

Summary of Yukon Geological Survey 2015-16 Activities

Carolyn Relf¹ and Maurice Colpron
Yukon Geological Survey

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INTRODUCTION

Staff at the Yukon Geological Survey (YGS) carried out fieldwork on 12 projects in 2015-16 (Fig. 1). These multi-year projects included regional bedrock mapping, detailed surficial mapping, stratigraphic studies (in sedimentary basins and surficial materials), and a thematic metallogeny study. In addition, field reconnaissance was carried out in preparation for the installation of an array of seismometers in southeastern Yukon, and planning is currently underway to deliver one or more thematic geophysical projects.

Three desktop studies are currently underway or completed: these include modeling of stream sediment geochemical data, creation of a new mineral potential map of the Selwyn basin (currently focused on the traditional territory of Ross River Dena Council) and a compilation of historic placer data from Dominion Creek.

In addition to the above, YGS funded the field and/or analytical work of seven university-based studies, some of which are supporting more than one graduate or undergraduate thesis.

YGS continued to monitor hard rock and placer exploration and production, and provided clients with information on Yukon geology, both in person and online. Public outreach is an important part of the survey's program; activities in 2015 included educator workshops, hands-on classroom activities, geology-themed hikes and engagement of communities in the monitoring of permafrost.

Highlights of YGS' activities are summarized in this paper; overviews of hard rock and placer activities and highlights of YGS's Yukon Mineral Exploration Program are presented elsewhere in this volume (Lewis *et al.*, 2016; Bond and van Loon, 2016; Torgerson, 2016, respectively). More detailed descriptions of individual geology projects results will be released separately, either in the upcoming Yukon Exploration and Geology 2015 (available early in 2016) or in stand-alone publications.

¹ carolyn.relf@gov.yk.ca

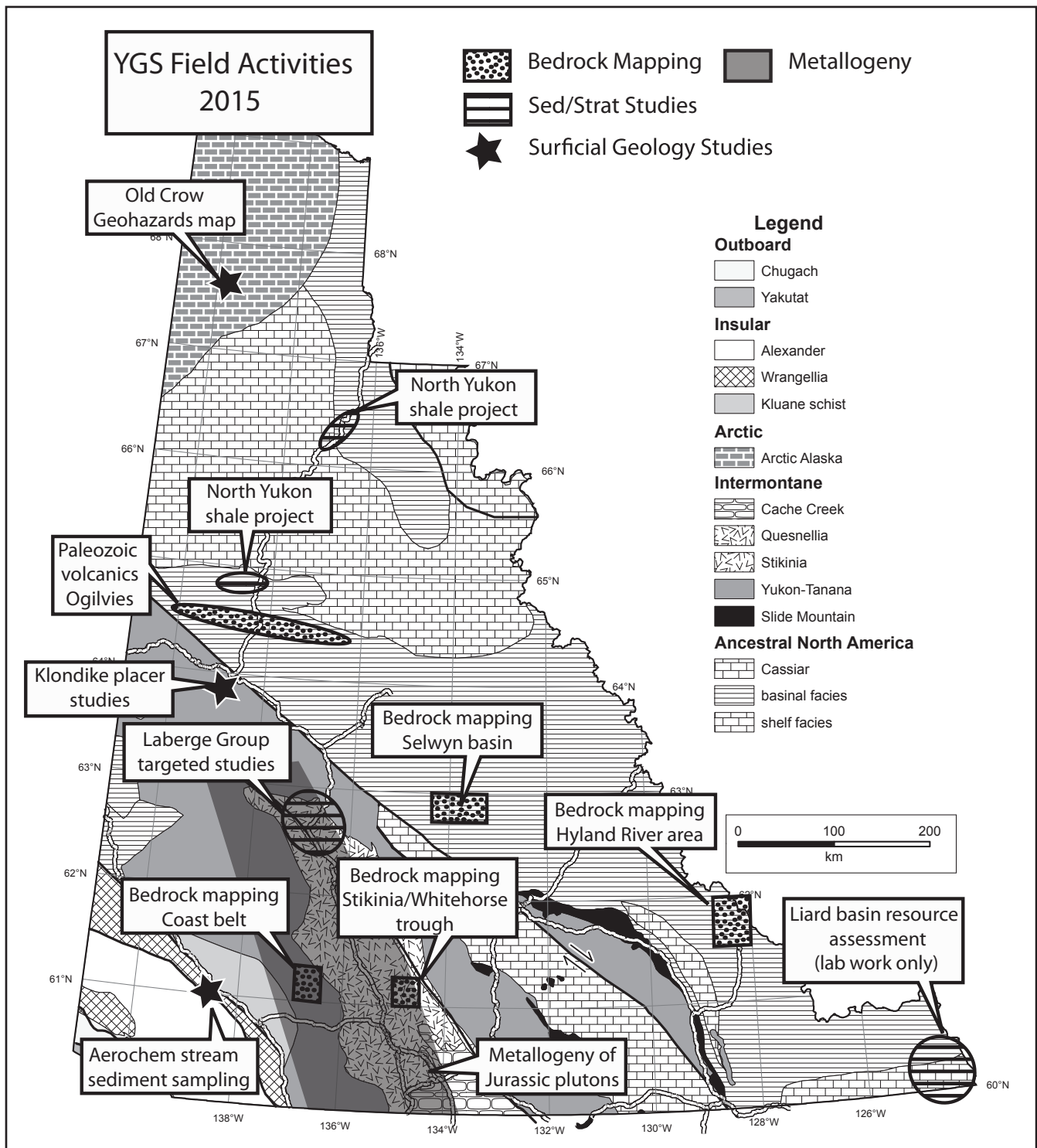


Figure 1. Locations of field activities carried out or supervised by YGS staff in 2015. Descriptions of individual projects provided in the text.

YUKON GEOLOGICAL SURVEY PROGRAM FUNDING AND OVERSIGHT

YGS' mandate is to support the stewardship of Yukon's energy and mineral resources, and to contribute to the sustainability of Yukon's communities. To that end, the projects delivered by the survey are developed with specific intended outcomes, such as regional mapping to attract exploration investment, delineating aggregate resources to assist infrastructure development, collecting baseline data to support regulatory decisions and assessing geologic hazards to protect Yukon communities. A beneficial upshot of the work carried out by the survey is the training opportunities provided to seasonal field assistants; YGS has employed and trained numerous Yukon students over the years. All of YGS' data and the products derived from the data (maps, sections, reports) are made publicly available; most can be downloaded from the YGS website (www.geology.gov.yk.ca).

Annual work plans are developed with input from two Technical Advisory Committees (one for minerals; one for oil and gas). Yukon Government priorities and collaborative research opportunities (e.g., with Yukon College, university researchers and Yukon First Nations) also influence work planning, as does the Yukon geoscience needs report which is updated every five years.

YGS OPERATING BUDGET

Yukon Geological Survey's 2015-16 operating budget totaled \$3 615 000. The budget includes \$1 265 000 in O&M funds, \$1 400 000 for the Yukon Mineral Exploration Program (for grants) and \$950 000 from the Canadian Northern Economic Development Agency's Strategic Investments in Northern Economic Development (SINED) Fund. This report provides highlights of projects that were funded with O&M and SINED funds; a summary of YMEP-funded projects is provided elsewhere in this volume (Torgerson, 2016).

SINED FUNDING

The current 2015-16 fiscal year marks the second year of a two-year SINED grant (\$950 000 per year). Projects funded by this grant are intended to support economic development in the territory and require leveraged funding from YGS or other non-federal research partners (e.g., universities). SINED funding has been supplementing YGS' program activities for over a decade, and the program

has had a major impact on YGS' productivity by funding a number of targeted geophysical surveys and geophysical data processing projects, supporting numerous university researchers, upgrading regional geochemical datasets and allowing YGS to digitize over 100 Gb of data that would not otherwise be easily accessible to clients.

As in previous years, YGS is seeking feedback on the value and impact of SINED-funded projects. Readers are encouraged to contact the authors to provide comments on YGS' SINED-funded projects.

YUKON GEOLOGICAL SURVEY ORGANIZATIONAL OVERVIEW

STAFF CHANGES

Yukon Geological Survey's organization chart is shown in Figure 2. Survey staff are divided into four units: Bedrock Geology, Surficial Geology, Minerals Geology and Technical Services.

Over the past year, a number of staff changes have impacted the survey. Don Murphy, previously head of the bedrock geology unit, retired in June after 23 years, although he continues to have a presence at the survey as an emeritus scientist. Maurice Colpron was appointed as the new head, Bedrock Geology in July. Esther Bordet joined YGS in April 2015 as the newest member of the Bedrock Geology unit. She is filling the vacancy left by Maurice's move into the head of Bedrock Geology position.

Lara Lewis was formally appointed as head, Minerals Geology in April, filling a gap that was created when Lee Pigage retired in June 2014. She will be taking eight month's deferred leave between February and September 2016 and Patrick Sack will be acting head in her absence.

Johann Slam, Core Library manager, left the survey in November to pursue an opportunity in southern BC. Johann joined the survey just as the new H.S. Bostock Core Library building was completed, and he was the key force behind setting up the facilities. His legacy will be a well-organized and highly functional core library, lapidary facility and warehouse.

