New contributions to the bedrock geology of the Mount Freegold district, Dawson Range, Yukon (NTS 115I/2, 6 and 7)

M.A. Friend, M.M. Allan and C.J.R. Hart
Mineral Deposit Research Unit, University of British Columbia

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ABSTRACT

The Mount Freegold district is an ideal natural laboratory to evaluate the structural and magmatic framework for porphyry, skarn and epithermal mineralization in the Dawson Range. The district is located within a major extensional relay zone of the Big Creek fault system, a regionally significant dextral strike-slip structure in which localized extension facilitated the emplacement of mid to Late Cretaceous magmatic rocks. New mapping defines a previously unrecognized granite pluton at Mount Freegold, as well as the *ca*. 77 Ma Stoddart pluton, which represents the magmatic roots of hypabyssal intrusive rocks at the Revenue Cu-Mo-Au-Ag deposit and Nucleus Au-Ag-Cu deposit. The relay zone in the Big Creek fault system is partly plugged by the *ca*. 70 Ma Seymour Creek stock, which is cut by a southern strand of the fault system. Episodic fault movement took place over a minimum 35 m.y. interval during which at least three distinct epochs of magmatic-hydrothermal mineralization occurred.

* *mfriend@eoas.ubc.ca*

INTRODUCTION

The Dawson Range of west-central Yukon contains economically significant porphyry, epithermal and related styles of mineralization in a regionally extensive belt that stretches approximately 150 km from the Casino porphyry Cu-Mo-Au deposit to the town of Carmacks (Fig. 1). Three main magmatic episodes that span mid to Late Cretaceous time each generated magmatic-hydrothermal mineralization that contributes to this northwest-trending polymetallic belt, suggesting several pulses of fertile magma generation (Allan *et al.*, 2013). The concentration of mineral occurrences along the northern margin of the Dawson Range batholith, and especially along the Big Creek fault system, suggests a close link between magma emplacement and the structural evolution of the Dawson Range.

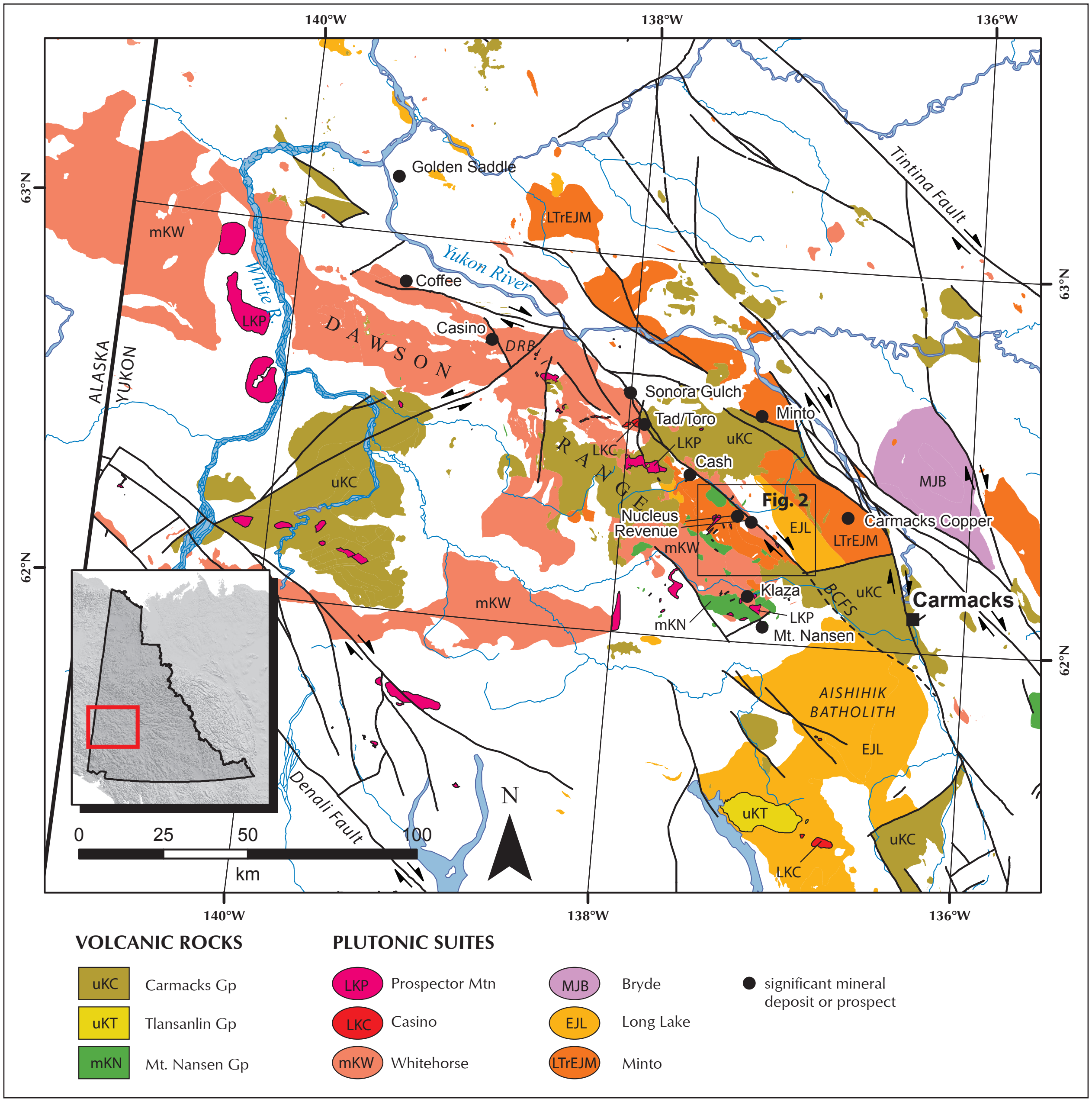

Figure 1. *Simplified regional geologic map of the Dawson Range showing plutonic suites and volcanic packages relative to significant mineral occurrences. Location of study area and Figure 2 is indicated by the black box. DRB = Dawson Range batholith. BCFS = Big Creek fault system. Inset map shows location of the map in Yukon. Geological information from Yukon Geological Survey (2017).*

The Big Creek fault system (BCFS) is a regionally significant dextral strike-slip deformation corridor that exerts a structural control on Cretaceous magmatic-hydrothermal mineralization in the Dawson Range (*e.g.*, Bennett *et al.*, 2010; Nelson *et al.*, 2013; Ryan *et al.*, 2013a,b). The Mount Freegold district in the eastern Dawson Range contains a dense cluster of mineral occurrences along the BCFS, and is herein defined as the area of historic and current bedrock and placer exploration and mining activity that includes, from northwest to southeast: the Klazan (Nitro) occurrence and Nucleus and Revenue deposits south of Big Creek; the numerous mineral occurrences north of Seymour Creek and south of Stoddart Creek in the vicinity of Mount Freegold; and the Tinta Hill occurrence southwest of Granite Mountain (Fig. 2). The Mount Freegold district represents an ideal natural laboratory to test the relationships between structural elements of the BCFS, magmatism and hydrothermal mineralization. Various mineral occurrences and three NI 43-101 compliant resources in the Mount Freegold district are interpreted to be associated with episodes of Cretaceous magmatism: (1) porphyry-related Revenue Cu-Au-Ag-Mo and Nucleus Au-Ag-Cu deposits, and Stoddart and Ridge Zone Cu-Au-Mo prospects; (2) Tinta Hill polymetallic precious-base metal vein deposit; (3) Laforma, Irene, Goldy, Whale, and Emmons Hill Au-Ag-enriched vein systems; (4) Margarete and Augusta Au magnetite skarn systems; and (5) Antoniuk breccia-hosted Au deposit (Yukon MINFILE, 2017; Fig. 2).

Recent studies have improved geochronological constraints on Cretaceous magmatism in the Mount Freegold district (*e.g.*, Bineli Betsi and Bennett, 2010; Allan *et al.*, 2013), but the petrogenetic and geochemical attributes of the causative intrusions have not been established on a systematic basis.

Here we present field descriptions of geologic units of the Mount Freegold district, based primarily on observations made during the 2017 field season, with unit assignments facilitated by previously published and yet unpublished U-Pb geochronological data obtained as part of this study. This report accompanies a new 1:25 000-scale map of the area (Allan and Friend, in press.; Fig. 2). Ongoing petrological, geochemical and geochronological studies will provide additional insights into the character and fertility of magmatic rocks in the Mount Freegold district, augmenting the field-based observations and interpretations presented herein.

PHYSIOGRAPHY

The Mount Freegold district is located in the Dawson Range, and is characterized by moderately mountainous terrain with typically gentle north-facing slopes and steep south-facing slopes. North-facing slopes are typically characterized by permafrost, thick moss accumulations, and stunted trees, whereas south-facing slopes are draped in an active layer of colluvium and have better outcrop exposure (Carlson, 1987). Lack of glacial scouring and minimal erosion in this region has resulted in deep penetrative weathering of near-surface rocks; however, fresh rocks are exposed in subalpine areas (Tempelman-Kluit, 1974; Carlson, 1987).

The Mount Freegold district is accessed via the Freegold Road, an 80-km-long maintained gravel road that extends northwest from the town of Carmacks. Rock exposures in the area are enhanced by exploration trenches and roadcuts along the extensive network of exploration roads. Most of the area is accessible by 4x4 truck or all-terrain vehicle, although the area west of the Nucleus deposit is only accessible by helicopter.

