Preliminary investigation into the geologic relationships in the Granite Lake area, parts of NTS 115A/10, 11, 14, and 15, southwest Yukon

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ABSTRACT

Bedrock mapping, during the summer of 2013, within the Granite Lake area was completed as part of the first year of a multi-year project to investigate the geological relationships in southwest Yukon. Several different tectonostratigraphic elements were identified including rocks of the Yukon-Tanana terrane, the Kluane schist, and the Bear Creek assemblage. These were tectonically juxtaposed into a northeast dipping structural stack with the Yukon-Tanana terrane occupying the highest structural level, followed by the Kluane schist and the Bear Creek assemblage. Two plutonic phases of probable mid-Cretaceous and Late Cretaceous age were identified to intrude the Kluane schist and the Yukon-Tanana terrane respectively. A large Paleocene aged batholithic intrusive suite, the Ruby Range suite, intrudes across all tectonic boundaries.

Tectonic and stratigraphic relationships observed in southwest Yukon are strikingly similar to those found in southeast Alaska, near Juneau. These similarities increase the potential for Juneau gold-belt type mineralizing systems extending into southwest Yukon.

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INTRODUCTION

The Granite Lake area (parts of NTS 115A/10, 11, 14, and 15) is located east of Haines Junction and north of Dezadeash Lake (Fig. 1). The area was last mapped as part of a regional examination of the bedrock geology within the area of the Dezadeash map sheet (NTS 115A) in 1946 to 1950 by Kindle (1952). Since then few geological investigations have been conducted in the area and those that were included the Granite Lake area only as a small part of much larger regional studies. These studies include work on the relationships of metamorphic and plutonic rocks and overall tectonic synthesis of southwest Yukon (Erdmer and Mortensen, 1993; Mezger *et al.*, 2001; Johnston and Canil, 2006).

The current study builds on previous detailed 1:50 000 scale bedrock mapping to the north and northeast (Israel *et al.*, 2011a,b; Israel and Westberg, 2011, 2012). The goals of this project are to determine the geologic relationships between diverse lithotectonic elements in order to gain better insight into the overall tectonic and metallogenic understanding of southwest Yukon.

Exposure in the area ranges from excellent near high peaks and ridges, to very poor in the wide bush covered valleys. Access is restricted to helicopter or float plane, and very few useable roads or trails.

REGIONAL GEOLOGY

Southwest Yukon comprises several tectonic terranes, overlapped and intruded by younger stratigraphy and plutons (Fig. 1). In the east and north, the Yukon-Tanana terrane is characterized by Proterozoic to mid-Paleozoic metamorphic rocks. The Yukon-Tanana terrane continues both to the southeast, into northern British Columbia, and to the northwest into eastern Alaska. The terrane has been affected by multiple phases of deformation and metamorphism that resulted in transposition of original layering, isoclinal folding, and upper greenschist to amphibolite grade metamorphism. In southwest Yukon the Yukon-Tanana terrane appears to be thrust to the west/southwest over younger, metamorphic rocks of the Kluane schist; however, much of this contact has been intruded by post-deformation plutonic rocks, making it difficult to characterize.

The Kluane schist occupies much of the central part of southwest Yukon, overthrust to the east/northeast by the Yukon-Tanana terrane, faulted against rocks of the Insular terranes across the Tertiary Denali fault to the west/southwest, and juxtaposed next to the Jura-Cretaceous Dezadeash Formation and the enigmatic Bear Creek assemblage across an unnamed fault in the southwest (Fig. 1). The rocks of the Kluane schist are characterized mainly by biotite and muscovite schist that were likely part of a forearc assemblage sourced from the exhumation of the Yukon-Tanana terrane and its younger intrusions sometime in the Early to Late Cretaceous (Israel *et al.*, 2011b). Metamorphism within the Kluane schist appears to be two stage with a medium pressure and temperature burial phase, related to overthrusting of Yukon-Tanana terrane, overprinted by a low pressure and high temperature phase related to intrusion of the Ruby Range batholith (Mezger *et al.*, 2001). Peak metamorphism is likely concurrent with overgrowths on detrital zircons dated at ~82 Ma (Israel *et al.*, 2011b). The age of the Kluane schist is not well constrained, but must be older than the metamorphic age and younger than ~94 Ma, the age of the youngest detrital zircon (Israel *et al.*, 2011b).

The boundary between the Kluane schist and the Yukon-Tanana terrane is presumed to be a faulted contact; however, it is intruded by the Paleocene Ruby Range suite and therefore not exposed.

The Ruby Range suite is found as a northwest trending batholith of felsic to intermediate composition that continues into northern BC at its southeast end, and is cut off by the Denali fault at its northwest end (Fig. 1). Where exposed, the structural base of the batholith is foliated, passing upwards into more massive undeformed intrusive rock (Israel *et al.*, 2011b). The age of the Ruby Range batholith ranges from ~64 Ma to ~57 Ma (Israel *et al.*, 2011b; Israel and Westberg, 2011).