In addition to the above, several temporary changes were accommodated. Tiffani Fraser started a year's deferred leave in August; she will be returning to YGS in September 2016. Scott Casselman joined the Minerals Geology unit in April for a term of 10 months; his extensive exploration

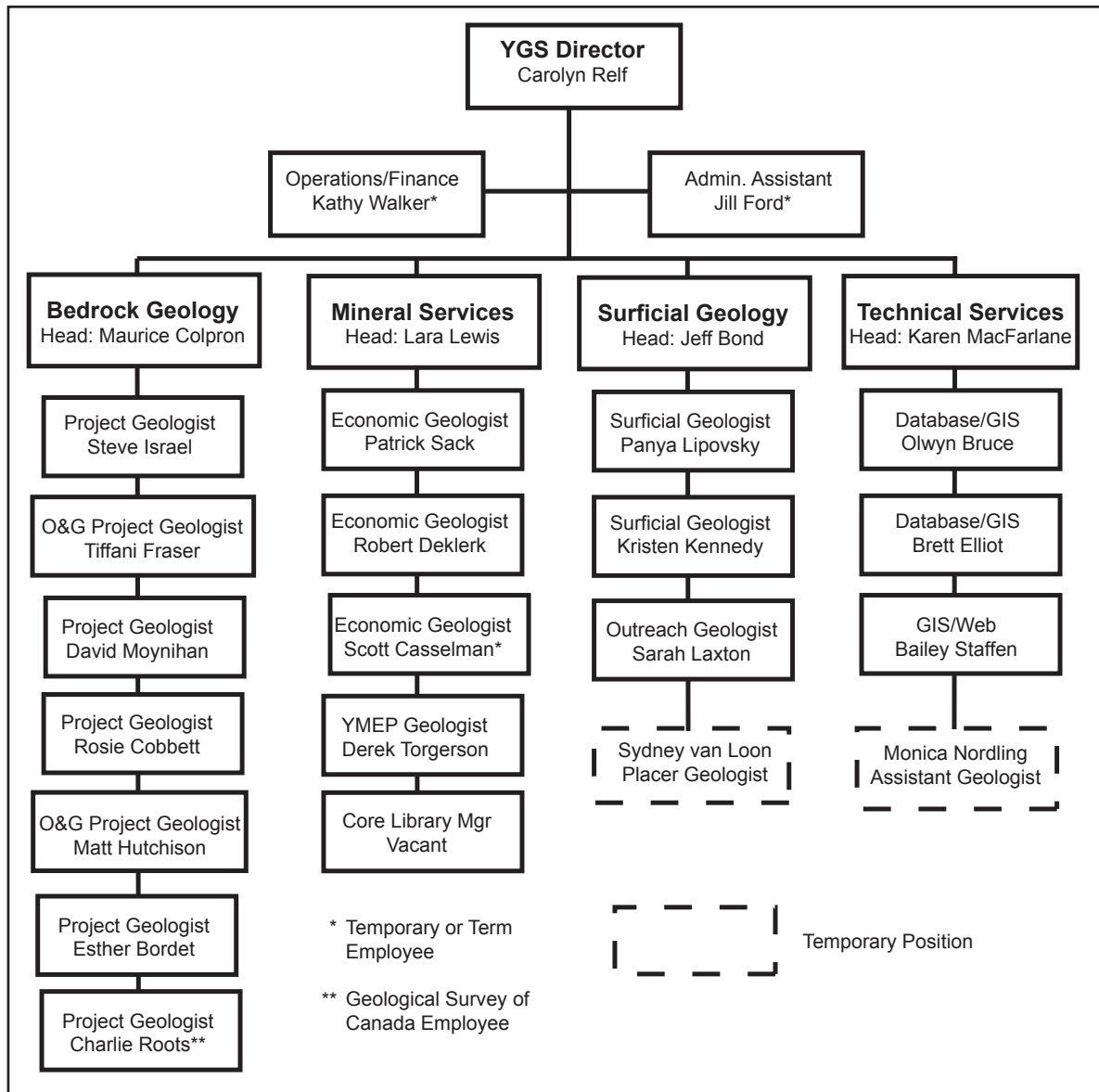


Figure 2. 2015 Organizational chart of Yukon Geological Survey.

experience has been an asset to the survey. Suzanne Roy, manager, Finance and Operations, has been on an extended leave and Kathy Walker has been back-filling on a temporary assignment since March 2015. Following the retirement of Brian Love (Assistant Deputy Minister of Oil, Gas and Mineral Resources), Carolyn Relf was acting ADM from May until December. During that time, Maurice Colpron and Lara Lewis back-filled as the director for YGS.

The first author would like to take this opportunity to acknowledge Maurice and Lara in their new roles, welcome Esther to the survey and to thank Johann for

the excellent work he did setting up the core library facility. Finally, Don is acknowledged for his long and distinguished career with YGS.

NEW STAFFING

YGS will be recruiting for a new Economic Geologist early in 2016, followed by recruitment for a new Core Library Manager. Positions will be posted on <https://yukongovernment.ats.hrsmart.com>. Interested individuals are encouraged to contact the first author for more information.

HIGHLIGHTS OF YGS FIELD ACTIVITIES

BEDROCK MAPPING

Hyland River Area

David Moynihan continued bedrock mapping in the Hyland River area, extending 2014 mapping in 105H/9 southward into 105H/8 (Fig. 1). Work to date has resulted in significant revisions to the stratigraphy of the Neoproterozoic Hyland Group, which comprises the oldest exposures of Selwyn basin. Clastic sedimentary rocks previously interpreted as Yusezyu Formation (lower Hyland Group) have been assigned to 12 newly-defined stratigraphic units (Moynihan, 2016). These revisions link to stratigraphic correlations established in the eastern Rackla belt (Moynihan, *in press*), and will be tested with follow-up geochronological data.

Structures identified include southwest-verging folds and faults in the eastern part of the map area (Fig. 3), and a younger crustal-scale fault in the Hyland River valley indicated by truncation of map units and expressed in aeromagnetic maps. These stratigraphic and structural observations help improve understanding of the setting of gold prospects such as the Justin and 3 Aces occurrences (Yukon MINFILE 105H035 and 105H066, respectively).

Stikinia/Whitehorse trough

Esther Bordet initiated a new 1:50 000 scale bedrock mapping project east of Lake Laberge in the Teslin Mountain area (105E/2; Fig. 1). The area is underlain by rocks of the Middle Triassic Joe Mountain Formation and Upper Triassic Lewes River Group (both part of Stikinia), and Lower-Middle Jurassic Laberge Group rocks of the Whitehorse trough. Mapping focused on the stratigraphic and structural relationships within and between these three units.

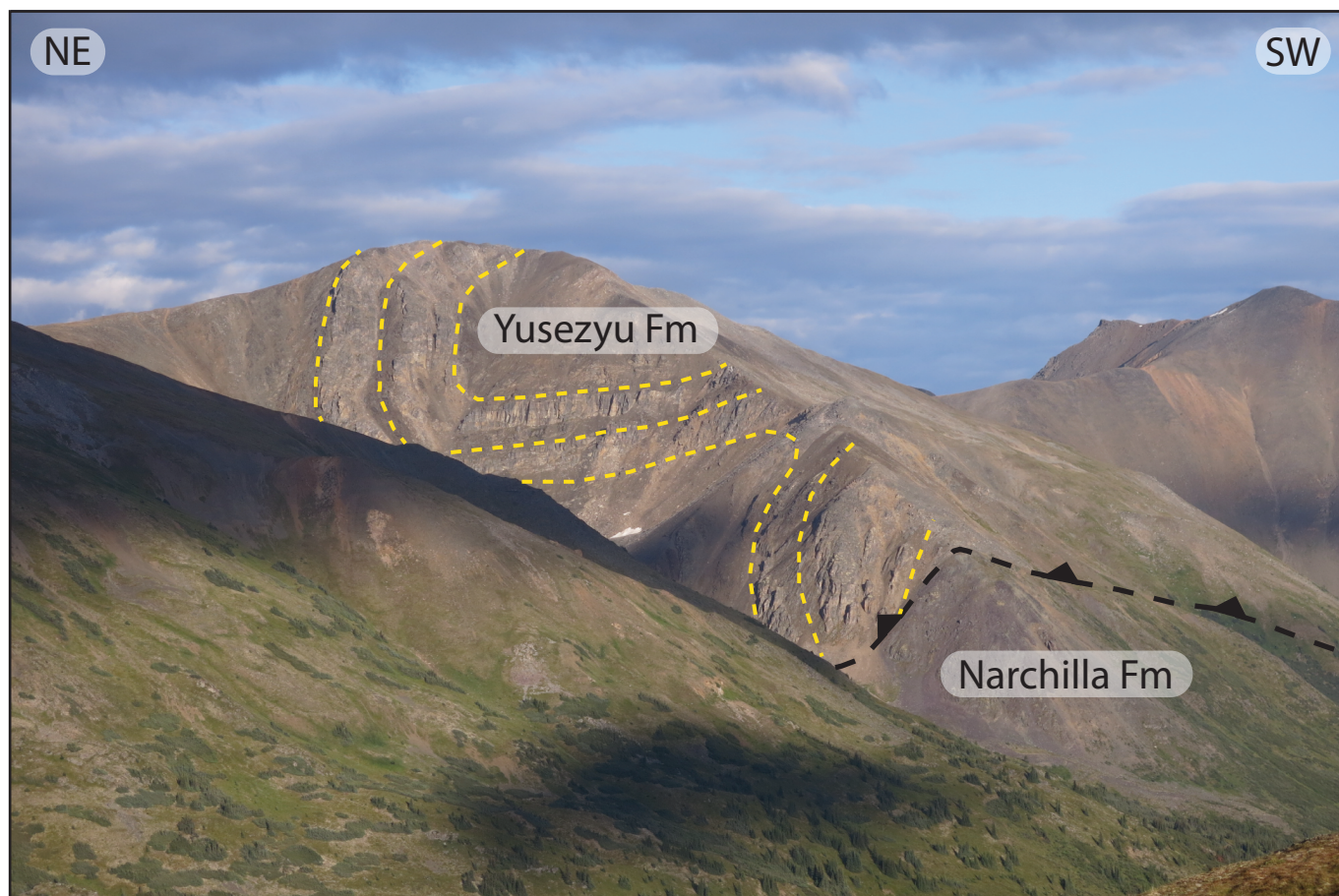


Figure 3. Folded strata of the Yusezyu Formation thrust over Narchilla Formation; Hyland River area. Photo by D. Moynihan.

