



Yukon

Exploration & Geology Overview

2019

- Yukon Geological Survey Activities
- Yukon Mineral Exploration Program
- Hard Rock Mining, Development & Exploration
- YGS Publications
- Placer Mining Development & Exploration
- Yukon Geological Survey Outreach



Yukon Geological Survey staff

Left to right: Nicole Eriks, Alex Sadurski, Patrick Sack, Tyler Ambrose, Carolyn Relf, Warwick Bullen, Julie Minor, Panya Lipovsky, Olwyn Bruce, Scott Casselman, Emilie Stewart-Jones, Maurice Colpron, Amanda O'Connor, David Moynihan, Kristen Kennedy, Bailey Staffen, Tiffani Fraser, Derek Torgerson, Leyla Weston, Jeff Bond, Diane Skipton, Justin Emberley and Brett Elliot.

Missing from photo: Rosie Cobbett, Lara Lewis, Karen MacFarlane, Sydney van Loon.



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Overview
2019

Edited by
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Front cover photograph: Don Murphy (YGS Emeritus Geologist) explains the geology of Tombstone Park during a 'Weekend on the Rocks'.

Preface

Yukon Exploration and Geology (YEG) papers and the Yukon Exploration and Geology Overview are two of the main publications of the Yukon Geological Survey (Energy, Mines and Resources, Government of Yukon). Individual YEG papers, with colour images, are available in digital format and can be downloaded from our website. The YEG Overview is available in digital format and in a limited colour print run.

YEG 2019 contains up-to-date information on mining and mineral exploration activity, studies by industry, and results of recent geological field studies. Information in this volume comes from prospectors, exploration and government geologists, mining companies, and students, all of whom are willing to contribute to public geoscience for the benefit of the scientific community, general public and mineral industries of Yukon. Their work is appreciated.

Once again my colleagues at the Yukon Geological Survey are thanked for their involvement in authoring and reviewing YEG papers. Their commitment to provide geoscience information to support informed decision making is to be commended.

The Queen's Printer ensured that the printing process went smoothly.

We welcome any input or suggestions that you may have to improve future YEG publications. Please contact me at (867) 667-8519, or by email at karen.macfarlane@gov.yk.ca.



Karen MacFarlane

In Memoriam



Julia Lane

1986 – 2019

Julia Lane was an exceptional geologist, widely admired for her ability to manage large and logistically difficult exploration projects in remote areas of Yukon. She tragically passed away on August 6, 2019, at the age of 33, in an aircraft accident during a routine flight from the field.

Julia started her career in 2007, working as a geology student for Archer, Cathro & Associates (1981) Limited on a variety of projects in Yukon. In 2009, she joined Archer Cathro full time as a senior project geologist working at ATAC Resources Ltd. Rackla Gold Project in central Yukon. Her exemplary management skills led to more responsibility the following year as Project Manager for the Rackla project. She was instrumental in ATAC's 2010 discovery and delineation of the Osiris Carlin-type gold deposits. Julia guided her colleagues and ATAC through the steep learning curve of understanding an unfamiliar deposit model in a rugged, remote area that had never previously been explored for gold and had only seen rudimentary

geological mapping. In peak exploration years, Julia effortlessly budgeted for and managed up to 5 helicopters, 6 diamond drills, 20 project geologists, a support staff of over 50, as well as ongoing academic research projects while providing a safe working environment and culture.

Julia grew up on a small family farm in the rural town of Summerland, in the Okanagan, where she developed a passion for science and nature at a young age. Her father, David, was a federal government scientist working on development of new varieties of cherries and apples. Her mother, Donna, a landscape architect and keen gardener, conducted business from a home office which gave Julia early exposure to the “work side of things”, and kindled her love of gardening. Julia's family went camping and hiking near Rodger's Pass and Banff every summer, where she had very positive experiences in the mountains from a young age; experiences that undoubtedly developed into her passion for geology and working in remote mountain locations. Julia's love of science was truly expressed in her frequent participation in Science Fairs, starting in grade 6. She made several appearances in National Science Fairs in high school, earning a gold medal, and went on to represent Canada at the International Science Fair in Taiwan where she received a bronze medal.

Julia graduated with a Bachelor of Science (B.Sc.) degree in geology from the University of British Columbia (UBC) in 2009. She was a registered Professional Geoscientist and became a partner in Archer Cathro in 2012. In 2015, she was appointed Vice President of Exploration for ATAC Resources Ltd. She was an active volunteer with the Association for Mineral Exploration (AME) as a participant in the mentorship program and as co-chair of the Roundup 2019 BC/Yukon/Alaska technical session. She will be remembered as a skilled communicator with an uncanny ability to simplify even the most complex geological concepts. She was a frequent speaker at conferences and short courses, and authored or co-authored a number of technical papers on the subject of Yukon exploration and Carlin-type deposits. Her work was recognized internationally.

Julia was always supportive of more 'academic' geological studies, whether at the deposit level or at a regional scale. In 2010, the Yukon Geological Survey and the Geological Survey of Canada began coordinated mapping and topical research focused at unravelling the regional geology and documenting the Carlin-type deposits of the Rackla Gold belt. This research was welcomed by Julia and facilitated with her enthusiasm and access to ATAC's logistical assistance and extensive geological and geochemical database. She extended similar support for academic researchers from the Colorado School of Mines, Dartmouth College, UBC, Harvard, McGill and Simon Fraser universities.

Julia was a strong advocate for women in geoscience, standing out as a role model, both to young women and men – not by any specific intention, but by embodying what it means to be professional, accomplished, passionate and dedicated to your work. She was a natural and humble leader who was excited to share her knowledge and encouraged others to excel. While known and respected as a rising star in Canada's mineral exploration industry, she will also be remembered for her kindness, positivity and enthusiasm and, above all, her ability to keep things fun.

Julia lived in the present and took great pleasure in what she called the "simple things in life". She loved the world around her and everything in it. She shared these simple things and a garden (with a house) in Vancouver with her partner of 14 years, Ryan Gandy. She leaves behind her parents Donna and David, her brothers Alex and Malcom, sisters-in-law Marta and Steph, nieces and nephews Emily, Mattie, George and Benjamin, and the many friends she made on her journey through life.

Archer Cathro established The Julia Lane Foundation to continue her passion to encourage young professionals. Its primary intent is to assist and encourage future generations to pursue advanced education in the sciences. Grants made by the foundation will support students pursuing degrees in earth sciences or related programs. Donations can be made at <https://tinyurl.com/JuliaLaneFoundation>.

Shawn Kitchen

1995–2019



Shawn Kitchen was passionate about flying.

In September 2014, Shawn began his Commercial Aviation diploma at Okanagan College in Kelowna. In the Spring of 2015, after his first year of college, he started working at Alkan Air as a dispatcher and moved to Mayo as Alkan's rampie. Everyone quickly learned that Alkan had hired a keen, positive and energetic individual who truly loved working in aviation. Working for Alkan Air only confirmed Shawn's decision to become a commercial pilot.

Shortly after receiving his diploma and his wings, Shawn purchased a Cessna 120 and took his family and friends flying, while at the same time building up his flight hours. Once Shawn reached the hours he needed to meet the medevac contract requirements in the Yukon, he began flying for Alkan Air as a First Officer medevac pilot on the King Airs. In this position, he flew all around the Yukon and major cities of British Columbia and Alberta. Shawn always prided himself for being able to help the Yukon community as a medevac pilot.

In Winter of 2017, Shawn served as a medevac pilot flying for Alkan Air out of their Nanaimo base. From here, Shawn was able to fly medevacs all across North America.

After flying the King Airs, Shawn became interested in bush flying and, in the Spring of 2017, he progressed onto the Dornier 228, Alkan Air's famous twin engine bush machine. Here he learned to appreciate a whole different aspect of flying. It was flying into remote strips in the most beautiful part of the country where you saw Shawn's smile come out the most.

Shawn progressed onto the Caravan 208 in the Spring of 2019 – and without hesitation relocated to Mayo, where his aviation career started. Shawn's care and professionalism were reflected on the day-to-day operations at the Mayo base and in Alkan as a whole.

Besides flying, Shawn was committed to Scouting. Beginning as a cub, Shawn grew to be a Scout, Venturer and Rover. Through Scouting, Shawn travelled to Germany, Sweden, Iceland, Madagascar and Switzerland, making friends wherever he went. It was through his travels that he became known as "Shawn of the Yukon". Shawn had strong community values and it was important to him to give back to the youth of Yukon. He believed that youth should have a voice in programs geared towards youth. As Area Commissioner for Scouting, Shawn provided leadership to Scouts Yukon as well as being a mentor and role model for many Cubs, Scouts and Leaders throughout the Yukon.

Shawn had an adventurous spirit and a love for the outdoors. His days off from Alkan Air were often spent hiking with friends to some of the most beautiful places around the Yukon. Shawn was always up to new challenges and had recently taken up rock climbing. Shawn was also a budding photographer and took his camera everywhere he went. He was inspired by the scenery, people and events around him and captured much of it with his camera. With a keen sense of perspective, Shawn's photos told stories about the places he visited, the people he met and life happening around him. He had the eye of a professional.

Shawn brought life and energy to everything he did. Shawn passed away on August 6, 2019. At just 24 years of age, he had touched the lives of many people on a personal and professional level. He will be missed and remembered by all who knew him.



Yukon Exploration and Geology Overview 2019

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Yukon Geological Survey: Planning for the future

Carolyn Relf*
Yukon Geological Survey

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Introduction

The Yukon Geological Survey (YGS) had a busy year in 2019, welcoming seven new staff and initiating several new projects. In addition to its regular activities, the survey hosted a planning workshop with clients and stakeholders in April to identify gaps in Yukon's geoscience knowledge base and engage participants in a discussion about their current and future information needs. The YGS holds these workshops every five years, and they are valuable for providing insights into research and exploration trends, generating ideas for new projects, and identifying opportunities for collaborative partnerships. As a backdrop for these discussions, participants were asked to consider how existing and emerging markets, climate change, societal needs and new technologies might influence how the YGS collects, manages and disseminates information.

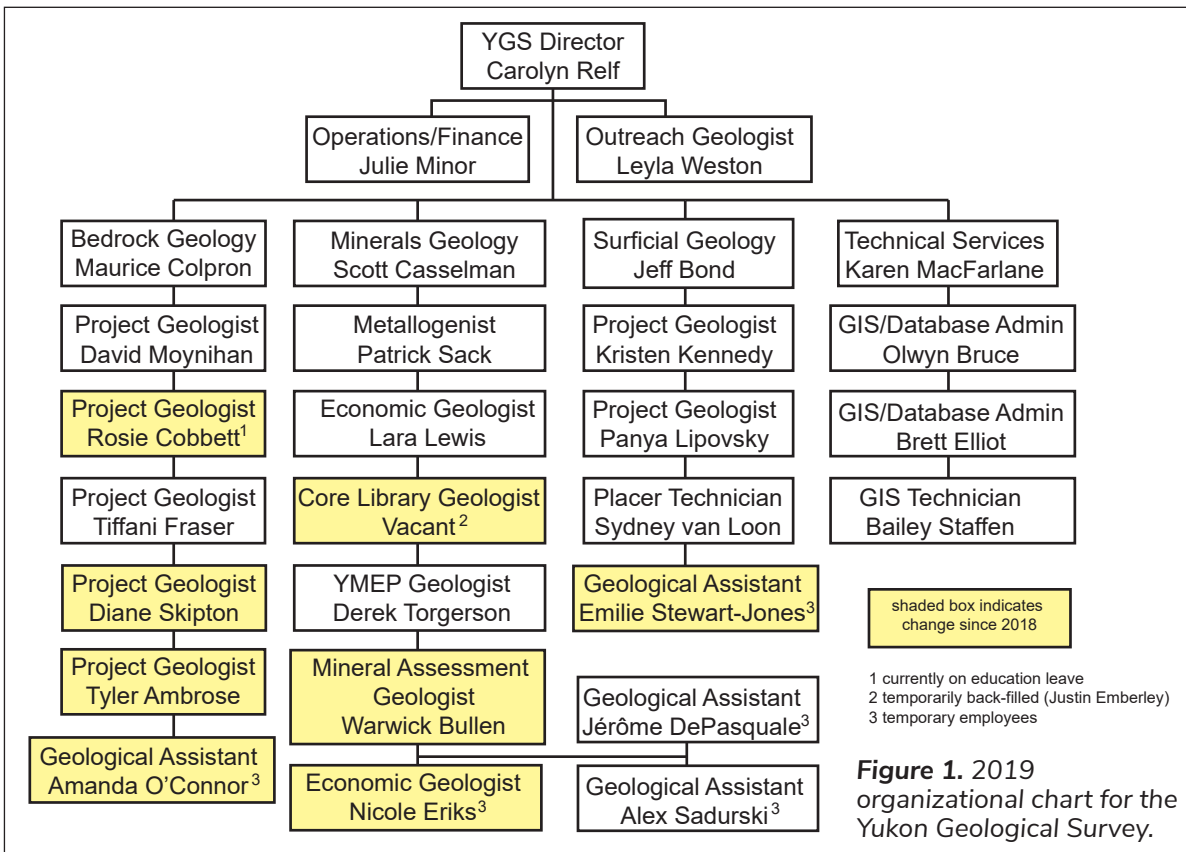
This paper provides both a brief overview of 2019 program activities and a summary of what was heard at the April planning workshop. Workshop discussions covered a broad range of topics and included both specific project ideas as well as general themes. The YGS has already initiated some of the projects that were proposed in April. The paper is organized based on the thematic breakout sessions at the workshop; current activities underway under each of the themes are presented first, followed by a summary of the input heard at the workshop.

Snapshot of YGS

An organizational chart for YGS' current staff is presented in Figure 1. Three new staff joined the Minerals Services unit in 2019. Warwick Bullen was hired in April and will be the lead for mineral resource assessments to support land use planning. Nicole Eriks was brought on board in August as a term Economic Geologist (to March 2021) to assist with MINFILE work, track industry activities and contribute to mineral deposit research projects. Justin Emberley transitioned from a part-time position organizing geochemical data to a temporary back-fill as the Core Library Geologist following the retirement of Craig Nicholson.

The Bedrock Geology unit hired two new bedrock mapping geologists in 2019. Diane Skipton started in February, and Tyler Ambrose in May. Both have initiated new mapping projects in central Yukon (described briefly below). Skipton is currently on maternity leave and will be resuming her duties in October 2020.

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In addition to the above, two temporary staff joined the Surficial Geology unit in May 2019. Kisa Elmer, a geotechnical engineer from Yukon’s Department of Highways and Public Works, was appointed to the survey on a temporary assignment for the summer, and Emilie Stewart-Jones was hired for a year. Both were brought on board to work on a permafrost database project (described below).

The YGS has an operating budget of \$3.33M for fiscal year 2019-20. This includes core operational funding of \$1.265M and \$665K in federal funding. The federal funds include a \$595K grant from CanNor under their Strategic Investments in Northern Economic Development program (year two of a two-year grant), and a \$70K grant from Indigenous and Northern Affairs Canada under a program called Climate Change Preparedness in the North (year three of a four-year grant). Funds from the latter grant are transferred from the YGS to Yukon College to support permafrost scientists at the college’s Research Centre. In addition to operating funds, the survey administered \$1.4M in grants under the Yukon Mineral Exploration Program in 2019-20.

With respect to the YGS’ broader operating environment, Yukon government is currently working on two major initiatives that will influence priorities for the YGS in the coming years. The first is “Our Clean Future” strategy (<https://yukon.ca/sites/yukon.ca/files/env/env-summary-our-clean-future.pdf>) which is currently in the final public engagement stage. The strategy’s action plan focuses on reducing carbon emissions and adapting to climate change impacts, with the YGS identified as lead for geothermal and permafrost/geohazard studies. To support this work, the YGS will continue to seek external sources of funding and leverage research partners to participate in these studies.

The second Yukon government initiative, for which stakeholder engagement is just getting underway, is the Yukon Mineral Development Strategy. It is anticipated that geoscience will be a component of the Strategy and that the provision of public geoscience to support exploration efforts and reduce investment risk will continue to be a priority. Information on this initiative can be found at <http://yukonmnds.com/>.

Current bedrock activities

Two new 1:50 000-scale bedrock mapping projects were initiated in 2019 in the Beaver River watershed. Both projects are designed to upgrade existing 1:250 000-scale maps and improve our understanding of the regional stratigraphic and structural framework of the areas. The primary driver for new mapping in the Beaver River area is to support the assessment of mineral potential for the subregional land use planning process that is underway (currently scheduled to wrap up in fall 2020).

The first project, led by Diane Skipton, is in the Scougale Lakes area west of the Tiger deposit (Fig. 2). The map area straddles the northern edge of the Selwyn basin and southern margin of the Ogilvie platform. Mapping in 2019 subdivided the Neoproterozoic Yusezyu Formation into four units that preserve an overall coarsening-upward sequence. Skipton also modified the trace of the Dawson thrust fault in the area and found metamorphic evidence for a buried pluton, which could have implications for mineralization. Results of her 2019 field work were presented at the Yukon

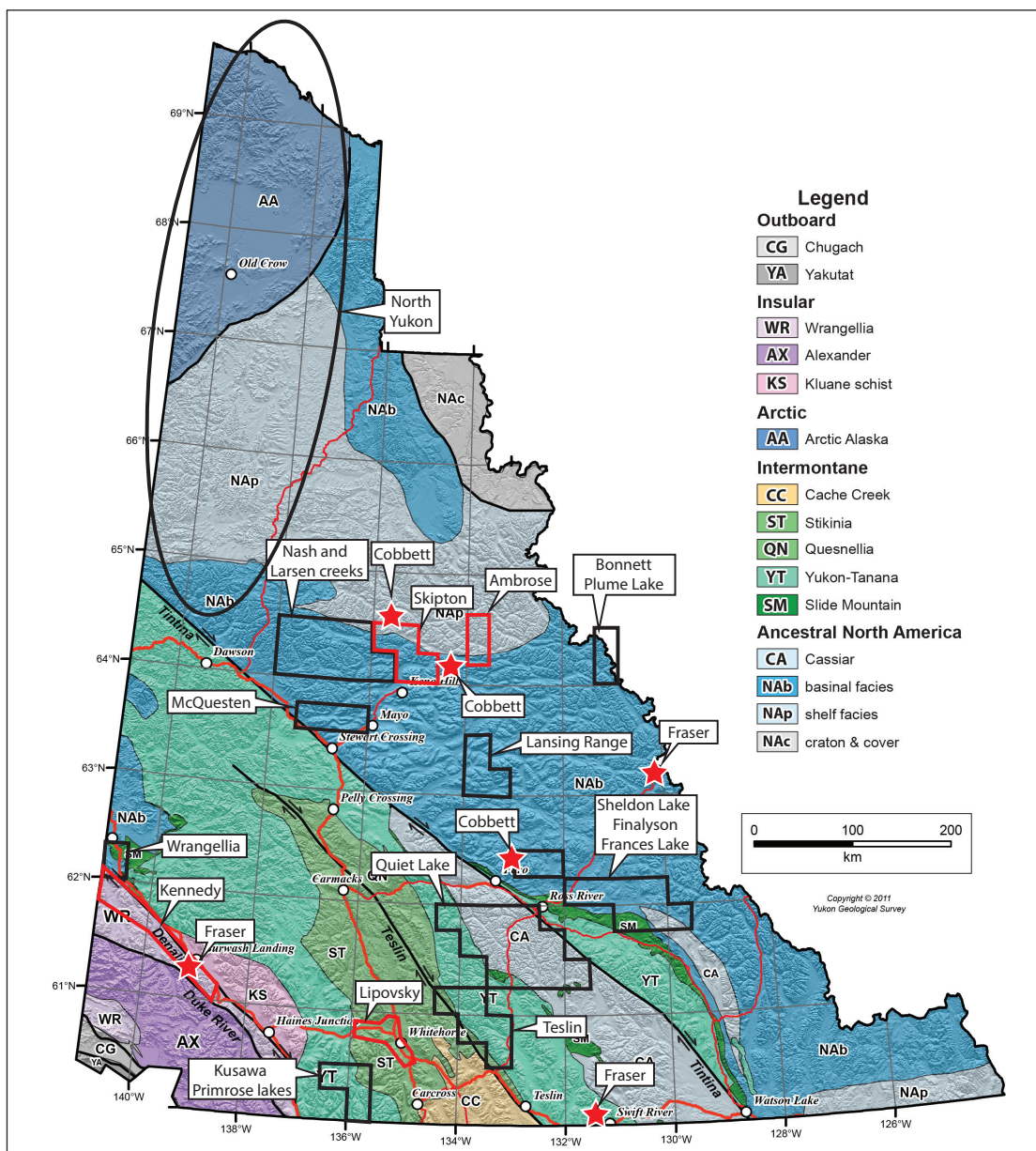


Figure 2. Locations of 2019 YGS field activities (red), and footprints of bedrock mapping project areas proposed at workshop (black).

Geoscience Forum in November. Mapping in this region could extend westward over the next several years into the western Nash Creek and Larsen Creek areas (106D, 116A; Fig. 2), as the stratigraphy to the west is poorly known. Additionally, although the Dawson fault exerts significant control on various styles of mineralization in the region, the timing of displacement is unknown.

The second mapping project is being led by Tyler Ambrose. The map area is located in the southern Wernecke Mountains (Fig. 2) near the recently discovered North Rackla Pb-Zn-Ag occurrence. Rocks here range from Paleoproterozoic to lower Paleozoic and are stratigraphic equivalents to parts of the Wernecke and Windermere supergroups. Ambrose's work extended the mapping of Colpron et al. (2013) northward, documenting the characteristics and contact relationships of units in this part of the belt. In collaboration with David Moynihan (YGS) and Justin Strauss (Dartmouth College), he made a number of revisions to stratigraphic units in the area (Fig. 3). A summary of project results to date is presented in this volume (Ambrose, 2020).

Paleozoic	Cambrian-Devonian		Bouvette Formation	Upper mbr Volc mbr Lower mbr
		Upper	Windermere Supergroup	Rackla Group
	Hay Creek Group			Ravensthorpe Fm Mt. Profit/IB
	Rapitan Group		Callison Lk Fm	
	Mackenzie Mtns Supergroup		Hematite Creek Group	
	Middle		Pinguicula Group (?)	"Val dolostone"
		Lower	Wernecke Supergroup	Gillespie Lake Group (?)
	Quartet Group (?)			lower clastic unit Hart River Sills

Figure 3. Simplified stratigraphy of the southern Wernecke Mountains area, from Ambrose, 2020.

Tiffani Fraser continues to lead a multi-disciplinary project characterizing the geothermal potential of Yukon. The 2019 activities focused in two areas: along Denali fault near Burwash Landing and in the area east of Teslin (Fig. 2). The Denali fault site was selected because southwestern Yukon records some of the shallowest Curie point depths in the territory (Witter and Miller, 2017; Witter et al., 2018), suggesting a high geothermal gradient here. The Teslin area is of interest due to the anomalously high radiogenic heat generative potential values recorded in the Seagull batholith (Friend and Colpron, 2017).

Work in the Burwash Landing area involved gravity and extremely low frequency electromagnetic (ELF-EM) surveys along a number of Denali fault strands to better delineate their geometry and identify locations of enhanced permeability such as along a fault bend. Upon completion of the geophysical surveys, fieldwork was carried out to examine exposed fault strands and collect samples for physical rock property measurements (Fig. 4). Near Teslin, granitoid samples were collected for geochemical analysis to confirm the high heat values documented by Friend and Colpron (2017) and fill gaps in the existing geochemical data set. The new analyses have been incorporated into an updated radiogenic heat map (Colpron, 2019) that also incorporates recently released GSC data (Ryan et al., 2019). Fraser presented a paper highlighting the YGS' geothermal research activities as part of a Geothermal Canada presentation at the annual Geothermal Research Council meeting in September.



Figure 4. Jeff Witter (Innovate Geothermal) examining a strand of the Denali fault in outcrop along the Duke River.

In addition to the geothermal project, Fraser spent several days in the field in the Macmillan Pass area, measuring stratigraphic sections and collecting samples to characterize their chemistry as part of a regional chemostratigraphic study focused on characterizing Middle Devonian sediments in Selwyn basin. This project is an extension of the shale studies conducted in northern Yukon from 2013 to 2017 that defined the Middle Devonian hyper-enriched black shale unit (locally the NiMo or Nick horizon) with Mike Gadd of the Geological Survey of Canada (GSC). Fraser continues to collaborate with researchers from Stanford, Dartmouth College and St. Frances Xavier universities on the compilation of the Cambrian-Devonian Road River Group strata in the Peel River area. This multi-year (2015 to present), multi-agency project aims to integrate geological mapping, facies analysis, isotope chemostratigraphy and biostratigraphic results to provide a revised paleoenvironmental reconstruction and new age model for the Road River Group.

Rosie Cobbett initiated fieldwork on her PhD thesis this year, examining Paleozoic volcanic sequences in three locations: the Castle Mountain and Tiger areas at the southern edge of Ogilvie platform, and in Selwyn basin north of Faro (Fig. 2). Fieldwork focused on measuring sections and mapping field relationships both within the volcanic sequences and with surrounding sedimentary rocks. Graptolites recovered from sedimentary rocks below a pyroxene \pm olivine-phyric basalt at Castle Mountain pin the maximum age of the flows to post-early Silurian. Zircons recovered from volcanic horizons at both Castle Mountain and Tiger will provide further age constraints on the timing and duration of volcanism. At both of these locations volcanism occurred during a pause in the development of the carbonate platform (Fig. 5). Detailed descriptions of field observations are included in this volume (Cobbett, 2020).



Figure 5. Photograph of thick basalt flows at Castle Mountain. Flows are underlain by thickly bedded dolostone and overlain by reefal carbonate.

David Moynihan remapped the basal contact of the Bouvette Formation around Nadaleen Mountain to better document offset across the Kathleen Lake fault, and revisited the geology in the Bonnet Plume Pass area, reclassifying a number of units in the Bonnet Plume Pass and Goz map sheets. He also spent some time in the field with Skipton and Ambrose, helping to familiarize them with the geology of this region. The bulk of Moynihan's summer focused on writing a Bulletin and completing a Geoscience Map for the Hyland project, both on track to be released in 2020. He also published a paper on the stratigraphy of the Nadaleen/Rackla area (Moynihan et al., 2019).

The YGS also supported a number of bedrock studies by students in 2019. Colpron is liaising with two graduate students at Memorial University on two thesis projects: one is examining the geochemistry of Devonian-Mississippian igneous rocks in the Finlayson Lake area (Matt Manor), and the other is studying the stratigraphy of the Faro Peak formation (Adam Wiest). He is also supporting a study of Jura-Cretaceous basin evolution in the Kluane plateau area (Will McKenzie, Simon Fraser University) and a provenance study of sedimentary rocks of the Yukon-Tanana terrane (Emma Krueger, University of Iowa). Fraser supervised Hubert Langevin (Institut national de la recherche scientifique), who is documenting thermal conductivity and porosity/permeability of drill core from the temperature gradient well near the Takhini hot spring (see Langevin et al., 2020; this volume). Finally, Moynihan has a student in the final stages of a thesis on the petrology of deep crustal and mantle xenoliths and metamorphic processes related to orogenic gold formation in the Hyland area (Colin Padget, University of Calgary).

Bedrock geology workshop session highlights

The bedrock geology breakout session covered ideas for future regional mapping and identified a number of thematic (e.g., tectonic, stratigraphic) questions. Participants also discussed energy geoscience opportunities and exchanged ideas for geophysical surveys and remotely-sensed data.

Ideas for new bedrock mapping

Workshop proponents discussed a number of ideas for new bedrock mapping, defining the outstanding questions that mapping could address (Fig. 2). These are summarized below.

McQuesten-Mayo-Lansing Range areas (115P, 105M, N)

In contrast to southeastern Yukon, very little is known about the stratigraphy of the Hyland Group in central Yukon. In addition to stratigraphic questions, the extent of the Tombstone strain zone and the timing of southwest-verging folds in the McQuesten area remain unknown. Two priority areas have been identified for new mapping of the Hyland Group in central Yukon. In map sheet 115P, three 1:50 000 map sheets north of Stewart Crossing will extend the work of Murphy (1997) and address several structural and stratigraphic questions. In southwestern 105N, new mapping will reveal information on the relationship between Paleozoic volcanic rocks and units of the Hyland Group.

