



A Triassic-Jurassic stratigraphic framework for the Golden Triangle, northwestern British Columbia: A project update

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Abstract

This paper provides an interim report on development of a Triassic-Jurassic stratigraphic framework for the Golden Triangle region in northwestern British Columbia. The project is aimed at providing improved constraints on the tectono-magmatic and metallogenic evolution of the region, which hosts numerous Triassic-Jurassic porphyry, epithermal, and VMS deposits. In 2022-2025, stratigraphic field studies were carried out at Red Chris, GJ, Galore Creek, Eskay Creek, Red Mountain, Johnny Mountain, and Bruce Glacier, which complement previously published British Columbia Geological Survey studies in the Galore Creek, Stikine arch, and Kitsault River areas. Further analytical work will include geochronological, paleontological, petrographic, lithochemical, and radiogenic isotope analyses.

Keywords: Stratigraphy, metallogeny, Golden Triangle, Triassic, Jurassic, Stuhini Group, Hazelton Group, exhalite, VMS

1. Introduction

Globally, significant magmatic-hydrothermal mineralizing events are broadly coeval with major tectonic events, commonly coinciding with the start and end of major magmatic cycles (e.g., Richards, 2009; Sillitoe, 2010). Establishing the record preserved in stratigraphic units is key for constraining the tectono-magmatic evolution of such metallotects. The British Columbia Geological Survey is continuing a multi-year project to establish a stratigraphic framework for Triassic to Jurassic strata in the 'Golden Triangle', which hosts broadly coeval porphyry, epithermal, and VMS systems (Figs. 1, 2). This work, on the traditional lands of the Tahltan Nation, Gitanyow Hereditary Chiefs, Metlakatla First Nation, Tsetsaut Skii Km Lax Ha, and Nisga'a Nation, complements ongoing investigations to establish the framework of plutonic rocks in the region (Bailey et al., 2025; Campbell and van Straaten, 2025; Campbell et al., 2026). Through detailed field studies of representative stratigraphic sections and magmatic-hydrothermal mineral deposits, supported by geochronological, paleontological, petrographic, lithochemical, and radiogenic isotope analyses, the project will provide improved constraints on the tectono-magmatic and metallogenic evolution of the region. It will shed light on major erosional events, the duration of major volcano-magmatic pulses, the timing of mineralization, the nature of pre-, syn-, and post-mineral strata, and regional prospectivity for magmatic-hydrothermal mineral systems. The project builds on previously reported fieldwork carried out in the Galore Creek area (van Straaten et al., 2023; Johnston, 2025), Stikine arch (van Straaten, 2024), and Kitsault River area (Miller et al., 2025a, 2025b; Fig. 2).

2. Geological setting

The Golden Triangle is a loosely defined region in northwestern British Columbia that includes numerous porphyry, epithermal, and VMS mineral deposits (Fig. 2). It is in Stikine terrane (Stikinia), which comprises a series of Paleozoic to Mesozoic arc-related successions and allied plutonic rocks. Most of the mineral systems in the Golden Triangle are Late Triassic to Middle Jurassic and are broadly coeval with three unconformity-bounded volcano-sedimentary successions: the Stuhini Group (Upper Triassic), lower Hazelton Group (uppermost Triassic to Lower Jurassic), and upper Hazelton Group (Lower to Middle Jurassic; Fig. 3).

The main axis of Late Triassic magmatism in Stikinia is defined by thick accumulations of predominantly mafic volcanic strata of the Stuhini Group and accompanying ca. 229-216 Ma Stikine plutonic suite intrusions. These volcanic and intrusive units extend for at least 1300 km along the eastern margin and northern part of Stikinia and have been interpreted to have formed as an east-facing magmatic arc (Nelson and van Straaten, 2020; van Straaten et al., 2023). Stuhini arc activity terminated in latest Triassic by a collision between northern Stikinia and the Yukon-Tanana terrane. This collision is expressed by deformation, localized small-volume alkalic magmatism, and a regional-scale unconformity between the Stuhini and Hazelton groups (Nelson et al., 2018, 2022; van Straaten et al., 2023). The lower Hazelton Group includes local basal conglomerate and sandstone of the Jack Formation and its correlatives (Rhaetian to Hettangian), succeeded by widespread intermediate and rare felsic volcanic rocks of the Betty Creek Formation (Rhaetian to Pliensbachian; Nelson et al., 2018). The Tatogga and

