

# Summary of Yukon Geological Survey 2016-17 Activities

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## INTRODUCTION

The mandate of the Yukon Geological Survey (YGS) is to support the stewardship of Yukon's energy and mineral resources and to contribute to the sustainability of Yukon's communities. The projects delivered each year by the survey help to increase our understanding of Yukon's geologic framework (in particular its mineral endowment) and to identify geohazards which could impact buildings and infrastructure. Another important aspect of YGS' work is the dissemination of information in the form of maps, reports, raw data, and outreach activities such as public lectures and school visits.

In 2016, YGS staff undertook twelve field-based projects and supported an additional seven (including three graduate student thesis studies). YGS also worked on several data management/data mining projects, and completed planning for a new geothermal study in the Whitehorse area. Fifty-two YGS publications were released, including results from a geophysical survey in the Livingstone Creek area, and staff published or contributed to eight external publications (including five in refereed journals).

YGS continued to liaise with industry to track hardrock and placer exploration and production (see Lewis and Casselman, 2017; Bond and van Loon, 2017, respectively) and to support clients via the provision of geologic information and advice. Under the Yukon Mineral Exploration Program (YMEP), fifty-seven proponents were offered exploration grants totaling \$1.4M; highlights of this year's projects are summarized in this volume (see Torgerson, 2017).

This paper provides an overview of YGS program activities in 2016. Several of the projects described here are presented in more detail in the accompanying Yukon Exploration and Geology volume, while others will be released as stand-alone publications.

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## YUKON GEOLOGICAL SURVEY PROGRAM FUNDING AND OVERSIGHT

Yukon Geological Survey's 2016-17 budget totals \$3 465 000. This includes \$1 265 000 in core O&M funding, \$1 400 000 for the Yukon Mineral Exploration Program (which helps to fund early-stage mineral exploration), and \$800 000 from the Canadian Northern Economic Development Agency's (CanNor's) Strategic Investments in Northern Economic Development (SINED) Program.

Annual allocations of funds are based on a number of factors, including Energy, Mines and Resources' (EMR's) strategic priorities, input from clients, and collaborative research opportunities. Client input is acquired via two formal advisory committees (one representing the mineral exploration sector and one representing the energy sector) and through annual workshops with representatives of the placer industry. Input regarding educators' needs is obtained at annual teacher workshops, and YGS liaises with EMR's Land Planning Branch and the Aboriginal Relations Branch of the Executive Council Office to meet requests for mineral potential assessments.

Collaborative research partners include the Geological Survey of Canada (GSC), who are delivering a multi-year project in southern Yukon comprising bedrock mapping, geophysical surveying and targeted thematic studies under their Geo-mapping for Energy and Minerals (GEM) program. Other examples of collaboration include work recently completed on community mapping with Yukon College, and studies being undertaken at universities with support from YGS.

Every five years YGS undertakes a multi-stakeholder workshop to identify geoscience knowledge gaps across the territory. Discussions span fundamental science questions, information needs of the exploration, transportation and development sectors, an evaluation of geohazards, and geoscience education opportunities. Participants provide insights into their current and future information needs (for example: exploration trends, plans for highway and community development, etc.) and delivery mechanisms. This input is immensely helpful for defining YGS research priorities and planning for future capacity requirements.

## SINED FUNDING

SINED funding has comprised a significant portion of YGS' total budget for more than a decade. Under the program, CanNor provides partial funding for projects that stimulate economic development in the territory. Matching funds are derived from YGS' operating budget, university research partners, and other Yukon government departments.

Performance measures are reported annually to CanNor, including outputs, such as numbers of reports, maps, raw data; and impacts, which are reported as summaries of client surveys on the influence SINED-funded projects have on exploration investment decisions. Performance measures indicate that clients see significant value in SINED investments.

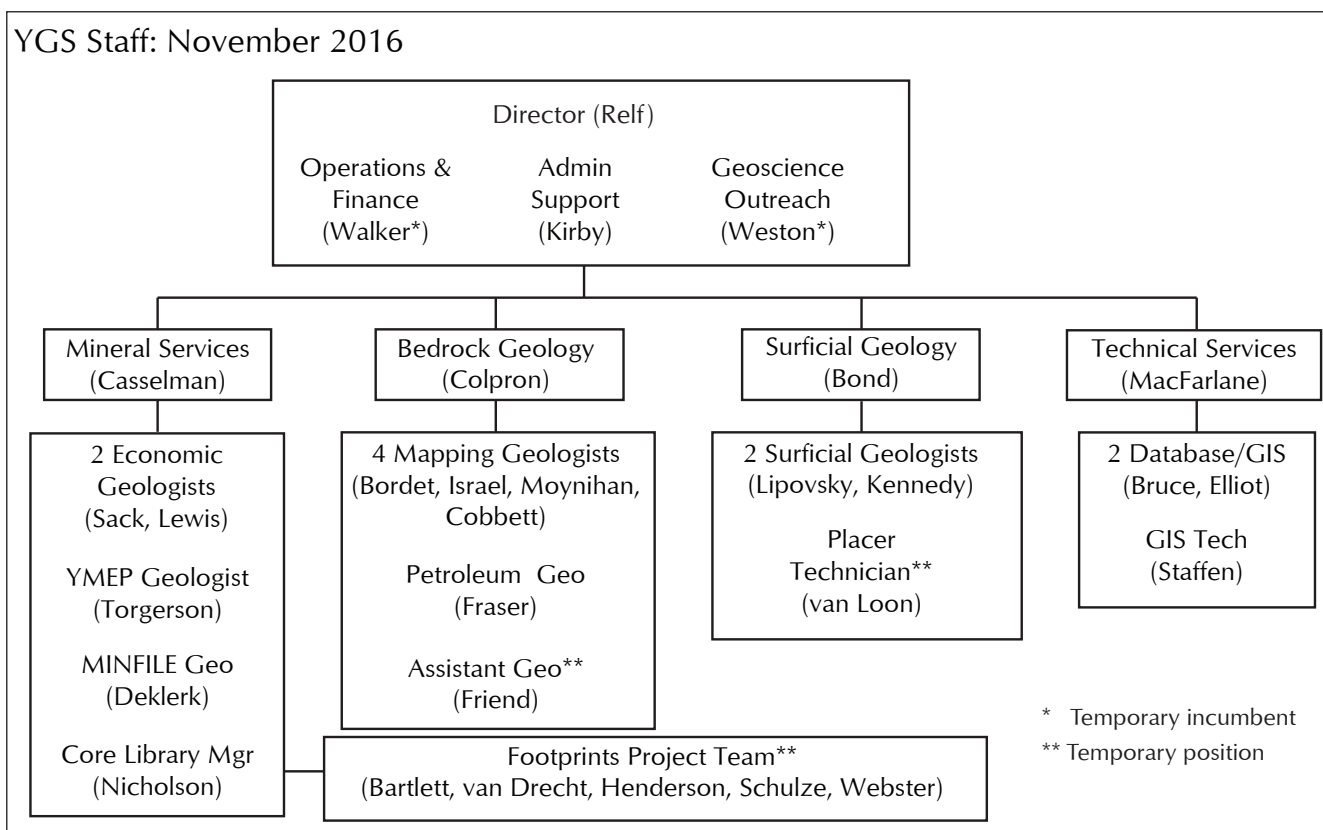
This fiscal year, YGS is spending \$800 000 on sixteen SINED projects, two of which (the "Footprints" project and a geothermal study, described below) are significant investments.

## YUKON GEOLOGICAL SURVEY ORGANIZATIONAL OVERVIEW

Yukon Geological Survey's organization chart is shown in Figure 1. The most notable staff changes this year were in the Minerals Geology unit, with the departure of Johann Slam, the addition of two new staff (Scott Casselman and Craig Nicholson) and some adjustments to the organizational structure. Nicholson backfilled Slam as the Core Library manager and Casselman was initially hired as an Economic Geologist. Over the course of the field season, staff in the Minerals unit undertook an assessment of the complementary strengths, expertise and key interests of everyone in the unit and developed a proposal to re-organize Minerals Geology with Casselman as head and Lewis as Economic Geologist. The re-organization was completed over the fall.

In the Bedrock Geology unit, Rosie Cobbett started a year of maternity leave in November following the birth of her second son. She is scheduled to return to YGS in November 2017.

