) deposits in till-covered terranes; 2) a new MEM-UVic project using the laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) laboratory at the University of Victoria to study resistate indicator minerals (RIMs) in glacial tills to fingerprint major mineral deposit types in BC and around the world; 3) new till-potential maps, using proprietary government airphotos, that will allow industry to reduce unnecessary till sampling by up to 75% in selected areas (joint BCGS-Geoscience BC project); and 4) use of portable bench-top or hand-held X-ray fluorescence (XRF) instruments to rapidly measure rare earth element (REE) abundances in field samples as a mapping aid during property evaluation.

Given the fiscal realities facing government today, virtually all of the BCGS projects are collaborative. Limited operational dollars means that we seek out partners to maximize research effectiveness. In the past 3 years, the BCGS has partnered directly with four companies (Imperial Metals Corp., Pacific Northwest Capital Corp., Kutcho Copper Corporation, and SEGO! Resources); undertaken seven joint research projects with the Geological Survey of Canada, including three Geo-Mapping for Energy and Minerals (GEM1) and four Targeted Geoscience Initiative 4 (TGI-4) projects; collaborated on seven MEM-UVic geoscience partnership projects; and partnered with Geoscience BC on large projects such as QUEST, QUEST-NW, Nechako, and TREK in addition to many smaller collaborations. Current university partners include the University of British Columbia, the University of Alberta, Simon Fraser University, and the University of Victoria.

As a government agency the BCGS doesn't lobby government, but will advocate for the industry and its needs. The MDO actively promotes British Columbia's mineral and coal resource opportunities to private investors and the general public. The new "Communities, Mineral and Coal Exploration Investment" map (see below), which summarizes exploration investment from 2010-2012 in relation to communities across the Province, is an example of how the BCGS and the Regional Geologists demonstrate the value of the exploration industry to local municipalities and First Nation communities.

## 2. Cordilleran Geoscience Section

The Cordilleran Geoscience Section is responsible for generating new geoscience knowledge through regional field-based geological mapping programs and targeted geoscience projects. Projects provide the regional tectonic and geological framework to enhance mineral exploration, develop mineral deposit models, and design and evaluate new exploration methods. These activities give the Section a key role in promoting mineral and coal exploration potential in British Columbia.

In addition to regional mapping, Cordilleran Section geologists activities include: bedrock stratigraphic and litho-geochemical studies; mineral deposit studies; evaluating the tectonic evolution of the North American Cordillera; developing methods for mineral exploration; documenting the

Quaternary history and surficial geology of the Province; drift prospecting, till geochemistry, and indicator mineral studies. Projects conducted in 2013 fall into four general themes: regional synthesis and map compilation; the BC Porphyry Deposits Initiative; targeted mineral deposit studies; and exploration methods (Table 1; Fig. 3).

### 2.1. New initiatives

#### 2.1.1. BC porphyry deposits

Porphyry Cu-Mo-Au deposits comprise a significant component of British Columbia's mineral wealth. Calc-alkaline and alkalic porphyry deposits are associated with plutonism in island arcs formed outboard of ancestral North America during Late Triassic to Early Jurassic (pre-accretionary), and in intracontinental arcs during the Late Mesozoic to Cenozoic, following accretion and assembly of the Cordilleran terranes (post-accretionary). Projects in the BC Porphyry Deposit Initiative are designed to: 1) determine the ages and structural controls on arc magmatism and porphyry pluton emplacement; 2) establish the geological framework for major porphyry trends; and 3) develop new exploration techniques to aid in the discovery of buried or blind deposits. This ongoing multi-year initiative includes six independent projects (Table 1; Figs. 3, 4). The first of these projects to be completed is a geological review of major porphyry mines in British Columbia's south-central Intermontane Belt. This project was undertaken as part of the Society of Economic Geologists (SEG) annual meeting, which was held in Canada for the first time. The resulting fieldtrip guidebook (Logan and Schroeter, 2013) is a valuable update for the exploration community. Four other ongoing studies in the Quesnel terrane of south-central British Columbia are collectively referred to as the Nicola Arc Project (Fig. 4). A new study in northwestern British Columbia is examining the geological controls on Stikinia arc magmatism and related porphyry mineralization (Fig. 3).

##### 2.1.1.1. Porphyry systems of central and southern British Columbia

A guidebook (Logan and Schroeter, 2013) to accompany a fieldtrip was delivered as part of the Society of Economic Geologists meeting held in Whistler, British Columbia in September. In addition to the itinerary, road log, and an overview article on porphyry systems, the volume included six review papers describing the geology of Endako (Thompson Creek Mining Limited), Gibraltar (Taseko Mines Limited), Mount Polley (Imperial Metals Corporation), Highland Valley (Teck Resources Limited), New Afton (New Gold Incorporated), and Copper Mountain (Copper Mountain Mining Corporation) mines.

##### 2.1.1.2. Nicola Arc project

The Nicola Arc project examined parts of three temporally distinct, north-trending plutonic belts that may represent the eastward migration of Mesozoic arc magmatism in southern Quesnellia (Fig. 4). These belts host important past and producing mines. The Nicola Arc project includes four studies that are divided geographically (north, central, and south; Fig. 4).