An unnamed fault, with unknown kinematics, separates the above rocks from a Jura-Cretaceous sedimentary unit, the Dezadeash Formation, and an enigmatic package of strongly metamorphosed and deformed rocks assigned to the informal Bear Creek assemblage (Fig. 1). The Dezadeash Formation has been correlated to other Jura-Cretaceous overlap assemblages found in east and southeast Alaska and British Columbia along the boundary between the outboard Insular terranes and the Intermontane terranes (McClelland *et al.*, 1992). The Bear Creek assemblage is found to structurally underlie the Dezadeash Formation. It is a unit composed of mainly metabasalt and meta-ultramafic rocks structurally interleaved with lesser metasedimentary rocks. Age and correlation of the assemblage is not constrained. Read and

Monger (1976) included it within the Taku-Skolai terrane, a terrane consisting largely of what is now referred to as Wrangellia. Gordey and Makepeace (2003) included the Bear Creek assemblage with the Nikolai formation, Triassic basalt of Wrangellia. It is most likely that the Bear Creek assemblage is part of the Paleozoic to early Mesozoic Taku terrane (Gehrels, 2002), found in southeast Alaska.

The Denali fault, with up to 400 km of dextral strike-slip offset, separates all of the above rocks from those of the Insular terranes to the south/southwest (Fig. 1). The Insular terranes include the Alexander terrane and Wrangellia, and were amalgamated to the margin of the Intermontane terranes during or before the Middle Jurassic (McClelland *et al.*, 1992; van der Heyden, 1992).

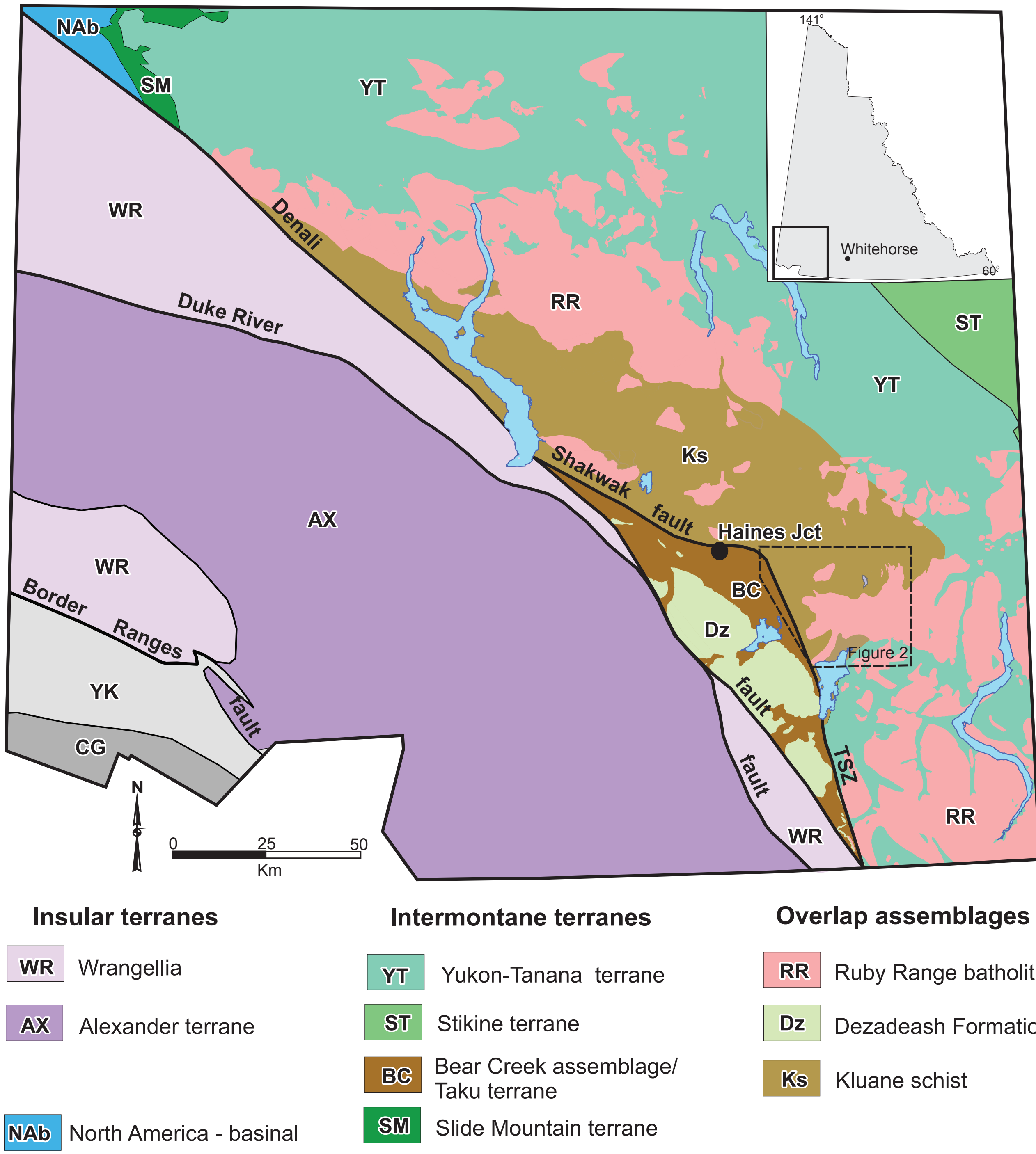
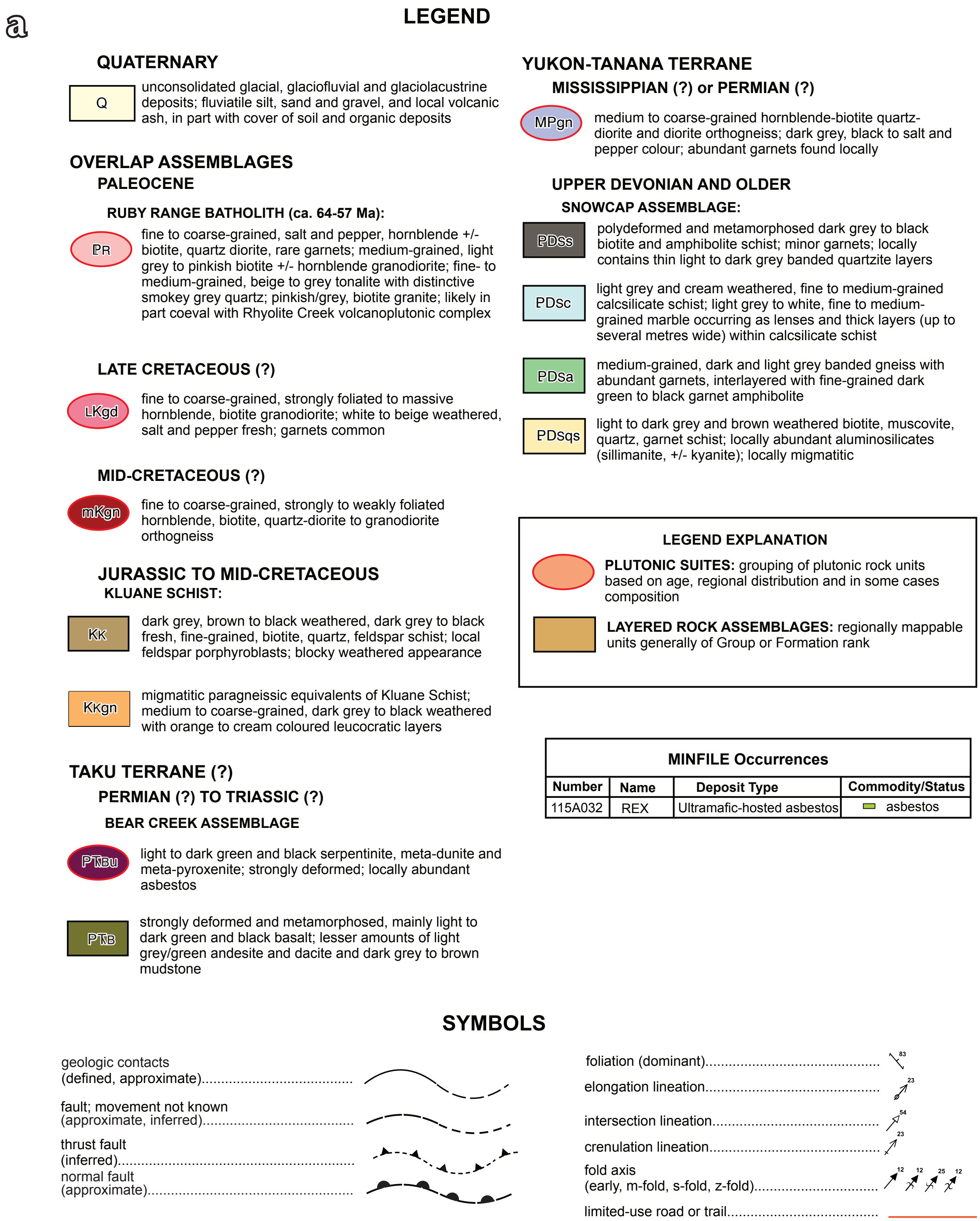


