Yukon

Exploration & Geology Overview

2023

Yukon Geological Survey Activities • Yukon Mineral Exploration Program
Placer Mining Development & Exploration • Yukon Geological Survey Outreach
Hardrock Mining, Development & Exploration • YGS Publications

Yukon Geological Survey staff

Left to right: Patrick Sack, Carolyn Relf, Sydney van Loon, David Moynihan, Rosie Cobbett, Tyler Ambrose, Justin Emberley, Sarah Ellis, Panya Lipovsky, Brett Elliot, Chad Cote, Moya Painter, Bailey Staffen, Julie Minor, Diane Skipton, Maurice Colpron, Leyla Weston, Derek Cronmiller, Amanda O'Connor, Yury Klyukin.

Yukon Exploration & Geology Overview 2023

Edited by
L.H. Weston and Purple Rock Inc.

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Front cover photograph: Yukon Geological Survey fly camp on the shores of a small lake in the Rackla Range of the southern Wernecke Mountains. The rocks are carbonate of the Mesoproterozoic Pass Mountain Formation (Pinguicula Group). View to the west. (Photo by Tyler Ambrose, Yukon Geological Survey.)

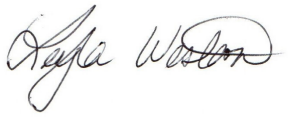
Preface

Yukon Exploration and Geology (YEG) papers and the Yukon Exploration and Geology Overview are two of the main publications of the Yukon Geological Survey (YGS; Energy, Mines and Resources, Government of Yukon). Individual YEG papers, with colour images, are available in digital format only. The YEG Overview is available in digital format and in a limited colour print run. All YGS publications can be downloaded from our website, https://data.geology.gov.yk.ca/.

Yukon Exploration and Geology 2023 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, the public and the mineral industry of the Yukon. Their work is appreciated.

This year marks a new chapter for Yukon Exploration and Geology. In September 2023, Karen MacFarlane, former Head of Technical Services for the YGS and Chief Editor of YEG retired. Karen started with YGS in 2009 and single-handedly edited and laid out 13 volumes of YEG. Her tireless effort and dedication to this volume over the last several years cannot be overstated. As a previous YEG editor, I have immense gratitude to Karen for the past 13 years during which I had the pleasure of enjoying the holiday season without having to work. After a long hiatus, I am back at it this year, but thankfully not alone. I have had the great pleasure to work with Nicole Barlow, Moretta Shuert and the team at Purple Rock Inc., whose hard work and professionalism have made the transition truly seamless. I do hope they'll stay!

I hope you enjoy the volume. Input or suggestions that you may have to improve future YEG publications are welcomed. Please contact us at (867) 393-7187, or by email at geology@yukon.ca.



Leyla Weston

Yukon Exploration and Geology Overview 2023

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Yukon Geological Survey 2023 overview

*Carolyn Relf**
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Relf, C., 2024. Yukon Geological Survey 2023 overview. *In:* Yukon Exploration and Geology Overview 2023, L.H. Weston and Purple Rock Inc. (eds.), Yukon Geological Survey, p. 1–16.

Introduction

This paper provides a high-level overview of the Yukon Geological Survey's (YGS) activities in 2023. Several of the projects described here are presented in more detail in the 2023 Yukon Exploration and Geology technical papers volume. References to these are included where applicable.

The YGS had a challenging year in 2023. Wildfires and landslides punctuated the field season, disrupting field plans for some, and requiring work priorities to be adapted. Additionally, the survey had six staff members leave and two others were on extended absences, which had an impact on operations. Despite a reduced capacity, YGS staff continued to deliver on projects and fill client requests for information. Recruitment efforts are underway and YGS anticipates seeing growth in the coming year.

Looking forward, 2024 marks the start of the survey's next five-year planning cycle. The YGS has started preparing for discussions among staff, research partners and clients about knowledge gaps and emerging needs. Readers are welcome to reach out and share their project ideas or suggest ways to improve on data delivery.

Snapshot of YGS

Staffing

The Minerals Geology and Surficial Geology units were most affected by staff vacancies in 2023. In January, Scott Casselman (Head of Minerals Geology) joined Rackla Metals as VP of exploration; he is now exploring for gold in the Tombstone belt in NWT and Yukon. Warwick Bullen (Mineral Assessment Geologist) joined Abyssinian Metals in February, working on mining projects in Ethiopia and other African countries. Collectively, they have more than 60 years of mineral exploration experience and their departures have left a big gap. In the Surficial Geology unit, Jeff Bond retired in September after more than 25 years working with YGS, mapping surficial geology and geohazards at a variety of scales and providing expert geological advice to placer miners. In March, Kristy Kennedy's secondment to Kluane First Nation was extended to November, and Panya Lipovsky took six months of deferred leave between April and September. As a result of these staff movements, the Surficial Geology unit was thin on capacity in 2023.

Other 2023 departures included Karen MacFarlane, who retired in July after 15 years leading the Technical Services unit and serving as publication editor. Sarah Sternbergh completed her term with the Bedrock Geology unit in March and joined Tetra Tech's Environmental Group in Whitehorse. In October, Julie Minor was offered the position of Finance Manager for Energy, Mines and Resources. Julie has managed YGS finances for the last seven years and her low-key competence has lulled the YGS into a sense of complacency, trusting that things will just get done. To all our ex-YGS staff, we wish you the best of luck in the various next chapters of your lives. We will miss you all.

While several people moved on from YGS, there were some additions as well. Chad Coté joined the survey as a Geomatics specialist, and Amanda O'Connor was hired as an Outreach Geologist. In the fall, Kristy Kennedy and Panya Lipovsky rejoined the Surficial Geology unit, and in December, Diane Skipton returned after a one-year maternity leave.

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For the past two years, YGS has been advancing plans for a minor re-organization. The organizational chart (Fig. 1) reflects these changes, which are anticipated to be finalized early in 2024. The reorganization involves two significant changes. First, a position has been created for a Geoscience Research Manager, to which all three geology units (Bedrock, Surficial and Minerals) will report. This manager will focus on coordinating studies across the three units to enhance collaboration between disciplines. They will also take some of the administrative burden off the unit heads, freeing up more of their time to focus on research. An additional role will be to help identify external sources of funding, which make up a significant portion of YGS' annual budget. The other structural change is the addition of a second Outreach Geologist position. This position was created to increase YGS' capacity to engage with Yukon First Nations on project plans, and to fill the growing demand for geoscience information by communities and the public. For instance, the recent increase in the number and frequency of landslides around the territory has led to greater awareness of climate change–induced landscape changes and their impacts. Ongoing land-use planning is also creating pressures, not only for the provision of mineral potential maps, but also for the role critical minerals will play as Yukoners work to reduce greenhouse gas emissions.

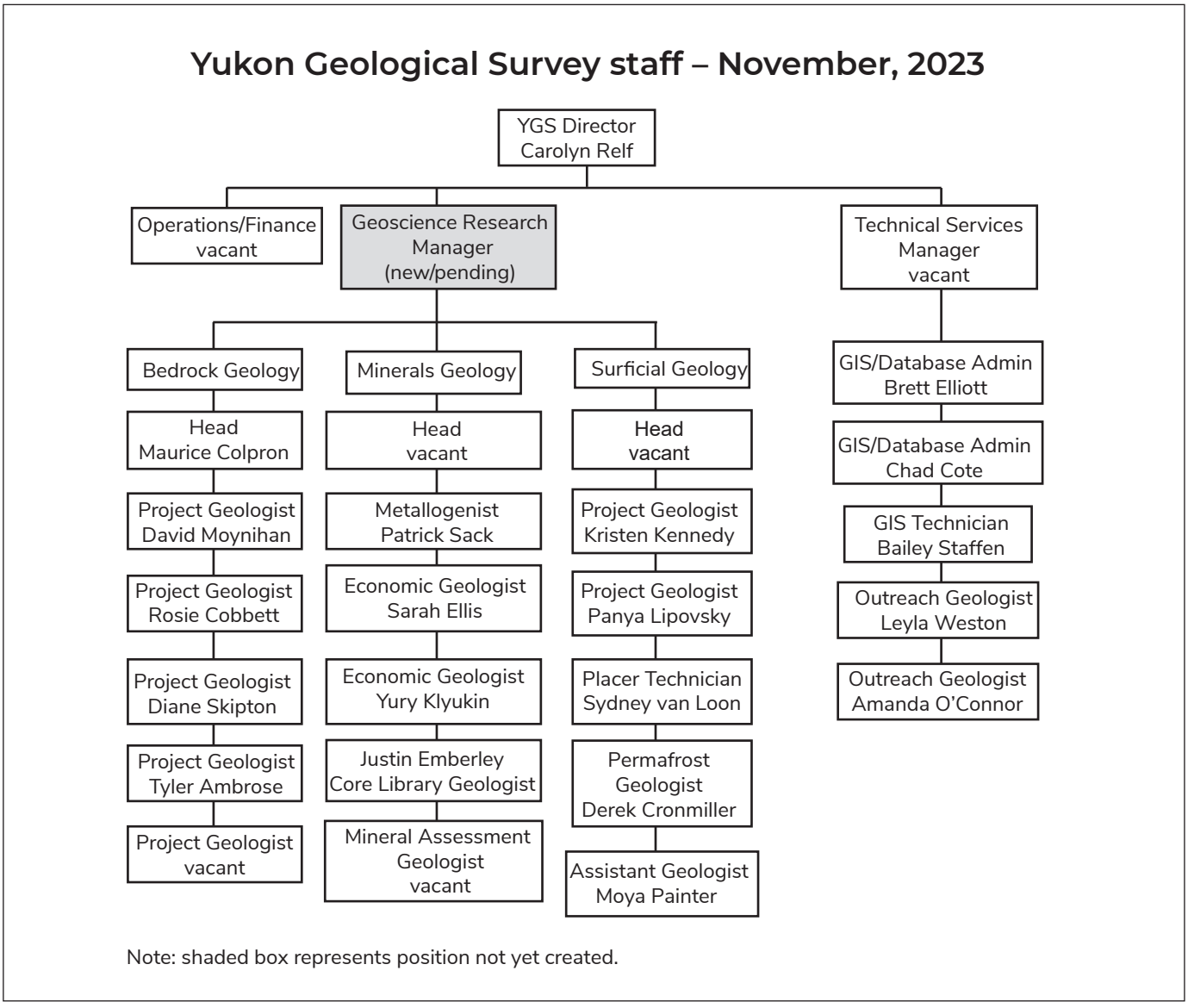

Figure 1. *Yukon Geological Survey organizational chart.*

Budget for YGS

The YGS' operational budget for 2023–24 was $4,083,000, broken down as follows:

- $1,365,000 Operation and Management, which covers core YGS project activities and administrative costs;
- $425,000 to support geothermal research ($300K) and geohazard assessments in communities and along highway corridors ($125K), as part of the Government of Yukon's 'Our Clean Future' initiative;
- $249,000 from (Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC)) to support geohazard studies in the Klondike Region and along the Dempster Highway;
- $230,000 of federal money committed by CIRNAC for drilling and instrumenting boreholes to enhance permafrost monitoring;
- $380,000 from the Geological Survey of Canada's Geo-mapping for Energy and Minerals (GEM) program for a regional magnetotelluric survey; and
- $1,433,000 for the Yukon Mineral Exploration Program (YMEP), of which $1.4M are allocated for grants under the program.

Details of the activities funded by these sources are presented in the sections that follow.

Bedrock studies

In 2023, fieldwork was carried out on eight bedrock projects (Fig. 2). These included regional bedrock mapping projects (four), stratigraphic studies (two), and projects focused on mineral deposits/metallogeny (two). Highlights of these projects are presented below.

Teslin map area

In 2023, David Moynihan wrapped up three seasons of bedrock mapping that covered the area between the Teslin fault and Quiet Lake. The map area is shown in Figure 2 (location 1); both the entire map area and the area of focus for 2023 fieldwork are outlined. Moynihan's mapping suggests that rocks of the Cassiar terrane are more widespread in this part of Yukon than shown on existing maps.

The central part of Moynihan's map area is underlain by the Quiet Lake batholith, which cores a northwest-striking upright anticlinorium (Fig. 3). The batholith intrudes into a sequence of rocks that is correlated with the Cassiar terrane (Askin and Earn groups). Garnet amphibolite and eclogite are exposed on the southwest (near the Teslin fault) and northeast (St. Cyre klippe) flanks of the anticlinorium, and are interpreted to form part of a thrust sheet that was arched over the batholith. Correlation of these high-grade rocks across the area is based on the *ca.* 266 Ma ages of metamorphic zircons (Moynihan and Crowley, unpublished data, 2022, 2023; Fallas *et al.*, 1998; Petrie *et al.*, 2016). The southwestern edge of the map area is bounded by the Teslin fault, along which deformed rocks of the Yukon-Tanana terrane are preserved.

Moynihan's observations from the 2023 field season are presented in Moynihan (2024). He will initiate compilation of a Geoscience Map and Bulletin on the entire study area in the spring of 2024.

Rackla River area

Tyler Ambrose completed a fifth and final season mapping in the Rackla River area in 2023 (Fig. 2, location 2) and has initiated work on a final Geoscience Map and Bulletin detailing the results of the project. Following last year's release of a compilation of whole-rock and sulphide isotope datasets (https://data.geology.gov.yk.ca/Compilations/), Ambrose and Patrick Sack have initiated a study investigating the lead isotope compositions of carbonate-hosted zinc occurrences in Selwyn basin and Ogilvie Platform.

Ambrose is also working with PhD student Lucy Webb (Stanford University) on a stratigraphic reinterpretation of Proterozoic rocks in the Coal Creek Inlier (Fig. 2, location 3). The rocks here are stratigraphic equivalents to the units he has been mapping near Rackla River. Preliminary results of this work are presented in Webb and Ambrose (2024).

Misty Lake area

Rosie Cobbett initiated a new bedrock-mapping project in the Misty Lake area (Fig. 2, location 4), and her 2023 fieldwork entailed a few weeks of reconnaissance work to familiarize herself with the geology of the area. The project will focus on subdividing rocks of the Hyland Group using stratigraphic subdivisions defined to

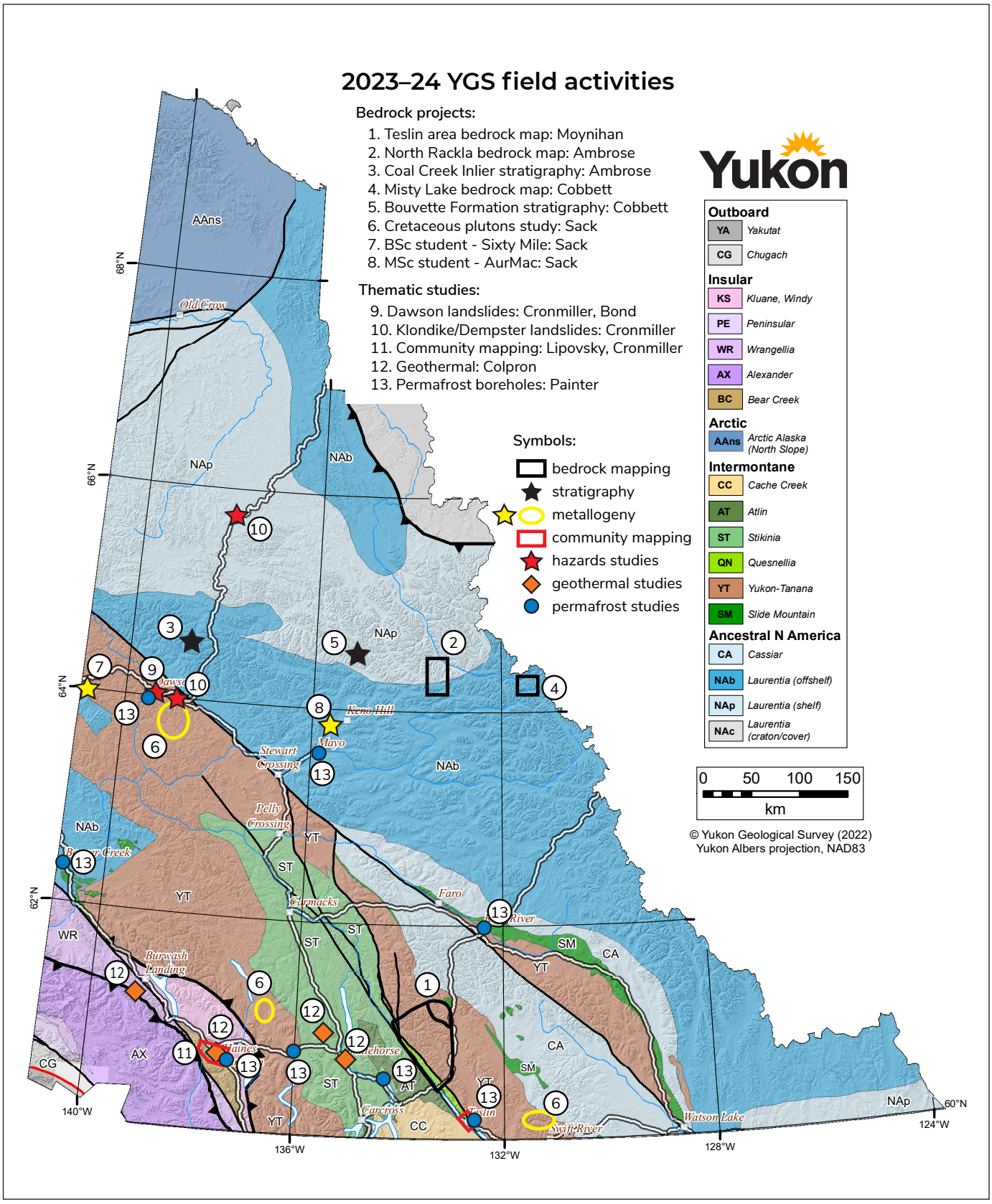

Figure 2. *Locations of 2023 YGS field activities. Terrane map from Yukon bedrock geology map (Colpron, 2022).*

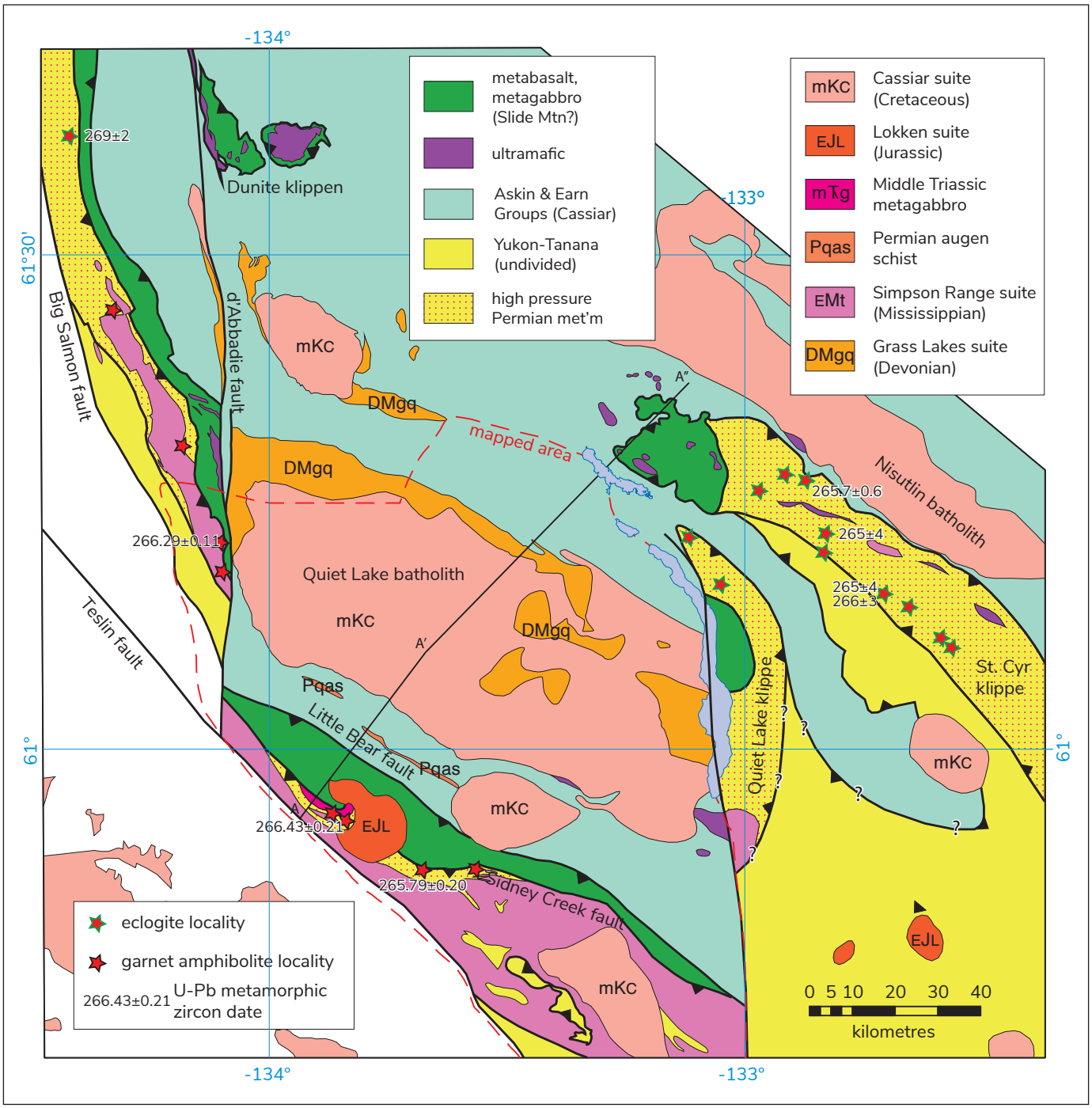

Figure 3. *Simplified geology map of the Quiet Lake batholith and surrounding area. Dashed red line indicates area mapped as part of the Teslin mapping project.*

the west (Moynihan *et al.*, 2019) and better defining Paleozoic rock units and structures northeast of the Hyland Group.

One of the units of particular interest in the area is the Algae Formation, which preserves fossils from the Ediacaran-Cambrian boundary. Cobbett collaborated with Reina Harding (Dartmouth College), who collected samples and data for her PhD thesis. A second PhD student (Prescott Vayda, Virginia Tech) participated in the fieldwork and collected fossils to support his research (Fig. 4).

Bouvette Formation

In addition to initiating new mapping at Misty Lake, Cobbett continued collaborating with Justin Strauss (Stanford University) on a study of the Bouvette Formation (Fig. 2, location 5). In 2022, they measured a section through the lower part of the formation. In 2023, they completed measuring the upper part of the formation. This represents the first complete stratigraphic section of the entire Bouvette Formation (approximately 2.5 km); a unit that records carbonate deposition and minor volcanism on the Yukon stable block throughout the Paleozoic (Morrow, 1999).

AurMac study

Patrick Sack initiated a project with Pilar Lecumberi-Sanchez (University of Alberta) for an MSc thesis study of the gold deposits at AurMac (Fig. 2, location 8). The pair are supervising student Keagan Parry, who started fieldwork in 2023. His first field season focused on logging core from the AurMac deposits and collecting samples for lab work. Preliminary graphite geothermometry shows a temperature gradient across the area, which may indicate the presence of a buried intrusion (heat source) to the north.

Late Cretaceous pluton metallogeny

Patrick Sack wrapped up his study of Late Cretaceous magmatism and metallogeny, focusing fieldwork in three areas in 2023: the Klondike, south Aishihik Lake and Rancheria areas (Fig. 2, locations labelled 6). Samples were collected for whole-rock geochemistry, isotope analysis and U-Pb geochronology to characterize this widespread magmatic event and assess the copper porphyry potential of these rocks.

Results of this project will be written up as an Open File atlas of Late Cretaceous plutons once all the analytical work is completed.

Figure 4. *Trilobite from the Sekwi Formation near Misty Lake.*

Sixty Mile area

Patrick Sack's student Emilia Butty (Queen's University) carried out fieldwork for a BSc thesis in 2023 (Fig. 2, location 7), mapping volcanic rocks in the Sixty Mile district and collecting samples for geochemical and geochronological analyses (Fig. 5). Two preliminary U-Pb ages of 69.8 Ma (J. Crowley, unpublished data, 2023) confirm the correlation of these rocks with Late Cretaceous volcanic rocks of the Carmacks Group. An Open File map of the area is anticipated for release in early 2024; Butty's thesis will be completed shortly thereafter.

Figure 5. *Patrick Sack examining Klondike Schist in Emilia Butty's thesis area. Photo taken on lower Bedrock Creek.*

Other bedrock projects

Rosie Cobbett continued writing up the results of her PhD thesis research on Paleozoic volcanic rocks that are preserved as part of the continental margin across central Yukon (e.g., Goodfellow *et al.*, 1995). This includes three papers—one of which was recently published (Cobbett *et al.*, 2023), and two of which are in prep (*Cambrian and Late Ordovician magmatism along the Dawson fault*, and *Implications of alkali igneous rocks in southwestern Northwest Territories-southeastern Yukon*). Cobbett anticipates completion of her thesis at Memorial University of Newfoundland in 2024.

David Moynihan continued working on a Bulletin that summarizes results of mapping in the Upper Hyland River area between 2015 and 2018. The project included a comprehensive study of the pressure-temperature history in the central part of the area. Completion of the Bulletin is anticipated in spring 2024.

Justin Emberley and Andrew Schaeffer of the Geological Survey of Canada–Pacific (GSC-Pacific) visited a broadband seismic station at Stokes Point over the summer to perform annual maintenance. The station was installed in 2022 as part of a Canadian network of earthquake-monitoring instruments for the GSC's Geohazards Program. The YGS has supported the network by providing field assistance during maintenance.

Thematic studies

Dawson landslide monitoring

In fall 2022, YGS installed a series of near-real time monitoring instruments on the Moosehide rock avalanche in Dawson City, and supported an MSc thesis study of a second large rock slide nearby (the Sunnydale slide; Fig. 2, location 9). The latter slide is located just upstream of Dawson City on the west bank (far shore) of the Yukon River. In 2023, YGS contracted BGC Engineering to complete a hazard assessment of the Sunnydale slide. The study modelled landslide runout as well as the magnitude and impact of a slide-generated displacement wave for six scenarios (based on two volumes of debris at low, high and average water levels). The study prompted the installation of near–real time instruments on the slide in spring 2023 (Fig. 6). Currently BGC Engineering is working with Derek Cronmiller of YGS to monitor these two large slides. Their contract with YGS runs through to March 2025, at which point YGS staff will take over the monitoring.

Cronmiller is also monitoring a number of landslides and permafrost issues in and around Dawson City. These include substantial erosion along creeks in West Dawson and Sunnydale (related to permafrost degradation), and widespread slope instabilities throughout the Klondike Valley. Several slopes that pose a risk to the public were documented and instrumented for long-term monitoring. These sites are being integrated into a permafrost modelling study in collaboration with Dr. Stephan Gruber (Carleton University) to understand how ground temperature change is driving regional instability.