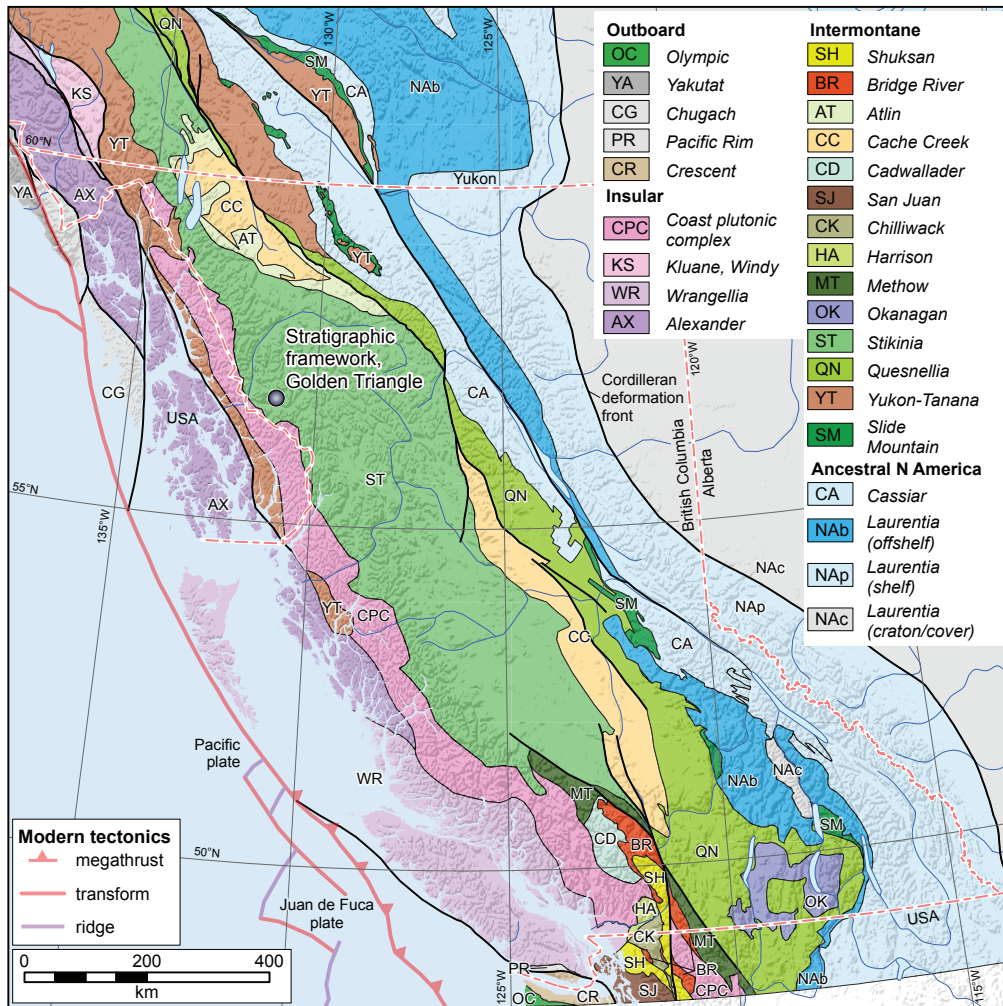


Fig. 1. Location of study area in Stikine terrane. Modified from Colpron (2020).

Texas Creek plutonic suites (latest Triassic to Early Jurassic) are coeval and comagmatic with lower Hazelton Group volcanic units and are responsible for the formation of numerous porphyry Cu-Au and epithermal Au-Ag deposits (Nelson and van Straaten, 2020). The upper Hazelton Group in the Golden Triangle comprises sedimentary rocks of the Spatsizi and Quock formations (Gagnon et al., 2012), local rift-related bimodal volcanic and sedimentary rocks of the Iskut River Formation that host the Eskay Creek VMS deposit (Nelson et al., 2018), and arc-like volcanic rocks (e.g., Kitsault unit and Horn Mountain Formation; van Straaten et al., 2022b; van Straaten, 2024; Miller et al., 2025a). Accretion of Stikinia to inboard terranes and the Ancestral North American margin is recorded by deposition of Bowser Lake Group siliciclastic rocks (Middle Jurassic to mid-Cretaceous) in a foreland basin atop Stikinia (Evenchick et al., 2007). Bowser Lake Group and older rocks are deformed by Cretaceous Skeena fold-and-thrust belt deformation, linked to continued convergence between accreted terranes and Ancestral North America (Evenchick et al., 2007).

3. Field stratigraphic studies

Development and refinement of Stuhini Group and Hazelton Group stratigraphy has guided field studies at the Red Chris porphyry Cu-Au mine, GJ porphyry Cu-Au deposit, Galore Creek porphyry Cu-Au deposit, Eskay Creek VMS Au-Ag deposit, past-producing Johnny Mountain gold mine, Red Mountain Au-Ag deposit, Treaty Creek porphyry Au-Cu deposit, VMS prospects near the Bruce Glacier, and the past-producing Scottie gold mine (Fig. 2). Work was largely carried out in 2022-2025, complemented by earlier work completed in 2015-2017. At each location studied, structural studies were used to reconstruct stratigraphic superposition, with unit thicknesses calculated by measuring the distance perpendicular to strike between stations and correcting for bedding dip, elevation change, and the presence of folds. Stratigraphic sections were constructed from detailed lithostratigraphic descriptions, the relationship between stratigraphy and mineralization was investigated, and samples were collected for further analytical studies.