***Figure 1**. Regional tectonic framework of southwest Yukon with Granite Lake area outlined.*

LOCAL GEOLOGY

The Granite Lake area is underlain by rocks of the Kluane schist, the Ruby Range batholith, the Yukon-Tanana terrane, and the Bear Creek assemblage (Fig. 2). Contacts between the different units are generally located in the valley bottoms and are therefore not well exposed. It is assumed that most contacts are structural in nature, yet the nature of the structures are not well constrained.



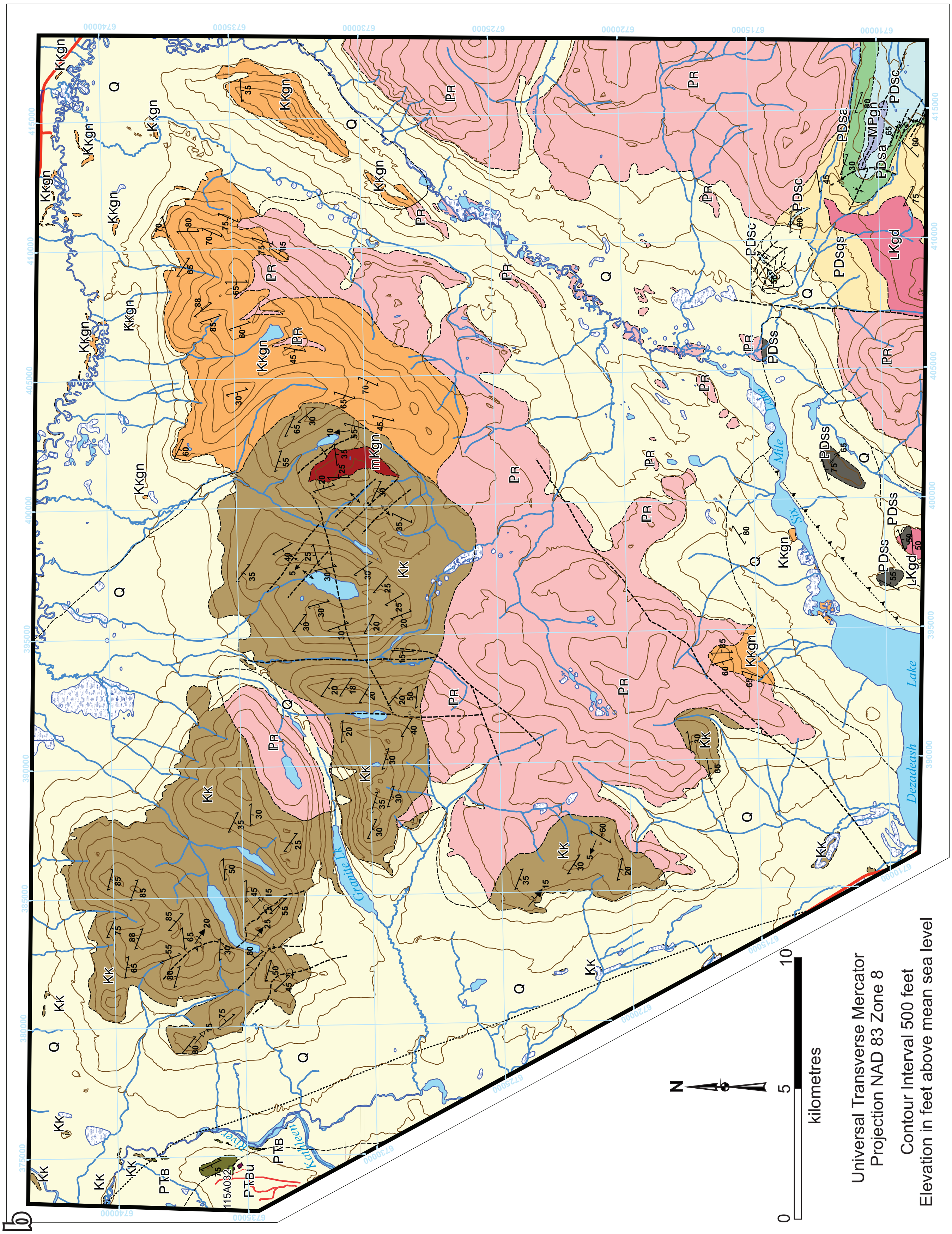


Figure 2. *(a) legend; and (b) generalized bedrock geology of the Granite Lake area. Modified from Israel and Kim (2013).*

STRATIGRAPHY

YUKON-TANANA TERRANE

The Yukon-Tanana terrane in the Granite Lake area is located mainly in the far southeast corner, where it is intruded by the Ruby Range batholith and apparently thrust over rocks of the Kluane schist (Fig. 2). Rocks assigned to the Yukon-Tanana terrane consist primarily of schist, orthogneiss, and calc-silicate that have been tentatively assigned to the Proterozoic to Devonian Snowcap assemblage. The assemblage has been subdivided into four mappable units, based mainly on lithologic composition. They occur in an upright, moderately to steeply, southeast plunging synform with tight antiform/synform pairs on its flanks (Fig. 2). This folding is likely a late phase of deformation as internally the units are more complexly deformed, showing evidence for multiple phases of deformation.

PDsqs

The structurally lowest unit of the Snowcap assemblage is a seemingly thick package of light to dark grey and brown weathered biotite, muscovite, quartz, garnet schist (Fig. 3a). Locally abundant sillimanite, (±) kyanite occurs within the schist. Limited field observations suggest sillimanite grew after kyanite, indicating fairly high temperatures and pressures were involved in metamorphism of this unit. Where intruded by Late Cretaceous (?) granitic rocks, the schist becomes migmatitic and in places almost completely recrystallized, giving the rock an igneous appearance (Fig. 3b).

PDsa

Structurally, and probably stratigraphically, overlying PDsqs is a package of medium to coarse-grained, dark and light grey banded orthogneiss, interlayered with fine-grained dark green to black garnet amphibolite (Fig. 3c). The thickness of this unit varies from several metres to tens of metres. The contact with the underlying schist is not exposed. At the upper contact, interlayering of amphibolite with calc-silicate schist may suggest a partial gradation between the two units. Much of PDsa appears to be meta-igneous in origin; however, some of the garnet amphibolite near the top of the unit may be metabasalt interlayered with the calc-silicate rocks. Garnet is abundant in all rock types within PDsa, in some places forming complete layers up to several centimetres thick (Fig. 3d). The orthogneiss is mainly diorite to quartz-diorite in composition with alternating layers of light coloured (quartz, plagioclase) and dark coloured (amphibole, ± biotite) minerals. Amphibolite is composed primarily of hornblende and plagioclase, with minor quartz and biotite. Age of this unit is not known.

PDsc

Overlying PDsa is a package of calc-silicate schist and marble (Fig. 2). Interlayering of amphibolite of unit PDsa and calc-silicate schist occurs at the lower contact of PDsc. A deformed intrusive contact defines the upper boundary of PDsc where it is next to a possible Mississippian to Permian orthogneiss unit (Fig. 2). No contact was observed between PDsc and PDss, the unit within the Yukon-Tanana terrane interpreted to be at the highest stratigraphic position (Fig. 2). The calc-silicate schist is light grey to beige and cream weathered and thinly to thickly layered (Fig. 3e). It is strongly deformed and metamorphosed but locally primary layering is preserved. The schist is fine to medium grained, and composed of calcite (± dolomite) and quartz. Locally, some layers are more psammitic in composition, being more quartz-rich with varying amounts of biotite. Thin light to dark grey quartzite layers are found within the more psammitic layers. The calc-silicate and quartz-rich schists pass up into strongly deformed, white to light grey weathered marble that can be up to several metres wide (Fig. 3f). The marble occurs as bands, interlayered within the calc-silicate rocks, at all levels within PDsc. It is difficult to determine if this is stratigraphic or reflecting internal structural complexities. The age of PDsc is unknown.

