Age of magmatism and mineralization at the Star (Sheslay, Copper Creek) copper porphyry prospect: Inception of the Late Triassic mineralized arc

Mitchell G. Mihalynuk[1, a], Alexandre Zagorevski[2], Nancy L. Joyce[2], and Robert A. Creaser[3]

[1] British Columbia Geological Survey, Ministry of Energy and Mines, Victoria, BC, V8W 9N3
[2] Geological Survey of Canada, 601 Booth Street, Ottawa, ON, K1A 0E8
[3] Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, T6G 2R3
[a] corresponding author: Mitch.Mihalynuk@gov.bc.ca

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Abstract
Cu-Mo porphyry style mineralization near the Star prospect was likely discovered during construction of the Telegraph Trail in the early 1900s, but it was probably not until about 1976 that the main Dick Creek zone was discovered. Previously, all mineralization was attributed to the Kaketsa pluton (~226 Ma), a small body extending across an area of ~20 km^2, and related satellite intrusions. New U-Pb zircon magmatic (229 ±3 Ma) and Re-Os mineralization (227.2 ±1.0 Ma) ages from the main Dick zone confirm this affiliation. Cu-Mo calc-alkalic style porphyry mineralization of this age is uncommon in the Canadian Cordillera. Although the Star mineralization is broadly similar in style to the huge Schaft Creek deposit (~222 Ma), Dick Creek zone mineralization is significantly older. It is perhaps the oldest well-dated Triassic porphyry mineralization in the Canadian Cordillera, and marks inception of porphyry mineralization in the Late Triassic arc.

Keywords: Copper, gold, molybdenum, silver, porphyry mineralization, Star, Sheslay, Copper Creek, Dick Creek, Kaketsa pluton, Schaft Creek, U-Pb, Re-Os, geochronology

1. Introduction

The Star Cu-Mo porphyry (Fig. 1) is the northernmost resource-bearing porphyry deposit in British Columbia. Why similar mineralization seems to be lacking in Late Triassic and Early Jurassic (~230-175 Ma) volcanic arc rocks between Star and allied deposits in Yukon, about 300 km to the north-northwest (Fig. 2), remains unclear. This problem is being addressed by projects forming part of the Geo-mapping for Energy and Minerals (GEM2) program. These projects are designed to characterize volcanic and intrusive rocks across the BC-Yukon border and to establish the regional temporal, tectonostratigraphic, and structural controls on copper-gold porphyry formation. Herein we report new U-Pb zircon magmatic and Re-Os mineralization ages for the Star porphyry prospect (Fig. 3; Dick Creek MINFILE 104J 035). These ages permit comparisons with deposits of similar age and help to define and extend prospective magmatic belts, especially northward.

2. Location and access

The Star porphyry prospect is in northwest British Columbia about 100 km west-southwest of Dease Lake and 50 km northwest of Telegraph Creek (Fig. 1). Access is by helicopter, or by fixed-wing aircraft that are capable of landing on a ~700 m-long gravel runway near the confluence of the Hackett and Sheslay rivers. A network of exploration roads links the

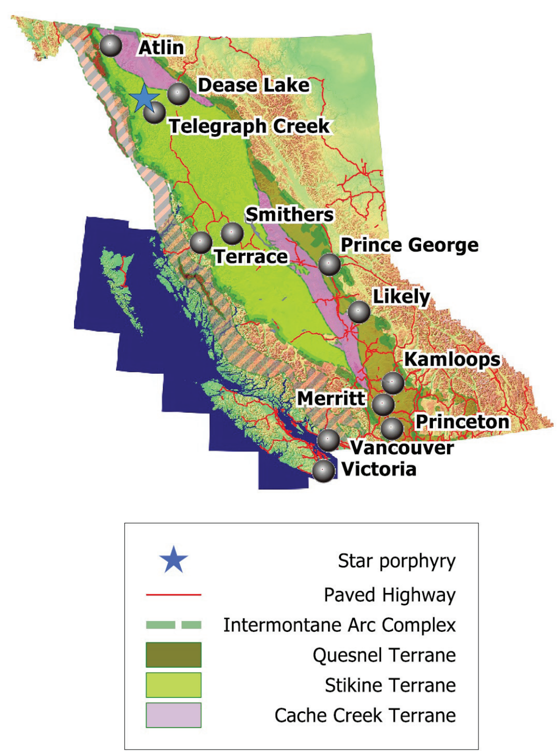

Fig. 1. Location and tectonic setting of the Star Cu-Mo porphyry prospect, which includes the Dick Creek, Hat (Copper Creek), and Pyrrhotite Creek mineralized areas.