REGIONAL GEOLOGIC SETTING

The Mount Freegold district is partly underlain by poly-deformed metasedimentary, metavolcanic and metaplutonic rocks of the composite pericratonic Yukon-Tanana terrane (YTT), and by post-accretionary Mesozoic plutonic and volcanic rocks. The oldest tectonostratigraphic unit of the YTT is the pre-Late Devonian Snowcap assemblage, a dominantly clastic assemblage deposited during passive margin sedimentation along the ancient Pacific margin of Laurentia. The Snowcap assemblage is interlayered with mafic to intermediate metavolcanic rocks, most likely of the Devonian to Mississippian Finlayson assemblage, an arc assemblage that was likely erupted on top of Snowcap assemblage rocks in a submarine environment (Colpron *et al.*, 2006b; Nelson *et al.*, 2013). These rocks are also interlayered with felsic to intermediate orthogneiss of the Early Mississippian Simpson Range suite, representing continental arc magmatism accompanying subduction beneath the rifted away Snowcap assemblage.

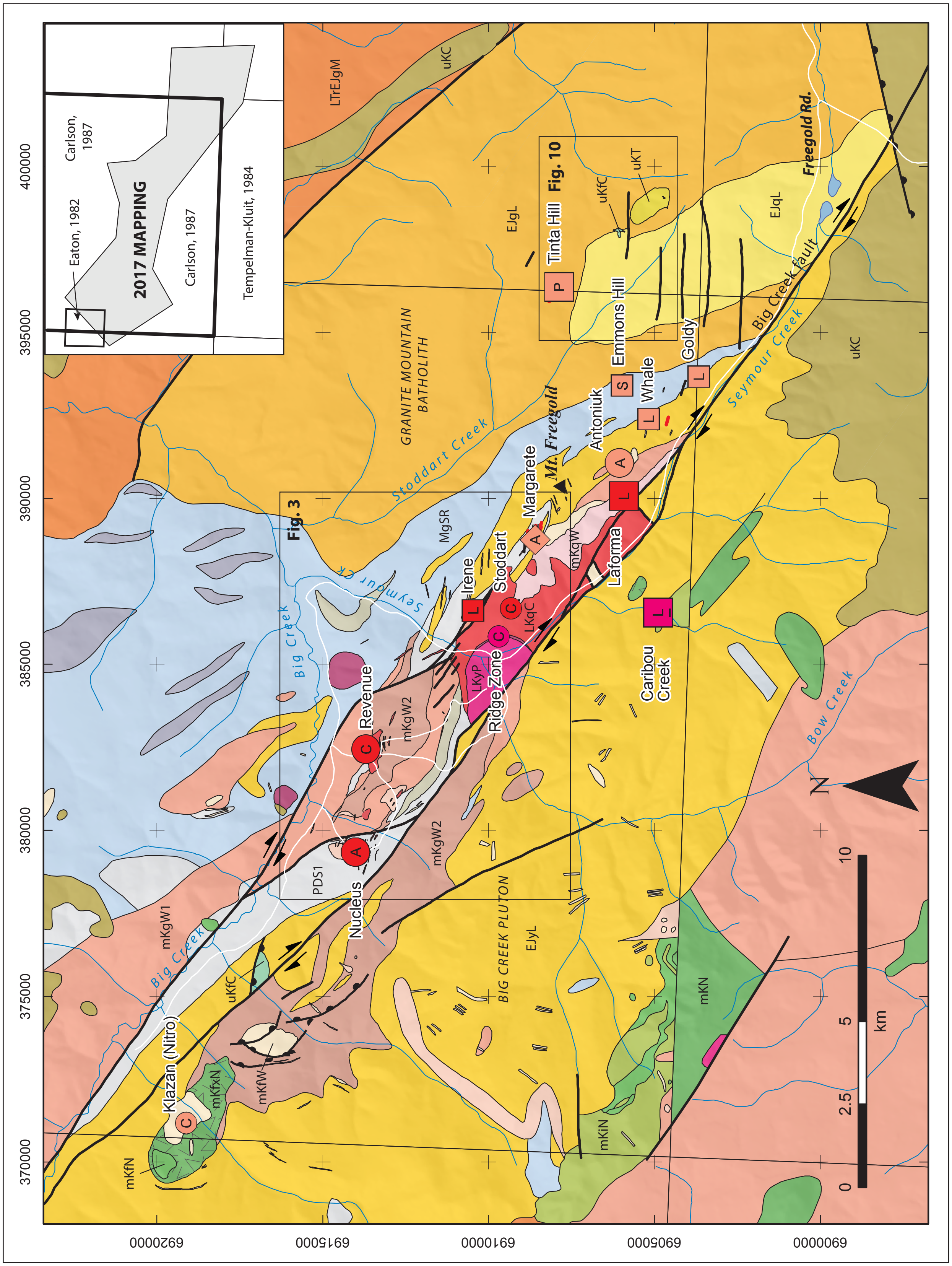

Figure 2. Bedrock geology map of the Mount Freegold district and Big Creek fault system based on 2017 field work, showing the distribution of significant mineral deposits and occurrences as referenced in the text. Geology is interpreted beyond the limit of mapping and incorporates previous mapping from Carlson (1987), Eaton (1982), and Tempelman-Kluit (1984) (see inset). The datum for this and all subsequent map figures is NAD83, UTM Zone 8N. Refer to legend for units and mineral occurrence symbology.

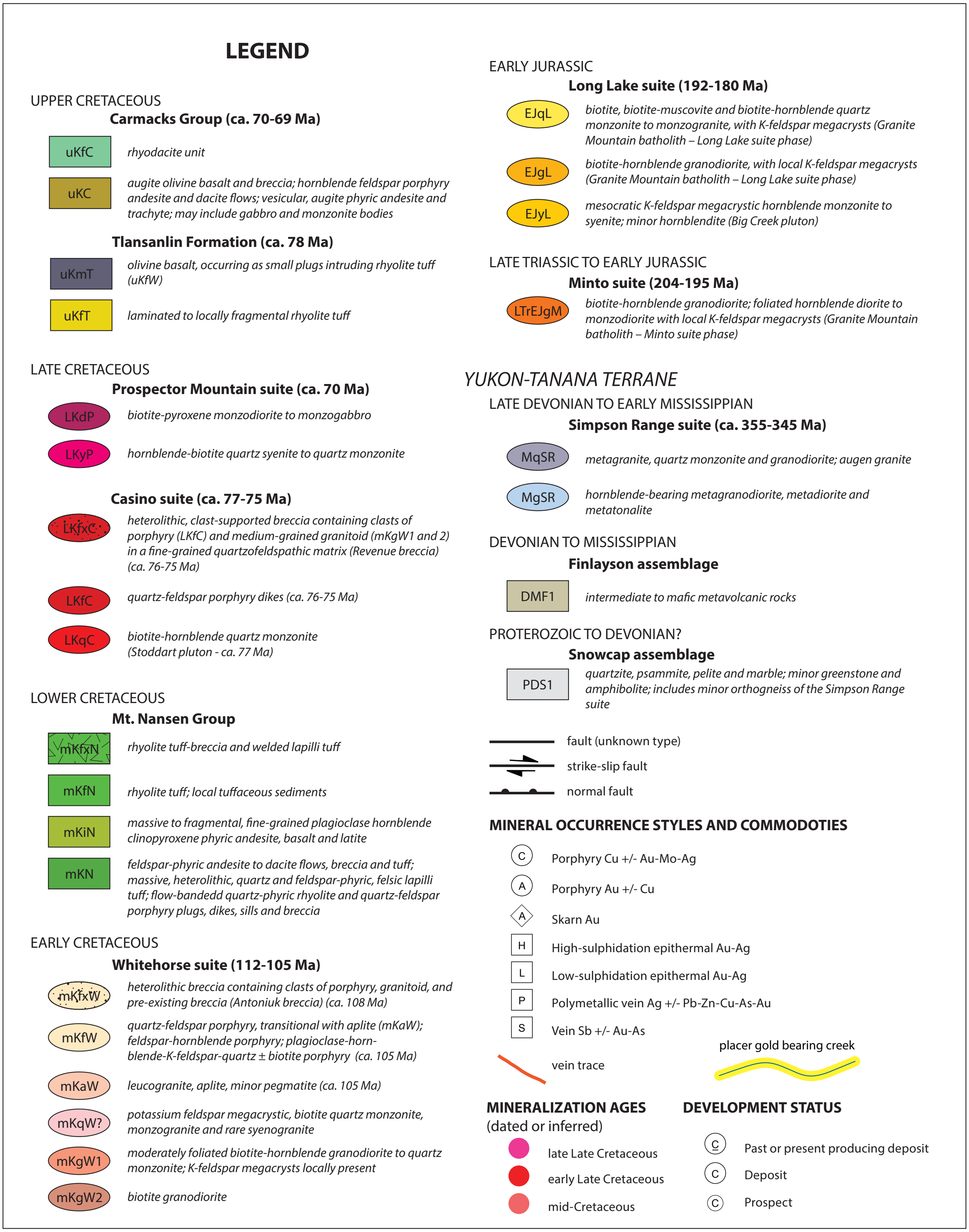

Figure 2 (cont'd). *Legend for Figure 2 and subsequent map figures.*

Yukon-Tanana terrane metamorphic rocks in the Freegold district are intruded by several generations of syn to post-accretionary plutonic rocks, including Early Jurassic Long Lake suite, mid-Cretaceous Whitehorse suite, early Late Cretaceous Casino suite, and late Late Cretaceous Prospector Mountain suite. Plutonic rocks of the Long Lake suite (EJL) include granodiorite, quartz monzonite, and granite of the Granite Mountain batholith, as well as monzonite to syenite of the Big Creek pluton and related intrusions (Tempelman-Kluit, 1984). Granodiorite, quartz monzonite, and granite of the mid-Cretaceous Whitehorse plutonic suite (mKW) occur as large plutons, and hypabyssal equivalents occur as dikes, sills, small stocks and intrusive breccia bodies. Whitehorse suite rocks represent a pulse of post-accretionary magmatism potentially associated with subduction outboard of the YTT. Mount Nansen Group volcanic rocks (mKN) are the eruptive equivalents of the Whitehorse suite (Klöcking *et al.*, 2016), and have been mapped at the Klazan occurrence (Eaton, 1982; Carlson, 1987) and in the Mt. Nansen area south of the Mount Freegold district (Tempelman-Kluit, 1984; Fig. 2).