In August, Sarah Laxton (Outreach Geologist in the Surficial Geology unit) started a ten-month leave to pursue a teaching degree at the University of Fraser Valley. The program in which she is enrolled focuses on engaging with students in small, remote communities, which will be a good fit with her role at YGS.



**Figure 1.** Yukon Geological Survey organizational chart.

In addition to indeterminate staff, YGS hired a number of temporary employees in the fall to assist with a short term project called the Footprints project (described under *Information management*, below). The project is expected to extend into 2017, likely wrapping up over the summer.

Finally, on a sad note, the Yukon Geological Survey suffered a loss this year with the passing of Charlie Roots in June (see the tribute at the front of this volume). An employee of the Geological Survey of Canada, Charlie had been co-located with the YGS for twenty-four years and was an integral part of YGS and the Whitehorse community generally. He is missed by staff and clients.

## HIGHLIGHTS OF 2016-17 FIELD ACTIVITIES

### BEDROCK GEOLOGY PROJECTS

YGS staff led or participated in six bedrock mapping projects and three thematic studies in 2016. Locations of the field areas are shown in Figure 2.

### ***Upper Hyland River area bedrock mapping***

David Moynihan continued bedrock mapping in the upper Hyland River area in 2016, extending map coverage in the northeastern part of NTS sheet 105H (Figs. 2 and 3). The area is underlain by Neoproterozoic to Cambrian rocks of the Hyland Group deposited during the breakup of Rodinia, overlain by Paleozoic sedimentary rocks associated with the formation of Selwyn basin.

Mapping in 2015 led to the definition of new stratigraphic subdivisions of the Yusezyu Formation of the lower Hyland Group (Moynihan, 2016a). The revised stratigraphy included two newly-identified limestone units which Moynihan was able to trace into the 2016 map area (Moynihan, 2016b); these units are not only useful stratigraphic markers but they are helpful in delineating structures.

Cretaceous folding and faulting overprints the supracrustal sequences and was accompanied by voluminous plutonism and regional low-pressure metamorphism; the latter is the subject of an MSc thesis being undertaken by

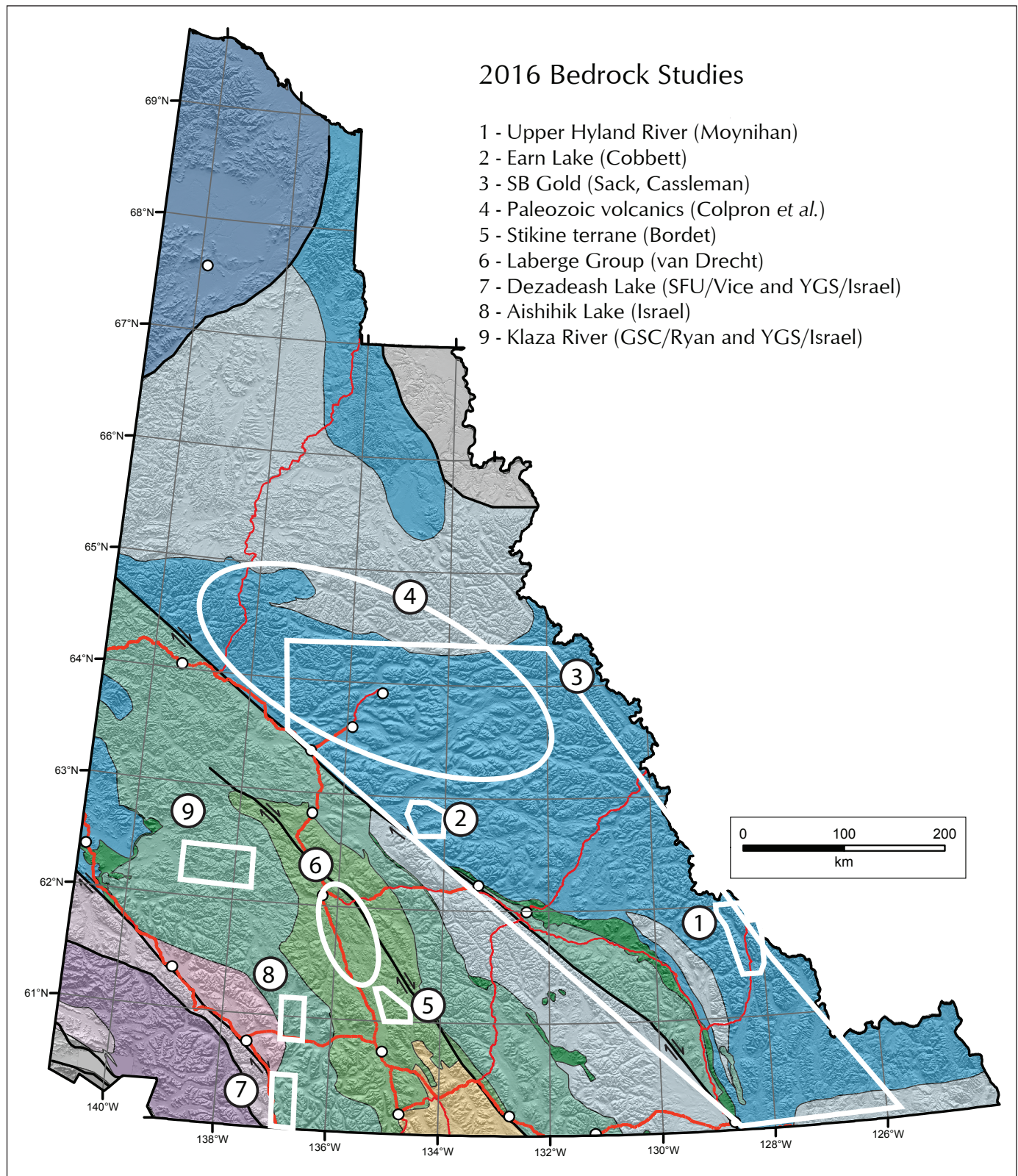


Figure 2. Locations of bedrock projects undertaken by YGS in 2016.



**Figure 3.** Geologist David Moynihan taking notes in the field.

Colin Paget at the University of Calgary and co-supervised by Moynihan. Newly-recognized structures in the area include several strands of a major dextral strike slip fault system that appears to have seen at least 80 km of displacement (Moynihan, 2017). Dextral faulting coincided with intrusion of some granitic plutons and may have implications for the distribution for gold prospects in the region. Moynihan (2016b) provides a more detailed description of the results of mapping.

### ***Earn Lake bedrock mapping***

Rosie Cobbett completed a third summer of mapping in the Glenlyon/Tay River area in 2016, focusing primarily in NTS sheet 105L/15 and surrounding area (Figs. 2 and 4). Field mapping and new geochronological data have led to some revisions of existing stratigraphic interpretations, including the reassignment of a widespread volcanic unit from the Devonian-Mississippian Earn Group to the Ordovician Menzie Creek Formation.

New mapping has also identified a series of northeast-vergent thrust faults that imbricate units. The recognition of these thrust faults, coupled with new age data, is enabling regional stratigraphic correlations that have implications elsewhere in Selwyn basin.

The results of 2016 mapping were recently released by Cobbett (2016) and will be incorporated, along with the earlier work on this project, in an updated version of the Yukon bedrock geology compilation early in 2017.