Two examples illustrate the importance of detailed field observations and strategic sampling for constructing composite

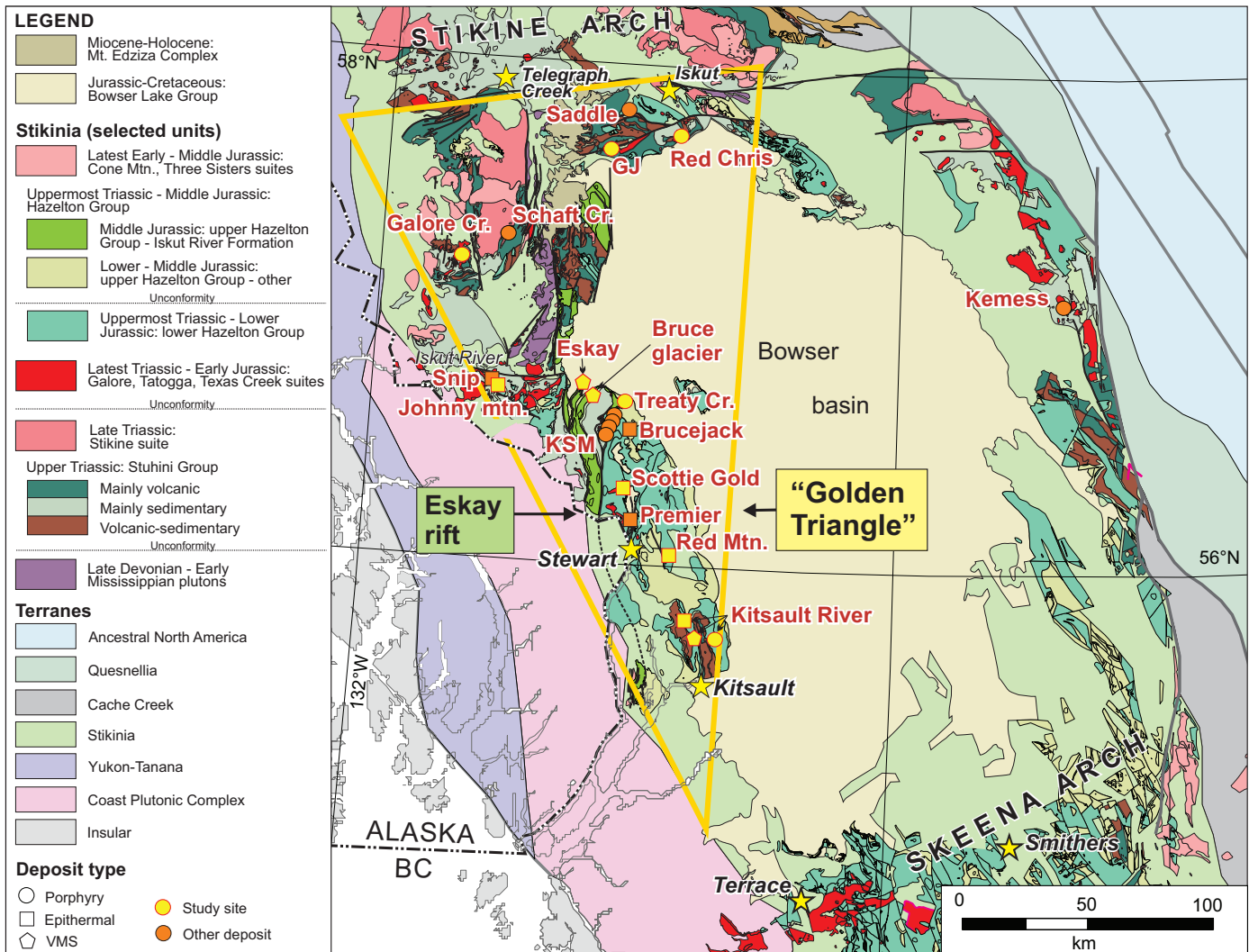


Fig. 2. Simplified geological map with Late Triassic to Middle Jurassic stratified rocks and intrusions of northwestern British Columbia. The Golden Triangle hosts numerous porphyry, epithermal, and volcanogenic massive sulphide deposits. After Nelson and van Straaten (2020).