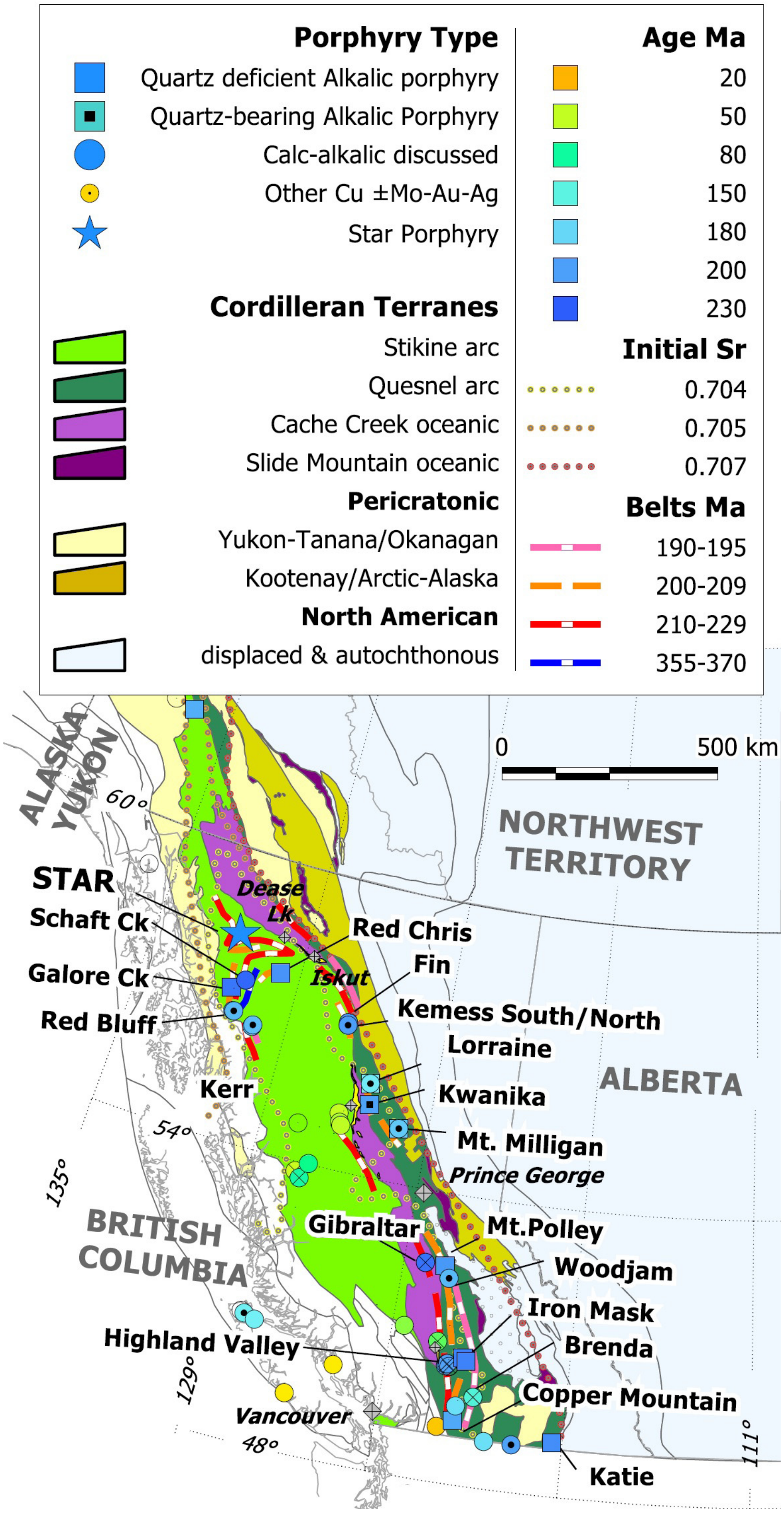

Fig. 2. Star porphyry (star symbol) among porphyry deposits colour coded according to age to show Late Triassic-Early Jurassic porphyry events (shades of blue). Schematic representation of Late Triassic and Early Jurassic arc pluton belts (modified after Logan and Mihalynuk, 2014) as discrete N-trending belts with eastward-progressing axes of magmatism along Quesnel terrane (QN). However, this pattern breaks down in northwestern Stikine terrane (ST), as indicated by Devonian-Mississippian, Late Triassic, and Early Jurassic arc plutons that show westward migration of magmatism and an apparent oroclinal folding along the northern margin of the Bowser basin. Initial strontium isopleths shown for Mesozoic plutons (Armstrong, 1988) mimic the distribution of pericratonic strata that envelop the QN-ST arc complex to the north (cf. Mihalynuk et al., 1994).