**Figure 4.** Chert pebble conglomerate from the Earn Group.

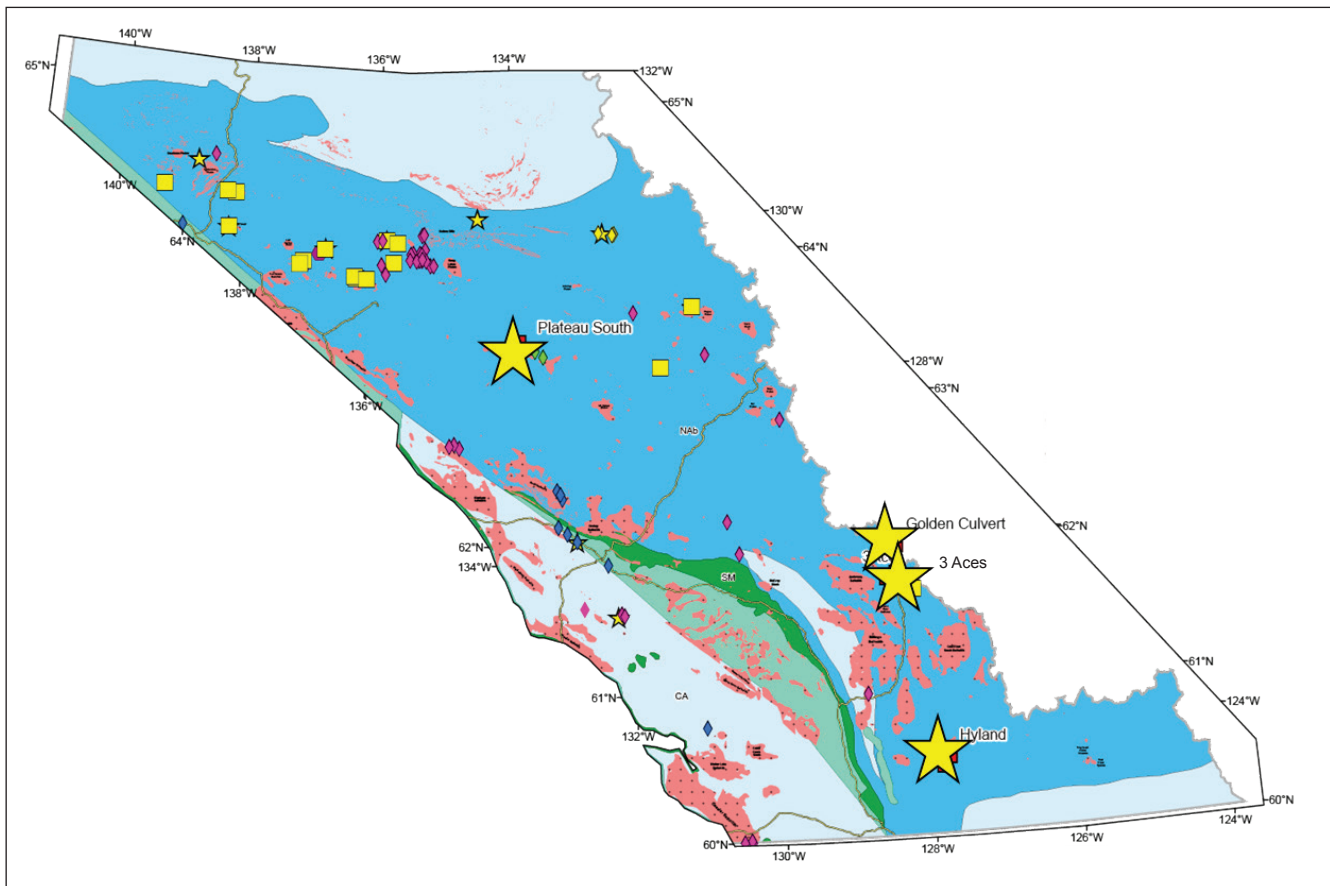
### ***Selwyn basin gold study***

A new thematic project aimed at understanding the timing and character of gold occurrences in Selwyn basin was initiated this year by Patrick Sack and Scott Casselman. Initial sampling focused on occurrences that do not appear to be related to Cretaceous intrusions (Fig. 5). Samples from 3 Aces, Golden Culvert, Hyland Gold and Plateau South were collected and have been submitted for age dating (Ar-Ar on micas and U-Pb in phosphate minerals). This preliminary work may lead to a broader study of gold metallogeny in Selwyn basin, allowing occurrences to be fit into the tectonic/stratigraphic/magmatic framework that is emerging from new mapping.

### ***Paleozoic volcanic rocks in Selwyn basin***

Other thematic studies underway in Selwyn basin focus on volcanic sequences and their age, setting and mineral potential (Fig. 2). Paleozoic volcanic rocks from the east end of the Rackla belt were sampled in 2014 by Maurice Colpron and David Moynihan. This work led to questions about stratigraphic correlations with volcanic rocks in the Ogilvie Mountains (sampled in 2015), in the area east of Mayo (2016), and other parts of Selwyn basin. The YGS work triggered the interest of university colleagues at Dartmouth College (Justin Strauss) and Memorial University (Luke Beranek and Stephen Piercey).

Ongoing studies, supported in part by SINED funds, are being carried out by Beranek and a student, who are examining the age, petrology and VMS potential of Cambro-Ordovician alkaline volcanic rocks; and Piercey, who is assessing the use of radiogenic isotopes as an



**Figure 5.** Simplified map of Selwyn basin in Yukon; stars indicate gold occurrences sampled to date by Sack and Casselman.

indicator of metal fertility in Devonian-Mississippian felsic volcanic rocks. These studies are timely in that data on the age and petrologic character of volcanic units will support regional stratigraphic correlations across Selwyn basin, further enhancing the stratigraphic framework that is emerging from ongoing bedrock mapping and supporting assessments of VMS and SEDEX potential. Preliminary results of both studies have been published in YGS' Yukon Exploration and Geology papers (Campbell and Beranek, 2017; Piercey *et al.*, 2017).

### ***Stikine terrane bedrock mapping***

Esther Bordet completed a second year of mapping in rocks of the Stikine terrane east of Lake Laberge (Fig. 2), focusing on the internal stratigraphy and structure of the Middle Triassic Joe Mountain Formation and Upper Triassic Lewes River Group (Fig. 6). Her work includes new age data (U-Pb geochronology and fossils) and whole rock geochemistry, which are providing an improved understanding of the evolution of the Stikinia arc and

its relationship with overlying sedimentary rocks of the Jurassic Laberge Group (Bordet, 2016, 2017).

A number of MINFILE occurrences have been documented in the area, including skarn Cu, porphyry Cu-Mo, and Au occurrences of unknown origin. This mapping project is providing an improved framework within which to understand the age and geological controls on these occurrences.

### ***Sedimentology of lower Laberge Group***

Leigh van Drecht from Memorial University of Newfoundland began field work on an MSc thesis in the Whitehorse trough (van Drecht and Beranek, 2017). The study, which is being co-supervised by Maurice Colpron, is examining the provenance, depositional environment and stratigraphy of the lower Laberge Group. The results will be a nice complement to Bordet's mapping, as the lower Laberge Group records the initial opening of the basin following the collapse of the Stikine arc.



**Figure 6.** Geologist Esther Bordet in the field, with Lake Laberge in the background.

### **Bedrock mapping in southwestern Yukon**

Mapping in the Coast Belt area of southwestern Yukon was undertaken in three areas in 2016 (Fig. 2). The southernmost map area was near Dezadeash Lake in the Takhanne and Kluhi rivers area, where Lianna Vice completed a summer of mapping as part of an MSc thesis at Simon Fraser University. Her project focuses on resolving the structural and metamorphic history recorded in supracrustal rocks of the Yukon-Tanana terrane and Late Cretaceous metasedimentary rocks of the Blanchard River assemblage (Fig. 7). Steve Israel is co-supervising the thesis.

Immediately north of this project, Steve Israel extended 2015 mapping in the Aishihik Lake area across the Alaska Highway into the Hutshi Lakes and Cracker Creek map areas (Israel *et al.*, 2017; Israel and Friend, 2016; Fig. 2). Here, Yukon-Tanana rocks are intruded by plutons of the Jurassic Long Lake and Paleocene Ruby Range suites. Mapping has focused on distinguishing the different magmatic events, documenting evidence for emplacement depths, and assessing intrusion-related mineral potential across the region.