In terms of economic interests, a number of quartz vein-hosted gold occurrences have been documented in the area, including the Plateau occurrences in 105N. Additionally, several skarn-type occurrences (including tungsten and copper) are documented in the MINFILE database.

Bonnet Plume Lake (106B)

Mapping in 106B/3 and 6 would tie Rackla stratigraphy (Moynihan, 2016) to the Mackenzie Mountains and provide an opportunity to study the southern Snake River fault and its relationship to structures in the Selwyn and Mackenzie fold belts.

Sheldon Lake–Finlayson River–Frances Lake area (105/K, J, H)

New mapping in this area will help to resolve outstanding questions regarding the relationship between Selwyn basin and the McEvoy platform. For example, are Road River Group rocks of Selwyn basin the stratigraphic equivalents of Askin Group rocks

of the McEvoy platform, or are these two packages tectonically juxtaposed? If they are age-equivalent, understanding their paleogeographic setting will help to address the question of stratigraphic linkages between basin and platform.

Another outstanding question in this region relates to the southwest limit of 'classic' Selwyn basin stratigraphy. In the west part of the proposed map area this boundary is marked by the Twopete fault. To the southeast, in the Hyland River area, a fault that truncates the Hyland structural/metamorphic culmination appears to play a similar role. These two faults converge in the area around McEvoy Lake/Pelly Lake. New mapping here will better define the southern limit of Selwyn basin rocks and reveal the relationship between these two major structures.

Quiet Lake area (105F)

Fundamental questions about the relationships between the Cassiar and McEvoy platforms and the Cassiar platform and Selwyn basin exist in this map area. For example, the Cassiar platform appears to be underlain by the same Neoproterozoic basement rocks as Selwyn basin but their lower Paleozoic depositional histories differ. New mapping will characterize these differences and determine when their depositional histories began to diverge.

Characteristic Cambrian rocks of the Cassiar platform appear to be absent from McEvoy platform, yet the Silurian-Devonian Askin Group is common to both. Prior to displacement on the Tintina fault, the Cassiar-McEvoy platforms may have formed a continuous linear belt. Is the absence of Cambrian sediments on McEvoy platform a result of along-strike variation in the Cassiar/McEvoy belt, or is there a more fundamental flaw in the Cassiar-McEvoy correlation?

In addition to the area's depositional history, magmatic events in the Quiet Lake area are also poorly understood. New geochronological data will provide constraints on Paleozoic and Mesozoic magmatism and its role in mineralization (e.g., Ketz River) and regional metamorphism (e.g., Pelly Mountains).

Finally, current mapping in the Quiet Lake map area precludes a clear understanding of the timing and nature of many of the major structures that transect the area. These include the curious box-shaped uplift of rocks hosting the Ketz River deposit; the nature of the Cassiar-Yukon-Tanana boundary; and the lithological repetitions that may be caused by structural imbrication rather than stratigraphic repetition.

Teslin area (105C)

Recent field observations in the Teslin area suggest that a number of units shown on current maps need revision. For example, volcano-sedimentary rocks of Mississippian age are likely more extensive than currently shown, and several metamorphosed plutons are missing from the existing map. Field visits have also revealed felsic metavolcanic rocks of Permian age that were previously not documented in the area. The proposed map area includes the Late Cretaceous Red Mountain molybdenum porphyry; new mapping would present an opportunity to study this occurrence.

The YGS has been in contact with the Geological Survey of Canada (GSC) regarding new fieldwork to upgrade the geology map of this region. The GSC has archived field data and samples that will be useful for identifying units and prioritizing sampling.

Kusawa-Primrose lakes area (SW 105D, 105E 115A)

Mapping in this area would extend the recent work of Israel and Bordet (2014) and Bordet and Israel (2014) southward to the border of British Columbia. The area straddles the contact between the Yukon-Tanana and Stikinia terranes. Clues to the relationship between these terranes may be preserved within large roof pendants in Paleocene granites that intrude the contact.

Western Wrangellia (115F)

Another gap in the area covered by Israel's recent mapping (Israel et al., 2007a,b) is a small area of Wrangellia terrane in westernmost Yukon. The area, which could be mapped in one field season, lies north of the Klauene Park border and south of Beaver Creek.

Yukon-Alaska border region in North Yukon between Yukon River and Arctic Ocean (116F–P, 117A–D)

The border area with Alaska in North Yukon is one of the most poorly documented regions in the territory. In particular, stratigraphic questions remain between Old Crow and Kandik basins, and the relationship between north/south-oriented structures of the North Yukon fold belt and east/west-oriented structures in the Ogilvie Mountains needs to be resolved.

Several bedrock maps are pending release by the GSC, and their release will assist in refining questions and prioritizing future work. Given the remoteness of North Yukon and the high cost of working there, workshop attendees agreed that the YGS should wait for an opportunity to leverage resources from one or more partners before initiating work in this region.

Ideas for new energy geoscience***Regional shale chemostratigraphy***

The moratorium on petroleum exploration in Whitehorse trough and public concerns over hydraulic fracturing have rendered a number of Yukon's sedimentary basins 'closed' for exploration. At present, opportunities for oil and gas development in Yukon are limited to the Eagle Plain and Kandik basins.

Basin studies by the YGS have recently focused on Paleozoic shale chemostratigraphy across the Eagle, Peel, and most recently, Selwyn basins. While Selwyn basin is not a petroleum exploration target, regional stratigraphic correlations aid in basin reconstructions and have implications for Ni-Zn-Mo-PGE exploration in the region (e.g., Fraser et al., 2018; Gadd et al., *in press*).

Workshop attendees proposed extending the shale studies to include Middle Triassic and Cretaceous shales, as these are important source rocks in Alaska, northeastern British Columbia and Alberta, and therefore potentially in Yukon.

Geothermal studies

With respect to geothermal energy, Yukon has seen very little exploration for geothermal resources to date. A paucity of data, the lack of legislation to regulate

activity, and high up-front costs of development are all impediments to investment. The YGS began a geothermal research program in 2016, of which the most recent activities are described above. The new program is beginning to provide insights into the most geothermally prospective areas of the territory.

Workshop attendees were told that capacity and resources for geothermal research are growing among Canadian universities, and that this research momentum will enable Yukon to leverage resources and expertise. Given these opportunities, participants supported further geothermal studies and provided a number of ideas for new research.

Among the activities proposed was the continued collection of subsurface temperature gradient data. This could involve opportunistically measuring down-hole temperature profiles from existing mineral exploration drill holes, and the drilling of one or more temperature gradient wells. The latter would enable temperature gradient data to be collected in areas of high potential, whereas the former would provide more regional information on Yukon's thermal regime. Workshop participants suggested that a long-term goal of the geothermal program would be temperature gradient and heat flow maps for Yukon.

Workshop attendees also supported updating the radiogenic heat generative potential map (completed in November: Colpron, 2019), and they encouraged modelling of gravity data to estimate pluton volumes.

The GSC has been collecting water chemistry data from hot and warm springs across Canada, including some in Yukon (Grasby et al., 2000, 2012). Attendees suggested that a publicly available thermal springs geochemistry database would allow external researchers to access and model the data. Collection of permeability and porosity data from potential geothermal reservoir rocks was also discussed. The YGS does not have capacity for this type of work; however, research partnerships could be explored to generate this type of data. A map showing the distribution of carbonate rock and porous sandstone was proposed as a complement to the radiogenic heat map.

Targeted bedrock studies

In addition to regional mapping and energy research, a number of topical studies were discussed at the workshop. Many are based on questions that emerged during mapping and could be resolved through targeted age dating or petrology. Examples of such questions include the following:

- Do the southwest-verging folds that deform rocks of the Cassiar platform in the Coal River area overprint the Cassiar/Yukon-Tanana boundary?
- What was the paleogeography of the Hyland and Ingenika groups in the Quiet Lake area?
- What is the age(s) of deformation across the Selwyn fold belt?
- What is the origin of ca. 215 Ma felsic volcanic rocks in the Donjek/White rivers area?
- What was the rate of exhumation of Whitehorse trough?
- What is the relationship between seismically active transcurrent faults in the Richardson Mountains and Blow trough, and structures in the Ogilvie Mountains?

Some of these questions would make good graduate student thesis projects.

Geophysical surveys and remote sensing

Regional and targeted geophysical surveys add considerable value to mapping projects; for example, by enabling bedrock units to be traced through regions of poor outcrop exposure or quantifying offset across faults. Although the YGS does not have the capacity to run geophysical surveys or process and interpret data, the GSC does. Under the recent Geo-mapping for Energy and Minerals (GEM) program, the GSC collected new regional aeromagnetic data at 400 m-line spacing across much of southern Yukon. Workshop participants strongly supported these surveys and expressed interest in seeing the GSC continue this type of work.

A number of areas were identified that would benefit from more detailed regional aeromagnetic coverage, including northern Selwyn basin and the southern Ogilvie Mountains. Both areas currently are covered by regional surveys with line spacing between 800 m and 1 km; it was recommended that these areas be

resurveyed at 400 m-line spacing. Areas of highest priority are the Dawson fault corridor, Nadaleen River (106C), Nash and Larsen creeks (106D, 116A), Mayo–Lansing Range (105M, N), and the northeastern part of McQuesten (115P). In response, the GSC has tendered an aeromagnetic survey in the Nash Creek area, to be flown in winter/spring 2020 as one of the final GEM activities, as the program will wind down in March 2020.

Remotely-sensed data were discussed at length in several of the workshop breakout sessions. Data and associated imagery that would benefit bedrock projects and support mineral exploration are presented here. Data that were recommended for use in surficial geology applications (including placer mining) are presented in the section on the Surficial Geology breakout session.

Workshop attendees recommended that the YGS acquire LiDAR data to support mapping (e.g., to delineate structures with subtle topographic expressions, particularly in areas with poor exposure). Other high-resolution imagery, such as World View satellite data, was also recommended. Hyperspectral imagery was proposed for use in mapping alteration related to mineralization. No specific areas for imagery were recommended, but as field-based projects are planned the YGS could review available imagery and look for opportunities to acquire additional images based on the requirements of the project.

Databases

Workshop participants proposed that the YGS create detrital zircon geochronology and whole-rock geochemistry databases to complement the existing bedrock geology and geochronology databases. With respect to the detrital geochronology database, it was suggested that data should be limited to those samples with a large number of analyses ($n \gg 10$, and ideally $n > 100$). Both databases are currently being worked on, and the YGS anticipates displaying the data online via the same viewer as the digital bedrock geology map by spring 2020.

Current activities of minerals services staff

YGS staff in the Minerals Services unit visited 39 hard rock exploration projects over the summer and early fall, documenting information on new discoveries and providing geologic advice to clients. Highlights of 2019 exploration and development activities are presented in this volume (Lewis and Casselman, 2020). In June, Scott Casselman and Warwick Bullen participated in the Yukon Mining Alliance's annual Investor and Media tour, providing insights into Yukon's geology and mineral resources to participants. In August, Lara Lewis, Patrick Sack and Jeff Bond organized a workshop and field trip ("Keno Rocks") to showcase the geology and mineral resources of the historic Keno district. The first day highlighted Alexco Resource Corporation's silver resources in the area (Fig. 6). Special thanks are extended to Al McConie and Peter Read for leading the Keno tour and presenting on the geology. The second day of the trip, led by Bond, featured tours of three placer operations in the Mayo area: Thunder Gulch, Duncan Creek and Minto Creek.

Warwick Bullen completed mineral potential assessments for the Beaver River and Dawson regional

land use planning areas. The results and methodology are presented in this volume (Bullen, 2020). The maps differ from previous regional mineral potential maps (Bradshaw and vanRanden, 2003) in that they are data-driven and use a block modelling approach to quantify categorical features. Polygons have been assigned both mineral potential rankings and confidence values. The maps are simple to understand for land use planners and highlight areas where further research is needed to ensure decisions are informed by strong evidence. Confidence values were derived from a database of metalotect values that link lithostratigraphic units from the YGS bedrock geology geodatabase to mineral deposit type potential. Jérôme de Pasquale presented a poster on the ranking system at the Yukon Geoscience Forum. He plans to release a paper describing the metalotect database in spring of 2020.

Patrick Sack and Maurice Colpron finished compiling a comprehensive atlas of late Triassic to Jurassic plutons in 2019. The atlas includes detailed field and petrographic descriptions, geochronology, geobarometry, geophysical characteristics, geochemistry and metallogeny of the nine suites that were studied. The volume is currently under review and will be released in spring 2020.



Figure 6. Keno Rocks participants gather near the Husky headframe at Keno.

Sack wrapped up a study of gold-bearing veins at the Plateau South property in central Yukon (Yukon MINFILE 105N 034, 035, 036). Results of U-Pb and $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology, Pb isotopes and mineralogy are presented in this volume (Sack et al., 2020) and provide insights into the possible age and origin of mineralizing fluids. Additionally, he assisted Well-Shen Lee (Laurentian University) with fieldwork and provided technical guidance for his study of the Klaza gold-silver-lead-zinc deposit in central Yukon. A summary of project results to date is presented in this volume (Lee et al., 2020).

The Yukon Mineral Exploration Program invested \$1.4M in 33 hard rock and 18 placer projects in 2019. Spending commitments by recipients totaled more than \$4.82M, corresponding to a leveraging ratio of more than 3.4:1. Highlights of this year's projects are presented in Torgerson (2020).

Minerals staff invested significant time working on the MINFILE database in 2019. A number of changes were made to the database, including updated definitions of occurrence status (i.e., anomaly, showing, prospect, deposit) and changes to table structure (e.g., a hierarchical structure has been created for deposit types). Ongoing work will include changes to the resource/reserve tables and modifications to workflow so that occurrence data are captured in conjunction with updates to the Assessment Report Footprints database. Nicole Eriks and Alex Sadurski presented a poster on MINFILE updates at the Yukon Geoscience Forum, inviting clients to provide feedback on the changes.

Significant progress was also made on the MINFILE data entry front. Lara Lewis and Nicole Eriks created a database manual that enables multiple users to enter data, and four staff (Lewis, Eriks, Sadurski and Scott Casselman) invested time in capturing new, and updating existing occurrence data. Since January 2019, 117 new occurrences have been added and 240 occurrences have been updated. This work has been facilitated by industry clients who provided location data and occurrence descriptions to staff. This 'wiki' approach, discussed at the April workshop (see below), appears to be an effective way to accelerate data capture.

The YGS' Technical Services staff have been making a number of changes to YGS web applications and services, most of which impact the data used by mineral industry clients. The changes are required to meet Yukon government's new look and feel, and staff have made efforts to ensure that the changes do not create any loss of functionality of the web applications that serve YGS data.

A new project to enhance the value of digital geophysical data submitted for assessment credit was initiated in 2019. Aurora Geosciences was contracted to examine airborne magnetic surveys and generate standardized files that are levelled with the GSC regional airborne surveys. The intent of the project is to make these industry surveys accessible to clients who lack the software and capacity to process the data themselves and generate maps. Products will include data files and geotiffs; the latter as both stand-alone magnetic maps, and integrated into 1:250 000-scale magnetic tiles generated from GSC data (Aurora Geosciences and Bruce, 2017). In early 2020, the YGS expects to start releasing these products; they will be linked to the original assessment reports (Fig. 7).

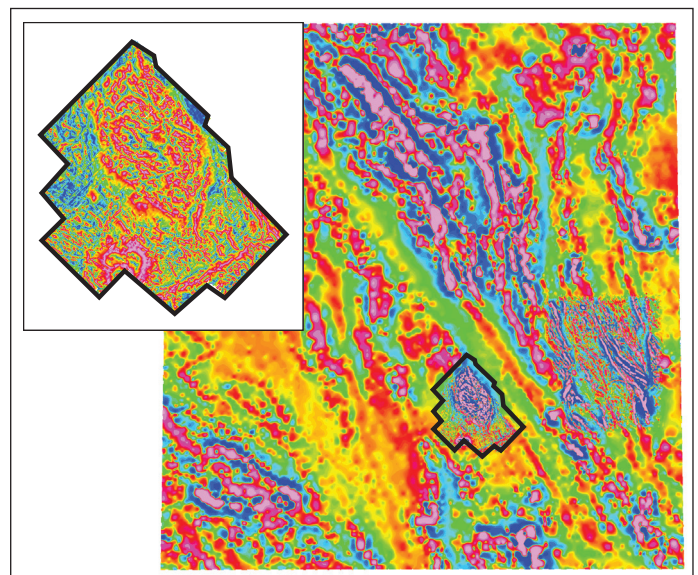


Figure 7. Image of reduced-to-pole magnetic field shaded colour contour map for NTS 105E (Lake Laberge) generated from NRCan's regional data set (Aurora Geosciences and Bruce, 2017), with industry airborne survey from the Mars gold porphyry (Assessment Report 093871) levelled and integrated with the regional map.

Regarding the drill core program, new core from a number of the Mount Nansen deposits were added to the collection in 2019. Data from the new core have been entered into the drill core database and can now be accessed for viewing/logging by clients.

Minerals workshop breakout session highlights

The Minerals Geology breakout session covered a wide range of topics including client services, minerals research and databases. Input provided by participants is summarized below.

Mineral industry liaison

Mineral industry liaison activities collectively refer to information exchanges between YGS staff and clients that occur via property visits, meetings and correspondence. Liaison includes workshops, field trips and short courses developed to enhance knowledge of Yukon geology and mineral deposits. The information gathered by the YGS through its liaison with industry is extremely valuable as it enables the survey to provide senior levels of government with up-to-date information on industry investment and new mineral discoveries. It also informs mineral potential assessment work and helps the YGS define research priorities by identifying industry information needs.

Workshop attendees encouraged the YGS to increase the number of exploration property visits carried out by staff. Based on this input, the YGS reviewed the number of property visits over the past several years and evaluated the benefits to both the YGS and industry clients. Based on this assessment, a targeted approach to property visits has been developed. For companies new to the territory, the YGS will make every effort to visit them in the field to provide some regional geologic context to their properties and share information about YGS' information resources. When survey staff are working in the vicinity of an exploration project (e.g., carrying out bedrock mapping or assessing mineral potential), staff will visit properties to inform the companies of their work and familiarize themselves with property-scale geology. As staff update data in the MINFILE database (see below), property visits will

be carried out to improve occurrence location accuracy and collect representative samples for the MINFILE collection. The YGS does not have the staff resources to ensure that all exploration projects are visited every year, but staff will make efforts to visit a project as new results are generated or when a company requests a visit. The number of property visits completed in 2019 nearly doubled from 2018.

Workshop participants strongly supported YGS-sponsored short courses and the continuation of annual 'Community Rocks' forums (e.g., Keno Rocks). Field trips, which have become an integral part of these community forums, are excellent 'hands-on' learning opportunities for exploration geologists and YGS staff alike, and attendees emphasized that YGS should continue to organize them.

Online data services

The provision of up-to-date, accurate data is ranked as a high priority by industry clients. In general, users appreciate the advances in web-based information services that the YGS has made over the past five years. Clients find the tools in the Web Map Gallery useful for displaying spatial data sets and discovering reports. However, workshop attendees emphasized that they want to be able to download entire data sets rather than simply view and query them. Specifically, requests were made for a spreadsheet extract of the drill core database, and a shapefile of assessment report footprints. A few participants noted that they have difficulty navigating some of the web maps and suggested that the YGS produce a simple guide or short video to demonstrate how to use the Map Gallery tools. As noted above, corporate changes to web services across Yukon government have rendered some YGS web content obsolete. An overview on how to navigate YGS databases using the new web tools was presented at the Yukon Geoscience Forum in November.

Workshop participants spent considerable time discussing the MINFILE database. They urged the YGS to accelerate data entry to ensure that MINFILE stays current, and they raised concerns about the location accuracy of mineral occurrences. In addition to data quality and quantity, some changes to how data are captured and stored need to be considered

(e.g., narrative fields could be replaced with data fields). Some attendees suggested MINFILE should be a purely descriptive database of occurrences, and exploration history could be captured in the mineral exploration database. Others proposed adding fields that describe the controlling features of mineral occurrences.

With respect to prioritizing MINFILE data entry, clients advised the YGS to be both strategic and opportunistic in its approach. Strategically, data entry needs to focus on maximizing information that will support land use planning, as it is recognized that both the Beaver River subregional plan and the Dawson regional plan have tight timelines. To this end, it was proposed that updates could focus on known deposits, emphasizing controlling features to enable the identification of prospective areas with similar geological features. Occurrences that are poorly documented — for example, those with little descriptive data or uncertain location information — should be flagged so that users recognize the limitations of these entries, and a review of the deposit models was recommended. Some participants proposed an online form to enable clients to submit occurrence data to the YGS. Additionally, it was suggested that bedrock geologists should visit occurrences in areas where they are mapping to confirm and/or update location data and occurrence characteristics. As noted above (see “Current Activities of Minerals Services Staff”), the YGS has started making a number of these changes and will continue to work on database improvements in consultation with industry.

Minerals-related research

A number of ideas were proposed at the workshop for research on Yukon’s mineral deposits. The proposed studies can be broken into three categories: regional metallogeny, mineral potential assessments and targeted studies. Some projects are mainly desktop compilations, whereas others involve fieldwork and new data collection. In addition to the project ideas presented here, many projects discussed in the Bedrock Geology breakout session were of interest to mineral industry clients.

Regional metallogeny

Attendees at the workshop strongly urged the YGS to undertake regional metallogeny studies. They noted that such studies are valuable both for identifying new exploration targets and for enabling companies to attract investors. Age and regional structural controls are two key elements required for metallogenic syntheses: this creates opportunities for collaboration with the Bedrock Geology unit and university-based researchers.

One project that was proposed involves the synthesis of Late Cretaceous magmatism and metallogeny across Yukon. The study would focus on the Dawson Range and be similar in scope to the recently completed Jurassic metallogeny study. Late Cretaceous plutons are currently being explored in Alaska, and the study has potential for cross-border collaborations with US Geological Survey (USGS) colleagues. It could also involve one or more university collaborators.

Mineral potential assessments

Doug Kreiner from the USGS gave a presentation at the workshop on the methodology used in Alaska for generating mineral prospectivity maps. The geodatabase integrates rock and sediment geochemistry, bedrock geology, and mineral occurrences (among other components) to generate a matrix that reflects both mineral potential and certainty. Certainty is quantified based on the number of data sets used to generate the mineral potential value.

Attendees at the workshop discussed the need for the YGS to generate mineral potential maps to support land use planning and highlight areas for future exploration. YGS’ new Mineral Assessment Geologist (Warwick Bullen) was hired shortly after the workshop. As noted above, his first priorities were to complete mineral potential maps for the Beaver River and Dawson regional land use planning areas.

Targeted mineral studies

A number of ideas for targeted mineral studies were discussed at the workshop, including thematic studies and deposit-specific questions. These are described briefly below.

Workshop participants proposed using existing or new geophysical surveys to generate a map showing buried intrusions. Such a map would be useful for identifying areas adjacent to plutons that may have been affected by intrusion-associated alteration. Additionally, geobarometry on exposed plutons would help to characterize their emplacement depths and associated mineralizing systems. Another thematic study proposed was a compilation of critical metals. Yukon currently has defined resources of tungsten, cobalt and PGEs, as well as historic (pre-NI 43-101) resources of tin, molybdenum, barite and antimony, but there is no easily accessible literature describing the host geology or features of these occurrences. Given the growing interest in these metals for clean energy and high tech applications, such information could help to attract new investment to the territory. Lara Lewis has begun compiling information on critical metals. The publication envisioned will be an overview booklet that presents commodity descriptions, uses, supply/demand outlook, and information on Yukon occurrences and their geologic settings.

Workshop attendees were told about a BC placer gold atlas being compiled by Robert Chapman (Leeds University). This thematic project, funded by Geoscience BC, will capture both physical parameters of placer gold (grain size, shape, character) and chemical properties. Such an atlas could be expanded to capture the abundant data available from Yukon's placer operations, and would be a useful hard rock exploration tool as certain placer gold deposits have very distinctive geochemical signatures.

Several area-specific project ideas were raised at the workshop as well. Questions that could be addressed include the following:

- Is the gold at Keno orogenic, or are the veins part of a reduced intrusion-related gold system (RIRGS)?
- What is the age and origin of gold along the Hyland thrust south of Mayo Lake?
- What is the age and origin of gold at 3 Aces? At Sprogge?

These questions could be resolved with some detailed mapping, petrology and targeted geochronology, either by YGS staff or through graduate student thesis projects.

Yukon Mineral Exploration Program (YMEP)

Workshop attendees expressed strong support for YMEP, noting a number of successful projects it has supported, and commenting positively on Yukon government's commitment to the program. A few participants expressed concerns regarding the reduction in the amount of funding available for the 2019-20 fiscal year (\$1.4M versus \$1.6M the previous two years), although it was acknowledged that the reallocation of funds was necessary to support resource assessments.

As part of the YMEP discussion, it was noted that the number of applications submitted under the Grassroots module of the program has been declining over the last several years. Attendees offered opinions on the reason for this: some noted that the requirement for 30 days of work was excessive; others felt the application and reporting requirements were excessive given the size of the grants.

Based on this input, the YGS committed to take a critical look at the module and consider ways to modify it to increase its appeal. The YGS supports eliminating the requirement for a minimum number of work days, and is looking at how to reduce the rigour of reporting requirements. A list of proposed changes was presented at the Yukon Geoscience Forum in November and engagement is currently underway to finalize the proposed changes in time for the 2020 field season. Details of the proposed changes are summarized in this volume (Torgerson, 2020).

Core library services

Use of the core library and its facilities has been increasing steadily over the last few years. Users include clients who access the YGS core collection for logging (\pm sampling), and clients who use the facilities

to log their own core. Workshop attendees advised the YGS to continue growing the drill core collection to capture a suite of representative samples from all major occurrences in the territory. They noted that a downloadable extract of the database would be useful, particularly when working offline in the field.

The YGS updated workshop attendees on the recently acquired physical rock property equipment and the status of rock property data collection. The YGS has set up a space for measuring magnetic susceptibility and specific gravity from hand samples, and in 2018 began to systematically collect data from the YGS' archived sample collections. The survey also has a core sample IP tester and a gamma ray spectrometer; all equipment are available for client use.

While rock property data collection has started, the data have not yet been imported into a spatial database or released publicly. The survey will continue to collect these measurements from hand samples as/when time allows, and when a significant volume of data have been collected the development of a database and associated web application will become a priority. In the meantime, clients can access the data upon request.

Current surficial geology activities

Kristen Kennedy continued surficial mapping in the Klauane Ranges in 2019, moving northwestward from her 2017–18 mapping of the Burwash Uplands (Fig. 2). She is focusing her current research on delineating glacial limits, including targeted sampling for cosmogenic dating to constrain the timing of ice retreat. A final release of the Burwash Uplands surficial geology map and accompanying report is planned for release in spring 2020.

In addition to this ongoing work, Kennedy has compiled a preliminary Quaternary geology layer for Yukon to put the “Q” back on the bedrock geology map. The layer is a derivative product of the Digital Surficial Database, and was produced as a thematic query of regional surficial geology maps. The queried data could be used for planning stream and soil sampling programs or as a filter for evaluating the reliability of existing surficial geochemical data, as distally-derived material can not

be relied on to reflect bedrock signatures. This new digital layer was presented at the Yukon Geoscience Forum in November to gauge industry interest, and determine whether the layer should be edited and released as a shapefile.

Kennedy is also serving on a committee for a graduate student at Simon Fraser University (Nora Whelan) who is studying co-seismic landslides along the Denali and Duke River faults.