Bordet (2016) documents complex lateral and vertical lithological and facies changes across the area; particularly within the Lewes River Group. Resolving these complexities will be key to understanding the latest stages of Stikinia arc volcanism and the initiation of Whitehorse trough sedimentation. Future work will include geochronology, geochemical analysis and further mapping to better characterize Stikinia's stratigraphy in Yukon, and how it relates to coeval, prospective strata in northern British Columbia. This will help refine models of Mesozoic arc development and terrane accretion in the Canadian Cordillera (e.g., Mihalynuk *et al.*, 1994; Colpron *et al.*, 2015).

Southwestern Selwyn basin

Rosie Cobbett carried out bedrock mapping in the Tay River (105K) and Glenlyon (105L) map sheets in 2015 (Fig. 1). This was the second field season mapping in this area. The purpose of the project is to upgrade stratigraphic correlations and improve understanding of the structural history of this part of the Selwyn basin. Results of 2015 fieldwork are presented in Cobbett (2016).

Field work in 2015 delineated two distinct stratigraphic domains in the area separated by the Twopete thrust fault. South of the fault, metamorphosed Neoproterozoic to Silurian rocks of the Selwyn basin (Fig. 4) are intruded by mid-Cretaceous plutons. These strata host important SEDEX lead-zinc-silver deposits in the region, including



Figure 4. Strongly foliated, quartz-rich, cordierite-bearing marble of the Cambro-Ordovician Vangorda Formation, southwestern Selwyn basin. Photo by R. Cobbett.

the previously-operating Faro Mine (Yukon MINFILE 105K061). North of the fault, a belt of Devonian to Triassic sedimentary and volcanic rocks are intruded by small mid-Cretaceous plutons and deformed by northeast-verging folds and thrust faults. This belt is host to numerous silver-bearing mineral occurrences on the Tay River map sheet, including the Keg deposit (Yukon MINFILE 105K078).

As a result of this project, significant areas of previously un-mapped Upper Devonian to Mississippian quartz-rich clastic and volcanic rocks of the Earn Group have been identified. These rocks were deposited in grabens and half-grabens that, along with volcanism, formed in response to rifting along the western edge of Laurentia during the Late Devonian to Early Mississippian; rifting that presumably led to development of the Yukon-Tanana terrane and opening of the Slide Mountain Ocean (e.g., Nelson *et al.*, 2006).

Coast belt project

Mapping continued in the Coast belt area of southwestern Yukon, led by Steve Israel. Work in 2015 focused on the geology of the Yukon-Tanana terrane and its contact relationships with the Early Jurassic Long Lake suite and Paleocene Ruby Range suite, as well as the distribution of metallogenically important Late Cretaceous Casino suite rocks. The area mapped covers parts of NTS 115H/2 and 7 (Fig. 1), near the southeastern part of Aishihik Lake. Several intrusion-related mineral occurrences are

found within this area, including the Hopper porphyry/skarn occurrence (Yukon MINFILE 115H019). The new mapping better defines the distribution of the Hopper pluton and the age-equivalent Aishihik dikes, themselves associated with several mineral occurrences. The work from the summer of 2015 has been compiled and released as YGS Open File 2015-32 (Israel and Borch, 2015).

Paleozoic magmatism along the Dawson fault corridor

In July 2015, Maurice Colpron spent three days with Jim Crowley (Boise State University) and Justin Strauss (Dartmouth University) examining magmatic rocks, of presumed Paleozoic age, occurring on both sides of the Dawson fault in the Ogilvie Mountains of western Yukon (Figs. 1 and 5). On current compilation maps (Gordey and Makepeace, 2001; Colpron *et al.*, *in press*), most Paleozoic volcanic units in continental margin strata (mainly in Selwyn basin) are lumped under unit CSM (or Marmot Formation), although it is generally recognized that these represent several distinct pulses of magmatism. Recent mapping in the Rackla belt, near the eastern termination of the Dawson fault, indicated at least four distinct episodes of volcanism (Colpron *et al.*, 2013; Moynihan, *in press*). The objective of 2015 fieldwork was to sample volcanic and plutonic rocks near the west end of the Dawson fault for litho-geochemistry and U-Pb geochronology, in order

to facilitate correlations with volcanic rocks in the Rackla belt and other parts of Selwyn basin. Part of the 2015 collection supports an Honours thesis by Peter Mamrol at Dartmouth University. Preliminary results already indicate that volcanic rocks, previously considered to be early Paleozoic in age, are in fact Neoproterozoic.

SEDIMENTARY BASIN STUDIES

North Yukon upper Paleozoic shale project

The North Yukon upper Paleozoic shale project was initiated in 2013 to determine the age, depositional controls and petroleum potential of shale in the region, and develop regional stratigraphic correlations (Hutchison and Fraser, 2015). Fieldwork carried out in 2014 examined the Trail River section of the Canol Formation and resulted in the definition of a formal reference section for this prospective shale unit. Results of this work are expected to be submitted for publication by this spring (Fraser and Hutchison, *in prep*).

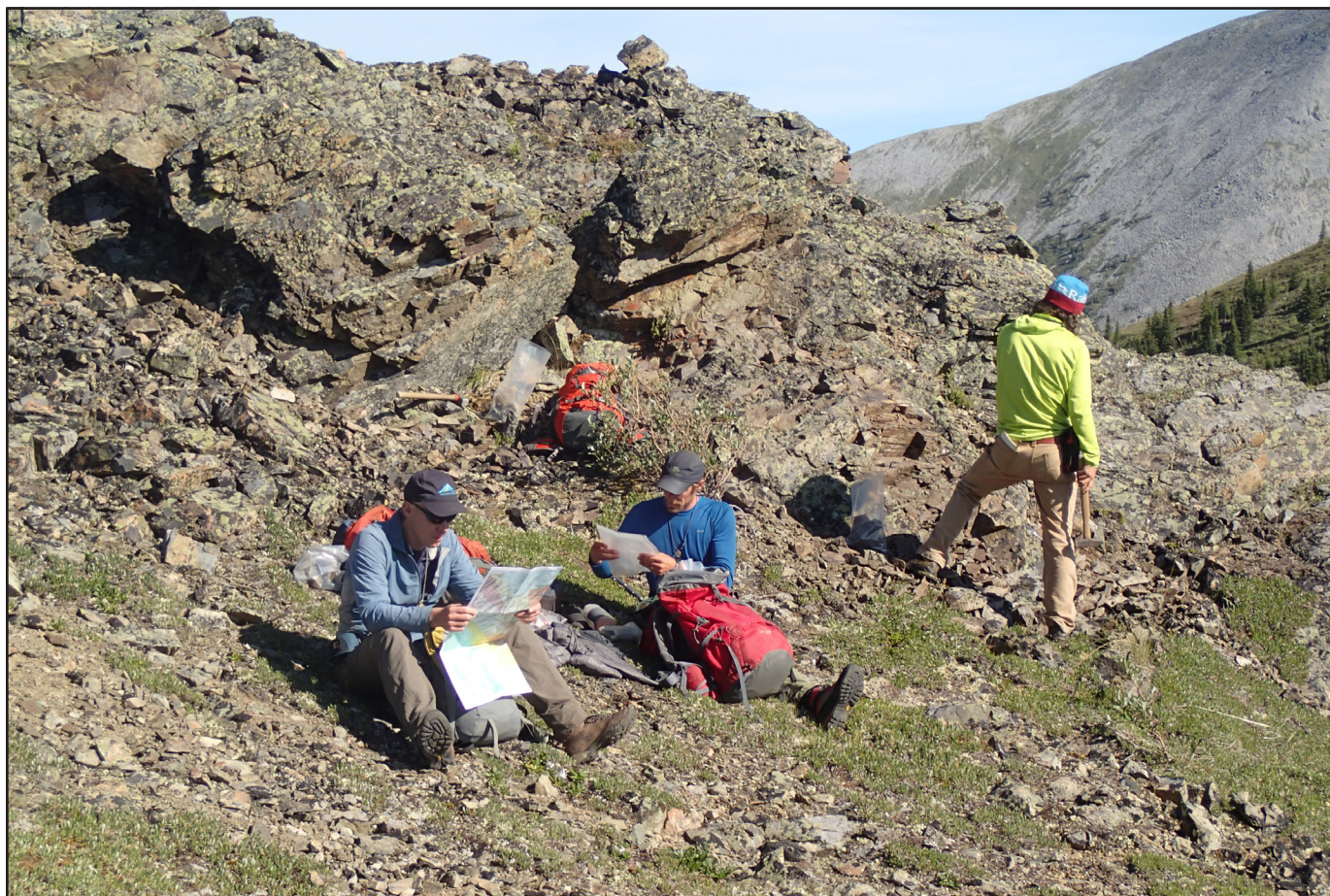


Figure 5. Jim Crowley, Justin Strauss and Peter Mamrol examining volcanic rocks in the Ogilvie Mountains. Photo by M. Colpron.