stratigraphic columns. Near the toe of the Jack Glacier (~3.5 km east-northeast of the Bruce Glacier; Fig. 2) we studied a well-exposed angular unconformity (Fig. 4a) between sedimentary rocks of the Stuhini Group (Upper Triassic) and overlying sedimentary rocks of the Jack Formation (part of the lower Hazelton Group, Lower Jurassic) as previously documented by Henderson et al. (1992). The Stuhini Group includes laminated to thinly bedded black mudstone, siltstone, and grey to orange fine-grained to rare medium-grained sandstone arranged in sharp-based fining-upward sequences (Fig. 4b). A rare very thick bed of very coarse-grained sandstone to granule conglomerate with ~10% quartz grains was sampled for U-Pb detrital zircon geochronology. The overlying Jack Formation includes interbedded siltstone, black mudstone, lime mudstone to wackestone, sandstone with ~10% quartz grains, and minor pebble conglomerate with stratified mud/siltstone, volcanic, and chert clasts. A lime mudstone bed was sampled for microfossil processing. Sampling was aimed at better constraining

the timing of deformation. Although the unconformity is widespread throughout the region (e.g., Nelson et al., 2018), detailed studies on the time span contained within the hiatus are limited. The unconformity marks the end of Stuhini Group arc volcanism, collision between Stikine and Yukon-Tanana terranes, and the onset of Hazelton Group, Tatogga plutonic suite, and Texas Creek plutonic suite magmatism which coincides with prolific porphyry- and epithermal-style mineralization in the region.

At Treaty Creek, strongly quartz-clay (advanced) argillic altered rocks interpreted as part of the Betty Creek Formation (lower Hazelton Group, uppermost Triassic to Lower Jurassic) are unconformably overlain by sedimentary rocks of the Spatsizi Formation (upper Hazelton Group, Lower to Middle Jurassic) and succeeded by bimodal volcanic rocks of the Iskut River Formation (upper Hazelton Group; Fig. 5). The upper Hazelton Group represents a post-mineral succession that partially covers a north-northeasterly trend of lithocap-style

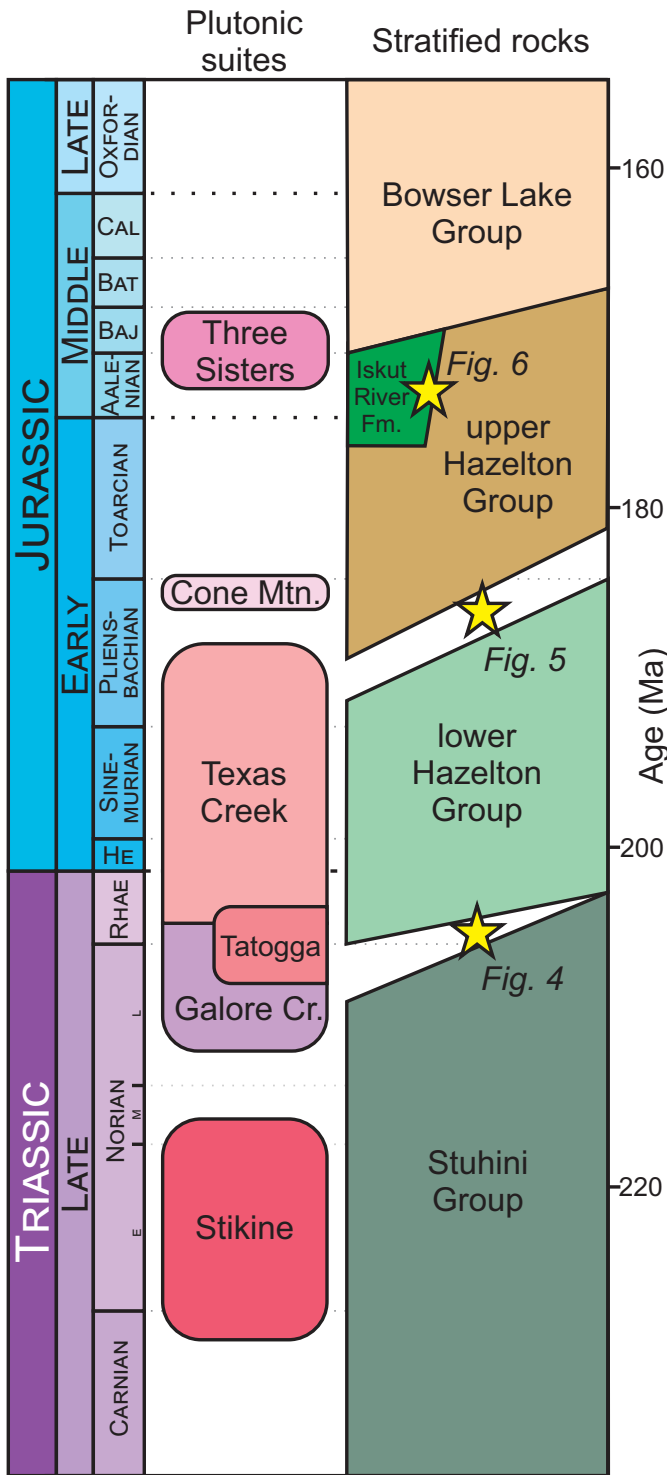


Fig. 3. Schematic Mesozoic stratigraphic and intrusive framework of the Golden Triangle. Approximate stratigraphic position of Figures 4, 5, and 6 shown for reference. Geological timescale after Cohen et al. (2025), Norian substages after Ogg et al. (2020). Modified after van Straaten (2024).