Panya Lipovsky led two projects in 2019. The first was the continuation of a multi-year study of surficial geology in the greater Whitehorse area (Fig. 2). The project, which targets the most densely populated region of Yukon, has a number of components including detailed mapping of surficial materials and landforms, characterization of permafrost, aggregate potential, radon gas in soil, and hazards classification. The permafrost component of the project is being undertaken in collaboration with the Yukon Research Centre at Yukon College, who will publish summary reports for key case study sites in spring 2020. A highlight of the project from a public interest perspective was a major thaw slump documented by Lipovsky and her colleagues on the south side of Takhini River in September. The slump deposited debris halfway across the river (Fig. 8). It is being monitored closely as the headscarp is within 50 m of the Alaska Highway and is advancing upslope at a rate of roughly 10 m/year.

The second project Lipovsky is leading focuses on the development of a Yukon-wide permafrost database. The database captures both geotechnical borehole information (including data on surficial materials and ice content) and temperature data collected over time from data loggers. Two temporary employees have been working on data capture and cleaning: Emilie Stewart Jones has been lead on the temperature data, and Kisa Elmer has been lead on the borehole data compilation. The drivers for this project are twofold: (1) Yukon government has initiated a new initiative called “Our Clean Future”, which identifies adaptation as a fundamental pillar and necessitates the systematic capture and centralized storage of permafrost data; and (2) a university-based research network was



Figure 8. Drone photograph of a thaw slump along the Takhini River west of Whitehorse. View looking southward.

recently funded to undertake permafrost research across Canada. The network, called PermafrostNet, is being spearheaded out of Carleton University and has funding for five years (2019–2024). The Yukon permafrost database will provide PermafrostNet researchers with crucial baseline data to support the development of new tools for mapping permafrost and predicting thaw impacts.

In addition to compiling permafrost data, the YGS is involved in a number of permafrost studies. For example, Lipovsky retains several community-based permafrost monitoring stations and she has acquired additional thermistors to enhance data collection. Kennedy has been collaborating with colleagues from Yukon College and Yukon government’s Department of Highways and Public Works on thaw-related issues on the Dempster Highway, and with the GSC on sites along the North Klondike Highway. Demand for Kennedy’s and Lipovsky’s involvement in targeted permafrost studies is likely to increase over the next few years as PermafrostNet activities ramp up.

Surficial geology workshop breakout session

Participants at the surficial geology breakout session discussed the YGS’ approach to surficial geology activities. There are pressures on the survey to upgrade regional surficial geology maps, improve the resolution of glacial limits, undertake geochemical studies to support till prospecting, document permafrost, and identify geologic hazards in and around communities and along transportation corridors. The range of activities eclipses the Surficial Geology unit’s capacity, requiring the YGS to prioritize activities. Defining criteria for setting priorities was not within the scope of the workshop, so attendees focused on the gaps in Yukon’s surficial geology data and provided ideas for research across a number of surficial geology sub-disciplines.

Community mapping and geohazard studies

The YGS has published surficial geology maps for the communities of Old Crow, Dawson City, Mayo, Pelly Crossing, Faro, Ross River, Burwash Landing and Destruction Bay. The maps range in scale from 1:10 000 to 1:25 000 and include both surficial materials and derivative maps illustrating geologic hazards (e.g., landslides, permafrost, floods). The maps have been well received by communities and the YGS was advised to continue community-based mapping. Priorities for future community mapping include Carcross, Teslin, Carmacks, Watson Lake, Haines Junction, and the Haines Junction-Whitehorse corridor (the latter study is currently underway). Hazards vary by community, but include landslides (both tectonic and climate-change triggers), flooding, ground slumping (due to permafrost thaw), and radon gas emissions.

Although documenting permafrost has been a component of all community mapping projects to date, Yukon government's "Our Clean Future" initiative has raised the profile of the impact that thawing permafrost is having across the territory. Permafrost monitoring and the population of the Yukon permafrost database are anticipated to be priorities in the coming years. Attendees noted gaps in understanding groundwater-permafrost interactions, challenges in predicting impacts of ground thawing, and the lack of an accurate ground-ice map for Yukon. Areas of particular interest for study include Chapman Lake (along the Dempster Highway), the Moosehide slide in Dawson, and the Takhini River valley where the agriculture industry is growing. These all represent opportunities to collaborate with PermafrostNet researchers to support thesis projects. Attendees also suggested that the YGS could approach exploration companies and install thermistors in abandoned boreholes to expand its network of shallow ground temperature monitoring stations.

In terms of base data to support community mapping, high quality imagery is a critical requirement for interpreting landforms and identifying features associated with ground movement. LiDAR imagery is the standard for mapping (particularly for flood hazard mapping), and drone-based imagery is valuable as it

can target specific features over time (e.g., thaw-related slumping). The YGS' surficial geology group presently owns two drones and they are proving to be valuable mapping tools in a number of settings.

While not specifically part of the community mapping projects completed to date, aggregate resources are of interest to communities, and in some cases, identifying new sources of aggregate is a priority. The YGS does not have a systematic approach to carrying out aggregate inventories; nor does it have a formal mechanism for seeking requests for information on aggregate. The aggregate studies the YGS has completed to date have been local, on-demand, short-term projects, typically initiated by conversations with colleagues in other Yukon government branches (e.g., Lands, or Highways). These studies are generally not published; the information is provided directly to the party seeking the information. Although they may not warrant formal publication, there would be value to capturing the information in a corporate database. Workshop attendees suggested that community mapping projects could include an assessment of aggregate within the map area.

Workshop attendees also proposed that the YGS participate in studies to characterize the nature of deformation along Yukon's active faults (e.g., Denali and Duke River faults), to assist with earthquake hazard risk assessments and document areas susceptible to earthquake-induced landslides. They further recommended that the YGS continue to monitor the ice cave near Haines Junction and collaborate with Parks Canada to track glacier behaviour (e.g., surges, retreats) and contribute to public outreach on these topics.

Regional surficial mapping

Some workshop attendees felt that regional surficial mapping (1:50 000) should be a priority for the YGS, as the regional context is the foundation for applied and thematic studies such as landslide mapping, drift geochemistry, etc. Given the current coverage of 1:50 000-scale surficial maps for Yukon, this goal is a challenging one for the YGS. Coordinating with YGS bedrock mappers to leverage logistical support was proposed as a means to support and advance mapping. Other participants felt that systematic mapping of areas on a map sheet-by-map sheet basis had less

value than targeting corridors of high interest such as the Nahanni and Mac Pass road corridors. Still other attendees noted that upgrading of the glacial limits map should be a priority, as the current ice limits are locally inaccurate and chronology data are minimal. A number of gaps in glacial chronology in southwestern Yukon were pointed out, including sites along Telluride and Wolverine creeks, and White and Donjek rivers. As a means to accelerate regional surficial geology mapping, it was suggested that graduate students could undertake mapping as part of their thesis work. The YGS has done this in the past and it has proven to be a cost-effective way to expand coverage. To ensure the geologic knowledge is retained by the YGS, it requires a commitment to supervise and engage with the student.

Although they recognize it as a long term goal, workshop attendees expressed interest in seeing a regional surficial compilation map of the Canadian Cordillera. Such a project would not only require significant upgrading of existing maps, but a change in how data (including legends) are managed; for example, Yukon's legend currently differs from that of BC's. While such an overhaul would require a lot of work, it would simplify map updates and enable the generation of thematic maps. In the meantime, the YGS has compiled a digital 'patchwork' surficial map that levels map units to the BC Terrain Classification System. A map index is available on the YGS' website with links to the original maps and GIS data (<http://yukon2.maps.arcgis.com/home/webmap/viewer.html?webmap=e819fd4b0e874422b0386270985d798a>).

Thematic studies

Attendees raised a number of thematic surficial geology questions, such as:

- What are the ages of Quaternary glaciations?
- What do we know about Neogene environments in Yukon?
- How did Quaternary landscapes evolve?
- What are the primary controls of radon gas distribution in surficial materials?
- What are the key hazards associated with glaciers in Yukon?
- How effective are various geophysical tools for mapping permafrost?

The YGS has very limited capacity to take on new projects to address these and other questions, although the survey could support and/or facilitate university-based studies, or collaborate with other Yukon government departments who are lead on some of these issues. It was noted that high-quality imagery (especially LiDAR and ortho-rectified air photos) will be critical for many of the above studies, and the YGS should continue to collect imagery opportunistically as they become available.

Current placer geology activities

In 2019 Jeff Bond and Sydney van Loon visited 88 placer operations, collecting geologic data and production information. An overview of 2019 placer industry activities is presented in this volume (Bond and van Loon, 2020).

Progress continued on the compilation of historic placer data; to date, 272 maps have been digitized, including 1427 points (drill holes, shafts) and 985 polygons (dredged ground, historic workings). The data have been posted on YGS' Historic Placer Data web map. Bond and van Loon visited Library and Archives Canada in Ottawa in December to search for additional maps and reports that could be added to the database. They identified 131 maps and have set them aside to be scanned over the next few months.

While the primary rationale for property visits is to collect information on placer operations, these visits also enable the collection of geologic data that support thematic studies. At the 2019 Yukon Geoscience Forum, Bond and van Loon presented a poster on Quaternary intermediate-level terrace deposits that may host placer gold concentrated from Pliocene high-level terrace deposits. Such deposits are commonly masked under hillside colluvium and are targets for modern placer miners. The poster was first presented at the International Quaternary Association meeting in Dublin, Ireland in July.

Bond also co-supervised an MSc student thesis (Derek Cronmiller; Simon Fraser University) that examined surficial stratigraphy and placer potential in the Gladstone Creek area.

Placer workshop breakout session

The Placer breakout session focused on the needs of Yukon's placer miners, examining placer-related research and information services that would benefit this sector. The YGS' role in supporting placer mining has grown significantly in the last few years. Bond currently invests the bulk of his time in placer-related work, and van Loon is committed full-time to placer interests.

Industry liaison

Workshop attendees expressed appreciation for the annual field visits by Bond and van Loon, and encouraged them to continue this work. They also noted that field trips are beneficial for learning about how different operators address different geological and technical challenges and they encouraged the YGS to organize trips during the annual Gold Show.

Participants expressed an interest in seeing additional information captured in the Placer Industry Report, such as cut sizes and volumes, and a glossary of geological terms. They would also like to see an expanded section on reclamation in the report, and information on different methods of defining a resource. The volume already includes information on stratigraphy, gold grade and characteristics, equipment and water treatment; the YGS committed to looking at adding this extra information, noting that some of it (e.g., the request for cut sizes and volumes) would be easy to accommodate.

The group also discussed the merits of developing a digital database that captures the information in the Placer Industry Report, supplemented with additional photographs (e.g., of gold grains) and stratigraphic sections.

Since it was initiated in 2009 the annual Placer Forum has grown in scope and has seen a steady increase in attendance. The forum features presentations on annual production, as well as new placer research, and provides a venue for placer miners, geologists, and regulators to exchange information on topics ranging from mining techniques to heritage assessments to regulatory changes. Workshop attendees agreed that the Forum should continue to be held on an annual basis and made a number of suggestions for future

agenda items, including presentations on production costs and geophysical exploration techniques. Some attendees proposed moving the Forum to late October, as many operators have wrapped up for the season by then. The YGS committed to considering an earlier date.

Reclamation and wetland studies

Preservation of wetlands and mine site reclamation are becoming issues of increasing concern to the placer sector. While the YGS does not have a regulatory role, its frequent site visits and regular interactions with operators provide survey staff with first-hand knowledge of the nature of the ground being mined and the status of reclamation. Workshop delegates noted that the YGS could play a role in supporting a reclamation 'best practices' guide in collaboration with the Client Monitoring & Inspections Branch.

The YGS recognizes that helping industry showcase good reclamation practices would benefit the sector and address some of the public's concerns regarding the impacts of placer mining on wetlands. However, given other demands on staff time, the YGS will need to focus on supporting studies on reclamation best practices, while continuing to liaise with regulators who apply these studies. The YGS will keep working with the department of Environment to generate wetland distribution maps for the territory, and provide input and advice on wetland mapping.

Communication/Outreach

Workshop participants noted that the public's understanding of modern placer mining is fraught with misperceptions. They would like to see the YGS undertake more public outreach, targeting youth to better inform them on the placer industry. They also felt that mining recorder staff would benefit from a "Placer 101" course similar to the "Mining 101" that is offered regularly to staff. In response to this input, Bond organized a September field trip for students at the Robert Service School in Dawson City. Students visited three placer operations in the area and had an opportunity to learn about the region's Quaternary geology (Fig. 9). This, and other outreach activities, are described in more detail in this volume (see Weston, 2020).

Placer geology research

Several ideas for placer research were proposed at the workshop. Among the input were suggestions to acquire more LiDAR data and drone images along creeks, and use these data to generate detailed creek maps. Such maps could aid in identifying subtle topographic features such as benches, and would be useful for remediation planning.

Attendees also encouraged YGS to consider producing a synthesis publication of geophysical surveys of creeks. Many operators use geophysics — in particular, resistivity — to image subsurface geology. The surveys can reveal permafrost and groundwater-rich lenses as well as depth to bedrock, but interpreting the data can be challenging for miners. The study could include a compilation of case studies comparing survey results in different geologic settings, to assist miners in optimizing surveys. The YGS does not have internal capacity for such an undertaking but could coordinate the sharing of industry surveys and liaise with a contractor or graduate student to undertake the work.

Attendees also proposed a number of site-specific project ideas. These are detailed below.

Stratigraphic study of the Wolfhead claims near Clear Creek

Wolfhead Discovery and Mining recently drilled several 300-foot deep holes on their claims on the edge of Tintina Trench, intersecting a gravel of possible Pliocene age. The surficial geology in this area is poorly known. A detailed stratigraphic study would confirm the age of the gravel, enable an assessment of its placer potential, and allow regional stratigraphic correlation to other gold-bearing gravels in Yukon.

Hydraulic conditions of Stewart River bars

Significant amounts of fine gold have been recovered from bars on the Stewart River. Very little is understood about the hydraulic conditions that concentrated the gold, or whether the environment is unique to the Stewart River. A better understanding of the depositional environment of these gravel bars might help to identify analogous settings on bars in other large rivers.

Potential for buried placer targets in the Ruby Range

Mining along the Fourth of July and Twelfth of July creeks in the Ruby Range has yielded gold in the past, but in recent years, work has ceased. Potential for deeper targets exists along benches and at depth under the main creek channels, although current surficial maps do not provide sufficient detail to identify the most prospective areas. New mapping could open up new targets and re-invigorate interest in the area.

Targeted mapping on Matson and Ladue creeks

Workshop participants also recommended some new mapping along Matson and Ladue creeks. This area is currently inactive, but potential exists to identify prospective targets and stimulate new interest.

Targeted mapping in the Big Creek–Hobo Creek area

Recent placer activity in the Big Creek–Hobo Creek area has highlighted the inadequacy of the existing 1:250 000-scale surficial geology map. Alpine glaciation in this area has likely complicated gold distribution, although details of the glacial and interglacial environments are not well documented. New mining activity will create exposures and enable an improved understanding of the surficial history of the area.

Summary

The YGS appreciates the time and effort invested by clients and stakeholders who participated in the planning workshop. The advice and feedback that was recorded will be valuable for work planning over the next five years and beyond. As noted in this overview, several of the project ideas discussed at the workshop have already been initiated by the YGS, and the survey will continue to engage with clients and stakeholders as current projects wrap up and new ones are started.

It is difficult to summarize all of the work being undertaken by the YGS in a single paper. Readers are encouraged to peruse the technical papers in this

year's Yukon Exploration and Geology volume to learn more about individual projects. On a similar vein, it is impossible to capture all of the discussion that led to the project ideas presented above. The workshop did not include a separate breakout session on information services; instead, data management and web services were discussed in each of the themed sessions. As a result, it is likely that some comments (e.g., feedback on YGS' Facebook site) were not shared and captured. While the next planning workshop will not be until 2024, the YGS welcomes discussion on ways to improve its services at any time.

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Yukon placer mining 2019 development and exploration overview

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Yukon Geological Survey

Bond, J. and van Loon, S., 2020. Yukon placer mining 2019 development and exploration overview. In: Yukon Exploration and Geology Overview 2019, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 23–34.

Introduction

The Yukon placer mining industry recorded strong production in 2019. This was largely due to favourable gold prices, coupled with a beneficial exchange rate, which resulted in high selling prices during most of the summer. The industry also benefited from an early start to the season due to warm early spring temperatures. Shifts in regional production values reflect movement of certain large operations to both new and historic locations. The shift reflects permitting challenges in the Indian River, as well as the need to discover and develop new deposits based on diminishing resources within specific claim holdings.

Climate for mining

The onset of the mining season began abruptly in 2019 when temperatures soared during the later half of March. The average high during this period in Dawson City was 9.4°C, whereas during the previous 10 years it averaged 0°C. Similarly, the average low during the later half of March was -4°C, when it normally has been closer to -18°C. Most of the snow disappeared during this warm spell and allowed ice breakup to commence in many of the creeks. Reports of sluicing and gold sales prior to the start of May were an encouraging start for some in the industry. End of season temperatures in Dawson were slightly cooler with the average high and low equalling 0.8°C and -6.2°C respectively for the month of October. Precipitation trends varied between the southwestern and central parts of Yukon. The Kluane district experienced a wet summer overall with 135 mm falling during the month of July. In contrast, central Yukon was considerably drier with only 17 mm falling in the Dawson City area and 9.4 mm falling in the Mayo area during the month of August. This created some challenges for mines operating in smaller, first-order drainages.

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Gold production and value summary

Placer gold production, according to export tax reporting at the time of publication, was 75,228 crude ounces and valued at \$116M CDN (Fig. 1). The 2019 production value was nearly \$27M CDN greater than that of 2018, largely owing to a favourable gold price that averaged more than \$1900 CDN/fine ounce throughout much of the mining season. This was nearly \$400 CDN/fine ounce more than the average 2018 gold price. When accounting for inflation, the 2019 production value is the highest value since 1988.

The 2019 season experienced regional shifts in production distribution due to major operations commencing mining at sites outside of the Indian River drainage. Indian River and its tributaries contributed 28% less placer gold in 2019 largely due to reductions on Quartz Creek and the main stem of the Indian River. A production increase occurred in the Klondike River drainage where a modern high of 16,234 crude ounces was extracted, and the glaciated districts of Clear Creek and Mayo doubled their production from 2018.

Development highlights

Indian River drainage

Despite the production drop from the Indian River drainage it still accounted for 34% of the overall production with 25,000 crude ounces of gold reported (Fig. 2). The majority of this gold was mined from the main stem of the Indian River, Dominion Creek, Quartz Creek, Eureka Creek and Sulphur Creek.

The largest placer gold producer in Yukon for 2019 was the Little Flake Mine on the Indian River (Fig. 3). One of their locations focused on mining the left limit of the Indian River where they processed 210 yd³/hr on a 24 hr/day schedule. The gold was primarily extracted from the lower 1.5 m of gravel and upper 1 m of bedrock on low terrace surfaces against the hillside. The use of conveyor feeders facilitated production.

Fine Gold Resources focused on three locations with their largest cut located on the left limit of the Indian River upstream of Eureka Creek. The cut measured 122 × 1280 m (400 × 4200 ft), and up to 1.2 m (4 ft) of gravel on bedrock was sluiced. Their other two plants

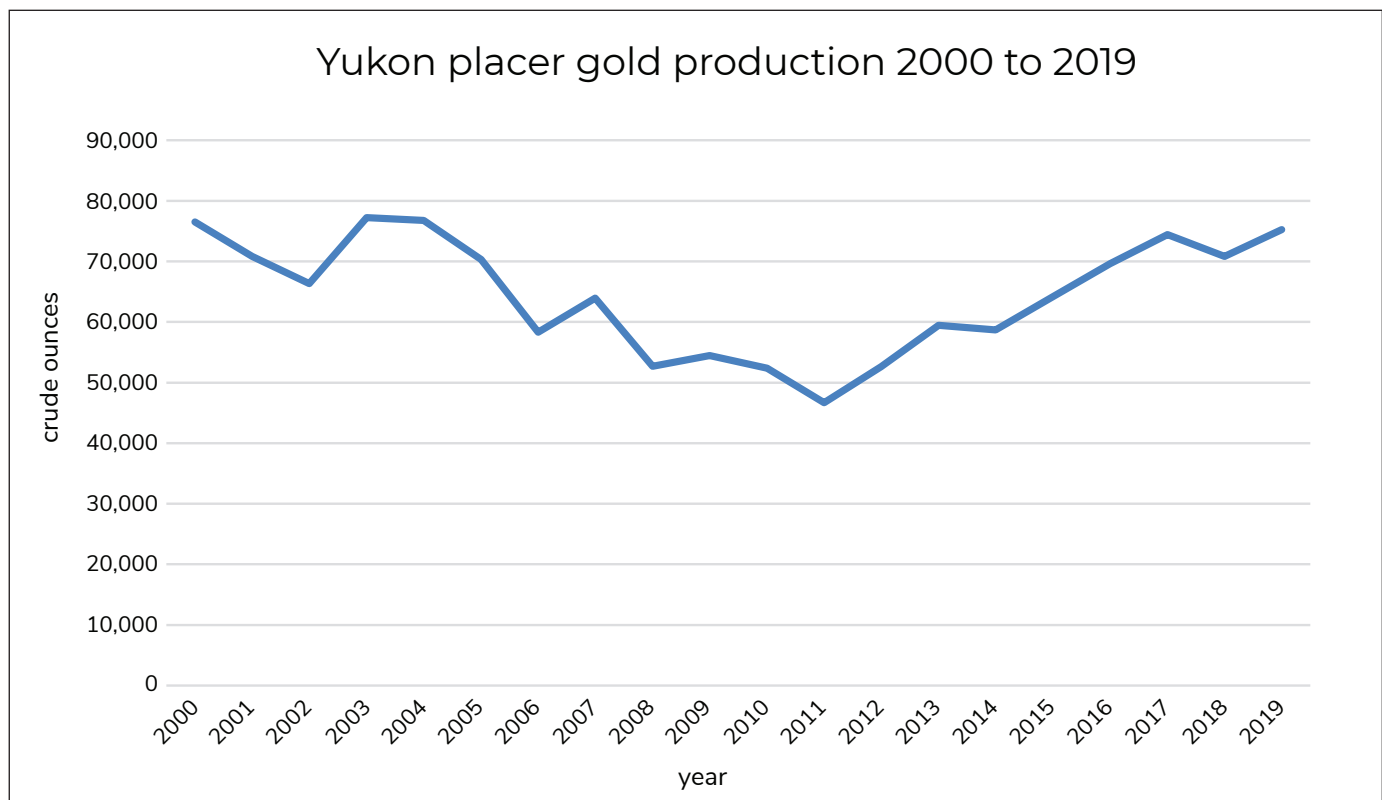


Figure 1. Yukon placer gold production according to export tax reporting since the year 2000.

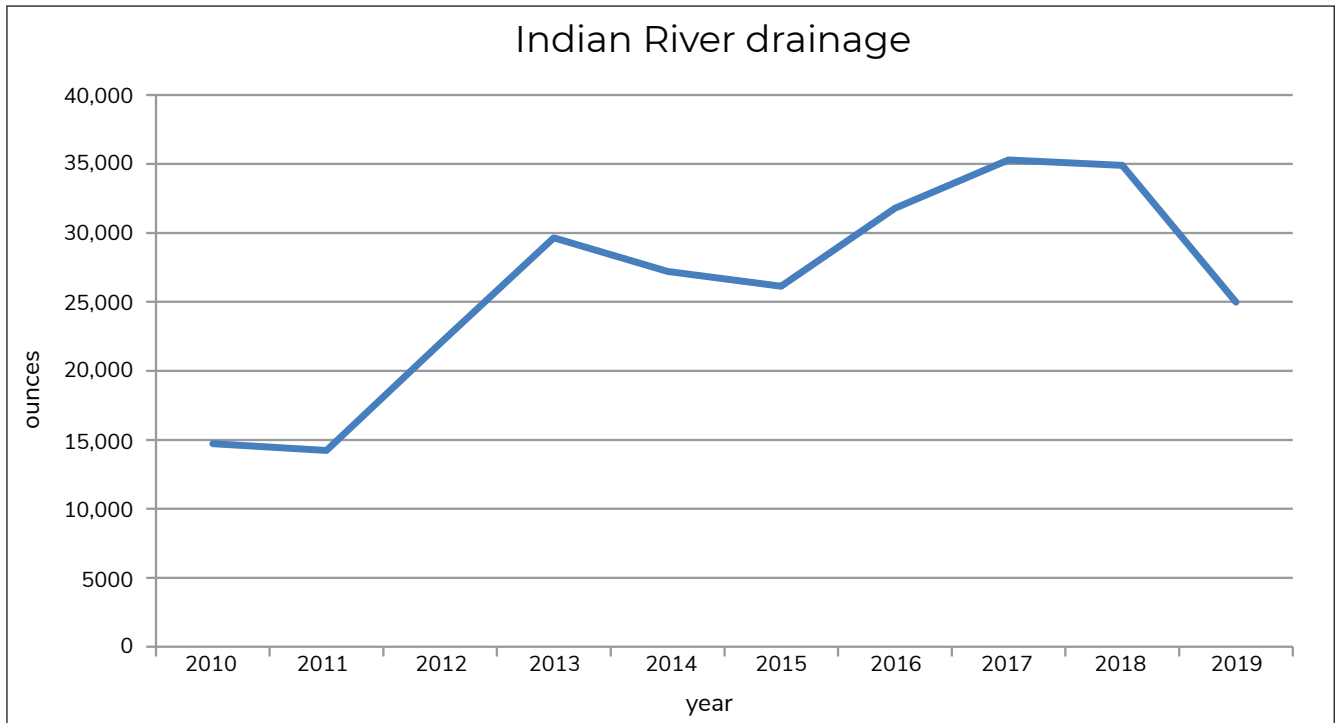


Figure 2. Placer gold production from the Indian River drainage for the last ten years.



Figure 3. An aerial view of Little Flake Mines processing plant on the left limit of the Indian River below Eureka Creek.

operated within Eureka Creek where they mined both valley bottom and bench material. This year, significant effort was dedicated towards reclamation whereby they levelled, contoured and top-coated mined areas dating back to the mid-1980s to early 2000s (Fig. 4). In total, 160 acres of previously mined ground was reclaimed in mid-Eureka Creek and near the mouth of the drainage.



Figure 4. Aerial view of the mouth of Eureka Creek where Fine Gold Resources undertook a substantial reclamation project that involved surface grading and top-coating of legacy placer mine workings.

Yukon Heliski continued mining on Sulphur Creek's right limit and while doing so entered into a unique value-added reclamation partnership with RESOLVE, a solutions-based non-profit organization from Washington, D.C. RESOLVE's Salmon Gold project facilitated a connection between Yukon Heliski, and Tiffany & Co. and Apple, which enabled these multinational companies to source responsibly-mined gold. Apple and Tiffany & Co. contributed funds to a stream channel reclamation project in an area considered mined-out on Sulphur Creek and supported a general waste clean-up initiative. The channel design included a meandering coarse aggregate base, graded, stabilized and top-coated embankments having vegetation features (Fig. 5). Within days, dozens of Arctic Grayling were observed occupying this new reach of Sulphur Creek.

Farther downstream on Sulphur Creek, Favron Enterprises opened up a 700,000 ft² cut on the right limit after moving their operation from Dago Hill. The total depth to bedrock was 10.6 m (35 ft) and the plant operated 24 hrs/day. Progressive reclamation occurred throughout the season.



Figure 5. A view of the new Sulphur Creek channel being constructed on Yukon Heliski's ground in partnership with RESOLVE, Tiffany & Co., and Apple. Photo courtesy of Pete Wright.

Klondike River drainage

Mining in the Klondike River drainage reached a modern high and 16,234 crude ounces of gold was reported, which is 5000 crude ounces more than 2018 (Fig. 6). The significant boost largely came from Hunker Creek where production increased to 8000 crude ounces for the season.

The largest producer in the Klondike River drainage was Tamarack Inc. on Paradise Hill. The left limit high-

level Pliocene terrace deposit has a long history of development dating back to the gold rush. Tamarack Inc. is mining Paradise gravel, a pre-White Channel gravel, which outcrops adjacent to the White Channel deposit. This year they discovered a zone containing very little muck overburden and were able to process the entire column of Paradise gravel (Fig. 7). The decomposed nature of the gravel requires a long wash in a trommel to break down the clay effectively.