**Table 1.** British Columbia Geological Survey field projects in 2013.

Project	Theme	Lead Geologist
Porphyry systems of central and southern BC: Prince George to Princeton	BC Porphyry Deposits	Jim Logan
Geological setting of the Granite Mountain batholith, host to the Gibraltar porphyry Cu-Mo deposit, south-central British Columbia (Nicola Arc - North)		Paul Schiarizza
The Rayfield River pluton, south-central British Columbia (NTS 92P/6): Geologic setting and copper mineralization		Jim Logan
Regional Mapping and Cu-Au porphyry deposits between Princeton and Merritt (Nicola Arc - South)		Mitch Mihalynuk
Porphyry indicator minerals in till from the British Columbia Interior Plateau (Nicola Arc - North/TGI-4)		Travis Ferbey
Structural and stratigraphic control of porphyry and related mineralization in the Treaty Glacier – KSM – Brucejack – Stewart trend of western Stikinia		JoAnne Nelson
Carlin-type Au in North-Central British Columbia?	Exploration Methods	Alexei Rukhlov
Trace element systematics in apatite and other resistate minerals (MEM-UVic Partnership)		Alexei Rukhlov
Lead isotopes and trace element geochemistry of till at select Volcanogenic massive sulphide deposits west of Harrison Lake		Alexei Rukhlov
Specialty metal studies in British Columbia (TGI-4)	Mineral Deposits	George Simandl
Orogenic Ni-Cu-PGE at Giant Mascot and Turnagain (TGI-4)		Graham Nixon
The Cordillera of British Columbia, Yukon, and Alaska: tectonics and metallogeny	Regional Synthesis and Map Compilation	JoAnne Nelson
British Columbia Quaternary geology interactive map index		Travis Ferbey
Ice-flow indicators of British Columbia		Travis Ferbey
Towards a British Columbia digital Quaternary geology map		Travis Ferbey
Basal till potential maps for the TREK Project area		Travis Ferbey
British Columbia Coal Field Map Compilation		Janet Riddell

#### 2.1.1.2.1. Nicola Arc – North

Two projects are included in the Nicola Arc – North region (Fig. 4). First, bedrock mapping surrounding the Gibraltar Cu-Mo mine was initiated to establish if the host intrusions are part of the Late Paleozoic to Early Mesozoic Cache Creek terrane or part of the Late Triassic Quesnel terrane, which hosts the Highland Valley Cu-Mo mine. Second, a program is tracking the glacial dispersion of trace elements and porphyry indicator minerals (PIMs) in till from mineralization near the Mount Polley and Gibraltar mines and the Woodjam porphyry prospect. Outcomes include developing methods that use till matrix geochemistry and PIMs to discover buried porphyry deposits. This project is a partnership with the Geological Survey of Canada and is funded through the Intrusion Related Ore Systems Targeted Geoscience Initiative (TGI-4), which concludes in 2015.

#### 2.1.1.2.2. Nicola Arc – Central

The northern part of the Nicola Arc – Central region is challenging to explore because prospective rocks are hidden by a thick cover of Cenozoic volcanic rocks and unconsolidated Quaternary sediments. However, the potential for discovering buried deposits is significant, if the axes of the migrating

magmatic arcs can be traced beneath this cover (Fig. 4). The Rayfield River intrusion is a Late Triassic syenite pluton that is being investigated to determine if a link can be established with alkalic plutons to the north and south, thus defining the trace of the magmatic arc axis of the alkaline plutonic belt (Copper Mountain suite) throughout the Nicola arc.