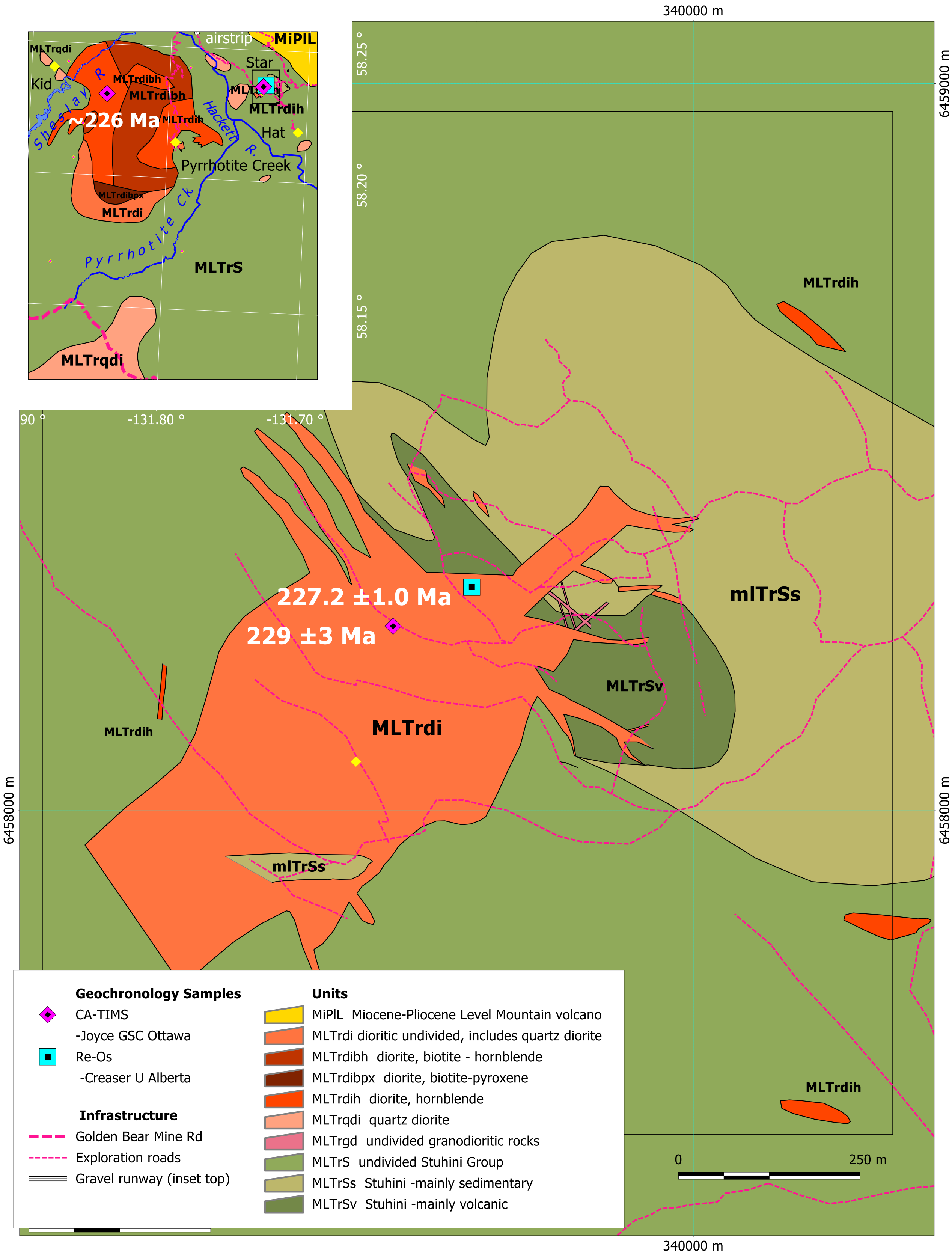

Fig. 3. Property scale geology at the Star prospect based on reconnaissance mapping, data from T.E. Lisle in Panteleyev (1983), and Lane (2005), and drill logs (Prosper Gold Corp., 2015). Most contacts are inferred. Inset shows regional geology and the polyphase, elliptical Kaketsa pluton (after Massey et al., 2005). See text for age data sources. Location of property geology on inset is shown by the rectangle. Both figures are Universal Transverse Mercator (zone 9) projections using North American Datum 1983.

airstrip with the two principal mineralized areas, Dick Creek (MINFILE 104J 035) and Copper Creek (MINFILE 104J 005, currently referred to as 'Hat'), about 3 and 6.5 km southeast, respectively. Old roads also extend from the airstrip to the Pyrrhotite Creek (MINFILE 104J 018) developed prospect, which is included in the Star Property tenures, about 5 km southwest of the Dick Creek mineralized area, and on the opposite side of the Hackett River.

If future road linkage to the provincial highway network is warranted, it would most likely be via the Golden Bear mine access road which, at its closest point, is within 8 km of the Star (Fig. 3). Presently, however, the Golden Bear road is washed out about 23 km from its junction with the Telegraph Creek road (80 km from the community of Dease Lake).

3. Geological setting

Most of British Columbia is underlain by island arc terranes that accreted to the North American margin in Triassic to Cretaceous times (e.g. Monger et al., 1982; Dickinson, 2004). The largest of these terranes is Stikinia (Stikine terrane, Figs. 1, 2), which consists of arc successions ranging from Early Devonian, based on the oldest fossil-bearing strata intercalated with volcanic rocks (Logan et al., 2000), to early Middle Jurassic (Cutts et al., 2015). Stikinia may have been loosely attached to North America by the Early Jurassic (~185 Ma, e.g., Murphy et al., 1995; Colpron et al., 1998), but it did not fully collapse against the margin until the early Middle Jurassic, when subduction in northern Stikinia ceased (Mihalynuk et al., 2004; possibly later in the south, Cordey and Schiarizza, 1993).

Most porphyry-style mineralization in British Columbia is related to Late Triassic and Early Jurassic intrusions in Stikinia and its continent-ward sister terrane, Quesnellia, from which it is separated along much of its southern length by oceanic crustal rocks and mantle slices of the exotic Cache Creek terrane (Fig. 2). Stikinia and Quesnellia appear to be joined at their northern ends where they are also enveloped by pericratonic strata as old as Proterozoic (Watson et al., 1981). This hairpin arrangement of Stikinia-Quesnellia with intervening exotic oceanic rocks and an enveloping belt of craton-derived strata has been attributed to oroclinal folding of once continuous, adjacent arc segments about a northern hinge (Mihalynuk et al., 1994). As a possible analogue, a similar arrangement of arc terranes separated by exotic oceanic rocks, may result if the Pacific Ocean between Asia and North America closes completely, trapping the Hawaii-Emperor seamounts between Japan-Kurile and the Aleutian arcs.