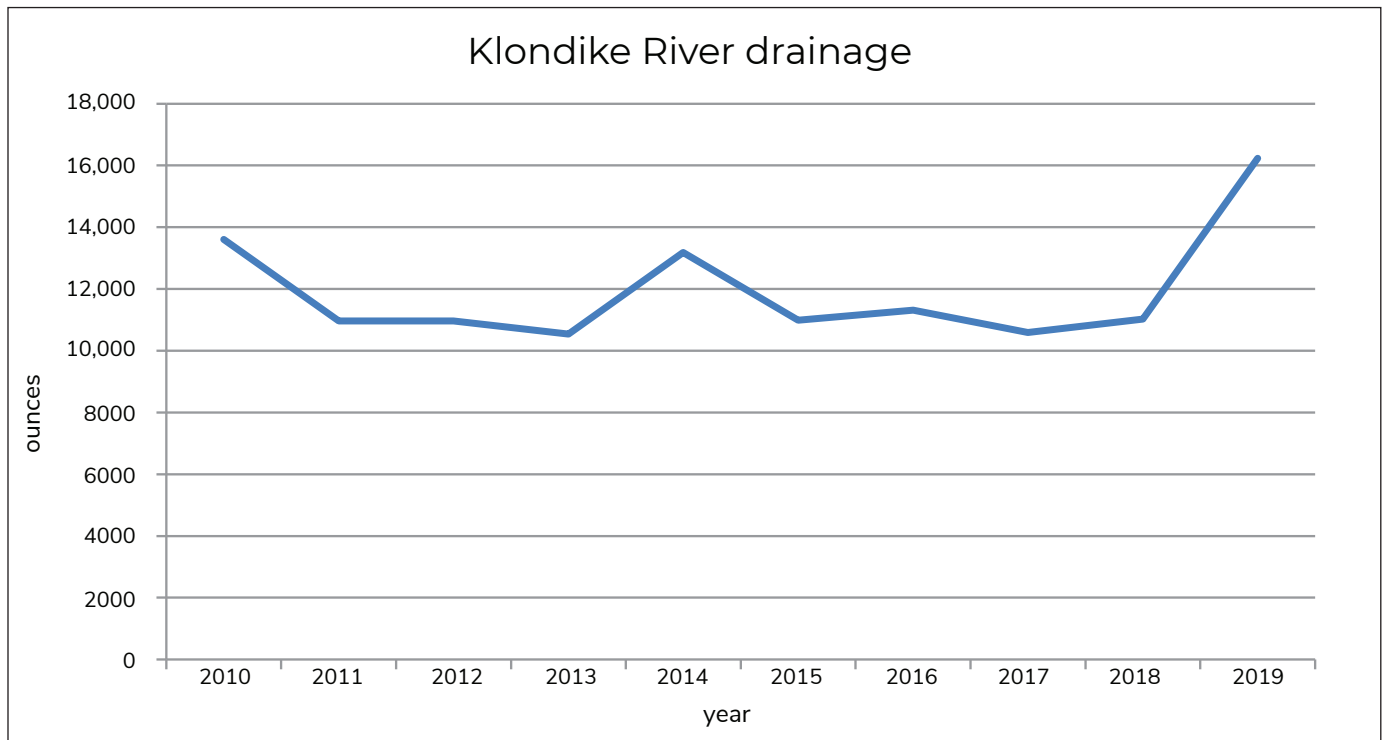


Figure 6. Placer gold production from the Klondike River drainage for the last ten years.



Figure 7. A view of the Paradise Hill cut showing a thin layer of White Channel gravel overlying the orange oxidized Paradise gravel. Virtually no muck overburden is present at this location.

Northern Shovelers continued mining White Channel gravel at Lovett Hill this year. The cut was located on the right limit side of the pay streak and consisted of 22 m (72 ft) of Klondike Wash gravel overlying 48 m (157 ft) of White Channel gravel (Fig. 8). Only the lower 7.5 m (25 ft) of White Channel gravel were processed for pay. The operation is stripping intensive and benefits from short haul distances that are relatively level, which reduces wear on the trucks. A second cut was started on the left limit side of the pay streak, which is thought to be higher grade than the right limit margin.



Figure 8. A view of the Lovett Hill cut in 2019 showing the orange bedrock surface near the excavator. Undocumented underground old-timer workings from 1917 (based on a preserved newspaper) were discovered in the vicinity of the cut.

West Yukon

Production from drainages west of the Yukon River continued to be dominated by production from the Sixty Mile River. This year, 8493 crude ounces of gold were reported, almost 2000 crude ounces more than in 2018 (Fig. 9). Production reporting from a number of Fortymile River tributaries, including Moose, Bruin and Browns creeks, occurred this year.

The largest operation is M2 Gold Mines located near the mouth of 12 Mile Creek. They primarily mined adjacent to the Sixty Mile River and completed a 700 m (2300 ft) diversion near camp. A 14-person crew were employed, operating two shifts daily. A new belt feeder that was added to the trommel increased feed rate from 140 yd³/hr to 180 yd³/hr.

No Name Resources Inc. started sluicing on Ten Mile Creek on April 26 this year, thanks to warm spring temperatures. They mined at a variety of locations and finished the season on the high-level Pliocene bench located on the left limit just upstream from camp (Fig. 10). The gravel deposit is thinnest near the rim of the bench and thickens into the face to a maximum of 13.5 m (44 ft). Their cut measured 44 m (144 ft) in width and the lower 3.5 m (11.5 ft) of boulder gravel was processed in their trommel. They identified lower grade gold concentrations above the main pay unit that average about half the value.

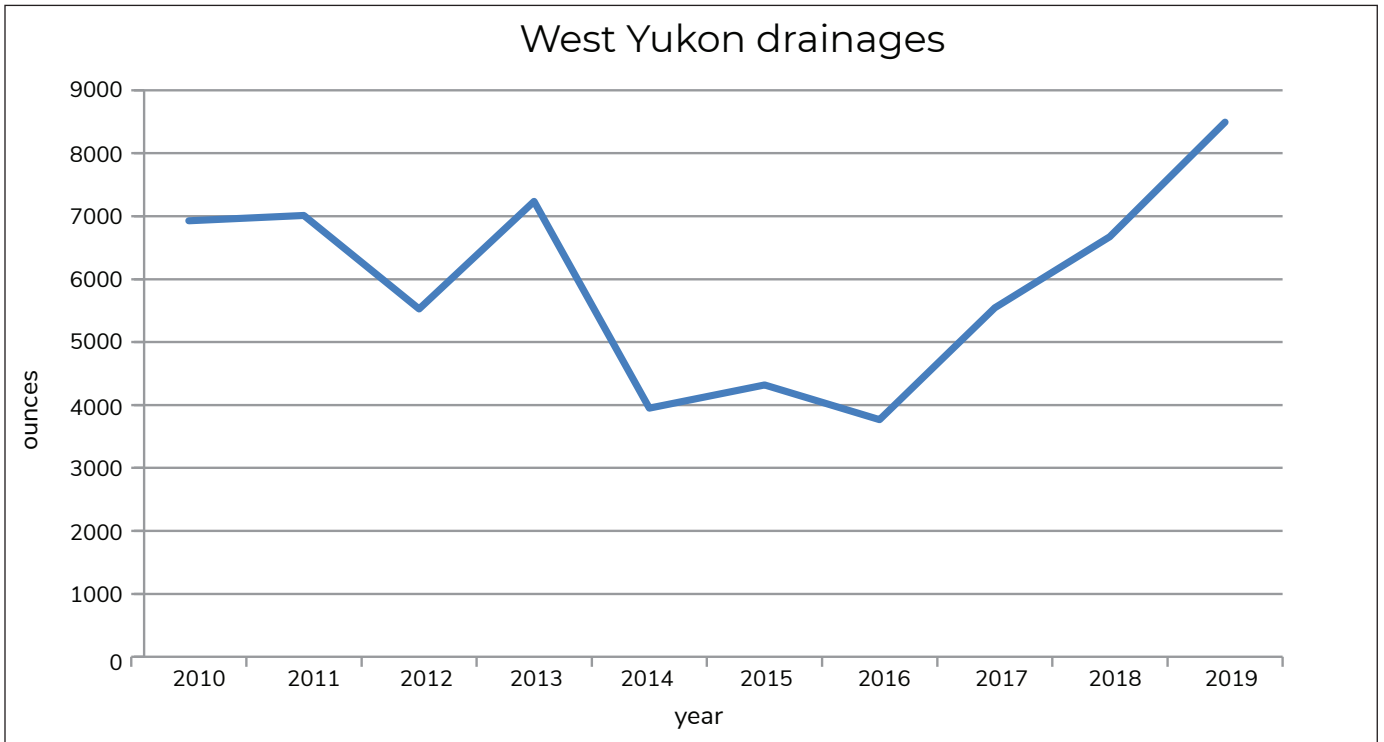


Figure 9. Placer gold production from the West Yukon drainages for the last ten years.



Figure 10. Aerial view looking upstream of the right limit Pliocene bench on Ten Mile Creek and No Name Resources mine operation.

Lower Stewart

Production from the lower Stewart River placer region increased to 9742 crude ounces from 6118 crude ounces in 2018 (Fig. 11). Production is spread out among a number of drainages including Henderson, Barker, Kirkman, Scroggie, Maisy May and Black Hills creeks.

The largest producer in the region is H.C. Mining on Henderson Creek, and they boosted their efficiency by incorporating two new conveyors to deliver pay to their wash plant. As a result, only two personnel are needed to work the cut during each shift. Their largest cut in 2019 measured 61 × 426 m (200 × 1400 ft) and the bottom 1 m (3 ft) of gravel including the mixing zone and weathered bedrock was processed as pay.

Seven crew worked for Schmidt Mining on Barker Creek in 2019 and tackled several placer settings. Part of the Dixie bench, a Pliocene high-level terrace, and a low-level bench were mined. Towards the end of the season, the valley-bottom cut intersected a very coarse, blocky bedrock, which contained some of the better grades they have encountered on the creek.

Ace Mining continued their operation on lower Scroggie Creek near its confluence with Walhalla Creek. Mining was affected by a change in the configuration of the valley, from steeper and narrower to flatter and wider in shape as they progress upstream. As a result, the overburden increases in thickness and permafrost is more pervasive. Fortunately they were able to stay on the pay streak and with a stripping plan will be able to manage the change. The acquisition of an Elrus conveyor feeder reduced production costs; the feed rate increased by 40 yd³/hr and 300 fewer sluicing hours were required to achieve the similar volume as 2018.

Clear Creek and Mayo

Production from both Clear Creek and the Mayo district more than doubled in 2019 due to increased activity on Big and Granite creeks (Fig. 12). The combined production from both areas is 11,430 crude ounces, which is the highest since 1997.

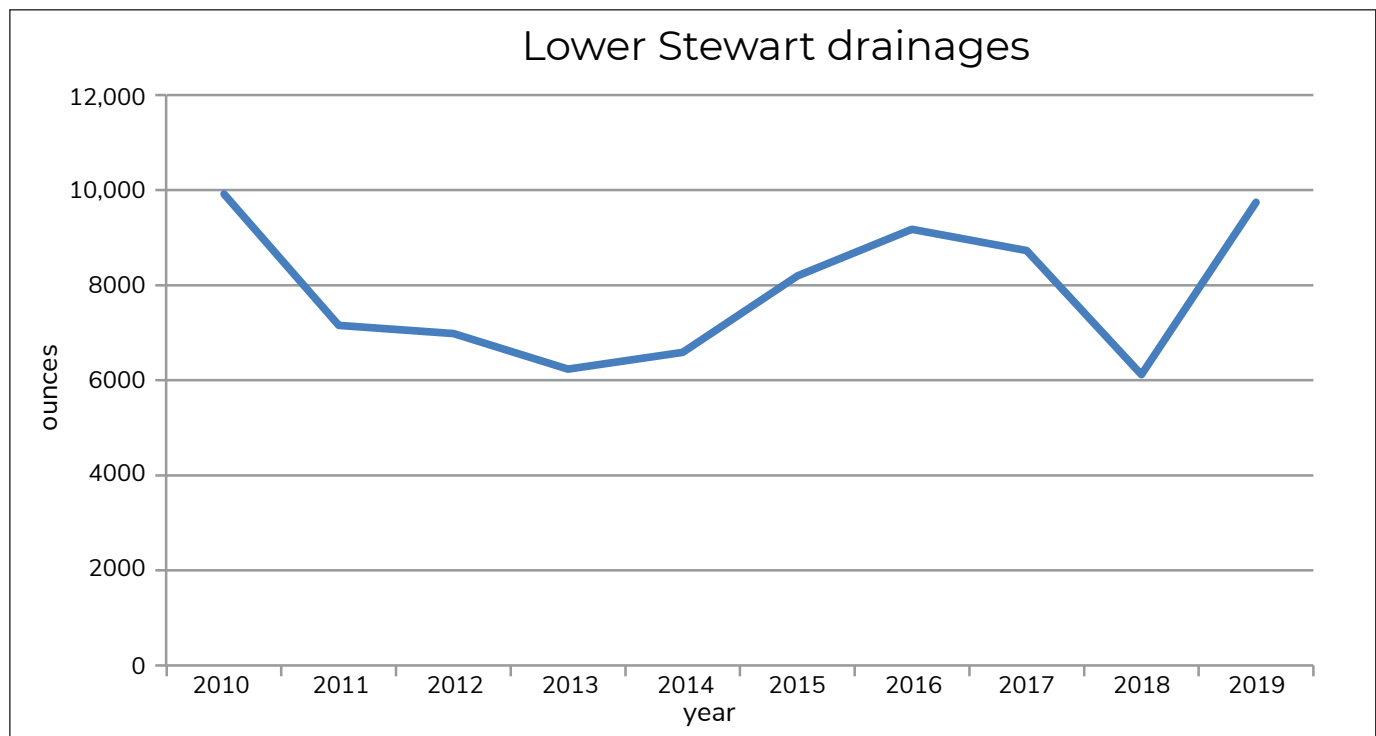


Figure 11. Placer gold production from the Lower Stewart drainages for the last ten years.

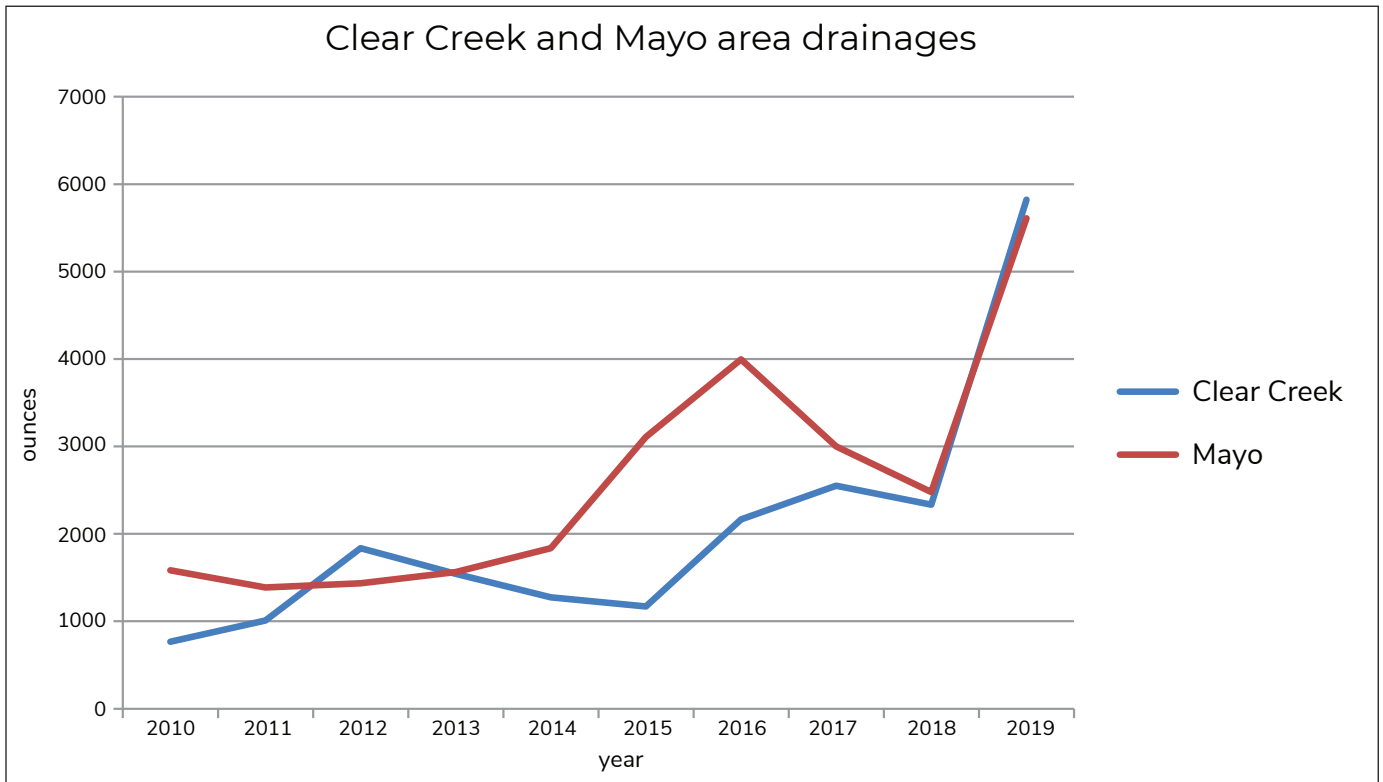


Figure 12. Placer gold production for the Clear Creek and Mayo area drainages for the last ten years.

Schmidt Mining moved their primary plant to Big Creek in 2019 to commence full production (Fig. 13). Two shifts managed the operation in the relatively shallow ground that averaged 4.5 to 6 m (15 to 20 ft) to bedrock. Prospecting near camp resulted in the discovery of a former ice-marginal meltwater channel related to an early Pleistocene alpine glacier originating from the headwaters of Big Creek. Testing of the deposit will resume early next season.

Yukon Exploration Green Gold Inc. made the Big Creek discovery in 2014 while conducting an exploration program that benefited from Yukon Mineral Exploration Program (YMEP) funding. The YMEP investment amounted to \$35,000 and has now resulted in more than a 200:1 return based on the development work, additional exploration expenses, and recent production.



Figure 13. A view looking downstream on Big Creek of Schmidt Mining's operation.

Earth and Iron ramped up operations on Granite Creek in 2019 focusing on placer gold-bearing till immediately beyond the last glaciation end moraine. The till is buried under lower grade morainal sediments. A second cut was exploited closer to the baseline where modern fluvial deposits overlie gold-bearing till. Operations benefited from the opening of the Keystone Creek road, which eliminated steep grades associated with the Mount Hinton route.

Bardusan Placers worked at the mouth of Thunder Gulch where they excavated into a coarse fluvial fan deposit that overlies gold-bearing till near bedrock (Fig. 14). Throughout the summer, the five-person crew excavated the 23 m (75 ft)-deep cut near the confluence with Lightning Creek. The till deposit is 4 m (13 ft) thick and contains boulders up to 1.5 m (5 ft) in length. Sluicing requires the use of a Derocker wash plant to handle the large rocks. Plans to mine farther up Thunder Gulch later in the season were put on hold due to low water levels this summer.

Ken Wilson continued to mine on Minto Creek near the mouth of Hight Creek. The 8 person crew is mining fluvial terraces that were buried under a last glaciation deltaic sand deposit. Surface fluvial lag deposits are the target pay material and the grade is improving as they progress toward the mouth of Hight Creek. In 2019, a new 120 yd³/hr plant that screens to ½" and has an oscillating sluice box was utilized. Water is 100% recycled in their mining process, and progressive reclamation occurs.

Placer mining activity was boosted in the Dawson Range with increased production from Canadian and Nansen creeks. The total production, according to export tax reporting, increased from 782 to 1626 crude ounces for the area (Fig. 15).

536214 Yukon Inc. continued to mine Discovery Creek, a tributary to Nansen Creek, in 2019. The operation has excavated a cut 20 m (65 ft) to bedrock through a thick cover of aeolian sand and fluvial gravel. Extensive old-timer workings were discovered on a left limit bench that is yielding coarse gold.



Figure 14. An aerial view of the mouth of Thunder Gulch showing Bardusan Placer Ltd.'s mine operation with Lightning Creek in the foreground.

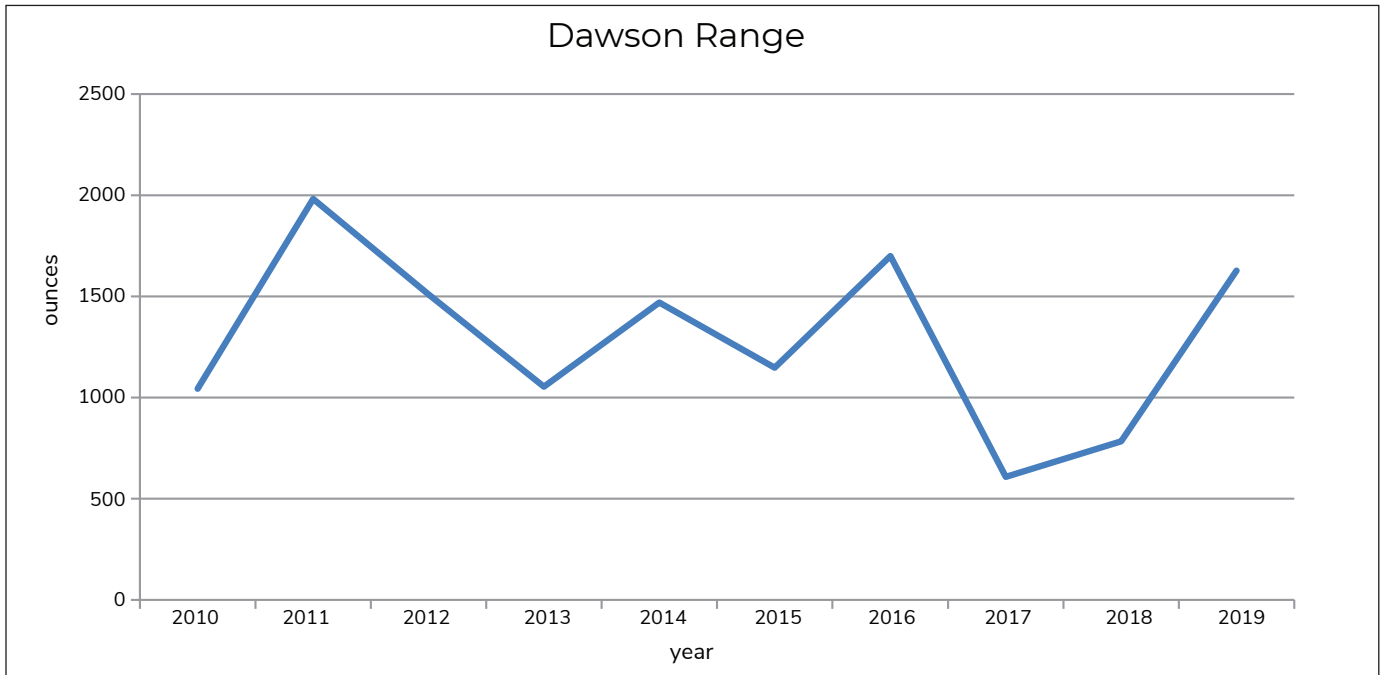


Figure 15. Placer gold production from the Dawson Range for the last ten years.

Derek Dodge opened up a deep channel cut in Seymour Creek in 2019. He had started this cut in 2016 and partially sluiced the top of pay before letting it flood due to ground water volumes. The pay unit is a poorly sorted, rounded, boulder gravel that was likely emplaced during erosion of the channel by outwash off the Reid ice sheet 120,000 years ago. Coarse magnetite pebbles and cobbles can be found unevenly distributed within the pay gravel. The base of the channel is 30 m (100 ft) in width but is expected to increase upstream. The depth of the channel is approximately 27 m (90 ft).

Ryanwood Exploration undertook the largest placer exploration project in Yukon on Shovel Creek in the Dawson Range. This project is heli-portable and utilizes a light footprint approach including a track mounted rotary air-blast drill, argos, resistivity geophysics and LiDAR to delineate the pay streak (Fig. 16). A late season shafting program and 199 drill holes were completed in 2019. The depth to bedrock is relatively shallow with an average depth of 3.0 to 4.5 m (10–15 ft). More than 9 km of ground have been delineated in two drainages.



Figure 16. Shawn Ryan holding the old-timer shovel his crew discovered while exploring Shovel Creek in the Dawson Range.

Kluane

Placer production increased in the Kluane Range district partially due to new mining activity on Fourth of July Creek. Production increased from 449 crude ounces in 2018 to 1485 crude ounces in 2019 and is expected to increase as winter mining continues on Gladstone Creek (Fig. 17).

FTG Placers leased Fourth of July Creek claims from Sidhu Trucking in 2019 and commenced mining on June 13. A crew of seven people completed approximately 1000 hrs of sluicing that focused on running right limit side pay (Fig. 18). Most areas mined on the right limit excavated down to a false bedrock of yellow gravel that was overlain by a boulder gravel in erosion contact with the underlying unit. Pay is extracted from the boulder gravel, possibly from an alpine glacial source, which is overlain by non-gold bearing glacial deposits originating from up-valley ice flow during the last glaciation.

Steve Johnson operated on Burwash Creek in 2019 and primarily focused on running tailings from previous operations near camp. Additional testing was completed on a right limit bench deposit that was previously

exploited by old timers. The right limit of Burwash Creek appears to contain significant prospects that were buried by colluviation and landslides of glacial sediment off the north-facing permafrost-rich slope. This has caused Burwash Creek to hug the left limit of the valley and is locally forced to cut canyons into bedrock.



Figure 18. A view looking upstream on Fourth of July Creek of FTG Placers operation. Active excavation is visible on the left hand side of the valley bottom (right limit).

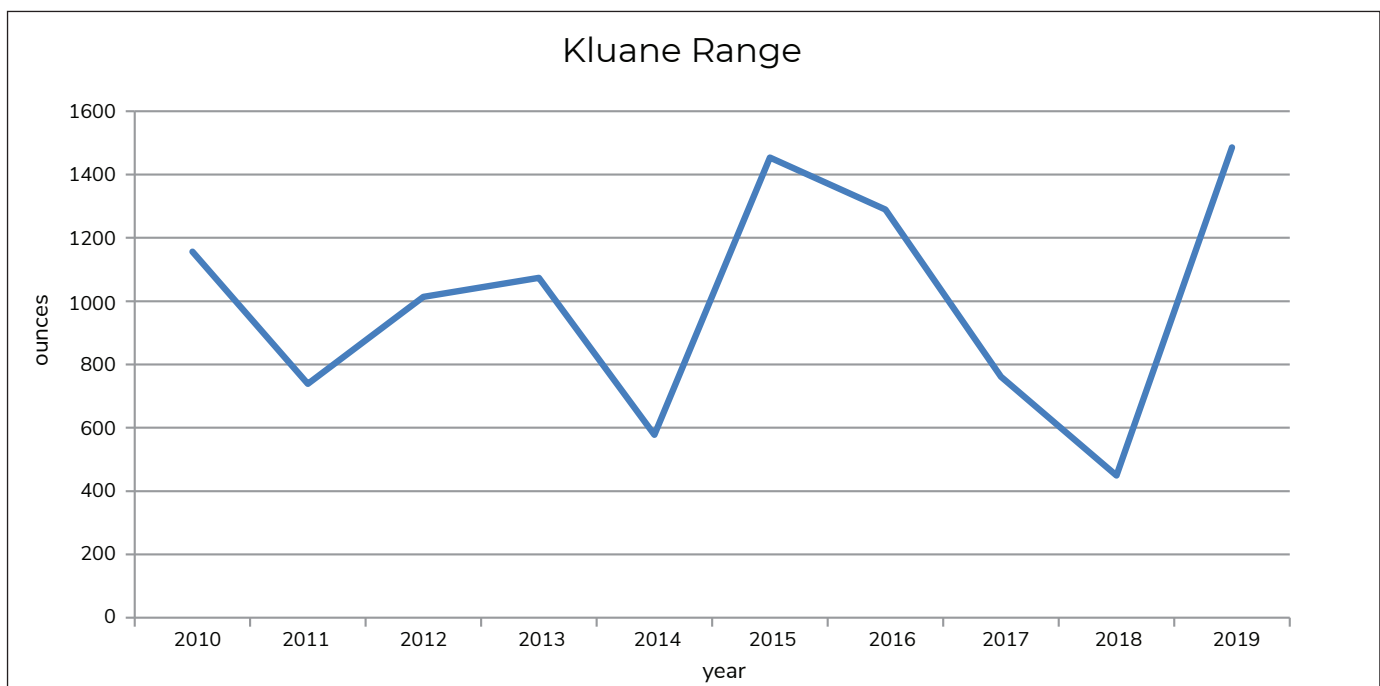


Figure 17. Placer gold production from the Kluane Range for the last ten years.