Landslides on the North Klondike and Dempster highways

Landslides along the North Klondike and Dempster highways continued to cause road closures and pose risks to motorists in 2023. Cronmiller installed near–real time tilt meters and ground temperature sensors at sites near Rock Creek and Dempster corner (North Klondike Highway), and worked with colleagues from Yukon's Department of Highways and Public Works to coordinate road closures.

To help understand how permafrost degradation and landslides are affecting the Dempster Highway,

Figure 6. *Panya Lipovsky adjusting a GPS unit installed on the Sunnydale landslide.*

Cronmiller initiated an MSc thesis study with Heather Clarke (Simon Fraser University). Clarke is examining slides in areas where recent wildfires have affected permafrost between KM 130 and 370 (Fig. 2, location 10 on the Dempster Highway). Preliminary results of her work are presented in Clarke *et al.* (2024).

Community geohazards mapping

Upon completion of the Greater Whitehorse Area community geohazards study, Panya Lipovsky resumed work in 2023 on the Haines Junction map (Fig. 2, location labelled 11). The 1:15 000-scale map covers approximately 200 km^2 and documents surficial geology in and around the community, integrating remotely sensed data (air photos, satellite images and lidar) with field observations. Moya Painter and Derek Cronmiller also contributed to the project by facilitating targeted drilling for long-term permafrost monitoring wells. The map reveals widespread but discontinuous permafrost across the area, including local ground ice, and helps to constrain the limits of Neoglacial Lake Alsek. The final map and accompanying report will be valuable for informing community infrastructure planning and agricultural developments. It will also serve as a tool for identifying aggregate resources and geohazards (e.g., landslides, permafrost). Lipovsky plans to complete the map and report by summer 2024.

In collaboration with Lipovsky and Cronmiller, Jan Dettmer and Jeremy Gosselin (University of Calgary) initiated a novel study using passive seismic data from anthropogenic sources to characterize near-surface ground conditions around Haines Junction and Whitehorse. Specifically, the goal of the study is to identify areas where thawing permafrost may lead to increased seismic risk due to unconsolidated sediments being subject to more intense shaking during an earthquake. Their work is described in more detail in Dettmer and Gosselin (2024).

The YGS has been mapping the surficial geology and associated geohazards for the communities of Teslin and Beaver Creek. The Teslin map builds on work completed by Cronmiller when he was employed by Palmer Environmental and is supplemented with additional mapping and borehole logging by Lipovsky in 2022. In 2023, Cronmiller undertook additional field mapping and plans to release the map in 2024. The map of Beaver Creek is scheduled for release early in 2024; an associated hazards report will follow in the spring/summer of 2024.

Community-based geothermal studies

In 2023, YGS began winding down a series of geothermal studies targeting communities located near major faults (Fig. 2, locations labelled 12). A systematic approach was taken for the studies by collecting geological, geophysical and lidar data, and compiling the information to generate three-dimensional geological models. Modelling focused on identifying sites where fault bends may create local areas of extension (potential pathways for geothermal fluids) and near-surface anomalies characterized by high conductivity values (potential brines). The intent of these studies was to locate geothermal targets near these communities that could be tested with temperature gradient wells. To date, work around Watson Lake (Witter, 2022) and Teslin (Witter, 2023) has been completed. At Haines Junction, gravity and magnetotelluric data have been collected, and work will begin this winter to compile and interpret these data.

Near Burwash Landing, geothermal research has been ongoing since 2018. Geological modelling of the type described above was completed in 2020 (Witter, 2020) and a drill target was identified along the Duke River, 10 km west of the community. Since then, work has focused on refining the geophysical model with additional datasets: more detailed magnetotelluric data (Tshirhart *et al.*, 2022a, b), drone lidar surveys (Finley *et al.*, 2022), and fracture analysis (Chapman *et al.*, 2023). More recently, there has been seismic data analysis (Han *et al.*, 2024; Berumen-Borrego *et al.*, 2024), and data collection from shallow temperature loggers (S. Grasby, unpublished data, 2022). Han *et al.*'s (2024) study reveals that the Denali fault near the Duke River drill site is not active; instead, displacement is occurring on nearby faults that parallel the Denali fault. The authors suggest that seismicity along these structures may enhance permeability and have implications for geothermal potential. Modelling of broadband seismic data by Berumen-Borrego *et al.* (2024) enabled estimates of the thickness of surficial sediment cover in the area. Such information is valuable for the design of temperature gradient and/or production wells, if there is interest for additional wells in the future.

The first phase of a temperature gradient well at the Duke River site was drilled to a depth of 220 m in fall 2022. The well was instrumented with a fibre-optic cable capable of measuring both temperature and seismic signals. In 2023, PhD student Fiona Chapman

(Institut national de la recherche scientifique – INRS) measured the temperature gradient and conducted a heat injection test to determine the downhole thermal conductivity and calculate heat flow at the Duke River site. She also collected temperature gradient data and conducted a heat injection test from a 384 m deep well in surficial sediments within the community of Burwash Landing. The community well was drilled by Kluane First Nation. Temperature gradients from the two wells are shown in Figure 7.

A new geothermal study was initiated late in 2023 in collaboration with the Business Transformation Branch (BTB) at Highways and Public Works. Under Yukon's 'Our Clean Future' initiative, BTB has been tasked with identifying ways to reduce greenhouse gas emissions generated by heating public buildings. In 2022, they commissioned a study to assess the feasibility of geothermal heating opportunities in and around Whitehorse, focusing on areas around Yukon University, Whistlebend and Riverdale. The geology around the university campus is particularly appealing because it has many parallels with the geology surrounding the Takhini Hot Springs; specifically, a number of warm springs occur at the contact between Upper Triassic limestone and sandstone units in the Porter Creek and Crestview neighbourhoods. These rocks are intruded by the Haeckel granite pluton, which is inferred to be similar to the radiogenic Eocene granite found to the west of Takhini Hot Springs (Fraser et *al.*, 2019). In October, YGS partnered with BTB to collect gravity data as a first step in assessing the area's potential. Data collection was completed in 2023 and processing of the data is expected to be completed by spring 2024.

Although not specifically within a community, YGS supported a geothermal research project in the Takhini Hot Springs area, led by Xavier Léveillée-Dallaire of INRS. The study (Léveillée-Dallaire and Raymond, 2024) generated a hydrothermal model of the area surrounding the Tahkini Hot Springs, using temperature and petrophysical data from a well drilled by YGS in 2017 near the spring (Fraser et *al.*, 2019). The model, which attempts to simulate the observed water temperatures at the hot spring and in the well, suggests that basal heat flux, surface recharge, thermal conductivity and permeability of the rocks are all key factors in the observed conditions.

Maurice Colpron will coordinate the synthesis of the results from the above geothermal studies. Publication of the results is anticipated in 2024.

Regional geothermal investigations

In addition to geothermal studies at the community scale, YGS contracted a regional magnetotelluric (MT) survey across southern Yukon in 2022 and 2023 (Fig. 8). This contract was funded by the GSC through their GEM-GeoNorth program. The survey followed highway corridors, infilling areas that were not covered by the Slave Northern Cordilleran Lithosphere Experiment (SNORCLE) transect under the LITHOPROBE program of the 1990s. Data were also collected by helicopter

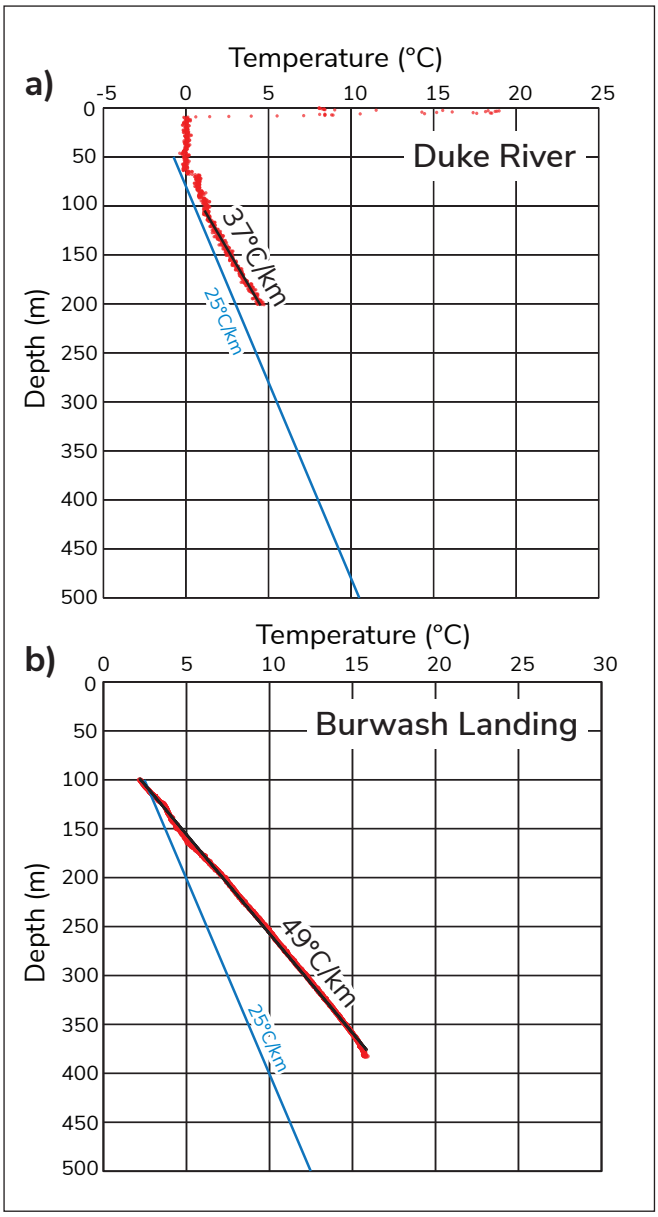

Figure 7. *Temperature gradient data:* ***a)*** *the Duke River well (10 km west of Burwash Landing), and* ***b)*** *the Burwash Landing well in the community.*

along a remote transect to fill a gap between data acquired in the Klondike area and the Kluane Lake region.

The intent of this survey is to characterize regional crustal-scale magnetic and conductive features that may reflect the presence of large-scale structures in order to target areas for future geothermal assessment.

Permafrost monitoring

Moya Painter took the lead role in permafrost monitoring for YGS in 2023, overseeing drilling of 19 new boreholes in targeted locations (Fig. 2, locations labelled 13). These include boreholes in Haines Junction and Teslin (two per community), and single boreholes in Mendenhall, Marsh Lake, Dawson City, Ross River and Beaver Creek. These boreholes range in depth from 7 to 10 m and are instrumented with thermistors. The boreholes in Dawson City, Ross River and Beaver Creek were located next to new water wells. In addition to these, 10 deep boreholes (ranging in depth from 15 to 30 m) were drilled in 5 communities in the fall (Dawson City, Mayo, Ross River, Beaver Creek and Haines Junction; Fig. 9). These boreholes were designed to enable monitoring of temperature changes at the base of permafrost. Thermistors will be installed in these wells in 2024.

The 19 boreholes drilled in 2023 brings the total number of YGS permafrost monitoring wells to 47. Temperature data were downloaded from the wells this summer, and Painter will upload the new data to the permafrost database (https://service.yukon.ca/permafrost/) over the winter. More details on the borehole project are presented in Painter *et al.* (2024).

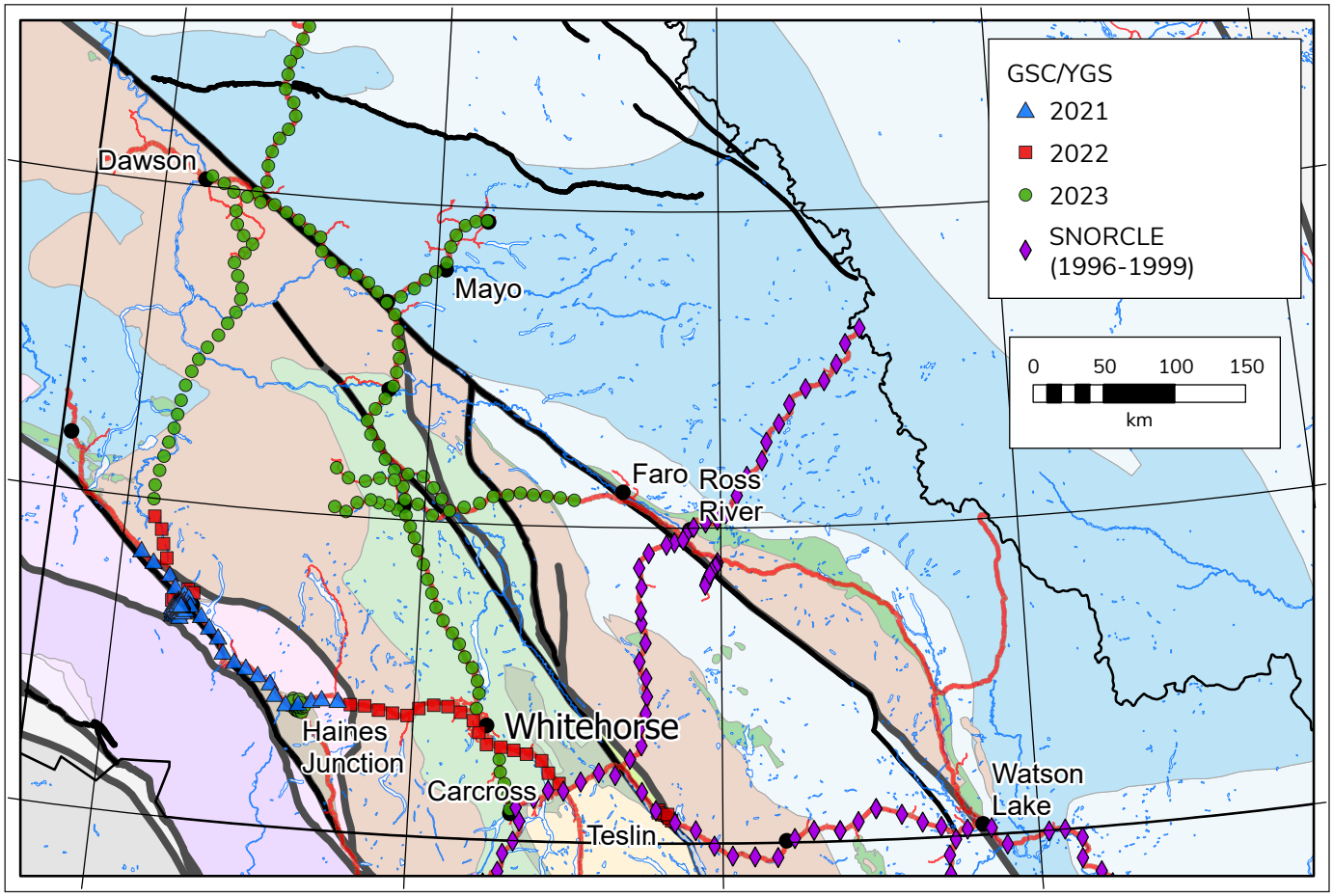

Figure 8. *Map illustrating magnetotelluric (MT) station locations. Green dots indicate sites where data were collected in 2023.*

Mineral industry services

Hardrock industry liaison

Staff carried out visits to 30 exploration properties in 2023. Sarah Ellis led the team, visiting 28 properties and capturing data from colleagues on properties she did not see in person. These visits provide staff an opportunity to familiarize themselves with property-scale geology, document preliminary exploration results, and collect data on exploration spending. One of the highlights of the 2023 exploration season was the keen interest in exploration for reduced intrusion-related gold systems, triggered by the discovery of the Valley gold occurrence by Snowline Gold Corp. in 2022.

Preliminary exploration, development and production results from 2023 are presented in Ellis and Sack (2024). Exploration data for 2023 will continue to be tracked into 2024 and will be presented by Ellis at the 2024 Mineral Exploration Roundup in Vancouver.

Figure 9. *Ice-rich core from a permafrost-monitoring borehole in Ross River.*

The YGS' Core Library facility was used for 17 days by 8 different clients in 2023; usage consisted mainly of core logging. During the summer, Justin Emberly continued to oversee the move of drill core from the old core storage facility on Range Road to the H.S. Bostock Core Library on the Alaska Highway. Two students were hired to assist with the move; they moved, catalogued and photographed more than 1600 boxes (15 properties) in 2023. The YGS anticipates that all remaining core will be removed from the old facility by the end of 2024.

Placer industry liaison

Sydney van Loon and Jeff Bond visited 70 placer operations in 2023, collecting data that will be compiled in the next Placer Industry Report and liaising with researchers working in the Klondike (Fig. 10). Both geologists attended the annual Gold Show in May, where they promoted YGS' historical placer database and recent publications related to the placer industry (*e.g.*, van Loon and Bond, 2021, Steinke *et al.*, 2023), and planned 2023 field visits. They also attended the Klondike Placer Miners Association's annual barbeque in August, where members honoured Bond's career and his contributions to the sector.

As Bond wrapped up YGS commitments in advance of his retirement, van Loon stepped in to manage placer-related activities for YGS. In July, she spent a week in the Sixty Mile area with Patrick Sack, investigating links between hardrock mineral occurrences and placer activities to help assess placer potential. In late August, she led a field trip for Vancouver Island University students who were studying placer geology.

November marked the 13th anniversary of the annual Placer Forum that takes place during the Yukon Geoscience Forum. The 2023 Forum featured presentations ranging from wetlands research and the implementation of the Yukon Wetland Policy to a discussion on drone use in the placer industry. It also included an exhibition from the Klondike Placer Miners Association celebrating 125 years of gold mining. Of particular interest to the audience were presentations by staff from the Department of Environment, who shared information on the Government of Yukon's wetland inventory framework. This was a very relevant topic due to the upcoming regulations regarding wetland disturbance and reclamation.

Highlights from the 2023 field season are summarized in van Loon (this volume).

Yukon Mineral Exploration Program (YMEP)

At the time of writing, 44 proponents had completed work on YMEP-supported exploration projects, which included 27 hardrock and 17 placer projects. Spending commitments from these proponents total more than $3.7M, representing a leveraging ratio (total spend versus total grants) of 2.6:1, based on the $1.4M in available funding.

The YGS recently started collecting data from YMEP recipients on their expenditures. These data, collected each January as part of the final reporting requirements, are intended to provide indicators on the economic impact of the program. Data from 2022 recipients showed that 83% of funds spent on YMEP projects stayed in the territory. Of this, 41% was spent on local contracts (drilling, air charters, camp services, etc.), 25% went to wages, and 17% was spent on supplies (groceries, fuel, lumber, etc.). Statistics on 2023 spending will be submitted in January 2024, and will be reported in next year's overview.

More details on YMEP activities are presented in Ellis and Sack (this volume).

Compilation of geochemical data from assessment reports

In 2022, Yury Klyukin initiated the compilation of geochemical data from assessment reports. These data are expected to be released in early 2024 via GeoYukon (https://data.geology.gov.yk.ca/Compilations), and through YGS' web map application. Included in the compilation are geochemical data from more than 300 000 soil, rock, stream sediment, and vegetation samples from more than 300 assessment reports. Klyukin has been working on a tool to simplify data extraction from new assessment reports and streamline its capture in the database going forward. The project is described in more detail in Klyukin (2024).

Drill core update

In 2022, Calgary-based GeologicAI was funded through Canada's Innovation Supercluster to develop logarithms to aid in logging drill core. As part of the project, they scanned 82 drillholes from YGS' core collection (60 from the Tom & Jason deposits; 12 from Minto; 7 Kudz Ze Kayah, and 1 each from Klaza, Rusk and Cyprus). The company generated high-resolution photos, X-ray fluorescence (XRF) analyses, lidar and

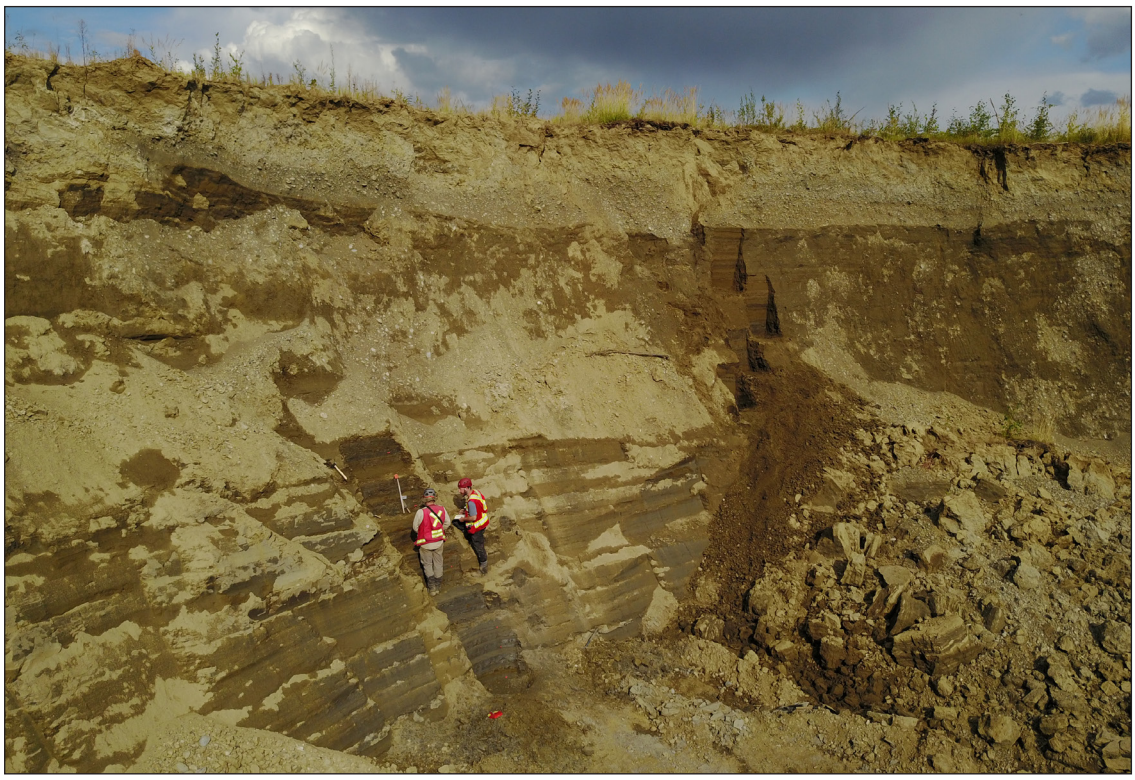

Figure 10. *Brent Ward (Simon Fraser University) examining a section of Klondike outwash gravel at Lovett Hill with one of his graduate students.*

hyperspectral images from the cores. These logs are now available to view via YGS' website: https://yukon.maps.arcgis.com/home/item.html?id=87457fac7009430189f95d909cba55a6

MINFILE

In 2023, YGS' Technical Services staff worked with colleagues from the Geological Survey of Canada and other provincial and territorial surveys to develop a single portal through which all mineral occurrence data in Canada could be queried and viewed. The intent of this project is to remove provincial and territorial borders from online searches for mineral occurrence data and present a unified national view. A prototype has been developed with data from seven of twelve jurisdictions, including data from the Yukon. It is anticipated that the portal will soon be publicly accessible.

In the meantime, YGS has initiated discussions for ways to improve MINFILE, which currently has a number of issues, including location inaccuracies, inconsistencies in how data are captured, and errors inherited from the original data files. The national online mineral occurrence project is serving as a catalyst for YGS to upgrade MINFILE.

Updates to online data

In collaboration with various YGS geologists, Chad Coté updated several online data layers available on GeoYukon (https://data.geology.gov.yk.ca/Compilations/). These include the bedrock and surficial geology layers, lithogeochemistry, geochronology, and the sulphur and lead isotope datasets. Additionally, a new compilation of the geothermal dataset is being finalized and is expected to be released early in 2024.

Outreach activities

Requests for classroom visits continued to grow in 2023. With Amanda O'Connor joining YGS in August, the survey's capacity for outreach and engagement has doubled, enabling the YGS to respond to more requests (Fig. 11). In Whitehorse, Leyla Weston and O'Connor organized in-class workshops and led tours of the Whitehorse Copper Belt for 14 classes. Whitehorse students also had an opportunity to participate in Mining Week activities. Beyond Whitehorse, O'Connor and Weston visited classes in Carmacks, Mayo and Haines Junction. While in Haines Junction, they organized outreach activities at the Dakwäkäda Mountain Festival, and Weston presented an overview of the territory's geothermal energy potential.

To the broader public, YGS hosted Weekend on the Rocks (involving interpretive hikes and public lectures at Tombstone Park), organized geology hikes in Kluane Park, and ran tours of the Whitehorse Copper Belt.

In addition to educational activities, YGS participated in three targeted events to engage with Yukon citizens on geoscience-related work. The first was a workshop organized by Yukon's Water Resources Branch. The intent of the workshop was to share information on a flood-mapping initiative and prioritize communities for mapping based on their level of risk. Staff from YGS participated in the event, presenting information on some of its geohazards work. Discussions focused on hazards that are associated with flooding, such as bank erosion and precipitation-induced landslides. The second event was an open house in Dawson City to share results of a recent hazard assessment that was undertaken by BGC Engineering on the Sunnydale slide. This work is part of a broader initiative by Yukon government, Dawson City and Tr'ondëk Hwëch'in First Nation government to raise awareness of landslide hazards in the community and develop a system to warn residents if a slide appears likely to occur. The third event was a workshop attended by 26 representatives

Figure 11. *Amanda O'Connor (back left) and Leyla Weston (back right) demonstrate YGS' augmented reality sandbox to students.*

from Yukon First Nation and municipal governments to share results of YGS' geothermal research program. Until this year, YGS had been engaging in geothermal studies on a community-by-community basis, providing information on the proposed activities and results. This was the first opportunity to provide an overview of the emerging picture of Yukon's geothermal potential to all communities.

Engagement with Yukon First Nations on YGS' research activities continues to be a priority for YGS. Weston led the bulk of this work in 2023, reaching out to First Nations to seek input on their geoscience needs and request feedback on YGS project plans.

Weston and O'Connor (this volume) present a more detailed summary of 2023 geoscience outreach activities.

Summary

In 2023, fieldwork on a number of multi-year projects wrapped up; final reports and maps from these projects are planned for release in 2024/25. Despite several staff vacancies, YMEP grants were issued in a timely manner, and staff still managed to spend a significant amount of time carrying out property visits to hardrock and placer projects.

Efforts are currently underway to fill YGS staff vacancies. Looking forward, we hope that most positions will be staffed by the 2024 field season. With YGS' five-year planning cycle approaching in spring 2024, the survey has begun work to organize a series of thematic workshops in the winter and early spring. Information on the timing and themes of these workshops will be posted on social media (https://www.facebook.com/YukonGeologicalSurvey/); please reach out if you are interested in participating.

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Yukon placer mining 2023 development and exploration overview

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van Loon, S., 2024. Yukon placer mining 2023 development and exploration overview. *In:* Yukon Exploration and Geology Overview 2023, L.H. Weston and Purple Rock Inc. (eds.), Yukon Geological Survey, p. 17–27.