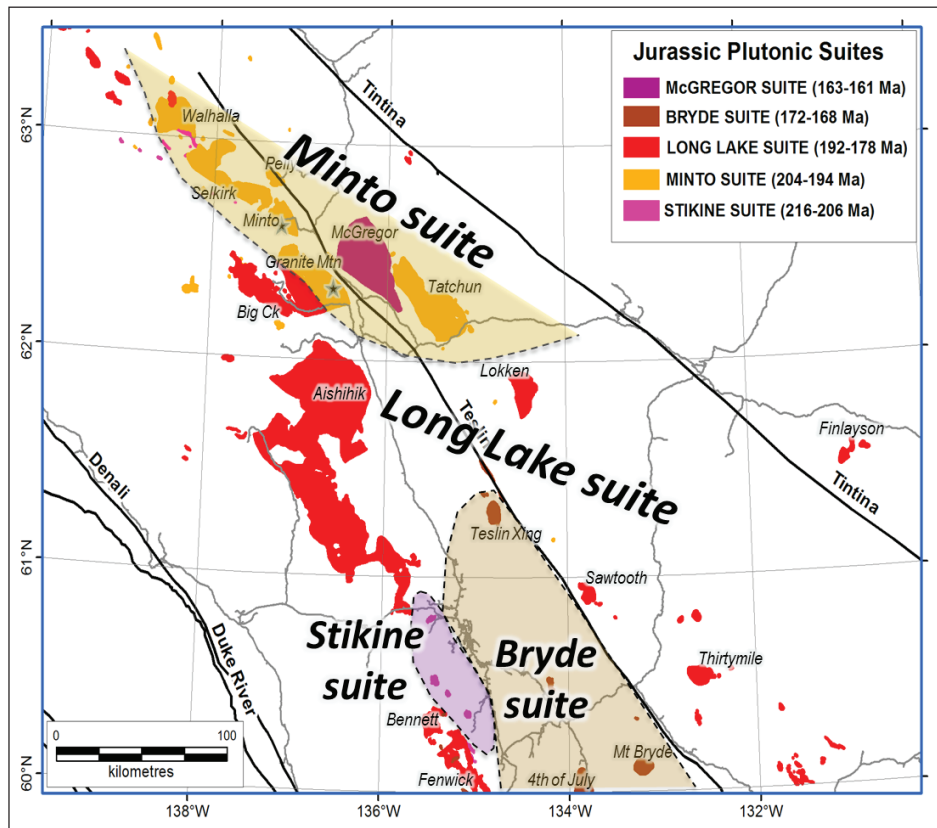
**Figure 7.** Metamorphosed rocks of the Yukon-Tanana terrane in the Takhanne River area.

Israel spent part of the summer mapping in the Klaza River area with Jim Ryan of the Geological Survey of Canada. This project was funded by the GSC under the GEM Program. The mapping had similar goals to those in the Hutshi Lakes/Cracker Creek area: document the relationships between supracrustal rocks of the Yukon-Tanana terrane and Cretaceous to Paleocene plutons that intrude them. Of particular interest in the Klaza River area is the potential for mineralization associated with Casino-age equivalent intrusions (ca. 78-72 Ma). The bedrock map will be released by the GSC.

### **Metallogeny of Jurassic plutons**

Patrick Sack and Maurice Colpron are wrapping up the final stages of a study that examines the petrology and metallogeny of Late Triassic to Jurassic plutons in south-central Yukon. Based on field relationships and geochronological data they have subdivided the plutons into five suites (Fig. 8). New geochemical and isotopic data have allowed a petrologic characterization of the suites, and Al-in-hornblende geobarometry has yielded information regarding depth of emplacement.

Sack and Colpron plan to publish an Atlas of Late Triassic to Jurassic plutons by the end of 2017. The atlas will include lithologic descriptions, field and laboratory photos, analytical data (including physical properties, geochemistry and isotopic results) and a discussion of the metallogenic implications of the suites.



**Figure 8.** Distribution of Late Triassic to Jurassic plutons suites in southern Yukon.

### **Yukon-Alaska metallogeny project**

The Yukon-Alaska metallogeny project is a joint university-industry-government partnership initiated in 2014 that is focused on defining gold metallotects in southwestern Yukon and eastern Alaska. The project is being led by Murray Allan, Craig Hart and Jim Mortensen at the Mineral Deposits Research Unit at the University of British Columbia, and is examining local and regional structural and magmatic controls on gold mineralization in the region. YGS is supporting the project through the contribution of SINED funds.

### **SURFICIAL GEOLOGY PROJECTS**

In 2016 YGS staff undertook five placer-related projects (two within the Klondike and three in glaciated areas) and two geohazard studies. Locations of these projects are shown in Figure 9.

### **Klondike area studies**

Last year, Jeff Bond (Bond, 2016) reported on the results of a stratigraphic re-interpretation of Pliocene gravels in the Klondike. He identified a pre-White Channel Gravel deposit which he named the Paradise gravel, and reported that it was likely the primary source of gold on benches in the area.

In 2016, Bond returned to the area with Paul Sanborn (University of Northern BC) to examine paleoweathering surfaces within the White Channel Gravel and collect samples of paleosols. This study will provide insights into paleoclimate conditions during deposition of these important gravels.

Between 2013 and 2016 Sydney van Loon oversaw the scanning of historic Yukon Consolidated Gold Corporation files that are housed at the National Archives in Ottawa. These documents are now available

from the YGS, and YGS has started to digitize the data to enhance its value (e.g., see van Loon, 2016). This year, van Loon “mined” data from a 28 km long section of Sulphur Creek, digitizing spatial information on gold grades, depth to bedrock, and the footprint of historic workings. Figure 10 shows the distribution of gold grades encountered by historic drill holes; when integrated with historic workings, a number of previously-unmined pay streaks are revealed. This project is reported on in more detail elsewhere (van Loon, 2017).

### **Placer studies in glaciated areas**

Jeff Bond began examining placer deposits in the Mayo mining district in 2016 (Fig. 9), documenting the character of the pay, which tends to be extensively reworked by glaciers. He plans to extend his observations to other mines in the area over the next year or two, in order to better understand the factors that influence the preservation of placer deposits in glaciated terrains.