Calc-alkaline rocks of the early Late Cretaceous Casino suite are exposed as a discontinuous belt of intrusions in the Dawson Range that is largely coincident with the Big Creek fault system (Ryan *et al.*, 2013a,b). Rocks of this suite are represented in the Mount Freegold district by plutons, dikes, and intrusive breccia bodies. This pulse of magmatism was followed in the late Late Cretaceous by eruption of Carmacks Group volcanic rocks and intrusion of plutons and high-level stocks of the Prospector Mountain suite (Tempelman-Kluit, 1984). Exposures of Carmacks Group volcanic rocks surrounding the Mount Freegold district are the erosional remnants of laterally extensive volcanic cover that lies unconformably over all older rock units (Tempelman-Kluit, 1984; Johnston *et al.*, 1996). Proposed mechanisms for generation of these typically high-K mafic melts include mantle melting driven by slab break off (Ciolkiewicz *et al.*, 2012), lithospheric delamination (Mortensen and Hart, 2010), or plume-related magmatism (Johnston *et al.*, 1996).

The dextral strike-slip Big Creek fault system has a prominent northwest-trending topographic and aeromagnetic expression along its entire strike length. In the Freegold district, a major step-over in the Big Creek fault system results in an area of structural complexity that was investigated during mapping (Figs. 2 and 3).

METHODS

Geologic map units established during 1:25 000-scale field mapping were correlated to regionally defined bedrock units based on rock composition and age constraints, either from previously published and unpublished sources, or from new high-resolution U-Pb zircon data obtained as part of this study (Fig. 3; Colpron *et al.*, 2016a). All rock units and descriptions presented here are based on field observations, and will be further refined using petrography, feldspar staining, lithogeochemistry and geochronology. Outcrop observations are supplemented by observations of diamond drill core where available, and of locally derived subcrop and colluvium. Geologic contacts were established in areas of poor rock exposure with the aid of detailed aeromagnetic data provided by Triumph Gold Corp. Topographic features, such as linear valleys and slope breaks, were also utilized in combination with aeromagnetic data to establish geologic contacts and faults in covered or inaccessible areas.

GEOLOGIC UNITS

The Mount Freegold district is underlain by metamorphic rocks of the Yukon-Tanana terrane; plutonic rocks of the Long Lake suite, Whitehorse suite, Casino suite, and Prospector Mountain suite; and volcanic rocks of the Mount Nansen Group and Carmacks Group. Each map unit is described below, in decreasing order of age.

YUKON-TANANA TERRANE

Snowcap assemblage

The Mount Freegold district is partly underlain by greenschist facies metamorphic rocks of the Proterozoic to Devonian Snowcap assemblage, which are intruded by plutonic rocks of the Long Lake suite, Whitehorse suite, Casino suite, and Prospector Mountain suite. The Snowcap assemblage is dominated by siliciclastic rocks, including psammitic to pelitic schist, interlayered locally with marble, felsic orthogneiss, and intermediate to mafic metavolcanic rocks.

Quartz-biotite schist (PDS1)

Quartz-biotite schist is the most abundant rock of the Snowcap Assemblage in the Mount Freegold district. This unit occurs as coherent belts forming ridges as well as blocky enclaves or pendants within the granodiorite to quartz monzonite of the Whitehorse suite (Figs. 2 and 3).

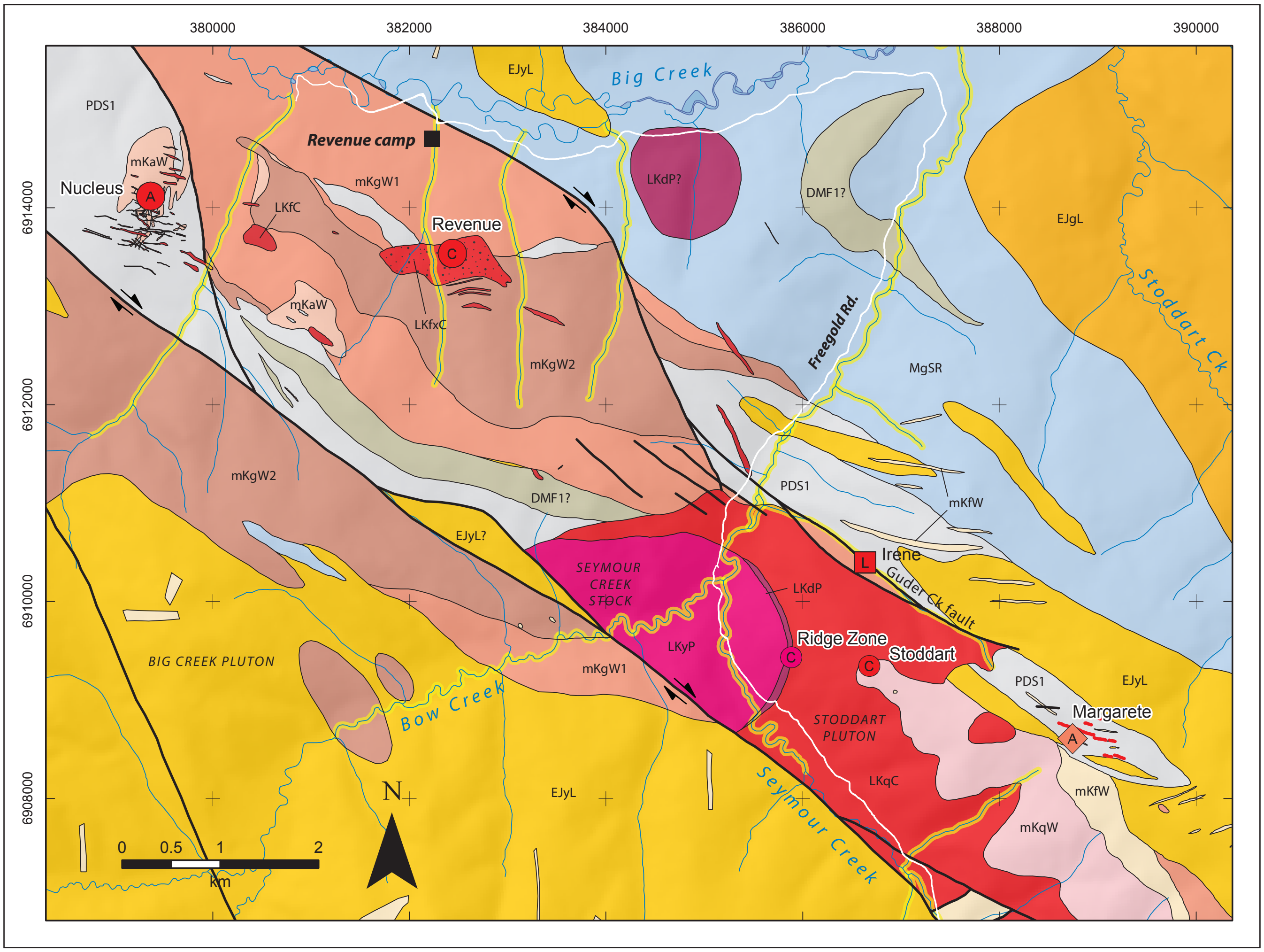

Figure 3. *Bedrock geology map focused on the area between Big Creek and the confluence of Bow and Seymour creeks, showing the distribution of significant mineral deposits and occurrences as referenced in the text. Refer to Figure 2 legend for lithologic and symbol descriptions.*

Locally it occurs as centimetre to metre-scale xenoliths (Fig 4a). The schist is brown weathered and locally gossanous, dark grey fresh, fine to fine-medium-grained, thinly foliated quartz-biotite-schist and quartz-feldspar-biotite schist. Locally the schist contains up to 40% biotite, which defines a well-developed foliation that is locally crenulated. Where the unit has been hornfelsed, it occurs as more prominent spurs on ridges. In proximity to the Revenue and Nucleus deposits, the schist is variably affected by pervasive silica alteration in which metamorphic fabrics are locally obliterated (Fig. 4b). This unit includes minor marble lenses and local garnet-pyroxene skarn in the Mount Freegold area (*e.g.*, Margarete occurrence, Yukon MINFILE 115I053; Fig. 3), and layers of amphibolite (Finlayson assemblage?) and orthogneiss of the Simpson Range suite (below).

Amphibolite schist to amphibolite gneiss (DMF1?)

Massive to foliated, intermediate to mafic amphibolite occurs in ridge-forming belts south and east of the Revenue deposit, and is locally interlayered with metasedimentary rocks of the Snowcap assemblage and orthogneiss of the Simpson Range suite (Figs. 2 and 3). The amphibolite is dark grey-green to black weathered, cream-green fresh, fine to medium-grained, and composed predominantly of actinolite ± hornblende and plagioclase. Locally the rock is medium to coarse-grained and has a gneissic texture. The gneissic variant typically contains feldspar augen 0.5 to 2 cm in length and locally developed hornblende augen up to 3 cm in length (Fig. 4c). The unit is tentatively assigned to the Finlayson assemblage based on analogous belts of amphibolite elsewhere along the northern margin of the Dawson Range batholith (Ryan *et al.*, 2013a,b).