Introduction

Placer districts across the Yukon yielded strong production this season as a result of favourable conditions. A continued rise in gold prices and stable fuel prices were complemented by mild temperatures that allowed for an extended sluicing season. As of November 10, 2023, the 146 active placer operations in the Yukon had collectively generated $143.7M in production revenue. The Dawson Mining District was the primary contributor to gold production, accounting for 89% of the total production for the Yukon. The Mayo Mining District followed with a 7% contribution and Whitehorse Mining District reported 4% of the overall production.

Climate for mining

The winter period (November 2022 to April 2023) was marked by warmer-than-average air temperatures in November, January and February but colder than normal in December, March and April. The average low temperature for Dawson City in April was –9°C. These colder spring temperatures across the Yukon contributed to a late spring thaw, and winter conditions persisted in the valleys into early May.

Precipitation in Dawson City was very high in December and January, whereas the Whitehorse area experienced the third driest period in the precipitation record (Government of Yukon, 2023). The Upper Yukon Basin (Southern Lakes area) snowpack estimate on April 1, 2023 was 114% from median, and the White River Basin was 147% from median (Government of Yukon, 2023). A rain-on-snow event in early June led to washouts and flooding in the Klondike, and most streams in the Klondike exhibited flows above the 75th percentile for the entire open water period. In the rest of the territory, flows were below average (Emily-Jeanne Bercier, Water Resources Branch, Government of Yukon, pers. comm., 2023). As the sluicing months arrived, temperatures became more favourable across the Yukon, and mean temperatures remained in the normal range in Dawson City for June (14.4°C). In July, mean temperatures in Dawson City were 18% higher than those recorded in 2022, and in August, temperatures were 16% higher compared to the same period in 2022. Similarly, in Whitehorse, temperatures for July were 14% higher and August temperatures had a 7% increase compared to 2022. Dawson City's total precipitation for July to October 2023 was slightly less compared to the same period in 2022. Meanwhile, in Whitehorse, there was an increase in precipitation reported from June to September 2023 compared to 2022. Fall 2023 was marked by warmer-than-average temperatures across the territory and significant precipitation in October. Drier-than-average conditions in November resulted in a delay with the onset of winter snowfall.

Gold production summary

Placer gold production reported from April 1 to November 10, 2023, was 68,577 crude ounces (Fig. 1). Using $2620 as an average gold price per ounce, the reported gold production equates to a value of $143.7M for this season.

The Yukon is divided into eleven placer mining areas: Klondike River, Indian River, Lower Stewart, West

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Yukon, Clear Creek, Mayo/Duncan, Dawson Range, Livingstone, Kluane/Gladstone, Whitehorse South and Watson/Hyland (Fig. 2). Most of Yukon's production (82%) is from placer areas in the Dawson Mining District, which includes four areas: Indian River, which contributes 43% of the Yukon's total; Klondike River contributing 15%; Lower Stewart River contributing 14%; and West Yukon, contributing 10% (Fig. 3). Mayo/Duncan, the fifth largest placer gold producing area, contributed 7% of the Yukon's total production in 2023. The remaining placer mining areas contributed 4% to the total Yukon placer gold production. Placer gold production is derived from the royalty reporting collected by the Yukon Mining Recorders.

Development highlights

Klondike River area

The Klondike River is the second-highest gold-producing area, yielding 10,055 crude ounces. Responsible for contributing 15% of the total Yukon placer gold production, most of the Klondike River production is reported from Lovett Hill (2579 crude ounces), Hunker Creek (2518 crude ounces) and Bonanza Creek (2163 crude ounces). Of note was a 30% decrease in production from 2022, which could be due to a shift in operations that were once active on the Klondike River proper.

Lovett Hill Corporation had a successful second year on their lower Bonanza Creek property as one of the largest placer projects in the Yukon. They stripped the left limit of Lovett Gulch including the rim of the Trail Hill bench. The primary target is reworked White Channel gravel deposited on a bedrock surface and concentrated on the lower slopes of the bench rim (Fig. 4). The north-facing hillside is underlain by permafrost and consists of an apron of wind-blown silt (loess) that thickens toward the valley bottom. A combination of hydraulic monitoring and a Caterpillar D11 bulldozer was used to strip the loess unit. A two-person crew with a Hitachi excavator and Caterpillar D11 bulldozer sluiced the rim material and valley-side fluvial deposits. A Macon™ T-600 trommel was used for processing pay.

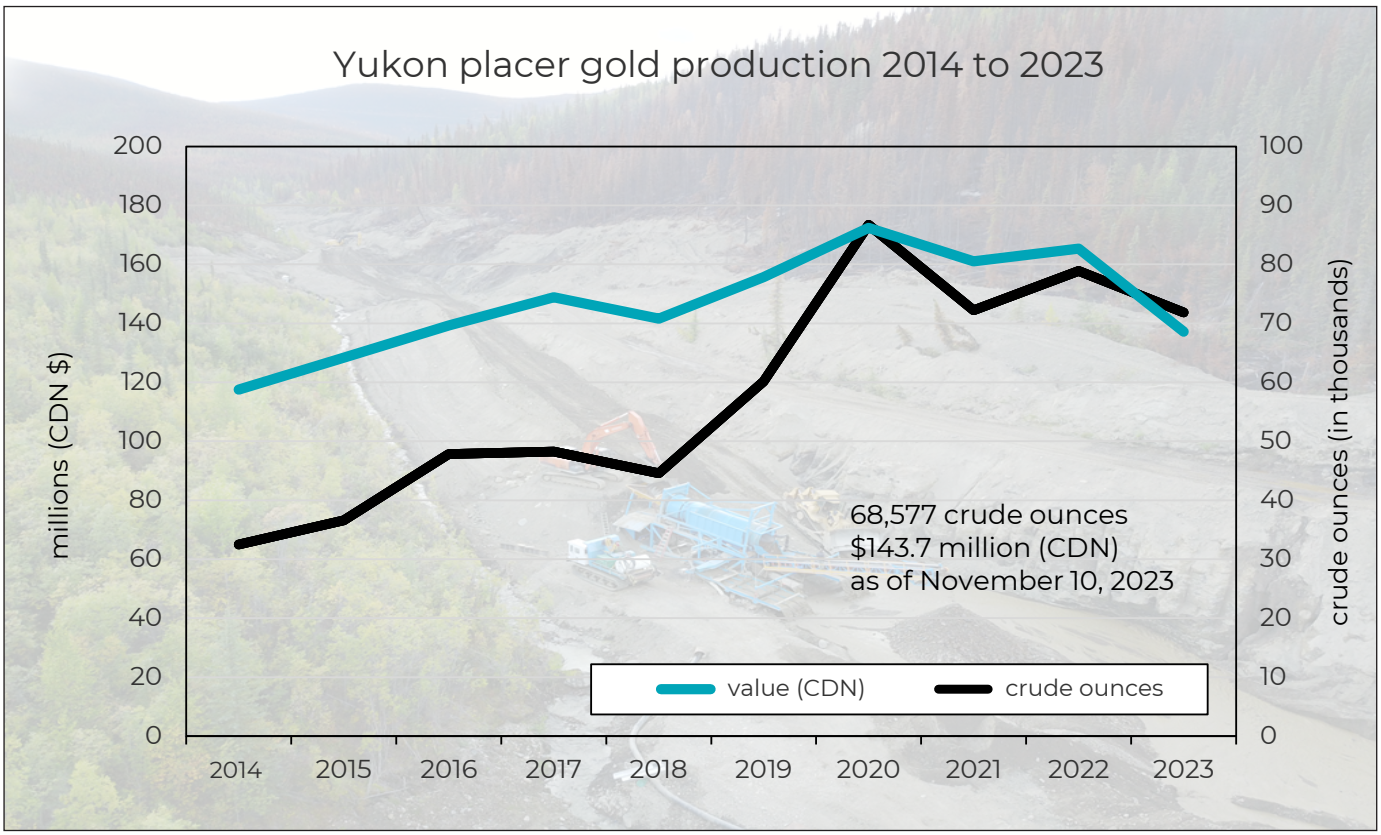

Figure 1. *Total placer gold production in crude ounces and its value in Canadian dollars for the past 10 years.*

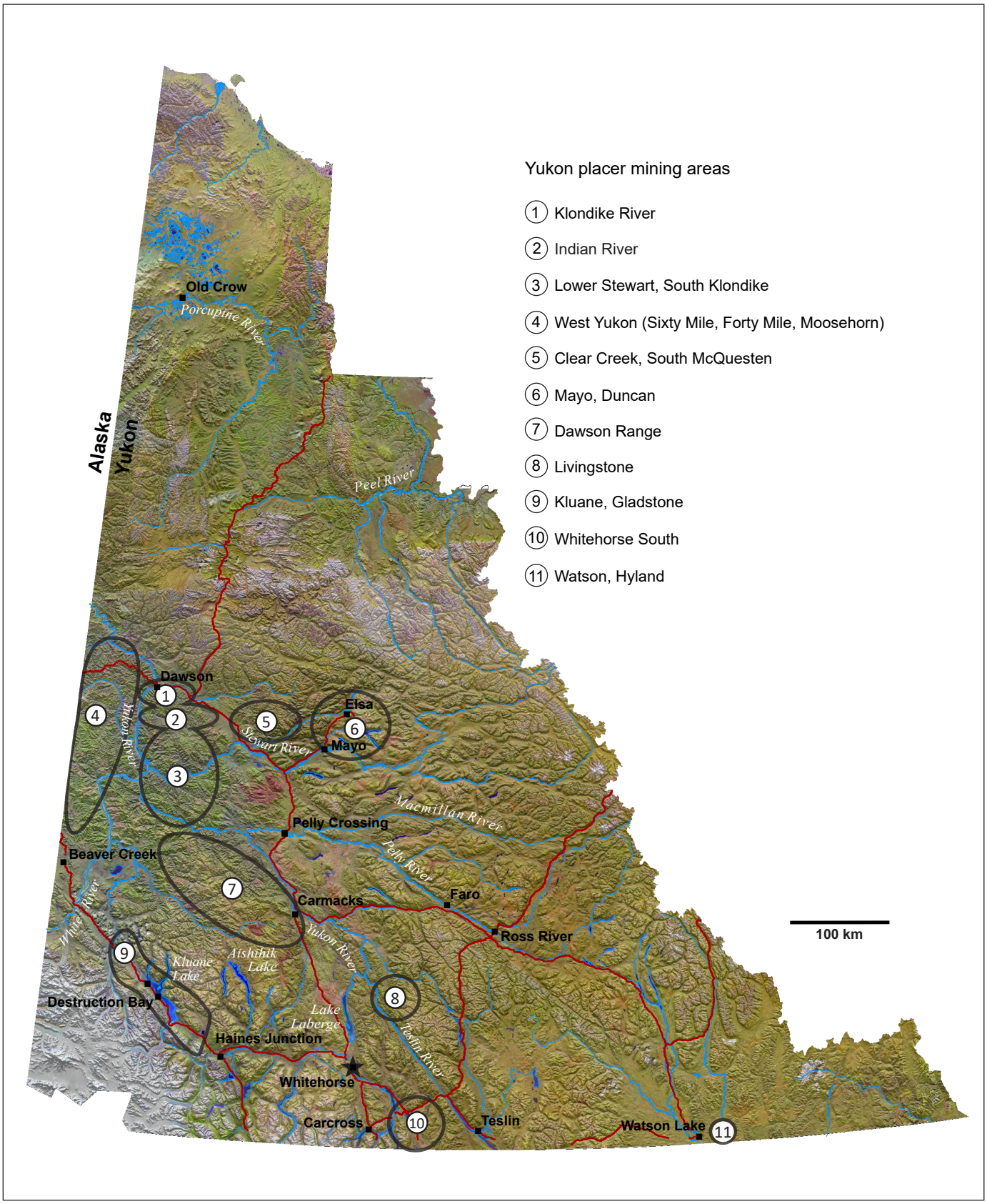

Figure 2. *Yukon placer mining areas.*

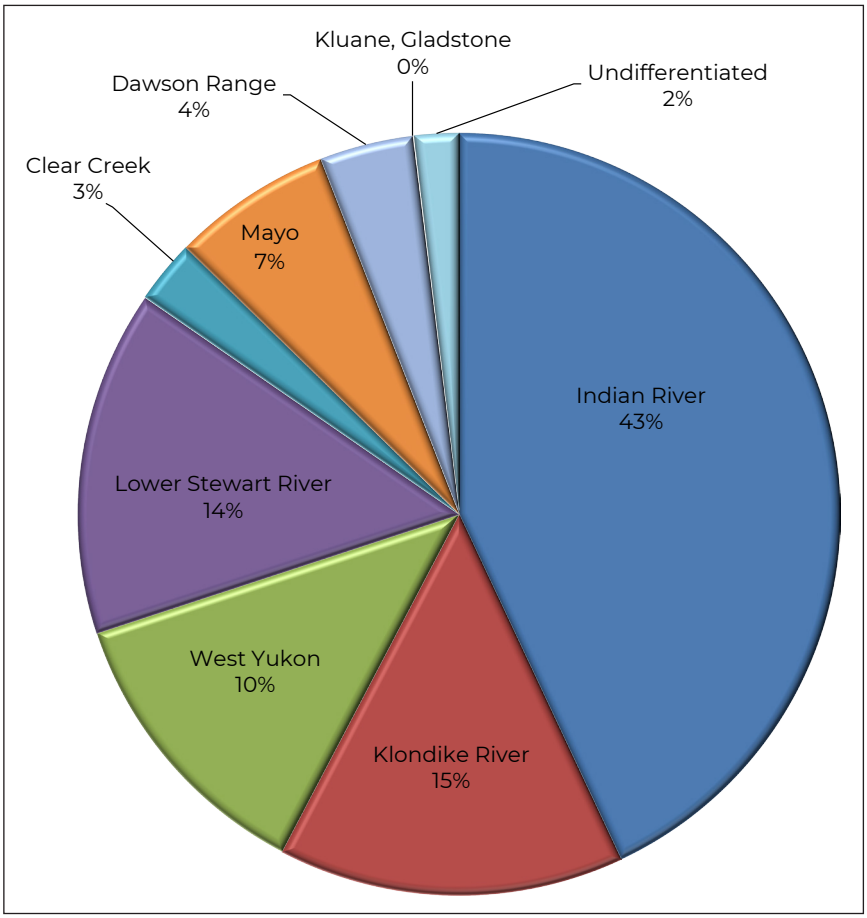

Figure 3. *Distribution of placer gold production derived from each placer area, according to the reported royalties as of November 10, 2023.*

Figure 4. *Lovett Hill Corporation's mining cut at their Lovett Hill property.*

Adrian Hollis completed a second season on his newly acquired Bonanza Creek property, mining claims in the modern creek and on the high-level White Channel bench deposits. He spent a significant amount of time reviewing air photos and compiling historical drilling and dredging data prior to conducting an exploration auger-drilling and bulk-sampling program in July. This property has undergone several phases of mining activity throughout the last century—from hand mining and shafting, to extensive hydraulic mining and dredging, and finally to modern mining methods used since the 1970s. Understanding the extensive work history and resulting modern deposits is essential for evaluating claims in these previously mined areas. The two-person crew sluiced 6116 m^3 (8,000 yd^3) of White Channel gravel from Monte Cristo Hill and King Solomon Hill (Fig. 5).

Tatra Ventures Ltd. reinstated activity on their Last Chance Creek claims this season, an area that has been inactive since they last mined in 2015. Previous mining occurred beneath the tailing stacker of Dredge 11 that had protected in-situ Hunker Creek gravel. This year they investigated the extent of the remaining Last Chance Creek side pay upstream from Dredge 11 (Fig. 6). By mid-season, they had completed a 76 by 107 m (250 by 350 ft) long cut. They continued to extend the cut throughout the season as they followed the lateral continuation of the side pay. Uncovering this extensive Last Chance Creek side-pay unit in a heavily mined area is an example of the importance of exploration programs, particularly in locations where there is a high density of mining activity.

Whiskey Hill Mining spent the first half of the season leasing claims from Mogul Gold on Temperance Hill. In mid-July, the two-person operation

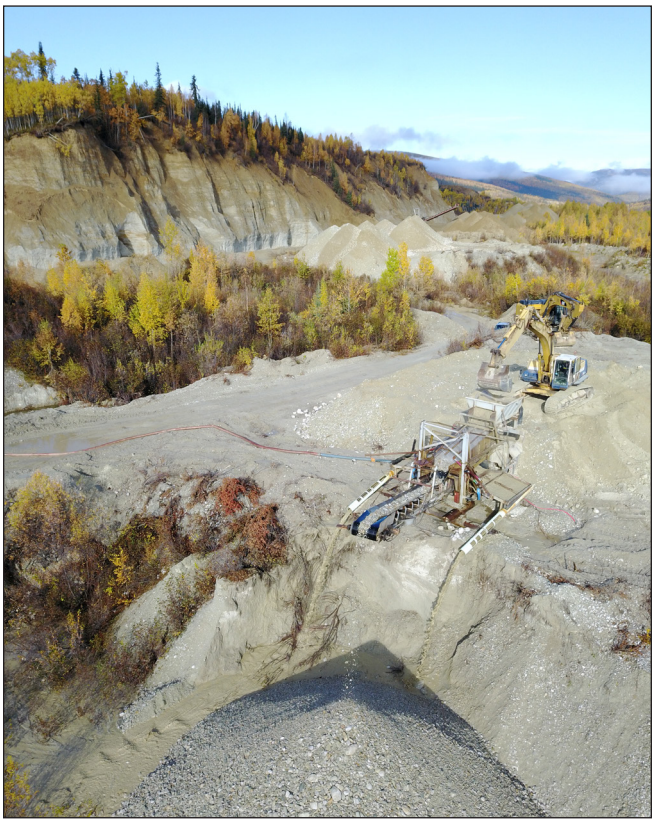

Figure 5. *Adrian Hollis processing material from King Solomon Hill on Bonanza Creek.*

Figure 6. *Dredge 11 at the mouth of Last Chance Creek; Tatra Ventures Ltd.'s cut is exposed behind the dredge.*

relocated to their own claims at the base of Whiskey Hill, situated 2.3 km downstream from Mint Gulch, a left-limit tributary to Hunker Creek. This section of Hunker Creek is narrow. On the left limit of Hunker Creek, a blanket of colluvium containing massive ice overlies the pay gravel, which has protected it from dredging efforts and modern mining. The operation uncovered up to 1.5 m (5 ft) of Hunker Creek gravel, overlain by 12.0 m (40 ft) of overburden.

Indian River area

The Indian River and its tributaries continue to be the highest placer-producing area in the Yukon, yielding 29,503 crude ounces, equating to 43% of the Yukon's total placer production. High numbers in placer gold reporting is due to the high density of large-scale operations (more than 20 employees) in this area (e.g., Quartz Creek, Eureka Creek and Dominion Creek). Of note is a 20% decrease in production this season, which could be attributed to the closure of a large-scale operation on Dominion Creek. The largest contributors in the Indian River area are Quartz Creek (7772 crude ounces), Eureka Creek (5898 crude ounces) and Dominion Creek (5783 crude ounces).

Little Flake Mining ULC purchased Dominion Gold Resources Ltd.'s property on middle to lower Dominion Creek this season. Little Flake began relocating in early spring and conducted an extensive sonic drilling program to establish a multi-year mine plan at the new location. The crew focused their mining on the middle to right limit of Dominion Creek, and an additional four claims were stripped in preparation for next season. Stratigraphy in their cut at the mouth of Washington Creek consists of 1.7 m (6 ft) of Ross gravel overlain by 2.0 m (7 ft) of Dominion Creek gravel.

Ace Placer Mining, a third-generation operation active in the Dominion Creek drainage, mined in two locations in 2023. They focused most of their season at the mouth of Lemare Gulch (Fig. 7), where local, high-energy gulch gravel incised into a low-level Dominion Creek bench. The gulch gravel likely incised into the bedrock surface easily because it was extensively oxidized and fractured. A second right-limit location, approximately 800 m upstream from the mouth of Portland Creek, was stripped and prepared for sluicing in 2024. While this area has been dredged, remnant pillars of in-situ Dominion Creek gravel may have been preserved by the inconsistent steam thawing method used at the time. Additionally, Ace Placer Mining will be evaluating the technogenic deposits derived from dredging for their economic potential.

Figure 7. *Ace Placer Mining active in 2023 at the mouth of Lemare Gulch in the Dominion Creek valley.*

Schmidt Mining purchased Dominion Creek and Brimstone Gulch claims from Lucky Lady Placers in 2019. The first earth-moving activities occurred in fall 2022 and consisted of a stripping program on the right limit. This program continued throughout the 2023 season, resulting in a stripped 120,000 ft^2 (11 148 m^2) cut ready for sluicing in 2024. Another cut along the right limit was also completed, revealing a section of in-situ Dominion Creek side pay. The gravel thickness ranges from 1.2 to 3.0 m (4 to 10 ft), and this cut is also slated for sluicing in the upcoming 2024 season.

Metallic Minerals Corp. leased out their Australia Creek claims to Little Flake Mining ULC in 2023. This year marks the first time gold production has been reported from this drainage. A large cut (Fig. 8) located 2.5 km upstream from its confluence with the Indian River was completed in 2023 and all gravel encountered was sluiced (up to 1.8 m or 6 ft). Gold is medium to coarse grained and has a fineness of 880.

Slate River Mining's operation is located on the lowermost reach of the Indian River, and the company had a crew of three individuals during the 2023 season.

Figure 8. *Looking downstream at Australia Creek; the Indian River valley is in the background.*

Efforts on these claims were concentrated on mining three distinct placer settings in the drainage: the modern Indian River valley bottom, an intermediate-level bench deposit, and a high-level bench deposit situated on the right limit. This was the first evaluation of placer potential in the high-level bench on the lower Indian River. Two cuts were successfully completed immediately downstream from the camp as part of this exploration effort. The high-level bench project was undertaken as a test mining initiative, aimed at gaining a better understanding of the placer potential of this location.

West Yukon area

There were 8415 crude ounces of placer gold produced from the West Yukon area in 2023, which equates to 10% of total Yukon production. This is the third highest placer-producing area, and within this area, the Sixty Mile River produces 60% of the total regional production (5072 crude ounces). Browns Creek is the second largest contributor, producing 11% (892 crude ounces) of the reported production for the West Yukon area. The third largest contributor is Bruin Creek, producing 512 crude ounces, followed closely by Ten Mile Creek, which yielded 487 crude ounces.

Boucher Creek, actively mined for the past four seasons by Schmid and de Windt, is one of the newer

placer creeks in the Yukon to report placer production. Boucher Creek is a tributary to the Sixty Mile River and was explored in 1892; it has remained relatively underexplored until the current owners staked it in 2016. Schmid and de Windt initiated sluicing in 2017, and operations continue to expand in the drainage. A three-person crew completed a cut on Boucher Creek, as well as a 137 by 222 m (450 by 730 ft) cut on Butler Gulch, a right-limit tributary of Boucher Creek. Figure 9 is a photo of the gold recovered from Boucher Creek.

Husky Wood and Exploration Ltd. began prospecting the lower reaches of Browns Creek, beginning with a shafting program in 2016. Sluicing began in 2017, and they have been mining the entire width of the modern valley bottom as well as a variably preserved, low-level bench deposit on the right limit. In 2023, they completed two cuts with a crew of six employees.

K-1 Mining and Services has been active in Bedrock Creek since 2020. This season, they had a crew of three people who extended their cut farther downstream on the Bedrock Creek bench to the mouth of Winters Gulch (Fig. 10). Mining efforts focused on a fan deposit at the mouth of Winters Gulch that has incised into a bench on Bedrock Creek. The average thickness of pay was 3.6 m (12 ft) and they sluiced 34 596 m^3 (45,250 yd^3) of pay gravel.

2074098 Alberta Ltd. leased claims from V. Bondarchuk this season on the middle to upper reaches of Moose Creek. The crew mobilized to the site in July. They began by first designing a mine plan that would allow them to operate efficiently in Moose Creek, which has a narrow width of 37 m (120 ft; Fig. 11). The bedrock surface undulates significantly in the creek bed and controls pay thickness. Pay ranges from 0.6 to 4.6 m (2 to 15 ft) thick and has an average thickness of 1.2 m (4 ft). A mixing zone is present at the contact between bedrock and the overlying gravel. Gravel in the creek is coarse and has an abundance of large boulders and bedrock fragments that have been remobilized into the drainage area as colluvium. The largest gold nugget recovered was one ounce or 28.3 g.

Figure 9. *Gold recovered from Boucher Creek.*

Figure 10*. K-1 Mining and Services' operation on Bedrock Creek.*

Figure 11. *Aerial view of Moose Creek; a John Deere 992 excavator (yellow) gives perspective of the narrow nature of the creek.*

Lower Stewart area

Lower Stewart area is the fourth largest gold-producing area, contributing 14% to the Yukon's total placer gold production. Reporting decreased by 11% compared to 2022 values and yielded 10,050 crude ounces for the 2023 season. Henderson Creek contributed 55% of Lower Stewart area's total production, generating 5484 crude ounces. The highest producing drainages include Black Hills Creek (1038 crude ounces), Scroggie Creek (978 crude ounces) and Maisy May Creek (693 crude ounces).

Bedrock Mining Company Inc., on Maisy May Creek, completed a significant amount of reclamation on their lowermost claims. By July, 11 claims in the valley bottom were reclaimed by contouring overburden and top coating the area. This exceptional work is just one example of the ongoing reclamation that placer miners are undertaking throughout the Yukon (Fig. 12). A crew of five employees processed 87 924 m^3 (115,000 yd^3) of gravel this season. They mined two placer settings: the modern Maisy May Creek valley and a mid-level, left-limit bench that has undergone minimal activity until this season. A cut 40 by 50 m (130 by 165 ft) was completed on the bench, which initiated further interest in conducting additional mid-level bench exploration in the creek.

Figure 12. *Reclamation on lower Maisy May Creek completed by Bedrock Mining Company Inc. this season. The view is looking upstream.*

R. Smith Placer Mining has been active in the headwaters of Black Hills Creek since 1996. This season was the first time the one-person operation processed a cut in an unnamed left-limit tributary 2.6 km downstream from the headwaters of the drainage (Fig. 13). Locally named 'Lucky Gulch', this tributary drains Eureka Dome and contains a poorly sorted, high-energy gravel deposit. At the confluence of Lucky Gulch and Black Hills Creek, the local high-energy gravel is incised into a Black Hills Creek bench and is overlain by frozen black muck containing massive ice. The crew sluiced gravel up to 5.5 m (18 ft) thick, including up to 0.6 m (2 ft) of the underlying bedrock. A 45 by 145 m (150 by 475 ft) cut was prepared for mining in the 2023 season, and the operator remained on the creek until mid-October to complete processing the thawed gravel.

Stuart Placers Ltd. has been mining on mid–Black Hills Creek, progressively mining upstream from Kernine Creek to McCrimmon Creek during the last three seasons. They operated a single 12-hour shift with a crew of six employees. The crew targeted the Modern Black Hills Creek gravel, mining the entire width of the valley bottom, and processing the lowermost 1.8 m (6 ft) of gravel and up to 0.9 m (3 ft) of bedrock. The company conducted exploration during the past two seasons by processing bulk samples from a low-level, right-limit bench near McCrimmon Creek, as well as samples from an upstream mid-level bench near Mills Creek.