A particularly prolific ~6 m.y. pulse of Late Triassic Cu-Au-Ag porphyry production occurred in Stikinia and Quesnellia, centered on ~205 Ma (Logan and Mihalynuk, 2014). Intrusive activity associated with this pulse of mineralization is alkalic, and attributed to diachronous collision of another arc, the Kutcho-Sitlika arc, with Stikinia-Quesnellia (see Logan and Mihalynuk, 2014 for details). Worldwide, the best developed belts of these quartz-deficient alkalic Cu-Au-Ag porphyry deposits are in British Columbia. Porphyry-style mineralization of the Kaketsa stock and related quartz-saturated intrusions at the Star and nearby Hat prospect is of the Cu-Mo ±Au type, similar to the huge Highland Valley deposit in southern British Columbia (Fig. 2). As we show here, Star porphyry mineralization significantly predates the main ~205 ±3 Ma pulse of alkalic mineralization, consistent with the more variable ages of calc-alkalic deposits elsewhere in the province. Other calc-alkalic deposits older than ~205 include: Highland Valley (~210-206 Ma); Gibraltar (~210 Ma); Fin (~218 - 221 Ma; Dickinson, 2006); and Schaft Creek (222 Ma; see Logan and Mihalynuk, 2014 for a discussion of deposit ages).

Published regional geological maps of the area near the Star and Hat prospects are available at 1:250,000 scale (Gabrielse, 1998; or smaller and in digital format, Massey et al., 2005) and show the area as underlain by undivided volcanic and sedimentary rocks of the Stuhini Group (Late Triassic; Fig. 3). Property scale mapping generally confirms this gross subdivision (e.g., Panteleyev, 1983; Lane, 2005), as does our reconnaissance mapping (Fig. 3). However, future systematic mapping should permit further subdivision of the volcano-sedimentary succession into discrete units and their intrusive equivalents. For example, intrusive rocks, some with evidence of potassic alteration and copper mineralization, are exposed in new roadcuts along the Golden Bear Mine in an area previously mapped as the undivided volcano-sedimentary unit (Fig. 3; Mihalynuk and Zagorevski, 2016).

4. Exploration history

Mineralization near the Star prospect may have been known as early as 1899, when the Canadian Government began constructing the Ashcroft-Yukon telegraph line, linking the Atlin-Klondike goldfields to areas in the south. Earlier surveys for the ill-fated Collins Overland telegraph line in 1867 travelled north along the Tahltan and Hackett River valleys, a route later used by the Hudson's Bay Company, beginning ca. 1891 (Gauvreau, 1893), to access its post at Egnell, at the junction of the Hackett and Sheslay rivers (later known as 'Sheslay'). A track survey of northwest British Columbia commissioned by the Provincial Government began along this route in 1892 (Gauvreau, 1893); it encountered evidence of unsuccessful placer operations, but Gauvreau reported neither base metal occurrences nor exploration thereof. Similarly, from his reconnaissance geological survey along this same route in 1887, Dawson (1888) made no mention of significant mineralization. Not until 1937 are the first written reports of mineralization uncovered by prospecting in Copper Creek (now 'Hat', for a summary of more recent exploration see Caron, 2013). A long history of additional exploration in the area commenced with trenching, mapping, and drilling at Copper Creek in 1955-56 (James, 1956). Copper mineralization discoveries at the Star were staked in 1976, and the most recent diamond drilling was conducted in 2014 by Prosper Gold Corporation (Bernier, 2015). At the nearby Hat prospect, Doubleview Capital Corp. was preparing for a drill program in the fall of 2015 (Shirvani, 2015).

5. Mineralization

Mineralization at the Star property was attributed to the Katetsa pluton and related intrusions (Panteleyev and Duda, 1973). The pluton is a polyphase elliptical body that cuts the Stuhini Group and underlies an area of ~20 km^2 (inset, Fig. 3). We did not map mineralization at the eastern margin of the pluton (Pyrrhotite Creek, also known as Go, G), and the following descriptions are from Panteleyev (1983). The pluton is foliated and zoned, with a biotite-hornblende granodiorite core and hornblende diorite margins. Contact zones may include hornblende-pyroxene gabbro, in some cases as dikes within and outside of the pluton. A stock cutting the northeast contact zone is biotite-hornblende quartz diorite (Fig. 3). Younger dikes vary in composition: quartz diorite, monzonite, syenite and aplite. Panteleyev (1983) described alteration as K-feldspar flooding along fractures with quartz, siderite, and calcite. Pyrite and subordinate chalcopyrite occur as fracture-controlled veinlets in volcanic country rocks and as disseminations in the diorite dikes. Chalcopyrite is concentrated in fractures and shear zones, and in thin bands of mylonite in the main Pyrrhotite Creek prospect (~60 m by 90 m area).

The Dick Creek (Star) prospect is approximately 5km east of the main Kaketsa pluton (Fig. 3). Dick Creek (Star) was the focus of exploration by Prosper Gold Corporation in 2014. Based on work by Prosper Gold Corporation, copper mineralization at the Star prospect occurs in acicular hornblende ±quartz diorite, monzodiorite and adjacent volcano-sedimentary strata, mainly as veinlets, blebs, and disseminations of chalcopyrite together with magnetite and pyrite. Alteration mineralogy includes secondary K-feldspar, and secondary biotite, which is only rarely coarse enough for individual crystals to be seen in hand sample. In some areas, extensive quartz stockworks are developed; some veins are banded and carry molybdenite (see below). Locally, quartz has also flooded the host rock. Late epidote, chlorite and carbonate veinlets are common. The presence of late, cross-cutting, unmineralized hornblende-feldspar porphyritic monzodiorite indicates that there were several pulses of magmatism at the Star property.