Felsic to intermediate orthogneiss (MgSR)

Felsic to intermediate gneissic metaplutonic rocks form a coherent belt in the eastern part of the map near Mount Freegold (Fig. 3), but also occurs as narrow layers within packages otherwise dominated by Snowcap assemblage siliciclastic rocks. The gneissic rocks are cut by plutonic rocks of both the Early Jurassic Long Lake suite and mid-Cretaceous Whitehorse suite (Figs. 2 and 3). The orthogneiss forms minor ridges and boulder rubble of pale orange to pink weathered, fine to medium-grained, biotite hornblende granodiorite to quartz monzonite orthogneiss, with local diorite gneiss (Fig. 4d). Locally quartz monzonite orthogneiss contains potassium feldspar augen up to 3 cm. A sample of the orthogneiss collected near the Whale gold occurrence (Yukon MINFILE 115I112) yielded a U-Pb zircon age of 354.9±4.6 Ma (Allan, unpublished data, 2016).

PLUTONIC ROCKS

Long Lake suite

Plutonic rocks of the Early Jurassic Long Lake suite (EJL) are present in the eastern part of the Mount Freegold district, where they form large spires and prominent tors (Fig. 2). These rocks vary from massive to foliated. Foliations generally strike west-northwest and have either northeast or southwest dips. Both magmatic and tectonic fabrics are present. The age of the Long Lake suite ranges from 192-178 Ma (Joyce *et al.*, 2016). Three compositionally distinct phases are mapped in the Mount Freegold area: granodiorite (EJgL) and granite (EJqL) of the Granite Mountain batholith, and monzonite (EJyL) of the Big Creek pluton and satellite intrusions.

Figure 4. *Metamorphic rocks of the Yukon-Tanana terrane.* ***(a)*** *Xenolith of Snowcap assemblage quartz-biotite schist being digested by mid-Cretaceous granodiorite (mKgW2);* ***(b)*** *pervasive silica alteration and recrystallization of quartz-biotite schist of the Snowcap assemblage;* ***(c)*** *chalky weathered amphibolite gneiss with hornblende augen; and* ***(d)*** *granitic orthogneiss of the Simpson Range suite.*

Biotite hornblende granodiorite (EJgL)

Biotite hornblende granodiorite of Long Lake suite (EJgL) underlies the eastern part of the Mount Freegold district, where it forms part of the southern lobe of the Granite Mountain batholith (Fig. 2). This phase outcrops as spires and tors (Fig. 5a) of buff to white weathered, white fresh, medium-grained, biotite hornblende granodiorite (Fig. 5b). Rocks of this phase typically possess a weak to moderate tectonic foliation. Magnetic susceptibility of the unit ranges from 8.7 to 21.8×10^{-3} SI units (Table 1).

Biotite hornblende quartz monzonite to monzogranite (EJqL)

Biotite hornblende quartz monzonite to monzogranite of the Long Lake suite (EJqL) occurs in a part of the southern lobe of the Granite Mountain batholith, where it is the main host rock of the Tinta Hill polymetallic Au-Ag-Pb-Zn-Cu vein system (Yukon MINFILE 115I058). It outcrops as prominent tors and subdued outcrops of white to pink weathered, sparsely potassium feldspar megacrystic, medium-grained biotite hornblende quartz monzonite to monzogranite (Fig. 5c). Potassium feldspar megacrysts are typically tabular, opaque pink, and 1 to 4 cm in length. A quartz monzonite sample from an adit at the Tinta Hill occurrence yielded a U-Pb zircon date of 188.7 ± 1.2 Ma (Mortensen, J.K., unpublished data, 2011). Magnetic susceptibility of the unit is slightly less magnetic than EJgL, with values ranging from 8.0 to 13.3×10^{-3} SI units (Table 1).

K-feldspar megacrystic hornblende monzonite (EJyL)

K-feldspar megacrystic hornblende monzonite of the Long Lake suite (EJyL) is the main phase of the Big Creek pluton, which occurs south of the Big Creek fault system in the Mount Freegold district. The same unit occurs as numerous, narrow plutons that intrude metamorphic rocks of the YTT semi-conformably with the regional fabric (Fig. 2). The unit forms resistant, blocky to subrounded ridges of pink weathered, greenish pink fresh, coarse to very coarse grained hornblende monzonite to quartz monzonite, typically containing a high modal abundance of tabular potassium feldspar megacrysts (Fig. 5d). Historically, the unit has been referred to as the 'Big Creek syenite' in recognition of its high K-feldspar content, but field estimates of modal mineralogy suggest the bulk composition is generally monzonitic.

Rocks of this unit contain 5-15% interstitial blebby quartz (Fig. 5e). Locally, a fine-grained phase is in gradational contact with the more typical coarse-grained phase. Dark green to brown weathered, dark green fresh, coarse-grained, massive to moderately foliated hornblendite occurs as centimetre to metre-thick zones (Fig. 5f), and in one locality, as an approximately 75 m thick sequence interpreted as hornblende cumulate. The main fabric in the Big Creek syenite is defined by cumulate layering of potassium feldspar and hornblende; however, local overprinting tectonic foliations and shear fabrics are well developed. Analysis of a sample collected near Mount Freegold yielded a U-Pb zircon date of 182.84 ± 0.05 Ma (J. Crowley, unpublished data, 2015). This result implies the unit is part of the Long Lake suite, in contrast with previous assignments of the 'Big Creek syenite' to the older Minto suite. This phase is strongly magnetic with values up to 40.5×10^{-3} SI units (Table 1).

mid-Cretaceous Whitehorse suite

Plutonic rocks of the Whitehorse suite intrude metamorphic rocks of the Yukon-Tanana terrane (YTT) in the Mount Freegold area, south of Big Creek, and southwest of Seymour Creek (Fig. 2). Rocks of this suite form low positive relief outcrops and are otherwise mapped through exposures of rubble along roads or in exploration trenches. Rocks of this suite are typically buff weathered, white fresh, equigranular monzogranite, quartz monzonite, granodiorite, monzodiorite and lesser syenogranite. The low relief outcrop and presence of enclaves or roof pendants of country rock distinguishes intrusive rocks of the Whitehorse suite from the Long Lake suite. The age of the Whitehorse suite is constrained to 112 to 105 Ma (Colpron *et al.*, 2016b).

*Figure 5. Plutonic rocks of the Long Lake suite. **(a)** Tor of buff to white weathered biotite hornblende granodiorite; **(b)** foliated biotite hornblende granodiorite (EJgL); **(c)** medium-grained hornblende quartz monzonite (EJqL); **(d)** coarse-grained potassium feldspar megacrystic hornblende monzonite (EJyL), historically termed the 'Big Creek syenite' in recognition of its high K-feldspar content; **(e)** interstitial quartz and minor hornblende in potassium feldspar dominated Big Creek syenite (EJyL); and **(f)** cumulate segregations in the Big Creek syenite (EJyL); dark green is hornblende cumulate, pale pink is dominantly potassium feldspar. Abbreviations: qtz=quartz; hbl=hornblende; Kfs=K-feldspar.*

Table 1. Selected samples and their magnetic susceptibilities.

Rock Unit	Locality	Latitude	Longitude	Magnetic Susceptibility (x10^{-3} SI units)	Sample
uKfC	Locality 88	62.272727	-136.963687	9.1 ± 2.0 (n = 12)	MF17-DRP52
LKyP	Locality 14	62.295776	-137.207378	8.2 ± 2.0 (n = 6)	MF17-DRP13
	Locality 181	62.306324	-137.227990	10.5 ± 2.3 (n = 10)	N/A
	Locality 453	62.302970	-137.231427	8.61 ± 0.82 (n = 10)	N/A
LKdP	Locality 443	62.309015	-137.214983	43.4 ± 8.0 (n = 10)	N/A
LKqC	Locality 8	62.280623	-137.173829	19.3 ± 5.4. (n = 10)	MF17-DRP9
	Locality 9	62.294258	-137.202347	23.7 ± 6.7 (n = 10)	MF17-DRP10
	Locality 24	62.292342	-137.163861	40.1 ± 5.2 (n = 10)	MF17-DRP20
uKmT	Locality 100	62.26068	-136.943365	11.0 ± 2.7 (n = 8)	N/A
uKfT	Locality 96	62.268946	-136.953976	0.34 ± 0.33 (n = 6)	N/A
mKfW	Locality 42	62.284817	-137.114611	17.8 ± 5.6 (n = 8)	MF17-DRP35
	Locality 335	62.28819	-136.998635	8.8 ± 3.4 (n = 10)	MF17-DRP86
	Locality 490	62.267223	-137.096439	0.54 ± 0.26 (n = 10)	N/A
mKaW	Locality 291	62.347361	-137.421616	0.24 ± 0.15 (n = 10)	N/A
	Locality 419	62.341176	-137.322944	0.04 ± 0.01 (n = 10)	N/A
mKqW?	Locality 20	62.296745	-137.180937	16.9 ± 3.0 (n = 10)	MF17-DRP21
	Locality 49	62.284040	-137.144230	19.0 ± 16.3 (n = 6)	MF17-DRP41
mKgW2	Locality 283	62.340271	-137.457920	16.0 ± 3.0 (n = 10)	N/A
	Locality 320	62.325366	-137.348657	18.5 ± 2.1 (n = 10)	N/A
	Locality 471	62.327050	-137.221718	0.04 ± 0.02 (n = 10)	N/A
mKgW	Locality 46	62.278267	-137.121602	21.8 ± 2.8 (n = 10)	MF17-DRP38
	Locality 173	62.315100	-137.240800	31.4 ± 11.4 (n = 10)	N/A
	Locality 256	62.383475	-137.471920	15.9 ± 9.2 (n = 10)	MF17-DRP76
EJqL	Locality 73	62.245130	-136.942107	13.3 ± 4.0 (n = 12)	N/A
	Locality 333	62.245089	-136.973366	8.0 ± 1.8 (n = 10)	N/A
EJgL	Locality 92	62.266226	-136.962096	8.7 ± 2.7 (n = 8)	N/A
	Locality 118	62.220381	-136.887677	21.8 ± 4.3 (n = 10)	N/A
EJyL	Locality 321	62.329185	-137.349618	40.5 ± 11.4 (n = 10)	N/A
	Locality 6	62.259460	-137.128655	39.9 ± 7.5 (n = 10)	MF17-DRP7