The Ford Lake Shale is also being targeted by this study (Fig. 1). Carbon isotope and palynological dating of shale exposed in southeastern Eagle Plain and the northern Ogilvie Mountains have yielded Viséan ages, confirming their correlation with the Ford Lake Formation. The compilation map of Gordey and Makepeace (2003) assigned the outcrops to either Canol Formation or the 'un-named' shale. This north Yukon C-isotope data will be presented at the upcoming American Association of Petroleum Geologists conference in June 2016.

The Ford Lake Shale is of interest as an exploration target for hydrocarbons. Analytical data gathered over the last year have allowed preliminary oil/gas maturity zones to be delineated. The data indicate this shale is likely oil-bearing in the Peel Plateau, transitioning westward to dry gas in southern Eagle Plain.

Liard basin shale project

In 2014, YGS engaged with British Columbia, Northwest Territories and the National Energy Board (NEB) to complete an assessment of unconventional resources of the Liard basin (Fig. 1; Relf, 2015). The assessment, initiated by the BC Oil & Gas Commission, originally focused on the portion of the basin south of 60°N, but it was expanded last year to include parts of Liard basin north of 60°. The targeted units in Yukon are the Exshaw Formation, and the Evie, Otter Park and Muskwa formations of the Horn River Group. The area being assessed is that portion of the basin that lies east of the main Cordilleran deformation front.

Over the past year, Matt Hutchison and Tiffani Fraser have sampled extensively from well cuttings stored at the Geological Survey of Canada's core facility in Calgary. Samples were analyzed for RockEval, vitrinite reflectance, whole rock lithochemistry, carbon isotopes and porosity (the latter for the Exshaw and Evie formations only). These data comprise the first publicly-available analytical data from subsurface samples in Yukon; they have been provided to NEB to support the resource assessment. The data will also be presented at the upcoming Canadian Society of Petroleum Geologists conference in March, and published in a joint YGS-GSC Open File publication by spring 2016.

The resource assessment is expected to be published by spring 2016. The shale gas volume estimates will be used to inform an economic analysis to be led by Yukon's department of Economic Development. The economic

analysis is one of several studies recommended by the Select Committee on the Risks and Benefits of Hydraulic Fracturing, to fill knowledge gaps identified by the Committee.

While the primary driver for generating the analytical data was the Liard basin resource assessment, the data are proving valuable for other studies such as regional stratigraphic correlations between Liard basin and basins in north Yukon based on C-isotope signatures.

Laberge Group study, Whitehorse trough

A new study was initiated in the Whitehorse trough in 2015 by Matt Hutchison. The project builds on the recently-published bedrock geology compilation map (Colpron, 2011) and provenance study (Colpron *et al.*, 2015) of Whitehorse trough, and is linked to efforts by Bordet to redefine the stratigraphy of Stikinia and Whitehorse trough near Lake Laberge (Bordet, 2016).

The study is documenting the regional distribution of proximal sandstone (in the northern part of the trough) and more distal shale (in the southeastern part of the trough) and their associated hydrocarbon reservoir quality (Fig. 6). Of particular focus is the potential sandstone reservoirs in the north, where preliminary net/gross ratios were estimated from measured outcrop and Division Mountain diamond drill core sections. Samples were collected for porosity, horizontal and vertical permeability, thin sections, X-ray diffraction, lithochemical analysis, and scanning electron microprobe analysis to support more detailed characterization and correlation of potential reservoirs.

METALLOGENIC STUDIES

Metallogeny of Late Triassic – Jurassic plutons

Patrick Sack completed a second field season examining the magmatic and metallogenic framework of Late Triassic to Jurassic plutons adjacent to the Whitehorse trough in south-central Yukon (Fig. 1). The study is being carried out in collaboration with the Geological Survey of Canada (under their Geo-mapping for Energy and Minerals Program) and the Mineral Deposit Research Unit at the University of British Columbia (MDRU).

Based on field observations coupled with preliminary geochemical and geochronological data, the plutons can be subdivided into at least four distinct plutonic suites. The Stikine suite (ca. 220-206 Ma) occurs mostly south of

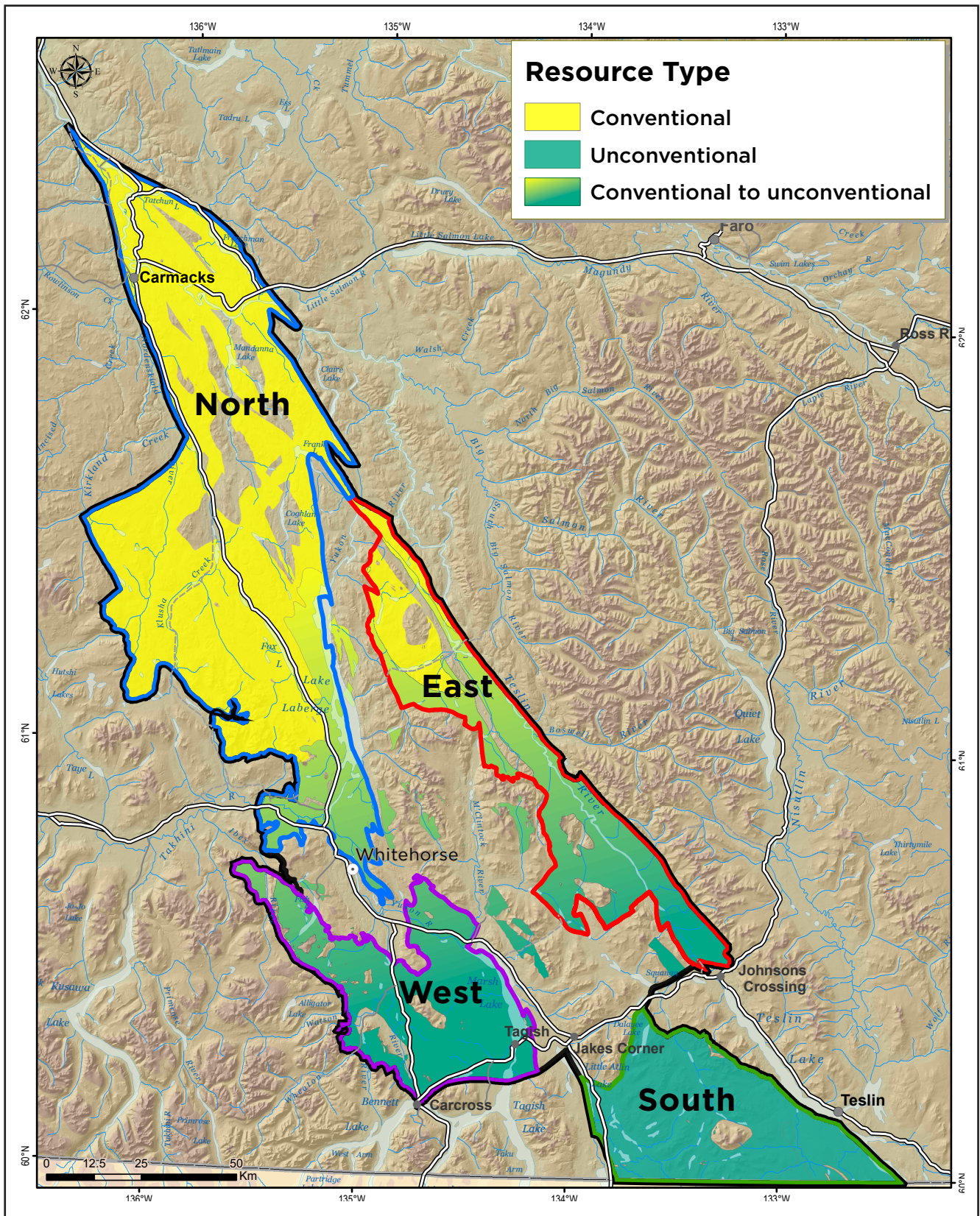


Figure 6. Distribution of hydrocarbon resource type for the Laberge Group in the Whitehorse trough.

Whitehorse and hosts the Inco porphyry occurrence (Yukon MINFILE 105D 100). The Minto suite (ca. 204-195 Ma) comprises granodiorite to quartz diorite that host copper + gold ± silver mineralization near Carmacks, including the Minto and Carmacks Copper deposits (Yukon MINFILE 115I 021 and 115I 008, respectively), and the Stu occurrence (Yukon MINFILE 115I011). The Long Lake suite (ca. 190-180 Ma) is best represented in the Aishihik batholith, but also occurs as small plutons in the Teslin map area. The Middle Jurassic Bryde-Bennett suite (ca. 176-160 Ma) is mostly exposed south of Whitehorse; it is host to the Mars occurrence (Yukon MINFILE 105E002) northeast of Whitehorse.