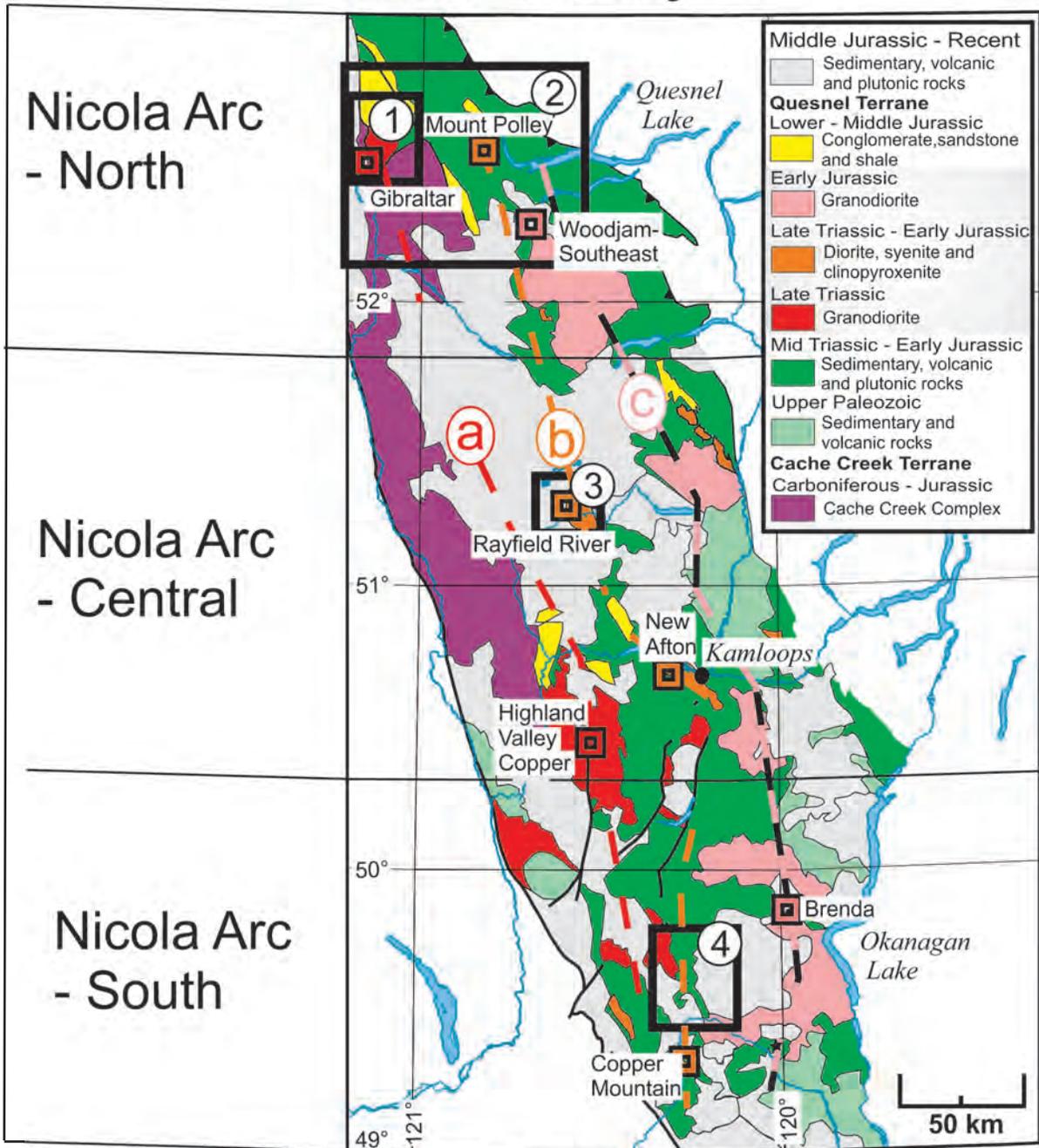
#### 2.1.1.2.3. Nicola Arc – South

The Southern Nicola Arc Project (SNAP) is the main project in the Nicola Arc – South region (Fig. 4). SNAP aims to refine the stratigraphic, structural, and mineral deposit evolution of the Nicola arc between Princeton and Merritt, through 1:20 000 scale geological mapping, geochronology and paleogeographic reconstructions (Fig. 5). The resultant geological framework should aid exploration programs in a region that has produced copper and gold for the past 50 years. The work is partly supported through an industry partnership agreement with Sego! Resources.

#### 2.1.1.3. Structural and stratigraphic control of porphyry Cu-Au and related mineralization in the Treaty Glacier – KSM – Brucejack – Stewart trend of northwestern Stikinia

One of the most important mineral trends of northwestern

# Nicola Arc Project



- ① Geological setting of the Granite Mountain batholith, host to the Gibraltar porphyry Cu-Mo deposit, south-central British Columbia
  - ② Porphyry indicator minerals in till from the British Columbia Interior Plateau
  - ③ The Rayfield River pluton, south-central British Columbia (NTS 92P/6): Geologic setting and copper mineralization
  - ④ Regional Mapping and Cu-Au porphyry deposits between Princeton and Merritt
- Plutonic Belts**
- a Late Triassic
  - b Late Triassic - Early Jurassic
  - c Early Jurassic

Fig. 4. Nicola Arc projects. Generalized geology of southern Quesnellia modified after Logan and Mihalynuk (2013).

British Columbia extends from immediately north of Stewart to the Treaty Glacier, in the western part of the Stikine arc (Figs. 3, 6). Major deposits along this trend include Kerr-Sulphurets-Mitchell (KSM), Brucejack, Silbak-Premier, Big Missouri, Scottie Gold and Red Mountain. All are hosted by volcanic and sedimentary rocks of the Hazelton Group (Lower Jurassic) and



**Fig. 5.** Drilling an oriented core for paleomagnetic study at Miner Mountain in the Nicola Arc-South project area.



**Fig. 6.** Examining a Mitchell intrusion breccia and mineralization near Pretium Resources Incorporated's Snowfield property.

its subvolcanic feeder intrusions. Cordilleran section geologists and Regional Geologist Jeff Kyba are collaborating on this project, which is assessing the role of basement structures on localizing Cu-Au mineralization. Development of this geological model will provide a predictive tool for targeting new Cu-Au occurrences in this area.

## 2.2. 2012-2013 Projects

### 2.2.1. Exploration methods

#### 2.2.1.1. Carlin-type gold in British Columbia?

Structurally controlled Carlin-type Au showings have recently been discovered in Proterozoic-Paleozoic Selwyn basin strata of the Rackla belt in east-central Yukon. These discoveries raise the possibility of similar occurrences in equivalent settings in British Columbia. This reconnaissance project uses the British Columbia Geological Survey's regional geochemical and MINFILE databases, in conjunction with digital geology and geophysics, to test for As  $\pm$  Au  $\pm$  Hg  $\pm$  Sb anomalies and minerals such as realgar and orpiment. These data may show spatial associations with long-lived regional structures, and to platform to deep-water transitions in the Kechika trough (the southward extension of Selwyn basin) of north-central British Columbia (Fig. 3). This project is an example of how the Provincial geochemical archive may be used to explore for a new type of deposit using existing survey databases.

#### 2.2.1.2. Trace-element systematics in apatite: Applications to metallogeny, petrogenesis, geochronology, and mineral exploration

Regional geochemical surveys that collect resistate indicator minerals (RIMs) in surficial materials have proven successful in diamond exploration and are now being applied to other types of mineral deposits. Porphyry indicator minerals (PIMs) including apatite, rutile, titanite, and magnetite are related to the distinctive types of alteration that characterize porphyry Cu-Mo-Au mineralization. This project focuses on developing a new exploration tool for identifying source deposit types from RIMs in till in a variety of tectonic settings. The tool uses relatively inexpensive and rapid laser ablation inductively-coupled plasma mass spectrometry (LA-ICPMS) to measure trace element abundances in apatite and other resistate minerals to "fingerprint" apatite from specific deposits. The technique also can establish U-Pb, Th-Pb, and Pb-Pb ages of apatite. This project supports a post-doctoral fellow and is a collaboration with the School of Earth and Ocean Sciences at the University of Victoria, under the Ministry of Energy and Mines – University of Victoria Partnership Program.