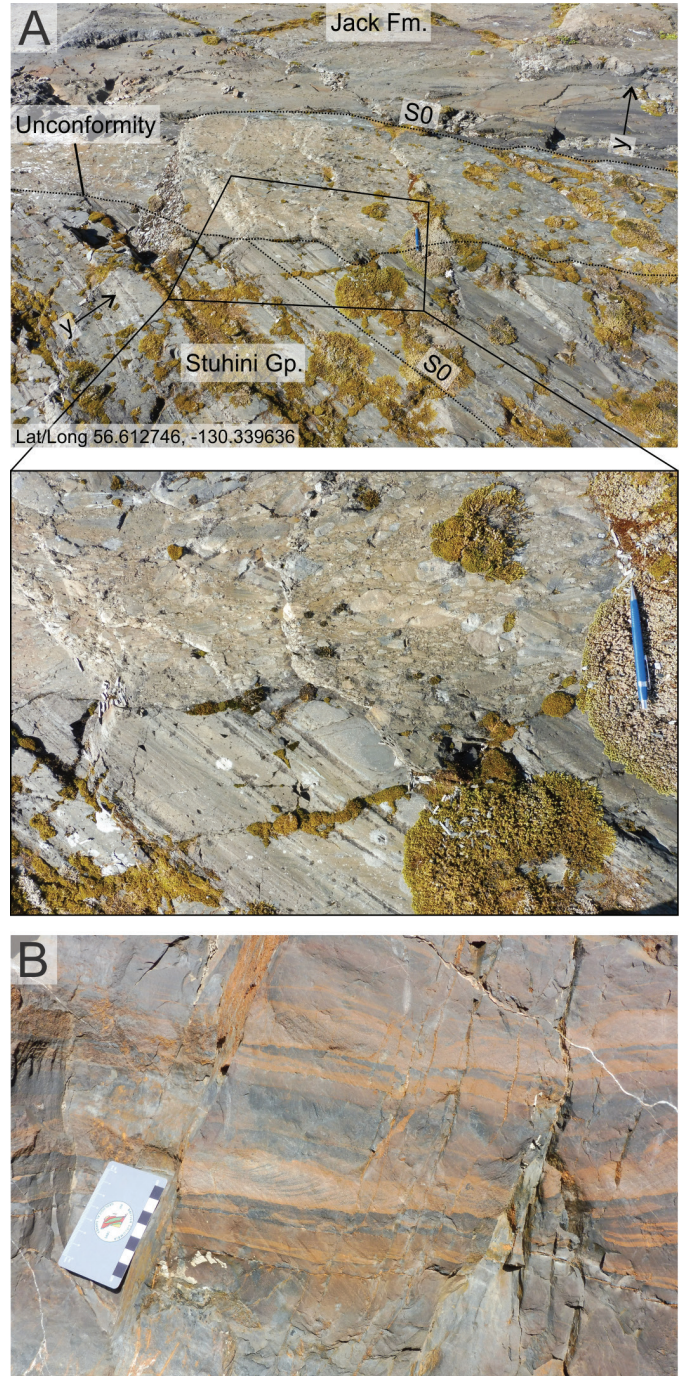


Fig. 4. a) Angular unconformity between Stuhini Group sedimentary rocks (Upper Triassic) and Jack Formation of the lower Hazelton Group (uppermost Triassic to Lower Jurassic) near the toe of the Jack Glacier (east of the Bruce Glacier). View towards the west. *y*=younging direction. **b)** Stuhini Group sedimentary unit with sharp-based sandstone (with small-scale cross-stratification) to mudstone fining upward sequences. Latitude/longitude here and elsewhere in this paper in WGS84 Web Mercator Auxiliary Sphere (EPSG 3857).

