Preliminary results from revision mapping of the Gladys Lake area, near Atlin, northwest British Columbia

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Recommended citation: Mihalynuk, M.G., Zagorevski, A., Campbell, R., Hajiegeh, A., and Vaillancourt, A., 2024. Preliminary results from revision mapping of the Gladys Lake area, near Atlin, northwest British Columbia. In: Geological Fieldwork 2023, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey Paper 2024-01, pp. 131-148.

Abstract

Geological mapping and sampling immediately south of the Yukon border, in the Gladys Lake area near Atlin, updates mapping of 1950s vintage that predates concepts derived from plate tectonics. Much of the area is underlain by deformed chert, primitive arc basalt, and slivers of mantle peridotite; all are extensively intruded by Jurassic and Cretaceous plutons. This study further documents the newly defined ophiolitic Atlin terrane, its obduction onto the Cache Creek terrane, and overlap of chert and siliciclastic deposits. Oceanic crustal sections in the map area record evidence of having formed during ocean floor detachment. Mineralized hemipelagic strata deposited atop mantle peridotite exposed by seafloor detachment contain Ag, Zn, Pb, Cu sulphides. These strata may be distal precipitates of hydrothermal plumes from ultramafic-associated seabed massive sulphide fields formed atop exposed, cooling mantle. Atlin terrane detachments have been identified along strike of the map area for more than 400 km, representing a significant untested mineral exploration opportunity.

Keywords: Atlin terrane, Cache Creek terrane, ophiolite, harzburgite, seafloor detachment, ultramafic associated massive sulphide, battery metals, molybdenite, Three Sisters suite, Surprise Lake suite, Gladys Lake, Fourth of July Creek, placer gold

1. Introduction

Western North America consists of crustal blocks (terranes) that originated along and outboard (west) of the Ancestral North America (Fig. 1). Accretion and translation of these crustal blocks along the margin since the Jurassic has resulted in formation of the mountainous Cordillera. Tectonic setting, paleo-environment, and subsequent geologic events that shaped these terranes are primary determinants of the types of mineral deposits contained within them and likelihood of their preservation. Correct terrane definition is, therefore, a critical first step in mineral potential evaluation and exploration strategy in the Cordillera. Recent re-evaluation of the formerly undifferentiated Cache Creek terrane in the Atlin area of northwest British Columbia (Zagorevski et al., 2015, 2016, 2021) revealed that it is composite, and comprises two separate terranes. Ophiolitic rocks that were previously included in Cache Creek terrane are now included in Atlin terrane (Figs. 2-4). A classic ophiolite section represents ocean crust from its mantle peridotite underpinnings, through ultramafic cumulate, gabbro, sheeted dikes, pillow basalt and pelagic sediment blanket (Anonymous, 1972; herein referred to as 'Penrose-style'). However, well-developed sheeted dike complexes or extensive sections of pillow basalts, the distinctive magmatic components at the subseafloor to seafloor interface of a normal spreading ridge, are missing in ophiolite sections preserved near Atlin. Instead, the Atlin ophiolites are like those formed by asymmetric slow spreading systems that lead to detachment faulting and development of oceanic core complexes (Escartin et al., 2017, and citations therein), with basalt and sediments deposited directly atop mantle.

Tracking the Atlin terrane through areas last systematically mapped in the 1950s (Aitken, 1959), before plate tectonics was recognized and the tectonic significance of ophiolites and subduction melanges was realized, is a challenge. Such areas include a ~85 km long and ~30 km wide, mostly forested transect between Taku and Teslin lakes, bordered to the north by Yukon (NTS sheets 104N/14, 15, 16; ~2400 km^2; Fig. 3). This report presents preliminary findings from the first of two planned field seasons of geological mapping and sampling along the transect, in the traditional territories of the Taku River Tlingit First Nation, Carcross/Tagish First Nation, and Teslin Tlingit Council. This mapping is part of the joint Federal-Provincial project begun in 2023 in the Gladys Lake area (NTS 104N/15, and adjacent 14E, 16W; Fig. 3). In this area, rocks of the Atlin and Cache Creek terranes are extensively intruded by Jurassic and Cretaceous plutons, which host the past producing polymetallic Atlin-Ruffner mine (MINFILE 104N 011) and the Adanac molybdenum deposit (MINFILE 104N 052) immediately south of the transect area. Herein we describe the regional geological setting of previously unrecognized mineralization in fine-grained rocks deposited above Atlin terrane mantle peridotite. Such mineralization may