Biotite hornblende quartz monzonite to granodiorite (mKgW1)

Biotite hornblende quartz monzonite to granodiorite of the Whitehorse suite intrudes YTT rocks north of the Big Creek fault in the central part of the Mount Freegold district (Fig. 2), where it forms blocky outcrops of buff weathered, pinkish grey fresh, medium-grained biotite hornblende granodiorite to quartz monzonite and lesser monzodiorite. Euhedral blocky hornblende and dark, fine-grained diorite autoliths inclusions are characteristic of this suite of rocks within the map area (Fig. 6a). Sparse white to pink potassium feldspar megacrysts are typical in the granodiorite to quartz monzonite. The unit is locally foliated, which distinguishes this phase from the separate biotite granodiorite phase (mKgW2, below; Fig. 6b). A sample of a monzodiorite member of this unit exposed in Revenue Creek was dated at 107.1 ± 0.6 Ma (Bineli Betsi and Bennett, 2010). Magnetic susceptibility of this unit is variable from 15.9 to 31.4 x 10^{-3} SI units (Table 1).

Biotite granodiorite (mKgW2)

Massive, biotite granodiorite of the Whitehorse suite occurs as a mappable unit south of the Revenue deposit, and as a large body intruding the Big Creek pluton south of the Big Creek fault system (Fig. 3). Rocks of this unit form low relief outcrops and subcrop of white to pink weathered, white fresh, medium-grained equigranular, biotite granodiorite with distinctive euhedral plagioclase grains. Rare megacrysts of potassium feldspar are observed (Fig. 6c). Enclaves and xenoliths of metamorphic wall rock are common in this phase, which preserve the attitude of metamorphic layering (Fig. 6d). A diamond drill core sample of this unit from the Revenue deposit yielded a U-Pb zircon age of 102.5 ± 2.7 Ma (Mortensen and Allan, unpublished data, 2012). Magnetic susceptibility of this phase is variable from <1 to 18.5 x 10^{-3} SI units (Table 1).

K-feldspar megacrystic biotite quartz monzonite and minor monzogranite to syenogranite (mKqW)

A previously unmapped body of coarse-grained granitoid is exposed on the southern slope of Mount Freegold, and is one of the host rocks of the Laforma high-sulphidation epithermal vein system (Yukon MINFILE 115I054). The unit intrudes the monzonite phase of the Long Lake suite (EJyL) and is cut along the south by Late Cretaceous granitoid rocks (Fig. 3). The unit forms saddles and topographic lows of buff to grey weathered, greyish pink fresh, coarse to very coarse grained, potassium feldspar megacrystic biotite quartz monzonite, monzogranite and rare syenogranite (Fig. 6e,f). The unit is tentatively assigned to the mid-Cretaceous Whitehorse suite, but absolute age control is pending U-Pb zircon analysis. Magnetic susceptibility of this phase ranges from 16.9 to 19 x 10^{-3} SI units (Table 1).

Leucogranite (mKaW)

A leucogranite phase of Whitehorse suite occurs in in the far west, near Klazan (Nitro) and in the Mount Freegold area as plugs, sills and dikes that intrude YTT metamorphic rocks and mid-Cretaceous granitoid rocks (Figs. 2 and 7). The leucogranite is locally transitional with the mid-Cretaceous granitoid rocks. At the Nucleus deposit, field evidence and drill data suggest that this leucogranite unit is a swarm of sills intruding the Yukon-Tanana country rocks rather than a single intrusive body. Rocks assigned to this unit form hillocks of low relief outcrop to blocky rubble that are white to beige weathered. This unit is texturally variable, and includes (1) a very fine grained, aplitic phase (Fig. 7a); (2) a fine to medium-grained equigranular phase; (3) a fine-grained phase that contains sparse phenocrysts of feldspar and quartz; and (4) a rare coarse-grained to pegmatitic phase. The quartzofeldspathic groundmass is locally granophyric and exhibits a magmatic fabric with alternating laminae of quartz and feldspar. Locally the unit is cut by bluish-grey quartz veinlets (Fig. 7b). These quartz veins, along with granophyric textures and local flow banding are interpreted to reflect the rapid quenching of wet, silicic magma cooling during deformation (Campbell *et al.*, 2010). Textural changes in the unit are gradational and typically subtle, and the unit is texturally transitional with granodiorite of the Whitehorse suite (mKgW2), suggesting the units are co-magmatic. Overall, the unit is leucocratic and contains less than 10% mafic minerals. A sample of leucogranite hosting mineralization at the Nucleus deposit yielded a U-Pb zircon age of 104.3 ± 3.5 Ma (Allan, unpublished data, 2012). Magnetic susceptibility of this phase ranges from 16.9 to 19 x 10^{-3} SI units (Table 1).

Porphyritic rocks (mKfW)

Hypabyssal porphyritic rocks occur in the vicinity of Mount Freegold, Nucleus and Klazan (Nitro) as dikes, sills and plugs that intrude granitoid rocks of the Whitehorse and Long Lake suites, and YTT metamorphic rocks (Figs. 2 and 3). Where exposed at surface, the porphyritic rocks generally form subcrop or rubble with rare angular to blocky outcrop.

*Figure 6. Plutonic rocks of the Whitehorse suite. **(a)** Biotite hornblende granodiorite; note the fine-grained dioritic autolith (dashed circle), a characteristic feature of this phase (mKgW1); **(b)** foliation observed in granodiorite (mKgW1); note this is a feature that distinguishes it from the biotite granodiorite (mKgW2); **(c)** equigranular, biotite granodiorite with rare megacrysts of potassium feldspar (mKgW2); **(d)** biotite granodiorite (mKgW2) with xenoliths of metamorphic wall rock that give it a foliation (white arrow); note the distinctive euhedral plagioclase grains; **(e)** coarse-grained, potassium feldspar megacrystic biotite quartz monzonite (mKqW); and **(f)** left: weathered surface of the coarse-grained biotite quartz monzonite, note the abundance of potassium feldspar megacrysts (mKqW); right: buff weathered quartz feldspar porphyry dike (mKfW) that cuts the quartz monzonite (mKqW).*

The main phase of this unit is blocky, grey to orange weathered, dark grey to pink fresh, crowded feldspar-hornblende to quartz-feldspar-hornblende porphyry with a greenish pink granular granitic to monzogranitic groundmass (Fig. 7c). Strong silicification and potassium feldspar alteration is common. Less abundant is a pink to grey weathered, densely porphyritic, plagioclase-hornblende-potassium feldspar ± quartz - biotite porphyry in a fine-grained granite to monzonite groundmass (Fig. 7d). Quartz phenocrysts are rounded and embayed. Potassium feldspar phenocrysts up to 8 mm in diameter locally contain inclusions of plagioclase and hornblende. Rocks of this unit are constrained to *ca.* 105-102 Ma (M. Allan, unpublished data, 2016). Magnetic susceptibility of this phase ranges from 0.54 to 17.8×10^{-3} SI units (Table 1).

Late Cretaceous Casino Suite

Within the Mount Freegold district, rocks of the Casino suite include small plutons, dikes, and intrusive breccia complexes that intrude YTT metamorphic rocks and plutonic rocks of the Long Lake and Whitehorse suites. A pluton of this suite outcrops north of Seymour Creek where it forms blocky outcrops with trapezoidal joint patterns, whereas dikes and intrusive breccia complexes are exposed as strongly altered rubble in the Revenue and Nucleus deposit area (Fig. 8). Plutonic rocks of the Casino suite are typically beige weathered, equigranular monzogranite.