#### 2.2.1.3. Lead isotopes and trace element geochemistry of till at selected volcanogenic massive sulphide deposits west of Harrison Lake

Lead isotope analysis of silt and clay fractions in tills can aid mineral exploration in glaciated terrains. In situ weathering or destruction of sulphide minerals during till formation can mask elemental signals of buried mineralization, but such signals may be retained by Pb isotopic compositions. This project is an orientation study that examines the Pb isotopic ratios of tills above and down ice-flow direction of known volcanogenic massive sulphide occurrences in the Jurassic Harrison Lake

Formation west of Harrison Lake in southwestern British Columbia (Fig. 3). Because of large differences in Pb isotopic ratios between anomalous and background samples, high-precision analytical techniques are not required, and commercial ICP-MS methods are suitable. Consequently, the method is readily accessible to the exploration community and may be an effective prospecting tool in glaciated terrains.

## 2.2.2. Mineral deposits

### 2.2.2.1. Specialty metals (TGI-4)

The British Columbia Geological Survey and the Geological Survey of Canada continued to collaborate on a five-year (2010-2015) province-wide study of specialty metals and rare earth elements. Specialty metals are uncommon, nonferrous metals used in small quantities (typically < 150 000 tonnes/year or derived from geographically restricted areas). The Specialty Metals Program is part of the Targeted Geoscience Initiatives program (TGI-4) and has two major components: 1) reviewing ore deposits and their mineral economics in Canada; and 2) developing techniques to guide exploration toward ore-grade zones in host deposits. This project is supporting three M.Sc. theses (at McGill University, Simon Fraser University, and the University of Victoria). The 2013 field programs focused on the Lonnie Creek niobium prospect and the Aley carbonatite (Figs. 3, 7). The results of the Specialty Metals project will aid exploration and development of these strategic metal resources.

### 2.2.2.2. Orogenic Ni-Cu-PGE (TGI-4)

The Ni-Cu-PGE-Cr Ore Systems project is another national Targeted Geoscience Initiative (TGI-4) of the Geological Survey of Canada, under the Intrusion Related Ore Systems program. The British Columbia component is a collaboration between the British Columbia Geological Survey, the Geological Survey of Canada, and the University of British Columbia. The project is examining the potential for orogenic Ni-Cu-PGE-Cr deposits associated with supra-subduction zone ultramafic-mafic intrusions exclusive of ophiolites and accreted large igneous provinces (e.g., Wrangellia). The goal is to establish mineral deposit models and exploration criteria for two poorly understood magmatic sulphide deposits in BC: 1) Giant Mascot, British Columbia's only past-producing nickel mine (1958-74); and 2) the Turnagain Alaskan-type intrusion, which has a substantial resource of low-grade Ni and Co (Fig. 3). The project supports two graduate students at the University of British Columbia.

## 2.2.3. Regional synthesis and map compilation

### 2.2.3.1. The Cordillera of British Columbia, Yukon, and Alaska: Tectonics and metallogeny

Success in mineral exploration can be greatly enhanced by understanding the regional geology and metallogeny of a prospective area. In 2013, the British Columbia Geological Survey and the Yukon Geological Survey released an update of the 2007 synthesis on the tectonics and metallogeny of the northern Cordillera (Nelson and Colpron, 2007) as part of the Society of Economic Geologists annual meeting at Whistler, British Columbia. The new publication (Nelson et al., 2013) integrates the origin of major metallic mineral deposits and mineral belts in the northern Cordillera with its protracted

tectonic evolution.

### 2.2.3.2. British Columbia Quaternary geology interactive map index

The British Columbia Geological Survey has updated and enhanced the British Columbia surficial geology map index. This index is now interactive and available on MapPlace and through Google Earth. The index consists of all surficial and Quaternary geology maps produced by the British Columbia Geological Survey, the Geological Survey of Canada, and Geoscience BC. All maps are available for digital download free of charge. Each footprint in the index provides an accurate representation of the areal extent of surficial geology mapping for British Columbia.

### 2.2.3.3. British Columbia ice-flow indicator compilation

British Columbia was last glaciated in the Late Wisconsinan (~ 22-10 ka). As a result, much of the province is blanketed by thick accumulations of unconsolidated sediments that obscure the underlying bedrock. Traditional soil geochemical surveys commonly sample glacially transported material or derivative products that have been displaced from their initial bedrock source along a path determined by the transporting agent (i.e., water, ice, or wind). In the case of till, the sediment has been relocated by the flow of ice. Therefore, in order to locate the bedrock source of a geochemical anomaly, it is critical to know



Fig. 7. Stream-sediment sampling at the Aley carbonatite.

the direction of ice-flow. To address this, the British Columbia Geological Survey compiled and digitally captured over 119,000 ice-flow indicators from published and unpublished surficial geology, terrain, glacial features, and bedrock geology maps in British Columbia. Ice-flow indicators include outcrop-scale features such as striations and grooves, and landform-scale features such as drumlins and flutes. These data illustrate ice-flow directions for the Cordilleran ice sheet during the Late Pleistocene.

