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J.J. Ryan, A.J. Parsons, S.A. Israel, J.W. Haggart,
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Publications in this series have not been edited; they are released as submitted by the author.

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Foreword

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to investment in responsible resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the summer 2016, GEM program has successfully carried out 17 research activities that include geological, geochemical and geophysical surveying. These activities have been undertaken in collaboration with provincial and territorial governments, northerners and their institutions, academia and the private sector. GEM will continue to work with these key collaborators as the program advances.

Project summary

This open file report present preliminary findings of geological fieldwork carried out under the crustal blocks activity of the GEM2 Cordillera project. We report on a 2 week mapping project in the Klaza River area that improved on reconnaissance mapping completed in the 1970's. This work modernizes understanding of the regional geology of this important area that hosts the now closed Mount Nansen gold mine, and the recently discovered Klaza mineral deposit. Detailed mapping was carried out in the Dunite Peak area of the Big Salmon Range to study a classic example of a rock assemblage believed to have represent part of the Earth's mantle from Paleozoic times, and reconcile its role in the tectonic evolution of the Canadian Cordillera. We report on a detailed examination of an important thrust fault (Yukon River thrust) that may have

been responsible for Cordilleran mountain building and stacking within terranes back in latest Triassic time (i.e. 200 million years ago). We report on collaborative work across the Yukon and Alaska border to reconcile the extent of an important geological unit known regionally as the Klondike assemblage; thought to be an important source rock of placer gold in the region. We also provide an update of research on Cretaceous and younger clastic sedimentary strata of south-central and western Yukon that will help provide constraints on the tectonic setting of sedimentation that took place in northern Cordillera ca. 100-70 million years ago, which is currently poorly understood.

Introduction

The Canadian Cordillera is considered the world's type example of an accretionary orogen (ancient mountain belt) and comprises distinct tectonic blocks referred to as terranes, some of which are bounded by faults. Recent and ongoing activities within GEM have prompted the hypothesis that mineralization in the Cordillera is controlled by the complex internal architecture of the blocks, and not only by their bounding structures. As a test of this hypothesis, the *Ancient Faults and Their Controls on Mineralization in Northern BC and Southern Yukon* activity (referred to informally as Crustal Blocks) of the GEM 2 Cordilleran Project (Fig. 1), conducted detailed mapping of select target areas in the Yukon-Tanana, Slide Mountain, and neighbouring terranes to constrain regional controls on disposition of units and mineral deposits as well as the nature of the boundaries of these terranes with ancient North America (Laurentia) through time. This field-based project involves detailed mapping that is complemented by new geochronological, geophysical, and geochemical analyses of key crustal blocks and their bounding structures.

The main science questions being addressed by the Crustal Blocks activity are:

1) Where are the major suture zones in the northern Cordillera, what do they represent tectonically, and what is the resulting provinciality of mineral potential in the newly subdivided terranes?
2) What are the lithospheric and crustal scale controls on gold and base metal fertility?

The 2016 field program is the last of three planned field seasons wherein Geological Survey of Canada (GSC) geoscientists will collaborate with Yukon Geological Survey, British Columbia Geological Survey, and Canadian universities. These field activities conducted in western and southern Yukon and northern British Columbia investigate major structural breaks in the regional geology, and their potential role in controlling mineralization in this area which has significant but poorly understood mineral potential.