PDss

Rocks assigned to unit PDss include biotite and amphibolite schist. Their position within the stratigraphy of the Yukon-Tanana terrane is not well constrained, mainly because of the poor outcrop exposure of this unit, which occurs mainly as small, almost hidden exposures in the bush south of Six Mile Lake, and as small roof pendants within Late Cretaceous (?) plutons (Fig. 2). As interpreted it represents the highest level of Yukon-Tanana stratigraphy. This is based mainly on field observations that appear to show these rocks are the least metamorphosed, but until further analyses can be done this assignment is tenuous at best. The dominant rock type is a biotite, hornblende schist, and minor garnet (Fig. 3g). Locally the rock approaches garnet amphibolite with little to no biotite. The largest exposure of the unit shows interlayering of biotite, ± hornblende schist, quartz-rich psammitic schist, and thin (10 cm) dark grey quartzite layers (Fig. 3h). As with the other rocks assigned to the Yukon-Tanana terrane, the age of this unit is unknown.

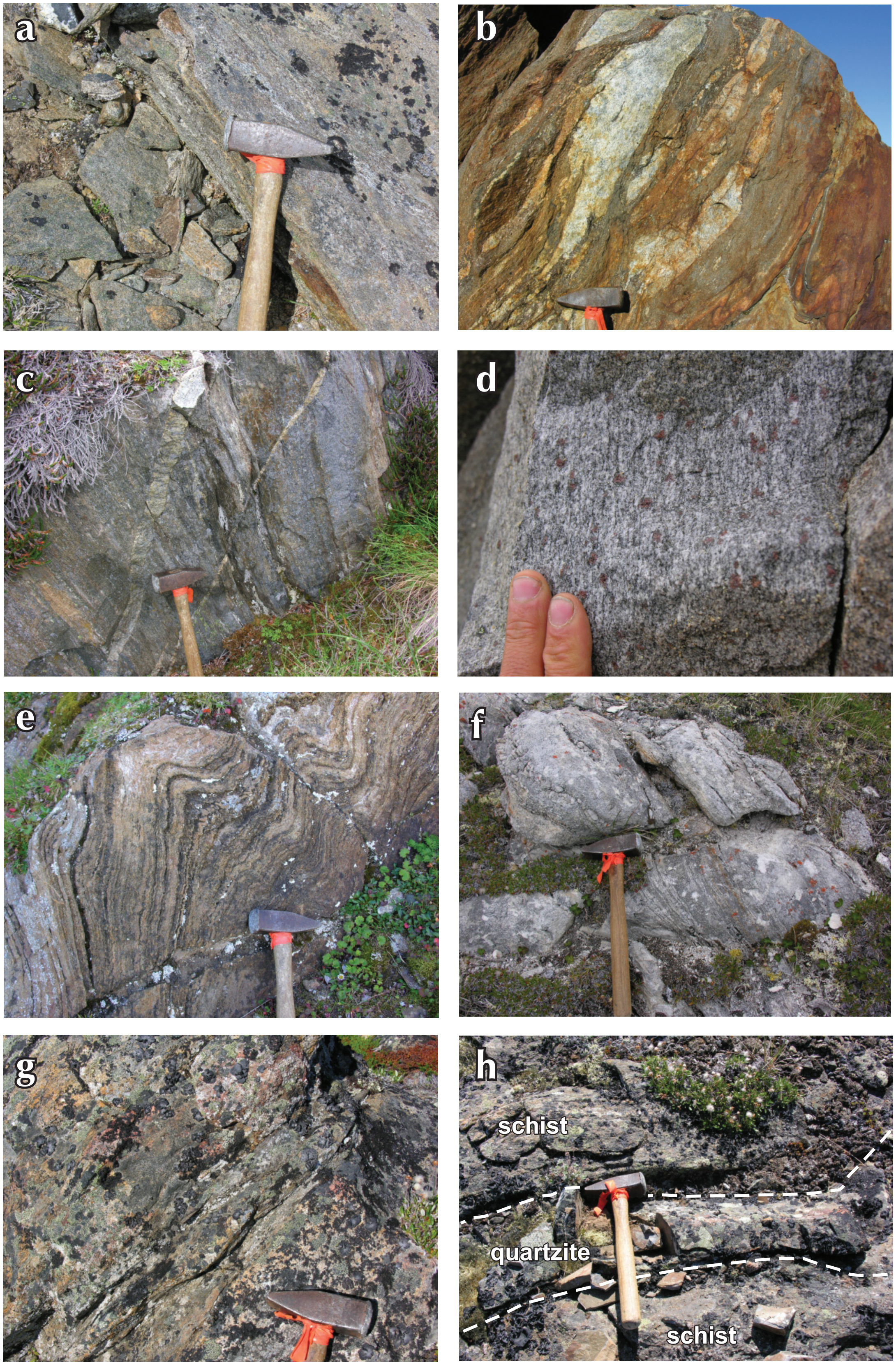


***Figure 3**. Rocks assigned to the Yukon-Tanana terrane: (a) biotite, quartz, garnet schist of unit PDsqs; (b) migmatitic schist of unit PDsqs; (c) garnet amphibolite of unit PDSa; (d) abundant garnets within rocks of unit PDsa; (e) folded calc-silicates of unit PDSc; (f) strongly deformed marble of unit PDSc; (g) lichen covered outcrop of biotite, hornblende schist of unit PDSs; and (h) thin quartzite layer within biotite, hornblende schist of unit PDSs.*