Yukon Mineral Exploration Program: 2019 update

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Torgerson, D., 2020. Yukon Mineral Exploration Program 2019 update. In: Yukon Exploration and Geology Overview 2019, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 35–42.

Program summary

The Yukon Mineral Exploration Program (YMEP) is a funding program, administered by the Yukon Geological Survey (YGS), and is designed to support individual prospectors, partnerships and companies by providing a portion of the risk capital required to locate, explore and develop mineral occurrences in Yukon (Table 1). YMEP funding has consistently demonstrated its impact as an effective economic incentive by supporting exploration work that has led to numerous discoveries, which in turn, have provided significant long-term economic benefits to the territory.

YMEP funding supports placer and hard rock exploration projects by reimbursing a percentage of approved exploration expenditures. Funding is merit-based; a panel of geologists evaluate submissions using a ranking system designed to score a range of criteria, quantifying the quality of the target, the proposal, the work plan, and the applicant's previous YMEP performance.

Update for 2019

Financing of Yukon exploration projects on equity markets was extremely challenging in 2019. This lack of investment had a trickle-down effect to many Yukon exploration projects. The exploration industry cited a number of factors as the cause of the decline in the attractiveness of Yukon for investment including permitting uncertainty, land withdrawals, and a general lack of infrastructure. Because of these challenges explorers showed considerable interest in the 2019 YMEP program as one of the few sources of risk capital. The YGS received 99 applications seeking more than \$3.2M. Funding for the YMEP was \$1.4M in 2019.

Table 1. Summary highlights of YMEP program guidelines. For more detailed information please reference the YMEP guidebook (<https://yukon.ca/en/mineral-exploration-funding>).

	Grassroots	Focused Regional	Target Evaluation	Placer
Funding	max \$15 000	max \$25 000	max \$40 000	max \$40 000
Reimbursement rate	up to 100% of eligible expenses	up to 75% of eligible expenses	up to 50% of eligible expenses	Up to 50% of eligible expenses
Eligible expenses (See Rate Schedule for details)	conventional exploration work, travel within Yukon (truck, helicopter, etc.; up to 25% of eligible claim), assays, shipping, wages (applicant not eligible in grassroots module), WCB, contracts, equipment rental, daily field expenses, fuel, claim staking (up to 20% of eligible claim), reclamation			
Non-eligible expenses	recording fees, management fees, costs of applying for permits or licenses, project planning and compilation, legal fees, promotional expenses, transportation outside Yukon, underground work, preparation for mining, mining, acquisitions, repairs			
Compliance	applicants must ensure that proper permitting is in place and that their work programs satisfy existing laws and regulations			

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YMEP Highlights

Fifty-one applicants were offered funding. Thirty-three of the funded applications are for hard rock exploration projects (nine are focused regional, and twenty-four are target evaluation); and eighteen placer applications have been funded. The success rate for funding over the last ten years is presented in Table 2; this year's success rate was 52%.

Hard rock projects account for 65% of the successful applications and placer projects account for the remaining 35%. Individual prospectors and private

companies secured 72% of available funds, while public junior mining/exploration companies received 28% of the funds. The breakdown between the different modules and the demographics of the applicants over the past five years are outlined in Table 3. Over this period, the funding split between placer and hard rock sectors has been relatively consistent. The biggest change has been the increase in the share granted to placer projects, from a historical average of approximately 25 to 37% this year.

Table 2. Summary of YMEP funding over the last 10 years.

Historical funding	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Available funding	\$1.67M	\$570 000	\$570 000	\$1.17M	\$1.4M	\$1.4M	\$1.4M	\$1.6M	\$1.6M	\$1.4M
No. of applications	165	83	79	81	111	103	100	78	74	99
Approved projects	83	34	29	55	51	62	57	59	62	51
Max funding grassroots	\$15 000									
Max funding focused regional	\$25 000	\$15 000	\$15 000	\$15 000	\$25 000	\$25 000	\$25 000	\$25 000	\$25 000	\$25 000
Max funding target evaluation	\$50 000	\$25 000	\$25 000	\$25 000	\$50 000	\$40 000	\$40 000	\$40 000	\$40 000	\$40 000
Max funding placer	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$40 000	\$40 000	\$40 000

Table 3. YMEP fund allocation for the last five years.

Approved projects	2015-16		2016-17		2017-18		2018-19		2019-20	
	No. of projects	% of funding	No. of projects	% of funding	No. of projects	% of funding	No. of projects	% of funding	No. of projects	% of funding
Placer	15	28	15	26	21	35	22	36	18	37
Hard rock	47	72	34	74	38	65	40	64	33	63
Total	62		57		59		62		51	
Prospectors/ individuals	24	34	24	39	18	29	28	46	19	37
Private companies	21	32	16	30	22	26	17	27	18	35
Public companies	17	34	17	31	19	45	17	47	14	28

Figure 1 illustrates the locations of funded YMEP projects. The majority of placer projects (seven) are centered in the Klondike placer district; three projects are in the Fortymile and Sixty Mile areas; two projects are in the Mayo/Keno area; one is in the Clear Creek area; three are in the Kluane region; and two are in the Livingstone region. Hard rock projects are evenly distributed throughout the territory. Gold is the most sought-after hard rock commodity with eighteen proponents exploring for structurally-controlled, epithermal, Carlin style, intrusion related, or orogenic gold. Other targets include vein-hosted silver (5),

porphyry copper (5), vanadium (2), cobalt (1), tin (1), and magmatic massive sulphide copper/nickel/PGE prospects (1).

Thirty-one exploration projects focused on soil and silt sampling, prospecting and geological mapping; four undertook ground-based or airborne geophysical surveys; twelve involved drilling and/or trenching; and four undertook hand shafting.

As of mid-December, most YMEP projects have been successfully completed and preliminary results suggest there are several potentially significant discoveries resulting from the work.

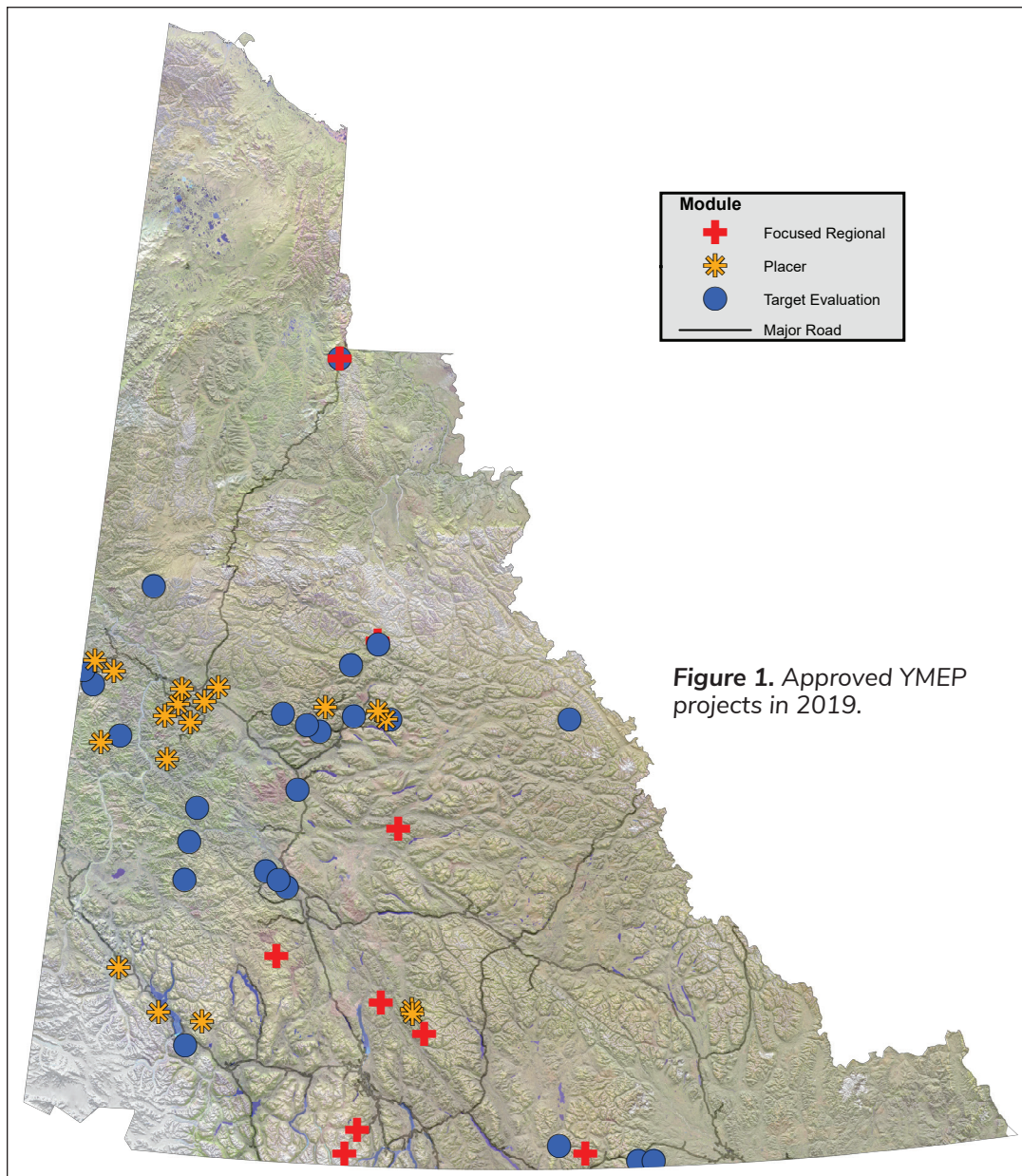


Figure 1. Approved YMEP projects in 2019.

YMEP successes

The YMEP plays a very important role in helping to advance grass roots programs, to de-risk early stage exploration and to support exploration in financially lean years. The mandate of the YMEP is to keep a variety of projects at various stages of advancement operating in Yukon. A number of projects have progressed through the YMEP and have advanced beyond the scope of the program. Three projects that now have deposit resource estimates are the Coffee, Andrew and Red Mountain. These projects stand out as having stimulated significant investment beyond their initial YMEP-funded expenditures. The projects collectively represent development and exploration expenditures in excess of \$315M; combined they have resources of 7.14 Moz gold, 990 Mlb zinc and 238 Mlb lead, and a contained value in excess of \$14.1B. The total YMEP investment in these projects was \$396K, corresponding to a leveraging ratio of 758:1.

Recently, Victoria Gold's Eagle Gold Project, in the Dublin Gulch area, came online as a producing mine. Having received YMEP funding early on has contributed to the development of the project.

The Dublin Gulch area received YMEP funding between 1980 and 2003 (grant numbers 1986-002, 1987-019, 2002-077, 2003-071). The YMEP contributed a total of \$44,143.39 to these exploration programs. Work included mechanical and blast trenching, RC drilling, prospecting, geological mapping, soil sampling. In 1980, Bema Industries conducted a program of trenching and sampling of the Cabin vein that produced 332 tons of material, which averaged 0.479 oz/ton gold and 1.71 oz/ton silver. It is estimated that this bulk sample contained 160 oz of gold. Numerous other vein structures were excavated and sampled in 1980 and results returned up to 0.748 oz/ton gold and 0.12 oz/ton silver. The 1987 YMEP program for Canada Tungsten Mining Corp. consisted of a 9 hole RC drilling program designed to test the placer potential of Dublin Gulch. This 286 m drill program returned gold values of up to 0.1561 oz/yd³ and indicated strongly the placer potential of Dublin Gulch. The 2002 YMEP project for Brent Walden and Kelly Bensen focused on Tin Dome and consisted of prospecting and geological mapping. Twenty-two rock

samples were collected; analysis returned values up to 549 ppb gold. The 2003 YMEP project completed by J. Peter Ross consisted of prospecting, soil sampling and blast trenching and focused on the Lynx and Skate creek areas. Soil sampling returned very significant results of up to 3895 ppb gold and numerous other samples over between 300 and 2378 ppb gold. The subsequent blast trenching program returned trench panel samples of up to 2378 ppb gold over 5 m.

In subsequent years, the Dublin Gulch property claims were consolidated into a contiguous package, which was acquired by Victoria Gold (www.vitgoldcorp.com) in 2009. Victoria Gold immediately began an aggressive drilling and exploration program on the property. To date Victoria Gold has outlined 3.3 Moz of gold with a current value in excess of \$6B. Since the initial \$44K YMEP investment, exploration expenditures at Dublin Gulch are in excess of \$110M and development expenditures of greater than \$600M. The leveraged dollars on exploration expenditures alone represent a ratio of 2517:1.

Sixtymile - Bernie Kreft

This 133 claim (2,500 ha), road accessible, epithermal gold target is located northwest of Dawson City in the Sixtymile goldfields. Fieldwork consisted of prospecting and soil sampling designed to locate sources for the significant placer gold deposits found within creeks draining the property.

Eight mineralized zones, showings, or significant soil anomalies associated with north-trending silicified, stockwork and brecciated zones were identified. A 1.0 m chip sample of quartz stockwork and silicified schist assayed 1.679 g/t gold (Fig. 2); a sample of heavily silicified and pyritic quartz breccia assayed 0.812 g/t gold; and a 1.0 m chip sample of weakly pyritic quartz fluorite breccia assayed 0.308 g/t gold (Fig. 3). Silicified and brecciated zones, up to 80 m wide and 1.65 km long have gold values associated with anomalous Ag-As-Sb.

Further soil sampling, prospecting, and a CSAMT geophysical survey are planned; results will guide a preliminary trenching program.



Figure 2. Brecciated stockwork and heavily silicified quartzite with trace disseminated pyrite – 1.679 g/t Au.



Figure 3. Quartz fluorite breccia cut by vuggy quartz veins and mineralized with trace disseminated pyrite – 0.308 g/t Au.

RC Gold property - Sitka Gold Corp

To further define the existing gold in soil anomalies on the RC property, the 2019 YMEP program focused on additional soil and rock sampling; 288 soil samples and 16 rock samples were collected (Fig. 4). An IP survey was completed to extend the 2018 IP survey lines beyond the chargeability anomalies at the southern end. Approximately 3.2 km of IP was completed. The RC property was optioned to Sitka Gold Corp. in July in conjunction with the BEE and BOP claims (together the “RC Gold Property”).

An additional 28 contiguous claims were staked during the work program. The total number of claims at the RC Gold property is now 132, covering an area of approximately 2600 ha. Sitka Gold plans to follow up on these encouraging results with a drill program in 2020.

Results from infill soil sampling completed between the Far Grid and the Big Creek anomalies suggests that they are contiguous and represent a larger intrusion related gold target more than 2 km long and 500 m wide. Soil sampling is difficult due to terrain and soil material on the RC property and therefore targets are potentially larger and stronger than what is reflected in the geochemical results.



Figure 4. Soil sampling on the RC property.

Aurex-McQuesten - Banyan Gold

During the 2019 Aurex-McQuesten program, 39 holes (4897 m; Fig. 5) were drilled. Excavation, mapping, and sampling occurred in two trenches (totaling 175 m) at the McQuesten target. Fifty-six soil samples were collected and analyzed by XRF.

Four drill holes targeted the Powerline zone, an undrilled area one kilometre south of the main McQuesten Gold zone, on the Aurex Claim block. These shallow holes were designed to test a prospective target identified by applying the geologic model developed at McQuesten to the property-wide drilling database, surface (rocks, soils, trenches) geochemical database, and airborne geophysical surveys.

The McQuesten Gold zone is a known unit that consists of an approximately 90 m thick calcareous package that transects the McQuesten claim block and is interpreted to host gold mineralization preferentially stratabound retrograde skarn (actinolite-chlorite; Fig. 6) altered horizons with semi-massive to massive pyrrhotite ± arsenopyrite ± sheelite ± chalcopyrite and anomalous in bismuth and tellurium. Similar geologic controls were noted in the 2019 Powerline core.



Figure 5. Drill core from Aurex-McQuesten project



Figure 6. Retrograde actinolite-chlorite skarn with semi-massive pyrrhotite.

Highlights from the Powerline discovery and McQuesten zone drill holes include consistent, long intervals of approximately 0.5 g/t Au from surface (as at the McQuesten showing) punctuated by higher-grade intervals such as:

- 2.89 g/t Au over 4.6 m from 25.9 m in AX-19-30
- 1.46 g/t Au over 7.4 m from 44.2 m in AX-19-30
- 1.42 g/t Au over 4.6 m from 30.5 m in AX-19-31
- 48.1 g/t Au over 0.4 m from 71.6 m in AX-19-31
- 1.24 g/t Au over 4.2 m from 49.6 m in AX-19-33

Trenches at the McQuesten Gold zone were constructed to test the strike extent of the McQuesten Gold zone and identified large intervals of oxidized gold mineralization at surface. Limestone, graphitic schist, calcareous schist, and quartzite were all noted within these trenches, consistent with what has been observed in core from McQuesten drilling. Reported gold grades and widths from trenching:

- 144.0 m of 0.56 g/t Au in TR-MQ-19-01
- 31.0 m of 1.06 g/t Au in TR-MQ-19-02
- 0.94 g/t Au over 71.4 m, including 3.1 g/t Au over 8.8 m from 127.4 m in MQ-19-44
- 5.01 g/t Au over 5.3 m from 94.7 m in MQ-19-42
- 3.23 g/t Au over 11.8 m from 89.3 m in MQ-19-43
- 112.3 g/t Au over 0.1 m from 18.2 m in MQ-19-45

2019 streamlined application form

The YGS introduced the new YMEP application form in 2019. In an attempt to simplify the process, the project proposal and application form became a single document. All relevant text, maps, photos and figures are now inserted into the new application form. A copy of this form is available on line at <https://yukon.ca/en/mineral-exploration-funding>. Applicants who wish to apply with a separate exploration proposal may continue to do so.

2020 Grassroots module changes

Based on feedback received during the YGS' 5-year planning session, changes to the YMEP Grassroots module are being implemented. Low uptake for the module has led us to consider ways in which to make it more appealing to prospectors. Changes aim to allow individual prospectors to work in underexplored areas

to support new discoveries. Key changes include the elimination of the 30-man-day fieldwork requirement, the reduction of the confidentiality period to 2 years, and a priority given to underexplored areas and targets. Below is a comparison between the current and proposed requirements.

Table 4. Proposed changes to the Grassroots module of YMEP.

Grassroots current		Grassroots proposed
Funding		max \$15 000
Reimbursement rate		up to 100% of eligible expenses
Scope of work	to generate new targets and advance existing ones	to generate new targets and advance existing ones. Priority will be given to new areas and targets without significant previous exploration work
Field time requirements	minimum 30-person-days in field, daily log	no minimum
Technical reporting requirements	daily log and final technical report	daily log and brief summary report with all samples and data points in digital format. (summary report may not qualify as an assessment report)
Confidentiality	confidential for 5 years	confidential for 2 years
Module-specific eligible expenses	applicant cannot draw wages but wages for one assistant are eligible	all wages are ineligible
Eligible expenses (See Rate Schedule for details)	conventional exploration work, travel within Yukon (truck, helicopter, etc.; up to 25% of eligible claim), assays, shipping, wages (applicant not eligible in grassroots module), WCB, contracts, equipment rental, daily field expenses, fuel, claim staking (up to 20% of eligible claim), reclamation	conventional exploration work, travel within Yukon (truck, helicopter, fixed wing), assays, shipping, WCB, equipment rental, daily field expenses (\$100/person/day), fuel, claim staking (up to 20% of eligible claim)
Reimbursement rate guidelines	expenses reimbursed according to YG guidelines. Private and commercial rates are provided. Private rates for heavy equipment are 75% of commercial rate as approved by YG.	expenses reimbursed according to YG guidelines. Private and commercial rates are provided
Travel	travel within Yukon (truck, helicopter, etc.) up to 25% of eligible contribution	travel within Yukon (truck travel capped at \$1000) helicopter, fixed wing)
Eligible use of machinery	use of light equipment (<5 tons)	No mechanical equipment
Non-eligible expenses	recording fees, management fees, costs of applying for permits or licenses, project planning and compilation, legal fees, promotional expenses, transportation outside Yukon, underground work, preparation for mining, mining, acquisitions, repairs	recording fees, management fees, costs of applying for permits or licenses, project planning and compilation, legal fees, promotional expenses, transportation outside Yukon, underground work, preparation for mining, mining, acquisitions, repairs, wages
Compliance	applicants must ensure that proper permitting is in place and that their work programs satisfy existing laws and regulations	

Summary

Since 2000, YMEP has invested \$20.55M in 1013 projects, leveraging \$55.32M of additional exploration expenditures in the year the grants were awarded. Dollars leveraged, new discoveries and option agreements entered are all indicators of the success of the YMEP. In 2019, YMEP recipients committed ~\$4.8M in exploration investment, corresponding to a leveraging ratio of 3.4:1. While easily measured, leveraging ratios are relatively modest indicators of success. The greater impacts are linked to the discoveries made and the further investments they trigger in the medium to long term. The discoveries in 2019 will continue to stimulate exploration expenditures in the years ahead and enable the discovery of the mines of the future.

Property visits to YMEP-funded projects are conducted by YGS staff annually (Figs. 7 and 8). Staff try to visit new projects or those that have not been visited by us in the past.



Figure 7. Cobalt bloom (erythrite) mineralization on Go Metals' Monster property.



Figure 8. RC drilling at G. Richards' All-In project.

Yukon hard rock mining, development and exploration overview 2019

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Lewis, L.L. and Casselman, S.G., 2020. Yukon hard rock mining, development and exploration overview 2019. In: Yukon Exploration and Geology Overview 2019, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 43–60.

Introduction

Yukon mineral exploration activity dipped slightly in 2019 (Fig. 1). Exploration expenditures were approximately \$105 million, compared to \$120 million in 2018. Development expenditures are estimated at \$240 million, primarily for the development of Victoria Gold Corp.'s Eagle mine (\$183M), and, to a lesser extent the advancement of Newmont Goldcorp.'s Coffee gold project and the reopening of the Minto gold-copper-silver mine by Pembridge Resources. Production dollars are attributable to operations at Victoria Gold's new Eagle mine and the newly reopened Minto mine of Pembridge Resources plc (Fig. 2).

The number of active exploration projects dropped significantly from 155 projects in 2018 to 80 projects in 2019. To some degree, this reflects the continuing tight equity markets. Thirty-six of the 80 projects spent more than \$1M, while 44 projects spent less than \$500 000. The majority of smaller projects received Yukon Mineral Exploration Program (YMEP) grant funding. YMEP funds were distributed to 33 hard rock and 18 placer exploration projects (see Torgerson, 2020 in this volume for more information). In terms of all Yukon projects, gold continues to be the most sought-after commodity, with 68% of the projects targeting it. The remainder of projects focused on exploring for lead-zinc, copper, silver, or nickel-PGEs, and to a lesser extent, tin, cobalt or vanadium.

Claim staking in 2019 was down significantly over the previous year to 2212 claims. The number of claims in good standing is 173,161, down from an all-time high of 252,902 in 2012 (Fig. 3). Drilling numbers were down slightly. Total drilling in 2019 was 221 596 m, compared to 246 282 m in 2018 (Fig. 4).

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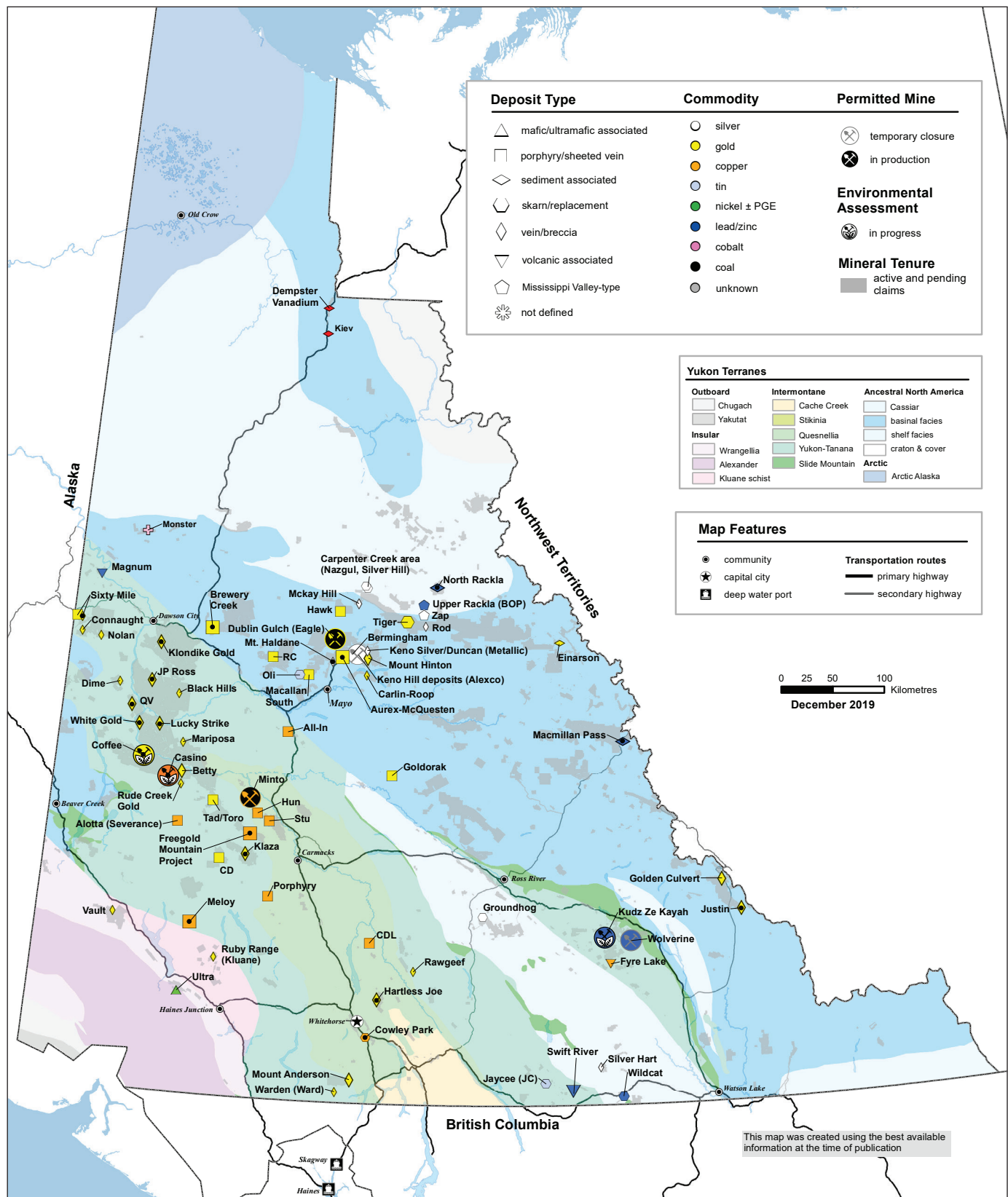


Figure 1. Yukon exploration projects, 2019. Large symbols represent projects with estimated expenditures \geq \$500,000; small symbols with $<$ \$500,000. Black dot in the centre of a symbol indicates that drilling constituted part of the exploration activities.