Figure 13. *Confluence of Black Hills Creek and locally named 'Lucky Gulch', where R. Smith Placer Mining focused mining this season.*

Clear Creek, Mayo and Keno area

Production in Clear Creek decreased by 48% this year and 1863 crude ounces was reported. Most production was from Clear Creek proper, which produced 1815 crude ounces. Meanwhile, to the east, a 15% increase was reported in the Mayo/Duncan area. The notable production came from Granite Creek (2437 crude ounces) in 2023. Other producing creeks in the Mayo/Duncan placer area include Highet Creek (586 crude ounces), Owl Creek (427 crude ounces) and Duncan Creek (338 crude ounces).

Rally! Mining ULC leased claims from Duncan Creek Golddusters Ltd. on Duncan Creek this season. Three separate placer deposits were mined in the creek. The first target was modern Duncan Creek gravel, a near-surface deposit in which they sluiced 18 349 m^3 (24,000 yd^3). The second target is a deep channel on the right limit of the creek, immediately upstream from the camp, where they sluiced 19 878 m^3 (26,000 yd^3). Finally, they proved up an exciting deposit of a buried, left-limit bench (Fig. 14) that extends much farther into the slope than initially believed. Although they knew a preglacial bench existed on the left limit of the creek, Rally! Mining ULC used geophysics and a large cut to further expand the previously known extent of the deposit. The crew sluiced approximately 25 995 m^3 (34,000 yd^3) of the preglacial bench deposit.

Figure 14. *Rally! Mining ULC's buried left limit bench on Duncan Creek. The view is looking upstream at a large cut that was completed to evaluate the deposit.*

Yukon Mining Ventures Ltd. first staked Ross Creek in 2018 and began mining the following year. This season, the one-person operation sluiced 15 292 m^3 (20,000 yd^3) with a 4 ft (1.2 m) diameter trommel capable of processing 38 m^3 (50 yd^3)/h. The 17 by 35 m (55 by 115 ft) cut on the left limit targeted a buried glaciofluvial bench deposit. The total thickness of mined section was 3.0 m (10 ft) after stripping 6.0 m (20 ft) of overburden. The lowermost 1.5 m (5 ft) and up to 0.6 m (2 ft) of bedrock was processed as pay.

L. Andre and his crew of five employees completed their second season sluicing on 15 Pup. The 15 Pup property is a right-limit tributary of Haggart Creek, situated immediately to the west of Victoria Gold's Eagle Gold mine. A 52 by 198 m (170 by 650 ft) cut was completed, and the entire creek width was processed. As the cut evolved on 15 Pup, the stratigraphy began to indicate the potential of a buried left-limit deposit. Mining in the narrow valley of 15 Pup (20 m, or 66 ft wide) requires thorough mine planning and a well-developed total recirculation system. L. Andre spent the last few years fabricating a new trommel (Fig. 15), which can process 76 m^3 (100 yd^3)/h.

Figure 15. *L. Andre's operation on 15 Pup, and his newly fabricated trommel actively sluicing pay.*

Owl Creek is a tributary on the south side of Mayo Lake that has not been mined since the early 2000s. This season, Dulac Mining mobilized to the site and began mining on the lower reaches of the creek immediately above the fan. The pay gravel is a high-energy, poorly sorted deposit with abundant bedrock fragments and is interpreted to be a debris flow. Gold recovered from Owl Creek is typically coarse.

Faith and Allen creeks are two relatively new placer creeks that are located approximately 12 km east of Keno City and drain into the Keno Ladue River. Metallic Minerals Corp. staked the claims in 2017, and this season they contracted the Unrau's to conduct 16 excavator test pits. Gold is coarse and is believed to be locally derived from the vein system on the north side of Mt. Hinton. It is encouraging for the industry and for the Mayo placer area to see exploration unfolding in underexplored drainages.

Scott and Sons continued to mine upstream on the left fork of Clear Creek, starting this year's operations just downstream of Barney Creek (Fig. 16). This is an area of Clear Creek that has been previously dredged by Queenstake Resources. Scott and Sons is a third-generation placer operation, and they continue to target areas of the creek that were previously missed by the dredge. They are also targeting intermittently preserved, in-situ Clear Creek side pay that is masked by a blanket of colluvium. This season, 10 employees worked a double 12-hour shift, and mined 53 000 m^2 (570,487 ft^2) of pay.

Figure 16. *Scott and Sons operation on the left fork of Clear Creek. The view is looking downstream.*

Whitehorse Mining District

Whitehorse Mining District includes four placer mining areas: Dawson Range, Livingstone, Kluane/Gladstone and Whitehorse South. Cumulatively, these four placer mining areas contributed 4% (2901 crude ounces) of the Yukon's total placer gold production as of November 10, 2023. Additional reporting is forthcoming from southern Yukon due to operators mining longer into the season compared to those situated in the Dawson area. The Dawson Range placer area contributed 95% of the placer gold reported in the Whitehorse Mining District. The three highest producing creeks in the Whitehorse Mining District are all situated in the Dawson Range placer area. The largest contributors are Canadian Creek (1306 crude ounces), Nansen Creek (575 crude ounces) and Discovery Creek (555 crude ounces).

B. Gow, primarily mining independently, continued to focus his mining efforts at the mouth of Mechanic Creek (Fig. 17). He has been targeting a series of coarse boulder channel deposits derived from Mechanic Creek, which incised into a bench on Big Creek. These coarse boulder channels were preserved by the Big Creek bench deposits, after incision of Big Creek following the end of the last glacial period. This pay unit overlies a frozen silt unit, which acts as a false bedrock. Each individual channel is up to 1.8 m (6 ft) thick. This season, 7646 m^3 (10,000 yd^3) of material was processed for placer gold.

TIC Exploration has been mining on Gladstone Creek since 1992. This season they focused on the right limit above a canyon. A crew of up to five people completed a 30 by 100 m (98 by 328 ft) cut on a low fluvial bench deposit of Gladstone Creek. The bench deposit consists of a boulder gravel unit overlain by a wedge-shaped colluvial apron. The colluvium was 4 m (13 ft) thick on the north wall of the cut against the hillside and tapered to 0 m in the middle of the cut. Mining operations continued intermittently into the winter months when temperatures remained above –15°C. Sluicing in these temperatures was possible using groundwater sources as opposed to surface water.

S. Johnson remains active in Burwash Creek, holding claims in the middle reaches of the drainage and extending up Tatamagouche Creek. This season his

Figure 17. *View from the Big Creek valley, looking upstream Mechanic Creek; B. Gow's operation is shown at the mouth of the drainage.*

operation was scaled down and he focused mainly on exploration. A series of bulk samples were collected from test pits to determine the extent of buried, low-level bench deposits variably preserved on the right limit of the creek. A. Johnson plans to continue with exploration in 2024 by completing a drill program to define additional targets for future mining.

Summary

This year's placer operations benefitted from favourable weather conditions that extended the sluicing season. This was clearly reflected in the robust gold production that was reported. Activity expanded into previously underexplored areas, and with a predicted strong gold price throughout the winter months, the outlook for the next mining season is optimistic. The author sends out a sincere thank-you to all the placer miners and operators whose contributions were invaluable to the field season. The collaboration between those working on the creeks and the Yukon Geological Survey staff is what makes our data collection and geological discussions possible (Fig. 18).

Figure 18. *A. Hollis displays a test pan from his claims on King Solomon Hill.*

References

Government of Yukon, 2023. Yukon Snow Survey Bulletin and Water Supply Forecast, April 1, 2023 https://yukon.ca/en/april-1-2023-yukon-snow-survey-bulletin-and-water-supply-forecast [accessed November, 2023].

Yukon hardrock mining, development and exploration overview 2023

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Ellis, S. and Sack, P.J., 2024. Yukon hardrock mining, development and exploration overview 2023. *In*: Yukon Exploration and Geology Overview 2023, L.H. Weston and Purple Rock Inc. (eds.), Yukon Geological Survey, p. 29–52.

Introduction

Despite tough market conditions, the Yukon saw another year of significant exploration results and new discoveries. At the time of writing, Yukon Geological Survey (YGS) estimated exploration expenditures in the territory to be $147M for the year, based on company press releases, SEDAR (System for Electronic Document Analysis and Retrieval Overview) postings and conversations with industry clients. This estimate is up 18% from $124M in 2022 (Fig. 1). Development expenditures for 2023 are estimated to be $95M (Fig. 1) and mineral production is estimated to be $495M (approximately 87% attributed to gold production, 10% to silver production and 3% to copper production), down from a total of $543M in 2022; Fig. 2).[1] It was a challenging year for production due to the closure of the Minto mine and the two-week closure of Victoria Gold's Eagle Gold mine due to wildfires in the Mayo region; however, strong precious and base-metal prices throughout the year, increased production at Eagle Gold mine, and the re-opening of the Keno Hill mine suggests that 2023 production revenue will remain strong.

There were 82 active exploration projects in the territory in 2023 (Fig. 3, Appendix 1), which was similar to 2022; however, the number of active companies and individual prospectors continues to decline. The notable increase in exploration expenditures compared with 2022 can be attributed to the progression of several exploration projects into more advanced stages. In total, 31 companies spent more than $500K on exploration and development; 19 of those spent more than $1M. Additionally, several companies were able to raise extra funding mid-season, which extended their initial proposed exploration programs.

The primary commodity in terms of total exploration expenditures in the territory continues to be gold, representing 55% of spending ($80.5M), followed by zinc-lead (25%, $37.7M), silver (9%, $13.4M), copper (9%, $13.2M), tungsten (1%, $1.0M) and nickel-PGE (1%, $900K; Fig. 4). Gold exploration has dominated expenditures since the late 1980s, often representing upward of 80% of total expenditures; however, in recent years there has been a progressive shift to a more equal split between precious metal and critical mineral exploration expenditures.

As of November 1, 2023, 5119 quartz claims had been staked in 2023 (Fig. 5). Most of the new claims were in the Mayo Mining District (60%), followed by the Whitehorse (25%) and Dawson (15%) mining districts; no new claims were staked in the Watson Lake Mining District (Fig. 6). A total of 162 564 claims remain in good standing, down from 164 924 in 2022.

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1. All estimated expenditure projections reflect the current estimates as of November 30, 2023 and will not be finalized until the end of January 2024.

There has been a renewed interest in gold exploration in the Selwyn basin due to the 2021 discovery of a significant reduced intrusion-related gold (RIRG) target by Snowline Gold at their Rogue property (Valley occurrence). This has led to a substantial increase in exploration in the region and a number of companies assessing the potential for RIRG at their properties.

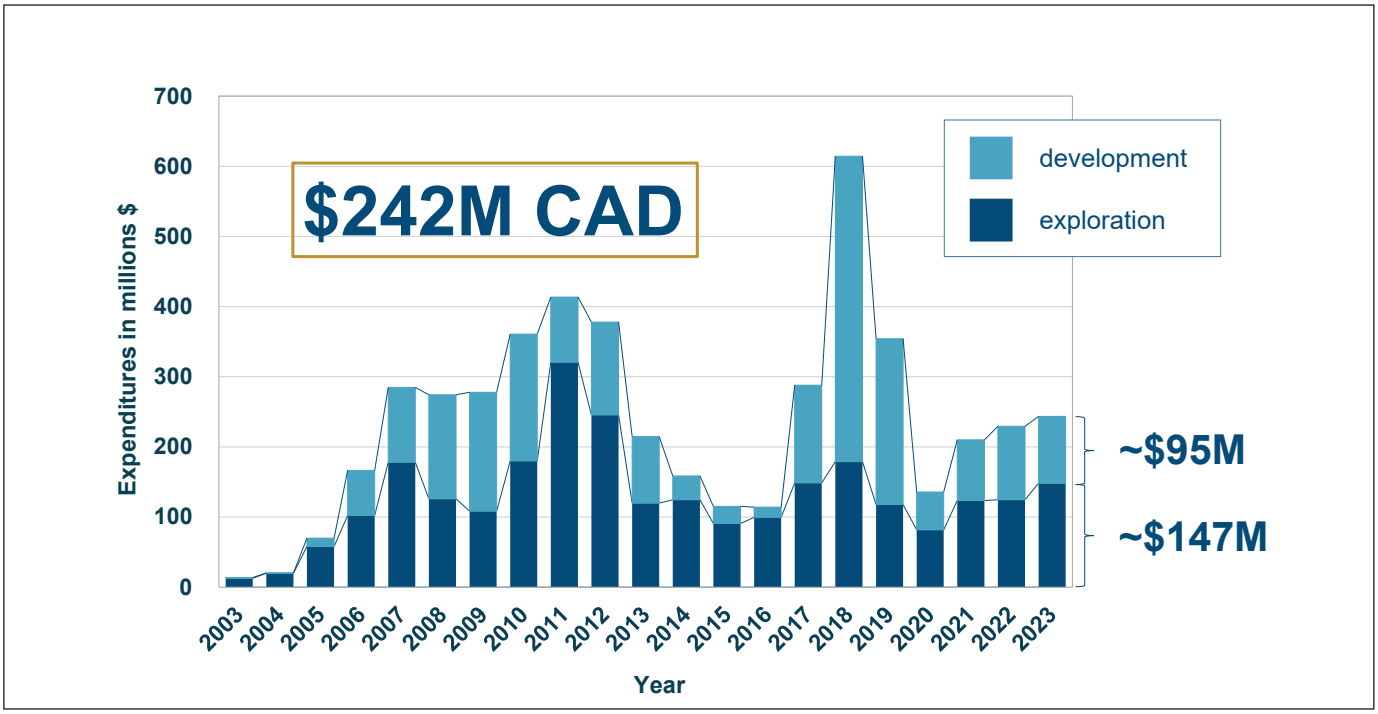

Figure 1. *Yukon Geological Survey–estimated exploration and development expenditures for 2023.*

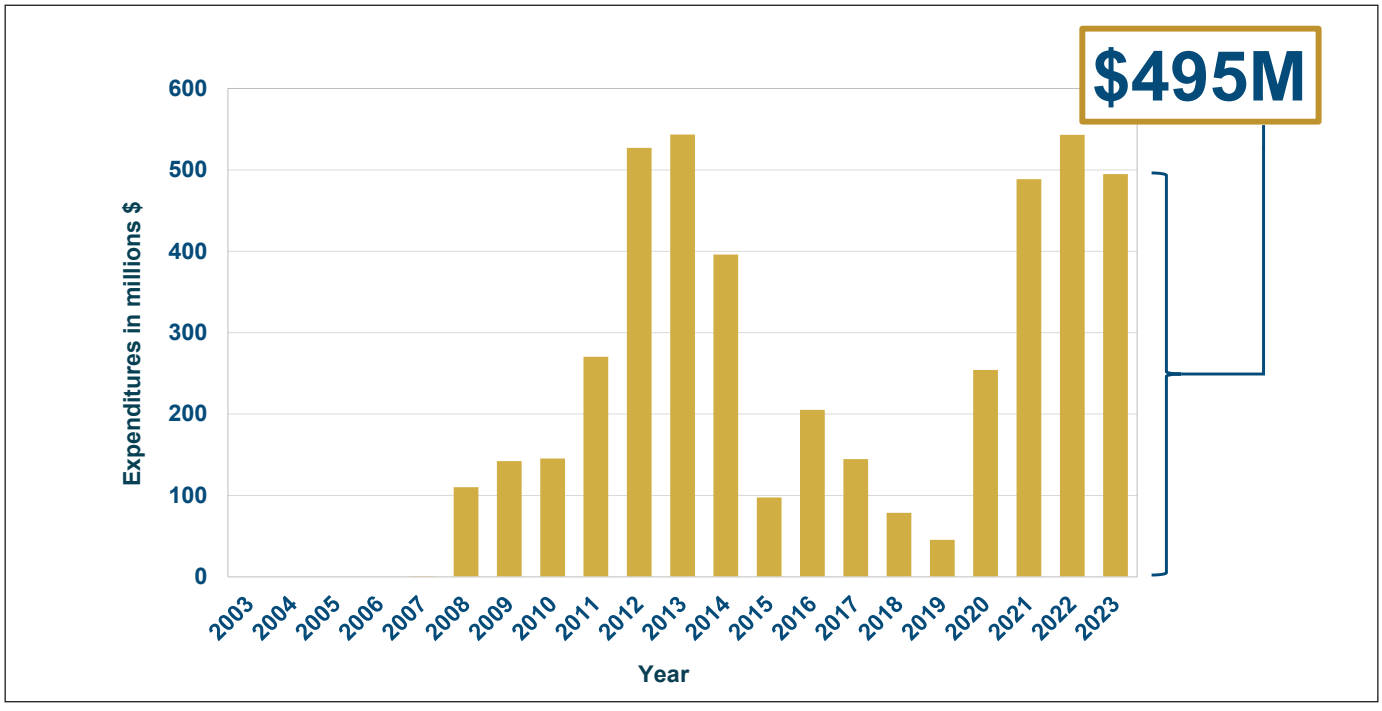

Figure 2. *Yukon Geological Survey–estimated production values for 2023.*

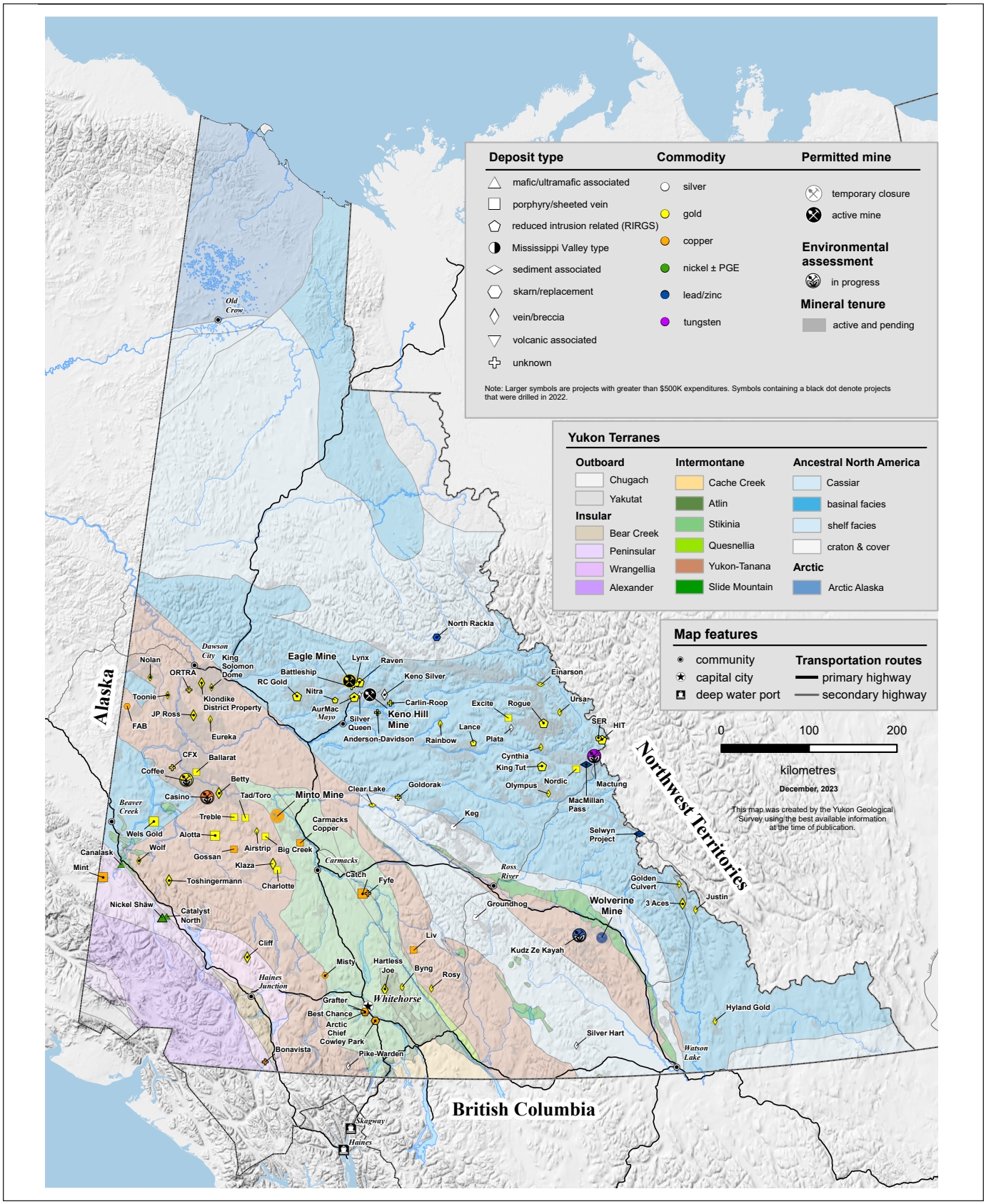

Figure 3. *Active hardrock projects in the Yukon, 2023.*

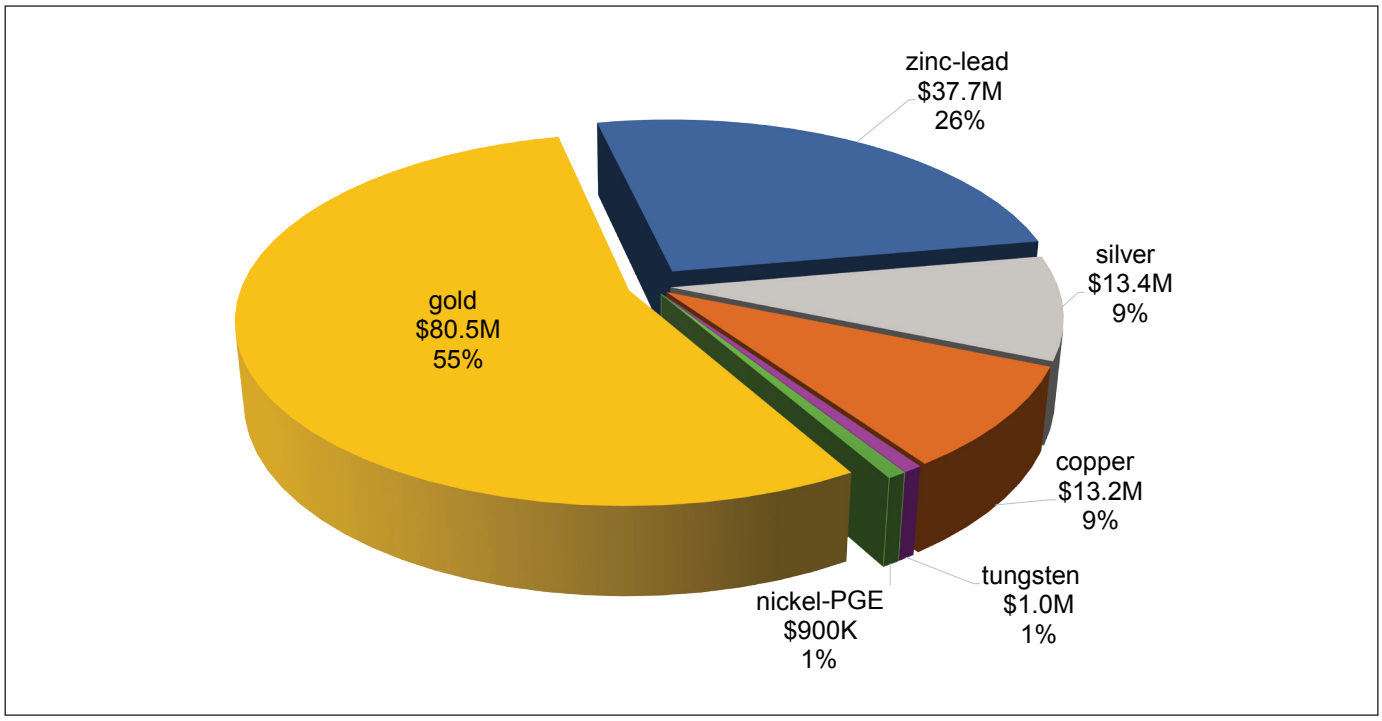

Figure 4. *Breakdown of 2023 exploration expenditures in the Yukon by commodity.*