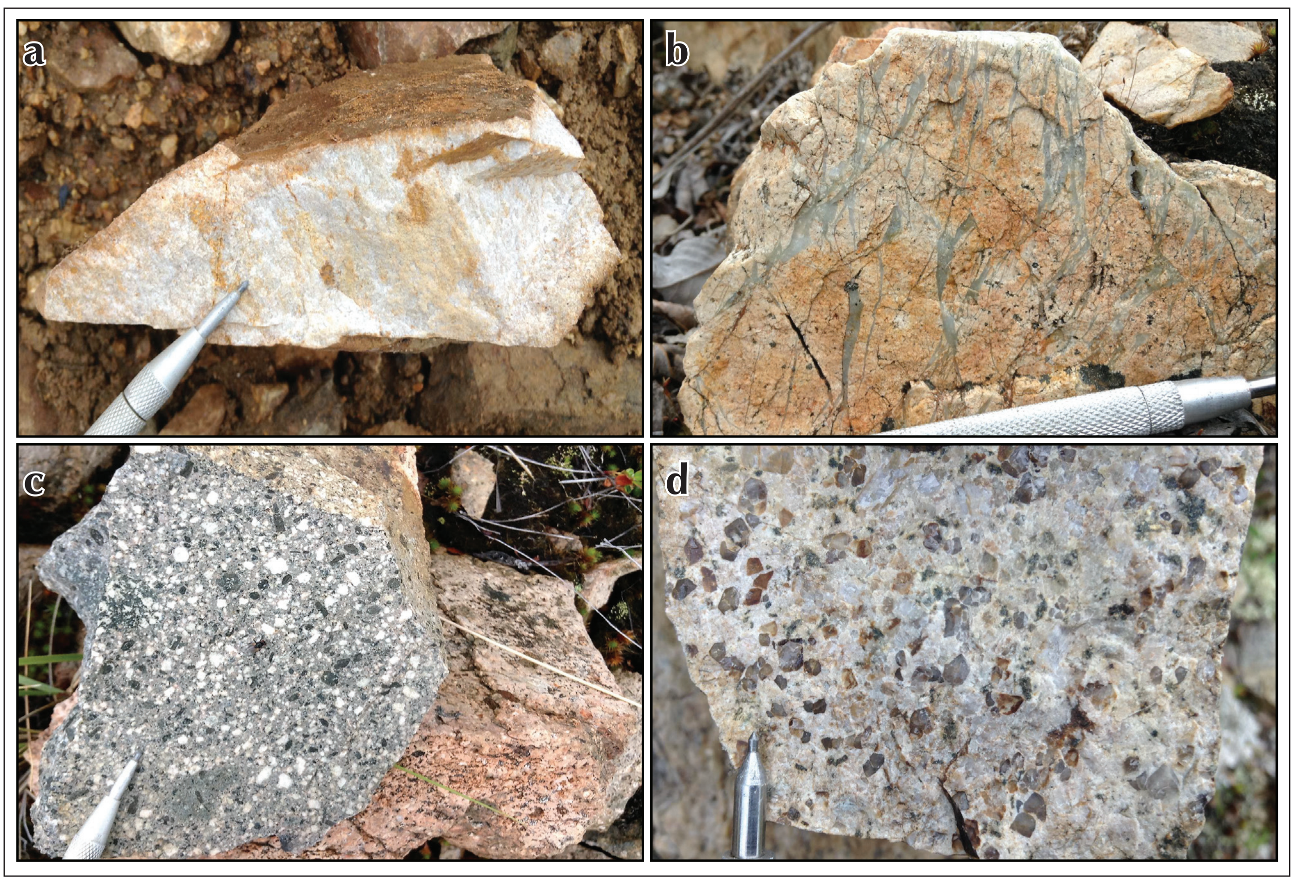

Figure 7. *Hypabyssal rocks of the Whitehorse suite.* ***(a)*** *Aplitic phase of the ca. 105 Ma leucogranite at Nucleus (mKaW);* ***(b)*** *bluish-grey quartz veinlet swarm cutting the sparsely porphyritic phase of the leucogranite;* ***(c)*** *crowded feldspar-hornblende porphyry typical of the Whitehorse suite (mKfW); and* ***(d)*** *plagioclase-hornblende-potassium feldspar ± quartz-biotite porphyry with distinctive smoky grey embayed quartz phenocrysts (mKfW).*

Biotite hornblende quartz monzonite (LKqC)

The largest intrusion of the Casino suite in the Mount Freegold district is the previously unmapped Stoddart pluton, which occurs north of Seymour Creek (Figs. 2 and 3). This unit is exposed on outcropping ridges and in roadcuts of blocky, massive, beige weathered, pink to pinkish grey fresh, medium-grained biotite hornblende quartz monzonite (Fig. 8a; LKqC). This unit is characterized by sparse tabular bluish-grey potassium feldspar megacrysts and greenish saussuritized plagioclase grains in a hypidiomorphic groundmass. Biotite phenocrysts are black and euhedral. Locally the unit is cut by widely spaced (one per metre), subvertical quartz-chalcopyrite-pyrite veinlets with narrow potassium feldspar haloes, and weathered to limonite and malachite. The unit also hosts Cu-Mo-Au mineralization at the Stoddart prospect (Yukon MINFILE 115I121). The age of the Stoddart pluton is *ca.* 77 Ma (J. Crowley, pers. comm., 2017). The unit is highly magnetic, with susceptibilities ranging from 20 to 40×10^{-3} SI units (Table 1).

Porphyritic rocks (LKfC)

Variably Cu-Au-Ag-Mo mineralized porphyritic dikes of early Late Cretaceous age are common in the vicinity of the Revenue and Nucleus deposits (Allan *et al.*, 2013), where they occur in west to northwest-striking swarms that cut mid-Cretaceous granitoid rocks and Paleozoic basement rocks (Fig. 3). Where dikes are exposed at surface, they rarely outcrop and instead form rubble of orange-beige weathered, crowded feldspar quartz to quartz feldspar porphyry containing 5-10% phenocrysts in a fine-grained groundmass (Fig. 8b). The groundmass is typically silicified in the Nucleus deposit (Fig. 8c). Feldspar phenocrysts are typically sericite altered and rare tabular remnants of potassium feldspar phenocrysts weather to orange clay. A sample of feldspar quartz porphyry dike that cuts leucogranite at the Nucleus deposit yielded a U-Pb zircon age of 75.0 ± 0.4 Ma. (Allan and Mortensen, unpublished data, 2012).

Figure 8. *Plutonic and hypabyssal rocks of the Casino suite.* ***(a)*** *Biotite hornblende quartz monzonite of the ca. 77 Ma Stoddart pluton (LKqC);* ***(b)*** *feldspar quartz porphyry dike of the Casino suite at surface; potassium feldspar phenocrysts are weathered to clay (LKfC);* ***(c)*** *diamond drill core sample of the crowded feldspar quartz porphyry dike (LKfC) with a medium-grey silicified groundmass; dike cuts the leucogranite at the Nucleus deposit; and* ***(d)*** *intrusive breccia at the Revenue deposit (LKfxC).*

Intrusive breccia (LKfxC)

The Revenue Cu-Au-Ag-Mo deposit is hosted primarily by an east-west elongate intrusive breccia complex that intrudes along the contact of biotite hornblende granodiorite (mKgW) to the north, and biotite granodiorite (mKgW2) to the south. The unit is exposed at surface in exploration roadcuts and trenches as buff to pink weathered clast-supported breccia with sand to pebble-sized igneous clasts in a strongly altered and weathered very fine grained matrix (Fig. 8d). The breccia is cut by dikes (LKfC) and is locally transitional with porphyritic rocks, consistent with a magmatic-hydrothermal origin. The breccia body narrows with depth and potentially represents a diatreme (T. Barresi, pers. comm., 2017).

Late Cretaceous Prospector Mountain suite

Biotite hornblende quartz syenite (LKyP)

The Late Cretaceous Prospector Mountain suite is represented in the Mount Freegold district by the Seymour Creek stock, a one kilometre diameter intrusion that is exposed at the confluence of Bow Creek and Seymour Creek (Figs. 2 and 3). The stock intrudes metamorphic rocks of the YTT as well as granitoid rocks of the Long Lake, Whitehorse, and Casino suites, and is cut to the south by the Big Creek fault, as indicated by field mapping and interpretations of aeromagnetic data (Fig. 3). The unit also hosts polymetallic Au-Ag-Pb-Cu mineralization of the Ridge zone east of Stoddart Creek (Fig. 3). The most common phase of the Seymour Creek stock outcrops as angular blocks of white weathered, pink fresh, fine to medium-grained biotite hornblende quartz syenite to quartz monzonite and lesser syenogranite with glomerophyric hornblende ± biotite in an equigranular hypidiomorphic groundmass (Fig. 9a; LKyP). A sample of the Seymour Creek stock collected near the confluence of Bow Creek and Seymour Creek yielded a U-Pb zircon age of 69.99 ± 0.02 Ma (J. Crowley, pers. comm., 2017). Magnetic susceptibility of this unit is consistently in the range of 8 to 11×10^{-3} SI units (Table 1).

Biotite monzodiorite to monzogabbro (LKdP)

The eastern margin of the Seymour Creek stock is characterized by a 5 to 20 m-wide, intermediate to mafic border phase (LKdP) that is in sharp, but locally texturally transitional, contact with the main quartz syenite to monzonite phase (Figs. 3 and 9b,c). This recessive unit is exposed in roadcuts and trenches as rounded, brown black weathered, medium-grained biotite monzodiorite to monzogabbro that weathers largely to grus (Fig. 9d,e). Sparse, disseminated blebs of copper limonite after chalcopyrite occur in the monzogabbro, and are interpreted as a magmatic sulphide phase (Fig. 9d). Magnetic susceptibility of this phase of the Prospector Mountain suite is $43.4 \pm 8.0 \times 10^{-3}$ SI units (Table 1).

A small, circular intrusion of monzogabbro flanked by mafic volcanic rocks of the Carmacks Group was mapped by Carlson (1987) north of Big Creek, and is interpreted here as age-equivalent to Prospector Mountain suite (Fig. 3). A similar circular feature characterized by a prominent negative magnetic anomaly is present northeast of the Revenue deposit (Fig. 3). The feature is not expressed in outcrop, but is also tentatively interpreted as an intermediate to mafic stock of the Prospector Mountain suite.