6. Previous ages of intrusion and mineralization

Previously published geochronology from the Star tenures is limited to two K-Ar cooling ages. Hornblende from a sample of quartz diorite collected ~800 m west of the Pyrrhotite Creek prospect on the eastern margin of the Kaketsa pluton (Fig. 3) yielded an age reported by Panteleyev and Dudas (1973) as 218 ±8 Ma. Biotite from a similar quartz diorite (Panteleyev, 1976) yielded an age of 214 ±6 Ma, which was recalculated using more modern decay constants as 218 ±12 Ma (Breitsprecher and Mortensen, 2004). A sample from the west side of Kaketsa pluton yielded a U-Pb zircon age of ~226 Ma (Friedman unpublished, in Zagorevski et al., 2015) confirming earlier suggestions (Panteleyev and Dudas, 1973) that the mineralized intrusive rocks at Dick Creek and Pyrrhotite Creek are broadly parts of the same intrusive and mineralizing event.

7. Geochronology

To determine more precise crystallization and mineralization ages at the Star property, we selected two samples for geochronological analysis (Fig. 3). A sample of the quartz diorite that hosts porphyry mineralization at the main Dick Creek zone was taken from diamond-drill hole (DDH) SH028 (sample 14ZE-920A, Fig. 4) to determine the U-Pb zircon age of the magmatic event. A sample of quartz stockwork veining containing molybdenite partings up to ~2 mm thick in and on the margins of cm-thick quartz veins (Fig. 5) was selected for Re-Os age determination to test if mineralization is the same

Fig. 4. Ragged hornblende quartz diorite porphyry, a mineralized intrusive phase in DDH SH028 at the Dick Creek zone, sampled for U-Pb-zircon SHRIMP geochronology (sample 14ZE920A).

Fig. 5. a) Drill core of altered quartz diorite cut by stockworks of quartz-pyrite-molybdenite ±chalcopyrite-epidote-chlorite veinlets and veins up to ~1.5 cm wide. Indicated on the core box is the segment of the core collected for molybdenite extraction and Re-Os age determination (DDH S040, 89.7-90.3m). **b)** Close up of a) with blue-grey molybdenite concentrated along vein margins.

age as the intrusion (sample MMI14-35-11 from DDH S040, 89.7-90.3 m).

7.1. U-Pb zircon methods

Zircon separates were obtained using standard crushing, disk mill, Wilfley table, heavy liquid, and magnetic separation techniques. Analytical procedures and calibration details for the Sensitive High Resolution Ion Microprobe (SHRIMP) at the Geological Survey of Canada in Ottawa followed those described by Stern (1997) and Stern and Amelin (2003). Briefly, zircons were cast in a 2.5 cm diameter epoxy mount along with the Temora 2 zircon primary standard, the accepted $^{206}Pb/^{238}U$ age of which is 416.8 ±0.33 Ma (Black et al., 2004). Fragments of the GSC laboratory zircon standard (z6266, with $^{206}Pb/^{238}U$ age=559 Ma) were also included on the mount as a secondary standard, analyses of which were interspersed among the sample analyses throughout the data session to verify the accuracy of the U-Pb calibration. The mid-sections of the zircons were exposed using 9, 6, and 1 µm diamond compound, and the internal features of the zircons (such as zoning, structures, and alteration) were characterized in both back-scattered electron mode (BSE) and cathodoluminescence mode (CL) using a Zeiss Evo 50 scanning electron microscope. The mount surface was evaporatively coated with 10 nm of high purity Au. Analyses were conducted using an 16O- primary beam, projected onto the zircons at 10 kV. Before analysis, the ion beam was rastered over the area of interest for 2 minutes in order to locally remove the Au coating and eliminate effects of surface common lead. The sputtered area used for analysis was ca. 16 µm in diameter with a beam current of ca. 3.5 nA. The count rates at ten masses including background were sequentially measured over 6 scans with a single electron multiplier and a pulse counting system with deadtime of 23 ns. The 1σ external errors of $^{206}Pb/^{238}U$ ratios reported in the data table incorporate a ±1.39% error in calibrating the standard Temora 2 zircon. Additional details of the analytical conditions and instrument settings are presented in the footnotes of the Table 1. Off-line data processing was accomplished using customized in-house software. Isoplot v. 3.00 (Ludwig, 2003) was used to generate concordia plots and to calculate weighted means. Errors for isotopic ratios in Table 1 are given at 1σ uncertainty, as are the apparent SHRIMP ages. Age errors reported in the text are at the 2σ uncertainty level, and encompass the combined statistical uncertainty of the weighted mean age for the population and the 2σ error of the mean of the Temora 2 zircon calibration standard. No fractionation correction was applied to the Pb-isotope data; common Pb correction used the Pb composition of the surface blank (Stern, 1997). All ages are reported as the ^{207}Pb-corrected weighted mean $^{206}Pb/^{238}U$ age. The error ellipses on the concordia diagrams and the weighted mean errors are reported at 2σ.

7.2. Re-Os methods

A molybdenite mineral separate was prepared by metal-free crushing followed by gravity and magnetic concentration methods, as described in detail by Selby and Creaser (2004). The ^{187}Re and ^{187}Os concentrations in molybdenite were determined by isotope dilution mass spectrometry using Carius-tube, solvent extraction, anion chromatography and negative thermal ionization mass spectrometry techniques. A mixed double spike containing known amounts of isotopically enriched ^{185}Re, ^{190}Os, and ^{188}Os analysis was used (Markey et al., 2007). Isotopic analysis used a ThermoScientific Triton mass spectrometer by Faraday collector. Total procedural blanks for Re and Os are less than <3 picograms and 2 picograms, respectively, which are insignificant for the Re and Os concentrations in molybdenite. The molybdenite powder HLP-5 (Markey et al., 1998), was analyzed as a standard, and

Table 1. SHRIMP U-Pb zircon results.