BEAR CREEK ASSEMBLAGE (PTrB)

Rocks of the Bear Creek assemblage are found at the western margin of the Granite Lake map area (Fig. 2). They comprise a small collection of outcrops just west of the Kathleen River. The Bear Creek assemblage is interpreted to be in fault contact with rocks of the Kluane schist and Ruby Range batholith to the east, and likely occur under thick quaternary cover as far south as Dezadeash Lake (Fig. 2). The assemblage is characterized by metabasalt and meta-ultramafic rocks that are strongly deformed and structurally interleaved. A limited use road into this area was established in order to gain access to asbestos showings related to the ultramafic rocks (Yukon MINFILE 115A 032; Fig. 2). The ultramafic rocks were not examined during this study, but elsewhere in the assemblage outside of the project area, are observed to comprise strongly deformed and metamorphosed pyroxenite, dunite, and peridotite, all intensely altered and serpentinite and epidote are common. Metabasalt is fine grained, dark and light green to black, and shows layering of these colours on the centimetre to metre scale (Fig. 4a). It is strongly deformed and the layering likely reflects this deformation rather than original depositional characteristics. The age of the Bear Creek assemblage is not known. If the correlation with the Taku terrane in southeast Alaska is correct, it would date these rocks as Late Paleozoic to early Mesozoic.

KLUANE SCHIST

By far the largest, non-intrusive, spatially represented unit in the Granite Lake map area is the Kluane schist (Fig. 2). The Kluane schist is faulted against the Bear Creek assemblage in the west and is interpreted to be overthrust by the Yukon-Tanana terrane in the southeast. The Ruby Range batholith intrudes across these boundaries and throughout the heart of the unit. Large outcrops of the schist occur in the northern and western halves of the project area comprising much of the higher peaks and ridges. In the Granite Lake area, two main mappable units of the schist are found, a lower unit of paragneiss and an upper unit of biotite schist.

Kkgn

The lowest, structurally and likely stratigraphically, unit of the Kluane schist is characterized by a banded paragneiss. It outcrops mainly in the northeast part of the project area, continuing to the west, just north of Dezadeash Lake (Fig. 2). The paragneiss is extensively intruded by the Ruby Range batholith concealing the contact between the gneiss and the Yukon-Tanana terrane to the south. Contact with the overlying schist of the Kluane schist is not very well exposed either, making the nature of this contact unclear. It appears from limited examination to be a gradational contact; however, elsewhere in southwest Yukon this contact is structural, characterized by a thrust fault that places the paragneiss over biotite schist (Israel *et al.*, 2011a,b).

The paragneiss is distinctly banded and weathers an orange to brown. It is medium to coarse grained, dominantly composed of quartz, biotite, and feldspar, and a minor local abundance of muscovite. The banding is defined by dark layers of mainly biotite and quartz, and the more leucocratic layers of plagioclase, ± potassium feldspar, and quartz (Fig. 4b). The layers range in thickness from less than one centimetre to several centimetres. Garnet was only rarely observed and only within pockets of what appears to be melt, comprising quartz, muscovite, feldspar, and garnet.

The age of Kkgn is not well constrained. Detrital zircon analyses from other parts of the unit in southwest Yukon suggest it could be as young as 94 Ma (Israel *et al.*, 2011b); however more work needs to be done to confirm this age.

Kk

The most prominent, rock type within the Kluane schist is quartz, biotite schist. It is distinct from the paragneiss and from other schist assigned to the Yukon-Tanana terrane. In the Granite Lake area, the schist is fairly monotonous, not changing its appearance very much from one area to another. It is characterized by blocky, brown to dark grey weathered outcrops comprising fine to medium-grained biotite, quartz, schist (Fig. 4c). Locally, abundant 1-2 mm feldspar porphyroblasts are present. Laterally discontinuous, foliation parallel quartz veins, 1-5 cm thick, are found throughout the schist. The schist has been deformed by at least two phases of folds. The dominant phase of folding resulted in tight, overturned, north to northeast verging structures having northwest to southeast, shallow to moderate plunging axes (Fig. 4d). These have been deformed by broad, open folds with shallow north plunges.

The age of the schist is thought to be Late Cretaceous, based on the youngest detrital zircons analyzed from rocks elsewhere in the belt (Israel *et al.*, 2011b).

Figure 4. *(a) Metabasalt of the Bear Creek assemblage; (b) strongly deformed paragneiss of the lower Kluane schist (Kkgn); (c) biotite, quartz schist of the Kluane schist (Kk); and (d) northeast verging, overturned folds within biotite schist of the Kluane schist.*

INTRUSIVE ROCKS

Several different intrusive units are found within the Granite Lake area, ranging in composition from granodiorite to diorite, and are strongly deformed to massive. The age assignments to the different units below are based upon field observations; to better constrain the age of emplacement of these bodies, and to determine relative ages of deformation that affected the area, samples of each were collected for U-Pb dating.