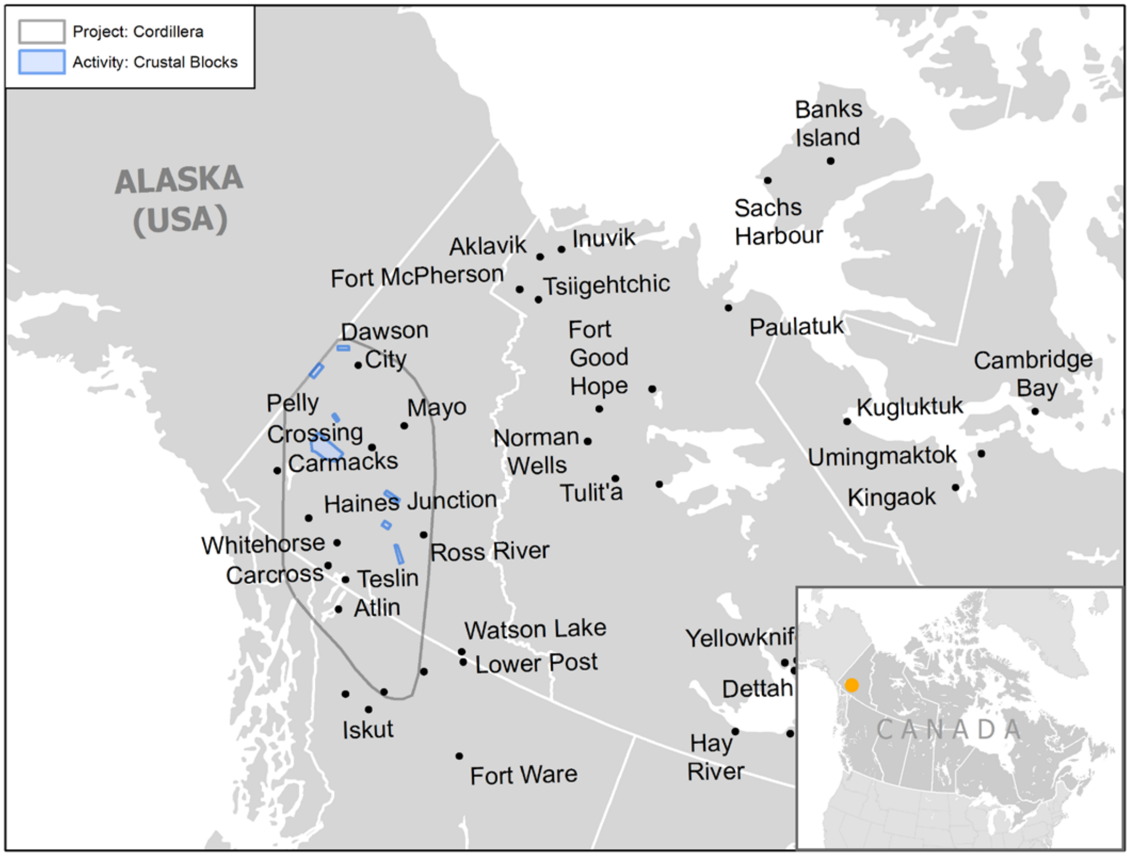

Figure 1: Overview map illustrating the footprint of the Cordillera project in northwest Canada. The footprints of the Crustal Blocks activity is highlighted in blue.

During 2016, field investigations were carried out in several areas in west central Yukon (Fig. 2) under the Crustal Blocks activity, whose main goals and objectives were:

1) A mapping project in the Klaza River area to:
   - Update reconnaissance bedrock geology (Tempelman-Kluit, 1974, 1984; Carlson, 1987), and integrate it into modern tectono-stratigraphic framework of western Yukon (e.g., Colpron et al., 2006; Murphy et al., 2006; Ryan et al., 2014a; 2016; Colpron et al., 2016), with seamless transition with 2015 mapping of the Mountain Nansen – Nisling River area;
   - Help elucidate the regional geological context of the Klaza mineral deposit;
   - Improve understanding of map distribution and mineral potential of Cretaceous to Tertiary magmatic suites, particularly the late Cretaceous Casino suite
2) Reconnaissance and detailed mapping of mafic-ultramafic complexes in the Dunite Peak and Quiet Lake areas to:
   - Determine their origin and mode and history of emplacement
   - Determine the nature of the structural basement of these complexes

   This sub-activity is described in Parsons et al. (2016)

3) Detailed investigation of the Yukon River thrust;
   - Determine its exact position and significance
   - Evaluate its kinematic history and age of activity
4) Detailed traverses through the Klondike assemblage of western Yukon and eastern Alaska to reconcile the western extent of this important geological unit, and determine if and where it traces across the international border into eastern Alaska
5) Review the stratigraphy and paleontology of mid-Cretaceous sedimentary rocks in west-central Yukon (Indian River Formation) in order to constrain the paleotectonic setting of these strata and to assess their importance in the mid-Cretaceous evolution of the greater Cordillera.