Petrographic studies are underway to define the compositional and textural characteristics of these suites, and petrological and geochronological studies will help to determine their magmatic character, timing of emplacement and metallogeny. Results of some of this ongoing work are presented elsewhere in this volume: Joyce *et al.* (2016) present new U-Pb geochronological data from the Aishihik batholith, and Sack *et al.* (2016) provide more detailed description of the Minto suite-

hosted Stu copper-gold-silver occurrence. The paper by Topham *et al.* (2016) presents results of thermobarometric studies conducted on the Aishihik and Tatchun batholiths. Other work underway includes a BSc Honours thesis study of the Bennett Lake pluton; the study is described in more detail in the section titled “University Collaborations”.

SURFICIAL GEOLOGY PROJECTS

Paradise gravel

In 2015, Jeff Bond investigated the White Channel Gravel deposits in lower Hunker Creek in the Klondike area (Fig. 1; see Bond, 2016). Stratigraphic reinterpretation of the unit led to the definition of a pre-White Channel Gravel deposit – the Paradise gravel – which is the primary source of gold on benches in the area (Fig. 7). The discovery of this distinct pay unit has implications both for the evolution of placer deposits in the region and for the potential discovery of new reserves on high level benches in the Klondike.

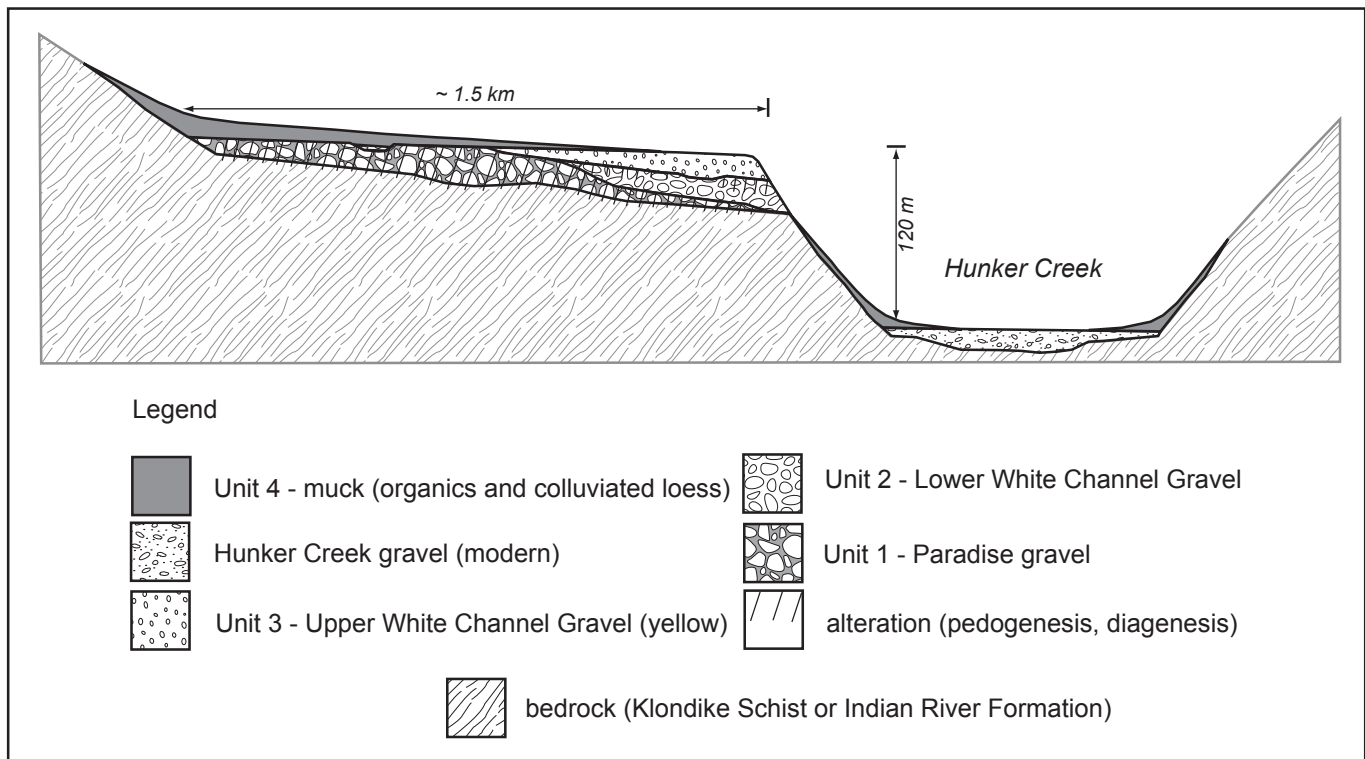


Figure 7. Revised stratigraphic interpretation of Hunker creek surficial geology, showing the distribution of the Paradise gravel pay unit.

Geohazard mapping in Old Crow

Kristen Kennedy continued community-based mapping as part of a multi-year collaboration with the Northern Climate ExChange at Yukon College. The mapping projects are underpinned by 1:20000 scale surficial geology maps which identify potential geologic hazards (e.g., landslides, degrading permafrost, floods, etc.) and assess their risk against climate change models.

This year's project focused in and around Old Crow in northern Yukon (Figs. 1 and 8). A surficial geology map, technical report summarizing landscape parameters (geology, hydrology, cryosphere, climate, etc.) and a weighted cumulative risk map will be released and presented to the community by spring 2016.

Holocene history of Llewellyn Glacier

Sarah Laxton continued to collaborate in 2015 with colleagues at Yukon College and Simon Fraser University on a study of the Holocene history of the Llewellyn Glacier south of Atlin Lake in northern British Columbia. The study, funded by Yukon Energy Corporation, is focused on ice volume estimates, as these have implications for potential future volumes of water that could flow through their hydro-electric facility at Whitehorse (Samolczyk *et al.*, 2016). The project is using models for climate warming coupled with Holocene ice advances/retreats to estimate melt rates.

GEOPHYSICAL AND GEOCHEMICAL SURVEYS

GEOPHYSICS PROJECTS

Seismic (earthquake) monitoring of the Liard sedimentary basin, southeast Yukon

YGS is in the process of acquiring four seismometers that will be deployed in and around the Liard sedimentary basin (Fig. 9), in southeastern Yukon, to monitor baseline seismic (earthquake) activity in the region. These instruments will be installed in spring 2016, along with an additional seismometer purchased by Natural Resources Canada (NRCan). Establishment of this earthquake monitoring network is in response to a recommendation by the Select Committee on the Risks and Benefits of Hydraulic Fracturing that baseline data on natural seismicity be collected ahead of potential development in the region.

The five new seismometers will add to an existing earthquake monitoring network in northeast British Columbia, operated by the BC Seismic Research Consortium (a collaboration between Geoscience BC, the BC Oil & Gas Commission, NRCan and the Canadian Association of Petroleum Producers). The objective of the Liard network is to monitor natural earthquakes with magnitude as low as 1-2 in order to identify potential active faults in the region. The current network of seismometers can only detect earthquakes with magnitude 3 or greater. The anticipated life of this monitoring network is 3-5 years, and is partially funded by SINED program resources.



Figure 8. Sarah Laxton and student setting up a weather monitoring station near Old Crow.

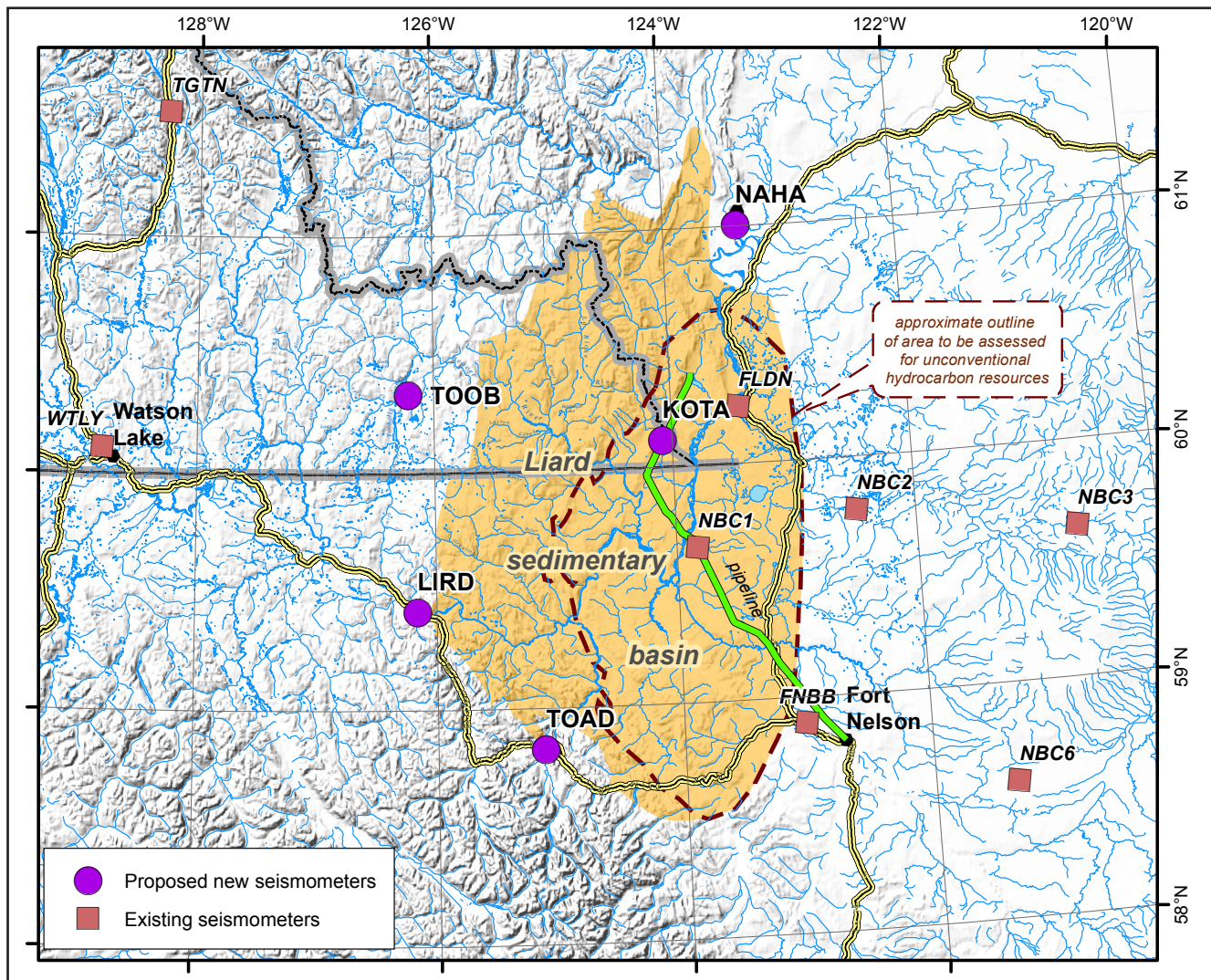


Figure 9. Liard seismic network.