MID-CRETACEOUS (?) ORTHOGNEISS (MKGN)

A large body of granodioritic to quartz-dioritic orthogneiss is found in the central part of the Granite Lake map area, intruding into biotite schist of the Kluane schist (Fig. 2). It is characterized by light and dark grey banding that reflects the change in abundance of biotite and hornblende within a dominantly quartz, feldspar matrix (Fig. 5a). The foliation within the orthogneiss is parallel to the surrounding schist, and small dikes off the main body are seen to intrude along foliation and are folded with the schist. It is likely that this orthogneiss intruded during deformation, possibly in the mid to Late Cretaceous.

LATE (?) CRETACEOUS (LKGD)

A unit of garnet bearing, foliated to massive, granodiorite to gabbro is found south of Six Mile Lake where it intrudes exclusively into rocks of the Yukon-Tanana terrane (Fig. 2). These rocks consist of hornblende (± pyroxene), biotite, quartz, and feldspar with abundant 1-3 mm pink garnets.

Evidence for deformation within the unit is highly variable and ranges from a well-developed foliation near contacts with the country rock, to very weakly-developed away from the contact (Fig. 5b). The contacts of this intrusive unit and the Yukon-Tanana rocks appear to be both intrusive and structural, suggesting a syn-deformation timing for its emplacement.

RUBY RANGE SUITE

The most abundant rock unit in the Granite Lake area belongs to the Ruby Range suite. It outcrops across the project area and intrudes into all other rock units and across all ductile fabrics (Fig. 2). Regionally the Ruby Range suite ranges in composition from granodiorite to quartz-diorite and quartz-monzonite. In the Granite Lake area the suite is dominated by a medium-grained, light grey to beige weathered biotite, granodiorite to tonalite with distinctive smoky grey quartz crystals up to 3-4 mm (Fig. 5c). The suite shows no evidence of ductile fabrics and is only deformed by the latest stage of brittle faulting. Miarolitic cavities are found locally, suggesting a relatively high level of emplacement for the Ruby Range suite in the project area (Fig. 5d). The age of the Ruby Range suite is early Paleocene (~64 Ma) to early Eocene (~54 Ma).

DISCUSSION

TECTONIC IMPLICATIONS

Although it is early on in the investigation into the geological relationships of the southern Coast belt region of southwest Yukon, it is apparent that some fundamental

Figure 5*. Intrusive rocks from the Granite Lake area: (a) orthogneiss intruding into the Kluane schist; (b) strongly foliated garnet bearing granodiorite found intruding the Yukon-Tanana terrane; (c) massive biotite granodiorite to tonalite of the Ruby Range suite; and (d) miarolitic cavities filled with quartz crystals observed within plutons of the Ruby Range suite.*

tectonic relationships are present. These relationships are centred on the nature of the boundaries between three distinct tectonostratigraphic units; the Yukon-Tanana terrane, the Kluane schist, and the Bear Creek assemblage. The timing and characteristics of these boundaries are important in determining the overall tectonic evolution of southwest Yukon.

Metamorphism within the Yukon-Tanana terrane in this region appears to coincide with high temperatures and pressures shown by the presence of sillimanite, kyanite, and migmatite in unit PDsqs. Metamorphism within the Kluane schist is not as dramatic. Mezger *et al.* (*2001*) suggest the Kluane schist underwent medium pressure and temperature metamorphism (upper greenschist to lowermost amphibolite) *ca.* 72 Ma. This is below the apparent sillimanite after kyanite upper amphibolite metamorphism observed within the Yukon-Tanana terrane, suggesting some kind of non-stratigraphic boundary between the two packages of rocks. Based on limited structural information (including stretching lineations and c-s fabrics noted in outcrops) a thrust fault is inferred to accommodate the juxtaposition of the higher-grade Yukon-Tanana rocks over the lower grade Kluane schist (Fig. 2). The timing of this structural stacking is not well-constrained but had to occur before the intrusion of the Ruby Range suite (*ca*. 64-57 Ma). It is likely that this deformation event occurred during the emplacement of the foliated garnet bearing granodiorite that intrudes the Yukon-Tanana terrane.

The boundary between the Bear Creek assemblage and the other rock units is somewhat ambiguous. Kindle (1952) interprets a structure that separates the Dezadeash Formation and metamorphic rocks that include the Kluane schist and the Yukon-Tanana terrane. Kindle (1952) shows this structure to continue south into northern British Columbia. Just north of the Yukon/British Columbia border, Lowey (2000) proposed that this fault (referred to as the Tatshenshini shear zone) had northeast dipping fabrics within it and suggested that the shear zone accommodated southwest directed thrusting of the Ruby Range suite over the Dezadeash Formation. Limited outcrop information hampers direct observation of the fault zone in the Granite Lake area, however if the interpretations along the Tatshenshini shear zone are correct, then the Kluane schist and Yukon-Tanana terrane (along with the Ruby Range suite) is thrust over rocks of the Bear Creek assemblage.

This northeast dipping structural stack of tectonic elements was proposed by Johnston and Canil (2006) to explain regional structural fabrics. The exact tectonic driver and timing of deformation for this crustal juxtaposition remains ambiguous.

METALLOGENIC IMPLICATIONS

Previous investigations into the geologic relationships of southwest Yukon have shown that the areas comprising the tectonic elements in the Granite Lake area are highly prospective with respect to both orogenic and intrusion related mineralizing systems (Israel *et al.*, 2011a,b; Israel and Westberg, 2012).