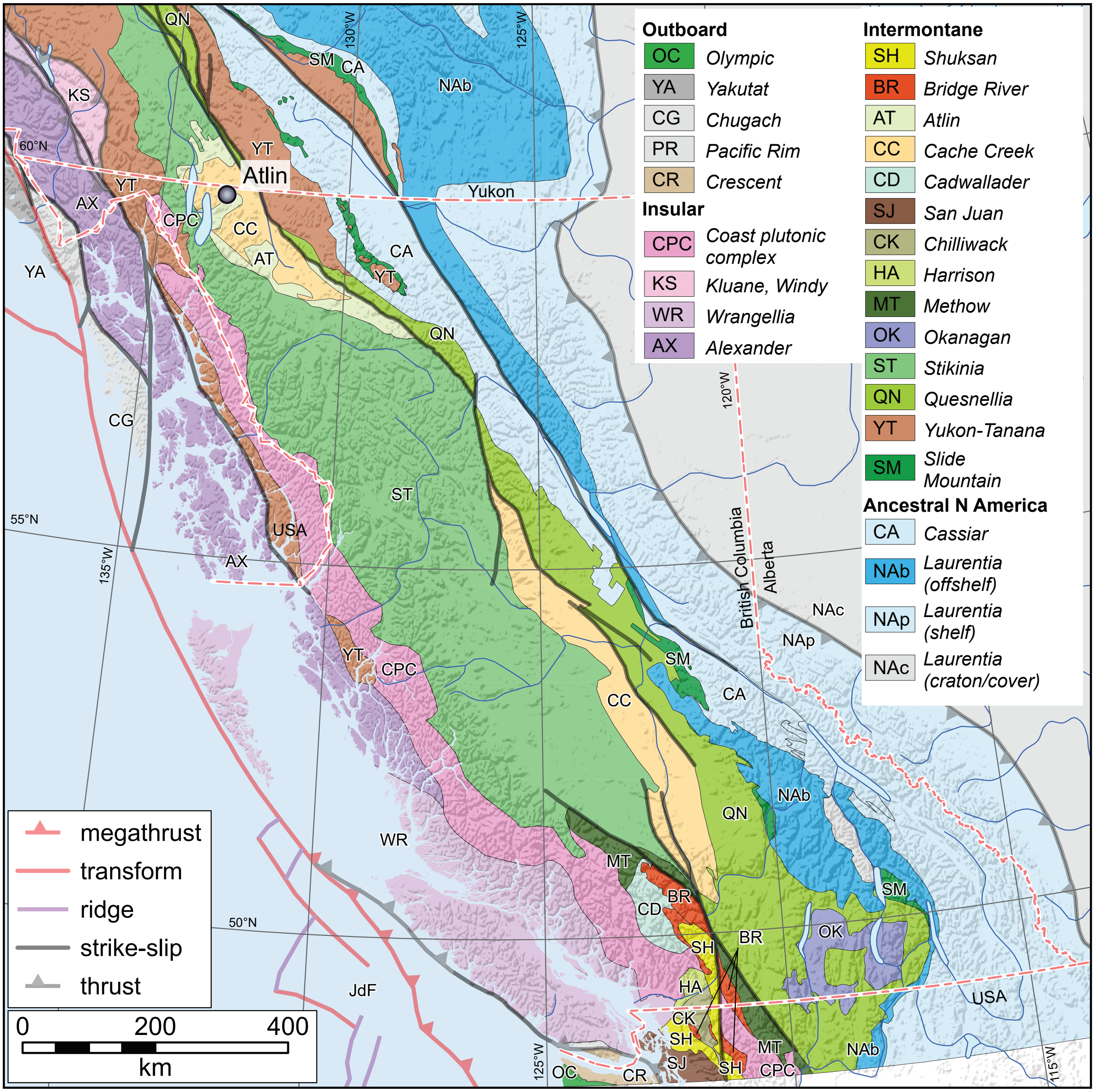

Fig. 1. Location of Gladys Lake-Atlin study area. Terranes after Colpron (2020) and Zagorevski et al. (2021).

represent an example of distal ultramafic-associated massive sulphide (UAMS) accumulations in submarine hydrothermal vent fields at sea-floor detachment faults.

2. Physiography and access

Our mapping crosses Atlin Lake and the paved Atlin Road, which follows the east shore, linking the Alaska Highway with the community of Atlin. A well-maintained gravel road extends from Atlin Road up Fourth of July Creek to MacDonald lakes (Fig. 2). Access to the areas farther northeast is limited to mineral exploration and placer mining roads that reach to Marble Dome area, south of Gladys Lake. However, lack of road maintenance has rendered portions of the road unpassable by 4x4 pickup east of Consolation Creek (Fig. 3), limiting access to the 30 km-long Gladys Lake which would otherwise provide boat-based access across the east-central part of the transect. Boat access to the south-central part of the transect area can be gained from the northern tip of the 25-km long Surprise Lake, which is reached by gravel road from Atlin.

Much of the area is covered by well-drained glacial outflow

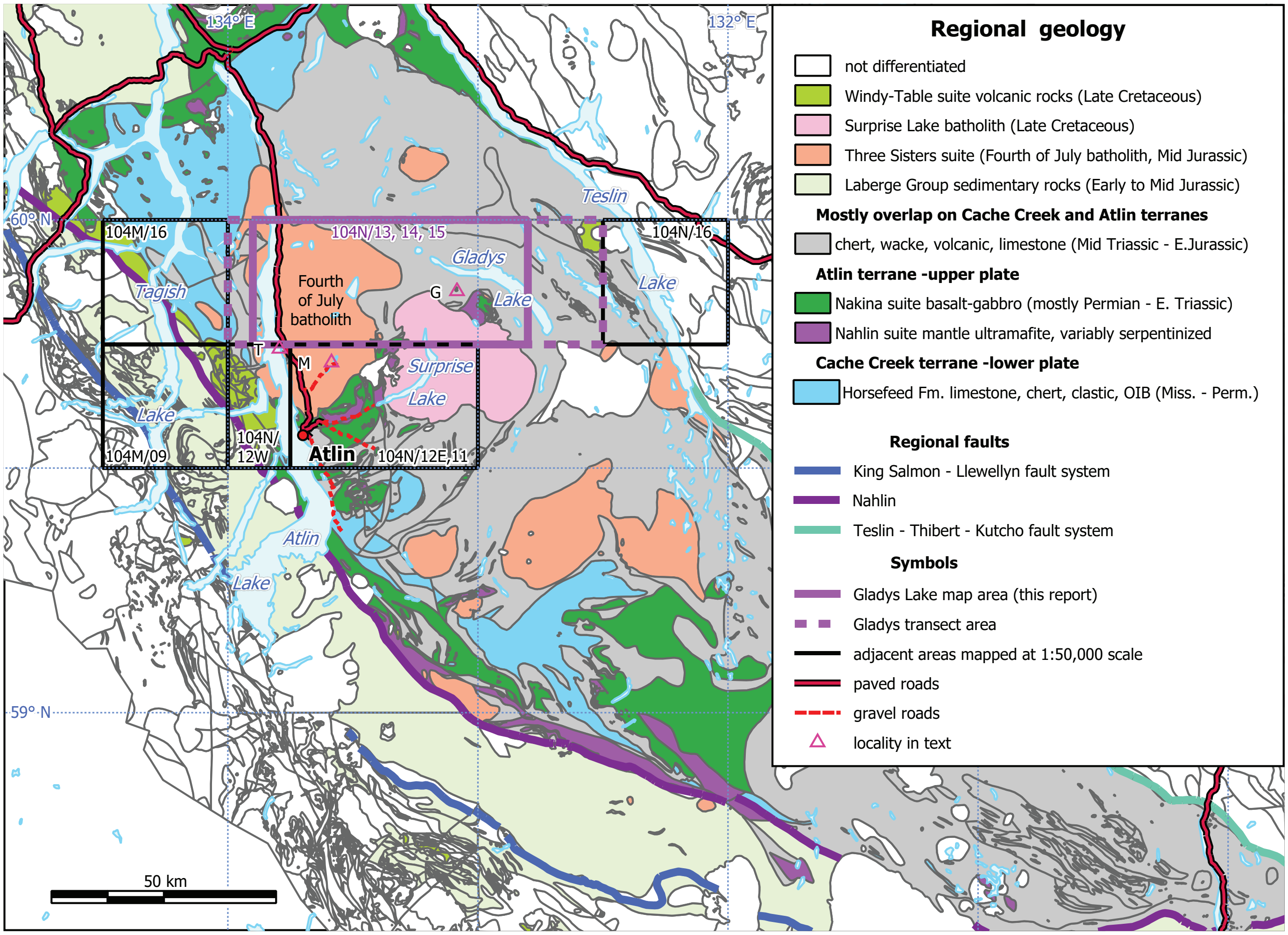

Fig. 2. Generalized geologic setting of the northern Cache Creek and Atlin terranes. Locality symbols: G, Gladys Lake property porphyry; M, McDonald lakes; T, Telegraph Bay.

terraces and open pine forest that can crossed by long single, or multi-day foot traverses. However, the most efficient mode of travel is by helicopter based in Atlin. Most other areas are covered by extensive forest and brushy swamps requiring foot traverses between sparse helicopter landing sites. Less than 15% of the area is above tree line and many of the alpine areas marked on NTS topographic maps are extensively overgrown by dwarf birch and willow.