Electromagnetic survey, Livingstone Creek area

As in previous years, YGS plans to invest SINED funds in a geophysical survey late in the fiscal year. This year, an airborne electromagnetic (EM) survey is planned over the Livingstone Creek area, where placer gold production indicates the presence of one or more bedrock lode sources for gold. The Livingstone camp is renowned for its coarse nuggets suggesting local sources. The area is underlain primarily by metasedimentary and meta-igneous rocks of the Yukon-Tanana terrane that were exhumed in the Jurassic (Nelson *et al.*, 2013). It is bounded by two Cretaceous strike-slip faults, the Big Salmon to the west and the d'Abbadie fault to the east, and dissected by a number of northeast-striking minor faults (Colpron, 2005). Gold mineralization is most likely derived from

structurally-controlled vein systems. As rock exposures are locally hampered by a till veneer, an EM survey will help develop the structural framework of the area and provide exploration vectors.

Survey specifications are currently being developed. A request for proposals is anticipated by late January/early February, with the survey being flown in early March.

REGIONAL STREAM SEDIMENT GEOCHEMISTRY MAPS

Upgrading of Yukon's stream sediment geochemical (Regional Geochemical Survey – RGS) dataset has been ongoing for the past several years, funded primarily through SINED. Two different, but related sets of activities were carried out in 2015-16 (Fig. 10).

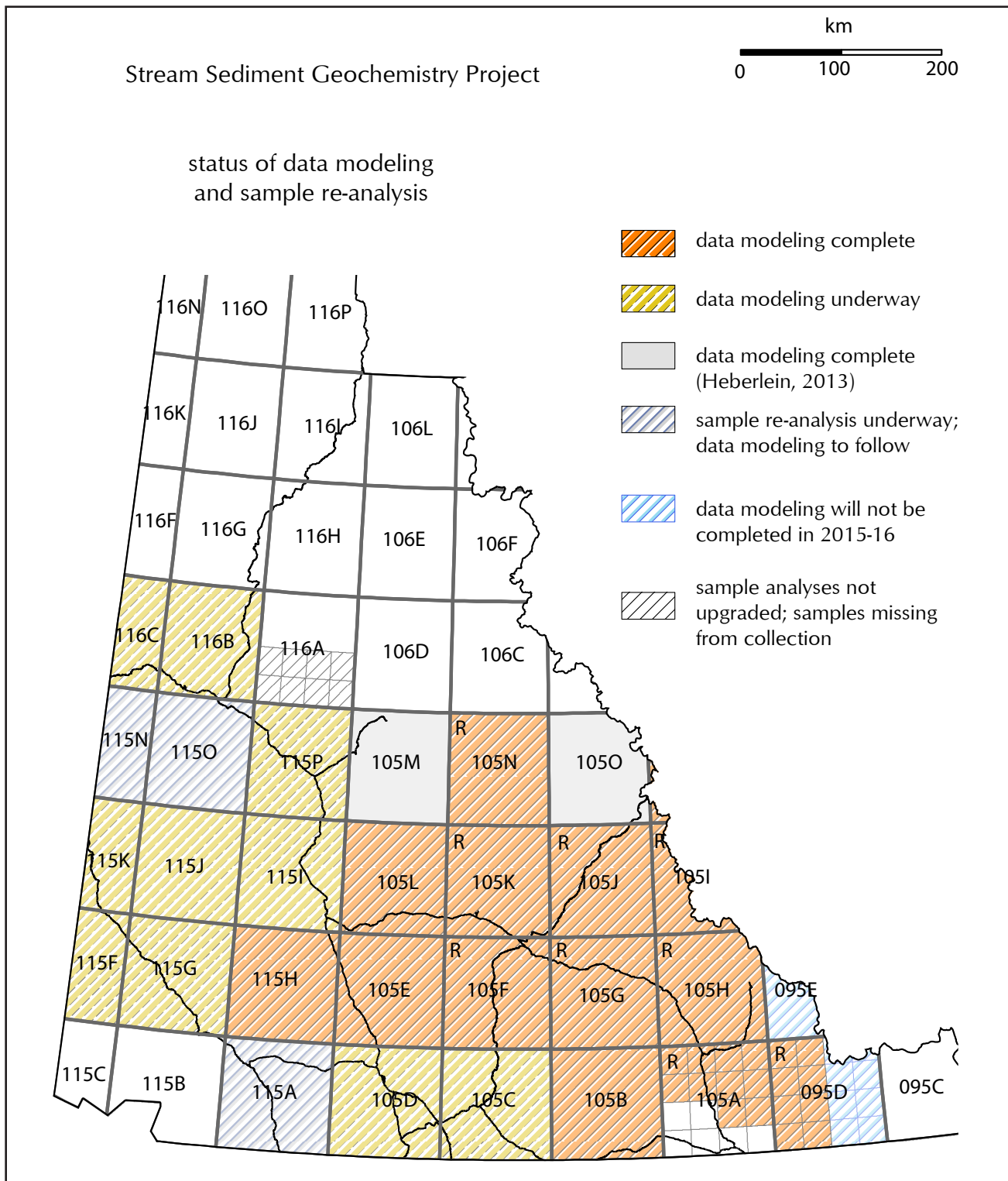


Figure 10. Summary of stream sediment geochemistry projects underway, showing status of sample re-analysis (sample data for three maps sheets currently being upgraded) and data modeling (data for 12.5 map sheets completed; 10 map sheets underway). "R" indicates map sheets released to date (see Mackie et al., 2015 references)

The first RGS-related activity was the re-analysis of samples archived in Ottawa with the Geological Survey of Canada's collection. Wayne Jackaman (Noble Exploration) is recovering up to 2691 samples from six areas (095D, 105A, 105I, 115A, 115N and 115O) and analyzing them for 53 elements via inductively coupled plasma mass spectrometry (ICP-MS). This work, anticipated for completion by March 2016, will complete the upgrading of all available Yukon stream sediment samples collected south of 65°N to modern standards¹.

The second RGS activity involved the modelling of raw RGS data to add value for end-users. This work has two components: the creation of catchment areas for each sample, and the modelling of the sample composition to reflect a probability value for different mineral deposit types.

Significant effort was put into the generation of catchment basins; particularly with the verification of sample locations, as many samples on the original maps did not plot on an existing stream. The catchment area layer is a critical base layer for the modelling step, as catchment areas represent the source area for each sample and the integration of background geology is heavily influenced by the delineated catchment. Additionally, catchment size provides insights into the dilution factor of anomalies, and the exercise of generating the basins highlights drainages that were never sampled by the original survey.

CSA Global was awarded a contract in December 2014 to undertake the RGS modelling work. The contract wraps up in March 2016, and in that time they will have modelled a total of 26 map areas (095D, 105A, B, C, D, E, F, G, H, I, J, K, L, N, 115A; F, G, H, I, J, K, N, O, P; 116B, C). The initial stages of the work involve attributing bedrock and surficial geology to each catchment area, assessing dilution (based on catchment size) and normalizing the sample data (e.g., levelling to reflect dominant lithology(ies)). Principal component analysis is then undertaken on the sample data to "filter" bedrock influence on sample chemistry and enhance anomalies. Weighted sums, which assigns rankings to selected elements based on the mineralogical and chemical characteristics of various target deposit types, is then undertaken to further enhance anomalies.

¹ 53-element ICP-MS analyses of all archived stream sediment samples in Yukon south of 65°N will exist, with the exception of samples from map sheets 116A, 106D and western 106C (archived samples do not exist) and 095C (RGS samples have never been collected for this map sheet).

Multiple weighted sums maps are generated for each map area, based on the mineral deposit types likely to occur in that area (determined by bedrock geology).

The modeling technique is described in more detail in Mackie *et al.* (2015a). To date, weighted sums maps for seven map areas have been published (Fig. 10; Mackie *et al.*, 2015b-h).