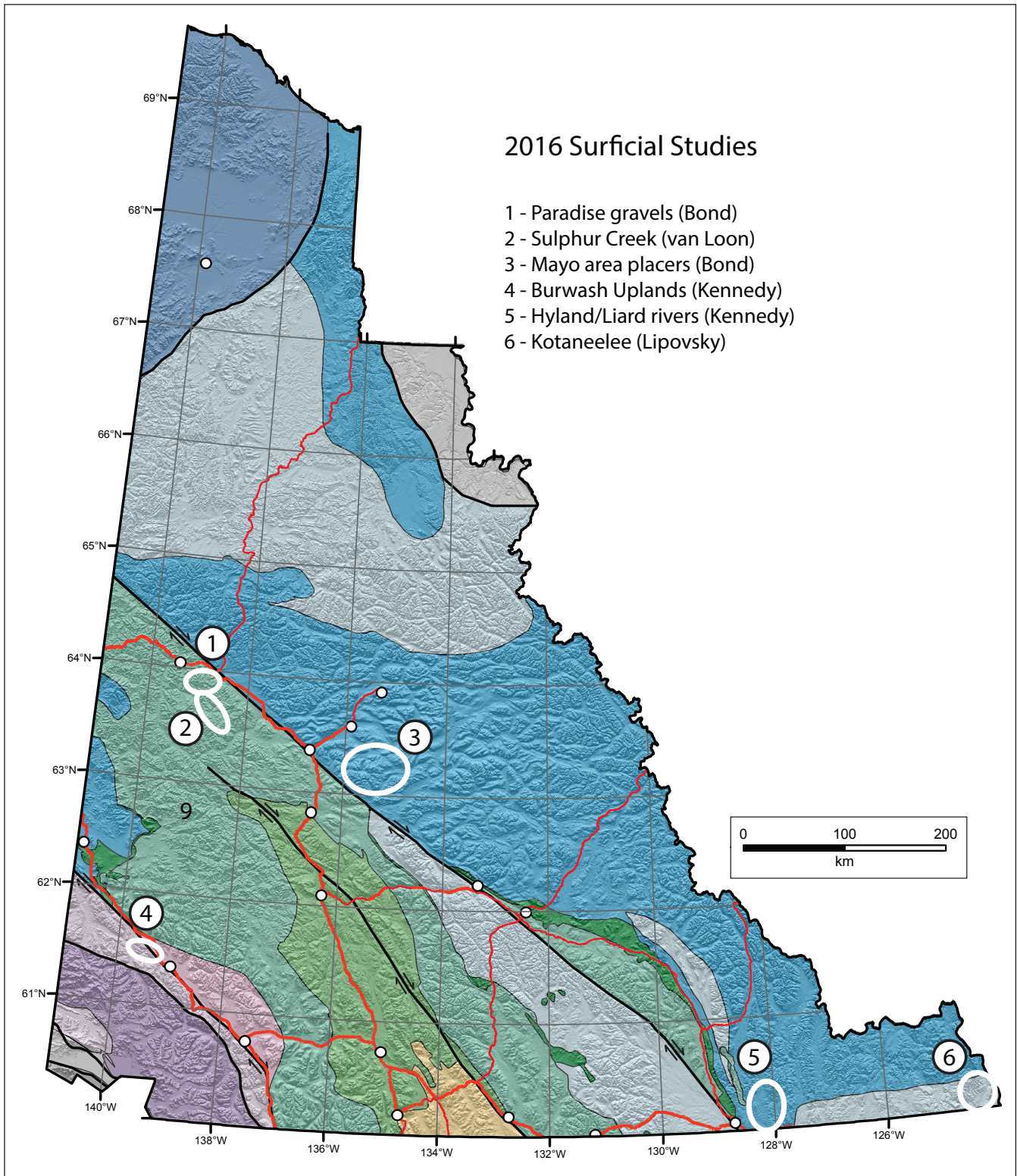
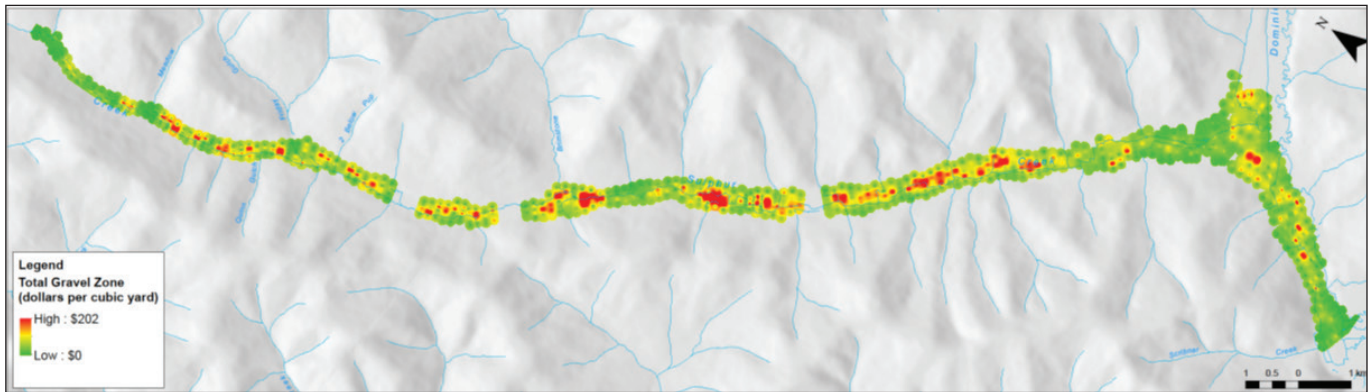


Figure 9. Locations of surficial projects undertaken by YGS in 2016.



**Figure 10.** Distribution of gold grades along Sulphur Creek, generated from data derived from Yukon Consolidated Gold Corporation files (van Loon, 2017).

Kristen Kennedy undertook ten days’ reconnaissance work along creeks that drain the Burwash Uplands southwest of Kluane Lake (Fig. 11). Over the next year, the project will examine the stratigraphy, glacial history and distribution of pay gravel of creeks in this region. Preliminary results of the work are summarized in Kennedy and van Loon (2017).

In southeastern Yukon, Kennedy visited two sites where a pre-glacial quartz pebble-rich gravel unit is exposed along the Liard and Hyland rivers (Figs. 9 and 12). She undertook the fieldwork with Nick Roberts (University of Lethbridge), who collected samples for paleomagnetic analysis to test the possibility that this gravel unit is age-equivalent to the White Channel Gravel.

### ***Geohazard mapping in Old Crow***

2016 marked the final year of collaboration between YGS and the Northern Climate Exchange (Yukon College) on a program to support climate change adaptation planning for communities. The community-based studies were underpinned by detailed surficial mapping led by Kristen Kennedy. The maps identify potential geologic hazards (e.g., landslides, degrading permafrost, floods, etc.) and assess their risk against climate change models.

The most recently completed map was in the Old Crow area in northern Yukon (Kennedy, 2016). Kennedy travelled to Old Crow in the fall to present the results of mapping to the community.



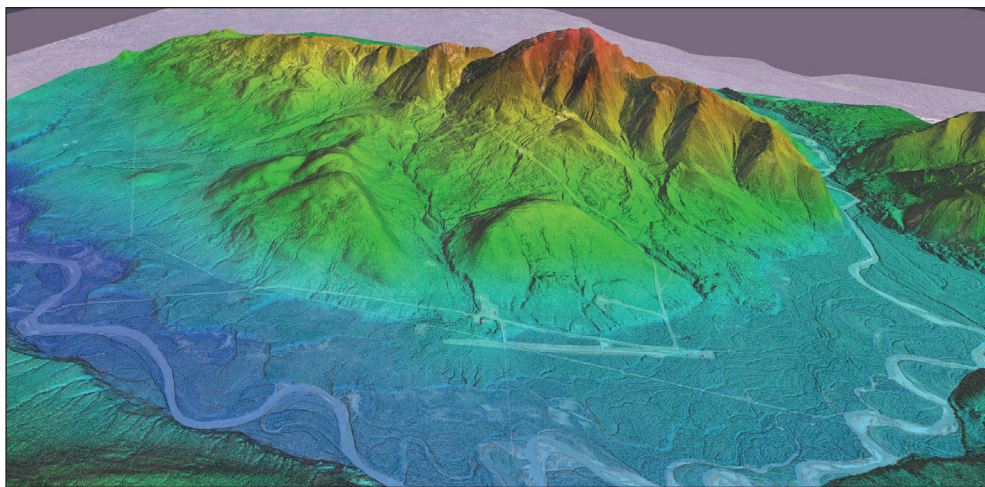
**Figure 11.** Kristen Kennedy examining sediments exposed in a section along Arch Creek in the Kluane area.



**Figure 12.** Section of pre-glacial quartz-rich gravel exposed on the Liard River.

### **Landslide monitoring in Liard basin area**

In September, Panya Lipovsky initiated a multi-year landslide monitoring project in the Liard basin area. Work included collection of LiDAR data from the Kotaneelee area (Figs. 9 and 13), funded by CanNor, and the installation and differential GPS measurement of 13 rebar monuments. The monument locations will be re-measured annually for three to four years to determine whether the area is seeing any active ground movement. Yukon government is currently overseeing well abandonment and remediation of the Kotaneelee site, and knowledge of slope stability will be an important factor in regulating the work.



**Figure 13.** 3-dimensional image of the Kotaneelee area derived from LiDAR data draped over a satellite image.

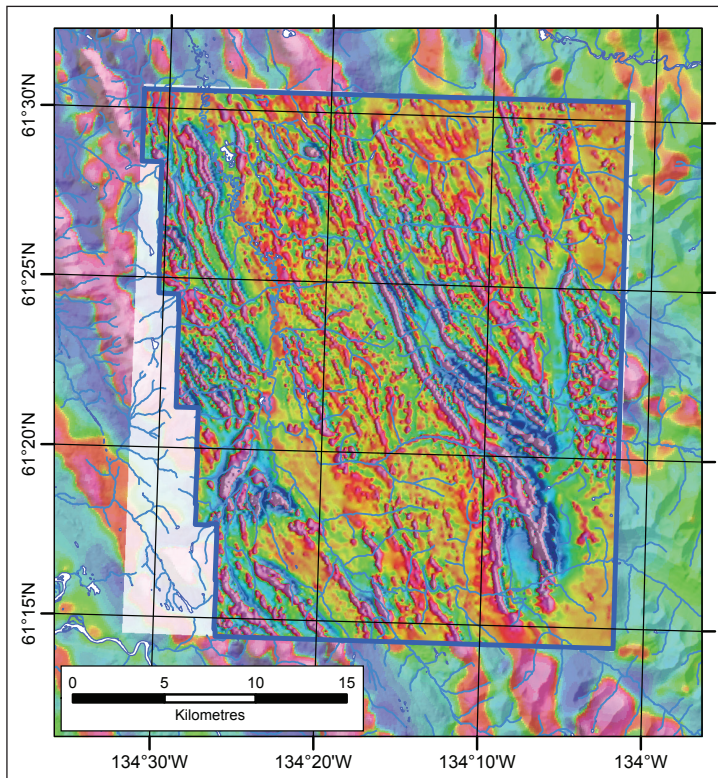
## **GEOPHYSICAL AND GEOCHEMICAL SURVEYS**