Due to its location on the lee side of the Coast Mountains, the Gladys Lake area is part of an orographic dry belt that receives only moderate winter snow and lacks glaciers. The highest points are Mount Carter (1784 m), Mount Hitchcock (1792 m), the northeast ridge (2049 m) of Mount Barham and an unnamed peak south of Marble Dome (2008 m).

3. Previous work

Systematic geologic surveys of the area began around 1900 (Gwillim, 1901). Quadrangle mapping in the 1950s by Aitken (1959) covered the area at 1:250,000 scale as part of the Atlin map (NTS 104N). More detailed surveys at 1:50,000 scale envelop the transect area in British Columbia, except south of Gladys Lake (Fig. 2). From west to east, they are: Mihalynuk et al. (2018, 2022, Turtle Lake); Mihalynuk et al. (1990, Fantail Lake east); Mihalynuk and Smith (1992a, b, Mihalynuk et al., 1999, Atlin west); Bloodgood et al. (1989, Atlin east and Surprise Lake west); Mihalynuk et al. (2001, Dawson Peaks east). In many areas, but particularly near Atlin, these maps have benefitted from detailed industry mapping on, and around, mineral claims recorded in Assessment Reports and in Minister of Mines Annual reports (Annual Report to the Minister, 1874-2005).

Discovery of placer gold east of Atlin in 1898 (Robertson, 1899) drove mineral exploration in the area, especially for bedrock gold sources. To date, no economic bedrock gold resource found has sustained production. Most lode discoveries have been identified beneath known placer pay gravels, in varied bedrock, but mainly altered ultramafic or quartz-veined argillaceous rocks (e.g. Mihalynuk et al., 2017). Placer mineralogy also indicates multiple gold sources (Sack et al., 2004; Barkov et al., 2008; Mihalynuk et al., 2011), although the Surprise Lake batholith (Windy Table suite) may be the progenitor of most placer gold in the Atlin area (Zagorevski et al., 2017).

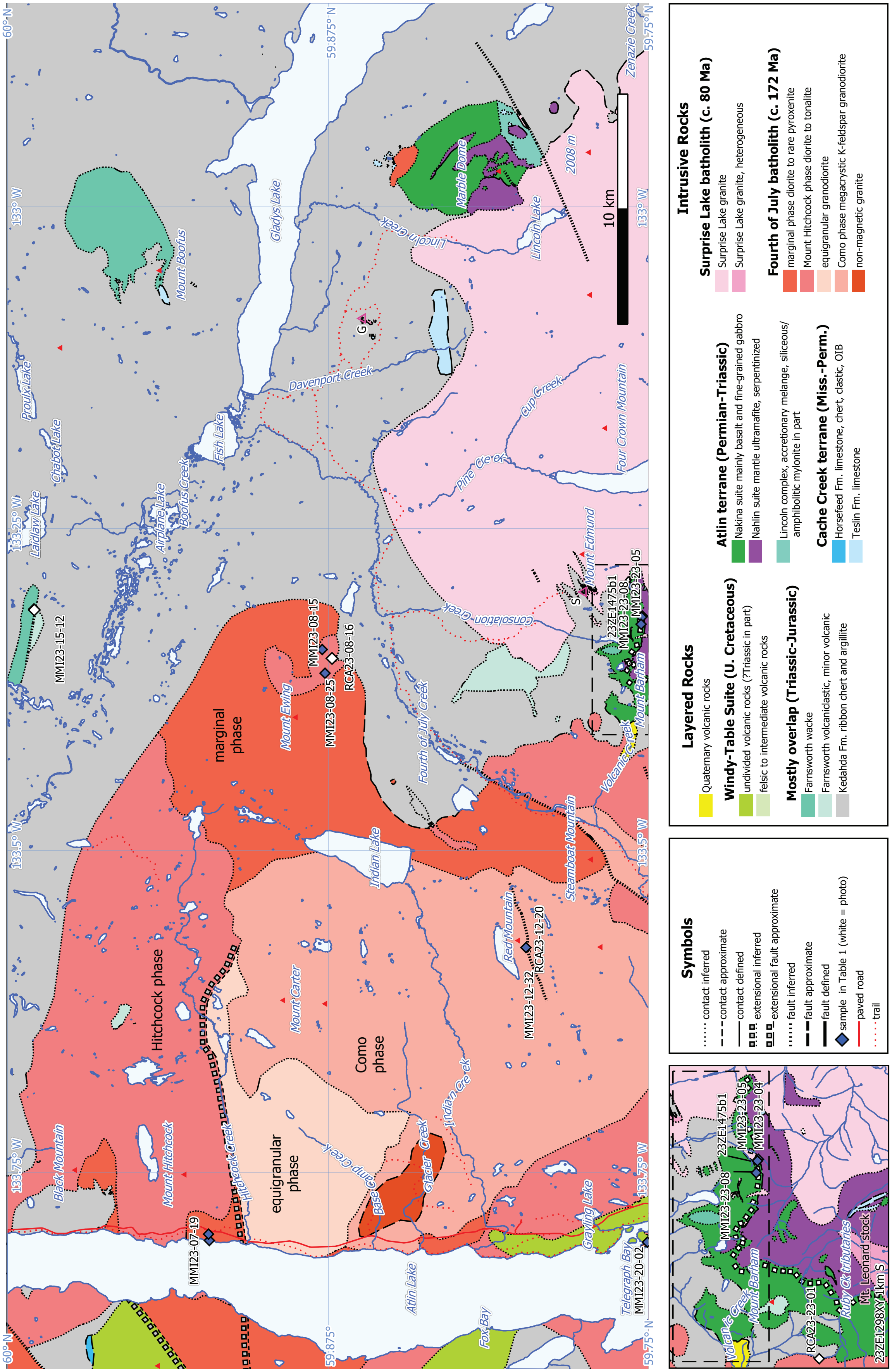

Fig. 3. Simplified geology of the Gladys Lake area.