#### **2.2.3.4. Towards a British Columbia digital Quaternary geology map**

Like bedrock geology, knowledge of the distribution and origin of surficial materials is fundamental for many applications in mineral exploration, geotechnical engineering, and public health and safety. Currently this information exists in a variety of maps and formats. In an effort to develop a universal provincial-scale Quaternary geology map, the British Columbia Geological Survey launched a pilot project to produce a continuous 1:50,000-scale digital surficial geology layer for the entire Interior Plateau. A framework-based data model will be developed and expanded to a province-wide digital surficial geology layer. This digital surficial geology layer will complement the current BC Digital Geology Map<sup>1</sup> and will be a source of information on surficial materials used in resource development projects and research on the Cordilleran ice sheet during the Late Pleistocene.

#### **2.2.3.5. Basal till potential maps for the TREK project**

As a contribution to the BC Geological Survey – Geoscience BC’s Targeting Resources for Exploration and Knowledge (TREK) partnership, the British Columbia Geological Survey is supervising the development and publication of “Basal Till Potential Maps” for the TREK study area in the Interior Plateau (Fig. 3). These maps are designed to assist in locating basal till, the variety of till ideally used for geochemical and mineralogical surveys. The maps identify areas where basal till is likely to occur and locations suitable for sampling. These maps will assist in the design of exploration programs by focusing expensive field based sampling to areas where the potential for collecting basal tills is high.

#### **2.2.3.6. Coalfield compilation maps**

Coal production in British Columbia accounts for most of the Province’s mine production revenues. Coal license applications have reached record levels in recent years. The approval of these applications must meet with the integrated resource development goals of the government, which has resulted in a growing need for information and maps explaining coal geology and its spatial relationship with other land values. In 2013, the British Columbia Geological Survey began compiling coalfield infographics on a coalfield-by-coalfield basis. These posters help both professionals and members of the general public understand the distribution of British Columbia’s coal resources in a readily understandable format. The Peace River Coal field in northeast British Columbia will be the first of these compilations (Fig. 3).

<sup>1</sup> BC Digital Geology Map: <http://www.empr.gov.bc.ca/mining/geoscience/bedrockmapping/pages/bcgeomap.aspx>

#### **2.2.4. Geochemical laboratories**

The British Columbia Geological Survey operates a geochemical laboratory that supports the Survey’s field programs, targeted mineral deposit studies, and development of mineral exploration methodologies. Increasingly, indicator minerals (e.g., garnet, apatite, and magnetite) in bedrock and derivative sediments, such as till or streams, are being used as an exploration tool. To aid the development of this powerful new exploration technique, the British Columbia Geological Survey’s geochemical laboratory underwent major upgrades in 2012-2013. Improvements included construction of a new rock storage facility and geochemical archive to accommodate over 600,000 geochemical pulps and rock and soil samples. New equipment included rock saws, a Linkam THMSG 600 heating-freezing stage for fluid inclusion microthermometry, an ultrapure water system, and a portable bench-top Thermo Scientific Niton X-Ray fluorescence (XRF) analyzer. The chemical fume hoods were refurbished and the addition of a Bico disk pulverizer and a Wilfley shaking table completes the laboratory’s full functionality for mineral separation and processing.

### **3. Resource Information Section**

A critical role of the British Columbia Geological Survey is to archive and disseminate geological information. The Survey is the data custodian of over 118 years of geoscience publications and geological databases created through field surveys, research, and document donations. Resource Information Section staff manage, disseminate, and guide the use of this information to support government decision making and enhance the success of the mineral exploration community. Free access to British Columbia’s geological information increases exploration effectiveness by enabling the efficient gathering of regional information useful for property scale evaluation. Archived exploration results and activities help explorers advance projects without unnecessary duplication of previous work. The MapPlace<sup>2</sup> is the Survey’s web service that has been providing visualization and query capacity to this extensive array of information since 1995.

#### **3.1. MapPlace and database activities**

##### **3.1.1. MapPlace**

Since 1995, the MapPlace web service has provided industry and government agencies with comprehensive tools and open geoscience data to aid in the discovery of mineral potential in British Columbia. MapPlace’s unique and interactive applications and tools assist in investment decision making. MapPlace continues to provide clients with efficiencies in research time, data costs, and analysis. Data themes and applications available on MapPlace include mineral potential, bedrock and surficial geology, publications, mineral and petroleum tenure, MINFILE, assessment reports, geochemistry, and geophysical surveys.

As of 2013, MapPlace will continue to operate and be maintained using Autodesk MapGuide 6.5 while the next generation of software is being developed. Recent new additions to MapPlace include geochemistry data (described

<sup>2</sup> MapPlace: <http://www.empr.gov.bc.ca/Mining/Geoscience/Mapplace/pages/default.aspx>

below) and QUEST-Northwest aeromagnetic survey data from Geoscience BC Reports 2012-02, 2012-03 and 2013-03. The main BCGS Geoscience Map displays data from Open File 2013-06, a compilation consisting of over 119,000 ice-flow indicators digitally captured from published and unpublished surficial geology, terrain, glacial features, and bedrock geology maps in British Columbia. A new Surficial Geology Index (Open File 2013-09), which includes over 200 maps available for download, was added to MapPlace.

The British Columbia Geological Survey is prototyping web services based on MapGuide Open Source. The goal is to determine if MapGuide Open Source is a suitable replacement platform for developing web applications and delivering public geoscience, as required by the current MapPlace web services. MapGuide Open Source can use third party topographic basemaps and imagery such as Google maps, Yahoo maps, Bing maps and Open Street Map. Users can switch between these basemap layers to serve their specific needs. It is essential to MapPlace web services to support complex spatial operations and query (e.g., select MINFILE records within the buffer of a given bedrock unit), visualization, and reporting. Currently, 152 geoscience data layers in 28 layer groups have been developed, representing 70% of the data layers in the current MapPlace. The important layer groups directly related to geosciences are mineral inventory, regional geochemistry, topographic basemaps, bedrock geology, and mineral resource assessment.