### **VTEM SURVEY OF LIVINGSTONE CREEK AREA**

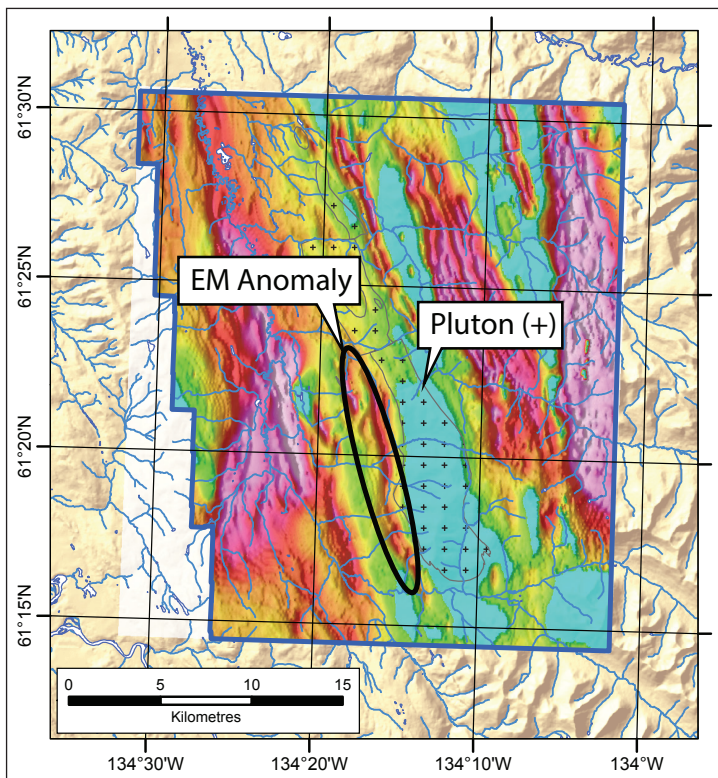
Between March and June, 2016, a SINED-funded airborne VTEM survey was flown over the Livingstone Creek area in south-central Yukon. Placer mines operating in this area have yielded anomalously large nuggets, but to date no bedrock source for the gold has been found. One of the intents of the survey was to refine the structural framework of the area to assist in targeting potential load sources for the gold.

Figure 14 is an image of the first vertical derivative magnetic map for the Livingstone Creek area, and Figure 15 shows conductivity. Colpron *et al.* (2017) have examined the survey results in detail, generating derivative maps and integrating them with bedrock geology observations. They identified a series of subtle, NNE-trending lineaments in the geophysics that locally coincide with late brittle faults. NNE-striking faults have been noted to exert control on gold grades along some of the few gold-bearing veins that have been found near Livingstone Creek. Colpron *et al.* (2017) also identified a number of interesting geophysical anomalies, including a conductor along the western contact of an Early Mississippian pluton in the central part of the study area (Fig. 15). The anomaly coincides with the headwaters of several gold-bearing creeks, suggesting a possible bedrock gold source.

The implications of the survey are not limited to bedrock mineral exploration, as magnetite-rich sediments along creek valleys locally reveal what appear to be stranded paleo-channels. These represent unexplored placer targets that justify further investigation.



**Figure 14.** Image of the first vertical derivative magnetic map for the Livingstone Creek area.



**Figure 15.** Conductivity map, showing outline of Early Mississippian pluton. Conductor along west side of pluton is indicated.

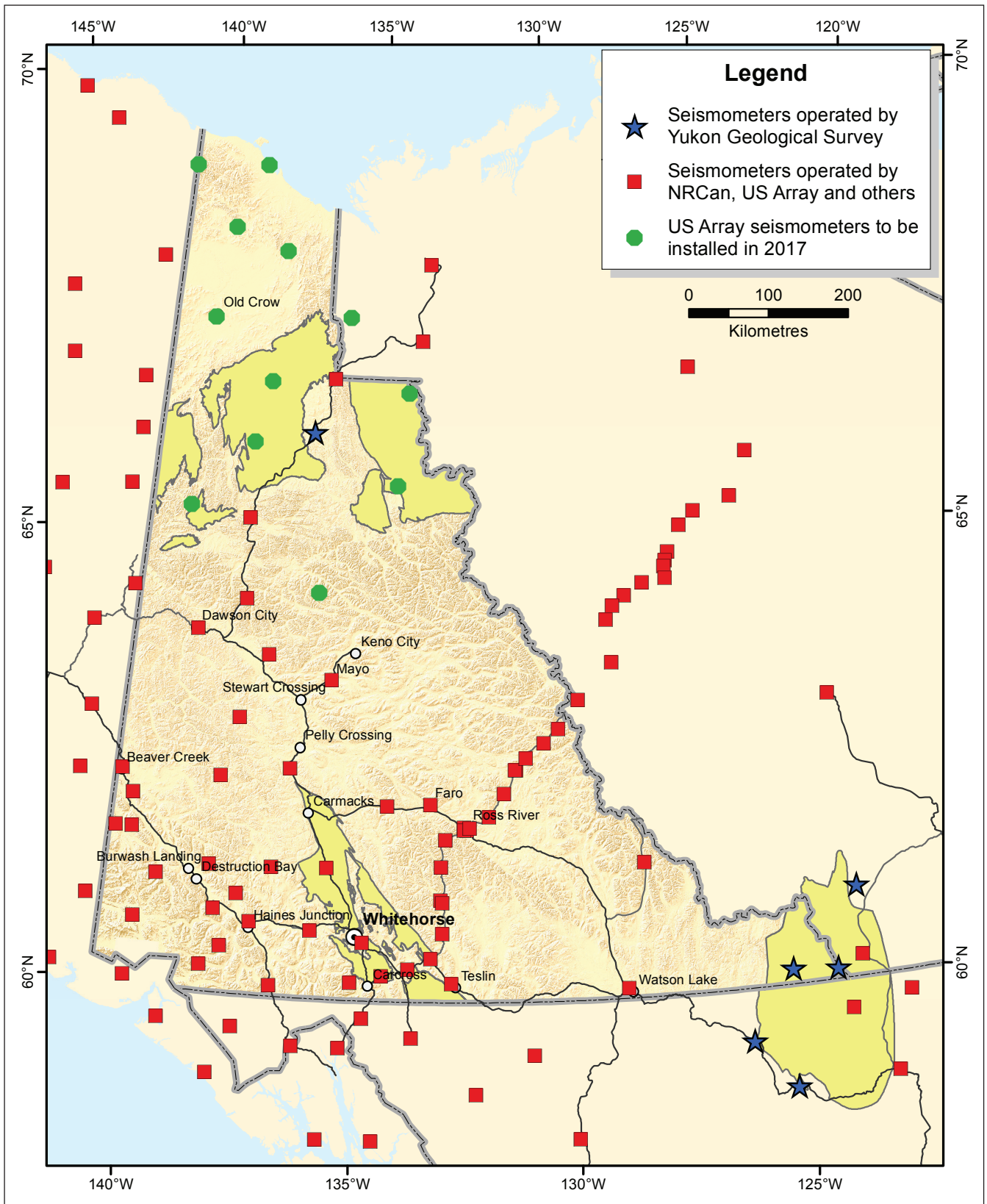
A more detailed description of the survey results and their geologic implications are presented by Colpron *et al.* (2017).

### EARTHQUAKE MONITORING IN LIARD BASIN

In June, YGS worked with Michael Schmidt (Arctic Institute of North America) and Nanometrics to install five seismometers in the northern part of the Liard sedimentary basin. Four of the instruments belong to YGS and the fifth was purchased by the GSC.