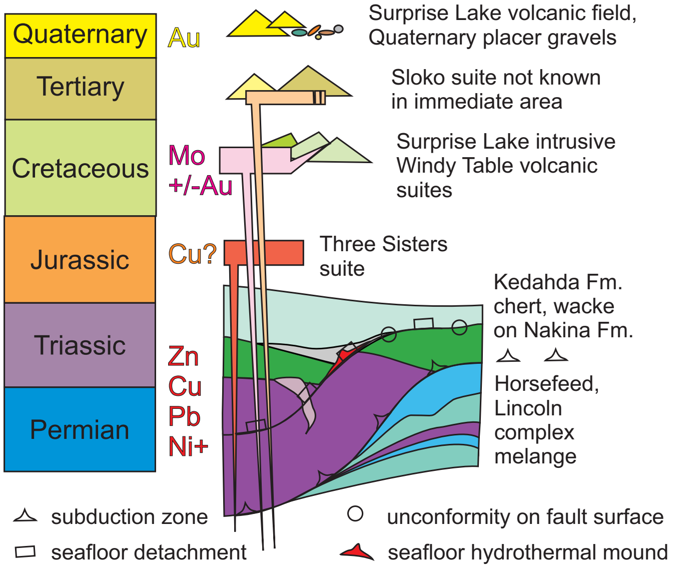

Fig. 4. Cartoon of tectonostratigraphic and metallogenic relations in the Gladys Lake area. Unit colours as in Figure 3.

4. Local geology

The map area is principally underlain by three layered successions (Figs. 3, 4). The oldest succession consists of Carboniferous to Late Permian marine strata of Cache Creek terrane. The terrane was formerly presumed to include widespread ribbon chert and minor Triassic limestone that are now largely included in 'probable overlap' units (see below). Middle Permian to Middle Triassic ophiolitic units (mantle peridotite and ultramafic cumulates of the Nahlin suite, and gabbro, diabase, and basalt of the Nakina suite) previously considered basement to Cache Creek terrane, were recognized by Zagorevski et al. (2021) as part of Atlin terrane. Probable Middle Triassic to Early Jurassic overlap units consist of chert (Kedahda Formation), siliciclastic rocks (Farnsworth wacke) and minor limestone. The siliciclastic rocks contain detritus from older units, as well as coarse pyroxene-phyric (±hornblende) pyroclastic rocks inferred to be sourced from volcanic arc rocks in Stikine and/or Quesnel terranes. These three successions are extensively cut by the Fourth of July batholith (Middle Jurassic; Mihalynuk et al., 2004, 2018 and citations therein) and rocks of the Surprise Lake batholith (Late Cretaceous; Zagorevski et al., 2017 and citations therein) which underlie most of the western and south-central parts of the area mapped in 2023.

Local units include a swarm of feldspar porphyritic dikes and stocks that cut deformed rocks of the Fourth of July batholith and thermally metamorphose ribbon chert along Atlin Lake at Telegraph Bay and epiclastic strata and flow-banded rhyolite that are tentatively correlated with the Windy Table suite (Mihalynuk et al., 1999; Late Cretaceous, ca. 83 Ma; Zagorevski et al., 2017). Cinder cones and discontinuous ash layers of the Surprise Lake volcanic field are preserved at the headwater of Volcanic Creek. They are inferred to be post glacial.

4.1. Quaternary deposits

4.1.1. Surprise Lake volcanic field

The Surprise Lake volcanic field includes two ~150-200 m wide, partially eroded, nested scoria cones in the upper Volcanic Creek drainage (Fig. 3). It is considered part of the Northern Cordilleran Volcanic Province, which extends from northern British Columbia into Yukon (Edwards et al., 2003). Scoria consists of black to red (oxidized) poorly consolidated to unconsolidated lapilli-to ash-sized pyroclasts, and rare bomb-sized blocks. A 1 m to 10 m-thick grey basaltic flow at least 2 km long is recorded near the modern Volcanic Creek channel, enclosed within red-weathering tephra (Edwards et al., 1996). Olivine phenocrysts and xenocrysts can be found within the dense flows and clasts. Major element geochemical analyses of these volcanic rocks show them to be trachybasalt (Edwards and Bye, 2003).

The age of the Volcanic Creek centre remains uncertain. Preservation of the semi-consolidated cinder cones on a glacial valley bottom suggests that they were constructed following the exposure of the valley after the last regional glacial maximum (ca. 10,000 BCE; Clague, 1992). Drilling through the base of the Volcanic Creek flows intersected weathered bedrock below 1.5 to 4 m of reddish to light-toned partially oxidised gravels with boulder and pebble sized clasts including basalt and cinder fragments (Mioduszewska, 1980; Hainsworth, 1997). This gravel unit has produced placer gold (MINFILE 104N 024) and is similar to the 'Miocene gravel'. which is considered the source of much historic gold production such as in the Ruby Creek drainage, immediately south of the study area (Fig. 3, inset). In Ruby Creek, lava flows covering placer gravels are dated at 0.54 ±0.02 Ma (whole rock K-Ar cooling age; Hunt and Roddick, 1992), and most likely predate the Volcanic Creek field.

4.1.2. Miocene-Early Quaternary gravels

Most of the economic placer gold gravels in the Atlin area were deposited prior to Late Wisconsin continental glaciation (e.g., Aitken, 1959; Proudlock and Proudlock, 1976; Levson, 1992), which reached its northwestern limit about 23-24 ka BP and was in full recession by 14 ka BP (Dyke et al., 2002). Late Wisconsin glaciation was responsible for extensive glacial erosion and the blanketing of large parts of the map area with till deposits (e.g., Tallman, 1975), and other glaciogenic sediments locally more than 45 m thick (Aitken, 1959), and up to elevations of 1500 m (Tallman, 1975).

Most of the productive placer paleochannels contain weakly consolidated, ochre-stained gravels resting on bedrock. These gravels are commonly cobble to pebble clast supported, and directly overlie bedrock (e.g., Levson, 1992; Levson, and Blyth, 1993). They are locally referred to as 'Miocene gravel' or pre-glacial 'yellow gravel' (e.g., Black, 1953) and are blanketed by extensive grey-weathering glacial till deposits (Aitken, 1959).

The age of productive placer gravels is constrained in the Ruby Creek drainage where they are overlain by the late Pleistocene (ca. 0.5 Ma) Ruby Creek volcanic flows (see above).

Local basalt clasts, potential pillow lavas, and other primary volcanic products within the upper auriferous placer gravels (Levson and Blyth, 1993) suggest that volcanism was broadly contemporaneous with placer gravel sedimentation. Levson and Blyth (2001) obtained a radiocarbon date of >41,180 BP from charcoal in one part of the upper placer gravels in Ruby Creek.

Preservation of placer deposits is in part related to paleogeography, where valleys that were oblique to Wisconsinan ice flow were not eroded, especially those protected by thick glacial deposits or Quaternary volcanic flows (Levson and Blyth, 1993; 2001). Previous placer exploration and production work has focused on the creeks between Atlin and the southern end of Surprise Lake (e.g., Proudlock and Proudlock, 1976; Levson, 1992), but placer deposits are found in most drainages underlain by the Surprise Lake batholith (Sack and Mihalynuk, 2004) suggesting a genetic relationship. As early as the mid-1900s it was widely held that the possibility of discovering pre-glacial placer gravels, other than continuations of known deposits, was slight (Black, 1953). However, recent shoreline erosion at the northern end of Surprise Lake has exposed a 2-3 m section of semi-lithified, oxidised, red weathering gravel with several pebble to cobble, clast supported layers, overlain by grey-weathering till. There are no recorded placer showings (in MINFILE) or past exploration work (in ARIS) at the site, and the gravels remain untested.