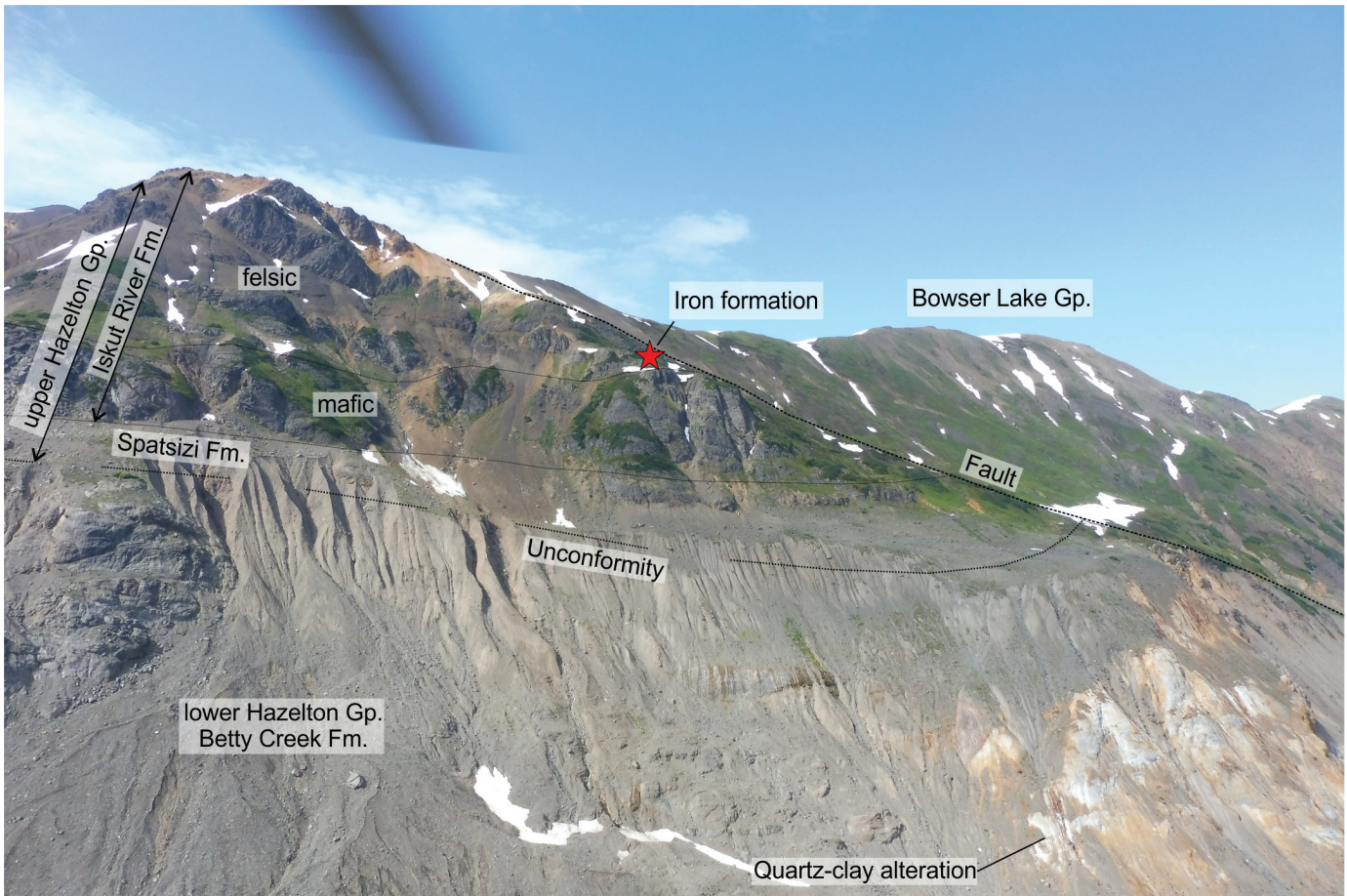


Fig. 5. Unconformity between strong quartz-clay lithocap-style alteration of the Orpiment showing (MINFILE 104B 590) in the Betty Creek Formation of the lower Hazelton Group (Lower Jurassic) and Spatsizi Formation sedimentary rocks succeeded by Iskut River Formation mafic and felsic volcanic rocks (both upper Hazelton Group, Lower to Middle Jurassic) at Treaty Creek. View towards the north.

alteration developed in lower Hazelton Group rocks that extends for at least 6 km from the Treaty Gossan (MINFILE 104B 078) to the Orpiment showing (MINFILE 104B 590) above Treaty camp. The lithocap may represent the dismembered upper portion of the nearby Goldstorm porphyry Cu-Au-Ag deposit (MINFILE 104B 704), or the upper expression of a previously unrecognized porphyry system.

The overlying upper Hazelton Group includes a lower sedimentary unit (Spatsizi Formation), overlain by a mafic volcanic succession, and succeeded by an upper felsic volcanic succession (Fig. 5; both volcanic successions part of the Iskut River Formation). The sedimentary unit includes interbedded mudstone, siltstone, sandstone, pebbly sandstone, and lesser reworked felsic lapilli-tuff to tuff and reworked mafic lapilli-tuff. Locally, fine-grained siliciclastic sedimentary strata contain ammonoid and shell fossils. The overlying mafic volcanic succession includes mafic tuff breccia containing amygdaloidal aphyric volcanic clasts. It is overlain by an upper succession of felsic lapilli-tuff, felsic crystal tuff, felsic lapillistone, lesser volcanic siltstone, mudstone, siltstone, volcanic sandstone, felsic tuff breccia, and a rare, disrupted limestone bed; clasts include white to medium grey