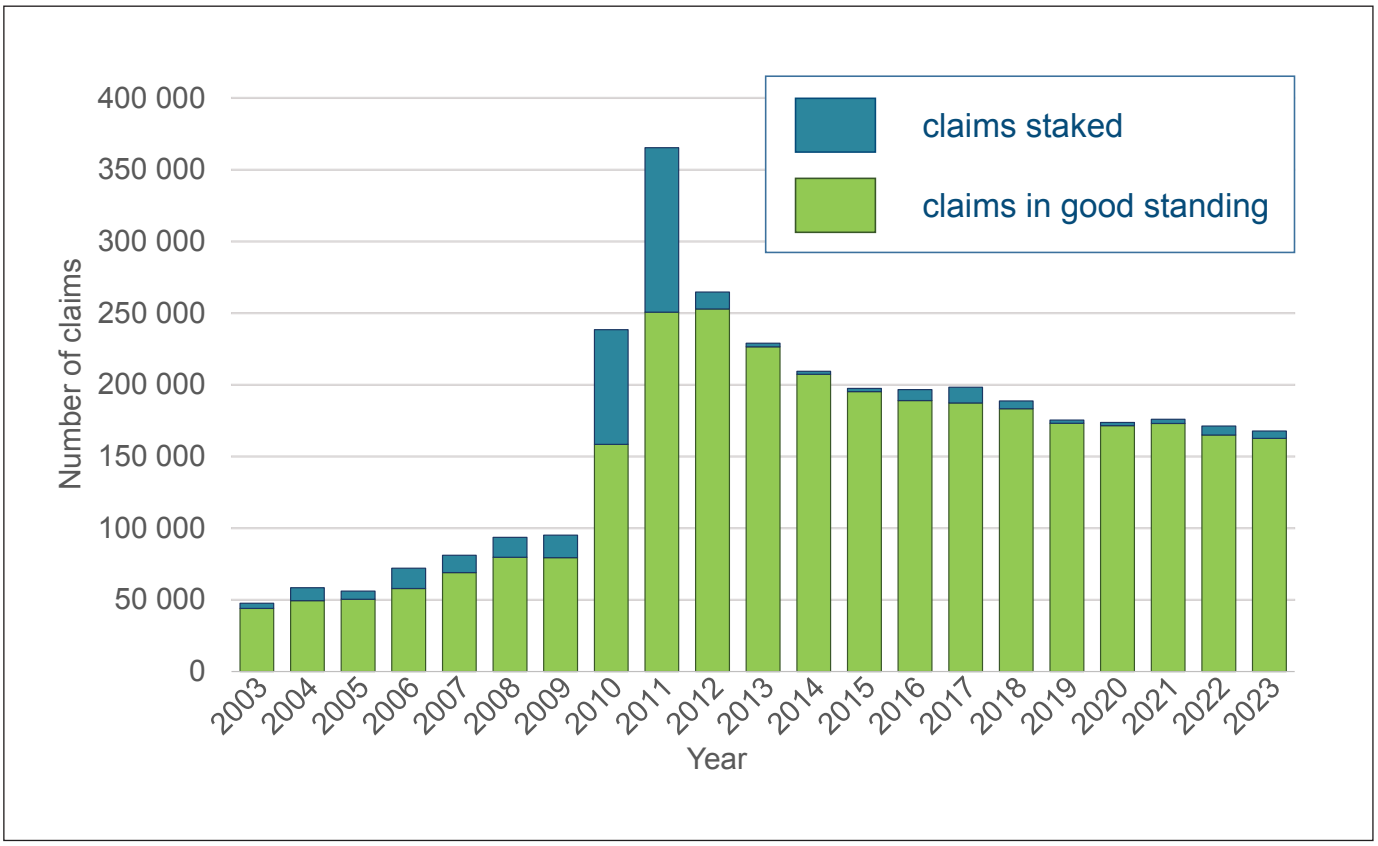

Figure 5. *Claim staking activity during 2023 in the Yukon.*

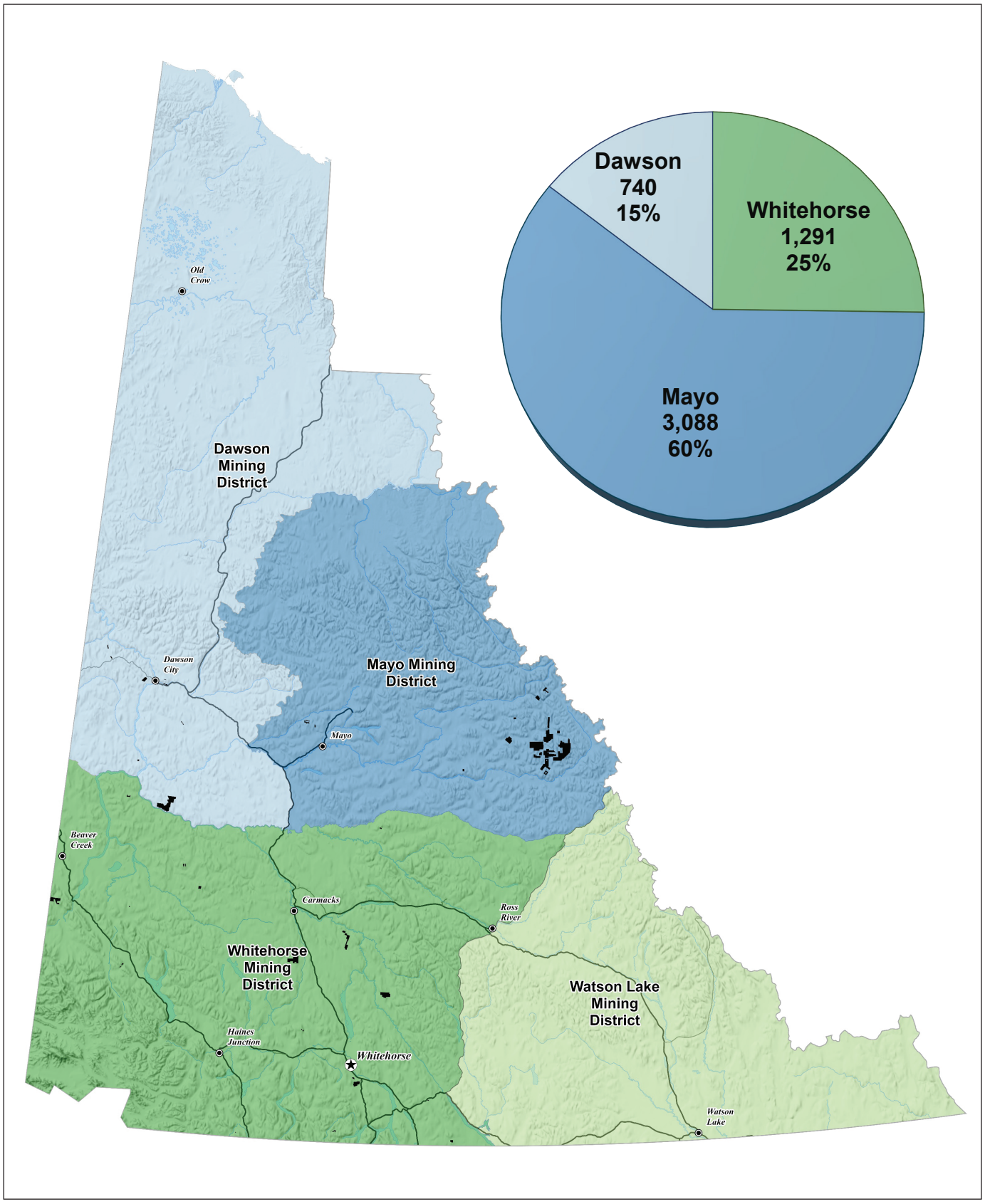

Figure 6. *Claim staking activity during 2023 in the Yukon by mining district.*

Mining activity

Victoria Gold Corporation's Eagle Gold mine is completing its fourth year of production. The first gold pour at the mine took place in September 2019 and commercial production began July 1, 2020. The mine produced 124 749 oz Au in the first three quarters of 2023, up 17% compared to 2022. Mine production was impacted in the third quarter by a two-week evacuation due to wildfires in the Mayo region; however, production guidance for year-end remains 160 000 to 180 000 oz of gold (Victoria Gold Corp., 2023a).

Victoria Gold's exploration focus was predominantly at their Raven project east of the Eagle Gold mine, which has an Inferred Mineral Resource of 1 070 239 oz gold (20 Mt at 1.67 g/t Au). Their drill program focused on confirming mineralization along strike of 1.7 km and increasing confidence in the resource. Drilling also identified several high-grade, base-metal vein intercepts that are distinctly different from the gold-bearing massive sulphide veins typically observed at the deposit. Victoria Gold anticipates releasing an updated Mineral Resource for Raven in 2024. In September 2023, the company also acquired Sabre Gold Mines Corporation's 100%-owned Gold Dome and Grew Creek exploration properties as well as the past-producing Brewery Creek mine, which has a Mineral Resource of 1.1 Moz Measured and Indicated and 1.0 Moz Inferred Au (Victoria Gold Corp., 2023b).

Minto Metals Corporation ceased operations at their Minto mine on May 13, 2023 and the mine was placed into court-appointed receivership in late July. As of the end of November 2023, the receiver is in the middle of a sales process, which it aims to complete by March 31, 2024. Site operation and reclamation are currently under the supervision of the Government of Yukon, who is working with Selkirk First Nation to advance reclamation and closure of the site.

Hecla Mining Company acquired Alexco Resource Corporation and the Keno Hill Silver project in September 2022. Hecla re-opened the Keno mill in May 2023, and was working toward full production. Production is focused on their Flame and Moth, and Bermingham deposits. The company produced 900 000 oz Ag during the first three quarters of the year and has a revised production guidance for 2023 of 1.6 to 1.8 Moz Ag (Hecla Mining Company, 2023).

Hecla's exploration program focused on surface and underground resource definition drilling. The surface program consisted of drilling at their Bermingham, Coral-Wigwam, Hector-Calumet and Silver King targets and their underground program was focused at Bermingham, primarily in the Bear zone.

Permitting and mine development

Newmont Corporation's Coffee project received a positive recommendation from the Yukon Environmental and Socio-economic Assessment Board (YESAB) in 2022 and their Quartz Mining License in November 2023. The Coffee project has a Mineral Resource (Measured, Indicated and Inferred) of 2.37 Moz Au (58.1 Mt grading 1.43 g/t Au; Newmont Corporation, 2023) and will be a heap-leach operation with a 10-year operation phase and 11-year closure plan. In 2023, the company focused on exploration drilling and drill-testing extensions of their current resource, completing 18 856 m in 216 holes (8406 m reverse circulation (RC); 10 450 m diamond drilling). The company also worked on geological and structural interpretations to better constrain deposit formation at the property and regional scale. Newmont also completed a regional bulk leach extractable gold (BLEG) stream sediment survey spanning a 3000 km2 area north of the Coffee property.

Western Copper and Gold Corporation's Casino project is one of Canada's largest undeveloped copper-gold deposits. The Casino project received strategic investments by Rio Tinto in 2021 ($25.6M) and 2023 ($6M), resulting in Rio Tinto's ownership of approximately 9.7% of Western Copper's outstanding common shares (Western Copper and Gold Corporation, 2023a). The company also received a $21.3M strategic investment in 2023 by Mitsubishi Materials, who now owns approximately 5% of outstanding common shares (Western Copper and Gold Corporation, 2023b). The 2023 program at Casino consisted of 2200 m of metallurgical and infill drilling in seven holes within the current pit boundaries. Western Copper also completed 800 m of geotechnical and hydrogeological drilling to test ground conditions for proposed mine infrastructure. The company is in the early stages of the assessment process and received a revised environmental and socio-economic effects (ESE) statement guideline from YESAB in September 2023. Casino has indicated that it plans to submit an ESE statement in the second half of 2024 (Western Copper and Gold Corporation, 2023c).

BMC Minerals Limited's Kudz Ze Kayah (KZK) project is a replacement-style volcanogenic massive sulphide (VMS) deposit with total Probable Reserves (open pit and underground) of 15.7 Mt of 0.9% Cu, 1.7% Pb, 5.8% Zn, 1.3 g/t Au and 138 g/t Ag, and an Indicated and

Inferred Mineral Resource Estimate of 19.1 Mt grading 6.3% Zn, 1.9% Pb, 0.9% Cu, 148 g/t Ag and 1.49 g/t Au (BMC Minerals Ltd., 2019). The company received a positive decision document from the governments of Yukon and Canada in June 2022, approving the proposed mine to proceed to the regulatory phase, and submitted Type A Water Licence and Quartz Mining Licence applications in September 2022. BMC was active at KZK in 2023, completing induced polarization (IP) and unmanned aerial vehicle magnetic (UAV-MAG) surveys to test potential for mineralization extension at their ABM deposit. Additionally, BMC received a positive Economic Review for the project on October 9, 2023, confirming the robust economics of the proposed ABM mine (BMC Minerals Ltd, 2023a), and acquired 100% ownership of the Kona copper-gold deposit located 20 km south of the proposed ABM mine (BMC Minerals Ltd., 2023b).

Exploration activities in 2023

Most exploration activities and exploration-related expenditures were in the Mayo Mining District in 2023; this has been a consistent trend during the last couple of years. The Mayo Mining District comprises the Clear Creek, Keno and Mayo regions, as well as most of Selwyn basin northwest of the North Canol Road (Figs. 3, 6). This region hosts a variety of mineralization styles, including reduced intrusion-related gold (RIRG), carbonate replacement, vein and breccia hosted gold, high-grade silver-lead-zinc veins, and sediment-hosted massive sulphide.

Gold exploration projects

There were 51 active exploration gold projects in the Yukon in 2023. Exploration expenditures related to these projects represented approximately 55% of total expenditures this year ($80.5M).

Banyan Gold Corporation's AurMac project is interpreted to be a reduced intrusion-related deposit. In May 2023, Banyan released a new pit-constrained Inferred Mineral Resource estimate of approximately 6.2 Moz across their three deposits (Aurex Hill, Powerline and Airstrip; Table 1). Their drill program of 24 700 m was able to connect mineralization between Aurex Hill and Powerline as well as expand mineralization within and proximal to the current Mineral Resource at Aurex Hill and Powerline. Banyan also completed property-wide surface exploration programs at their AurMac and Nitra properties. Highlights from the 2023 drill program include 39.9 m of 0.60 g/t Au from 61.6 m downhole (AX-23-455), 34.2 m of 0.95 g/t Au from 33.5 m downhole (AX-23-458), 16.1 m of 1.66 g/t Au from 85.8 m downhole (AX-23-458), and 70.0 m of 0.31 g/t Au from 10.0 m downhole (AX-23-460; Banyan Gold Corp., 2023).

Snowline Gold Corporation's Rogue project has generated renewed interest in gold exploration in the Selwyn basin following the Valley discovery in 2021 and a successful drill program in 2022. Rogue is a RIRG target associated with a coarse-grained, mid-Cretaceous granodiorite of the Mayo suite. The company completed 15 917 m in 38 holes at Valley in 2023, testing, expanding and proving continuity of mineralization in three dimensions (Fig. 7). Selected drilling highlights from the program include 553.8 m at 2.48 g/t Au from 2.7 m downhole, including 183.3 m at 4.34 g/t Au (V-23-039); and 383.8 m at 2.47 g/t Au from 6.2 m downhole, including 120.0 m at 4.06 g/t Au (V-23-037; Snowline Gold Corp., 2023a). A NI 43-101 Technical Report for the Rogue property was filed in June 2023, effective May 15, 2023 (Snowline Gold Corp., 2023b). At the time of writing, assay results from 8300 m of drilling at Valley and satellite drill targets were still pending.

Snowline completed additional exploration drilling at their Rogue property on their Gracie (2061 m), LM/Reid (623 m) and Cujo (452 m) targets. They were also active at two of their exploration projects in southwestern Yukon, carrying out prospecting and mapping, as well as maiden drill programs at both their Cliff (1283 m) and Tosh (1716 m) projects. At the Cliff project, selected highlights from assays received from three of five drill

Table 1. *Banyan Gold's Mineral Resource Estimate, effective May 18, 2023*

Deposit	Au cut-off (g/t)	Tonnage (Mt)	Average Au grade (g/t)	Contained Au (koz)
Airstrip	0.25	41.2	0.68	897
Powerline	0.25	197.4	0.61	3840
Aurex Hill	0.30	74.3	0.60	1444
Average grade and cut off	0.25–0.30		0.61	
Total combined		312.9		6181

holes at the time of writing include 3.0 m at 1.42 g/t Au including 1.5 m at 2.04 g/t Au (CL-23-001) and 6.0 m at 0.94 g/t Au, 1.5 m at 4.58 g/t Au, and 1.8 m at 6.64 g/t Au (CL-23-003; Snowline Gold Corp., 2023c). At the Tosh project, assay results from two of the six drill holes had been received at the time of writing; selected highlights include localized elevated Au (0.10–0.45 g/t) and lenses of semi-massive sulphides returning 9.50 to 48.4 g/t Ag, 0.02 to 0.27% Cu and >1% Zn (Snowline Gold Corp., 2023d).

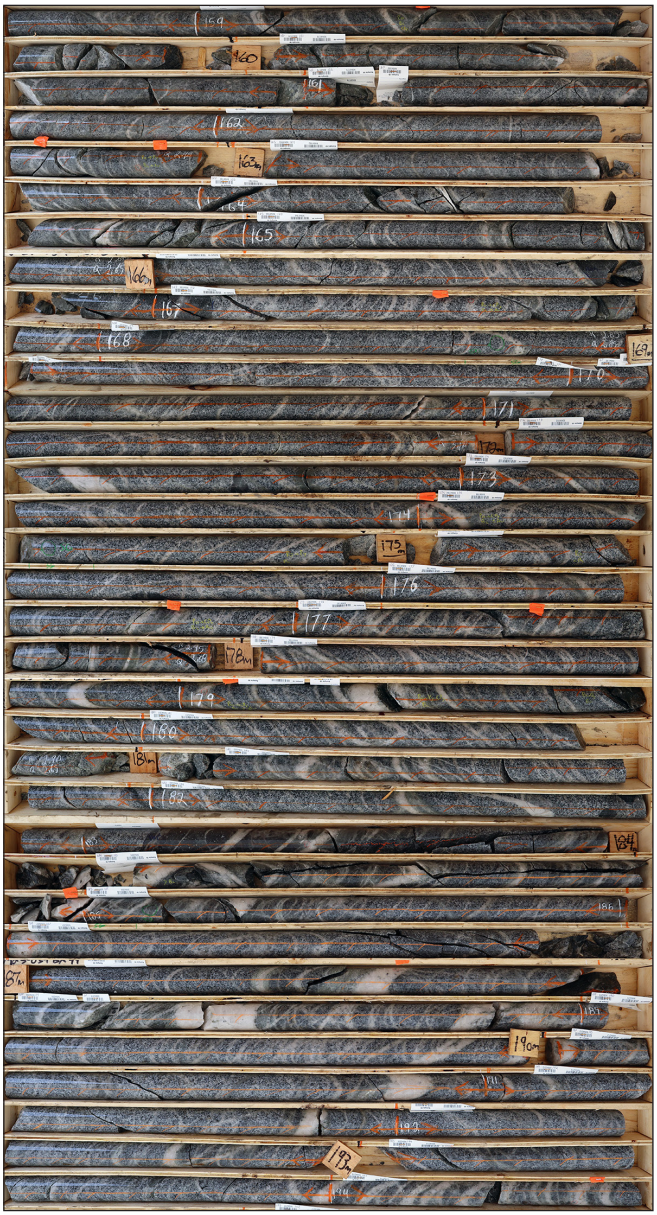

Figure 7. *Moderate to high-density, quartz-sulphide sheeted veins at Snowline Gold's Rogue property Valley target as seen in drillhole V-23-034 from 158.7 to 194.5 m; average grade of this section is 4.32 g/t Au (Snowline Gold Corp., 2023e).*

On January 19, 2023, Sitka Gold Corporation released a maiden Mineral Resource Estimate of 1.34 Moz Au at their Blackjack and Eiger deposits (Table 2). Their 2023 program comprised 6515 m of drilling in 16 holes, and focused on stepping out at Blackjack to test the margins of their current resource. They also completed a maiden drill program and property-scale airborne magnetics and lidar at their Josephine target. Highlights from one of their best drillholes to date are 219.0 m of 1.34 g/t Au from 190.0 m downhole, including 124.8 m of 2.01 g/t Au from 233.0 m downhole; and 55.0 m of 3.11 g/t Au from 276.0 m downhole, including 14.0 m of 5.53 g/t Au from 311.0 m downhole (DDRCCC-23-047; Sitka Gold Corp., 2023).

Additional RIRG targets are Rackla Metals Incorporated's HIT and SER properties in the eastern Selwyn basin, associated with mid-Cretaceous Tungsten suite intrusions. The company optioned the claims in late 2022 to early 2023 and completed their first field season on both properties in 2023. At HIT, mapping identified sheeted quartz-sulphide veins over a 2.2 by 1.2 km area, and soil and talus sampling defined a gold-bismuth-arsenic anomaly over a 1.5 by 1.0 km area. The latter area guided a maiden drill program consisting of five drillholes (997.5 m); two out of five holes encountered millimetre-scale sheeted quartz-sulphide veins with wide sericitic alteration halos (Fig. 8). Highlights from the drill program include 129.8 m grading 0.248 g/t Au (HIT-003) and 45.5 m grading 0.516 g/t Au (HIT-004; Rackla Metals Inc., 2023a).

Onyx Gold Corporation was spun out of HighGold Mining in May 2023 and spent the 2023 field season at their King Tut property testing the RIRG potential of Main Tut and Golden Mask. The company initially completed property-wide lidar, drone magnetic surveys,

Table 2. *Mineral Resource Estimate for Sitka Gold's RC Gold property.*

Deposit	Au cut-off (g/t)	Tonnage (Mt)	Average Au grade (g/t)	Contained Au (koz)
Blackjack	0.25	33 743	0.83	900
Eiger	0.25	27 362	0.50	440
Average grade and cut-off	0.25		0.68	
Total combined		61 105		1340

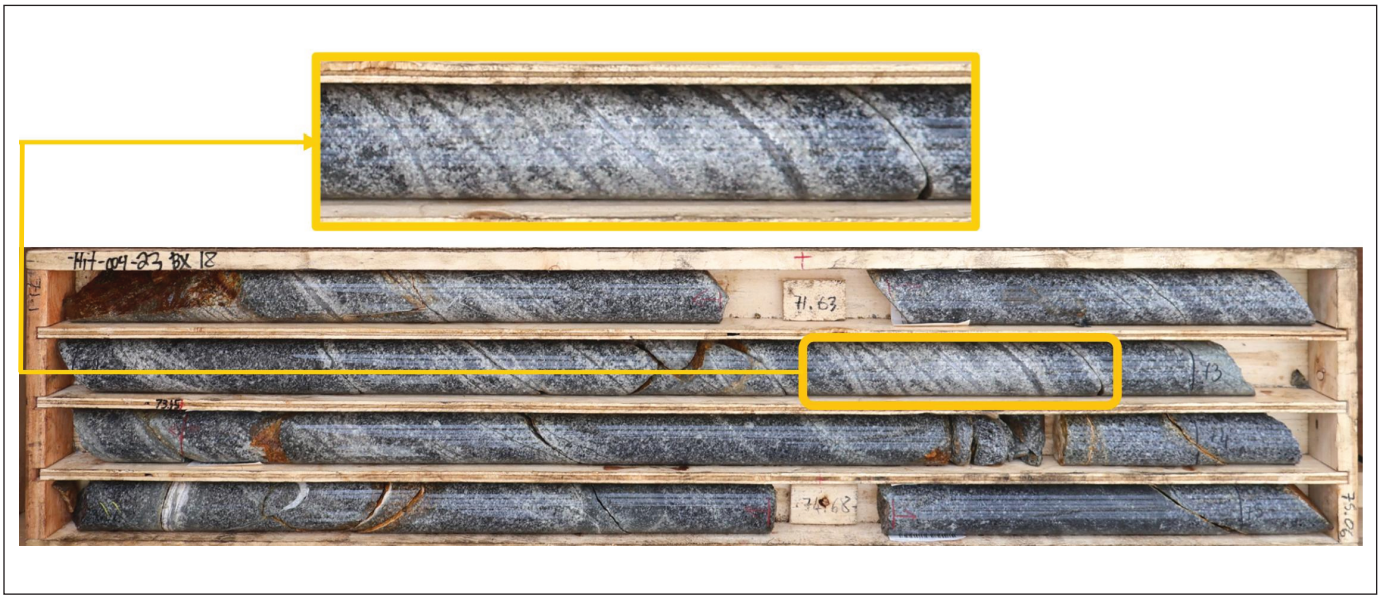

Figure 8. *Sheeted quartz-sulphide veins with wide sericitic halos from drillhole HIT-004 at Rackla Metal's HIT property; close-up photograph is from the inset outlined in yellow (Rackla Metals Inc., 2023b).*

soil surveys, mapping and prospecting. Following their surface programs, Onyx Gold completed a maiden drill program of 2123 m on Golden Mask and Main Tut. Selected drilling highlights include 0.13 g/t Au over 187.0 m, including 0.36 g/t Au over 21.0 m and 2.93 g/t Au over 1.0 m (KT23-002), and 0.30 g/t Au over 32.5 m including 0.56 g/t Au over 8.0 m (KT23-005; Onyx Gold Corp., 2023).

Honey Badger Silver Incorporated completed fieldwork at their Plata project, a past-producing silver-zinc-lead mine west of Snowline Gold that produced 290 000 oz Ag during operations between 1983 and 1984. Previous exploration focused on narrow, structurally controlled silver-zinc-lead veins similar to those in the Keno Hill district. The 2023 field program assessed RIRG potential at the property through prospecting, mapping and soil sampling.

In April 2023, White Gold Corporation released an updated Mineral Resource Estimate for their Golden Saddle, Arc, Ryan's Surprise and QV deposits. The resource contains 1.15 Moz Au (15.5 Mt at 2.28 g/t Au) Indicated and 0.94 Moz Au (19 Mt at 1.54 g/t Au) Inferred. White Gold completed two drill programs in 2023: one at the Vertigo target on their JP Ross property (five holes totalling 1022 m) and the other at Betty Ford (four holes totalling 1165 m). The Betty Ford target is a complex, multi-phase, polylithic breccia system where mineralization observed to date is vein controlled as well as hosted in the matrix and breccia clasts. Select drill highlights from BETFD23D015 include 5.04 g/t Au over 20.85 m from a depth of 18.65 m, including 13.34 g/t Au over 2.3 m and 11.47 g/t Au over 2.05 m, and 0.44 g/t Au over 28.55 m from a depth of 107.85 m, including 1.38 g/t Au over 6.15 m (White Gold Corp., 2023).

Klondike Gold Corporation continued to explore at their Klondike District property, completing 25 drillholes totalling 2340 m at Gold Run, Gay Gulch and eastern Stander. Highlights from the drill program include 4.39 g/t Au over 6.95 m (EC23-501) and 14.08 g/t Au over 1.10 m (EC23-502; Klondike Gold Corp., 2023). Surface programs included detailed mapping focused on identifying structural controls on emplacement of gold mineralization and rock sampling. The company has partnered with several universities to help characterize controls on mineralization in the district.

Farther south in the Dawson Range, K2 Gold Corporation was active at their Wels project, where they completed a 12-hole RC drill program totalling 1961 m at their Saddle (North, South, West), Chair and Pekoe targets. Drilling identified eight high-angle stacked mineralized structures within a corridor more than 400 m wide at their Saddle zone. Selected drilling highlights include 34.7 g/t Au over 1.52 m from 82.3 m downhole (WRC23-0006) and 1.60 g/t Au over 21.34 m from 3.05 m downhole, including 3.22 g/t Au over 9.14 m (WRC23-005; K2 Gold Corporation, 2023).

In southeastern Yukon, Seabridge Gold Incorporated focused exploration at 3 Aces on their Spades, Hearts,

Hearts West and Clubs targets in 2023. The drill program totalled 7500 m and tested a new exploration model for Hearts to better understand the structural controls and extent of mineralization. Results from the 2023 drill program were pending at the time of writing.

Strategic Metals Limited was active at several of their properties across the Yukon. Of note, Strategic completed small programs at their Byng, Lance and Mint projects. Byng is located 50 km northeast of Whitehorse and is interpreted as a low to intermediate-sulphidation epithermal gold target. A two-week field program comprising mapping and prospecting was completed; highlights include identification of a vein 1 to 3 m wide along a north-trending structure that returned 4.15 g/t Au and 29.5 g/t Ag. The Lance property is a RIRG target in the Selwyn basin. The company mapped, prospected and silt sampled within, and adjacent to, a mid-Cretaceous intrusion. Fieldwork identified sheeted quartz-arsenopyrite-pyrite veins with vein densities ranging from 2 to 11 veins per metre in outcrop. The Mint target in southwestern Yukon is a gold-copper porphyry target. Strategic drilled 1000 m in two drillholes testing mineralization at their Upper Canyon zone; results have not been made public yet. Drilling in 2023 followed up on encouraging drill results from 2012.

Copper exploration projects

In 2023, there were 14 active copper exploration projects. These projects accounted for 9% ($13.2M) of total exploration expenditures.

Cascadia Minerals Limited was spun out from ATAC Resource Limited in 2023 after Hecla acquired ATAC in July 2023. Cascadia was active at their Catch property where they were targeting porphyry-style mineralization hosted in Late Triassic basalt of Stikinia. Cascadia's field program comprised surface sampling, IP, ZTEM and aeromagnetic surveys to define drill targets, followed by a maiden drill program of five holes on the Diorite and Main zones. The company completed almost 2500 m of drilling: two holes, totalling 1066 m, at their Diorite zone and three holes, totalling 1400 m, at their Main zone. Drilling tested chargeability and magnetic anomalies coincident with mineralization at surface (Fig. 9). As of November 2023, results had been received from two of five holes and selected highlights include 116.60 m of 0.31% Cu and 0.30 g/t Au from 356.0 m within a broader, 435.0-m interval of 0.16% Cu and 0.09 g/t Au in CA-23-002 (Cascadia Minerals Ltd., 2023). Results from the remainder of the drill program are pending.