4.2. Late Cretaceous magmatic rocks

Late Cretaceous igneous rocks in the area include the Surprise Lake plutonic suite (Woodsworth et al., 1992) and volcanic and minor coeval intrusive rocks of the Windy Table suite (Mihalynuk et al., 1999).

4.2.1. Surprise Lake plutonic suite

The Surprise Lake batholith is extensively exposed southwest of Gladys Lake and underlies approximately 10% of the map area. White-weathering monzogranite typical of the suite can be distinguished by intensely smoky quartz (grey-brown to almost black), low mafic content (represented by biotite, ~5%), minor muscovite, chalky plagioclase, and generally non-magnetic character; interstitial fluorite is local. Roof rocks and miarolitic cavities (Aitken, 1959), as well as syn-magmatic high-level hydrothermal vein complexes (Ballantyne and Littlejohn, 1982) are commonly preserved. This suggests that the batholith was emplaced at shallow depth and has experienced limited unroofing.

The plutonic suite is texturally variable with gradational to sharp contacts between different textural phases (Aitken, 1959). Most textural variation can be assigned to one of three phases: 1) medium- to coarse-grained weakly porphyritic to equigranular hypidiomorphic monzogranite (volumetrically predominant); 2) potassium feldspar megacrystic monzogranite with 5 to 40%, 2-3 cm phenocrysts; and 3) texturally variable, fine- to medium-grained aplitic to porphyritic. The suite includes nested intrusions such as the Mount Leonard stock, containing the Ruby Creek Mo deposit (Fig. 2; Ballantyne and Littlejohn, 1982; Smith and Arehart, 2009) and satellite intrusions such as the Gladys Lake body ('G' on Fig. 3). The Mount Leonard stock preserves successive intrusions with an early coarse equigranular phase, cut by the megacrystic and porphyritic phases, followed by post-silicification (post-mineralisation?) finer grained aplitic phases (Smith, 2009; Smith and Arehart, 2009).

Parts of the Gladys Lake body are porphyritic with a fine-grained matrix cut by multiple generations of quartz veins. Veining can be intense, forming quartz domains across tens of square m. In many areas, early generations of mm-scale, contorted, verticulate, quartz vein arrays within a porphyritic aplite are crosscut by later 'planar' cm-scale quartz veins (±disseminated white mica). These early veins were likely emplaced during incomplete crystallization of a fluid-rich magma and are like 'brain rock' or unidirectional solidification texture (Fig. 5; Shannon et al., 1982; Müller et al., 2023).

Fig. 5. Dark grey verticulate quartz veins ('brain rock') and smoky, almost black, quartz eyes in a fine-grained, aplitic matrix is the high-level, porphyritic part of the Gladys Lake body (Surprise Lake intrusive suite). Traces of molybdenite have been found in some of these veins.

Magnetic susceptibility of Surprise Lake batholith rocks is low (0.01 to 0.07 x 10^{-3} SI (Campbell et al., 2024) consistent with their regional aeromagnetic signature (Lowe and Anderson, 2002). Exceptions include a series of northwest-trending magnetic structures (Lowe and Anderson, 2002) spatially coincident with magnetite-sphalerite vein occurrences of uncertain age (which appear to crosscut fluorite veins; Ballantyne and Littlejohn, 1982), and phases associated with molybdenum mineralization at the Mount Leonard Stock (1 to 1.58 x 10^{-3} SI), and at the north end of Surprise Lake (1.5 to 2.5 x 10^{-3} SI).

Geochemical analyses of the Surprise Lake plutonic suite indicate a highly fractionated, alkalic and peraluminous character (Zagorevski et al., 2017) with strong Cs, Rb, Pb, Th, and U enrichments. The suite plots in ‘within plate granite’ (Pearce et al., 1984), and anorogenic granite fields (A-type granite; Loiselle and Wones, 1979; Collins et al., 1982; Whalen et al., 1987). U-Pb crystallization ages from the Surprise Lake plutonic suite indicate emplacement between 83 to 78 Ma (Mihalynuk et al., 1992; Smith and Arehart, 2009; Zagorevski et al., 2017). Re/Os age determinations from molybdenite yield significantly younger ages, to ca. 70 Ma (Smith and Arehart, 2009).

4.2.2. Windy Table suite

Rocks tentatively correlated with the Windy Table suite include andesitic to rhyolitic volcanic and hypabyssal units underlying only the southwest-most corner of the 2023 study area (Figs. 2, 3) where they were identified by Aitken (1959) as “Undifferentiated, mainly volcanic rocks of uncertain, possibly several, ages.” They are an extension of volcanic strata more recently mapped to the south and west (Mihalynuk et al., 1992, 2022; Zagorevski et al., 2017). Four map units are identified in the southwest part of the map area: andesitic hypabyssal intrusions that cut lithologically similar lapilli tuff; augite-phyric tuffite, and rare flow-banded rhyolite.

4.2.2.1. Andesitic hypabyssal intrusions and tuff

Grey-green homogeneous porphyritic lapilli to block tuff contains fine- to medium-grained hornblende (15 %) and tabular feldspar (15%). It is cut by similar and presumably comagmatic hypabyssal intrusions rocks that are cut by compositionally similar, but finer grained and dark grey-green dikes.

4.2.2.2. Augite porphyry

Dark green augite porphyritic lapilli tuff and well-bedded, possibly waterlain and reworked ash tuff is found on both sides of Atlin Lake near the southern margin of the map area. Augite is medium to coarse-grained (20-25%) in an aphanitic, dark green groundmass (Fig. 6). This unit is visually similar to the Stuhini Group (Late Triassic) augite porphyry unit found in adjacent map areas and in epiclastic layers and clasts in the Farnsworth formation (see below). Samples of the epiclastic unit were collected for detrital zircon extraction to help evaluate the possibility of a Late Triassic correlation.


Fig. 6. Augite porphyry at Telegraph Bay mapped as Windy Table suite (Cretaceous) but could be correlative with similar but older units in adjacent Stikine terrane (Triassic?).

4.2.2.3. Rhyolite

Yellow to rust, flow-banded rocks of presumed rhyodacite composition form a single set of shoreline outcrops at the southern edge of the map area. They are cut by the andesitic hypabyssal intrusions. Similar aphyric, flow-banded rhyolite west of Atlin Lake contains zircons that yielded a U-Pb age of 85.0 ±1.6 Ma (Zagorevski et al., 2017).