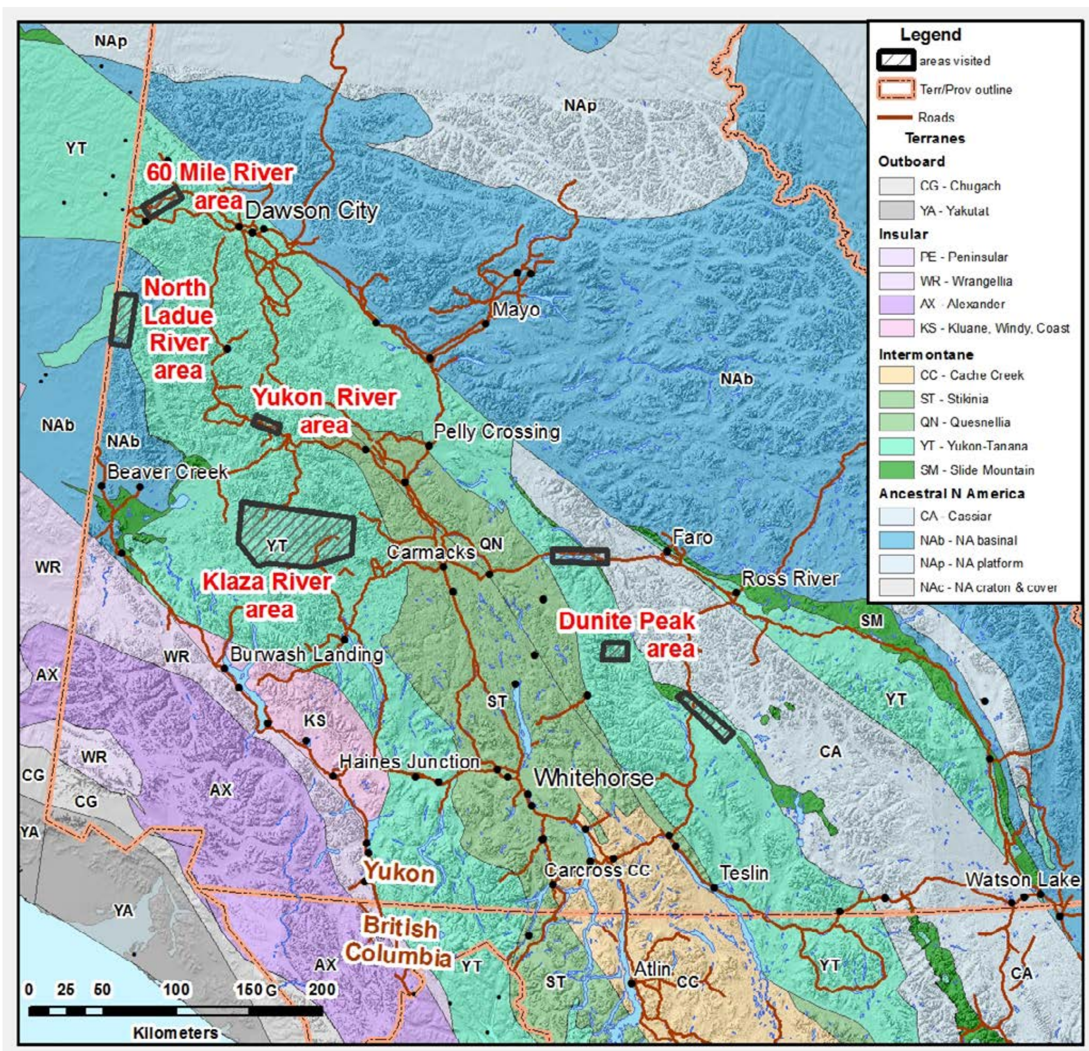

Figure 2: A simplified terrane map of the Northern Canadian Cordillera showing the location of the field areas visited during summer 2016 Crustal Blocks activity (modified from Colpron and Nelson, 2011).