Spot name	U (ppm)	Th (ppm)	Th/U	^{206}Pb* (ppm)	^{204}Pb/^{206}Pb	% ±	f(206)^{204} %	^{208*}Pb/^{206*}Pb	% ±	^{238}U/^{206}Pb	% ±	^{207}Pb/^{206}Pb	% ±	^{207*}Pb/^{235}U	% ±	^{206*}Pb/^{238}U	% ±	Corr Coeff	^{207*}Pb/^{206*}Pb	% ±	Apparent Ages (Ma) 204 corrected ^{206}Pb/^{238}U	204 corrected ±^{206}Pb/^{238}U	207 corrected ^{206}Pb/^{238}U	207 corrected ±^{206}Pb/^{238}U
Sample Number: 14ZE920A (Z11315) Star quartz diorite																								
11315-027.1	419	210	0.52	12.9	2.7E-4	50	0.59	0.176	7.3	27.6	1.5	0.0554	3.6	0.26	5.7	0.036	1.5	0.3	0.0514	5.5	228	3	**228**	**3**
11315-033.1	327	132	0.42	10.0	1.7E-4	71	1.24	0.137	10.2	27.8	1.5	0.0606	3.9	0.29	5.3	0.036	1.5	0.3	0.0581	5.1	227	3	**225**	**3**
11315-034.1	228	87	0.39	7.0	5.5E-4	50	1.47	0.109	15.3	27.5	1.6	0.0624	5.0	0.27	9.7	0.036	1.7	0.2	0.0544	9.5	228	4	**227**	**4**
11315-037.1	344	166	0.50	10.8	1.6E-4	71	0.76	0.144	8.9	27.2	1.5	0.0569	3.8	0.28	5.2	0.037	1.5	0.3	0.0546	5.0	232	3	**231**	**3**
11315-042.1	566	418	0.76	17.8	*bdl*		0.10	0.271	5.1	27.3	1.5	0.0516	5.3	0.26	5.5	0.037	1.5	0.3	0.0516	5.3	232	3	**232**	**3**
11315-046.1	336	121	0.37	10.6	-2.5E-4	58	0.01	0.112	10.4	27.3	1.8	0.0509	4.2	0.28	5.7	0.037	1.8	0.3	0.0545	5.4	233	4	**232**	**4**
11315-047.1	395	175	0.46	12.3	2.1E-4	58	0.54	0.138	8.6	27.3	1.5	0.0551	3.7	0.26	5.4	0.036	1.5	0.3	0.0521	5.2	231	3	**230**	**3**
11315-049.1[a]	*99*	*23*	*0.24*	*3.0*	*3.6E-3*	*29*	*5.84*	*0.030*	*127.4*	*26.3*	*1.8*	*0.0974*	*10.4*	*0.21*	*45.6*	*0.036*	*2.7*	*0.1*	*0.0437*	*45.5*	*225*	*6*	*227*	*5*
11315-053.1	238	92	0.40	7.4	*bdl*		0.96	0.111	15.1	27.2	1.9	0.0585	5.2	0.30	5.6	0.037	1.9	0.3	0.0585	5.2	233	4	**231**	**4**
11315-054.1	226	95	0.43	6.9	-3.1E-4	71	1.33	0.129	16.8	27.6	1.6	0.0613	8.6	0.33	9.4	0.036	1.7	0.2	0.0659	9.3	231	4	**226**	**4**
11315-060.1[a]	*163*	*51*	*0.32*	*5.1*	*2.5E-3*	*27*	*2.43*	*0.092*	*21.7*	*27.0*	*2.1*	*0.0702*	*5.2*	*0.16*	*33.5*	*0.035*	*2.5*	*0.1*	*0.0332*	*33.4*	*224*	*5*	*229*	*5*
11315-070.1	315	140	0.46	9.9	3.2E-4	58	0.83	0.118	12.5	27.1	1.6	0.0574	4.5	0.27	7.3	0.037	1.6	0.2	0.0528	7.1	232	4	**231**	**4**
11315-077.1	419	188	0.46	13.1	-8.2E-5	100	0.20	0.142	9.1	27.5	1.5	0.0524	4.2	0.27	5.0	0.036	1.5	0.3	0.0536	4.7	230	3	**230**	**3**

Notes (see Stern, 1997):
Mount IP747, K100a spot size (13x16µm), 2 minute raster, 6 mass scans
Primary beam intensity ~3-3.5 nA,Weighted mean ^{207}Pb-corrected ^{206}Pb/^{238}U age of the analyses of secondary standard z6266 zircon was determined to be 563 ±5 Ma (2σ), MSWD=0.77, n=23 (no rejections) (accepted ^{206}Pb/^{238}U age is 559 Ma).
Spot name follows the convention x-y.z; where x = lab number, y = grain number and z = spot number
Uncertainties reported at 1σ, unless otherwise indicated, and are calculated by using SQUID 2.50.11.10.15, rev. 15 Oct 2011

f(206)^{204} refers to mole percent of total ^{206}Pb that is due to common Pb, calculated using the ^{204}Pb-method; common Pb composition used is the surface blank (4/6: 0.05770; 7/6: 0.89500; 8/6: 2.13840)

* refers to radiogenic Pb (corrected for common Pb)
Calibration standard Temora2; Age = 416.8 +/-0.33 Ma (Black et al., 2004)
Error in ^{206}Pb/^{238}U calibration 1.39% (1σ, included)
Standard Error in Standard calibration was 0.37% (1σ, not included in above errors but required when comparing data from different mounts).
Apparent ages shown in bold font are those which were used in the weighted mean age calculations
a: analysis was not included in the age calculation because of high common Pb content (f(206)^{204} > 2%)
bdl : below detection limit

over a period of two years an average Re-Os age of 221.56 ±0.40 Ma (1SD uncertainty, n=10) was obtained. This Re-Os age is identical to that reported by Markey et al. (1998) of 221.0 ±1.0 Ma.