The seismic instruments serve two purposes. First, a widespread network of seismic instruments is deployed (or will soon be deployed) across Alaska, Yukon, northern British Columbia and western Northwest Territories (Fig. 16). The bulk of the instruments are part of the U.S. Array project, a multi-year National Science Foundation-funded study being managed by a consortium of U.S. based universities. Other instruments currently installed in Yukon include ones operated by NRCan, and the universities of Ottawa and Colorado. South of the border, a BC-based seismic consortium operates several instruments to monitor seismicity induced by oil and gas development activity. The seismometers installed by YGS in the Liard basin area fill a gap in the existing coverage and will contribute to a more complete picture of seismic activity in Yukon.

The second reason for the Liard seismic installation is linked to the regulation of potential future oil and gas exploration in the region. The Exshaw-Patry shale in Yukon’s portion of the basin was recently estimated to contain eight trillion cubic feet of marketable natural gas (National Energy Board, 2016), and although there are currently no plans for development of that gas, collection of regional baseline data will help to determine background levels of seismicity in the area in advance of any potential future development, as recommended in 2015 by the Select Committee on the Risks and Benefits of Hydraulic Fracturing. Data from the five new instruments will be integrated with seismic information being collected in northeastern BC to provide a more comprehensive picture of the crust in this area. This study is being supported with SINED funds.



**Figure 16.** Distribution of existing and planned seismic instruments in Yukon. Blue stars indicate instruments that are owned by YGS.

## REGIONAL STREAM SEDIMENT GEOCHEMISTRY

Upgrading of Yukon's stream sediment geochemical database has been ongoing for the past several years, funded primarily through SINED. In May, upgraded data for the final six map sheets were released (Jackaman 2016a to d). All available archived samples south of 65°N have now been re-analyzed via 53-element inductively coupled plasma mass spectrometry.

The upgraded geochemical data have been merged into a single layer that is viewable and queryable via the online Mapviewer, and can be downloaded as a single file by users. Metadata such as analytical technique, sample location and Open File number are linked to the individual samples.

In addition to upgraded geochemical analyses, YGS contracted CSA Global to generate probabilistic models for different mineral deposit types by integrating geochemical data with bedrock and surficial geology for each sample catchment. This SINED-funded project wrapped up last fiscal year and the final ten map sheets were released this fall (Mackie *et al.*, 2016a to g).

The sample catchment areas that were digitized for the modeling exercise are in the process of being merged across all Yukon map sheets south of 65°N (corresponding to the area for which modern geochemical data are available). These merged catchments will provide a useful backdrop for evaluating the geochemical data; for example, polygon size will provide information on sample dilution when interpreting the data, and will also highlight drainages where in-fill sampling would be beneficial.

## GEOSCIENCE OUTREACH

In early June YGS and Yukon College co-hosted the annual joint meeting of the Geological Association of Canada and the Mineralogical Association of Canada (GAC®-MAC). The conference featured technical sessions highlighting northern Cordilleran geology and resources, and included five field trips and three workshops. Field trip guides, which were released by YGS in the fall, are a legacy product of the conference (Colpron *et al.*, 2016; McOnie, 2016; Mortensen *et al.*, 2016; Pigage and Rainey, 2016; Sack *et al.*, 2016).

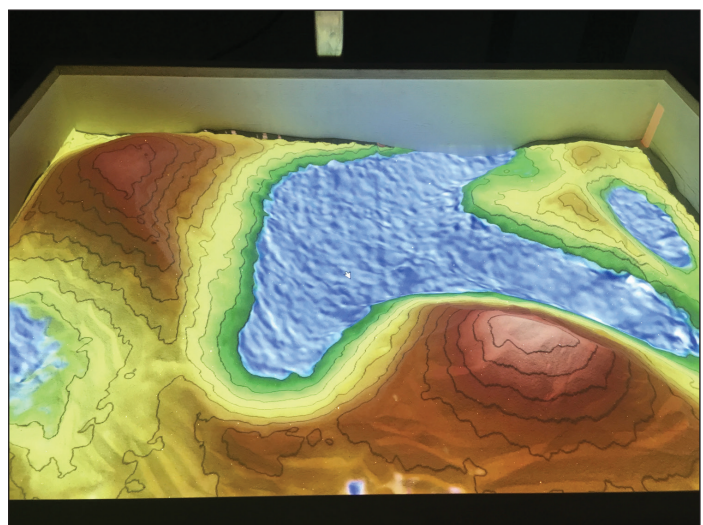
A geologic highway map for southern Yukon (Laxton *et al.*, 2016) was also released at the GAC®-MAC conference; all conference delegates received a copy, and copies were distributed to schools and visitors'

centres in communities over the summer. This map is the culmination of work started by Karen Pelletier, who delivered YGS' outreach program until her retirement in 2011.

Rather than holding YGS' annual geoscience teachers' workshop in the fall, this year's workshop was held in June, in conjunction with the GAC®-MAC conference. This allowed educators attending the conference from outside of Yukon to participate, and leveraged some of the resources associated with the conference for the workshop.

Over the summer, Laxton organized activities for classes attending Yukon Mining Week and led interpretive hikes in the Whitehorse area (Miles Canyon, Fish Lake, Whitehorse waterfront) and at Tombstone Territorial Park. The latter event included installing a plaque at the park centre commemorating the contributions made to geo-education over the years by Charlie Roots.

Leyla Weston backfilled the Outreach Geologist position early in the fall, organizing a number of school field trips and classroom visits. At the annual Geoscience Forum, she debuted YGS' new Augmented Reality Sandbox, a hands-on teaching tool that projects colour-shaded elevation topography onto hills and valleys created by students in a sandbox (Fig. 17). As users "play" in the sand, the topographic projection adjusts in real time to reflect changes in the sandbox landscape. The system, created at the University of California, Davis, was built by Brett Elliott and Craig Nicholson for YGS' outreach program, and will be brought into schools over the next year.



**Figure 17.** Photo of coloured relief projected on "topography" in the Augmented Reality Sandbox.

## NEW ACTIVITIES

Following the territorial election in October 2016, the incoming government confirmed its commitments to exploring opportunities for renewable energy and to re-starting land use planning. Both commitments have implications for YGS priorities going forward, and as it turns out, and the survey already has work underway that align with these interests.

In response to federal commitments to renewable energy research, YGS initiated a SINED-funded study of geothermal energy potential over the summer, and following recent concerns about exploration in areas with unsettled land claims, YGS has been examining ways to update mineral potential maps in a timely manner to support land use discussions.

### HEAT FLOW STUDY IN WHITEHORSE TROUGH

In 2015 the Canadian Geothermal Energy Association (CanGEA) undertook a Yukon-wide assessment of geothermal energy potential. Their report can be accessed at <http://www.energy.gov.yk.ca/geothermal.html>. The study, supported with SINED funds through EMR's Energy Solutions Centre Branch, concluded that Yukon has potential to generate 1700 MW of power from geothermal resources to a depth of 5 km, and it identified a number of areas with moderate to high potential for geothermal energy development.

One of the areas identified as having moderate to high potential corresponds closely with the Whitehorse trough sedimentary basin. The area's favourable potential, coupled the presence of an existing power grid and the fact that the bulk of Yukon's population lives in the area, led YGS to propose further work to assess the trough's attractiveness for geothermal exploration. The two-year study (2016-18), being coordinated by Maurice Colpron and Tiffani Fraser, will involve drilling two wells and instrumenting them with thermistor strings to directly measure heat flow.

The first well, scheduled to be drilled in spring 2017, will target an area near Whitehorse that is underlain by a young granite pluton. The planned well will be 500 m deep and will allow YGS to assess whether the pluton is a significant source of radiogenic heat. The second well, targeted for fall 2017, will test heat flow in a deeper well (to 1 km) within a thick section of sedimentary rocks of the Laberge Group along the Robert Campbell Highway.

In addition to the work focused on Whitehorse trough, YGS plans two additional studies. The first involves calculating the heat-generating potential of various Cretaceous and younger plutons for which whole rock geochemical data (in particular, U, Th and K) exist. The second will entail calculating Curie point depths from regional aeromagnetic data to generate a ~580°C isothermal surface map. The latter study will be carried out by Innovate Geothermal. Both studies are designed to advance knowledge of Yukon's geothermal potential by identifying areas with anomalous heat flow.