MapGuide Open Source has demonstrated impressive preliminary performance. It is capable of displaying province-wide bedrock geology with over 32,000 polygons in less than two seconds, and over 61,000 RGS sample locations in less than 3 seconds. Time to display large raster layers is also acceptable, and zoom-in and zoom-out functionality is smooth and fast. The utility of MapGuide Open Source will continue to be tested to ensure that service is maintained if a decision to migrate from Autodesk MapGuide 6.5 is made.

### 3.1.2. Property File, MINFILE, ARIS and geochemical data

Property File<sup>3</sup> is a collection of over 60,000 documents, most of which were collected by British Columbia Geological Survey staff or donated by industry. These documents span the last 150 years and include hand-drawn maps, drill core records, correspondence, thin sections, reports, and prospectuses, and other items. Given the change in commodity prices and the expansion of infrastructure over time, past fieldwork that was not followed up could now be a viable exploration target. The Property File project is managed by Purple Rock Inc. Recent additions include 3300 documents from the Chevron file, over 1600 from the Placer Dome file, and 2300 from the R.V. Kirkham file. These documents complement the 1640 documents from collections donated by the estates of Dennis Gorc, W.G. Hainsworth, and W.M. Sharp; and over 9400 documents from former geological survey staff geologists (Tom Schroeter, Bill McMillan and Andre Panteleyev). Other company collections include 2800 Cyprus-Anvil, 400 Falconbridge, and 7600 Rimfire documents. In 2007, University of British Columbia donated 680 undergraduate theses and reports. Over 2760 mine

plans are in Property File. The Library file and other collections number over 18,000 documents and maps. Over 50,200 documents are online and are available for free download.

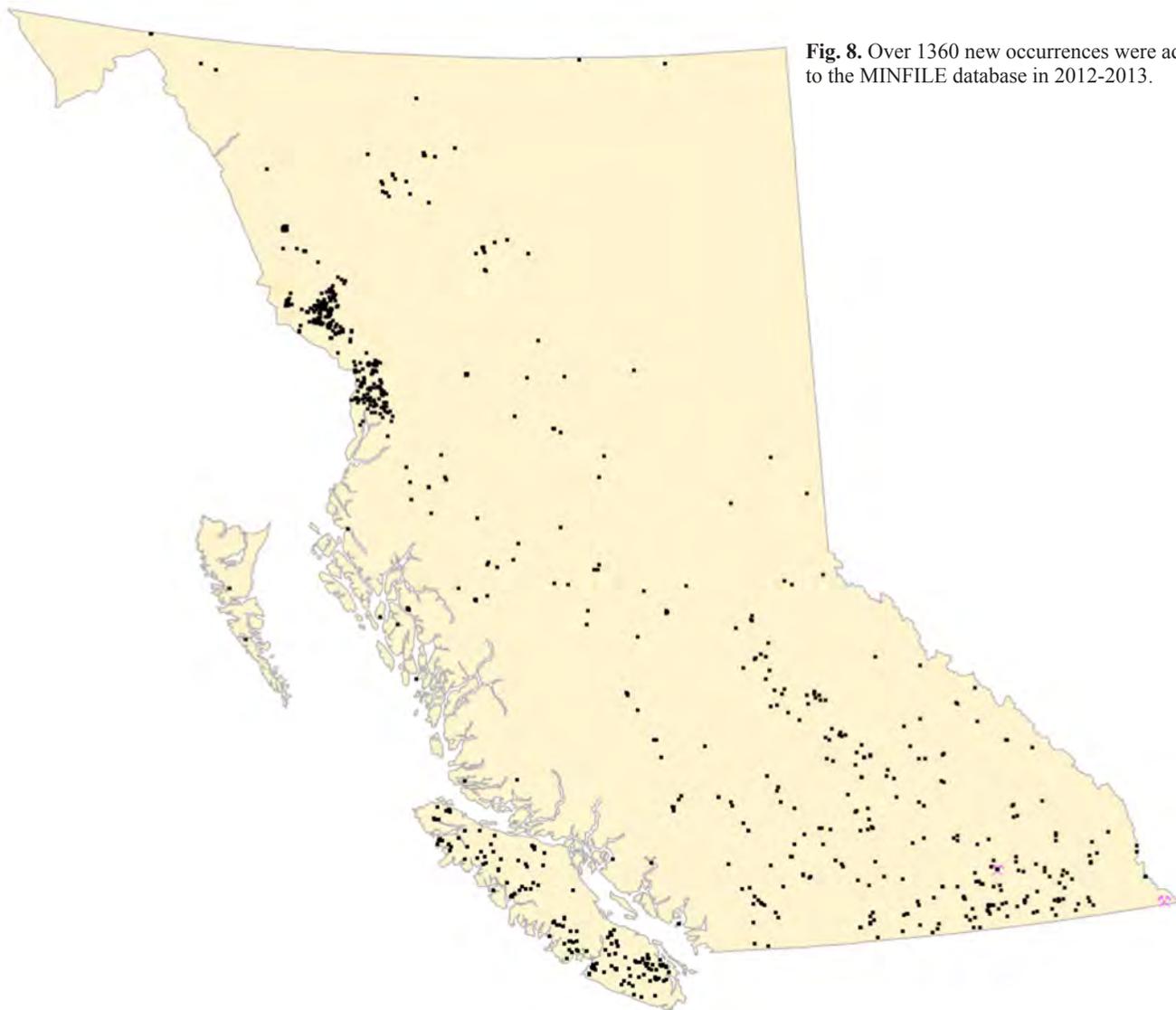
MINFILE<sup>4</sup> contains geological, location, and economic information on more than 13,364 metallic, industrial mineral, and coal mines, deposits and occurrences in BC. From January 2012 to March 2014, additional funding was allocated to update MINFILE and to add new discoveries by reviewing mineral assessment reports, recent publications, press releases, Property File, and company websites (Fig. 8). Contractors Total Earth Science Services and Purple Rock Inc. updated over 4300 occurrences, including the addition of 1366 new occurrences to the MINFILE database.