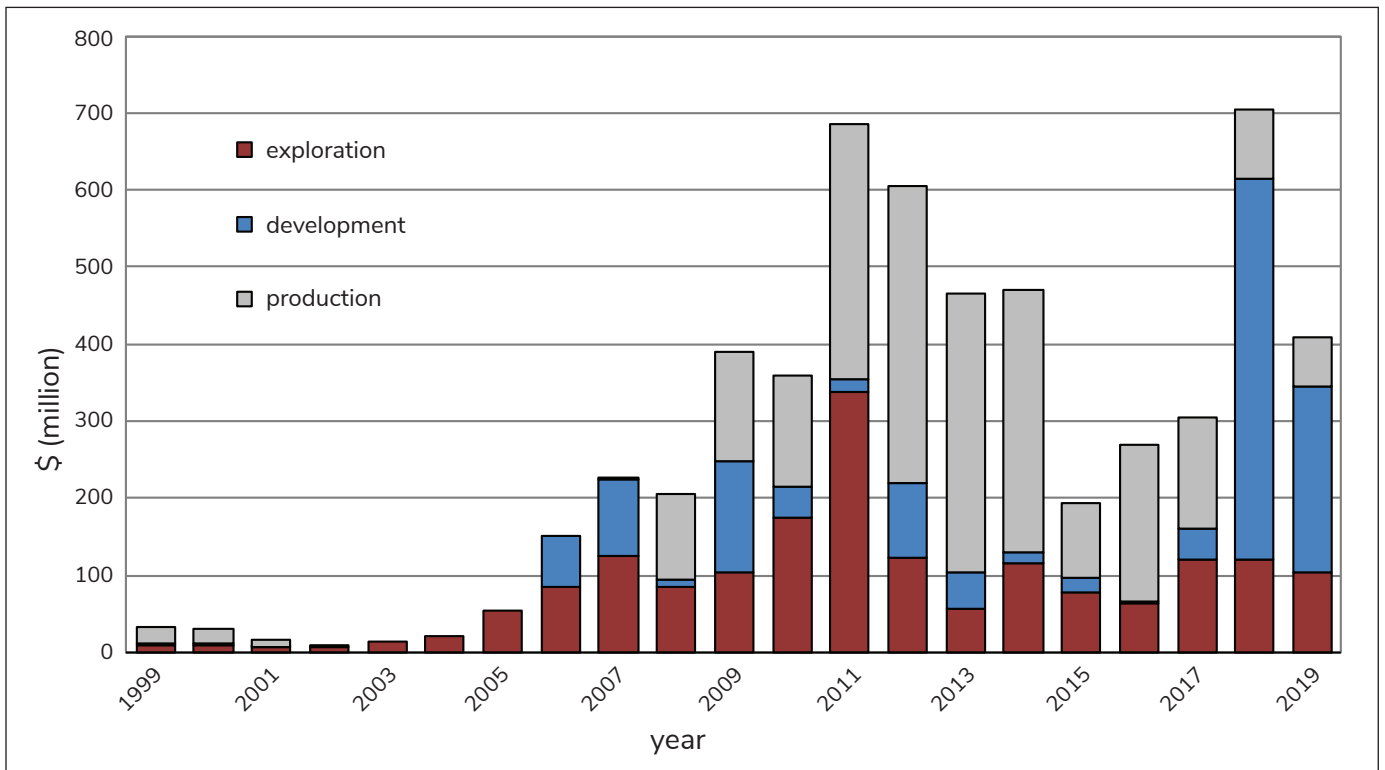


Figure 2. Estimated exploration and development expenditures on hard rock projects, 1999-2019.

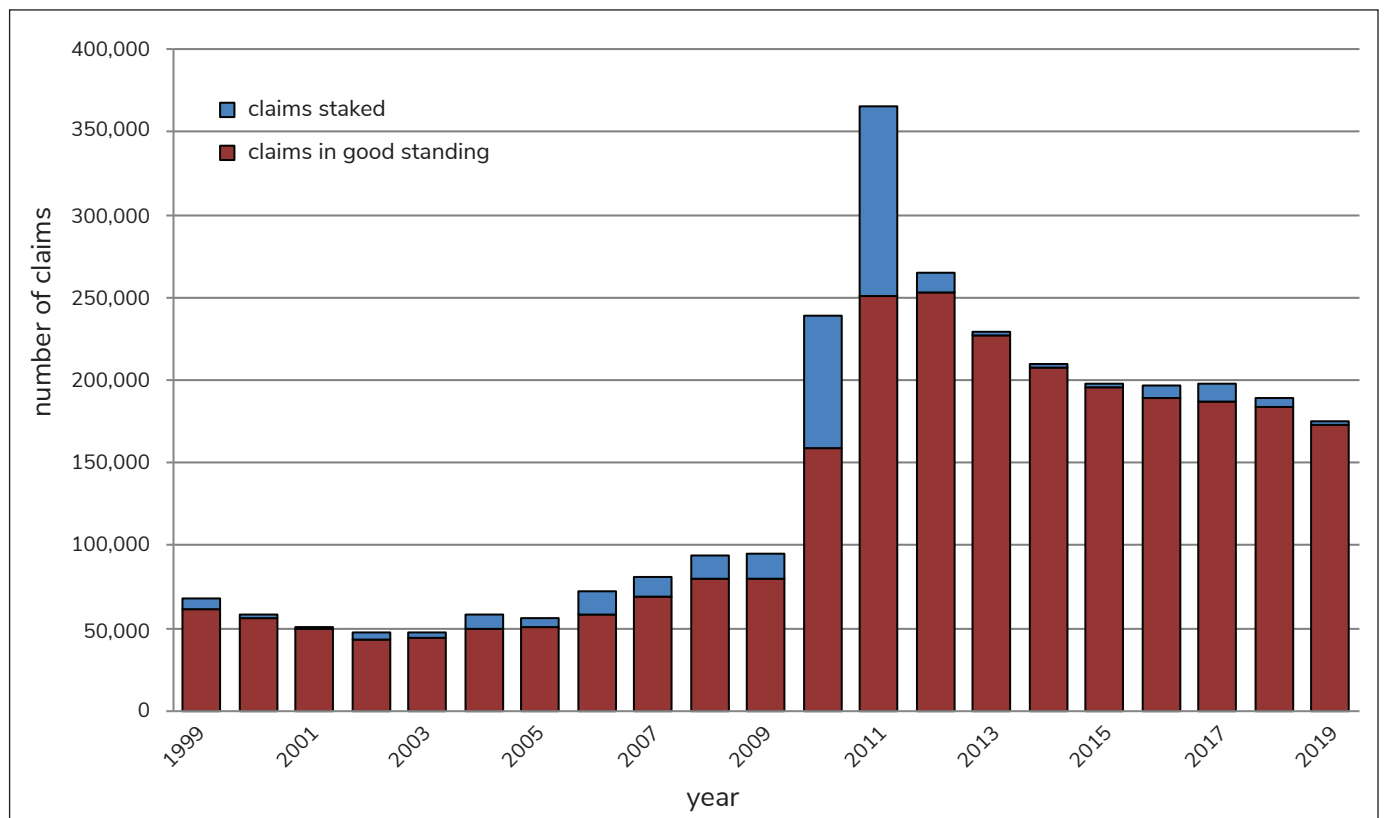


Figure 3. Hard rock claims staked and in good standing, 1999-2019.

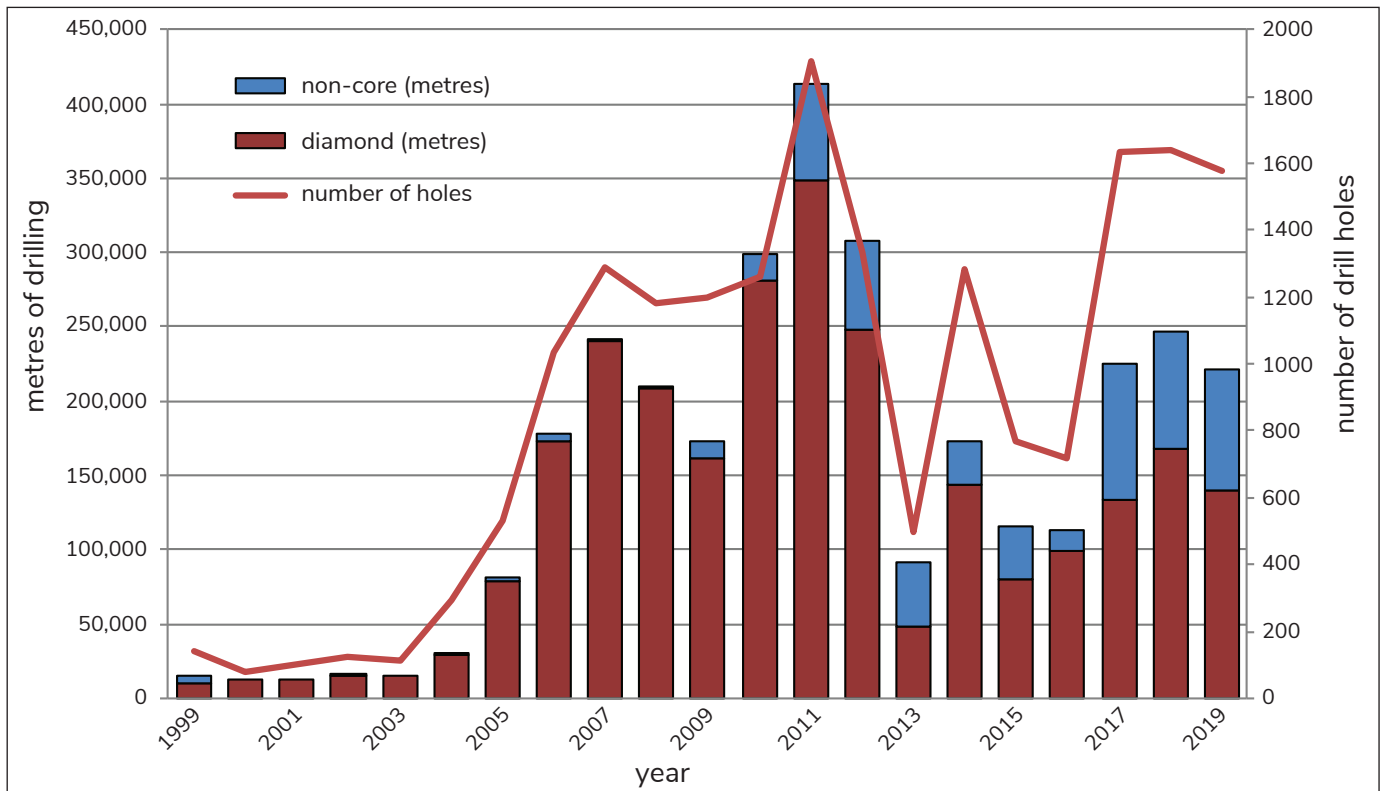


Figure 4. Diamond drilling and reverse-circulation or rotary air blast drilling, 1999-2019.

Mining and development

Hard rock mining

In October, 2018, Capstone Mining Corp. suspended mining activity at the Minto copper-gold-silver mine, after a tentative deal with Pembridge Resources plc (<https://www.pembridgeresources.com/>) fell through. However, continued negotiations through the winter and spring proved fruitful and the purchase was finalized in June, 2019. Pembridge completed the first

underground blast at Minto East in early October and milling operations were up and running by the end of the month.

Victoria Gold Corp. (www.vitgoldcorp.com) completed development of its Eagle intrusion-related gold deposit on its Dublin Gulch property after 26 months of construction (Fig. 5). The first gold pour was completed in September, 2019. Since that pour, the mine has produced approximately 13,000 oz of doré containing between 75 and 85% gold and between 7 and



Figure 5. Heap leach pad at Victoria Gold's Eagle Mine.

18% silver. The company announce an updated reserve in December with an increase of 0.6 Moz to 3.3 Moz and an increase in production to 220,000 ounces of gold per year from the open pit/heap leach operation at an all-in sustained cost of less than US\$774 per ounce gold. The mine life is +11 years.

Mine development

Newmont Goldcorp (<https://www.newmontgoldcorp.com/>) submitted its application for the Coffee gold mine to the Yukon Environmental and Socioeconomic Assessment Board (YESAB) in the spring of 2017. The 2.16 million ounce (Proven & Probable reserve) gold deposit is envisioned as an open pit/heap leach operation. The company is working to update the feasibility study while they await a mine permit. In 2019, the company explored the property with 30 000 m of diamond drilling and 60 000 m of RC drilling and plans to update the resource/reserve in early 2020. Drill results have not yet been released.

Alexco Resources Ltd. (www.alexcoresource.com) released the results of a pre-feasibility study for its Bermingham and Flame & Moth deposits in a technical report in May 2019. The report was based on the development of four deposits in the Keno Hill silver district: Bermingham (Fig. 6), Flame & Moth, Bellekeno and Lucky Queen, and envisioned an eight year mine life producing 1.18 million tonnes of ore at an average grade of 805 g/t Ag, 2.98% Pb, 4.13% Zn and 0.34 g/t Au. A new resource was calculated for the Bermingham deposit in March 2019 (Table 1). Its inclusion in the district resource increased the resource to 98.3 million ounces of contained silver. Alexco continued exploration in the district with 5100 m of diamond drilling at Bermingham to target a deeper structural zone which hosts the adjacent historic Hector Calumet deposit. K-19-0740 intersected the



Figure 6. Bermingham mine portal.

Bermingham footwall vein structure at 580.3 m depth and averaged 1414 g/t Ag over 8.15 m true width. The drill program also intersected the Bear vein at depth, with 4.13 m grading 1331 g/t Ag in drill hole K-19-0733. In December, the company announced a new discovery 3.7 km north of Bermingham called the Inca, where drilling intersected 7.44 m grading 832 g/t silver in hole K-19-0749.

BMC Minerals Ltd. (<http://bmcminerals.com>), a private company, submitted its application to YESAB in March 2017, to develop the ABM volcanogenic massive sulphide deposit of the Kudz Ze Kayah property. The project was moved to the “Screening Stage” of the process in January 2018 and “Draft Screening Report” stage in July 2019. Also in July, BMC released a positive feasibility report for the project. It reported a probable mineral reserve of 15.7 Mt grading 5.8% Zn, 1.7% Pb, 0.9% Cu, 138 g/t Ag and 1.3 g/t Au. The operation will be a majority open pit (89%) with minor underground (11%) mine, processing 2 million tonnes per year with a 9 year mine life. Preproduction capital costs are estimated at \$381M. The company also performed a small surface program at its nearby Fyre Lake VMS property.

Table 1. NI 43-101 compliant mineral resource for the Bermingham deposit.

zone	category	tonnage	Ag (g/t)	Au (g/t)	Pb (%)	Zn (%)	contained Ag (oz)
Bermingham	Indicated	1 102 300	930	0.1	2.4	1.7	32,959,000
	Inferred	509 400	717	0.2	1.7	1.5	11,743,000
total							44,702,000

Western Copper and Gold Corp. (www.westerncopperandgold.com) continues to advance its Casino porphyry copper-gold-molybdenum project in western Yukon. Drilling in 2019 (72 diamond drillholes, 13 592 m) intersected one of the highest grade intercepts on the deposit to date: 55.1 g/t Au over 2.97 m in hole DH19-21, starting at a depth of 147.98 m. High-gold intercepts have been correlated with faults associated with late phase alteration. The mine was originally submitted to YESAB for assessment in January 2014, but was bumped up to the “Panel Review” process, the highest level of assessment under the Yukon Environmental and Socio-economic Assessment Act, in February 2018. The company is preparing the necessary documentation to initiate the Panel Review process.

The quartz mining license and water license for Golden Predator Mining Corp.’s (www.goldenpredator.com) Brewery Creek gold mine were confirmed in July 2019. With these licenses, the Company is authorized to restart mining activities that follow the previously assessed mine plans without further assessment and review. There is slightly more than two years remaining on each of the licenses. The company is reviewing its 2011 feasibility study in order to advance the project. In 2019, Golden Predator carried out a large program involving drilling, infrastructure assessment, camp expansion, review of the previous mine plan, and assessment of reprocessing the historic heap leach pad. The company conducted substantial diamond and reverse circulation drilling in order to upgrade and expand known resources. The assessment of the historic heap leach pad involved drilling 31 holes to collect a 22 tonne sample for metallurgical testing. The company also conducted ground magnetics/VLF and ELF resistivity geophysical surveys over select deposits to better understand and delineate the ore-controlling structures on the property.

Yukon Zinc Corp.’s (www.yukonzinc.com) volcanogenic massive sulphide Wolverine Mine in eastern Yukon has been in temporary closure since 2015. The company owes \$26.4M in securities in addition to the \$10.5M already paid as security to cover the cost of environmental protection. In September 2019, a Yukon judge ordered that Yukon Zinc be put into receivership.

PricewaterhouseCoopers, the receiver, has taken over care and maintenance of the site. The Government of Yukon has been managing water issues at the site using some of the posted security. A water treatment plant has been installed to treat water in the tailings storage facility. The water will be treated and discharged over the next couple of years to reduce the amount of water stored in the tailings facility. Water currently in the tailings facility remains within safe operating levels.

Significant exploration projects

Precious metals

Atac Resources Ltd. (www.atacresources.com) received a positive recommendation from YESAB for a 65 km access road to advance its Tiger gold deposit toward development (Fig. 7). However, as part of the approval process, the Yukon government and First Nation of Na-cho Nyäk Dun agreed to a planning process for the Beaver River watershed within which the road would be constructed. The planning committee is hoping to complete the land use plan by November 2020. The 490,000 ounce Tiger deposit lies at the western end of Atac’s extensive Rackla gold belt claim block within an area called the Rau Trend. Atac continued to explore in 2019 with sampling, mapping, drilling and ground IP and magnetic geophysical surveys. Highlights of the 2019 drilling program (4 holes, 395.02 m) include drill hole RAU-19-166, which intersected 3.04 m of 13.40 g/t Au near surface. Atac has begun a preliminary economic assessment, which will include an updated resource estimate. Atac also explored a gold-copper skarn target, roughly 4 km east of the Tiger deposit; drilling at the Bobcat skarn target, intersected 17.75 g/t Au across 0.51 m in hole RPP-19-002.

White Gold Corp. (WGC; www.whitegoldcorp.ca) filed a new mineral resource estimate for the Golden Saddle and Arc deposits on the White Gold property in 2019 (Table 2). WGC’s 2019 exploration program was designed to expand Golden Saddle and Arc’s resources, follow up on the 2018 discovery of the Vertigo zone at the JP Ross property and to prove up further resources at the VG deposit. In addition to a planned 17 000 m diamond drilling program, the company performed soil sampling, prospecting, GT Probe sampling, trenching

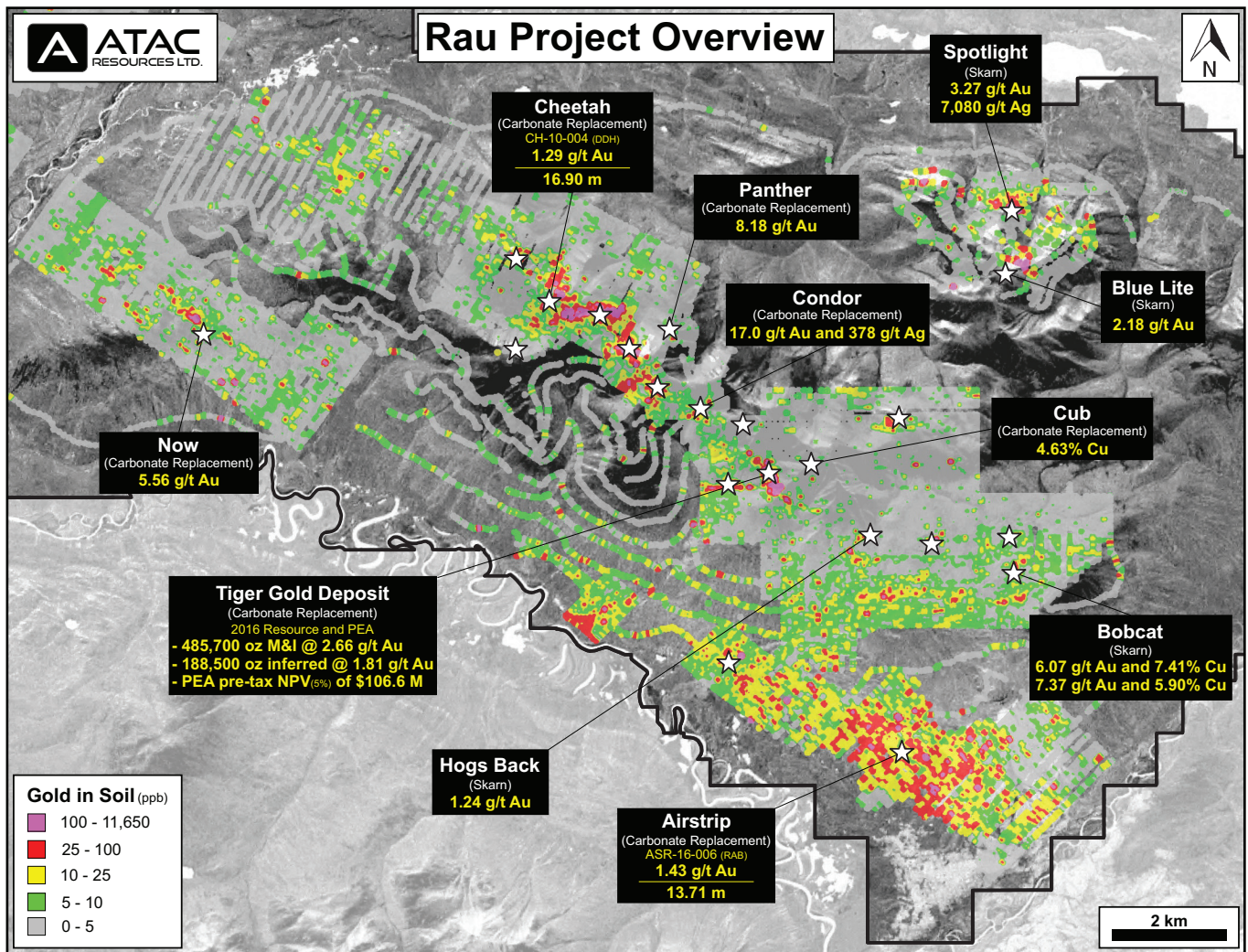


Figure 7. Sketch showing location of Atac's Tiger deposit and surrounding exploration targets. Figure from Atac Resources' website. Accessed Nov 28, 2019.

Table 2. NI 43-101 compliant mineral resource for the Golden Saddle and Arc deposits.

zone	type	category	cut-off (g/t)	tonnage (000s)	Au (g/t)	contained Au (oz)
Golden Saddle	open pit	Indicated	0.5	13 681	2.30	1,009,700
		Inferred		5120	1.58	259,600
	underground	Indicated	3.0	86	4.40	12,200
		Inferred		390	4.36	54,700
Arc	open pit	Indicated	3.0	562	0.98	17,700
		Inferred	0.5	5186	1.17	194,500

and RAB/RC drilling on a number of WGC properties in the region (Fig. 8). The GT Probe and surface sampling of outcrop at JP Ross identified several new high-grade gold trends within 10 km of the Vertigo discovery. Diamond drilling on the Golden Saddle extended the GS main zone 205 m down dip, established the continuity of the deposit through drilling the GS West zone and expanded mineralization beyond the envelope of the 2019 calculated resource. Significant drill results include hole WHTGS19D0198 – 3.59 g/t Au over 68.0 m at Golden Saddle. Diamond drillhole JPRVER19D0015 returned 11.64 g/t Au over 5.34 m near surface and a second interval of 18.46 g/t Au over 2.48 m from 92 m depth at Vertigo. Soil sampling (17,100 samples) at JP Ross and White Gold outlined and extended several trends and returned multiple samples over 1000 ppb. A new high-grade gold discovery, the Titan target, was made on WGC’s Hen property, with one soil sample assaying more than 100,000 ppb Au. Follow-up prospecting revealed fine-grained visible gold in subcrop of quartz-sericite altered mafic gneiss. Drilling identified a new discovery 2 km west of the Golden Saddle: Ryan’s surprise. Diamond drillhole WHTRS19D012 intersected two zones of mineralization: 2.66 g/t Au over 11.00 m and 2.10 g/t Au over 31.73 m.

Infill and step-out diamond drilling on the Arc extended mineralization and filled gaps in the geological model. Metallurgical tests from the Arc deposit were positive, resulting in recovery of 85.2% of gold, proving it to be non-refractory. Results from drilling at the QV gold deposit have yet to be released.



Figure 8. Greenfields target 15 km west of Vertigo that assayed 100 g/t Au in soil.

Victoria Gold Corp. (www.vitgoldcorp.com) continues to explore the larger Dublin Gulch property outside the Eagle deposit. The 2019 exploration program consisted of trenching (5400 m) and drilling (9 holes, 1617 m) at the Raven target within the Nugget zone, 12 km east of the Eagle deposit. The program concentrated on the central part of an 1800 × 900 m gold + arsenic + bismuth anomaly defined by soil sampling in 2018. Drill hole NG19-012C intersected 166.4 m of 0.46 g/t Au, including 42.4 m of 1.06 g/t Au. The trenching program uncovered multiple scorodite, bismuth and siderite-bearing sulphide veins. Structural control of the mineralization is evident within the trenches and future work will focus on the large, high-grade, dilatational fracture zone which is interpreted to host the Raven gold mineralization.

Rockhaven Resources Ltd. (www.rockhavenresources.com) carried out a late season diamond drilling program at its epithermal gold-silver Klaza property (5750 m, 33 holes), including definition drilling and drilling adjacent to the area of the current mineral resource estimate. The program expanded the Pearl zone, discovered in 2017, and led to the discovery of the new Eastern Chevron zone. Results are pending.

Klondike Gold Corp. (www.klondikegoldcorp.com) explored its Klondike Gold property (Fig. 9) south of Dawson City with 94 drill holes testing various targets. Seven drill holes (595 m) were completed at Gay Gulch; results include 29.80 m grading 0.40 g/t Au in drill hole EC19-244 and two high-grade short intercepts in drill hole EC19-248 – 0.50 m grading 6.07 g/t Au and



Figure 9. Historic shaft at the Stander zone at the top of Glacier Gulch on the Klondike Gold property.

0.50 m grading 9.66 g/t Au. Gay Gulch is one of several occurrences of gold quartz veins in brittle felsic host rock occurring near the northwest-trending Eldorado fault.

Aben Resources Ltd. (<https://www.abenresources.com/>) completed a drill program at its Justin gold property in southeastern Yukon. Four diamond drillholes (963 m) tested the intrusion-related POW zone while 20 rotary air-blast (RAB) holes targeted the recently discovered Lost Ace zone, which is more analogous to an orogenic-style gold occurrence. Drilling at POW targeted a magnetic high and intersected massive sulphide, mineralized skarn and mineralized quartz veins. Results include 1.5 g/t Au over 15.4 m in drill hole JN19020. RAB drilling at the Lost Ace zone intersected mineralized phyllite/quartz-pebble conglomerate and returned 0.9 g/t Au over 1.5 m in drill hole JN19026.

In 2019, Triumph Gold Corp. (www.triumphgoldcorp.com) focused its exploration efforts on deep porphyry targets at the WAu Breccia and Blue Sky zones, as well as testing an IP anomaly at the Big Red zone on its Freegold Mountain property. The strategy proved successful with an intercept of 601.80 m averaging 1.1 g/t gold-equivalent at the WAu Breccia and 304.39 m grading 0.638 g/t Au, 5.9 g/t Ag and 0.23% Cu in drill hole RVD19-04 at Blue Sky. Results for drilling at the Big Red have not yet been reported. Results are also pending for the trenching, mapping and hyperspectral surveys carried out at the Goldstar/Irene epithermal gold target, the Cabin porphyry target and the Tinta Hill polymetallic vein deposits.