VOLCANIC ROCKS

Volcanic rocks are present locally in the Mount Freegold district, most notably in the Klazan (Nitro) area south of Big Creek (Fig. 2), and south of the Tinta Hill deposit (Fig. 10).

mid-Cretaceous Mount Nansen Group (mKN)

The Klazan (Nitro) occurrence located at the far western end of the Mount Freegold district (Fig. 2) is located within an exposure of rhyolite tuff (mKfN) and rhyolite tuff-breccia (mKfxN) cored by an intrusive complex that includes felsic porphyry and intrusive breccia (mKfW; Eaton, 1982). Fragmental volcanic rocks exposed as rubble in trenches are buff weathered, white to green fresh, and contain subangular coarse sand to pebble-sized, clay-altered lapilli in a crystal rich groundmass (Fig. 11a). Fine-grained angular quartz crystals occur in the groundmass. Locally lapilli are flattened and define volcanic layering. The volcanic unit is tentatively assigned to the mid-Cretaceous Mount Nansen Group according to previous mapping (Eaton, 1982; Tempelman-Kluit, 1984; Carlson, 1987), but absolute age control is pending U-Pb zircon analysis.

Figure 9. *Plutonic rocks of the Prospector Mountain suite.* ***(a)*** *Typical biotite hornblende quartz syenite of the ca. 70 Ma Seymour Creek stock; note the glomerophyric aggregates of hornblende ± biotite (white arrows);* ***(b)*** *malachite and azurite stained shear and carbonate vein at the contact between the biotite quartz syenite (LKyP) and the biotite monzogabbro (LKdP) in the Ridge zone (refer to Fig. 3);* ***(c)*** *biotite-hornblende quartz syenite (LKyP) dikelet cutting biotite monzogabbro (LKdP) in the Ridge zone (refer to Fig. 3);* ***(d)*** *equigranular biotite monzodiorite phase at the eastern margin of the Seymour Creek stock;* ***(e)*** *biotite monzogabbro with sparse dark red blebs of copper limonite after chalcopyrite (white arrows); and* ***(f)*** *left to right: biotite monzogabbro, biotite monzodiorite, and biotite quartz syenite of the Seymour Creek stock. cp = chalcopyrite, cb = carbonate, bt = biotite.*

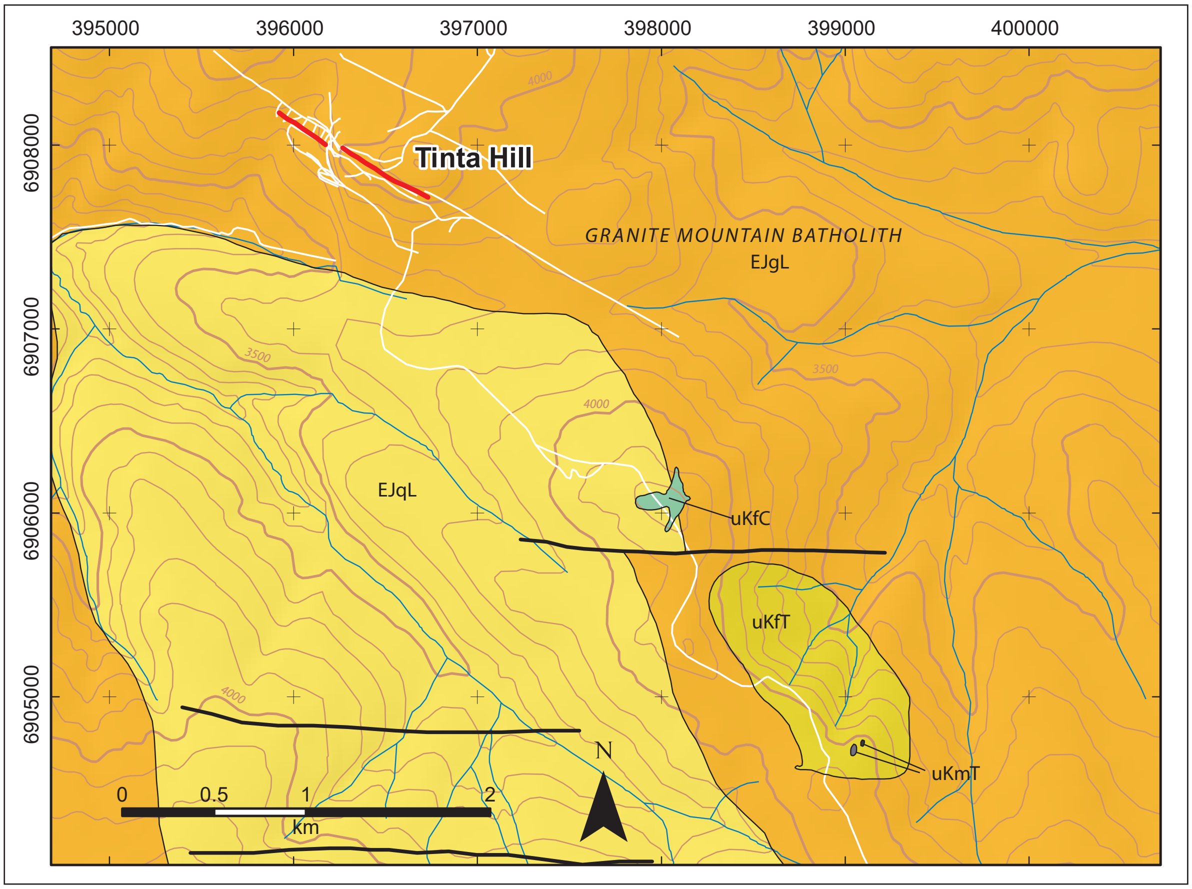

Figure 10. *Bedrock geology map of the Tinta Hill deposit area, showing felsic flow-dome complexes of the Tlansanlin Formation (uKfT) and Carmacks Group (uKfC). Refer to Figure 2 legend.*

Upper Cretaceous Tlansanlin Formation (uKfT and uKmT)

An elliptical, approximately one square kilometre exposure of felsic flows and tuffs occurs north of Seymour Creek along the Tinta Hill road (Figs. 2 and 10). Volcanic rocks unconformably overlie granodiorite of the Long Lake suite and occur as splintery to flaggy subcropping rubble of pale pink weathered, laminated to locally fragmental rhyolite tuff (uKfT) with 1 to 2% quartz phenocrysts and trace disseminated pyrite (Fig. 11b). The southwestern margin of the exposure consists of whitish pink to maroon weathered, clast-supported pyroclastic breccia to volcanic sandstone dominated by subrounded clasts of rhyolite with lesser jasper and altered granitoid (EJgL; Fig. 11c). Two small plugs of columnar jointed, dark brown weathered, olivine pyroxene phyric basalt (uKmT) with rare granitic xenoliths intrude rhyolite near the southeastern margin of the volcanic exposure (Fig. 11d). On the basis of the elliptical map pattern, felsic volcanic rocks are interpreted as the extrusive facies of a flow-dome complex. The marginal breccia phase is interpreted to be a basal facies as the contact appears to be depositional. This rhyolite yielded a U-Pb zircon age of 78.18 ± 0.03 Ma (J. Crowley, pers. comm., 2017), suggesting correlation with the Tlansanlin Formation – the extrusive equivalent of the Casino suite. Magnetic susceptibilities of the volcanic rocks range from 0.34 to 11×10^{-3} SI units (Table 1).

Upper Cretaceous Carmacks Group (uKC)

Two exposures of rhyodacite tuff were mapped in the Mount Freegold district: one south of Big Creek and west of the Nucleus deposit (Fig. 2); and one along Tinta Hill Road north of the previously described rhyolite flow dome (Fig. 10). The latter forms a prominent hillock of splintery to flaggy rhyodacite that locally unconformably overlies Early Jurassic granitoid rocks of the Granite Mountain batholith (Figs. 10 and 11e). The unit is a pale grey to mauve, plagioclase biotite quartz phyric rhyodacite tuff with locally developed dark glassy laminae (Fig. 11f). The eastern exposure of this unit along Tinta Hill Road has a massive core compared to laminated, tuffaceous margins, suggesting a flow dome architecture. A sample of rhyodacite at this locality yielded a U-Pb zircon age of 70.04 ± 0.02 Ma, which demonstrates age equivalence to the Seymour Creek stock (J. Crowley, pers. comm., 2017). Magnetic susceptibility of the rhyodacite is $9.1 \pm 2.0 \times 10^{-3}$ SI units (Table 1). The unit is broadly contemporaneous with mafic volcanic rocks of the Upper Cretaceous Carmacks Group (UKC) that are exposed north and west of Big Creek, and in the Seymour Creek drainage southeast of the Mount Freegold area (Fig. 3).