In compliance with the Mineral Tenure Act (MTA) Regulations, results of mineral exploration programs on mineral claims in British Columbia are submitted to the Ministry of Energy and Mines. These assessment reports contain information on geology, geophysics, geochemistry, drilling, prospecting and physical work. After a one-year confidentiality period, the reports become an open resource for planning mineral exploration investment, research, land-use planning and resource management. Users can now access more than 33,470 company mineral assessment reports using the online ARIS database. More than \$2 billion of exploration expenditures have been recorded in assessment reports since 1947. The value of expenditures on 2012 exploration programs reported in 804 assessment reports, moved to off-confidential status in 2013, was \$196 million. The mining industry is encouraged to submit assessment reports in digital form (PDF by email, CD-ROM, DVD, or USB drive) to the Mineral Titles Branch. Benefits include higher quality digital reports; faster approval; and lower costs for printing, mailing, storage, scanning and processing. During 2013, 789 reports were approved. Four criteria improve approval rates: adequate detail in the cost statements; plot geochemical values; submit full-scale geophysical maps; and cross sections and proper scales for drillhole data. The ARIS website sees about 1.4 million hits in a month.

Ongoing efforts by government-funded agencies to update and maintain the geochemical database established by the British Columbia Regional Geochemical Survey (RGS) and the National Geochemical Reconnaissance programs have produced one of the most comprehensive collections of field information and multi-element analytical data in Canada. The database has benefitted from a series of large-scale reanalysis initiatives, which have been sponsored by Geoscience BC since 2007. To compliment the RGS 2011 data displayed on MapPlace, the following Geoscience BC Reports have been added as separate layers to display the locations for stream-sediment sample reanalysis: 2013-04 Lardeau (082K) 1297 samples by ICP-MS; 2013-06: McLeod Lake (093J) 1152 samples by INAA; 2013-09 Nelson (082F) 1394 samples by ICP-MS; and 2012-5 and 6 QUEST-Northwest (104K) 932 samples by ICP-MS and (NTS 104F & G) 1414 samples by INAA. Reports 2013-11 and 12 Northern Vancouver Island (092L, 092K and 102I) represent new data for 721 new moss mat and water from 681 stream sites, and new ICP-MS results

<sup>3</sup> Property File: <http://www.empr.gov.bc.ca/mining/geoscience/propertyFile/Pages/default.aspx>

<sup>4</sup> MINFILE: <http://www.empr.gov.bc.ca/mining/geoscience/minfile/Pages/default.aspx>



**Fig. 8.** Over 1360 new occurrences were added to the MINFILE database in 2012-2013.

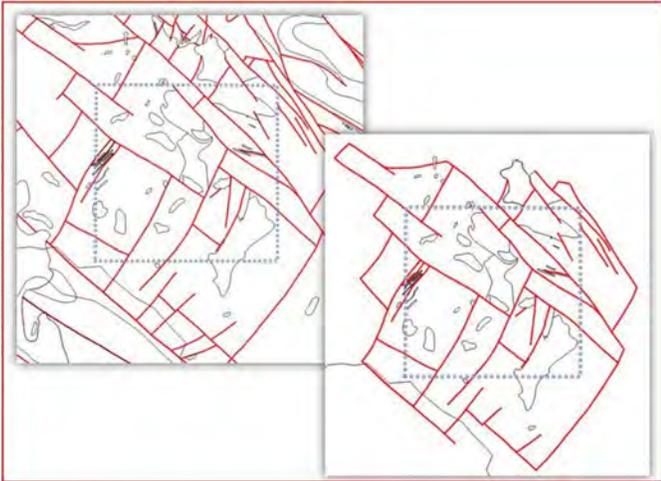
for 433 till samples. BCGS GeoFile 2013-07 represents rock geochemistry data, collected in 1998, for 60 samples in 082L, 082M and 092P.

### 3.2. British Columbia's digital bedrock geology map: BCGeology Map

The BCGS has developed techniques to deliver to the exploration industry a continuously updated geological map of the province. The “geologic framework data” (GFD) model enables rapid integration of new mapping (Fig. 9). Traditionally, polygons, to define map units, are used as the base to update and integrate digital geology. However, using polygons as the base can lead to errors in editing and take excessive time to reconcile shared boundaries between adjacent map units and coincident planar geological features such as faults. To avoid these issues, the BCGS dispensed with polygons for integrating updated maps and developed the GFD model. This model consists of centroids describing map units and lines defining

geological boundaries, as the source and the base to carry out data quality assurance, revision, and map integration. Bedrock polygons are not part of the GFD but are generated from GFD in the finished map.