to green-grey aphanitic to rarely flow-banded felsic volcanic clasts, and locally subordinate limestone clasts. The upper succession is locally cut by aphanitic felsic subvolcanic intrusions. Ammonoids and rare limestone indicate that the bimodal succession was emplaced in a submarine environment. Field studies in 2025 documented a new mineral occurrence ('Red brick', MINFILE 104B 768) comprising a bed of iron formation (~0.8 m thick) intercalated with fragmental felsic volcanic to reworked felsic volcanic rocks (Figs. 5, 6a). Transmitted and reflected light microscopy show that the iron formation consists of hematite, minor magnetite, trace pyrite, and irregular blebs and veinlets of prehnite(?) and quartz (Fig. 6b). Newly acquired lithogeochemical data from the iron formation show high Fe and low Ti, Mn, and Al concentrations (Table 1; Fig. 7), and supports classification as an Algoma-type iron formation precipitated from venting of hydrothermal fluids such as in a submarine volcanic arc, back arc, spreading ridge, or rift (see Peter, 2003; Piercey, 2005). Lithogeochemistry data show moderately enriched Sb and As concentrations (Table 1), with values greater than ten times average upper continental crustal abundance (Rudnick and Gao, 2014). Its geochemical signature is similar to VMS-associated iron formations

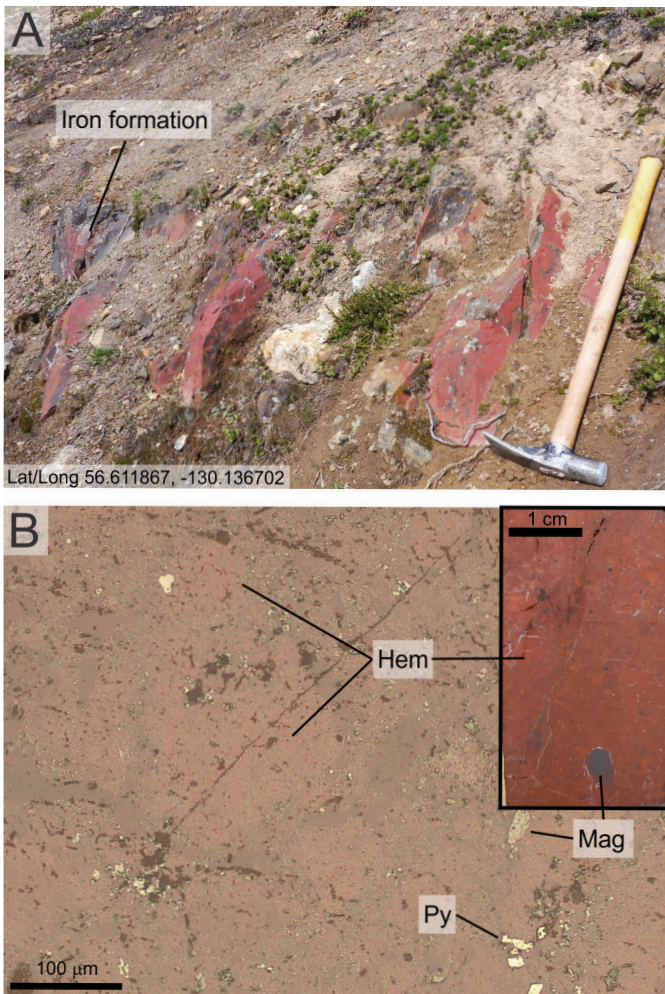


Fig. 6. a) Outcrop of iron formation bed at the new ‘Red brick’ occurrence near Treaty Creek. b) Reflected light microscope photograph of iron formation with hematite (Hem), minor magnetite (Mag), and rare pyrite (Py); inset shows thin section outcut.

globally and suggests potential for the broader area to host VMS mineralization. In known VMS camps such as Bathurst (New Brunswick, Canada), iron formation extends laterally from massive sulphide mineralization for distances up to 12 km (Peter, 2003 and references therein). Further interpretation of the stratigraphy using lithochemical and geochronological data is aimed at better understanding prospectivity for VMS mineralization.

Conclusion

As part of an ongoing project examining the Triassic-Jurassic stratigraphy and metallogeny of the Golden Triangle, new