Alianza Minerals Ltd. (<https://alianzaminerals.com/>) explored its Mt. Haldane property, a high-grade silver target, with four diamond drillholes (963 m). The program tested the Bighorn soil anomaly with its first drill holes, located almost 3 km away from known mineralization. Drill hole HLD19-15 intersected silver-bearing veins assaying 125.7 g/t Ag and 4.4% Pb over 2.35 m. Drilling at the Ross target returned only anomalous lead and silver but did intersect weakly mineralized structures that may be more prominent at depth. Results from drilling the Middlecoff zone of the Mt. Haldane vein system are pending.

Strategic Metals Ltd. (www.strategicmetalsltd.com) worked on 15 properties in Yukon in 2019 and completed small drill programs at the Hartless Joe, Meloy and Sixty Mile projects. Results from the drilling are pending. The company explored the Mount Hinton gold-silver property with soil sampling, prospecting and geological mapping. Spectacular results were received from prospecting where a grab sample from a quartz talus train assayed 2340 g/t Au and 497 g/t Ag. The outcrop source of the train, an altered and oxidized breccia, assayed 33.3 g/t Au and 654 g/t Ag. Rock sample assays from the main soil anomaly area included 15.9 g/t Au with 9.6 g/t Ag and 9.26 g/t Au with 1.59 g/t Ag.

Banyan Gold Corp. (www.banyangold.com) completed a first-phase eight-hole 1000 m drill program early in the summer at its road-accessible Aurex-McQuesten gold project, near Mayo, Yukon. This program returned several long intervals of lower grade gold punctuated by higher grade intervals, e.g., AX-19-31 assayed 0.48 g/t Au over 85.8 m, including 4.6 m of 1.42 g/t Au and 0.4 m of 48.1 g/t Au. Hole MQ-19-44 returned 0.94 g/t Au over 71.4 m, including 3.1 g/t Au over 8.8 m. A follow-up diamond drill program, consisting of 3385 m in 26 holes, and a reverse-circulation program (497 m in 5 holes) was designed to expand the Airstrip and Powerline targets. All holes intersected broad intervals of gold mineralization. Highlights include hole MQ-19-49, which intersected 36.2 m of 0.61 g/t Au, including several higher grade intervals, e.g., 4.54 g/t Au over 2.3 m at 84.6 m depth (Fig. 10).



Figure 10. Trench on Banyan Gold's Aurex-McQuesten property.

Luckystrike Resources Ltd. (<https://www.luckystrikeres.com/>) drilled four diamond drillholes (1105.82 m) on the Monte Carlo zone of the Lucky Strike property in the White Gold district to test a 1.8 km IP chargeability anomaly. Drill hole DDLS-19-01 intersected ten separate intervals assaying between 0.45 g/t Au and 2.68 g/t Au.

Stratabound Minerals Corp. (<https://www.stratabound.ca/>) carried out road construction and an extensive trenching program at its greenfield Golden Culvert gold project in southeastern Yukon. A total of 23 trenches were excavated and resulted in the extension of the Main Discovery Vein structure. The best result came from trench TR1923-B which assayed 24.41 g/t Au over 6.0 m and included the highest gold assay on the property: 95.0 g/t Au over 1.5 m. This occurrence has been interpreted as a new vein, the Mid-Vein, which occurs between the Main Vein and West 1 Vein. Four other new gold-bearing quartz vein structures were also discovered through trenching at the Main zone, the highlight of which returned 12.30 g/t Au over 1.0 m within 7.26 g/t Au over 5.0 m in trench TR1917-B.

Late season reconnaissance work 7 km north of the Main Discovery zone uncovered a new outcropping gold-bearing vein exposed over 15.8 m of strike length, which assayed 1.02 g/t Au over 1.0 m.

Metallic Minerals Corp. (www.metallic-minerals.com) completed a broad-scale surface geochemical sampling program in the 2019 field season, which included widespread soil sampling across the underexplored eastern half of the Keno Silver project, soil sampling at Duncan Creek, along with smaller geochemical programs within the main claim block. Work was also completed in the Keno North region, which encompassed a small soil program at McKay Hill, and two YMEP programs composed of prospecting, rock, and soil sampling in the Carpenter Creek area.

CMC Metals Ltd. (www.cmcmetals.ca) explored its Silver Hart silver-lead-zinc property in southern Yukon with soil sampling, sampling across the waste pile, channel sampling in the TM pit zone and 16 diamond drillholes (1048 m). At the TM pit, sampling returned 26 m of 258.6 g/t Ag, 10.16% Zn and 0.6% Pb (Fig. 11).



Figure 11. Geologist Ryan Versloot at the TM pit zone on CMC Metals' Silver Hart property.

Base metals

Fireweed Zinc Ltd. (<http://www.fireweedzinc.com/>) continued to advance its Macmillan Pass sedimentary exhalative lead-zinc project (Tom and Jason deposits) through diamond drilling (16 holes; 2357 m), ground geophysics, soil sampling and mapping. Drilling highlights include 6.13% Zn and 0.95% Pb over 22.54 m true width in Tom North hole TS19-006 starting at 8.3 m depth. Near surface mineralization encountered in drilling at Tom North demonstrated proof of concept for its potential to be mined as an open pit operation. At the Boundary zone, previously thought to be a large tonnage, low-grade occurrence, Fireweed drilled significant high grade intervals within wider, lower grade intervals; NB19-001 intersected 250 m of 3.44% Zn, 0.10% Pb and 5.6 g/t Ag, but included 23.31 m of 16.35% Zn and 27.9 g/t Ag and 5.70 m of 12.16% Zn, 7.09% Pb and 109.3 g/t Ag. Hole NB19-002, returned 4.14% Zn over 230 m, including 7.94% Zn over 100 m.

Cantex Mine Development Corp. (www.cantex.ca) conducted the second largest exploration program in Yukon in 2019 at its North Rackla lead-zinc-silver project (Fig.12). The \$15M exploration program included ground gravity, electromagnetic, IP/resistivity

and magnetic surveys; and drilling. In April, 2019, the company announced a 78 hole, 18 000 m drill program mainly targeting the massive sulphide zone. The geophysical surveys were undertaken to help define the massive sulphide mineralization, between the Discovery and Extension zones, that lies under a cover of glacial till. The surveys were also run over the known boundary of the mineralized zone and over an area that could be a second mineralized zone parallel to the Massive Sulphide zone. Infill soil-talus sampling was also conducted adjacent to previous geochemical anomalies throughout the property. Diamond drilling at the Massive Sulphide zone was along a 760 m fence of 14 drill pads. Highlights of the 2019 drill campaign include drill hole YKDD19-042, which assayed 114 g/t silver, 9.34% lead and 12.37% Zn over 14.15 m.

Granite Creek Copper Ltd. (www.gcxcopper.com) acquired the Stu copper-gold project, contiguous with the Carmacks Copper property, in 2019 (Fig.13). The company carried out data compilation and preliminary field work, which included groundtruthing targets, sampling and claim staking. The compilation work resulted in the identification of several high-priority targets, including a new 2 × 4 km copper-in-soil anomaly along the northeastern side of the project.



Figure 12. Cantex's exploration camp at its North Rackla property.

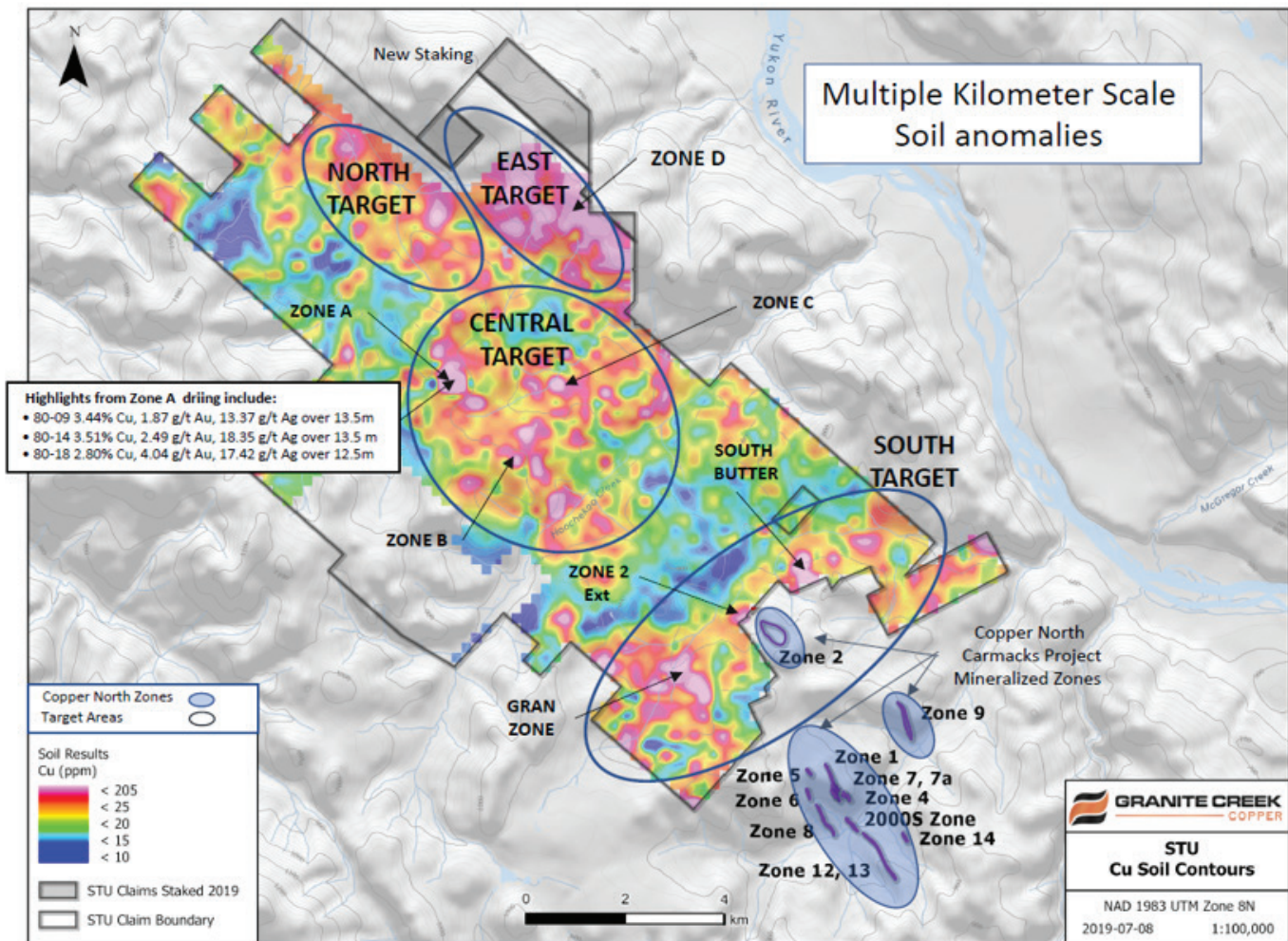


Figure 13. Sketch showing copper-in-soils and zones on Granite Creek Copper’s Stu property. Figure from Granite Creek’s website. Accessed Nov. 28, 2019.

Although gold was the most attractive commodity for Yukon explorers, one company, Go Metals Corp. (<https://gometals.ca/>) explored its Monster iron oxide-copper-gold property for copper and cobalt with geophysical surveys (ground gravity and IP/resistivity), alteration mapping, drone photogrammetry and digital elevation modelling and rock sampling. Alteration mapping revealed that intense chlorite and specular hematite alteration were important vectors to mineralization, and led to the discovery of many new surface copper showings. Assay results for the 90 grab samples collected ranged up to 22.3% Cu and 1.5% Co. The 2019 program generated several drill targets for the 2020 season through integration of geophysical data, surface geochemistry and alteration mapping.

Other critical metals being explored for include vanadium along the Dempster highway in northern Yukon and tin in southern Yukon.

References

Mining Plus Canada, 2019. NI 43-101 Technical Report Prefeasibility Study Of The Keno Hill Silver District Project Yukon Territory, Canada. Report prepared for Alexco Resource Corp. Issue Date May 8, 2019. Effective Date March 28, 2019.

Appendix 1. Exploration projects 2019.

Project	Owner/Optioner	MINFILE	Commodity	Deposit Type	Level of Advancement	YMEP-funded
All-In	Richards, Gord	-	copper	porphyry/sheeted vein	grassroots – never drilled	Yes
Alotta (Severance)	Strategic Metals Ltd.	115J 003	copper	porphyry/sheeted vein	grassroots – never drilled	Yes
Aurex – McQuesten	Banyan Gold Corp.	105M 060	gold	porphyry/sheeted vein	diamond drilled	Yes
Birmingham	Alexco Resource Corp.	105M 086	silver	vein/breccia	NI 43-101 defined resource	No
Betty	White Gold Corp.	115J 074	gold	vein/breccia	R/C or RAB drilled	No
Black Hills	White Gold Corp.	-	gold	vein/breccia	R/C or RAB drilled	No
Brewery Creek	Golden Predator Mining Corp.	116B 160	gold	porphyry/sheeted vein	NI 43-101 defined resource	No
Carlin-Roop	Mayo Lake Minerals	-	gold	vein/breccia	grassroots – never drilled	Yes
Casino	Western Copper Corp.	115J 028	copper	porphyry/sheeted vein	in permitting	No
CD	Strategic Metals Ltd.	-	gold	porphyry/sheeted vein	grassroots – never drilled	No
CDL	Walton, Lori	105E 027	copper	porphyry/sheeted vein	grassroots – never drilled	Yes
Coffee Project	Newmont-Goldcorp	115J 110	gold	vein/breccia	in permitting	No
Connaught	ATAC Resources Ltd.	115N 040	gold	vein/breccia	diamond drilled	Yes
Cowley Park	H. Coyne & Sons Ltd.	105D 230	copper	skarn/replacement	diamond drilled	No
Dempster Vanadium	DV196 Holding Corp.	116I 084	vanadium	sediment associated	diamond drilled	Yes
Dime	White Gold Corp.	-	gold	vein/breccia	diamond drilled	No
Dublin Gulch (Eagle)	Victoria Gold Corp.	106D 025	gold	porphyry/sheeted vein	operating mine	No
Einarson	18526 Yukon Inc.	-	gold	sediment associated	diamond drilled	Yes
Freegold Mountain Project	Triumph Gold Corp.	115I 107	gold	porphyry/sheeted vein	NI 43-101 defined resource	No
Fyre Lake	BMC Minerals	105G 034	copper	volcanic associated	NI 43-101 defined resource	No
GDR	K2 Gold Corp.		zinc-lead	not defined	grassroots – never drilled	No
Golden Culvert	Stratabound Minerals Corp.	105H 067	gold	vein/breccia	diamond drilled	No
Goldorak	Hulstein, Roger	105L 051	gold	porphyry/sheeted vein	grassroots – never drilled	Yes
Green Gulch	Strategic Metals Ltd.		gold	not defined	grassroots – never drilled	No
Groundhog	Strategic Metals Ltd.	105F 029	silver	skarn/replacement	diamond drilled	No

Appendix 1 (continued). Exploration projects 2019.

Project	Owner/Optioner	MINFILE	Commodity	Deposit Type	Level of Advancement	YMEP-funded
Hartless Joe	Strategic Metals Ltd.	105D 203	gold	vein/breccia	diamond drilled	No
Hawk	StrataGold Corp.	106D 035	gold	vein/breccia	grassroots – never drilled	Yes
Hun (Verlene)	536445 Yukon Inc.	115I 014	copper	porphyry/sheeted vein	grassroots – never drilled	Yes
Jaycee (JC)	Huber, Marty	105B 040	tin, copper, tungsten	skarn/replacement	diamond drilled	Yes
JP Ross	White Gold Corp.	115O 160	gold	vein/breccia	NI 43-101 defined resource	No
Justin	Aben Resources Ltd.	105H 035	gold	vein/breccia	diamond drilled	No
Keno District deposits	Alexco Resource Corp.	105M 047	silver	vein/breccia	permitted for mining	No
Kiev	Song, Tao	116I 071	vanadium	sediment associated	grassroots – never drilled	Yes
Klaza	Rockhaven Resources Ltd.	115I 067	gold	vein/breccia	NI 43-101 defined resource	No
Klondike Gold project	Klondike Gold Corp.	115O 072	gold	vein/breccia	NI 43-101 defined resource	No
Kudz Ze Kayah	BMC Minerals	105G 117	zinc-lead	volcanic associated	in permitting	No
Lucky Strike	Lucky Strike Resources Ltd.	115O 170	gold	vein/breccia	diamond drilled	No
Macallan South	Sans Peur Exploration Services Inc.	115P 059	gold	porphyry/sheeted vein	grassroots – never drilled	Yes
Magnum	Strategic Metals Ltd.	116C 118	zinc-lead	volcanic associated	diamond drilled	No
Mariposa	Pacific Ridge Exploration Ltd.	115O 075	gold	vein/breccia	diamond drilled	Yes
McKay Hill	Metallic Minerals Corp.	106D 038	silver	vein/breccia	historic drilling	No
McQ	Tectonic Metals Inc.	-	gold	vein/breccia	R/C or RAB drilled	No
McQ	Taku Gold Corp.	-	gold	vein/breccia	grassroots – never drilled	No
Meloy	Strategic Metals Ltd.	115G 070	copper	porphyry/sheeted vein	historic drilling	No
Minto	Pembridge Resources plc	115I 021	copper	porphyry/sheeted vein	operating mine	No
Monster	Go Metal Mining Corp.	116B 102	copper	iron oxide copper gold (IOCG)	historic drilling	Yes
Mount Anderson	Apex Resources Inc.	105D 029	gold	vein/breccia	historic drilling	No
Mount Hinton	Strategic Metals Ltd.	105M 052	gold	vein/breccia	historic drilling	No
Mt. Haldane	Alianza Minerals Ltd.	105M 032	silver	vein/breccia	diamond drilled	No
Nazgul	Metallic Minerals Corp.	106D 043	silver	skarn/replacement	grassroots – never drilled	Yes

Appendix 1 (continued). Exploration projects 2019.

Project	Owner/Optioner	MINFILE	Commodity	Deposit Type	Level of Advancement	YMEP-funded
Nolan	White Gold Corp.	-	gold	vein/breccia	R/C or RAB drilled	No
North Rackla	Cantex Mine Development Corp.	106C 088	zinc-lead	sediment associated	diamond drilled	No
Oli	Strategic Metals Ltd.	115P 030	tin, copper, tungsten	skarn/replacement	historic drilling	Yes
Porphyry	Mann, Bill	115H 038	copper	porphyry/sheeted vein	historic drilling	Yes
QV	White Gold Corp.	115O 004	gold	vein/breccia	NI 43-101 defined resource	No
Rawgeef	Bachynski, Ryan	-	gold	vein/breccia	grassroots – never drilled	Yes
RC	Sitka Gold Corp.	-	gold	porphyry/sheeted vein	grassroots – never drilled	Yes
Rod	Strategic Metals Ltd.	106C 087	silver	vein/breccia	grassroots – never drilled	No
Ruby Range (Kluane)	Strategic Metals Ltd.	115H 047	gold	vein/breccia	diamond drilled	No
Rude Creek Gold	Michelin Mining Corp.	115J 022	gold	vein/breccia	R/C or RAB drilled	Yes
Sawbuck	Strategic Metals Ltd.	-	silver	skarn/replacement	grassroots – never drilled	No
Silver Hart	CMC Metals Ltd.	105B 021	silver	vein/breccia	diamond drilled	No
Silver Hill Regional	Metallic Minerals Corp.	-	silver	skarn/replacement	grassroots – never drilled	Yes
Sixty Mile (BK 111)	Flow Metals Corp.	-	gold	vein/breccia	grassroots – never drilled	No
Sixty Mile (Toni claims)	Strategic Metals Ltd.	116C 153	gold	vein/breccia	diamond drilled	No
Sixtymile (BK 33)	Kreft, Bernie	116C 146	gold	vein/breccia	grassroots – never drilled	Yes
Stu	Granite Creek Copper Ltd.	115I 011	copper	porphyry/sheeted vein	historic drilling	Yes
Swift River	Prior, Glen	-	zinc-lead	volcanic associated	grassroots – never drilled	Yes
Tad/Toro	Triumph Gold Corp.	115I 031	gold	porphyry/sheeted vein	diamond drilled	No
Tiger (Rau Trend)	ATAC Resources Ltd.	106D 005	gold	skarn/replacement	NI 43-101 defined resource	No
Macmillan Pass (Tom Deposit)	Fireweed Zinc Ltd.	105O 001	zinc-lead	sediment associated	NI 43-101 defined resource	No
Ultra	Group Ten Metals Inc.	115B 008	nickel-PGE	mafic/ultramafic associated	historic drilling	Yes
Upper Rackla (BOP)	Kootenay Silver Inc.	-	zinc-lead	Mississippi Valley-type	grassroots – never drilled	No

Appendix 1 (continued). Exploration projects 2019.

Project	Owner/Optioner	MINFILE	Commodity	Deposit Type	Level of Advancement	YMEP-funded
Vault	Strategic Metals Ltd.	115G 027	gold	vein/breccia	grassroots – never drilled	No
Warden (Ward)	Burke, Ryan	105D 190	gold	vein/breccia	grassroots – never drilled	No
White Gold (Golden Saddle & Arc)	White Gold Corp.	115O 165	gold	vein/breccia	NI 43-101 defined resource	No
Wildcat	Lee, Gary	105B 001	zinc-lead	skarn/replacement	diamond drilled	Yes
Wolverine	Yukon Zinc Corp.	105G 072	zinc-lead	volcanic associated	care and maintenance	No
Zap	Strategic Metals Ltd.	106D 085	silver	Mississippi Valley-type	diamond drilled	No

Appendix 2. Drilling statistics by project, 2019.

Property	Optioner/Owner	# of drill holes	# of metres
Diamond Drilling			
Aurex	Banyan Gold Corp.	34	4382
Birmingham	Alexco Resource Corp.	10	5140
Brewery Creek	Golden Predator Mining Corp.	9	678
Casino	Western Copper Corp.	72	13 592
Coffee Project	Newmont-Goldcorp	194	30 203
Cowley Park	H. Coyne & Sons Ltd.	18	2300
Dublin Gulch	Victoria Gold Corp.	9	1617
Freegold Mountain Project	Triumph Gold Corp.	7	5557
Hartless Joe	Strategic Metals Ltd.	3	367
JP Ross	White Gold Corp.	46	9540
Justin	Aben Resources Ltd.	4	963
Keno District Deposits	Alexco Resource Corp.	19	3193
Klaza	Rockhaven Resources Ltd.	33	5750
Klondike Gold	Klondike Gold Corp.	94	8628
Lucky Strike	Lucky Strike Resources Ltd.	4	1106
Meloy	Strategic Metals Ltd.	3	941
Minto Mine	Pembridge Resources Plc		7000
Mt. Haldane	Alianza Minerals Ltd.	4	963
North Rackla	Cantex Mine Development Corp.	115	30 000
Tiger (Rau Trend)	ATAC Resources Ltd.	12	2700
Silver Hart	CMC Metals Ltd.	16	1048
Sixty Mile	Strategic Metals Ltd.	3	979
Tom Deposit	Fireweed Zinc Ltd.	16	2357
White Gold (Golden Saddle & Arc)	White Gold Corp.	29	6845
Total		754	145 849

Appendix 2 (continued). Drilling statistics by project, 2019.

Property	Optioner/Owner	# of drill holes	# of metres
Rotary Air Blast/Reverse Circulation			
All-In	Gord Richards	3	
Aurex	Banyan Gold Corp.	5	497
Brewery Creek	Golden Predator Mining Corp.	168	15 966
Coffee Project	Newmont-Goldcorp	550	60 366
JP Ross	White Gold Corp.	45	2924
Justin	Aben Resources Ltd.	20	592
QV	White Gold Corp.	8	870
Tiger (Rau Trend)	ATAC Resources Ltd.	7	275
White Gold (Golden Saddle & Arc)	White Gold Corp.	19	1257
Total		825	82 748

Yukon Geological Survey's outreach program: 2019 highlights

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Weston, L., 2020. Yukon Geological Survey's outreach program: 2019 highlights. In: Yukon Exploration and Geology Overview 2019, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 61–70.

Introduction

The Yukon Geological Survey (YGS) provides the geoscience information required for resource and land management for the benefit of all Yukoners. As this information can be highly complex and technical, public outreach and education is necessary in order to make this information accessible and meaningful.

In 2019, the YGS reached out to almost 2000 individuals from across Yukon. The majority of individuals were students, but we also met with members of the public and with First Nation citizens. While the author is the lead on most outreach activities, YGS staff also participate in public lectures, interpretive hikes and other outreach initiatives.

This paper provides a summary of outreach and education activities for 2019.

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Classroom visits and core library tours

Yukon schools follow the British Columbia curriculum, except for some Yukon-specific adaptations. Concepts of Earth science are introduced as early as grade three, or eight years of age. The YGS designs geoscience outreach and education in the classroom in a way that enhances the school curriculum by providing hands-on activities. Lessons are intended to last one class period (approximately 50-90 minutes; Fig. 1). Classroom activities will vary depending on the request by the teacher. Subjects may include any number of Earth science topics such as the rock cycle, rock and mineral identification, geologic time, geohazards, fossils or the uses of mineral resources in our everyday lives. Every attempt is made to feature rock samples from the local area. Knowledge of local rocks will help students identify them when exploring their backyard, outside of the classroom.



Figure 1. Grade 4/5 students of Golden Horn Elementary School in Whitehorse explore the various properties of identifying minerals.

Tours of the H.S. Bostock Core Library facility are always popular with Yukon students as it gives them access to tools, such as the lapidary slab saws (Fig. 2) and a petrographic microscope, used by both research and exploration geologists. While at the Core Library,

students may also use the Augmented Reality (AR) sandbox to learn about topography, or view some of the hundreds of rock and mineral specimens in the YGS' collection. In 2019, the author completed 11 classroom visits and 4 Core Library tours.



Figure 2. Grade 12 geology students from Vanier Catholic Secondary, learn how to use a rock saw.

Field trips

As with any science, the best way to engage Yukon students in geology is by bringing the classroom outdoors. Outdoor education has been proven to develop reflective and inquisitive thinking, while teaching students how to problem-solve in real-life situations. The proximity and accessibility to many geological sites in Whitehorse is ideal for taking students on field trips. These trips help students to develop a positive attitude towards science and a greater appreciation for nature.

In 2019, the YGS conducted 12 field trips. They focused on sites within the Whitehorse city limits such as the Whitehorse Copper Belt mineral occurrences and former mine sites; Miles Canyon basalt; Ibex Valley roadside geology; glacial landforms of the Chadburn Lake area; and gold panning in the Yukon River (Fig. 3). Panya Lipovsky, of the YGS, led a field trip for a class of secondary students from FH Collins (Whitehorse) to the Slims River in southwestern Yukon. Jeff Bond took grade 11 students from Robert Service School in Dawson City on a "White Channel gravel 101" tour of placer gold deposits on Bonanza Creek (Fig. 4).



Figure 3. (a) Grade 5 students from Golden Horn Elementary School collect mineralized samples of Whitehorse Copper Belt skarn. (b) Grade 12 students from Vanier Secondary School examine outcrop of the Whitehorse Trough along the Alaska Hwy west of Whitehorse. (c) A grade 2/3 class of Selkirk Elementary School explore glacial landforms in downtown Whitehorse. (d) Grade 12 students of Vanier Secondary School try their hand at gold panning on the Yukon River.



Figure 4. Jeff Bond of YGS and grade 11 students of Robert Service School in Dawson City at Lovett Hill on Bonanza Creek.

Events

Every year, the YGS participates in, and/or facilitates several geological events for Yukon students and the public that showcase aspects of Earth science.

Mining week

In Whitehorse, Mining and Geology Week takes place every year during the first week of May. The event celebrates the role that mining and geology plays in our society. The Yukon Chamber of Mines, in partnership with the Government of Yukon, hosts the event. The week includes an evening field trip for the public and culminates with a one-day, outdoor event – Mining & Geology Discovery Day Camp at the S.S. Klondike National Historic Site in downtown Whitehorse. Mining and exploration is the largest private industry in Yukon, and this event provides an opportunity to educate Yukoners about what this industry contributes to the territory.