4.2.3. Three Sisters suite, including Fourth of July batholith (~166-174 Ma)

The Three Sisters plutonic suite (Woodsworth et al., 1992) intrudes the Cache Creek and Atlin terranes in northern British Columbia and southern Yukon (Mihalynuk et al., 2004). In the Atlin area, this suite is represented by the Fourth of July batholith, which underlies most of the western half of the study area. Aitken (1959) broadly distinguished the Black Mountain and Fourth of July Creek phases in the Fourth of July batholith. Remapping of the Fourth of July batholith indicates that it can be regionally subdivided based on mineralogic and magnetic properties into a predominantly K-feldspar porphyritic monzogranite, equigranular magnetic and non-magnetic granodiorite, and quartz diorite generally restricted to near the margins of the batholith. Late aplite and lamprophyre dikes are locally common.

A characteristic feature of all but the most leucocratic phases of the Three Sisters suite intrusions near Atlin is pyroxene-cored hornblende crystals (Aitken, 1959; Mihalynuk et al., 1999, 2018). Petrographic analysis (Fig. 7) shows that transformation of clinopyroxene to more hydrous hornblende and biotite, results in excess titanium and growth of rutile (TiO_2). Also attributed to this hydration is the local introduction of chalcopyrite seen intergrown with hornblende (Fig. 8).

Three Sisters suite intrusions locally display igneous foliation but generally lack tectonic fabrics. Regional relationships suggest that the Three Sisters suite postdates much of the deformation in the area (e.g., Mihalynuk et al., 2004). This is supported by our mapping where foliated and folded Cache Creek and Atlin terrane rocks are intruded by the Fourth of July batholith. The Three Sisters suite yields Middle Jurassic crystallization ages in the Atlin region (ca. 174-172 Ma; summarized in Mihalynuk et al., 2004).

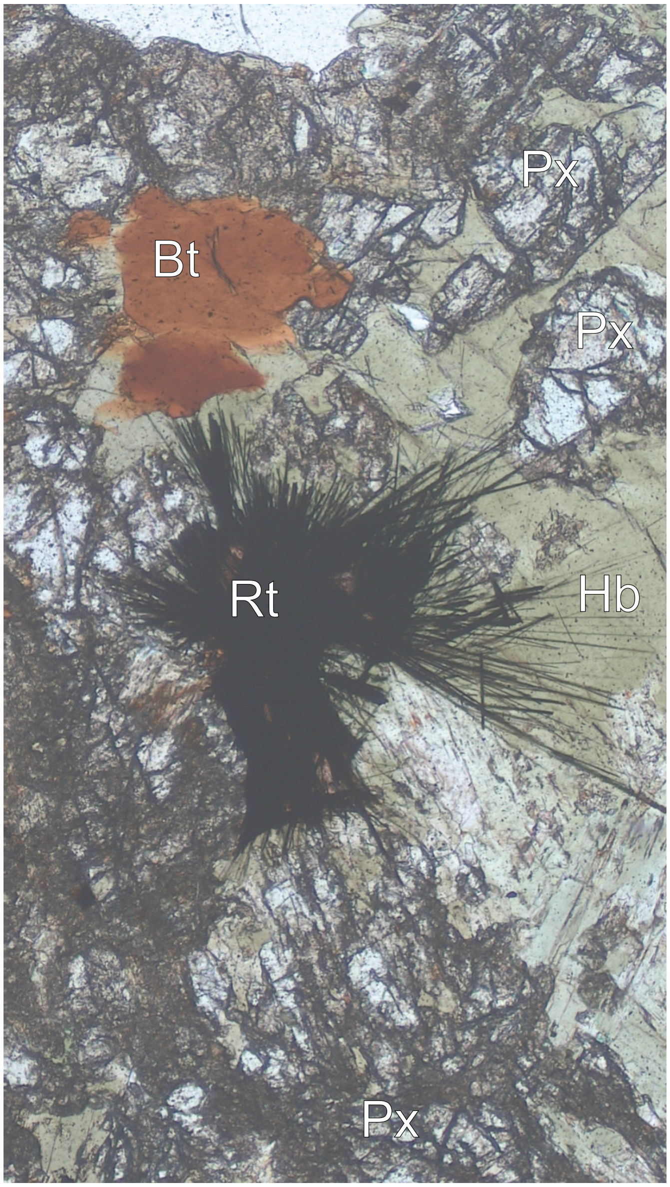

Fig. 7. Paragenetic sequence typical of the Fourth of July intrusions in plane polarized light: titanaugite (Px) replaced by hornblende (Hb), followed by biotite (Bt). Excess titanium from breakdown of titanaugite results in formation of rutile (Rt) sprays. Long dimension of photomicrograph represents 1.9 mm (Sample RCA23-08-16).

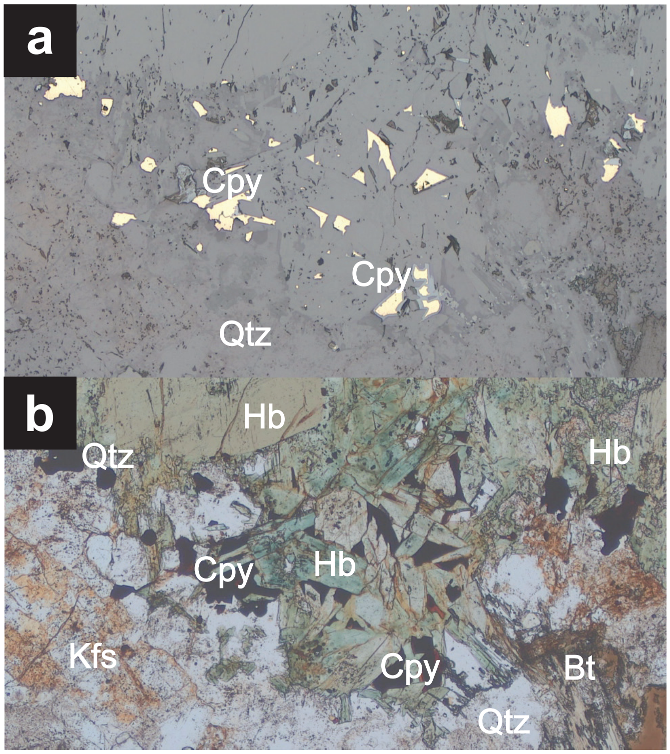

Fig. 8. A rare example of hypogene copper mineralization in a Fourth of July intrusion (marginal phase) is shown in **a)** reflected and **b)** plane polarized light. Chalcopyrite (Cpy) is interstitial to bladed hornblende (Hb), probably introduced with fluid causing hydration of pyroxene and replacement by hornblende and biotite (Bt). Orthoclase (Kfs) is hematite stained (red dusting). Long dimension of photomicrograph represents 1.9 mm (sample RCA23-23-01, see Figure 3 for location).