AEROCHEM STREAM SEDIMENT SAMPLING

This SINED-funded case study was undertaken to assess the effectiveness of Aurora Geoscience Ltd.'s Aerochem sampling bucket as a potential tool for collecting stream sediment samples. The sampling bucket, suspended on a long line from a helicopter, allows stream sediment samples to be collected without the use of ground-based field crews. This allows creek valleys with thick vegetation to be more easily accessed (to access on foot, personnel must be dropped some distance from the sample site and hike in). Initial testing of the system by Aurora indicated that samples can be collected faster, reducing field costs.

The Aerochem bucket has obvious applications for property-scale exploration. YGS' interest in the bucket is its potential as a cost-effective tool for infilling gaps in Yukon's regional RGS dataset. The generation of catchment basin polygons for existing RGS samples has revealed a number of drainages that were not sampled in the original surveys, as well as a number of catchment basins that are significantly larger than average, meaning samples with diluted geochemical signatures. A field campaign to systematically collect samples to level sampling density would be extremely costly and is unlikely to be a priority with current resources. However, the Aerochem bucket could be means to strategically fill targeted gaps to better image documented anomalies.

To compare the quality of Aerochem samples with those collected by hand, field crews collected two samples per site: one using the bucket and one by hand following the Geological Survey of Canada's sampling protocol. The analytical results from the two sampling techniques will be compared to assess whether the material collected with the bucket matches that collected by hand, and therefore whether Aerochem sampling is a viable technique for RGS infill. A final report will be submitted before the end of March and will be published shortly thereafter.

GEOSCIENCE OUTREACH

Sarah Laxton delivers and/or coordinates YGS' public outreach and education activities. This past year, public events included a variety of interpretive hikes in the Whitehorse area (Miles Canyon, Whitehorse waterfront, Fish Lake; Fig. 11), Tombstone Park (as part of a "Tombstone Rocks" weekend), the Yukon Wildlife Preserve and along the Alsek River.

Sarah also visited a number of schools, providing hands-on educational geoscience activities for students in Whitehorse, Haines Junction, Mayo and Dawson City. She also coordinated with other organizations (e.g., Yukon Department of Education, Environment, Yukon College, the Chamber of Mines) to deliver sessions under programs such as Rural Experiential Model, Canada Water Week, "Scientists Visiting Classrooms", Mining Week and the Yukon Geoscience Forum. The facilities at the Core Library are regularly used to teach geology and hold teacher workshops, and YGS was represented at the annual Career Expo and Lions Trade Show.

In addition to the above, Sarah collaborated with a colleague at the University of Toronto (Dr. Charly Bank) to deliver an undergraduate field course in near-surface geophysics. The course focused on the application of ground penetrating radar to exploration for aggregate and placer resources, and carried out a case study of the Moosehide slide north of Dawson City.

A geological highway map of Yukon is currently being developed by Sarah Laxton and Charlie Roots. Its release is planned to coincide with the Whitehorse 2016 GAC-MAC conference in June.

Other outreach activities in which YGS staff were involved were related to public concerns over potential impacts of oil and gas development. Matt Hutchison attended a number of public meetings, including an open house organized by the Yukon Environmental and Socio-economic Assessment District Office in Dawson, to provide information to the public on a proposed drilling project in Eagle Plain.

Finally, YGS has plans to deliver a series of public lectures on Yukon geology at the Beringia Interpretive Centre in winter 2016.

UNIVERSITY COLLABORATIONS

YGS provided logistical and/or financial support for a number of university projects this year. Interim results from a number of these projects were presented at the Yukon Geoscience Forum in November, and overviews of some of the projects are included in this year's YEG volume. Locations of these projects are illustrated in Figure 12.



Figure 11. Jeff Bond explaining the glacial history of the Whitehorse area to hikers during the 2015 Fish Lake Rock Walk.

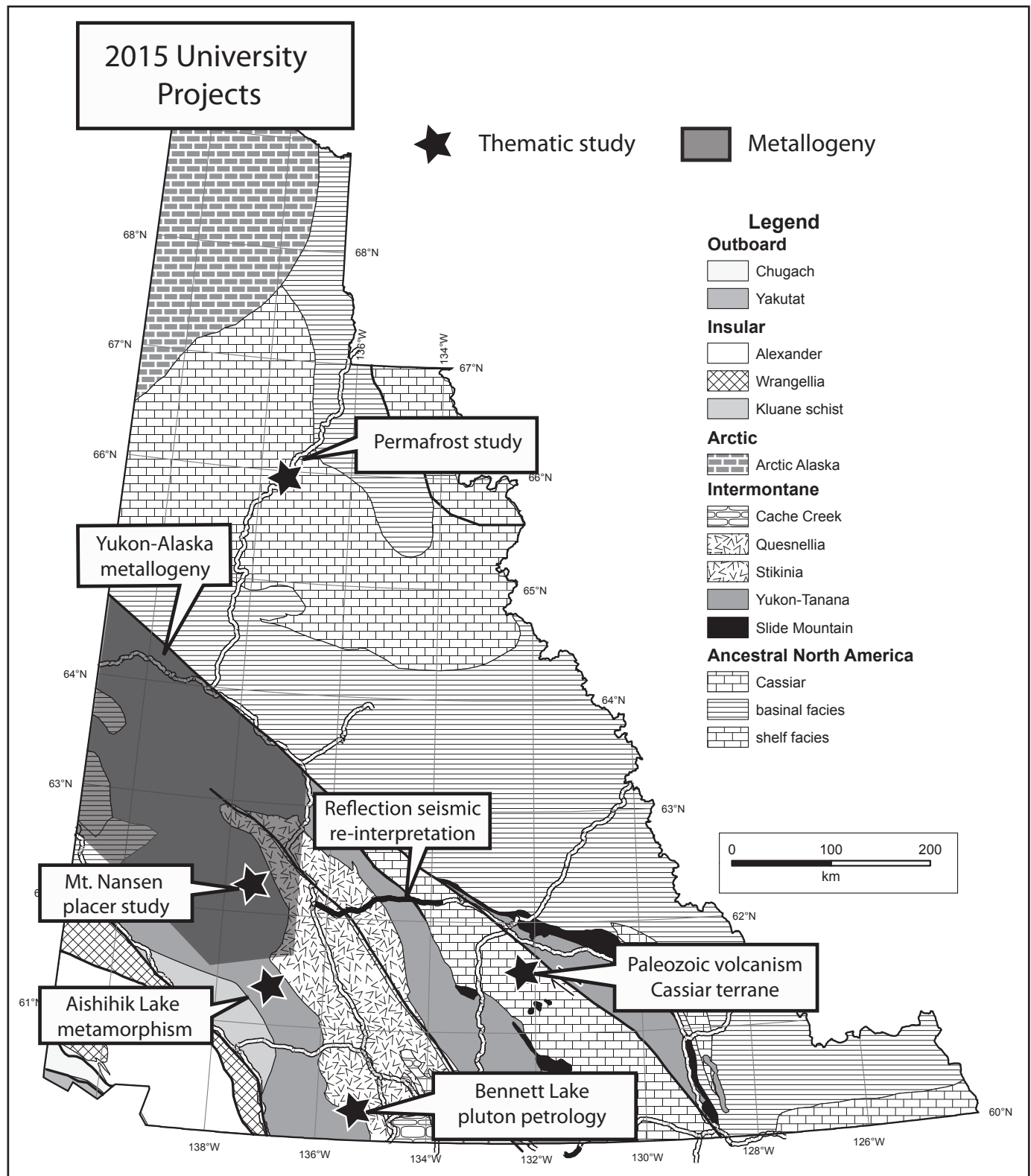


Figure 12. Locations of 2015 field projects carried out by university researchers with support from YGS. See text for project descriptions.

RE-INTERPRETATION OF SEISMIC REFLECTION DATA NEAR CARMACKS

In 2004, YGS and the Geological Survey of Canada undertook a reflection seismic survey across the northern Whitehorse trough (along the Robert Campbell and North Klondike highways) in order to improve understanding of the trough's subsurface architecture. Since the data were originally processed and interpreted (White *et al.*, 2006, 2012; Colpron *et al.*, 2007), new techniques have emerged for analyzing seismic data, allowing greater resolution of features.

This research project, supervised by Dr. Andy Calvert at Simon Fraser University, will generate 3D velocity models by using tomographic inversion in order to refine interpretation of the seismic reflection data. This should improve the resolution of the stratigraphic and structural interpretations for the northern Whitehorse trough and assist in assessing its prospect for hydrocarbon resources.

YUKON-ALASKA METALLOGENY PROJECT

The Yukon-Alaska Metallogeny project, initiated in August 2014, is being led by Murray Allan, Craig Hart and Jim Mortensen at the University of British Columbia's MDRU. The project is a joint university-industry-government partnership that is focused on defining gold metalotects in southwestern Yukon and eastern Alaska. The project comprises a number of integrated studies that are examining local and regional structural and magmatic controls on gold mineralization. YGS is supporting the project through the contribution of SINED funds, and through related studies focused on Jurassic magmatic suites and their metallogenic significance (see papers by Bartlett *et al.*, 2016; Joyce *et al.*, 2016 and Sack *et al.*, 2016).

TECTONO-METAMORPHISM AT AISHIHIK LAKE

Andy Clark is undertaking an MSc study of Paleozoic and Mesozoic metamorphism of rocks of the Yukon-Tanana terrane between Aishihik and Sekelmun lakes in southwest Yukon under the supervision of Dan Gibson at Simon Fraser University. The project builds on regional mapping of the area by Israel and Westberg (2011) and Israel and Borch (2015), and aims to document metamorphic assemblages and structural fabrics, and link thermal and tectonic events in a time-temperature-pressure framework using in-situ monazite dating and conventional

geothermobarometry. The constraints on the timing and conditions of metamorphism and deformation in this area will add to previous studies regionally in the Yukon-Tanana terrane (Staples *et al.*, 2013, 2014) and help better constrain crustal evolution of southwestern Yukon.