### MINERAL POTENTIAL MAPPING

Two key challenges for land use planners in integrating mineral potential information into the planning process are understanding the nuances of mineral potential values and accommodating uncertainties, to ensure that decisions do not preclude future economic opportunities. Over the past year, Scott Casselman and Patrick Sack have been evaluating methodologies used by different jurisdictions to generate mineral potential maps and assessing how effectively those maps reflect not just mineral potential values, but the inherent uncertainties associated with those values.

Based on what they have learned from this exercise, they have adopted a system that assigns mineral potential values for deposit types based on geologic attributes (such as lithology, age, structure, etc.) coupled with knowledge derived from MINFILE occurrences and stream sediment geochemical data. The mineral potential values assigned to each polygon subjectively reflect the confidence associated with the assigned values.

While this system is less rigorous than the Monte Carlo simulations undertaken for YGS' original mineral potential maps (Bradshaw and VanRanden, 2003) updating the maps will be relatively simple as the values are derived from the data tables behind the Yukon bedrock compilation map. As new data are incorporated into the compilation, the mineral potential values (and confidence for each value) can be updated very quickly, ensuring that land use planners have access to the most up-to-date information.

## ONGOING YGS ACTIVITIES

### INDUSTRY LIAISON

Scott Casselman, Patrick Sack and Derek Torgerson visited twenty-four mineral exploration properties in 2016, liaising with prospectors and company geologists, documenting exploration expenditures and tracking results. Highlights of this year's exploration and development activities are summarized elsewhere in this volume (Lewis and Casselman, 2017) and were presented at the annual Geoscience Forum in November.

In addition to field visits, Sack, Casselman and Relf represented YGS at the Yukon Mining Alliance's annual media tour and investors' forum in Dawson City in August, liaising with industry representatives and connecting with investors.

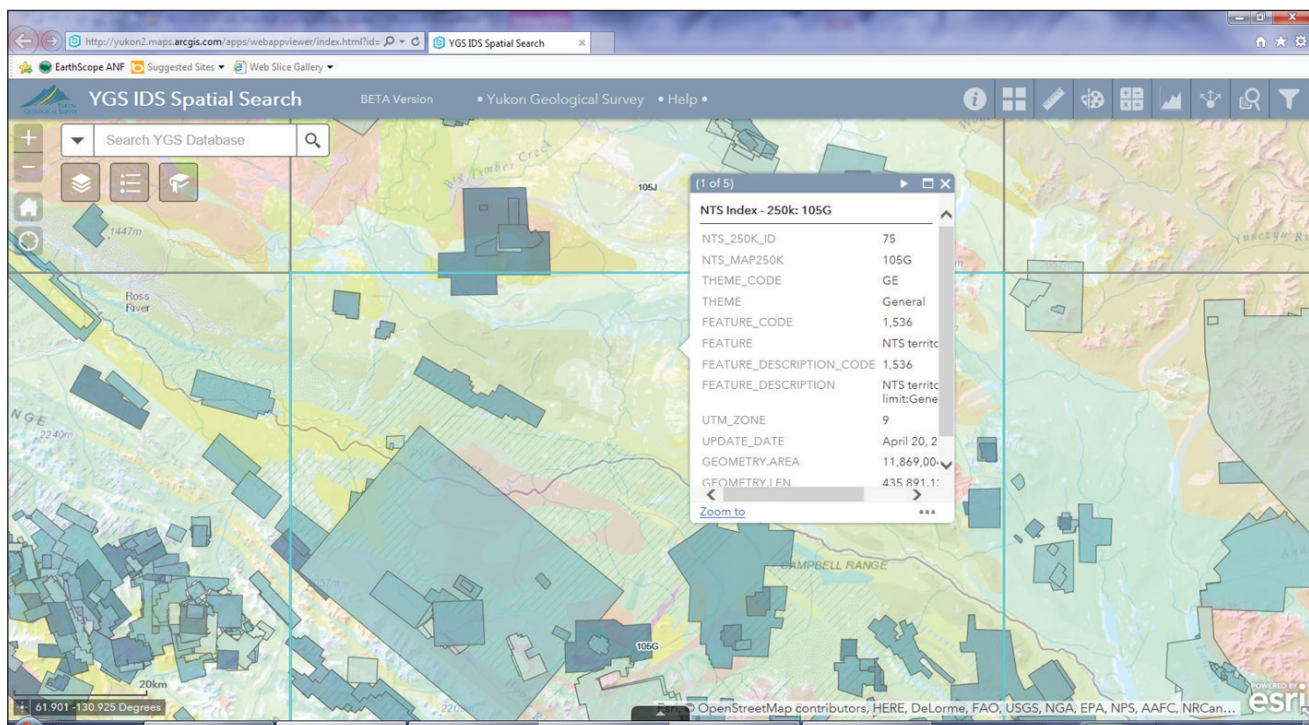
Jeff Bond and Sydney van Loon visited active placer operations in 2016, documenting information on gold distribution and character, work activity and geologic setting. An overview of 2016 placer highlights was presented at the 2016 Yukon Placer Forum and the Geoscience Forum, and is summarized in this volume (Bond and van Loon, 2017).

### INFORMATION MANAGEMENT

In 2016 YGS released fifty-two publications (see the appended list of 2016 publications at the end of this volume) and eight external publications (including five in refereed journals). The 2016 Yukon Exploration and Geology volume, to be released early in 2017, contains thirteen technical papers describing 2016 project highlights.

Regarding data management, a new feature was added to the MINFILE database in 2016: it is an interactive map that displays the location of mineral occurrence(s) queried by the user. The map has a bedrock geology backdrop to provide a geologic context for the occurrences.

In the spring, YGS initiated a new SINED-funded project that involves digitizing the footprints of Assessment Reports (ARs) and capturing key metadata such as company, year, type of work and exploration expenditures. A preliminary map-based web application has been developed to display ARs (Fig. 18); it was demonstrated at the Geoscience Forum. The application has several filters which allow searches to be further narrowed, for example, by selecting reports with drilling or soil sampling results, and individual ARs can be interrogated with a query tool. Queries return metadata and a \*.pdf copy of the report.



**Figure 18.** Screen capture of the Footprints web application, showing the areal coverage of assessment reports and the tools available to users to query the reports.

In addition to the AR Footprints application, ARs can be found via non-spatial YGS IDS searches, and MINFILE searches yield links to ARs (as references). Ultimately though, the spatial and temporal (*i.e.*, ARs by year) attributes of data in the AR Footprints application will make searches much simpler and will enable compilations of property work histories.

To date, roughly 3000 ARs have been captured (out of a total ~7000). YGS hopes to complete the backlog of reports by spring, after which point AR metadata will be captured as reports are submitted. YGS is working closely with the Mining Recorder to streamline the flow of AR metadata between offices so that footprint and metadata can be uploaded more efficiently. The survey is also contemplating creating an FTP site to allow clients to upload digital copies of ARs directly, as a first step in a longer-term vision to eliminate the requirement for paper submissions.

### DRILL CORE COLLECTION

Between 2013 and 2015 the bulk of YGS' existing drill core collection was moved to the new core library to allow clients year-round access to the core. The survey's longer-term vision is to expand the collection so that all significant mineral occurrences and deposits in the territory are represented. The intent is to retain sample suites that represent the variable character of Yukon's mineral occurrences and allow clients access to the samples to support exploration and research.

Over the summer, YGS received donations of new core and drill logs from the Minto, Casino and Kudz Ze Kayah deposits. Descriptions of 2 of the donated collections are presented by Sack *et al.* (2017; Minto core) and Casselman and Brown (2017; Casino core).

This spring, YGS will web-enable selected fields from the drill core database to allow users to peruse core metadata and request access to samples. In cases where enough material is available, core may be sampled for assaying, thin sections, or other analytical purposes. Requests for more information on the drill core can be made to the core library manager ([craig.nicholson@gov.yk.ca](mailto:craig.nicholson@gov.yk.ca)) or to the YGS Minerals Geology unit ([YGS-minerals@gov.yk.ca](mailto:YGS-minerals@gov.yk.ca)). Policies for sampling and analysis will be posted when the web application is launched.

## SUMMARY

2016 was another busy year for YGS, highlighted by capacity growth in the Mineral Geology unit. Mapping and industry liaison continue to be foundational activities of the survey, but new government commitments will see new research priorities and capacity emerge over the next few years.

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