The high level of crustal emplacement for the Ruby Range suite, coupled with extensive coeval volcanic deposition, increases the potential for porphyry and epithermal style mineralization. Both porphyry and epithermal associated alteration and mineralization are found north of the Granite Lake area, near Aishihik Lake and are believed to be related to Ruby Range plutons and coeval Rhyolite Creek volcanic rocks (Israel *et al.*, 2011b; Israel and Westberg, 2012).

Orogenic related mineralization occurs within the Kluane schist near Killermun Lake, northwest of the Granite Lake area. This mineralization includes several vein hosted gold occurrences over several kilometres of strike length. The veins are found near the structural boundary between the Yukon-Tanana terrane, the Ruby Range batholith, and the Kluane schist, with veins formed in both the schist and the granitic rocks. Gold mineralization is also found within the Bear Creek assemblage just to the west of the Granite Lake area, near Bear Creek. The nature of this mineralization is not well documented but appears to be structurally controlled.

The regional geologic setting observed in southwest Yukon is the same as that found in the Juneau, Alaska area, where several orogenic related gold deposits occur. Comparing the Juneau area with southwest Yukon indicates that the two areas share both stratigraphic and intrusive relationships as well as structural architecture (Fig. 6). These parallels in geologic relationships increase the potential for similar style mineral systems within the Granite Lake area.

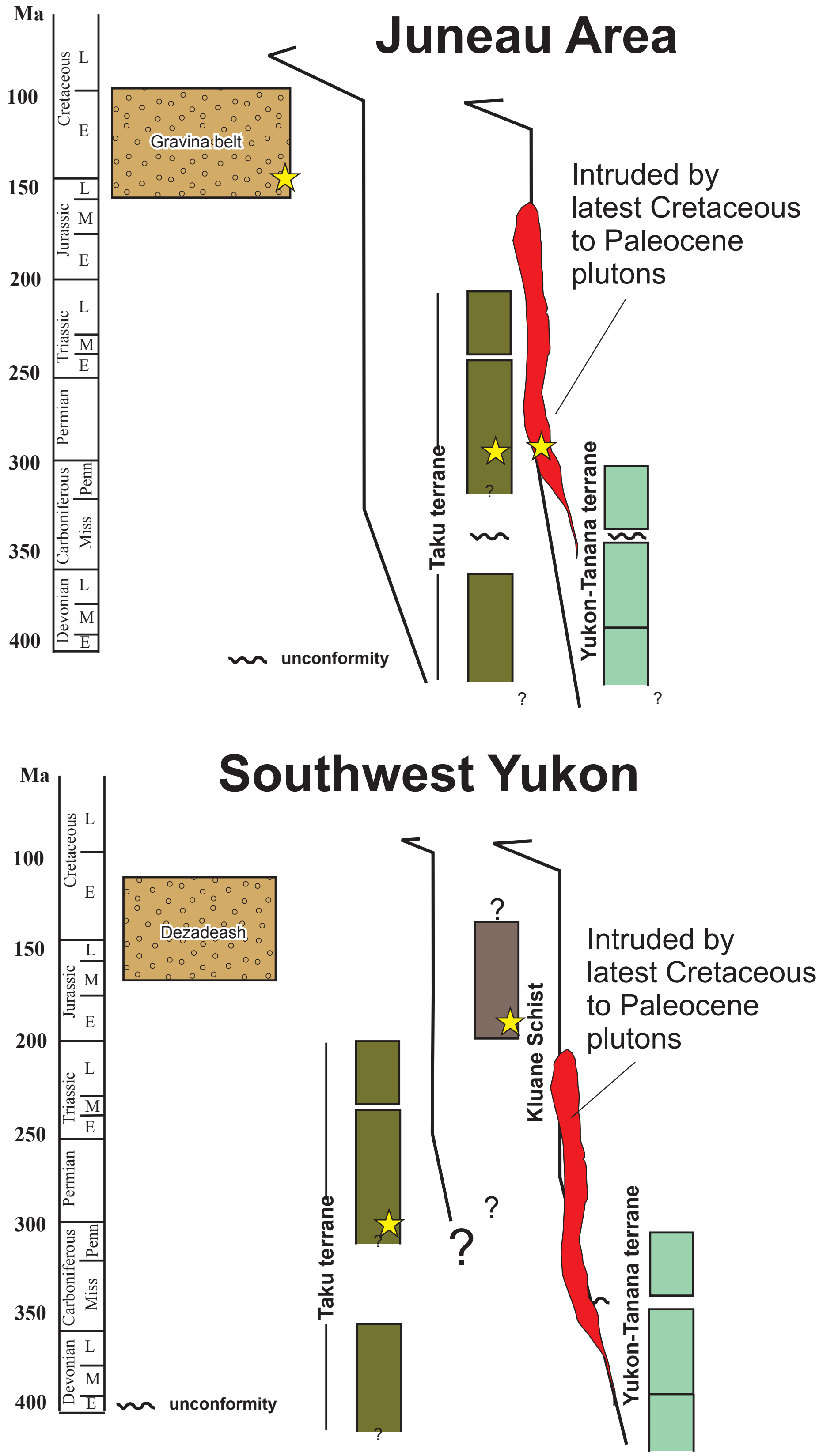


Figure 6*. Tectonostratigraphic diagrams for southwest Yukon and the Juneau areas. Gold stars indicate areas of known gold mineralization. Juneau stratigraphy modified from Goldfarb et al. (1988).*

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