Methodology

Fieldwork in the Klaza River area was conducted from the Klaza exploration camp, accessible by the Mount Nansen road. Mapping at 1:50 000 scale was conducted over 2 weeks by helicopter-supported foot traversing and spot checks, and supplemented by work from truck. Mapping was greatly assisted in this area of variable quality bedrock exposure by recently acquired 400 m resolution aeromagnetic data (e.g., Hayward et al., 2012). The locations of traverses were chosen to target key geological problems, particular lithological units, or test geophysical anomalies evident in the geophysical data or existing mapping (eg., Tempelman-Kluit, 1974, 1984; Ryan et al., 2016). Samples were collected for geochronology, petrography, lithogeochemistry, thermochronology, and isotopic analysis.

In the Big Salmon Range, 3 days of helicopter spot checks were completed around the mafic-ultramafic complexes in the Dunite Peak and Quiet Lake areas, followed up by 2 weeks of detailed mapping and sample collection in the Dunite Peak area, completed by helicopter-supported fly camps. Samples were collected for microstructural petrofabric analysis, thermobarometry, geochronology and geochemical analyses. These samples will be form the basis for a detailed PTtD study (Pressure-Temperature-time-Deformation) of the Slide Mountain terrane and its interaction with peri-Laurentian and parautochthonous terranes (for greater detail see Parsons et al., 2016).

Research on the Yukon River thrust was completed during a 3 day remote camp along the Yukon River in the vicinity of Pedlar Creek. Excellent quality shoreline exposures were easily accessed by boat along the Yukon River. Some small samples were collected for microstructural petrofabric analyses to determine the kinematics and pressure-temperature conditions of deformation.

Research on the Klondike assemblage was carried out over 6 days by helicopter assisted foot traverses and spot checks based out of Tok, Alaska and Dawson City, Yukon in collaboration with J.V. Jones, C.S. Holm-Denoma, and J.S. Caine of the United States Geological Survey (USGS) in early August. The location of traverses were planned using the existing compilation maps (Gordey and Ryan, 2005; Foster, 1970; 1976), with restrictions imposed by difficult access due to heavy vegetation.

Research on the Cretaceous clastic stratigraphy of west central Yukon builds on fieldwork done in 2014 (see Ryan et al., 2014b). Literature review identified a number of sites that may represent Cretaceous strata; in addition, revisits of previously known localities were undertaken to better understand the preliminary paleontological data obtained from 2014 sampling. Site visits were undertaken mostly by truck access, based out of the Dawson City area, with some foot traverses. Sites visited included 60 Mile River region, along Top of the World Highway west of Dawson, the Paradise Creek area of the Klondike, along Indian River, and at Clear Creek, north of Stewart River.

Results

Klaza River area mapping

A number of key findings resulted from field mapping in the Klaza River area (Fig. 2), which help to significantly update the known geology on reconnaissance maps by Tempelman-Kluit (1974; 1984). We were able to correlate many of the older, more deformed and metamorphosed rocks in the area to established units within Yukon-Tanana terrane, and to better differentiate the younger (Mesozoic) successor plutonic and volcanic rocks. The map pattern is dominated by two large Cretaceous batholiths exposed across much of the northern and southern parts of the map area, with an intervening panel dominated by the middle Paleozoic units of Yukon-Tanana terrane.