In 2019, a record number of people participated in YGS organized tours – a public evening field trip and student tours at Discovery Day Camp. Seventy people joined in on the field trip that explored the Whitehorse Copper Belt. This past year was an exceptional year as we were able to share Whitehorse's rich history in mining and geology with a visiting grade 10 class from Rossland Summit School in south-central British Columbia (Fig. 5).



Figure 5. This past year saw a record-number of participants at the evening field trip to the Whitehorse Copper Belt as part of Mining and Geology Week, 2019.

Student tours through the Mining & Geology Discovery Day Camp allow the YGS, participating mining and exploration companies, environmental firms, as well as other government organizations, to engage with Yukon students. Students take part in hands-on activities such as rock and mineral identification, mapping, gold panning, geode smashing and much more. In May 2019, more than 350 students from 11 Whitehorse schools, as well as ~100 members of the public visited Discovery Day Camp and learned about the sustainable and responsible mining and exploration industry in Yukon.

Yukon Mining Days

This past year, the YGS participated in Yukon Mining Days – a recently initiated event that brings awareness of mining and geology to communities of Yukon. It is a Yukon Women in Mining initiative, which brings government and industry partners together to give communities and youth the opportunity to learn more about Yukon's mining sector and its career, business and investment opportunities. In 2019, Yukon Mining Days took place in four communities: Watson Lake and Ross River in May, and Mayo and Carmacks in September. Each event provided education through interactive activities on topics of geology, mapping, exploration, infrastructure, technology and innovation. The YGS engaged with ~100 individuals at each event, which included students from the local schools as well as community members (Figs. 6 and 7).



Figure 6. Leyla Weston of YGS gives a lesson on topography using the AR sandbox to elementary students from J.V. Clark School, Mayo as part of Yukon Mining Days. Photo by Maitland Photography.



Figure 7. Amanda O'Connor of YGS teaches students from Tantalus Community School, Carmacks about the minerals that are found in products that we use in our everyday lives.

Keno Rocks

Since 2004, the YGS has organized an annual forum that brings together geologists from industry, government and academic institutions, as well as prospectors working in Yukon. The event is known as 'YGS rocks' and it is held in a different mining district each year. In 2019, approximately 40 participants gathered in Keno City (Fig. 8). A welcome BBQ and overview talks in the

historic Keno Mining Museum on the evening of August 21 were the precursor to two days of tours. The first day involved a whirlwind tour of Alexco Resource Corp.'s Keno Hill property; it included more than 10 stops at various open pits and vantage points around the Keno Hill district looking at silver and base metal-rich veins that have been mined for more than a hundred years. The second day was spent touring Thunder Gulch, Duncan Creek and Minto Creek placer operations and enjoying multigenerational stories about placer mining in a variety of surficial geology settings (Fig. 9).



Figure 9. Jeff Bond of YGS explains the modalities of glacier-related sedimentation and placer gold deposition at Duncan Creek.



Figure 8. Delegates of Keno Rocks pose at Keno City sign post.

Weekend on the Rocks

The Tombstone Interpretive Centre, situated in Tombstone Territorial Park, offers a variety of programming throughout the summer that exposes visitors to the dynamic and rich ecosystem of the Park. The YGS continues to facilitate 'Weekend on the Rocks', an event that was initiated by the late Charlie Roots, a former Geological Survey of Canada geologist with an incredible passion for geology and the outdoors.

Staff from the YGS, including Don Murphy (YGS Emeritus Geologist) provided a weekend of activities including two evening talks and three interpretive hikes. Visitors learned about the geology, tectonic history, as well as the processes of glaciation in the park. This weekend is always a popular event for Yukoners and tourists alike. Roughly 20 to 30 people braved the cool autumn weather to take part in the guided hikes and various activities (Fig. 10).



Figure 10. Tombstone Weekend on the Rocks: **(a)** Amanda O'Connor engages with tourists; **(b)** talk on the glacial history of Tombstone Park by Jeff Bond of YGS; and **(c)** geology hike up Goldensides.

Yukon Geoscience Forum

The Yukon Geoscience Forum and Trade Show continues to grow every year; in 2019, there were more than 700 delegates. The event is organized by the Yukon Chamber of Mines, and jointly funded by the Government of Yukon. It provides a great opportunity to engage students and inform them about the benefits of this important resource sector. The main outreach elements of the forum are Family Day and student tours, which both take place in the trade show area. The YGS continues to work with Mining Matters – a charitable organization based out of Toronto dedicated to bringing knowledge and awareness about Canada's geology and mineral resources to students, educators and the public. Together we provided a variety of hands-on activities to more than 150 people at Family Day, and 400 students over the two days of student tours (Fig. 11).

During the student tours, youth also had the opportunity to meet professionals working in the industry. The students were issued a 'Trade Show Passport' that included questions prepared by eight participating exhibitors/companies. Students engaged with the companies to answer the questions and in doing so, they learned about the modern technology applied to the discovery of mineral resources. Furthermore, they gained a better understanding of the global nature of the mining industry, discovered the wealth of career opportunities, and learned about the industry's social responsibilities to the environment and our communities (Fig. 12).

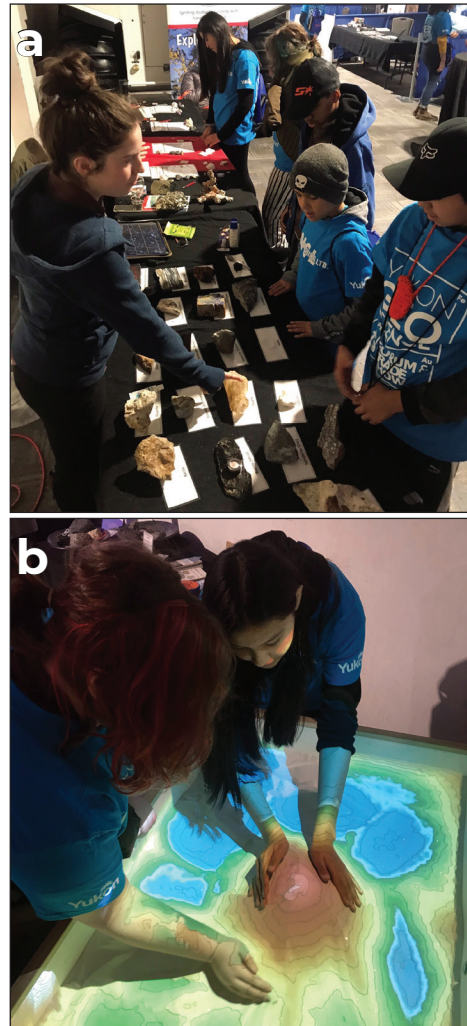


Figure 11. Students from the Ghùch Tlà Community School (Carcross) learn about (a) rocks and minerals, and (b) topography at the Yukon Geoscience Forum student tours.



Figure 12. A grade 7 student from Selkirk Elementary celebrates his win of an iPad for successfully completing his passport during the student tours.

Training

Parks and museum interpretive staff

Another component of outreach that the YGS offers is training to parks and museum interpretive staff by providing expertise in both bedrock and surficial geology of Yukon. Every spring, YGS surficial geologists participate in annual training for Beringia Centre interpretive staff. This includes presentations on current research pertaining to the Pleistocene geology of Yukon. Yukon Conservation Society also calls upon the YGS to train their summer staff on the geological history of Miles Canyon in preparation for their summer programming of free guided hikes and “Kids’ Ed-Ventures” in the canyon.

Public talks

Another effective way to communicate current research undertaken by the YGS, and geological phenomena happening around the territory is through public talks and presentations. Geological hazards such as earthquakes or landslides have a direct and measurable impact on the lives of Yukoners, and as such, it is important to keep the public informed and provide accurate scientific data on current events. Public talks are by request, and organizations such as the Yukon Science Institute have provided a great platform in the past through their public lecture series. Our staff of experienced geologists are always ready to share their knowledge and expertise on a broad range of geoscience topics. In 2019, YGS staff reached out to a wide sector of the public, both inside and outside of Yukon. Scott Casselman presented on Yukon’s mineral exploration highlights for 2018 to ~30 people at the Rotary Club of Whitehorse. In March, the author and Tiffani Fraser presented on the Denali fault project and geothermal research at a community open house in Burwash Landing. In late October, Warwick Bullen gave a talk to ~20 citizens of the First Nation of Na-Cho Nyäk Dun on the mineral potential of the Beaver River Watershed as part of the Beaver River Land Use Plan. Finally, Carolyn Relf spoke to approximately 70 students and faculty members at the University of Alberta on the YGS’ geothermal research in Yukon.

Media

The YGS has always maintained public outreach in the form of newspaper and radio media; however, local publishers (e.g., CBC radio, Yukon News, Whitehorse Star) typically initiate this. In 2016, the YGS delved into the world of social media through a Facebook page, which has transformed the way people learn about science and view our program activities. With billions of Facebook users around the world, there is no faster way to connect with people on a global scale. The YGS’ Facebook page currently has 1645 followers – a number that continues to grow. Most posts include geoscience events (e.g., Geoscience Forum, Keno Rocks, Mining Week, etc.), but also include updates on current research. The YGS’ most recent post about acquiring Yukon Consolidated Gold Corporation’s map scans from Libraries and Archives Canada (formerly known as the National Archives) reached 5.5 thousand people through shares and likes. This post sparked a CBC radio interview, as well as a potential podcast by Libraries and Archives (Fig. 13). Along with social media, Yukon North of Ordinary Magazine featured Panya Lipovksy in an article on the effects of permafrost thaw in Yukon.



Figure 13. Jeff Bond of YGS studies old maps from the Klondike.

First Nations engagement

The Yukon Geological Survey is committed to engaging with Yukon First Nations with respect to our program activities. In order to build trusting and meaningful relationships with Yukon's First Nation governments, the YGS is striving to increase communication and seek input from First Nations (FN) early on in the planning stages of projects. Routine engagement includes spring notification letters to all affected FNs with respect to our program activities, meetings with Lands and Resources staff of the FN governments, and fall follow-up letters detailing summer work.

Since 2016, the YGS has been actively engaging and collaborating with several First Nations on our geothermal research in Yukon, namely, Ta'an Kwäch'än Council, Kwanlin Dün First Nation, Little Salmon Carmacks First Nation, Ross River Dena Council, Kluane First Nation and Teslin Tlingit Council. Our research, to date, has highlighted certain areas in southern Yukon as having promising potential for geothermal resources. However, our work is still in its infancy and there are many knowledge gaps. In southern parts of Canada, geothermal is being used for many direct-use applications such as heat pumps, agriculture, aquaculture, bathing, etc.; however, nowhere in Canada is there power generation from geothermal sources.

There is great interest from Yukon First Nations to become self-reliant and to move toward cleaner energy solutions, particularly those communities that rely on burning diesel fuel for heat and energy. However, the question remains – is geothermal development feasible in Yukon? In order to answer this question, the YGS looked to our neighbours in Alaska where Chena Hot Springs Resort, near Fairbanks, operates the lowest temperature geothermal power plant in the world (Fig. 14).

In early September 2019, the YGS facilitated a half-day workshop in Burwash Landing, followed by a visit and private tour of the geothermal plant at Chena Hot Springs in order to gain some insight into how to develop a small geothermal power plant, and observe direct-use applications that could possibly serve as a model for Yukon. There were 12 participants: 5 representatives from 4 Yukon First Nations governments (Kluane First



Figure 14. Aerial view of Chena Hot Springs Resort near Fairbanks, Alaska.

Nation, Teslin Tlingit Council, Carcross Tagish First Nation and Little Salmon Carmacks First Nation); 4 Yukon government representatives; and 3 leading Canadian experts in geothermal (from outside Yukon; Fig. 15).

The main goals of the Chena Hot Springs workshop and fieldtrip were to share information with community members about the YGS' current geothermal research program, and to advance our understanding of geothermal applications in a northern setting, i.e., having a small population, limited infrastructure, and a reliance on diesel fuel where isolated from the North American power grid. Despite having a low-temperature geothermal resource (temperature at the wellhead is ~80°C), the two power plants at Chena produce 0.4 MW of electricity, which is enough power to run the entire resort (Fig. 16). Prior to switching over to geothermal in 2006, the resort burned \$1000 USD of diesel per day.



Figure 15. Participants of the geothermal workshop and Chena field trip.



Figure 16. Two binary-system power plants generate 0.4 MW of electricity at the Chena geothermal plant.

In addition to power generation, the Chena geothermal resource has several direct-use applications. One of the main attractions at the resort is undoubtedly the hot pool, which uses ‘waste heat’ from the power plant. Wastewater from the power plant is piped into the pool giving it an average temperature of 41°C or 106°F (Fig. 17). Warm water is also pumped into a number of greenhouses and garden beds to produce fresh vegetables and herbs year-round (Fig. 18). Additionally, direct-use geothermal heats 46 buildings (>100,000 sq. ft.), including 80 hotel rooms, a main lodge, restaurant and bar. Besides heating, geothermal is used to chill the Aurora Ice Museum 365 days a year through some of the hottest summers, which can exceed temperatures of 30°C.



Figure 17. Tourists take a soak in the hot pool at Chena Hot Springs Resort.



Figure 18 Geraldine Pope of Kluane First Nation (back) and Rebecca Freeman from Little Salmon Carmacks First Nation (front) admire the fresh peppers and other vegetables in the many greenhouses at Chena.

Conclusion

Our society relies on natural resources to support all aspects of our lives from recreation, to agriculture, manufacturing and building. Having geoscience knowledge is critical to maintaining a healthy, sustainable way of life for future generations. The Yukon Geological Survey is committed to continuing its outreach and providing all Yukoners and Yukon First Nations accurate geological information that will help our communities move toward greater sustainability.

Yukon Exploration and Geology 2019 abstracts

The following abstracts are from the Yukon Exploration and Geology 2019 volume. Full versions of the individual papers are available from the Yukon Geological Survey website, <http://data.geology.gov.yk.ca/>.

Preliminary report on the bedrock geology of the Rackla River area, southern Wernecke Mountains, Yukon (parts of NTS 106C/4,5 and 106D/1,8)

T. Ambrose and S. Bowie

The Rackla River area is underlain by normal faulted and gently folded sedimentary strata of the Paleoproterozoic Wernecke Supergroup, Mesoproterozoic Pinguicula Group, Neoproterozoic Hematite Creek Group and Windermere Supergroup, and Paleozoic Bouvette Formation. Gabbro dikes and sills that are likely age equivalent to the ca. 1380 Ma Hart River Sills cut the Wernecke Supergroup rocks. The presence of a mafic volcanoclastic horizon within the Bouvette allows its informal subdivision into a lower and upper member. These volcanoclastic rocks may be the distal equivalent to volcanic rocks near the Tiger deposit, located ~20 km to the southwest. Three major angular unconformities are documented in the map area: at the base of the Rapitan Group, the base of the lower Bouvette, and the base of the upper Bouvette Formation.

New mineral potential mapping methodology for Yukon: Case studies from the Beaver River and Dawson regional land use planning areas

W. Bullen

Territory-wide mineral potential mapping in Yukon was last conducted 18 years ago. An updated suite of maps for land use planning is, therefore, necessary. The Yukon Geological Survey has developed a new GIS-based mapping process for this purpose. Industry-based applications using the new method will be developed going forward.

The approach makes use of mineral system components that potentially contribute to metal accumulations in an area. The method is a hybrid between a classic data-driven probabilistic approach and an expert-driven fuzzy logic approach. It is non-specific in terms of commodity and/or deposit type – however, the claim and assessment report footprint data that are integral to the mapping process capture these important components.

The procedure makes use of block modeling techniques where each block is assigned a prospectivity and (bedrock mapping) confidence score. Calculations are based on the presence or absence of categorical features within unit cells, and the scores represent the posterior favourability of each cell. Evidential layers are weighted according to buffer distance and/or through the application of knowledge-based factors. Lithology classes are factored using a multiclass weights-of-evidence approach.

Mineral potential and confidence scores are converted to either a 1, 2 or 3 according to a defined mathematical schema. The values are then combined – blocks with scores of 1:1 have the lowest mineral potential/lowest confidence whereas blocks with scores of 3:3 have the highest mineral potential/highest confidence. Nine possible combinations exist. Mineral potential maps containing measures of both potential and confidence are generated based on the cumulative contrast values.

Areas cut by major structures along which significant displacement has occurred need to be evaluated separately, and then stitched back together at the end of the assessment process. Concurrently, the mineral potential data need to be leveled to account for prospectivity differences across the structure concerned.

Preliminary report on the bedrock geology of Castle Mountain area, Yukon (part of NTS 105D/6)

R. Cobbett

Carbonate strata of the Cambrian to Devonian Bouvette Formation underlies the Castle Mountain area in central Yukon. Locally, within the Bouvette Formation, calcareous, fossiliferous clastic rocks are interstratified with volcanoclastic and volcanic rocks. The volcanic rocks are inferred to be post-early Silurian based on preliminary fossil ages of graptolites found in underlying limestone. I propose extensional tectonism temporarily disrupted carbonate platform development in the early Silurian in this area. Crustal extension resulted in normal faulting and local subsidence. Thermal uplift, related to underplating of igneous bodies, resulted in subaerial exposure and subsequent erosion of chert, carbonate and volcanic rocks. Basins and slopes (areas between thermally uplifted blocks and subsiding areas) collected material eroding from exposed strata and volcanic rocks deposited during eruptions.

Assessment of thermo-hydraulic properties of rock samples near the Takhini Hot Spring, Yukon

H. Langevin, T. Fraser and J. Raymond

The Takhini Hot Spring area north of Whitehorse, Yukon overlies a geothermal heat source that manifests as a 46°C water seep at surface. Despite its long-term use as a tourist swimming facility, the origins and geological setting of the hot spring remains poorly understood. The objective of this study is to assess the thermo-hydraulic properties of rock samples from drill core and outcrops near the Takhini Hot Spring to better explain the presence of this hydrothermal system. A moderate rock thermal conductivity (average of $\sim 3 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$) and a low matrix hydraulic conductivity for consolidated rocks (on the order of 10^{-9} m/s^1) corresponding to a linear geothermal gradient of $16^\circ\text{C}/\text{km}^1$ in the upper part of the Takhini well indicate conductive heat transfer between 50 and 450 m depth. Hydraulic conductivity of fractured and brecciated rocks, on the order of 10^5 m/s^1 , and topographic contrasts affecting the hydrostatic pressure driving groundwater flow in the area suggest that forced convective heat transfer in the bottom of the Takhini well is responsible for the strong geothermal gradient of $250^\circ\text{C}/\text{km}^1$ observed between 450 and 500 m depth. Steep faults appear to be a key pathway for deep groundwater to seep to surface and can explain the geothermal context in the vicinity of the Takhini well. Such a framework is a typical geothermal play-type in orogenic belts. This research, therefore, helps to characterize the subsurface by using critical information needed for successful exploration of geothermal energy resources.

Updated geology and porphyry copper potential of the Klaza deposit, Mount Nansen district (Yukon MINFILE 1151 067)

W.-S. Lee, D.J. Kontak, J.P. Richards and P. Sack

Porphyry to epithermal deposit models are inferred to best describe the Late Cretaceous Klaza Au-Ag-Pb-Zn-(Cu) deposit. Here we report evidence for a protracted and complex magmatic–hydrothermal system typical of porphyry–epithermal deposits (e.g., multiple magmatic events, magma mingling, relevant vein-alteration types). In the Klaza area, there are at least four compositionally and texturally distinct intrusions interpreted as part of the Casino intrusive suite (ca. 80–76 Ma) that intrude granodiorite country rock of the Whitehorse suite (ca. 105 Ma). A ca. 72 Ma dike swarm (likely Prospector Mountain suite) was emplaced approximately 4–5 m.y. after emplacement of the Casino suite. Evidence of high-T hydrothermal activity consists of early dark micaceous (EDM) veins, sinuous and planar A-type veins, B-type, and D-type veins, and molybdenite-quartz veins. Composite epithermal-type sulphide veins cut high-T Cu-Au-Mo mineralization associated with phyllic and lesser potassic alteration assemblages. The age of porphyry-type mineralization is constrained by $^{187}\text{Re}/^{187}\text{Os}$ molybdenite dating to ca. 77 Ma (Kelly) and ca. 71 Ma (Cyprus). The $^{40}\text{Ar}/^{39}\text{Ar}$ muscovite dates from phyllic alteration in the Central Klaza zone yield ages of ca. 77 Ma. These field observations, integrated with archival Cu-Au-assay data, suggest the Klaza epithermal veins are located in the phyllic alteration shell of a two-stage Cu-Au-Mo porphyry system. It is possible that the Klaza epithermal veins represent a Prospector Mountain-age porphyry-epithermal system overprinting a Casino-age porphyry system.

Geochronologic and Pb-isotopic constraints on gold mineralization at the Plateau South property (Yukon MINFILE 105N 034, 035, 036), central Yukon

P. Sack, J. Gabites, J. Crowley, J. Benowitz, C. McFarlane, M. Gobadi and D. Ferraro

Quantitative mineralogy, U-Pb geochronology of zircon and monzonite, $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology of muscovite and sericite, and Pb isotopes from galena in veins and feldspar in plutons provide insight into the age of metamorphism, mineralization, intrusion emplacement and the sources of metals at the Plateau South (MINFILE 105N 034, 035, 036) occurrences in central Yukon. Orogenic mineralization and metamorphism is ca. 110 Ma to 100 Ma, and possibly as old as ca. 130 Ma. Following deformation and regional metamorphism, two biotite-muscovite plutons, the Russell stock and Armstrong pluton, were emplaced at 95.39 ± 0.03 Ma and 95.51 ± 0.03 Ma, respectively. These plutons are here reassigned to the Tungsten suite based on mineralogy, chemistry and age. Coeval with these plutons are contact metamorphism and possibly intrusion-related mineralization. Lead isotopic data from galena cluster into two groups: Group 1 is enriched in thorogenic Pb with $^{206}\text{Pb}/^{204}\text{Pb}$ values between 18.31 and 18.14, $^{207}\text{Pb}/^{204}\text{Pb}$ between 15.62 and 15.55 and $^{208}\text{Pb}/^{204}\text{Pb}$ between 38.77 and 38.30. Group 2 is isotopically evolved with $^{206}\text{Pb}/^{204}\text{Pb}$ values between 19.13 and 18.91, $^{207}\text{Pb}/^{204}\text{Pb}$ between 5.78 and 15.63 and $^{208}\text{Pb}/^{204}\text{Pb}$ between 39.24 and 39.07. We suggest that late Early Cretaceous mineralization is related to large-scale orogenic fluids that tapped primitive (deep?) metal sources and early Late Cretaceous mineralization, coeval with local intrusions, sourced isotopically distinct metals from the intrusions. Alternatively, all mineralization could relate to Early Cretaceous orogenic fluids but with heterogeneous, locally derived metal sources and thermal resetting of Ar ages near the intrusions.

Upper Triassic to Lower Jurassic stratigraphy of the Faro Peak formation, southern Tay River map area, central Yukon (NTS 105K)

A.C. Wiest, L.P. Beranek and M.J. Manor

The lower and upper members of the Faro Peak formation comprise Upper Triassic and Lower Jurassic successions, respectively, that are assigned to the Yukon-Tanana terrane in the southern Tay River map area (NTS 105K). The lower member is ~650 m-thick and contains a basal conglomerate overlain by argillite, limestone, basalt, and lithic feldspathic wacke to arenite, and represents part of an overlap assemblage that regionally covers Paleozoic rocks of the Yukon-Tanana terrane, Slide Mountain terrane, and ancestral Cordilleran margin. The upper member has >800 m of massive conglomerate and sandstone that overlies different stratigraphic levels of the lower member and locally sits on Yukon-Tanana basement. The upper member is coeval with Whitehorse trough strata of central Yukon and similarly records Early Jurassic exhumation of the northern Intermontane terranes. The two members are lithologically distinct, of mappable extent, and have unconformable contacts, and therefore should be separated into two new formations.

YGS list of publications and maps for 2019

YGS released 19 publications in 2019: 1 Geoscience Map, 16 Open Files and 2 Annual Reports

Geoscience Map

Bordet, E., 2019. Bedrock geology map of the eastern Lake Laberge area (parts of NTS 105E/2, 3, 6, 7 and 105D/15, 16). Yukon Geological Survey, **Geoscience Map 2019-1**, scale 1:50 000, 2 sheets.

Open Files

- Bordet, E., Crowley, J.L. and Piercey, S.J., 2019. Geology of the eastern Lake Laberge area (105E), south-central Yukon. Yukon Geological Survey, **Open File 2019-1**, 120 p.
- Bond, J.D., 2019. Paleodrainage map of Beringia. Yukon Geological Survey, **Open File 2019-2**.
- Cobbett, R. and Keevil, H., 2019. Geology of northeastern Glenlyon area (NTS 105L/10, 13, 14, 15). Yukon Geological Survey, **Open File 2019-3**, 2 sheets, scale 1:50 000.
- Kiss, F., 2019. Residual Total Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105F (south half). Geological Survey of Canada, Open File 8601; Yukon Geological Survey, **Open File 2019-4**, <https://doi.org/10.4095/314827>.
- Kiss, F., 2019. First Vertical Derivative of the Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105F (south half). Geological Survey of Canada, Open File 8602; Yukon Geological Survey, **Open File 2019-5**, <https://doi.org/10.4095/314828>.
- Kiss, F., 2019. Residual Total Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105G (south half). Geological Survey of Canada, Open File 8603; Yukon Geological Survey, **Open File 2019-6**, <https://doi.org/10.4095/314829>.
- Kiss, F., 2019. First Vertical Derivative of the Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105G (south half). Geological Survey of Canada, Open File 8604; Yukon Geological Survey, **Open File 2019-7**, <https://doi.org/10.4095/314831>.
- Kiss, F., 2019. Residual Total Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105C (north half). Geological Survey of Canada, Open File 8605; Yukon Geological Survey, **Open File 2019-8**, <https://doi.org/10.4095/314832>.
- Kiss, F., 2019. First Vertical Derivative of the Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105C (north half). Geological Survey of Canada, Open File 8606; Yukon Geological Survey, **Open File 2019-9**, <https://doi.org/10.4095/314833>.
- Kiss, F., 2019. Residual Total Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105B (north half). Geological Survey of Canada, Open File 8607; Yukon Geological Survey, **Open File 2019-10**, <https://doi.org/10.4095/314834>.
- Kiss, F., 2019. First Vertical Derivative of the Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105B (north half). Geological Survey of Canada, Open File 8602; Yukon Geological Survey, **Open File 2019-11**, <https://doi.org/10.4095/314836>.
- Kiss, F., 2019. Residual Total Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105B (south half) and 105C (south half). Geological Survey of Canada, Open File 8609; Yukon Geological Survey, **Open File 2019-12**, <https://doi.org/10.4095/314837>.

Kiss, F., 2019. First Vertical Derivative of the Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105B (south half) and 105C (south half). Geological Survey of Canada, Open File 8610; Yukon Geological Survey, **Open File 2019-13**, <https://doi.org/10.4095/314838>.

Kiss, F., 2019. Residual Total Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105B (south half). Geological Survey of Canada, Open File 8611; Yukon Geological Survey, **Open File 2019-14**, <https://doi.org/10.4095/314839>.

Kiss, F., 2019. First Vertical Derivative of the Magnetic Field, Aeromagnetic Survey of the Wolf Lake Area, Yukon, Part of NTS 105B (south half). Geological Survey of Canada, Open File 8612; Yukon Geological Survey, **Open File 2019-15**, <https://doi.org/10.4095/314840>.

Colpron, M., 2019. Potential radiogenic heat production from granitoid plutons in Yukon. Yukon Geological Survey, **Open File 2019-16**, 1 map and data.

Annual Reports

Yukon Exploration and Geology 2018. K.E. MacFarlane (ed.), 2019. Yukon Geological Survey, 142 p., digital only.

Yukon Exploration and Geology Overview 2018. K.E. MacFarlane (ed.), 2019. Yukon Geological Survey, 78 p.

Annual Overview Papers (YEG)

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