The Whitehorse Copper Belt is an advanced-stage exploration project that covers a number of copper ± molybdenum ± silver ± gold skarn targets and had past-producing mines that were in operation between 1967 and 1982. Gladiator Metals Corporation optioned the project in November 2022. In 2023, the company worked on regional mapping, chip sampling and drone aeromagnetic surveys as well as collating and digitizing all historical drilling results. The company also drilled 6632 m at the Cowley Park target in two phases: a 2632-m program in the spring and a 4000-m program in September. Highlights from their first phase of drilling include 13 m at 1.44% Cu and 0.15% Mo from 28 m downhole, and 33 m at 1.48% Cu from 71 m downhole within a broader interval of 113 m at 0.79% Cu (CPG-002; Gladiator Metals Corp., 2023). Results from the fall drill program were pending at the time of writing.

Triumph Gold Corporation received 2023 YMEP funding and was active at their Tad Toro and Big Creek properties. Work at Tad Toro comprised digital compilation of historical data, soil sampling, mapping and historical drillhole sampling. This work identified several broad multi-element soil anomalies, new geochemical anomalies at their Tad East zone, and porphyry-related alteration via hyperspectral analysis in historical drill core. At Big Creek, Triumph extended the multi-element soil geochemical anomaly in the Main zone to an area of 3 by 1 km.

The Alotta project in the Dawson Range is located approximately 40 km southeast of Casino and was recently optioned from Strategic Metals Limited to Benjamin Hill Mining Corporation in 2023. The company completed an IP survey and followed up with a maiden drill program to test chargeability anomalies coincident with copper and gold-in-soils. The 844-m drill program started November 8 and wrapped up November 28, 2023; results are pending.

Granite Creek Copper Limited was active at their Carmacks Copper project, completing a small YMEP-supported surface sampling program on the northern extent of their property. The company also filed a NI 43-101 Technical Report on January 19, 2023, as part of the project's Preliminary Economic Assessment and completed metallurgical work that aims to optimize copper oxide recoveries during mining (Granite Creek Copper Ltd., 2023).

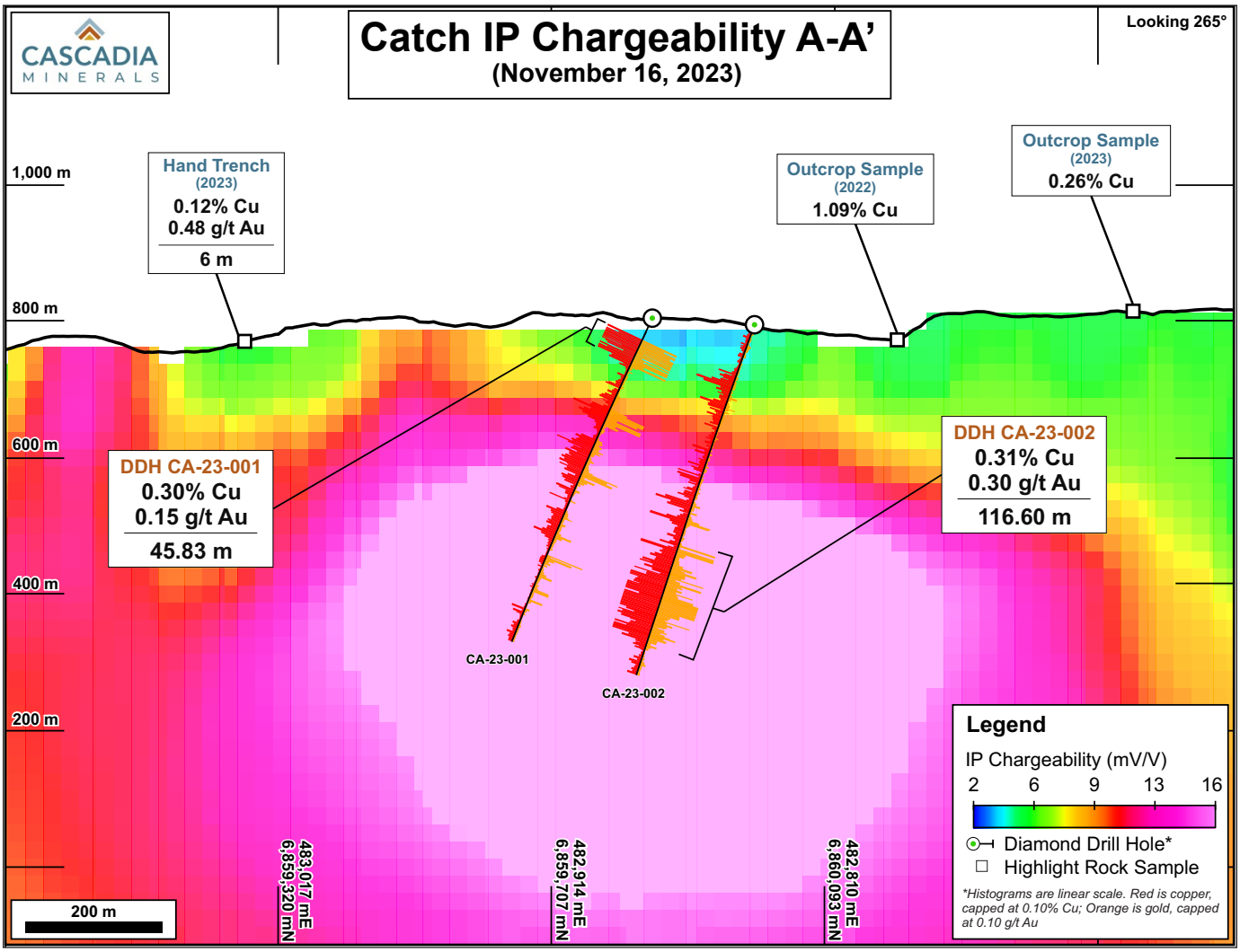

Figure 9. *Cross section showing IP chargeability, drill collar locations, assay results and surface sample highlights from Cascadia Minerals Diorite Zone (Cascadia Minerals Ltd., 2023).*

Silver, lead-zinc and tungsten exploration projects

There were 13 active silver and lead-zinc projects and 1 tungsten project in 2023. This accounted for approximately $52.1M in expenditures or 35% of total exploration spending in the territory.

Fireweed Metals Limited completed their largest field season ever at Macmillan Pass in 2023. Their program comprised 21 000 m in 57 holes, primarily focused at the Boundary zone as well as at the Tom and Jason deposits. Drilling aimed to expand the footprints of all known deposits and was able to connect mineralization in a high-grade feeder zone that linked their Boundary Main and Boundary West targets. Selected drill program highlights include 118 m grading 15.1% Zn, 2.8% Pb and 85.8 g/t Ag (NB23-007), including 77.07 m grading 18.7% Zn, 3.5% Pb and 101.4 g/t Ag (Fig. 10; Fireweed Metals Corp., 2023a). The company also completed a short field program to assess RIRG potential at MacMillan Pass and built an additional 48-person camp at the property, doubling their camp capacity. The company anticipates releasing an updated Mineral Resource Estimate in 2024.

In June 2022, Fireweed purchased the Mactung project, a tungsten skarn deposit associated with a mid-Cretaceous granitic intrusion(s) in eastern Yukon. The deposit straddles the border between Yukon and Northwest Territories and is one of the largest high-grade tungsten resources in the world (Fireweed Metals Corp., 2023b). In 2023, Fireweed released an updated Mineral Resource Estimate using historical drilling of 41.5 Mt of 0.73% WO_3 (Indicated) and 12.2 Mt of 0.59%

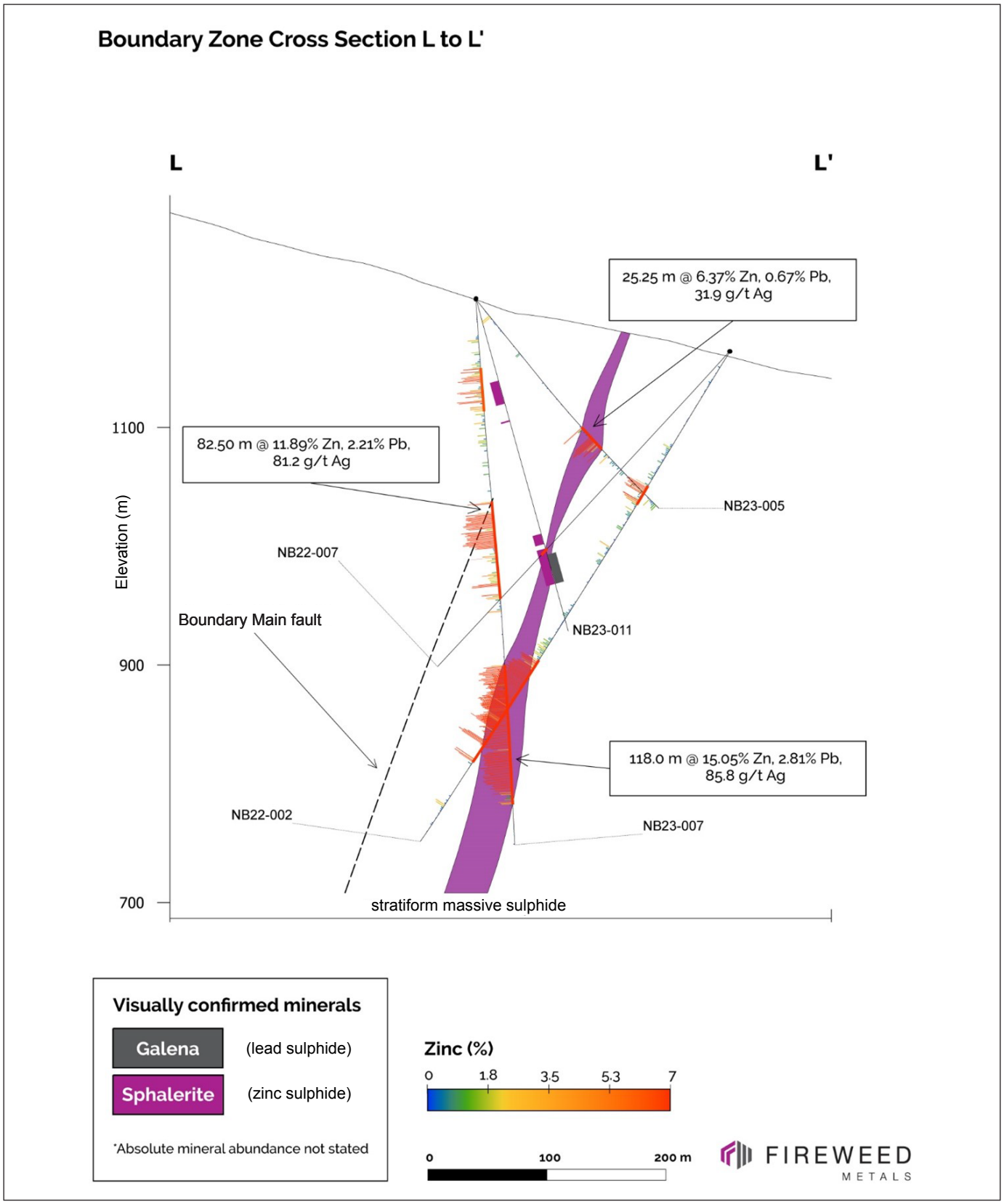

Figure 10. *Cross section of Fireweed Metal's Boundary zone showing drillhole NB23-007, which targets a high-grade feeder zone and intersects broad intervals of massive sulphides (Fireweed Metals Corp., 2023a).*

WO_3 (Inferred). The company completed 1500 m of drilling in 2023, including a metallurgical program to validate the Resource and optimize recovery, as well as environmental work and permafrost mapping.

Metallic Minerals Corporation was active at their Keno Silver project, which spans several different targets in the Keno Hill Silver District, including two small-scale, past-producing mines, and Caribou. In 2023, the company completed four drill holes at their Formo target focused on resource expansion, and they plan on releasing a maiden bulk-tonnage Mineral Resource Estimate for their Formo, Caribou, Homestake and Fox targets in early 2024.

The Pike Warden project is an epithermal-porphyry target south of the past-producing Mount Skukum mine. This project is currently under option by Transition Metals Corporation who received YMEP funding in 2022 and 2023. The 2023 exploration program was completed in two phases. The first phase involved lidar, orthophotography, multispectral satellite alteration mapping, and surface sampling programs, which were completed to identify new target areas. The second phase was a prospecting program that followed up on first phase exploration targets. Highlights from the program include 7 new showings, bringing the total number of showings to 25. The previously defined mineralization footprint was expanded at the ERT zone and two new occurrences of molybdenite were identified. Grab sample highlights include assays of up to 954, 832 and 347 g/t Ag (Transition Metals Corp., 2023).

Lastly, Cantex Mine Development Corporation announced on October 25 that they were starting a drill program at their North Rackla project. At the time of writing, results from this project were pending.

Nickel-PGE exploration projects

There were three active Nickel-PGE projects in southwest Yukon in 2023—Nickel Shäw, Catalyst North and Canalask—accounting for $900K or 1% of exploration spending in the territory. Nickel Creek Platinum Corporation did not carry out any fieldwork at Nickel Shäw in 2023; however, the company updated their Mineral Resource in April and filed a Pre-Feasibility Study Technical Report September 20, 2023 (Nickel Creek Platinum Corp., 2023). Their new resource, 1.12M tonnes (2.47 Blbs) of contained nickel grading 0.26% Ni, 0.13% Cu, 0.014% Co, 0.23 g/t Pd, 0.22 g/t Pt and 0.04 g/t Au Measured and Indicated, increases Measured tonnage by 31% and Indicated tonnage by 37%.

At Catalyst North, Stillwater Critical Minerals Corporation completed a field program comprising mapping, drone lidar and imagery acquisition, and prospecting. Stillwater is also examining the potential for carbon capture by identifying and mapping rocks for their potential to sequester carbon based on using existing data sources, remote sensing and imagery.

Palladium One Mining Incorporated completed a small airborne versatile time domain electromagnetic (VTEM™) survey at their Canalask project.

Yukon Mineral Exploration Program

The Yukon Mineral Exploration Program (YMEP) is a Government of Yukon-funded program designed to support early-stage exploration by individual prospectors, partnerships and companies. The funding supports placer and hardrock exploration projects by reimbursing a percentage of approved exploration expenditures. The program comprises four modules of varying reimbursement rates and funding limits: the Grassroots, Focused Regional and Target Evaluation modules apply to hardrock projects, and placer projects can receive funding from the Placer module. Applications for funding and submission of project proposals are due March 31 of each year. Detailed information on project modules, eligibility and levels of funding can be found in the YMEP guidebooks at https://yukon.ca/en/mineral-exploration-funding.

YMEP 2023

The total amount of YMEP funding available for the 2023–24 season was $1.4M. The program was oversubscribed and 57 applicants sought more than $1.9M. The breakdown of applications is shown in Table 3 and the geographic distribution of funded projects is shown in Figure 11. As of December 1, 2023, 43 applicants had funding agreements in place for the 2023–24 fiscal year: 26 (60%) hardrock and 17 (40%) placer (Table 3). An estimated $3.7M was spent on all YMEP-supported projects, $2.3M from industry and $1.4M from YMEP. Hardrock projects accounted for $2.0M of all program spending: $1.2M from industry and $800K from YMEP. Placer projects accounted for $1.7M: $1.1M from industry and $600K from YMEP.

Table 3. *YMEP 2023 application and funded project numbers.*

Type	Module	Total applicants	Total approved
Hardrock	grassroots	2	1
Hardrock	focused regional	8	8
Hardrock	target evaluation	23	17
Placer	target evaluation	24	17
Total		**57**	**43**

In 2023, YGS modified the YMEP evaluation criteria for hardrock applications to encourage exploration for critical mineral targets. Up to 10% of the total score was assigned to applications targeting critical minerals; 5% was assigned for projects that included critical minerals as a secondary target. In 2023, 27 hardrock projects included at least one critical mineral as a target, including 3 projects that focused exclusively on critical minerals.

Impacts of YMEP

The intent of the YMEP program is to support early-stage projects and stimulate new mineral discoveries in the Yukon. Several indicators can be used to measure the success of the program, including local economic benefits, dollars leveraged, new discoveries, and option agreements. The economic benefits of the program not only include the potential for same-year discoveries and long-term investment, but also short-term local spending in the territory. In 2021, YGS began collecting data from YMEP recipients to quantify the local economic impact of the program. Feedback received from 2022 YMEP recipients shows that 83% of total project expenditures stayed in the Yukon (Fig. 12).

YMEP 2023 project spotlights and discoveries

Projects that result in new discoveries or significant advancement of a target can lead to further investment in mineral exploration in the Yukon. Every year several YMEP-funded projects stand out and demonstrate exceptional initial results. Some projects raise additional funding on equity markets to conduct further work during the same field season; others enter into property option agreements. New discoveries can fuel property and district-scale exploration, and some progress to advanced stages of exploration. This section highlights one project from each of the four YMEP modules that returned exciting results in 2023, as well as a project that has seen ongoing YMEP investment for a few years and continues to yield promising results.

Grassroots module: Bonavista project

Prospector Chris Arsenault conducted a two-man, five-day work program near the confluence of Pirate Creek and the Tatshenshini River in southwestern Yukon. Several boulders of vein quartz up to 1 m across were found near an outcrop. These boulders, interpreted to be near source, yielded assays up to 2480 ppm Cu and 7.6 ppm Ag. Mineralized veins and a brecciated fault zone found in outcrop 200 m away assayed up to 1045 ppm Cu and 0.5 ppm Ag within a zone of massive epidote and sericite alteration. Both showings occur in granodiorite and quartz diorite of the Triassic Mount Beaton batholith. Arsenault staked two claims covering these showings.

Focused regional module: Fyfe Lake project

Prospector Ryan Burke worked his Fyfe Lake (MIL) property in 2023, discovering new epithermal veins, felsic volcanic rocks of unknown age, and significant structures immediately south of Fyfe Lake in south-central Yukon. The property was staked in 2022, and work in 2023 consisted of expanding and infilling soil sample grids plus prospecting, stream sediment sampling, and geological mapping. Burke found pervasive steam-heated alteration, strong oxidation, and brecciation of intermediate to felsic volcanic rocks (Fig. 13) coincident with Hg-As-Sb soil anomalies. He also observed coincident quartz-dickite-kaolinite alteration, and vuggy, latticed textures in outcrop, which suggest that a buried epithermal system may be nearby.

Target evaluation module: Nitra project

In addition to further drilling of the Airstrip, Powerline and Aurex Hill deposits at their AurMac property, Banyan Gold Corporation acquired YMEP funding to explore their adjacent Nitra property. The Nitra property is underlain by Neoproterozoic metasedimentary rocks of the Hyland Group intruded by mid-Cretaceous plutons of the Mayo suite. Situated between the AurMac property (6.2 Moz Au) and the producing Eagle gold mine (5.4 Moz Au), Nitra has good potential for RIRG. Banyan collected more than 4500 soil samples and had two prospectors following up on previous soil anomalies collecting 52 rock samples for assay; results are pending.

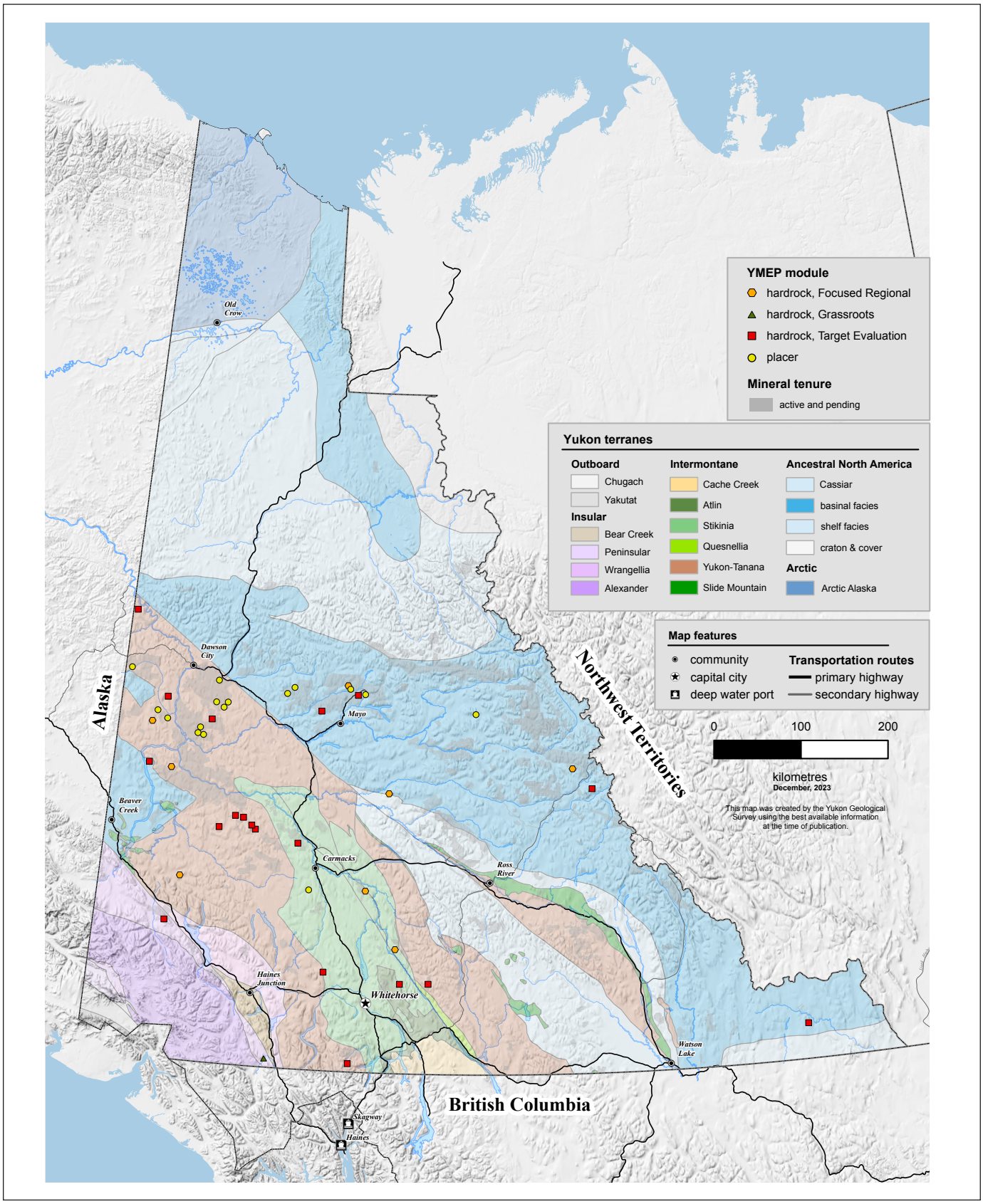

Figure 11. *The 43 projects funded by YMEP during 2023–24 are located throughout southern Yukon.*

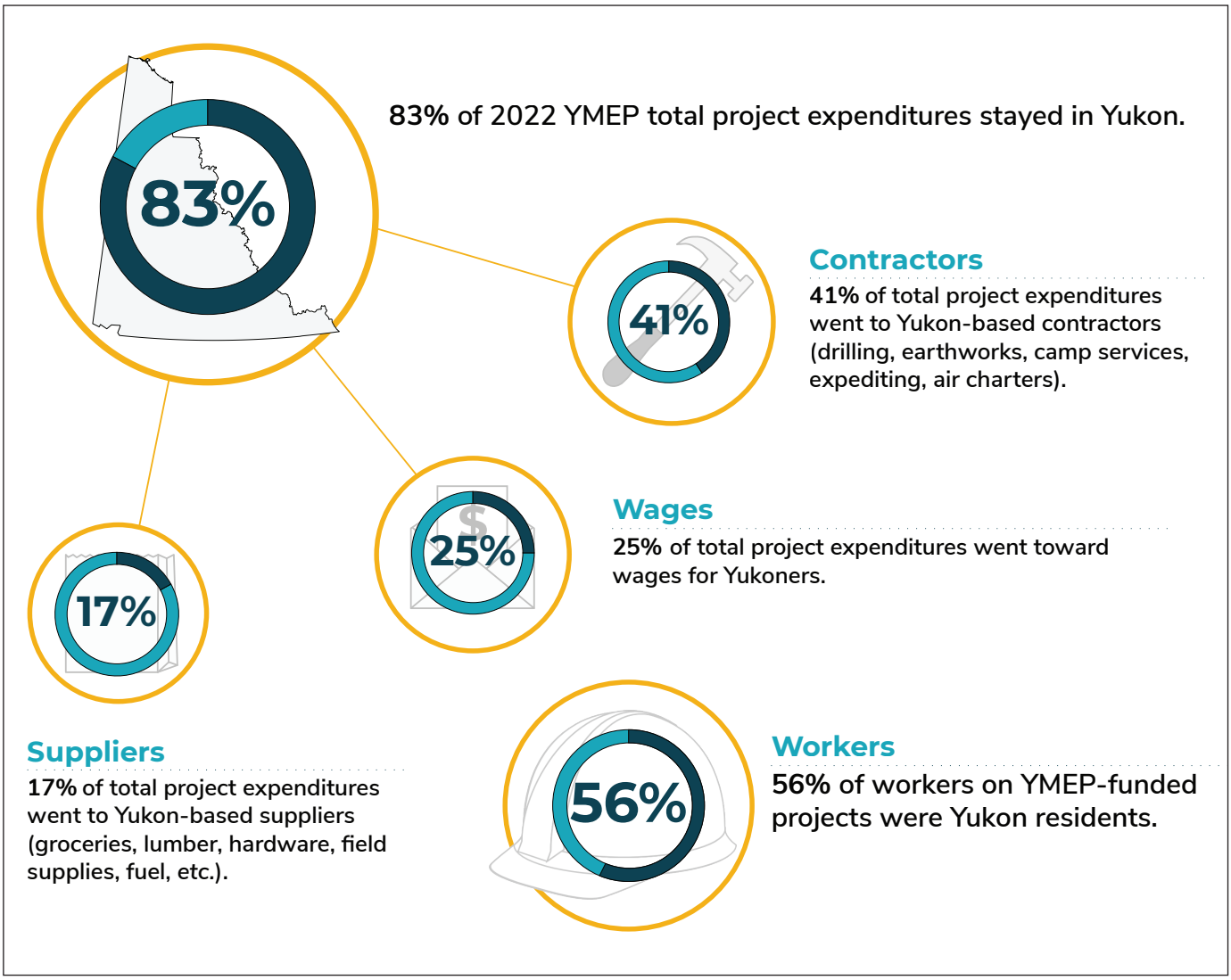

Figure 12. *Breakdown of where YMEP-supported projects spent their money in 2022.*

Placer module: Veronica bench project

Placer miner Jim Christie, owner and operator of Gimlex Entrprises Ltd., carried out test pitting on a left-limit White Channel bench deposit in the Dominion Creek valley at the confluence of Rob Roy and Veronica creeks using a Komatsu PC60 excavator. Exploration was focused along the edge of the bench, where the White Channel unit is thinnest and can be more easily prospected. Placer exploration success on this target could open up a significant amount of elevated bench ground in the lower Dominion Creek valley and is an example of the importance of exploration, even in locations with a high density of activity. To test the Veronica bench target, Christie processed three separate 1 yd^3 samples with a long tom and recovered appreciable gold. Results from the exposed stratigraphy in the test pits warrant additional investigation because the coarse diamicton in the pits is a new unit not previously known in the Dominion Creek valley.