The two major granitic batholiths that dominate the area are divided into the Dawson Range batholith (DRB) on the north side, and the Maloney Creek batholith (MCB) on the south side. The DRB has a very characteristic appearance and composition, defined by blocky hornblende bearing granodiorite (Fig 3). The MCB is distinguished from the DRB by its more monzogranitic nature (Fig. 4), light smoky quartz phenocrysts, and higher abundance of biotite. The MCB is similar in composition to, and may have an affiliation to, the Coffee Phase of the Whitehorse suite (see Ryan et al., 2013). Similar in physical character of the Coffee suite, it typically exhibits deep spheroidal weathering and the formation of grus. The map bounds of the DRB are in good agreement with previous mapping of Tempelman-Kluit (1974), however, our mapping altered the mapped extent of the MCB significantly, especially in the west where tree cover is more extensive and access by helicopter landings are much more difficult. The aeromagnetic data is generally helpful in guiding geological interpretation of both of these batholiths.

The intervening geology is dominated by metamorphosed siliciclastic rocks of variable composition, which we correlate with the pre-Late Devonian Snowcap assemblage. These siliciclastic rocks composed mainly of quartzite, micaceous quartzite and psammitic quartz-muscovite-biotite (± garnet) schist. Locally, amphibolite is interlayered with the siliciclastic rocks at a centimetre to decimetre scale. The Snowcap assemblage locally contains marble bands varying in thickness from decimeter to decameter. Other lithologies characteristic of Yukon-Tanana terrane are generally restricted to the easternmost extent of the area. These include sparse occurrences of amphibolite that we correlate with the early Mississippian Finlayson assemblage. Metaplutonic rocks that we correlate with the Early Mississippian Simpson Range plutonic are co-spatial with the amphibolite. Metaplutonic rocks that have prominent K-felspar augen (Fig. 5) are correlated with the middle Permian Klondike assemblage.

As with mapping in the neighbouring Mount Nansen area (Ryan et al., 2016) we attempted to discriminate younger (middle Cretaceous to Tertiary) volcanic and hypabyssal rock sequences in the Klaza River area in order better understand their map distribution, and their potential for mineralization (e.g., the Late Cretaceous Casino Suite; see Allan et al., 2013; Morris et al., 2014;

Figure 3: Photo of hornblende porphyritic granodiorite of the Dawson Range batholith. Pencil tip for scale.

Figure 4: Photo of biotite-hornblende monzogranite to granodiorite of the Maloney Creek batholith. Pencil tip for scale.

Mortensen et al., 2016). Discriminating these rocks is made difficult by some similarities in appearance and character. Our mapping improves the resolution of a sequence of volcanic and hypabyssal rocks in the northern part of the area, and correlates them with the mid-Cretaceous Mount Nansen group volcanic rocks, rather than with the early Late Cretaceous Open Creek volcanics as they are currently exhibited on the regional geology compilation in the area (Colpron et al., 2016). These are dominated by volcanic breccia of andesite to dacite composition, and locally contain massive layers of plagioclase-phyric dacite. It is very difficult locally to distinguish volcanic from hypabyssal rocks. We consider the blocky hornblende-phyric nature displayed by some of these rocks (Fig. 6) as supporting a cogenetic relationship with plutonic rocks of the Dawson Range batholith, which dates regionally between about 105 to 99 Ma (e.g., Mortensen et al., 2016).

Figure 5: Potassium feldspar augen textured biotite granodiorite of the Permian Sulphur Creek suite. Pencil tip for scale.

The late Cretaceous Carmacks Group volcanic rocks are most prominent in the northern limits of the area and are dominated by basaltic andesite flows. The flows vary from massive to brecciated, and are commonly pyroxene and olivine phyric. Volcanic flows of the Carmacks Group cap the high elevation in the north, and dip about 10 degrees to the north (Fig. 7). They have high magnetic magnitude in the regional aeromagnetic data, and there basal contact can be readily identified by an abrupt change in aeromagnetic signature.