7.3. U-Pb zircon results

Sample 14ZE920A was collected from Prosper Gold diamond-drill hole SH028 at approximately 85 m depth (Ganton, 2014). The sample comprises an interval of mineralized and veined ‘ragged hornblende’ quartz diorite that is locally cut by unmineralized hornblende-feldspar porphyry. The sample yielded abundant clear and colourless, equant to elongate, euhedral prismatic, 50-300 µm zircon crystals with very few clear bubble- or rod-shaped inclusions (Fig. 6). Most grains are needle-shaped with aspect ratios of up to 6:1. Backscatter SEM images of the grains mounted for SHRIMP analysis reveal few internal textures, with the exception of minor inclusions and fractures. Under cathodoluminescence, most grains exhibit c-axis-parallel broadly banded or striped zoning patterns. Distinct oscillatory zoning and faint sector zoning is visible in the more equant and stubby prisms. The central regions of four stubby prismatic grains showed disturbed zoning patterns that may represent earlier zircon growth; however these apparent cores were too small to be analyzed with the ~16 µm ion beam. Uranium content ranged between 99 and 566 ppm and Th/U values were moderate (0.24-0.76). Thirteen grains were analyzed (Table 1); however, two grains were excluded from the age calculation because of elevated common Pb content. Eleven spot analyses on individual grains formed a single population of zircon with a weighted mean $^{206}Pb/^{238}U$ age of 229 ±3 Ma (MSWD=0.44). This age is interpreted to represent the crystallization age of the quartz diorite.

7.4. Re-Os results

Sample MMI14-355-11 was collected from an altered quartz diorite cut by a stockwork of quartz-pyrite-molybdenite ±chalcopyrite-epidote-chlorite veinlets and veins up to ~1.5 cm thick (DDH S040, 89.7-90.3 m; Fig. 5). Molybdenite partings occurred on the margins of cm-thick quartz veins. Molybdenite contained high concentrations of both Re and Os (Table 2). Age uncertainty is quoted at the 2σ level, and includes all known analytical uncertainty, including uncertainty in the decay constant of ^{187}Re. A model age calculated as 227.2 ±1.0 Ma is within error of the U-Pb zircon age of the host intrusion.

8. Discussion

The U-Pb crystallization age (229 ±3 Ma) of the host quartz diorite and Re-Os molybdenite age (227.2 ±1.0 Ma) of mineralization in the Dick Creek zone are coeval within analytical error, supporting previous assertions by Panteleyev (1983) that intrusion and porphyry-style mineralization at the zone are related. Panteleyev (1983) also suggested that the