Catch project: ongoing success

The Catch project is in Stikinia in south-central Yukon, 56 km southeast of Carmacks. This under-explored region is prospective for Cu + Au ± Mo porphyry deposits. Catch was staked by prospector Ryan Burke in 2020, who carried out exploration work with support from a YMEP grant. In early 2022, Burke optioned the property to ATAC Resources, which spun out the Catch property as part of Cascadia Minerals Ltd. Cascadia's 2023 program built on Burke's work and saw the first diamond drilling on the property. The first two holes were in the Diorite zone and returned consistent low-grade Cu over long intersections including 116.6 m

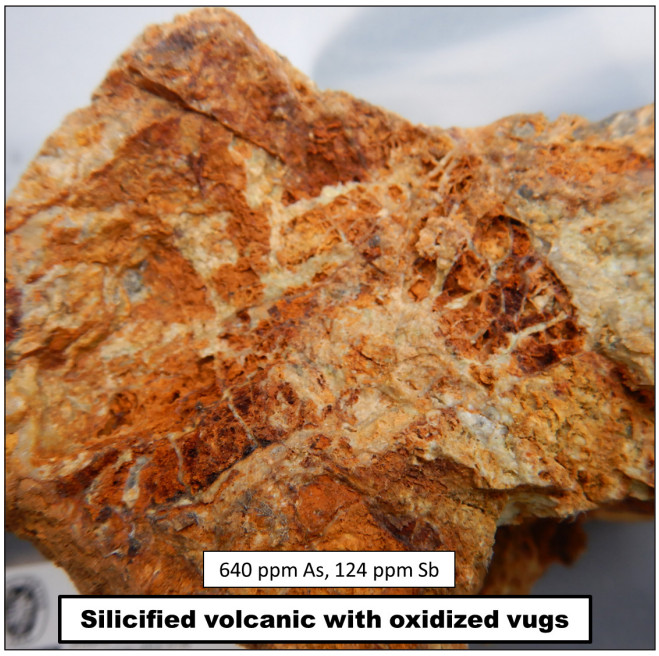

Figure 13. *Grab sample of silicified volcanic rock that assayed 640 ppm As and 124 ppm Sb.*

of 0.31% Cu and 0.30 g/t Au from 356 m downhole, within a broader interval of 435 m of 0.16% Cu and 0.09 g/t Au (Cascadia Minerals Ltd., 2023). Cascadia reported spending $2.5M on this project in 2023, which demonstrates how YMEP-supported discoveries continue to generate value.

Summary

Although there were many challenges in 2023 related to tough financial markets, wildfires and mine closures, the Yukon mining and exploration industry has continued to stabilize following the COVID-19 pandemic. A notable increase in exploration expenditures this year (up 18% compared to 2022) is a positive sign for exploration in the territory as companies continue to make new discoveries and advance their projects. The Yukon Geological Survey estimates that development expenditures and hardrock production revenue values will decline by 10% and 9% respectively in 2023, but anticipates them rebounding in 2024 pending the sale of Minto mine, continued increased production at the Eagle Gold mine, and the achievement of full production at the Keno Hill Silver mine.

A wave of renewed interest in RIRG exploration in the Selwyn basin resulted in significant drill intercepts and exploration results, including at Snowline Gold's Rogue project, Sitka Gold's RC project and Banyan Gold's AurMac project. Several companies that were previously active in Selwyn basin returned to explore their claims for RIRG deposits. Fireweed Metals completed their largest drill program to date and continued to make new discoveries and expand their orebodies. Many company's drill results were not released at the time of writing; the reader is encouraged to visit company websites for up-to-date exploration program results.

The YMEP continues to be well received by the Yukon exploration sector and has demonstrated significant benefits to the local economy over the years. The 2023–24 program funded 43 projects and the $1.4M government investment is expected to leverage an additional $2.3M in private funding for a total of $3.7M contributed to the Yukon economy. In addition to this immediate benefit, several projects yielded new discoveries that are likely to spur additional claim staking and exploration generating economic benefits well into the future.

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Appendix 1. Exploration projects active in 2023.

Project	Company/Owner	Commodity	Deposit type	Work type
Charlotte	1011308 BC Ltd.	gold, silver, copper, zinc, lead	vein/breccia	P, G, GGP, SGC, RGC
Justin	Aben Resources Ltd.	gold	vein/breccia	RGC
Bonavista	Arsenault, Chris	copper	unknown	P, SGC, RGC
Kudz Ze Kayah	BMC Minerals Ltd.	zinc, lead, copper, gold, silver	sediment associated	AGP
Hyland Gold	Banyan Gold Corp.	gold, silver, copper, zinc, lead	vein/breccia	SGC, RGC
AurMac	Banyan Gold Corp.	gold	reduced intrusion related	P, G, SGC, RGC, DD
Nitra	Banyan Gold Corp.	gold	reduced intrusion related	CS, P, G, SGC
Alotta	Benjamin Hill Mining Corp.	gold, copper	porphyry/sheeted vein	AGP, DD
Mil	Burke, Ryan	copper	unknown	SGC, RGC
CFX	Burke, Ryan	gold	unknown	SGC, RGC
Liv	Burke, Ryan	copper	porphyry/sheeted vein	P, G, SGC, RGC
Silver Hart	CMC Metals Ltd.	silver, lead, zinc, copper	manto, vein	RGC
North Rackla	Cantex Mine Development Corp.	zinc, lead, copper, silver, gold	skarn/replacement	DD
Rosy	Cascadia Minerals Ltd.	gold, copper, silver	vein/breccia	SGC, RGC
Catch	Cascadia Minerals Ltd.	copper, gold	porphyry/sheeted vein	P, G, AGP, SGC, RGC, T, DD
Misty	Coates, Jim	copper	skarn/replacement	P, GGP, RGC, RC
Battleship	Fekete, Mark	gold	unknown	P, SGC, RGC
MacMillan Pass	Fireweed Metals Ltd.	zinc, lead, silver	sediment associated	G, SGC, RGC, DD
Mactung	Fireweed Metals Ltd.	tungsten	skarn/replacement	DD
Cowley Park	Gladiator Metals	copper, gold, silver, molybdenum	skarn/replacement	DD, RGC
Best Chance	Gladiator Metals	copper, gold	skarn/replacement	P, RGC

Abbreviations
CS – claim staking
P – prospecting
G – geology
T – trenching

RGC – rock geochemistry
SGC – soil/silt geochemistry
DD – diamond drilling
RC – reverse circulation drilling

AGP – airborne geophysics
GGP – ground geophysics
ES – economic studies
DI – airborne drone imagery

Appendix 1. (continued) Exploration projects active in 2023.

Project	Company/Owner	Commodity	Deposit type	Work type
Arctic Chief	Gladiator Metals	copper, gold, silver, molybdenum	skarn/replacement	RGC
Grafter	Gladiator Metals	copper, gold, silver, molybdenum	skarn/replacement	P, RGC
Carmacks Copper	Granite Creek Copper Ltd.	copper, gold, silver	porphyry/sheeted vein	SGC
Keno Mine	Hecla Mining Company	silver, lead, zinc	vein/breccia	DD
Plata	Honey Badger Silver Inc.	silver, gold	vein/breccia	P, G, SGC, RGC
Clear Lake	Honey Badger Silver Inc.	lead, silver, zinc	sediment associated	P, G
Groundhog	Honey Badger Silver Inc.	silver, lead, zinc	skarn/replacement	P, G
Goldorak	Hulstein, Roger	gold	unknown	P, G, SGC, RGC
Wels Gold	K2 Gold Corp	gold	vein/breccia	RC
King Solomon Dome	Kestrel Gold Inc.	gold, copper, zinc, lead	vein/breccia	P, RGC, RC
Klondike District Property	Klondike Gold Corporation	gold	vein/breccia	P, G, RGC, DD
ORTRA	Kreft, Bernie	gold	unknown	P, G, SGC, RGC, T
FAB	Mann, Bill	copper	skarn/replacement	P, G, SGC, RGC
Carlin-Roop	Mayo Lake Minerals Inc.	gold, silver	unknown	T
Anderson-Davidson	Mayo Lake Minerals Inc.	gold	unknown	DD
Silver Queen (Keno)	Metallic Minerals Corp.	silver, lead, zinc, gold	vein/breccia	RGC
Keno Silver	Metallic Minerals Corp.	silver, lead, zinc	vein/breccia	P, G, SGC, RGC, DD
Coffee Project	Newmont Corporation	gold	vein/breccia	SGC, DD, RC
Nickel Shäw	Nickel Creek Platinum Corp.	nickel-pge	mafic/ultramafic associated	ES
King Tut	Onyx Gold Corp.	gold	reduced intrusion related	P, G, AGP, SGC, RGC, DD

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Appendix 1. (continued) Exploration projects active in 2023.

Project	Company/Owner	Commodity	Deposit type	Work type
Canalask	Palladium One Mining Inc.	nickel-pge	mafic/ultramafic associated	GGP
Hit (Mehitabel)	Rackla Metals Inc.	gold	reduced intrusion related	P, G, AGP, SGC, SGC, RGC, DD
Gossan	Rackla Metals Inc.	copper	porphyry/sheeted vein	CS, P, SGC
SER	Rackla Metals Inc.	gold	reduced intrusion related	P, G, SGC, SGC, RGC, DD
Excite	Rackla Metals Inc.	gold	porphyry/sheeted vein	P, G, AGP, SGC, RGC
Klaza	Rockhaven Resources Ltd.	gold	vein/breccia	ES
3 Aces	Seabridge Gold Inc.	gold	vein/breccia	DD, RC
Selwyn Project	Selwyn Chihong Mining Ltd.	zinc-lead	sediment associated	ES
Keg	Silver Range Resources Ltd	silver	skarn/replacement	
RC Gold	Sitka Gold Corp.	gold	reduced intrusion related	P, G, SGC, RGC, DD
Rainbow	Snowline Gold Corp.	gold	reduced intrusion related	CS, SGC, DD
Cliff	Snowline Gold Corp.	gold	vein/breccia	P, G, DD
Nordic	Snowline Gold Corp.	gold	reduced intrusion related	P, G, SGC, RGC
Cynthia	Snowline Gold Corp.	gold	reduced intrusion related	CS, SGC, G
Toshingermann	Snowline Gold Corp.	gold	vein/breccia	P, G, DD
Ursa	Snowline Gold Corp.	gold, silver	sediment associated	CS, SGC, G
Rogue	Snowline Gold Corp.	gold	reduced intrusion related	P, G, AGP, GGP, SGC, RGC, DD
Olympus	Snowline Gold Corp.	gold	vein/breccia	DI
Einarson	Snowline Gold Corp.	gold	sediment associated	CS, SGC, G
Ballarat Project	Stakeholder Gold Corp.	gold	porphyry/sheeted vein	P, G, AGP, SGC, RGC

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Appendix 1. (continued) Exploration projects active in 2023.

Project	Company/Owner	Commodity	Deposit type	Work type
Catalyst North	Stillwater Critical Minerals Corp.	nickel-pge	mafic/ultramafic associated	P, G, SGC, RGC
Golden Culvert	Stratabound Minerals Corp.	gold	vein/breccia	P, RGC
Mint	Strategic Metals Ltd.	copper	porphyry/sheeted vein	DD
Airstrip	Strategic Metals Ltd.	gold	vein/breccia	SGC, RGC
Byng	Strategic Metals Ltd.	gold, copper, silver	vein/breccia	P, G
Lance	Strategic Metals Ltd.	gold	reduced intrusion related	P, G
Pike-Warden	Transition Metals Corp.	silver, gold, copper	vein/breccia	P, G, RGC, T
Treble	Trifecta Gold Ltd.	gold, copper	porphyry/sheeted vein	SGC, RGC
Eureka	Trifecta Gold Ltd.	gold	vein/breccia	P, G, RGC
Big Creek	Triumph Gold Corp.	gold, copper	porphyry/sheeted vein	SGC, RGC
Tad/Toro	Triumph Gold Corp.	gold, copper	porphyry/sheeted vein	SGC, RGC
Lynx	Victoria Gold Corp.	gold	reduced intrusion related	P, G, SGC, T
Raven (Erin)	Victoria Gold Corp.	gold	reduced intrusion related	P, G, T, DD
Dublin Gulch (Eagle)	Victoria Gold Corp.	gold	reduced intrusion related	SGC, RGC, T
Casino	Western Copper and Gold Corp.	copper, gold, molybdenum, silver	porphyry/sheeted vein	DD, ES
Nolan	White Gold Corp.	gold	vein/breccia	DD
Wolf	White Gold Corp.	gold	vein/breccia	RC
Toonie	White Gold Corp.	gold	vein/breccia	RC
Betty	White Gold Corp.	gold	vein/breccia	DD
JP Ross	White Gold Corp.	gold	vein/breccia	DD
Hartless Joe	Private Company	gold	vein/breccia	DD

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Yukon Geological Survey's Outreach Program: 2023 highlights

Leyla Weston and Amanda O'Connor*
Yukon Geological Survey

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Introduction

The Yukon Geological Survey (YGS) includes a staff of approximately 20 geoscientists that conduct a wide variety of studies, including traditional bedrock and surficial mapping, community hazards mapping (e.g., monitoring landslides and thawing permafrost), mineral assessments, metallogeny and geothermal research. The role of geoscientists is to provide the knowledge required to meet society's demand for natural resources, environmental sustainability, and improved resiliency against geohazards (American Geosciences Institute, 2012).

The mandate of YGS is to provide objective, geoscience-related information to government, Yukon First Nations, and the public. Our research helps inform geoscience-related policy and investment decisions in Yukon, as well as support the land-use planning process. As a public government organization, we must improve geoscience literacy through effective communication so that all citizens of the Yukon understand how Earth's systems (lithosphere, biosphere, hydrosphere, and atmosphere) influence their everyday lives. Educating Yukoners will help them to make informed judgments that affect our territory and encourage public participation in policy making.

Yukon Geological Survey recognizes the importance of having geoscientists on staff who are dedicated to outreach and education. As of September 2023, YGS has two full-time, permanent Outreach Geologist positions. This paper is a summary of YGS' outreach and education activities over the last year.

Earth science education in Yukon schools

Geoscience is essential to tackling climate change, natural hazards, and the green energy transition, and yet enrolment in Earth science programs at Canadian universities has been on a steady decline since 2015 (Council of Chairs of Canadian Earth Science Departments, 2022). The Yukon, along with other parts of northern Canada, is seeing annual mean temperatures increase by almost three times the global mean average (Environment Canada, 2023), which will have tremendous impacts on the territory in terms of geohazards related to permafrost thaw, increased forest fire activity, and flooding. Furthermore, the green energy transition will require more geoscientists than ever. Our current generation of youth, including our Indigenous youth in the Yukon, have demonstrated a keen interest in taking action against climate change (Carter et al., 2021; Yukon Youth Panel on Climate Change, 2021; Yukon First Nations Climate Action Fellowship, 2023). There is a real need to educate our children and youth on the significant role that Earth science plays in climate change action:

> *"I've never learned much about mining in the Yukon. It's either been from TV shows who romanticize the industry or media discussing environmental disasters at mine sites. We'd all benefit from a clearer relationship with mining companies, that's how we guide constructive conversation."*
> *– Yukon youth (Yukon Youth Panel on Climate Change 2021)*

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Yukon schools follow the British Columbia curriculum with some Yukon-specific adaptations. Concepts of Earth science are introduced in grade three; however, the authors have recognized from experience that some concepts of Earth processes can be introduced even earlier (Fig. 1). To support Yukon teachers, YGS designs geoscience education lessons for the classroom that enhance the school curriculum. Lessons are designed to be engaging and predominantly consist of hands-on activities rather than a lecture-style format (Fig. 2). Activities vary depending on what is requested by the teacher and may include any number of Earth science topics such as the rock cycle, rock and mineral identification, geological time, geohazards, glacial landforms, or the uses of mineral resources in our everyday lives (Fig. 3). Every attempt is made to feature rock samples from the local area.

Whitehorse has incredible access to greenspace and provides great opportunities to bring the classroom outdoors for geology field trips to local points of interest. Field trips provide students with first-hand experiences of the local environment, allowing them to observe geological processes in the real world. Most trips focus on sites within the Whitehorse city limits such as the Whitehorse Copper Belt, Miles Canyon, Ibex Valley, Golden Horn, and Chadburn Lake area (Fig. 4). Science programs such as the Wood Street School's French Achievement, Challenge, Environment and Stewardship (FACES) and Experiential Science (ES) programs have participated in field trips farther afield, to places such as the Takhini thaw slump, Slims River in Kluane, and the Carcross dune fields. Through these field trips, students learn a variety of Earth science concepts, including (but not limited to) mineral and rock identification in the field, basic mapping techniques, the mining history of Whitehorse and the role that mining plays in our territory, permafrost and geohazards, and how to identify various glacial landforms. When weather permits, YGS outreach educators follow up school visits with a field trip to emphasize and illustrate concepts learned in the classroom. Although most geoscience education takes place during the school year, YGS outreach educators are also actively involved in leading guided field trips for youth day camps in the summer (Fig. 5).

Figure 1. *Amanda O'Connor describes the layers of the Earth and introduces concepts of the rock cycle to the grades 1 and 2 class of St. Elias Community School in Haines Junction.*

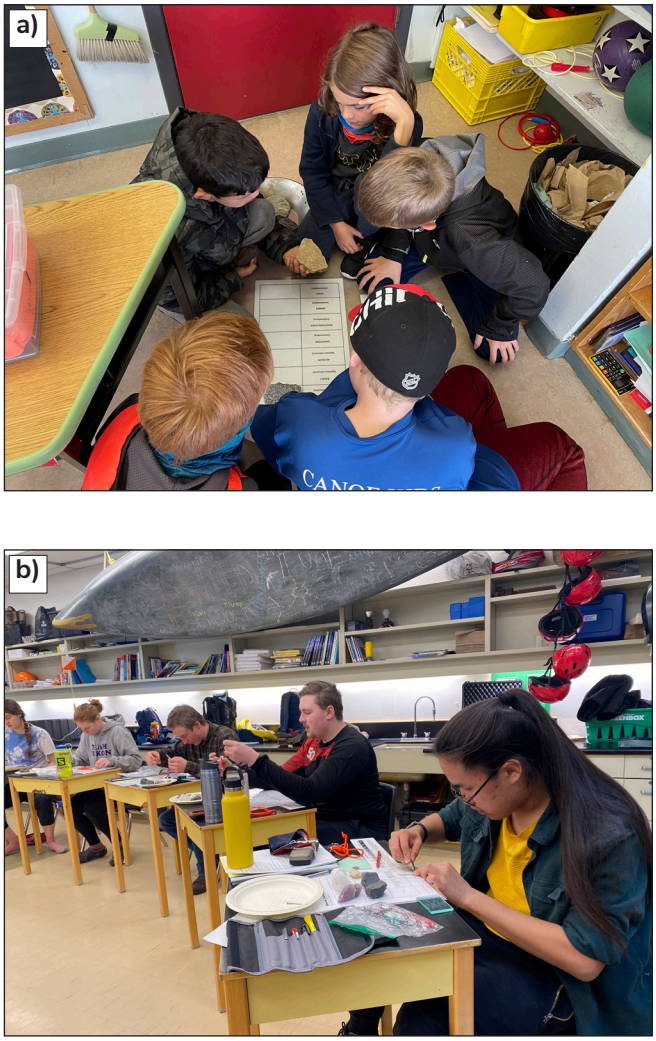

Figure 2. *Yukon Geological Survey–designed geoscience lessons to enhance the school curriculum:* **a)** *grade 5 students from Whitehorse Elementary work together on a rock identity activity;* **b)** *grade 11 students from the Porter Creek Secondary Wilderness Initiatives for Leadership Development (WILD) program learn about the physical properties of minerals.*

In 2023, YGS outreach educators, with support from other YGS staff, reached more than 540 students through classroom visits and field trips, including students at community schools in Mayo (J.V. Clark School), Carmacks (Tantalus Community School), and Haines Junction (St. Elias Community School).

Public and community outreach

Public geoscience literacy is also critical in our adult population so that residents can make intelligent and informed decisions that will not only affect the quality of their lives, but also those of their children. Public outreach by YGS is delivered through guided field trips, public talks, and open houses. This year, YGS staff participated in a few events of note, which are discussed below.

Figure 3. *Grade 5 students from Golden Horn Elementary learn how rocks and minerals are used in our everyday lives.*

Figure 4. *Yukon Geological Survey outreach educators bring the classroom outdoors in the form of geology field trips to local points of interest:* **a)** *grade 3 students from Selkirk Elementary learn about glacial landforms;* **b)** *grade 5 students from Whitehorse Elementary collect mineralized rock from the Whitehorse Copper Belt;* **c)** *grade 11 students from Wood Street's Experiential Science (ES) program work through a map and compass activity.*

Figure 5. *Leyla Weston of YGS leads an afternoon field trip to the Whitehorse Copper Belt for the Ta'an Kwäch'än Council's children's summer camp.*

Flood mapping workshop

In early March 2023, a two-day flood mapping workshop was hosted by the Water Resources Branch of the Government of Yukon. The intent of the forum was to bring together representatives from Yukon First Nation governments and the Government of Yukon to discuss the impacts of flooding on Yukon communities. Federal representatives from Climate Change Preparedness in the North and Canada Centre for Mapping and Earth Observation were also invited as observers. On Day 2, YGS was invited to present on geohazards associated with flooding. With so many Yukon First Nation governments together at one time, YGS saw an opportunity to also introduce some of their other program activities and research, including a presentation on how to access data and publications produced by YGS. Participant feedback was very positive and there was a clear desire for similar forums in the future.

> *"I thought this event was really well put together and connected related work. I would love to see the presenters from this event put together a concise presentation or open house that tours the communities and is open to the public."- First Nation Government participant.*

Sunnydale landslide open house

In August 2023, three YGS staff attended an open house in Dawson City to share results from their collaborative research with BGC Engineering on the Sunnydale landslide, situated on the west bank of the Yukon River at Dawson City. Citizens of the community learned about the recent hazards assessment of the Sunnydale slide, which modelled six different failure scenarios including predicted slide runouts and resultant displacement waves in the Yukon River. Derek Cronmiller, YGS permafrost geologist, who is the technical lead for the Sunnydale and Moosehide slides in Dawson City, also discussed the April 2023 installation of near–real-time monitoring stations on the Sunnydale slide. The monitoring equipment communicates the movement of the slide every hour to a base station at the Dawson City Fire Hall, and position data can also be checked by YGS staff through a web portal (Fig. 6). Similar monitoring equipment was also set up on the Moosehide slide in August 2022. The goal of the monitoring equipment is to provide an early warning system that will alert the community if ground movement accelerates, which could be an indicator of a pending slide. The landslide monitoring work is a joint initiative by the Government of Yukon, the Tr'ondëk Hwëch'in First Nation government, and the City of Dawson.

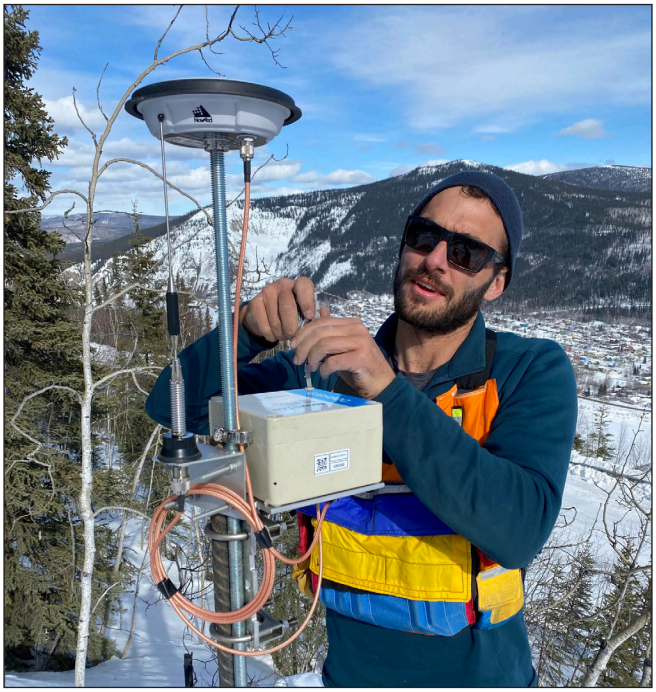

Figure 6. *Derek Cronmiller of YGS installs near–real-time monitoring equipment at the Sunnydale slide in Dawson City.*

Kluane Park interpretive hike

In June 2023, YGS geologists Rosie Cobbett, Jeff Bond, and Leyla Weston (the first author) led an interpretive hike near Sheep Mountain in Kluane Park. The interest was overwhelming, with more than 40 participants (Fig. 7). Cobbett, who has mapped extensively in southwest Yukon, led the bedrock geology component of the field trip, while Bond talked about the glacial history of the area with a focus on the Slims River piracy and paleoclimate. The event was a collaborative effort by YGS and Kluane National Park and Reserve staff. Park staff recognize that there is interest from the public to learn about the geology of the Kluane region and the goal is to provide a weekend of guided hikes and talks on a regular basis.

International Geodiversity Day

Enhancing public geoscience literacy has been a long-standing initiative for geological surveys across Canada. Recently, the National Geological Surveys Committee (NGSC) developed the Pan-Canadian Geoscience Strategy (PGS), which aims to develop a more coordinated effort between Canada's geological surveys to deliver public geoscience. The PGS' long-term vision is "to provide geoscience information that underpins the responsible development of Canada's geological resources and serves the public good." (National Geological Surveys Committee, 2022). Five interdependent priority areas for action are defined in the strategy: advancing framework geoscience, advancing mineral and energy potential modelling, facilitating access to online data, supporting the training of next-generation geoscientists, and enhancing public literacy (National Geological Surveys Committee, 2022, p. 2). Committees were set up for each of these priority areas; Weston and O'Connor sit on the committee for the 'enhancing public literacy' priority area, along with geoscientists from several territorial and provincial geological surveys. The committee decided to promote UNESCO's International Geodiversity Day, which occurs annually on October 6, to meet some of the goals of the PGS. The committee invited geological surveys across Canada to promote geodiversity in their respective provinces and territories. Participating geological surveys celebrated their jurisdiction's geodiversity by offering local field trips, talks, or other public events. At YGS, outreach educators put together a social media event titled 'Wake up to Yukon geology' that highlighted several features of Yukon's geology. Posts were made to Facebook and Instagram as the clock struck 8 a.m. across each of Canada's six time zones. Topics covered included the discovery of Nun cho ga, critical minerals in Yukon, the Moosehide slide in Dawson, the geothermal potential of Yukon, permafrost, and Mount Logan—the highest peak in Canada.