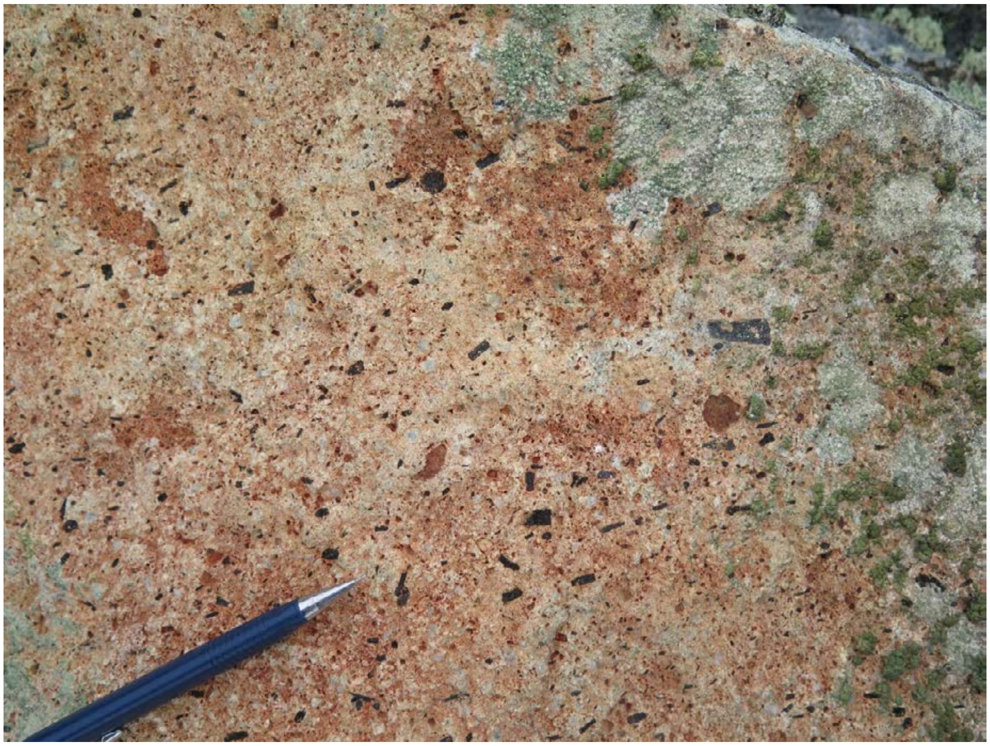

Figure 6: Mount Nansen Group volcanic breccia with quartz and blocky hornblende phenocrysts. Pumicious fragments of more andesitic composition floating in a dacite matrix. Pencil tip for scale.

Figure 7: Mafic volcanic flows of the Carmacks Group exposed on a north-south ridge wherein flows dip 10 degrees north. View looking to the west.

There are numerous occurrences of volcanic rocks through the north central, and particularly western margin of the map area that we interpret as the Paleocene Rhyolite Creek complex. These range in composition from quartz-feldspar porphyry, to dacite, to andesite. The felsic porphyries are broadly similar in appearance to the Casino suite but are less altered and quartz tends to be more euhedral and smoky in colour (Fig. 8), but the two can easily be miscorrelated. Casino suite quartz-feldspar porphyry that are prevalent in the Mount Nansen area just to the east (Ryan et al., 2016; Mortensen et al., 2016) do not appear to be prominent in the Klaza River area.

Figure 8: Quartz-feldspar porphyritic rhyolite of the Rhyolite Creek complex. Quartz phenocrysts in the photo are smoky to charcoal coloured. Pencil tip for scale.

Yukon River Thrust along the Yukon River

Targeted riverside fieldwork to investigate the Yukon River thrust (YRT) was done by boat along the Yukon River (Fig. 2) near Pedlar Creek, following up on geological interpretation made during mapping by Ryan et al. (2013; 2014a). Our work indicates that the location of the YRT at the regional scale needs to move by at least 100's of m locally but is well constrained near Britania Creek. At that locality we directly observed the thrust fault, and found it to be a ductile to brittle structure with a very wide damage zone. At the eastern end of ca. 100 m long exposure, there is a high-strain augen granite (Fig. 9) that we correlate with Mississippian Simpson Range suite, whose strain is higher than similar rocks we observe away from (above) the thrust. It is possible that the strain could well be older than the main thrust fault, or indicates that the Yukon River