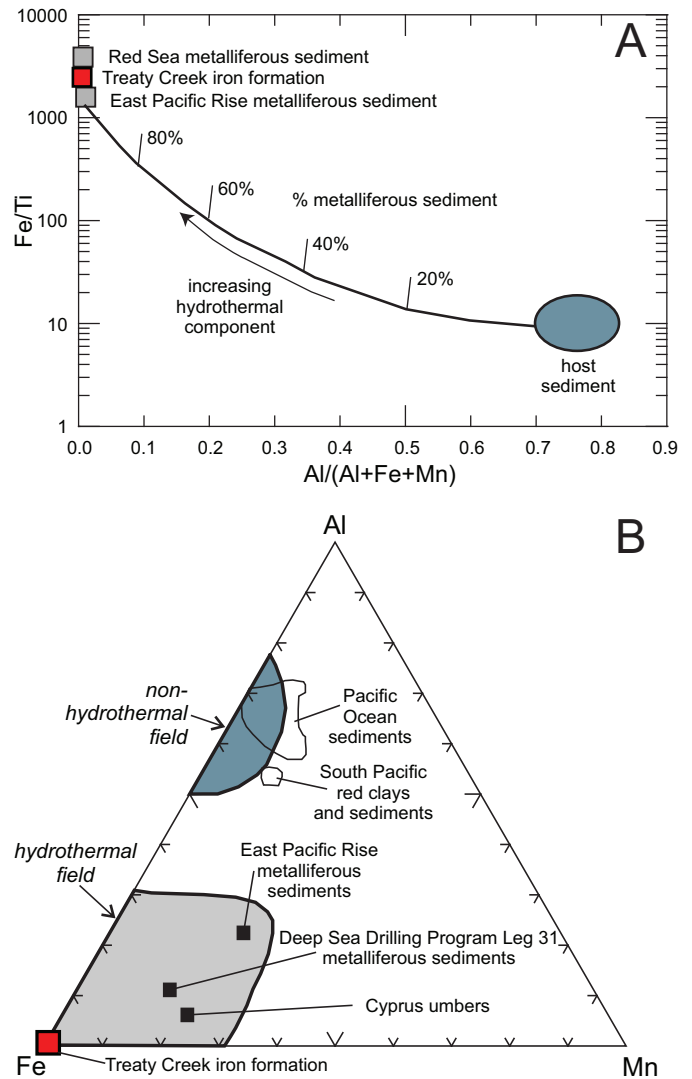


Fig. 7. Geochemistry of iron formation at the new ‘Red brick’ occurrence near Treaty Creek. a) Al/(Al+Fe+Mn) vs. Fe/Ti plot and b) Al-Fe-Mn ternary diagram showing that the iron formation has a composition similar to modern seafloor hydrothermal vent sediments. Figures modified from Peter (2003) and Piercey (2005).

stratigraphic field studies have been carried out at Red Chris, GJ, Galore Creek, Eskay Creek, Red Mountain, Johnny Mountain, and Bruce Glacier and will refine the tectono-magmatic and metallogenic evolution of the region. Further analytical work will include geochronological, paleontological, petrographic, lithochemical, and radiogenic isotope analyses. Geochronological studies will include U-Pb LA-ICP-MS and high-precision CA-TIMS detrital and igneous zircon analyses. Lithochemical analyses of igneous rocks will expand an existing dataset of fusion and four acid digestion data with ultra-low minimum detection limits (van Straaten et al., 2022a; Van der Vlugt et al., 2022).

Table 1. Lithogeochemical data for iron formation at the new ‘Red brick’ occurrence near Treaty Creek. The sample was coarse crushed at the BCGS laboratory in Victoria, followed by pulverization in a mild steel mill at ALS Global, and analyses at ALS Global using lithium borate fusion, four acid, and aqua regia digestion methods. Sample 25BvS-113a (geochem ID 67803); lat/long 56.611867, -130.136702.

%	Fusion	Four acid	Aqua regia	ppm	Fusion	Four acid	Aqua regia
Si	36.2			Hf	<0.05	0.04	
Al	0.08	0.08		Hg			0.008
Fe	15.1	15.15		Ho	0.11	0.112	
Ca	0.39	0.38		In	<0.05	<0.005	<0.005
Mg	0.012	0.01		La	1.7	1.625	
Na	0.015	0.017		Li		0.8	
K	0.017	0.01		Lu	0.06	0.061	
Cr	0.003	0.0041		Mo	4	3.88	
Ti	0.006	0.004		Nb	0.16	0.134	
Mn	0.046	0.0467		Nd	1.3	1.235	
P	0.14	0.141		Ni	5	1.23	
Sr	<0.008	0.0016		Pb	<5	1	
Ba	0.009	0.0048		Pd		<0.002	
LOI	0.6			Pr	0.27	0.265	
Total	100.77			Pt		<0.004	
C	0.05			Rb	0.3	0.31	
S	0.01	0.01		Re		<0.0004	<0.001
ppm	Fusion	Four acid	Aqua regia	Sb		22.9	17.75
Ag	<1	0.006		Sc	<0.5	0.22	
As		74.9	81.4	Se		0.016	<0.2
Au		0.0013		Sm	0.37	0.302	
B		30		Sn	<0.5	0.07	
Be	7	8.52		Ta	<0.1	0.005	
Bi		0.003	<0.01	Tb	0.07	0.066	
Cd		0.145		Te		<0.005	<0.01
Ce	1.6	1.64		Th	0.05	0.048	
Co	0.5	0.425		Tl	0.08	0.016	0.02
Cs	0.76	0.56		Tm	0.07	0.053	
Cu	<5	3		U	1	0.944	
Dy	0.58	0.493		V	249	244	
Er	0.44	0.351		W	11.4	12.25	
Eu	0.09	0.079		Y	7.4	6.59	
Ga	0.2	0.31		Yb	0.32	0.368	
Gd	0.59	0.446		Zn	19	18	
Ge	6.3	<0.05		Zr	2	1.5	

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