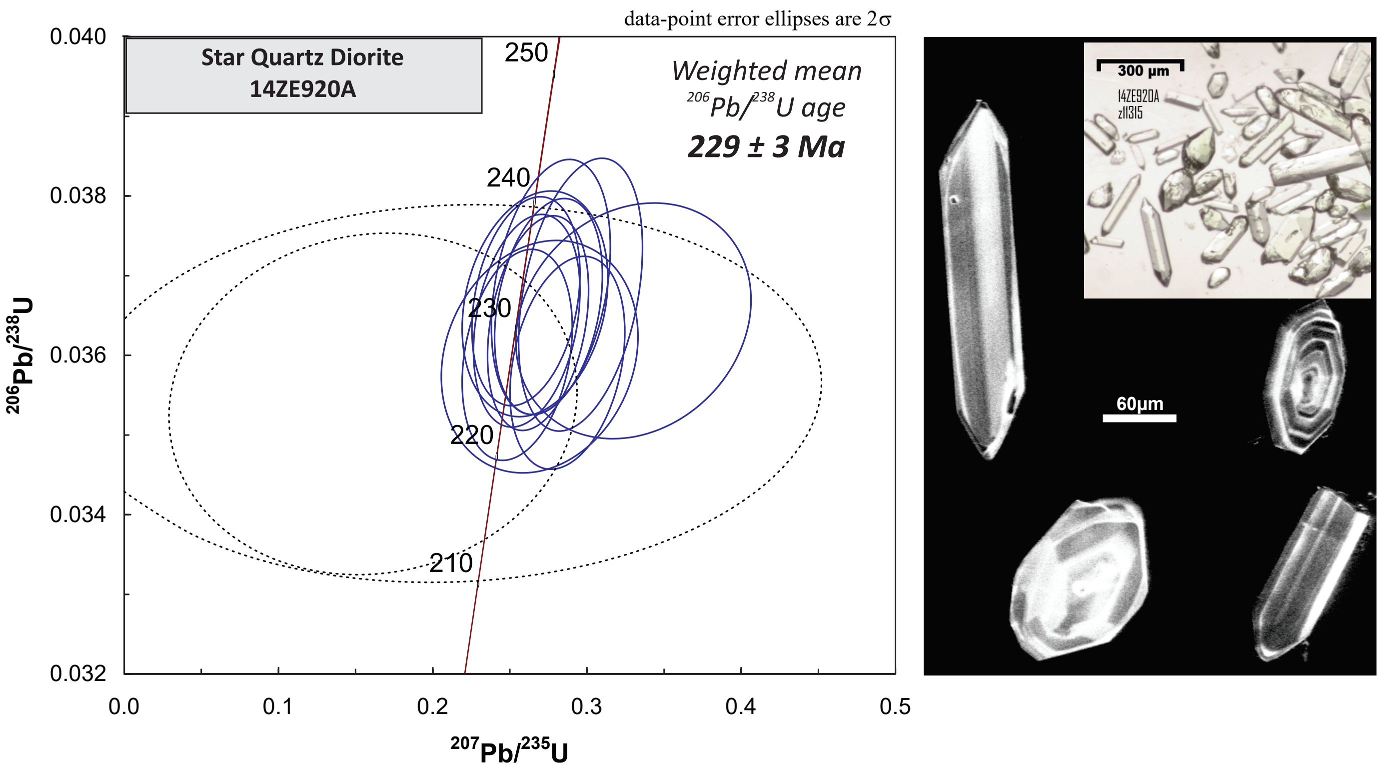

Fig. 6. Concordia plot of 12 zircon grains from sample 14ZE920A. Ellipses are shown with 2σ errors. Their combined age is 229 ±3 Ma. The dotted ellipses are the analyses for grains 49 and 60, which contained elevated common lead and were not included in the age calculations. Right: representative SEM-CL image of 14ZE920A zircons. Inset: photo in transmitted light of 14ZE920A zircons showing clarity, colour, and diverse grain sizes and habits.

Table 2. Re-Os results.

	Re ppm	± 2σ	^{187}Re ppm	± 2σ	^{187}Os ppb	± 2σ	Model age (Ma)	± 2σ (Ma)
MM114-35-11	1665	5	1046	3	3968	4	227.2	1.0

Kaketsa pluton and intrusions at the Star are cogenetic. The new crystallization age at the Star property (229 ±3 Ma) may support this suggestion because it overlaps the preliminary age from the Kaketsa pluton (~226 Ma, Friedman unpublished in Zagorevski et al., 2015) at their limits of error. The new crystallization ages are also older than K-Ar cooling ages of the Kaketsa pluton and satellite intrusions reported in Panteleyev (1976, and recalculated by Breitsprecher and Mortensen, 2004), which were interpreted to date mineralization at Pyrrhotite Creek. If mineralization at Pyrrhotite Creek is related to the small stock that cuts the main Kaketsa pluton, and the stock's relative cooling age (Panteleyev, 1976) is a reliable proxy for the crystallization age, mineralization there may be several m.y. younger than at the Dick Creek zone. Further work to constrain the age of the mineralization at Pyrrhotite Creek will be required to test this supposition.

Mineralization and magmatism at the Star property also overlap the age of magmatism (within the limits of error) at the Eagle property, approximately 17 km to the south (225.45 ±0.31, 227.2 ±0.7 Ma; U-Pb zircon, Takaichi and Johnson, 2012; Takaichi, 2013). Intrusions in the Sheslay area form part of the Stikine plutonic suite (Woodsworth et al., 1992), the emplacement of which is now known to extend from ~229 Ma to 215 Ma (Zagorevski et al., 2014; 2015). Intrusions and mineralization at the Dick Creek zone, Kaketsa Mountain, and Eagle property comprise the oldest phase of Stikine plutonic suite magmatism in the Stuhini arc. These ages demonstrate that birth of the arc occurred significantly before ~229 Ma, perhaps before ~238 Ma as is constrained in Quesnellia by the Nicola arc (Mihalynuk et al., 2015, 2016) and northern Stikinia by the Joe Mountain volcanic rocks in Yukon (Hart, 1997; Piercey, 2004) of Ladinian age (242-235 Ma timescale of Ikeda and Tada, 2014). Inception of porphyry-style mineralization by ~229 Ma suggests requisite crustal thickness of Stuhini arc by that time.

The Star property mineralization is older than the Schaft Creek deposit (222.0 ±0.8 Ma, Re–Os molybdenite, Scott et al., 2008) which was previously thought to be the oldest porphyry deposit in northern Stikinia, and significantly older than the Red Chris and Galore Creek Cu-Au porphyry deposits (~204-210 Ma; Logan and Mihalynuk, 2014).

9. Summary

New geochronological data on the host intrusion and Cu-Mo calc-alkalic porphyry-style mineralization at the Star property (Dick Creek zone) yielded 229 ±3 Ma U-Pb zircon and 227.2 ±1.0 Ma Re-Os molybdenite ages. Affiliation with the mineralized zones surrounding the Kaketsa pluton (~10 km to the west; Panteleyev, 1975), is confirmed with a new U-Pb ziron crystallization age determination from that body of ~226 Ma (Friedman unpublished in Zagorevski et al., 2015). Together with ages from the Eagle Property (Takaichi and Johnson, 2012; Takaichi, 2013), these ages confirm and extend the age range of the Stikine plutonic suite and associated mineralization back to ~229 Ma. Identification of widespread episodic magmatism and mineralization (at ~227, 222, 211, 205 Ma) highlights the need to develop robust regional frameworks that will guide identification of prospective magmatic suites and their trends. Future GEM2 work will acquire additional high quality isotopic ages and will integrate them with geochemical and isotopic studies to identify the characteristics of magmatic episodes during evolution of the Stuhini arc and its mineral deposits.

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