Figure 7. *Rosie Cobbett, Jeff Bond and Leyla Weston of YGS led a public field trip in Kluane that attracted more than 40 participants.*

Dakwäkäda Mountain Festival

Finally, in early November 2023, some of the YGS staff were invited to participate in the Dakwäkäda Mountain Festival in the community of Haines Junction. The annual festival, now hosted by the Champagne and Aishihik First Nation, returned after a hiatus due to the COVID-19 pandemic. The festival celebrates Dákeyi (the Traditional Territory of the Champagne and Aishihik First Nation) through First Nations culture, learning, science, research, and mountain culture. The one-day festival featured workshops, talks, art, films, live music, dance, and storytelling. Weston (first author) gave a talk on YGS geothermal research in Yukon with a focus on the community of Haines Junction. O'Connor (the second author) and Moya Painter of YGS ran a booth featuring the augmented reality (AR) sandbox along with an outreach activity designed to challenge the public to think about the rocks and minerals that make up items that are used in everyday life (Fig. 8).

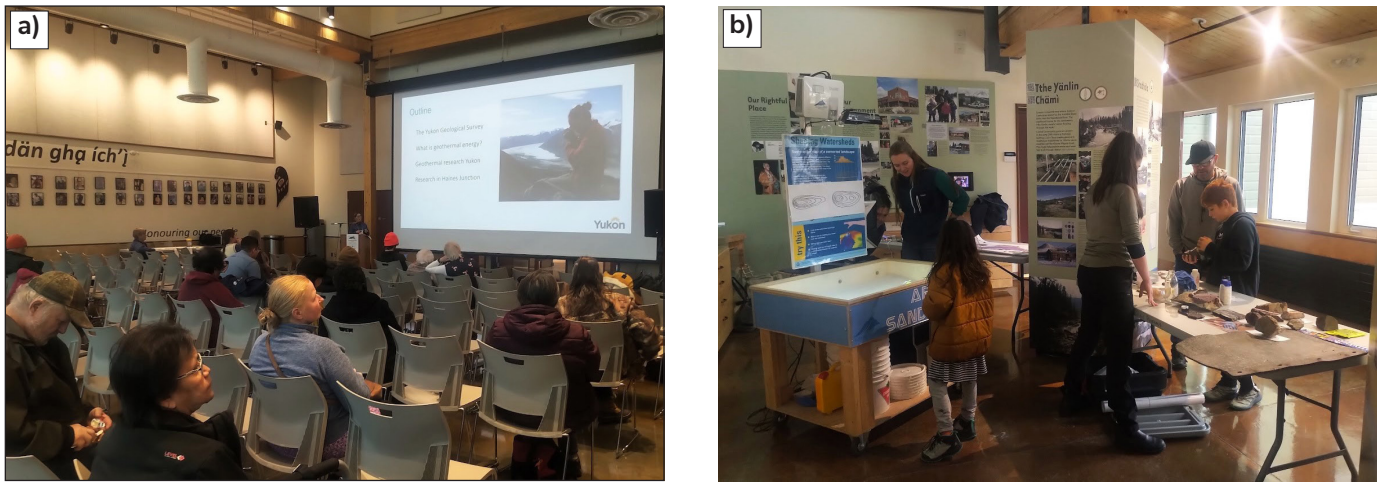

Figure 8. *Yukon Geological Survey participates in the Dakwäkäda Mountain Festival in Haines Junction:* **a)** *Leyla Weston presents on YGS' geothermal research in Yukon;* **b)** *Amanda O'Connor and Moya Painter facilitate geoscience outreach activities at the festival.*

Events

Every year, YGS participates in, and/or facilitates several geological events for Yukon students and the public that highlight aspects of Earth science and Yukon geology. Below are descriptions of the main events that bring together hundreds of students and the public each year.

Mining Week

Mining Week is an annual celebration that takes place in early May. The event is hosted by Yukon Women in Mining in partnership with the Yukon Chamber of Mines, and illustrates the importance of the role that mining and geology play in our society. The contribution of YGS, facilitated by Weston, is to organize an evening public field trip to the Whitehorse Copper Belt and student tours to the one-day Discovery Day Camp. Mining Week Discovery Day Camp is a highly anticipated event for teachers and students alike. In 2023, more than 200 students in grades 4–12 descended on Rotary Park in Whitehorse to participate in the event, which takes place partially within wall tents and partially outdoors. Students cycle through a variety of mining and geology-themed activities. The YGS ran rock and mineral identification activities for students, a product matching activity, and a geological mapping exercise (Fig. 9). Students also learned about topographic maps through an activity done in the AR sandbox.

Weekend on the Rocks

Tombstone Territorial Park, known as Ddhäl Ch'èl Cha Nän, which means 'ragged mountain land', is situated on the Traditional Territory of the Tr'öndëk Hwëch'in First Nation. The park is a very popular destination for tourists and Yukoners alike and offers a variety of programming throughout the summer. Every weekend in August, the Tombstone Interpretive Centre highlights a different aspect of the park's natural history. The YGS hosts 'Weekend on the Rocks' at the end of August each year. In 2023, YGS geologists led three guided walks and two evening talks highlighting the geology of the Tombstone region. Guided hikes included Goldensides, Charlie's Canyon, and the Grizzly Lake trail, which ends at a viewpoint overlooking the valley leading to the spectacular peaks of Mount Monolith (Fig. 10). All hikes involved multiple stops to discuss the geology of the area and point out interesting rocks or features.

Figure 9. *Grade 8 students from the Wood Street French Achievement, Challenge, Environment and Stewardship (FACES) program build a simple geological map at Discovery Day Camp during Mining Week.*

Participants learned about the geological history of the park firsthand while observing some of the clues in the rocks and landscape that geologists have used to piece together this history. Rosie Cobbett and Jeff Bond, geologists from YGS, presented the evening talks. Cobbett gave an overview of the geological history of the park, and Bond spoke about the surficial geology and paleogeography of Beringia. Both talks were held in the Tombstone Park Interpretive Centre and were very well attended (Fig. 11).

Yukon Geoscience Forum Family Day

Every year in November, the Yukon Chamber of Mines hosts Yukon's Geoscience Forum and Trade Show in downtown Whitehorse. The four-day conference covers all aspects of the mining industry in Yukon and brings together industry experts, geoscientists from government and academia, representatives from First Nations and Yukon governments, investors, and members of the supply and service sector. Public outreach occurs on Family Day, a one-day event where residents of Whitehorse learn about the role the mining industry has in the Yukon while exploring a variety of interactive booths. Education activities in 2023 included a flight simulator; a tour of a mine site using a virtual reality headset; digging for stones, gems and metals; learning about biostratigraphy; identifying features in a placer mine through a diorama; and spotting hazards using various images of work in the office and in the field. The authors, along with Bailey Staffen, Moya Painter and Orlina Ménard of YGS, brought the AR sandbox, rock and mineral identification activities, and the ever-popular product-matching activity (Fig. 12). This year, Family Day attracted more than 300 people of all ages.

Figure 10. *Field trips led by YGS during Weekend on the Rocks in Tombstone Territorial Park:* **a)** *Rosie Cobbett searches for radiolarians in chert with a participant on a guided hike through Charlie's Canyon;* **b)** *Leyla Weston discusses the local geology on the Grizzly Lake trail.*

Training and inreach

Staff at YGS are often called upon throughout the year for their expertise on geological topics and sites in the Yukon. This can be in the form of outreach for private, non-profit organizations (e.g., Yukon Conservation Society) or inreach for other Government of Yukon branches (e.g., Water Resources Branch, Department of Highways and Public Works, Historic Sites, and the Yukon Beringia Interpretive Centre). In the past, Weston has been involved in providing non-technical text for Historic Sites on the geology of sites for their interpretive panels including the Tintina Trench, Mt. Haldane near Mayo, and the geology of Montana Mountain. Geoscience outreach and education have been a priority for YGS for more than a decade, and other

Figure 11. *Jeff Bond presents on the glacial history of Tombstone Park with highlights on Beringia during Weekend on the Rocks.*

Figure 12. *At the Yukon Geoscience Forum Family Day:* **a)** *Leyla Weston gives a lesson on topography in the augmented reality sandbox;* **b)** *Bailey Staffen helps participants match rocks and minerals to everyday products;* **c)** *Amanda O'Connor teaches a youngster about the physical properties of minerals.*

departments of the Government of Yukon are starting to look to YGS for how they can further develop their own outreach efforts or expand on their programming. This year, the Youth Programs Coordinator from Government of Yukon's Department of Environment asked Weston to provide training for the camp leaders of their Yukon Youth Conservation Corps (Y2C2), a summer employment and training program for Yukon students aged 16 and up. Students work in small groups on environment and conservation-related projects around the territory. Weston spent one day with senior Y2C2 camp leaders looking at the roadside geology along the Alaska Highway from Whitehorse to Marsh Lake. Later, Weston and Moya Painter followed up with a half-day discussion of bedrock geology and glacial history in the Annie Lake area south of Whitehorse (Fig. 13).

First Nations engagement

Yukon Geological Survey engages with Yukon First Nations (FN) with respect to our program activities. To build trusting and meaningful relationships with Yukon's FN governments, YGS endeavors to increase communication and seek input from FNs early in the planning stages of projects. Routine engagement includes spring and fall update letters to all affected FNs with respect to our program activities as well as meetings with the Lands and Resources staff of the FN governments. In 2023, YGS engaged with 12 Yukon FNs on bedrock mapping; targeted permafrost studies; community mapping; landslide studies; metallogeny; and a regional magnetotelluric geophysical survey (for geothermal research), which was in collaboration with the Geological Survey of Canada.

Figure 13. *Moya Painter of YGS discusses the glacial history of the Annie Lake area with camp leaders of the Yukon Youth Conservation Corps youth program.*

The Yukon Geological Survey also continues to actively engage and collaborate with several First Nations regarding ongoing geothermal research in southern Yukon. There is great interest from Yukon FNs to become self-reliant and to move toward cleaner energy solutions, particularly in communities that rely on diesel fuel for heat and energy (e.g., Watson Lake, Burwash Landing, Destruction Bay, Beaver Creek, and Old Crow). In 2020, YGS acquired $2M of funding over three years from Natural Resources Canada's Emerging Renewable Power Program to explore for geothermal resources associated with crustal-scale fault systems. With funding for this program nearing its end, YGS held an information session in October 2023 to share some results from the last several years of research. The one-day information session was by invitation only to Yukon FN governments and community administrators, and included several presentations and a panel discussion including perspectives of FN governments, industry professionals, and university researchers. Representatives from six FNs and five municipal governments attended, along with representatives from other organizations such as the Council of Yukon First Nations, the Government of Yukon's Energy Branch, and the Yukon Development Corporation.

Summary

Understanding geoscience is becoming increasingly vital for all citizens. For Yukoners, having a better understanding of Earth science will be necessary to meet the four goals outlined in the Government of Yukon's Our Clean Future strategy: reduce Yukon's greenhouse gas emissions by 45% by 2030; ensure Yukoners have access to reliable, affordable, and renewable energy; adapt to the impacts of climate change; and build a green economy (Government of Yukon, 2021). Geoscience knowledge is also critical to making informed decisions concerning land-use planning and development. The YGS views geoscience outreach and education as essential to provide all Yukoners and Yukon First Nations with accurate geological information that will help our communities move toward greater sustainability.

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Yukon Exploration and Geology 2023 abstracts

The following abstracts are from the Yukon Exploration and Geology 2023 volume. Full versions of the individual papers are available from the Yukon Geological Survey website, https://data.geology.gov.yk.ca/.

Shear-wave velocity from broadband HVSR measurements for geothermal resource assessment near Burwash Landing, Yukon

Fernando Berumen-Borrego, Hersh Gilbert, Jan Dettmer, Jeremy M. Gosselin and Pejman Shahsavari

As Canada pursues net-zero CO_2 emissions targets, geothermal energy represents a promising solution, especially in northern Yukon communities such as Burwash Landing. Currently, Burwash Landing relies on importing diesel for power and heating and would benefit from a reliable source of renewable energy. Our study uses horizontal-to-vertical spectral ratio (HVSR) measurements from nine temporary broadband seismometers to refine shear-wave velocity models for the upper 500 m of the crust. These models constrain layering and structure within shallow sediments, depth to bedrock, and discontinuities within the bedrock. These results provide reliable estimates of the thickness of sedimentary cover overlying bedrock. Bedrock depths vary from 50 to 450 m, deepening to the northeast of the Denali fault, and V_S follows a power-law increase with depth through sediments. These insights improve the geological understanding around this portion of the Denali fault and contribute to constructing comprehensive models for the development of geothermal energy in the region.

Permafrost-related landslides following 2017 wildfire, Dempster Highway, Yukon (parts of NTS 116G/9 and 116H/12)

Heather C. Clarke, Derek C. Cronmiller, Brent C. Ward and Katelyn Groeneveld

The Yukon is experiencing impacts of climate change, marked by elevated annual air temperatures, alterations in precipitation patterns and increased wildfire activity. These changes can lead to permafrost degradation, impacting highways and community infrastructure. In July 2017, a wildfire burned a slope in permafrost terrain above the Dempster Highway in the Yukon. In the years following the wildfire, two types of permafrost-related landslides have been observed on the slope. Active layer detachment activity was highest in the first year after the landslide, possibly influenced by warm temperatures and rainfall events. Retrogressive thaw flow slides formed in 2019 in areas of ice-rich permafrost and are still active in 2023. Deposition of sediment and influx of water has resulted in flooding near the highway, further degrading the permafrost in the valley bottom. This study characterizes the landslide timing and morphology following a wildfire on permafrost terrain, investigating potential triggers and controls.

Seismicity near the eastern Denali fault from temporary and long-term seismic recordings

Jongwon Han, Jan Dettmer, Jeremy M. Gosselin, Hersh Gilbert, Katherine Biegel and Seongryong Kim

We studied earthquakes near Burwash Landing, Yukon. Using data from temporary and permanent seismic stations, we enhanced the understanding of both regional and local earthquakes. The study used deep learning and template matching to effectively detect earthquakes, even from noisy data. Following detection, earthquake source parameters, location, and magnitude were estimated and refined. The analysis revealed 103 local earthquakes, with 28 located in an area of geothermal resource potential. Notable small-magnitude earthquakes were observed near Bock's Creek fault. No earthquakes were observed on the Denali fault during the study period. The existence of active faults strike-parallel to the Denali fault suggests that local permeable structures may exist in the area. Regional observations detected 46 432 regional earthquakes in 13 years, but none along a section of the Denali fault near Burwash Landing, Yukon, which we interpret as a seismic gap.

Surficial geochemical data extracted from Assessment reports: development and initial release of the database

Yury Klyukin

The Yukon archive of assessment reports contains a significant amount of data; however, accessing these data is challenging due to the absence of a centralized storage system. This paper introduces the Geochemical Assessment Report Data Extracted database (GARDEd), which is specifically designed to store these data. Initially, GARDEd was constructed using data from assessment reports from a 75 km radius of the Casino deposit in the Yukon, but this spatial limit was subsequently removed. The initial release of the database contains geochemical data describing more than 300 000 surficial samples from more than 300 assessment reports submitted after 2004.

The structure of GARDEd follows the data model developed by the British Columbia Geological Survey for storing surficial geochemical sample data acquired from their assessment reports. This paper outlines the structure of the database and discusses the workflow for extracting the data. The paper also describes a custom Python tool developed to automate data extraction from digital assessment reports.

Preliminary site characterization for earthquake hazard assessment using ambient vibration techniques in Haines Junction, Yukon (parts of NTS 115A/11, 12, 13, 14)

Tess Leishman, Jeremy M. Gosselin, Jan Dettmer, John F. Cassidy and Tae-Seob Kang

Regional mapping of soil stiffness improves understanding of seismic hazard in northern Canada, specifically southwestern Yukon, where local amplification hazards are largely unknown. Ambient vibration (AV) measurements record microtremor seismic noise used to calculate the horizontal-to-vertical spectral ratio (HVSR) and identify resonant frequencies at sites. In-situ estimation of fundamental frequency (f_0) is used to characterize sites and map local site amplification hazards. Furthermore, AV measurements permit the estimation of surface-wave propagation speeds at different frequencies (*i.e.*, dispersion). Dispersion measurements are used to infer profiles of shear-wave velocity as a function of depth. We present preliminary site characterization using AV measurements from 23 measured sites in Haines Junction, Yukon. The preliminary results suggest a spatial trend of fundamental frequency laterally, where higher frequencies are identified north of Haines Junction and lower f_0 values are identified in south-central Haines Junction. We attribute these observations to the proximity to the Dezadeash River basin.

Hydrothermal modeling of Takhini Hot Springs (NTS 105D/14)

Xavier Léveillée-Dallaire and Jasmin Raymond

The Takhini Hot Springs, located northeast of Whitehorse, Yukon, exhibits significant geothermal potential with a surface water temperature of 46°C. To address the limited geological knowledge in the region, a 500 m deep well was strategically drilled in this area and intercepted warm groundwater (25°C) at a depth of 450 m. The objective of this study was to assess the geothermal potential of the Takhini Hot Springs area using 2D subsurface flow and heat transfer simulations to numerically replicate the observed temperature and gain a better understanding of heat transfer mechanisms affecting the geothermal resource. Inclined permeable layers such as contacts between fractured sedimentary units appear to facilitate groundwater circulation, creating a path for geothermal fluids to rise. A fault that is assumed to be subvertical is present in the area but does not impact the model's water circulation. A sensitivity analysis was conducted to define the impact of each model parameter on the hot springs temperature and on temperature profiles simulated in the Takhini well. The analysis revealed that boundary conditions, including basal heat flux and surface recharge, as well as rock thermal conductivity and permeability, are the most influential parameters in the model.

Preliminary report on the bedrock geology southwest of Big Salmon Lake (parts of 105F/3, 4, 5, 6), south-central Yukon

David Moynihan

Two contrasting lower Paleozoic units underlie the region southwest of Big Salmon Lake in south-central Yukon. The lower unit comprises dolomitic quartzite, quartzite, dolostone, dolomitic shale, siltstone and sandstone, and their metamorphosed equivalents. Two-holed crinoid ossicles indicate an Early–Middle Devonian age for the dolostone. These dolomitic rocks are overlain by largely carbonate-free, dark, fine-grained and siliceous strata. Rock types include graphitic phyllite, siltstone, metachert and porphyroblastic metapelitic schist. The two units are correlated with the Askin and Earn Groups, respectively. An interval of metabasaltic schist locally marks the boundary between the Askin and Earn groups. Mafic and ultramafic rocks are intermittently exposed beneath the Askin Group in parts of the region.

The lower Paleozoic metasedimentary units are crosscut by deformed Devonian–Mississippian two-mica augen gneiss and by largely undeformed mid-Cretaceous megacrystic biotite granite to monzogranite. Deformation prior to the mid-Cretaceous produced close to tight folds that trend northwest. The associated axial-planar cleavage/schistosity dips northeast at moderate to steep angles, away from the crest of a major antiformal structure.

Characteristics of deep permafrost in Yukon communities

Moya Painter

A drilling program was conducted in fall 2023 to install deep (up to 35 m) ground temperature monitoring boreholes in communities at risk from permafrost thaw. These boreholes will serve as long-term reference sites in both undisturbed and developed locations within or adjacent to communities. These boreholes also filled knowledge gaps that included the thickness of permafrost, and temperature data at the bottom of permafrost. Prior to this program, only 3 of the 34 permafrost-monitoring boreholes managed by the Yukon Geological Survey recorded temperatures through to the bottom of permafrost; furthermore, none of these boreholes are in the extensive discontinuous or continuous permafrost zones. Fifteen boreholes were drilled in five different communities across the Yukon: Dawson City, Mayo, Ross River, Beaver Creek and Haines Junction. Permafrost was encountered in 10 of the 15 boreholes, and the bottom of permafrost, or bedrock, was reached in at least one borehole in each community.

Preliminary observations of the Mesoproterozoic Pinguicula Group in the Coal Creek inlier, Yukon (parts of NTS 116B/11, 14)

Lucy C. Webb and Tyler K. Ambrose

Proterozoic strata in central Yukon are exposed in the Coal Creek, Hart River and Wernecke inliers. The Paleoproterozoic and Neoproterozoic strata are well correlated across the inliers; however, correlation of the Mesoproterozoic units remains ambiguous. We present two stratigraphic logs of Mesoproterozoic units PP1 and PP2 (previously termed PR1 and PR2, respectively) in the Coal Creek inlier. PP1 is dominantly siltstone and sandstone, whereas PP2 is mostly dolostone. In one section where the contact is well exposed, PP2 gradationally overlies PP1, suggesting that these units, at least locally, are conformable. Based on similarities in the stratigraphy and contact relationships with underlying and overlying units, we suggest that PP1 and PP2 are correlative with the Pinguicula Group formally defined in the Hart River and Wernecke inliers. Resolving how PP1 and PP2 correlate with Proterozoic strata exposed in other inliers provides insight into basin development along northwest Laurentia during the Meso–Neoproterozoic.

YGS list of publications and data releases for 2023

YGS released 5 publications in 2023: 3 Open Files and 2 Annual Reports.

Open Files

Lipovsky, P.S., 2023. Surficial geology and geohazards of the greater Whitehorse area. Yukon Geological Survey, Open File 2023-1, 67 p. plus appendices

Steinke, J.L., Ward, B.C. and Bond, J.D., 2023. Surficial geology of Granite Creek (part of NTS 105M/15 and 105M/14), Yukon (scale 1: 15 000). Yukon Geological Survey, Energy, Mines and Resources, Government of Yukon, Open File 2023-2.

Witter, J.B, 2023. Analysis of geoscience data for geothermal exploration along the Teslin fault near Teslin, Yukon. Yukon Geological Survey, Open File 2023-3, 48 p. plus digital appendices.

Annual reports

Yukon Geological Survey, 2023. Yukon Exploration and Geology Overview 2022. K.E. MacFarlane (ed.), Yukon Geological Survey, 70 p.

Yukon Geological Survey, 2023. Yukon Exploration and Geology 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, 126 p.

Annual overview papers

(YEG overviews 2022)

Relf, C., 2023. Yukon Geological Survey 2022 overview. *In*: Yukon Exploration and Geology Overview 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 1–19.

van Loon, S. and Bond, J.D., 2023. Yukon placer mining 2022 development and exploration overview. *In*: Yukon Exploration and Geology Overview 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 21–31.

Ellis, S. and Casselman, S.G., 2023. Yukon Mineral Exploration Program 2022 update. *In*: Yukon Exploration and Geology Overview 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 33–42.

Casselman, S.G., 2023. Yukon hard rock mining, development and exploration overview 2022. *In*: Yukon Exploration and Geology Overview 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 43–59.

Annual report papers

(YEG technical papers 2022)

Biegel, K., Gosselin, J. and Dettmer, J., 2023. Preliminary double-difference relocation earthquake catalogue for southwestern Yukon centred along the Denali fault zone. *In*: Yukon Exploration and Geology 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 1–18, plus digital appendices.

Bodtker, J., Cronmiller, D.C, Bond, J.D. and Shugar, D., 2023. The Sunnydale landslide, current understanding and research, Dawson (NTS 116B/3). *In*: Yukon Exploration and Geology 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 19–33.

Chapman, F.M., Miranda, M., Soucy La Roche, R. and Raymond, J., 2023. Fracture network analysis in the Duke River area, southwestern Yukon. *In*: Yukon Exploration and Geology 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 35–62.

Gosselin, J.M, Biegel, K, Hamidbeygi, M. and Dettmer, J., 2023. Improvements in the regional earthquake focal mechanism catalogue for southwestern Yukon. *In*: Yukon Exploration and Geology 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 63–76 plus digital appendices.

Hatton, C., Ielpi, A., Cronmiller, D.C. and Painter, M., 2023. Geomorphic assessment of Tsälnjik Chú (Nordenskiold River) near Carmacks, Klondike region, Yukon. *In*: Yukon Exploration and Geology 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 77–91.

Moynihan, D., 2023. A preliminary geological interpretation of the Mount Grant–Evelyn Creek area, southern Yukon (parts of 105C/11, 12, 13, 14). *In*: Yukon Exploration and Geology 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 93–107.

Painter, M., Cronmiller, D.C. and Bond, J.D., 2023. Mapping the rate of change of select glaciers using satellite and ground-based observations, Yukon and northwestern British Columbia. *In*: Yukon Exploration Geology 2022, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 109–126.

Contributions to external publications

Cobbett, R.N., Beranek, L.P., Piercey, S.J., Crowley, J.L., **Colpron, M.**, 2023. Early Ordovician seamounts preserved in the Canadian Cordillera: Implications for the rift history of western Laurentia. Geosphere, vol. 19, no. 5, p. 1421–1451. https://doi.org/10.1130/GES02613.1. **YGS Contribution 063**

Kroeger, E.D.L., McClelland, W.C., **Colpron, M.**, Piercey, S.J., Gehrels, G.E., 2023. Detrital zircon U-Pb and Hf isotope signature of Carboniferous and older strata of the Yukon-Tanana terrane in Yukon, Canadian Cordillera: Implications for terrane correlations and the onset of Late Devonian arc magmatism. Geosphere, vol. 19, no. 4, p. 1032–1056. https://doi.org/10.1130/GES02607.1. **YGS Contribution 064**

Datasets

Updated:

Yukon Geological Survey, 2023. Yukon digital bedrock geology. Yukon Geological Survey, https://data.geology.gov.yk.ca/Compilation/3. Updated September 1, 2023.

Yukon Geological Survey, 2023. Yukon Lithogeochemistry data set. Yukon Geological Survey, https://data.geology.gov.yk.ca/Compilation/35. Updated July 31, 2023.

Yukon Geological Survey, 2023. Yukon Geochronology – A database of Yukon isotopic age determinations. Yukon Geological Survey, https://data.geology.gov.yk.ca/Compilation/22. Updated July 31, 2023.

Yukon Geological Survey, 2023. Yukon Permafrost Database. Government of Yukon, https://service.yukon.ca/permafrost/. Updated weekly, 2023.

Yukon Geological Survey, 2023. Surficial Geology dataset. Yukon Geological Survey, https://data.geology.gov.yk.ca/Compilation/33. Updated August 11, 2023.

Newly created:

Yukon Geological Survey, 2023. Yukon isotope data. Yukon Geological Survey, https://data.geology.gov.yk.ca/Compilation/37. Released November 15, 2022.

Yukon Geological Survey, 2023. Mineral Inventory Dataset. Government of Yukon, https://data.geology.gov.yk.ca/Compilation/40. Released December 1, 2023.

Yukon Geological Survey, 2023. YGS Core available for viewing on Digital Core Table (Geologic AI). Government of Yukon, https://www.arcgis.com/home/webmap/viewer.html?webmap=87457fac7009430189f95d909cba55a6. Released December 1, 2023.

Yukon Geological Survey

Yukon Geological Survey staff are located in two buildings in Whitehorse: the Elijah Smith Building at 300 Main Street, room 102, and the H.S. Bostock Core Library at Mile 918 on the Alaska Highway.

Operations

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