Applying the GFD model allows a ‘checking-out’ and ‘anchoring’ mechanism to address map boundary issues that commonly arise when new maps are integrated with historical work (Fig. 9). Checking-out extracts the GFD data for the geologists working in a given project area, but with an extended regional context, to include any map units and boundaries, contained by or intersected with the project boundary. The outermost boundaries of this extended project map are tagged as ‘anchor lines’, with nodes on the anchor lines as ‘hooks’ that connect to ‘rode lines’ in the project map. When the mapping project is complete, the updated GFD for the project area, with its extended regional context, are returned to the provincial GFD base. The rode lines in the project map are snapped to the hooks in the provincial base in lieu of edge matching. The



**Fig. 9.** Geological framework data showing checking-out an extended regional context, to include any map units and boundaries contained by or intersected with the project bounding area.

GFD in the project area, its extended regional context, and the anchor lines from the provincial base are used to update the provincial map.

The BCGS GFD model builds on the 2005 edition of the provincial bedrock map and operates in a spatial database. The spatial database makes it possible to handle large volumes of data, and permits multiple users to perform concurrent operations on the same GFD base. Applications developed to automate checking-out, anchoring, and integration, not only simplify the integration process, but also streamline rules-driven data quality assurance and content standardization, and automate auditing changes, populating bedrock attributes, generating map unit colour schemes, and creating customized maps for delivery via web services. The GFD model and the spatial database applications were used in integrating new mapping, and the current version of the BC Digital Geology database includes the latest work in the QUEST, North Coast, Terrace, and Kutcho project areas.

**4. Mineral Development Office**

The role of the BC Mineral Development Office (MDO) in Vancouver is to provide mineral and coal resource information, promote the province’s minerals and coal investment opportunities and form a point of contact on issues impacting the exploration and mining industries.

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 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 2014, we will release an updated version of “Opportunities to Explore”, a non-technical publication geared to new investors wanting to learn more about the province. Previous financial and content input for this document from the Association for Mineral Exploration British Columbia, Mining Association of British Columbia, Geoscience BC, and partner agencies have

allowed large print runs in two languages. The document forms a key sector-specific document for the Ministry of International Trade, who support its reproduction for use by trade and investment staff in their international offices.

A second annual version of “Coal Industry Overview” was created by the Survey’s coal geologist. Interest in the province’s coal sector is steady. The previous map “Communities that Benefit from Mining” was released this year as “Communities, Mineral and Coal Exploration Investment” (Fig. 10). The non-technical publication summarizes exploration investment from 2010-2012 by watersheds and in relation to communities across the province. The use of GIS software allowed the incorporation of tenure maintenance financial data alongside the Regional Geologist’s estimations of investment, giving a more comprehensive perspective to the final map. A three-year summary was adopted to smooth the annual data and allow the map to be updated less frequently.

After a decade long hiatus, the inventory of gold in the province has been updated and will be released in early 2014. “Gold Resources and Production in British Columbia (1890-

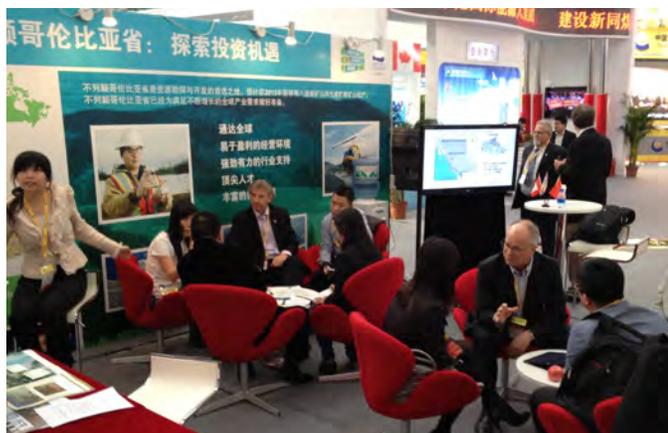


**Fig. 10.** The map “Communities, Mineral and Coal Exploration Investment” summarizes exploration investment from 2010-2012 relative to communities across the province.

2013)” will include a 2,000,000-scale map, spreadsheet, and infographic, and will be showcased on a new provincial basemap. The map will show occurrences by deposit type and grade category, using symbols for resources remaining verses extracted. The project has highlighted a significant increase in gold inventories in the province.

The MDO oversees the creation of provincial and regional level exploration and mining summary documents from the Regional Geologist program. These publications maintain a legacy that dates back to 1874 with the Annual Reports of the Minister of Mines.

The MDO actively promote the province’s minerals and coal industry domestically and abroad. This occurs at a variety of formal and informal locations including conferences, business meetings, investment missions, and over the counter contacts. This year included numerous events such as the: Asia Investment Mission to China and Japan alongside five partner provinces and territories; meetings with delegations from China, India, Japan, Chile, Australia, Germany; Mineral Exploration Roundup, Prospectors and Developers Association of Canada Convention; Northwest Mining Association Conference, China Mining Conference; Sparwood Coal Symposium and the KEG annual conference (Fig. 11).



**Fig. 11.** The MDO works closely with the Ministry of International Trade to promote the province’s minerals and coal opportunities domestically and abroad. British Columbia was joined by provincial representatives and a dozen industry partners for the Asian Investment Mission, which included the China Mining Conference in Tianjin, China.

### 5. Regional Geologists

The British Columbia Regional Geologists are government’s experts on geological matters at a regional level and capture information on industry activity in their respective jurisdictions. Within their communities, they are recognized professionals on matters of exploration trends, support investment attraction, land use processes, First Nation capacity building, public outreach and other key deliverables of government.

Regional Geologist	Office	Region
Jeff Kyba	Smithers	Skeena
Paul Jago	Prince George	Omineca and NE
Jim Britton	Kamloops	Thompson/Okanagan/Cariboo
Fiona Katay	Cranbrook	Kootenay/Boundary
Bruce Northcote	Vancouver	South/West Coast

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