Thrust represents a ductile shear zone with a late brittle overprint. Quartzite in the footwall appears mylonitic to ultramylonitic (Fig 10), with brittle fractures overprinting it. It was not possible to determine a sense of shear from the recrystallized quartz fabric. Between quartzite layers, subordinate pelitic layers form discrete thrust planes, upon which meter-scale duplex structures and shear-related folding occurs with a top-to-west shear sense. Samples of the quartz-mylonite have been taken for further microstructural investigation. Additionally, at this locality, the thrust is cut by a steep, brittle fault with gouge-covered surfaces. We collected geochronology and thermochronology samples from across the section, as well as in the hanging wall and footwall in an attempt to bracket the timing of movement(s) along this structure, and help constrain it role in the orogenic evolution of this portion of Yukon-Tanana terrane.

Western extent of the Klondike assemblage

The Klondike assemblage comprises Middle to Late Permian calc-alkaline felsic and minor mafic metavolcanic rocks (Klondike Schist) and comagmatic plutons of the Sulphur Creek suite (Colpron et al., 2006 and references therein) that form major component of Yukon-Tanana terrane in west-central Yukon. It has long been known to regionally prominent in the Stewart River and Dawson maps areas of western Yukon, particularly in the type locality of the Klondike region, and recent mapping has expended its extent greatly to the south and southeast into northern Stevenson Ridge, McQuesten and Carmacks map sheets and beyond (Ryan et al., 2010; 2013; 2016). The distribution of the Klondike assemblage is important in large part because of its common co-spatial nature with placer gold deposits as well as bedrock mineral occurrences. In westernmost Yukon, the extent of Klondike assemblage comes from the Gordey and Ryan (2005) compilation that relied heavily on the mapping and compiling by Tempelman-Kluit (1974), which relied in part on previous interpretations (e.g., Cockfield, 1921).

The distribution of rocks in eastern Alaska that would correlate with Klondike assemblage are far less certain. Mapping of Foster (1970, 1976) in the Eagle and Tanacross quadrangles correlated a highly deformed map unit with the Klondike schist of Cockfield (1921); however, follow up investigation by Dusel-Bacon et al. (2006) grouped those rocks in the Ladue River unit, and concluded that the general character of the rock package is more like the Lake George and Fortymile River assemblages than the Klondike schist. An ongoing new mapping project by the USGS is evaluating the very question of parentage and correlation of the Ladue River unit, and analytical results thus far have not yielded any Permian ages that would directly correlate with Klondike assemblage (e.g., Jones et al., 2016). However, the distribution of samples is fairly restricted.

Six days of traversing and helicopter spot checks that the first author carried out in collaboration with USGS colleagues specifically targeted locations where Klondike assemblage was interpreted on older maps. We observed metamorphic rocks with some typical characteristics of Klondike Schist and Sulphur Creek orthogneiss, as well as some characteristics of parauthochthonous