PERMAFROST MONITORING, EAGLE PLAIN

Pascale Roy-Léveillé at Laurentian University is establishing permafrost-monitoring infrastructure in the eastern Eagle Plain area to enhance existing baseline data on the distribution, thickness and nature of permafrost in the region. This area is currently the target of oil and gas exploration, and these data will assist with regulating activities such as road building and determining well casing requirements to protect permafrost. The data gathered will contribute to the Canadian Cryospheric Information Network, and be linked to Yukon's online Permafrost network.

MOUNT NANSEN QUATERNARY STRATIGRAPHY

Patrick Englehardt is in his second year of a MSc project at Simon Fraser University, under the supervision of Brent Ward. His thesis examines placer deposits in Back Creek in the Mount Nansen area (southwestern Yukon). Specifically, he is looking at the effect of Pleistocene glaciation on placer deposits, including the impact of late Pleistocene sands on stream sediment geochemistry. Preliminary results for this study are presented by Englehardt *et al.* (2016).

PALEOZOIC STRATIGRAPHY, TECTONICS AND METALLOGENY, PELLY MOUNTAINS

Luke Beranek and Steve Piercey of Memorial University are supervising two MSc students studying two stratigraphically distinct volcanic successions in the Pelly Mountains of Quiet Lake and Finlayson Lake areas (Cassiar terrane). The older succession of Cambrian to Ordovician mafic volcanic and clastic sedimentary rocks was deposited in a marine extensional environment and is host to a number of SEDEX lead-zinc-silver deposits. The younger succession comprises Devonian-Mississippian felsic volcanic and clastic sedimentary rocks correlated with Earn Group. They formed in a volcanic rift basin and are associated with VMS base metal occurrences (including the MM prospect, Yukon MINFILE 105F012, and Wolf deposit, Yukon MINFILE 105G008).

Field observations coupled with trace element geochemical and Nd-Hf isotope analyses are being used to further characterize the setting and metallogeny of the two volcanic successions, and to link them to the broader tectonic setting. Descriptions of the stratigraphic units and preliminary interpretations are presented in this volume (Beranek *et al.*, 2016). This study relates regionally with mapping by Cobbett (2016) in Tay River and Glenlyon map areas to the north.

STUDY OF THE BENNETT LAKE PLUTON

As a contribution to the Late Triassic-Jurassic pluton metallogeny project in south-central Yukon, Josh Pilsbury collected samples from the Bennett Lake pluton and is examining its age, petrology, and emplacement depth. The study is the subject of his BSc Honours thesis at UBC under the supervision of Murray Allan.

ONGOING YGS ACTIVITIES

INDUSTRY LIAISON

Lara Lewis, Patrick Sack and Derek Torgerson, from YGS' Minerals Geology unit, visited 11 mineral exploration properties in 2015 to monitor exploration results and they participated in the annual media tour, which visited seven exploration properties. Highlights of hard rock exploration projects were presented at the Yukon Geoscience Forum and are included in this volume (Lewis *et al.*, 2016).

Surficial geology staff, Jeff Bond and Sydney van Loon, visited placer mines throughout Yukon, documenting information on stratigraphy, gold distribution and character, and work activity. This information was presented at the Yukon Placer Forum and is compiled here (Bond and van Loon, 2016); it will also be included in the next Placer Industry Report in 2017.

In addition to tracking industry activities, YGS staff responded to a variety of information requests from clients and Yukon government departments.

PERMAFROST MONITORING

YGS continued its program of permafrost monitoring in Yukon communities in 2015. Sarah Laxton collected data on active layer thickness and ground temperature from stations in Whitehorse, Destruction Bay, Carmacks, Faro, Beaver Creek, and Dawson City. The information collected contributes to The Yukon Permafrost Network, can be accessed at <http://permafrost.gov.yk.ca>.

INFORMATION MANAGEMENT

PUBLICATIONS

YGS released thirty-two Open Files, two Miscellaneous Reports, one Bulletin, three Annual Reports and one brochure in 2015. The 2015 Yukon Exploration & Geology Annual Report and an Open File version of the recently-completed digital bedrock geology compilation are scheduled for release early in 2016. Scanned industry documents, while not technically YGS publications, are searchable via YGS' search tool and can be downloaded from the YGS website. In December, YGS staff travelled to Ottawa to identify a batch of YCGC files for scanning; once scanned, this will complete the YCGC scanning project.

NEW BEDROCK GEOLOGY COMPILATION MAP

The update of the Yukon digital bedrock geology map, which was in progress for the past few years, is now complete. The new GIS dataset is now available for download from either the YGS website (http://www.geology.gov.yk.ca/update_yukon_bedrock_geology_map.html) or Geomatics Yukon (ftp://ftp.geomaticsyukon.ca/GeoYukon//Geological/Bedrock_Geology), and through online map services: MapMaker Online (<http://mapservices.gov.yk.ca/YGS/SL/>) or GeoYukon (<http://mapservices.gov.yk.ca/GeoYukon/SL/>).

This update of the Yukon bedrock geology map builds upon the previous compilation by Gordey and Makepeace (1999, 2001). It includes new, detailed bedrock geology maps and regional compilations that have been published by the Yukon Geological Survey and the Geological Survey of Canada between 1999 and 2014, as well as some recent thesis works. The new GIS dataset includes an expanded attribute structure (compared to the 1999 dataset) that facilitates searching of the geodatabase. In addition, future maps produced by YGS will be quickly integrated into the digital compilation and regular updates of the GIS dataset will be made available through the various online access points. Finally, a new 1:1 000 000-scale wall map with legend is planned for release in early 2016 (Colpron *et al.*, in press).

DATA MINING YCGC FILES

Canada's National Archives retains historic placer mining records from Yukon Consolidated Gold Corporation (YCGC); the Klondike Placer Miners' Association has long advocated for access to these records. In response to

this demand, YGS began scanning YCGC files in 2014. To date, over 500 maps and 400 documents have been scanned and made available.

As a means to assess the value of the information contained in the YCGC files, Sydney van Loon undertook a pilot data-mining project over the summer (see van Loon, 2016). Focusing on a nine-kilometre section of Dominion Creek, which was a significant gold producer in the early 1900s, she geo-referenced old maps, integrating data on gold grades, material thickness, depth to bedrock from drill logs and dredging records from 1936. By rasterizing and contouring the data different ways, she was able to model the bedrock surface and a number of benches, highlighting areas where pay gravels were likely missed by the dredge. The map generated significant interest among attendees at the 2015 Placer Forum, and YGS was encouraged to undertake more compilations of this type.

WEB SERVICES

The technical services team is working on various web mapping applications that will allow users to explore our data in new ways. For example, MINFILE records, currently served via <http://data.geology.gov.yk.ca> and through GeoYukon, will soon be accessible with a new application on the YGS website that allows spatial (map-based) searches of records. In addition, a new interactive web map has been created that allows the user to explore the updated bedrock geology dataset.

A beta version of a form called 'Yukon Mining Assessment Report Submittal Form' has been created to enable clients to enter key metadata for their assessment reports, accelerating the capture of reference information. This form will be incorporated into the Enterprise database and made available for client use over the next year.

MINFILE DATA

Entry of data into MINFILE focused on Selwyn basin, where an upgraded regional mineral potential map is being generated to support land management planning. A total of thirteen new occurrences were added and numerous other occurrences were updated.

H.S. BOSTOCK CORE LIBRARY

Since opening the new building in November, 2011, client use of the facilities has increased steadily. Over the summer, the move of drill core for the old core library to the new facility was completed. Some core remains at the old facility, to allow room for growth of the collection.

The next phase of the drill core project will involve linking drill core records to MINFILE so clients can discover which mineral occurrences have drill core available for viewing and sampling. In the meantime, queries about the core collection can be directed to Lara Lewis (lara.lewis@gov.yk.ca) or Patrick Sack (patrick.sack@gov.yk.ca).

WHITEHORSE 2016: GAC-MAC CONFERENCE

In partnership with Yukon College, YGS has agreed to host the 2016 Geological Association of Canada – Mineralogical Association of Canada annual conference. The meeting, to be held June 1-3, will include technical sessions and workshops at the College, as well as a variety of field trips. Session themes range from Cordilleran tectonics, metallogeny, Beringia, geo-archeology, mine remediation and geo-education.

Abstracts for sessions will be accepted until the end of January, and registration will open in March. Information on the conference can be found at <http://whitehorse2016.ca>.

SUMMARY

2015 was another busy year for YGS. The Bedrock Geology unit was fully staffed and completed field work on eight projects. The Minerals Geology unit wrapped up the field component of a multi-year metallogeny study and started work to upgrade Yukon's mineral potential maps. They also invested some time in 2015 to evaluate internal capacities and client needs and will shortly be staffing two positions (Economic Geologist and Core Library manager). In addition to ongoing work on a number of thematic studies, the Surficial Geology unit is becoming increasingly recognized by the placer industry as a valuable resource.

Following the fall meeting of the Technical Liaison Committee YGS has committed to hold a workshop to get input on MINFILE priorities; this will be planned for late winter/early spring, and will likely include a broader discussion of client information needs.

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