4.2.4. Como Lake phase

The Como Lake phase is widely distributed in the southwestern part of the study area. It is characterized by abundant, pink orthoclase megacrystic monzogranite (Fig. 9). Orthoclase megacrysts typically comprise 25% of the unit (10-40%) and locally display growth zones outlined by concentrations of fine biotite, hornblende, and/or quartz. Interstitial medium to coarse K-feldspar occurs with quartz (average ~30%), plagioclase (average ~30%), hornblende and biotite (5-10% combined mafic minerals, 1:3 to 3:1 ratios). Trace titanite and fine-grained dusting of magnetite are typical. The Como Lake phase commonly contains rounded enclaves (<0.1 up to 1 m) comprising up to 1% to rarely 3% of the outcrop. These generally have sharp boundaries and lack any clear reaction rims suggesting that they represent cogenetic magmas. Generally, enclaves appear to be more mafic, or at least finer grained with more evenly distributed mafic minerals than the much coarser

Fig. 9. Typical appearance of the K-feldspar megacrystic Como phase of the Fourth of July batholith (hammer for scale).

host phase. However, many enclaves lack appreciable quartz, suggesting more monzodioritic compositions. Some enclaves are characterized by sparse orthoclase megacrysts suggesting that they are cognate magmas.

The Como Lake phase is well-exposed in accessible roadcuts east of Como Lake (17 km south of the study area, near Atlin). These exposures are representative of this phase and would make a suitable type locality.

4.2.5. Mount Hitchcock phase

The Mount Hitchcock phase is texturally variable with gradational to sharp contacts of constituent rock types, mostly grey to beige, fine- to medium-grained diorite to quartz diorite and tonalite. Aitken (1959) referred to these rocks as the 'Black Mountain body'. Because the intrusion at Black Mountain contains screens of country rock including chert, peridotite, and basalt, we consider it part of the marginal phase of the Fourth of July batholith (see below). Mount Hitchcock and its slopes expose rocks typical of the phase and, easily accessed along Atlin Road, would be good type localities.

Mafic minerals include brown biotite and medium- to coarse-grained green-black sparse pyroxene, or pyroxene-cored hornblende. Biotite may in part be secondary. Trace titanite is common. Plagioclase can form zoned laths with quartz which selectively replaces some zones. In part due to magnetite intergrowths in hornblende, the Mount Hitchcock phase is moderately to strongly magnetic.

4.2.6. Equigranular granodiorite

The equigranular granodiorite phase is medium- to coarse-grained and locally weakly porphyritic. It is generally tawny to grey weathering and is commonly cut by fine-grained 1 to 15 cm- thick pink granite and aplite dikes. Typical composition is 20-30% zoned K-feldspar, 25-30% interstitial quartz, 40-50% plagioclase, 10% mafic minerals with hornblende subequal to three times as abundant as biotite. Both hornblende and biotite display some degree of chloritization. The equigranular phase is well-exposed along the western shore of Atlin Lake, south of Hitchcock Creek, a good type locality.

4.2.7. Marginal phases

Marginal phases of the Fourth of July batholith are compositionally diverse. They include white to dark grey weathering, generally medium- to coarse-grained diorite to tonalite, and locally dark grey-green pyroxenite. Mafic minerals (15-30%) are typically clinopyroxene (probably titanaugite based on distinctive pleochroism) rimmed by amphibole, and biotite (although generally minor, biotite may locally be four times more abundant than hornblende). Mafic minerals commonly show some degree of alteration to chlorite and epidote. Outermost marginal phases are generally non-magnetic with magnetism increasing toward the core of the batholith.

Marginal phase mafic end member compositions are represented by pyroxenite that forms the lowest exposures west of southern Steamboat Mountain. Heterogeneity is well demonstrated east of Telegraph Bay where nonmagnetic, medium- to coarse- grained, diorite and tonalite grade into more homogeneous magnetic diorite. Intrusive contacts between country rocks and the marginal phase are exposed southwest of Black Mountain (on the mountain slopes, along the lakeshore, and along Atlin Road), which would be a suitable type locality.

4.2.8. Lamprophyre dikes

Lamprophyre dikes, decimetres to a few metres wide, are common in the western Gladys Lake area. Contact relations with the Three Sisters suite intrusive rocks west of Atlin Lake suggest that at least some lamprophyre dikes are late comagmatic phases, confirmed by cooling ages of 165.9 ±1.1 Ma and 174 ±2.7 Ma (Mihalynuk et al., 2018). These ages overlap the range of cooling ages from dikes near Atlin Lake that are reported by Harris et al. (2003) as 165.3 ±1.6 Ma and 161.8 ±1.6 Ma (see discussion in Mihalynuk et al., 2018).

4.3. Middle Triassic to Lower Jurassic overlap units

4.3.1. Kedahda Formation

The Kedahda Formation is widespread within the Gladys Lake transect where it comprises chert, argillite, and wacke. Common rusty appearance on weathered surfaces is due to widespread pyrite that constitutes up to several percent, especially near intrusions. Chert displays a broad variation in colour (black, grey, green, beige, white, yellow, rust), bed thickness and continuity, and proportion of interbedded siliciclastic rocks. Chert beds are commonly parallel-sided and discontinuous, but range through lozenge shaped to bulbous. Chert can be massive to thinly (2-5 cm) bedded 'ribbon' chert. Argillite interbeds vary from a mere partings to being the predominant lithology in outcrop. Radiolaria are commonly conspicuous and are locally visible to the unaided eye. Preservation of radiolaria varies over short distances. They can be abundant in one bed and completely absent in an adjacent bed or portions of the same bed.

Previous workers have attempted to subdivide the Kedahda Formation based on the proportion of chert and argillite. In the Gladys Lake transect, areas such as Davenport Creek are underlain mostly by argillite with minor chert and wacke, whereas parts of Mount Boofus are almost entirely chert. Argillite is typically black, rusty weathering, pyritic and graphitic. Strain is commonly partitioned into the argillite, and it is almost everywhere finely cleaved, recessive, and is under-represented by bedrock exposures. As a result, it has been included with the Kedahda chert unit (Fig. 3). Nearly parallel bedding and cleavage and isoclinal fold hinges show that these rocks are at least locally intensely folded.