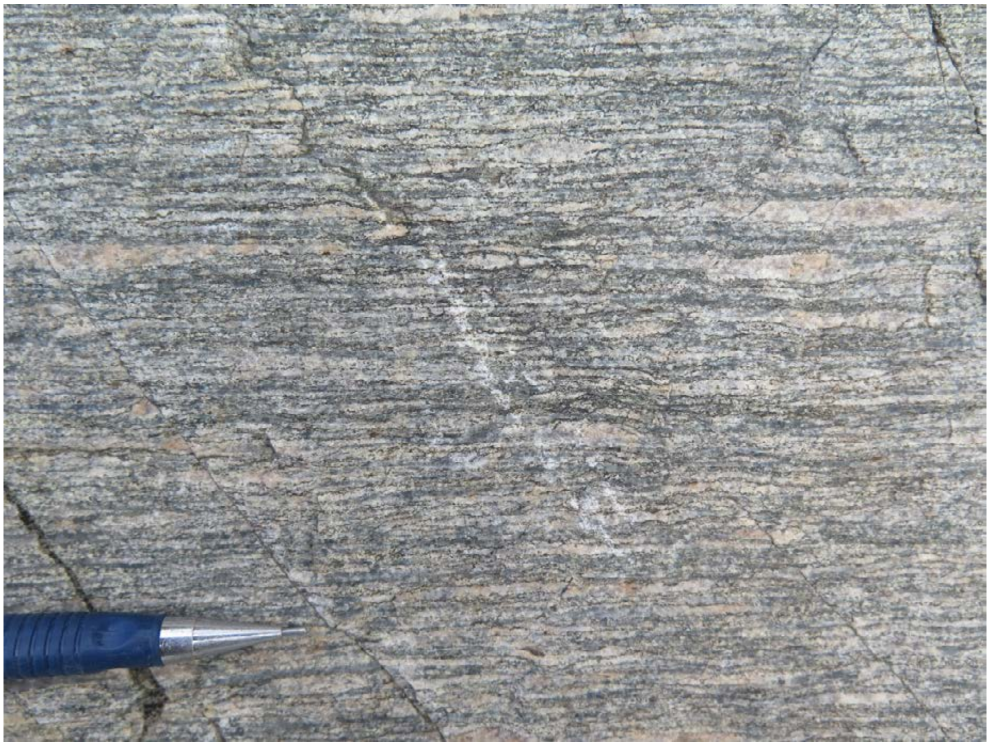

Figure 9: High-strain augen granite of the Mississippian Simpson Range suite, from within the Yukon River thrust. Pencil tip for scale.

Figure 10: Quartz mylonite from within the Yukon River thrust. Pencil for scale.

North American affinity (i.e. White River assemblage or Lake George assemblage) and the Finlayson assemblage. Ultimately, resolving correlations of these rocks are reliant on further geochronological and lithogeochemical analysis because metaigneous rocks of the late Devonian and middle Permian protoliths have very similar field characteristics. Appropriate material was observed and collected to fully test regional correlations.

Cretaceous and Younger Clastic Successions

Strata north of Stewart River and along Clear Creek near Belleview Point, mapped by Bostock (1964) as possible Eocene, were examined to assess for age and depositional environment. Access to these strata is now limited, with the old road shown along the west side of Clear Creek barely passable for only part of its length. Exposures of very poorly consolidated and lithified strata were noted at several localities along the road in the valley of Clear Creek and up to approximately one hundred metres above the valley floor, but it was not determinable whether these represent older strata or Quaternary glacial deposits.

Sedimentary strata associated with the Carmacks Group were studied in the vicinity of Paradise Hill, along the west side of Hunker Creek valley. Several 10's of metres of strata were measured at this locality, intercalated with Carmacks Group basaltic volcanic rocks. Palynological and detrital zircon samples were collected to better constrain the age of the succession.

Finally, strata above the 60 Mile River valley, first studied in 2014, were examined again in 2016 to better constrain their age and depositional environments. It is anticipated that ongoing palynological and detrital zircon studies will more precisely define the age and provenance of strata comprising this succession.

Next steps

The result of our Klaza River area mapping is currently being compiled, and upon completion, will be synthesized into the ongoing regional compilation of Yukon geology (e.g., Colpron et al., 2016). Ongoing petrological and geochronological investigation of samples from area will: 1) assist in cementing regional correlations of lithological units and help demarcate any major crustal breaks that may trace through the local geology, 2) help determine if Casino suite porphyries trace through the area. Samples from the Yukon River thrust will undergo microstructural analysis in combination with thermochronology analysis to evaluate the kinematic evolution of this zone of deformation, as well as constrain its age. We currently interpret this structure to be an important Cordilleran mountain building feature, that stacked internal components of Yukon-Tanana terrane in latest Triassic time (i.e. 200 Ma).

Next steps in the cross-border evaluation of the extent of the Klondike assemblage is to complete geochronology and lithogeochemistry analyses on key samples that appear to be characteristic of the well-established localities of the unit. These results would assist in reconciling the extent of the units on regional geology compilations on both sides of the Yukon-Alaska border.

The study of the Indian River formation involves further paleontological and geochronological analysis to constrain timing of deposition of this sequence, and bracket the age of unconformities throughout the sequence.

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