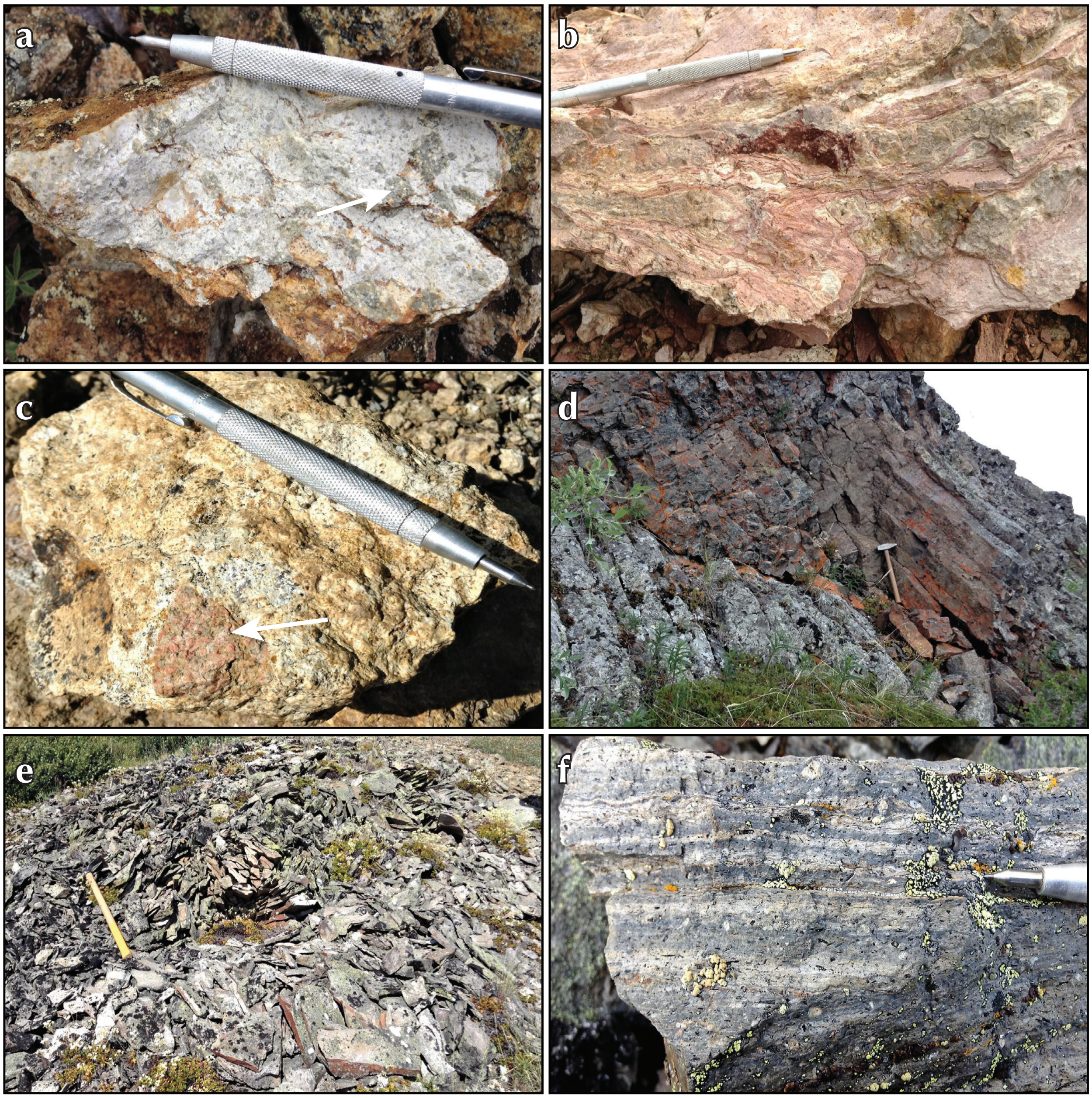

Figure 11. *Volcanic rocks in the Mount Freegold district.* ***(a)*** *Altered lapilli tuff tentatively assigned to the Mount Nansen Group from the Klazan (Nitro) occurrence (Yukon MINFILE 115I038); white arrow points to lapilli;* ***(b)*** *laminated rhyolite flow of the Tlansanlin formation near Tinta Hill (uKfT);* ***(c)*** *basal pyroclastic breccia to rhyolite tuff at the margin of the rhyolite flow-dome complex of the Tlansanlin formation;* ***(d)*** *columnar jointed basalt plug (uKmT) that intrudes the southeastern margin of the rhyolite flow-dome complex;* ***(e)*** *small hillock of splintery rubble of ca. 70 Ma rhyodacite (uKfC); and* ***(f)*** *plagioclase biotite quartz-phyric rhyodacite tuff with well-developed laminae (uKfC).*

STRUCTURE

The Mount Freegold district coincides with a right-stepping duplex in the dextral strike-slip Big Creek fault system. The duplex is bound to the north by a fault strand that tracks the southeast-trending segment of the Big Creek valley, and to the south by a fault strand that follows the Seymour Creek valley and traverses the north-facing slope south of the Nucleus and Revenue deposits (Fig. 2). The trace of the northern fault strand is interpreted from aeromagnetic data to bend southeastward approximately 1 km northeast of the Revenue deposit. Mapping demonstrates this fault strand to be plugged by both the 77 Ma Stoddart pluton and the 70 Ma Seymour Creek stock near the confluence of Seymour Creek and Bow Creek (Fig. 3). This northern fault strand thus records pre-77 Ma movement. A series of low-displacement, southeast-trending dextral strike-slip faults that are mapped or inferred from aeromagnetic data cut the northern intrusive contact of the Stoddart pluton, the most northerly of which defines the Guder Creek fault and controls epithermal mineralization of the Irene occurrence (Fig. 3). These faults thus define post-77 Ma movement. The Seymour Creek strand of the Big Creek fault system cuts both the Stoddart pluton and Seymour Creek stock to the south, thus defining post-70 Ma movement. The trace of this fault to the northwest is defined by geology, aeromagnetic data, and recessive topography, and appears to converge with the northern fault strand northwest of the Klazan occurrence (Fig. 2). A secondary north-northwest-trending linking fault is inferred between the Nucleus and Revenue deposits on the basis of geology and aeromagnetic data. Overall, no apparent strike-slip movement on the northern strand of the Big Creek fault system is recorded after Late Cretaceous emplacement of the Stoddart pluton, whereas movement on the southern strand outlasted emplacement of the 70 Ma Seymour Creek stock.

DISCUSSION

BIG CREEK FAULT SYSTEM AND MAGMATISM

The right-stepping duplex of the Big Creek fault system defines an extensional regime that accommodated emplacement of magmas, and localized magmatic-hydrothermal mineralization in the Mount Freegold district. Based on new field observations and mapping, the influence of the Big Creek fault system on the emplacement of three plutonic suites is considered: the mid-Cretaceous Whitehorse suite, early Late Cretaceous Casino suite, and late Late Cretaceous Prospector Mountain Suite.

The three plutonic units of the Whitehorse suite recognized in the Mount Freegold district (mKgW1, mKgW2, mKqW) intrude, and occur inboard of, Early Jurassic plutonic rocks. Mid-Cretaceous plutonic rocks surrounding the Revenue deposit were likely emplaced into a zone of extension facilitated by dextral movement on the right-stepping northern and southern strands of the Big Creek fault system. Furthermore, it is likely that the northwest-trending belt of mid-Cretaceous granitoid rocks exposed on the southern slope of Mount Freegold also intruded into an early strand of the Big Creek fault system. Mid-Cretaceous dikes and intrusive breccia at the Antoniuk gold deposit in the Mount Freegold area are hypabyssal expressions of these granitoid rocks at higher crustal level, and were also likely controlled by the Big Creek fault system.

Plutonic to hypabyssal rocks of the Casino suite are apparently contained entirely within the right-stepping duplex of the Big Creek fault system, strongly suggesting their emplacement into local zones of extension accommodated by dextral strike-slip movement on the main fault system. The spatial association of the Seymour Creek stock and related Prospector Mountain suite intrusions with the Big Creek fault system is also conspicuous, and likely suggests a fundamental structural control on pluton emplacement.

CRUSTAL LEVEL AND IMPLICATIONS FOR MINERALIZATION

Mid-Cretaceous dikes and a stock of felsic porphyry (mKfW) on Mount Freegold are present at a higher structural and topographic level than the coarse-grained quartz monzonite to monzogranite unit (mKqW), suggesting they are potentially hypabyssal equivalents. A similar relationship is observed in the western part of the Mount Freegold district, where transitional relationships among plutonic rocks (mKgW2), aplite (mKaW), and felsic porphyry (mKfW) indicate that the current erosional level exposes the carapace of an upper crustal magma chamber (Fig. 3).

Similarly, the Stoddart pluton (LKqC) that outcrops north of Seymour Creek locally exhibits transitional textures with aplite, pegmatite, and Cu-Mo bearing quartz veins at the Stoddart porphyry prospect. These relationships indicate a crustal level near the hydrous carapace of the magma chamber. In contrast, west of Seymour Creek, hypabyssal intrusions of the Revenue deposit, with no known exposures of Casino suite plutonic rocks, indicates a somewhat high level of crustal exposure. However, widespread high-temperature hydrothermal alteration and mineralization surrounding the Revenue deposit may indicate the presence of a laterally extensive Casino suite pluton at depth.

Elsewhere in the Mount Freegold district, the present-day erosional surface is equivalent to the Late Cretaceous unconformity, as indicated by *ca.* 78 Ma and 70 Ma flow domes built on Early Jurassic granitoid rocks south of the Tinta Hill deposit (Fig. 3).

CONCLUSIONS

Three distinct pulses of magmatism associated with mineralization are recognized in the Mount Freegold district that were, at least in part, controlled by episodic movement on the long-lived Big Creek fault system. An extensional relay zone in the Big Creek fault system controlled magmatism of the Casino and Prospector Mountain suites and associated magmatic-hydrothermal mineralization in the district. This dextral transtensional environment may also have had similar control on the emplacement of plutonic and hypabyssal phases of the mid-Cretaceous Whitehorse suite.

Ongoing investigations include systematic characterization of mid and Late Cretaceous plutonic and hypabyssal rocks, through lithogeochemistry, mineral staining, petrographic analysis, U-Pb dating and trace element chemistry of zircon.

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