Chert and siliciclastic rocks in the Atlin area have been traditionally included in the Kedahda Formation (Watson and Mathews, 1944; Gabrielse, 1969; Monger, 1975). Prior to the development of radiolaria biochronology, the age of the Kedahda Formation was considered to be mainly Paleozoic on the basis of apparent intercalation with limestone beds and limestone pods containing Paleozoic fusulinids (Monger, 1975). Although Paleozoic radiolaria have been recovered from some chert localities, most radiolaria in the Kedahda Formation chert yield Middle Triassic to Early Jurassic ages (Cordey et al., 1991; Mihalynuk et al., 2003; Cordey, 2020). Fetid limestone beds intercalated with chert and argillite have yielded Late Triassic conodonts (Cordey et al., 1991). The preponderance of Mesozoic fossils and apparent unconformable relationship with the Paleozoic rocks led Zagorevski et al. (2021) to revise the age of the Kedahda Formation to Middle Triassic to Early Jurassic. Paleozoic chert localities are associated with the Atlin terrane ophiolites or Horsefeed formation limestone of the Cache Creek terrane.

4.3.2. Farnsworth wacke (new informal unit)

Wacke and pebble to cobble conglomerate are widespread in the Gladys Lake area but are subordinate to chert and argillite. These are herein included in the Farnsworth wacke (new informal unit) named for exposures underlying Mount Farnsworth, about 30 km south of the Gladys Lake map area. The Farnsworth wacke is generally resistant and is exposed in many upland areas where it is intercalated with and surrounded by chert. The distribution shown on Figure 3 is the minimum extent of this unit as it likely underlies parts of low-lying areas. Lack of magnetic contrast between this unit and chert or argillite as well as isoclinal folding makes projection of this unit under the extensive glacial sediments difficult.

The Farnsworth wacke weathers orange, green, grey, and rusty and commonly is emerald to dull blue-green on fresh surfaces. It is almost always pyritic and locally calcareous. Fine- to medium-grained feldspathic wacke is the most common rock type with common coarse sandstone to granule conglomerate interbeds.

Locally, feldspar rich beds are intercalated with beds that are relatively quartz rich, containing 30-50% quartz grains that are whitish and subrounded to subangular. Lithic grains include angular to subangular (10-15%) grey, tawny and black chert (Fig. 10) and black cherty argillite, up to 5% rusty lithic fragments, 10-20% plagioclase porphyry with

Fig. 10. Resistant chert clasts in conglomerate of the Farnsworth wacke unit.

varied composition and texture, commonly with equant laths in a dark grey matrix. Chert clasts contain both recrystallized and pristine radiolaria (Fig. 11). Feldspar porphyry clasts are locally abundant, with less common pyroxene and hornblende porphyritic clasts (Fig. 11). Mineral grains include feldspar, monocrystalline quartz grains (including subidiomorphic, embayed, rectangular beta quartz), pyroxene, hornblende, titanite, and biotite. Detrital grains of secondary epidote and pumpellyite are relatively common.

Farnsworth wacke and conglomerate represent rapid deposition of immature sediment probably generated during unusual storm or tectonic events and carried into an otherwise quiescent environment. Some beds appear to be mass flow deposits with both sharpstone conglomerate and soft-sediment deformed chert and argillite. One of these beds contains a large raft of crinodial packstone that probably slumped from a highland of Paleozoic rocks.

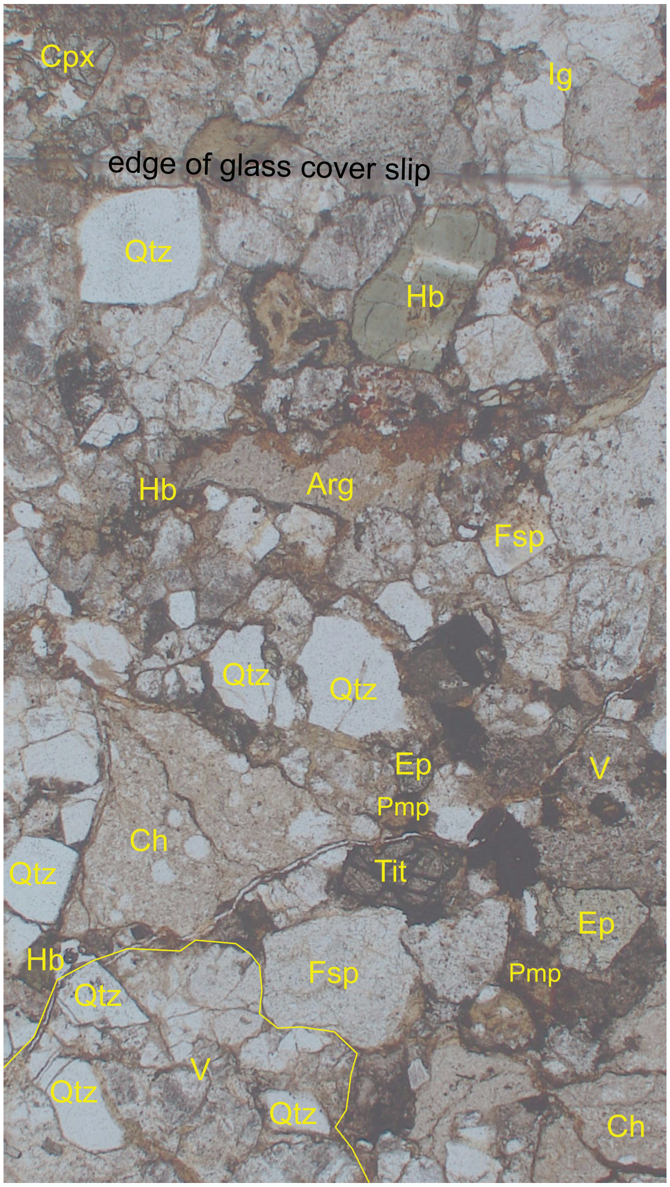

Fig. 11. Photomicrograph of Farnsworth wacke in plane polarized light. Hornblende (Hb), feldspar (Fsp), and quartz shards (Qtz) occur in clasts of felsic tuff (V, e.g., yellow outline), or occur as mineral grains, as does clinopyroxene (Cpx), titanite (Tit), and secondary minerals of (Ep) and ?pumpellyite (Pmp). Lithic grains also include holocrystalline granitoid (Ig), argillite (Arg), and chert (Ch, some with round radiolaria). Height of photo represents ~3.8 mm; sample MMI23-15-12.

Farnsworth wacke and ribbon chert locally rest on mantle ultramafite, gabbro and basaltic rocks of the Nakina suite in the southern map area, near Marble Dome and Mount Barham (Fig. 3).

4.4. Middle Permian to Middle Triassic ophiolitic rocks of Atlin terrane

Atlin terrane is bounded to the east by the Cretaceous Teslin-Thibert-Kutcho fault system, and to the west and south, predominantly by the King Salmon and Nahlin Faults, with some outliers occurring elsewhere (Fig. 2), including in the Gladys Lake area (Fig. 3). In the study area, Atlin terrane ophiolites are subdivided into the Nahlin and Nakina suites, and slivers of ophiolite are contained in the newly defined Lincoln complex.

4.4.1. Nahlin Suite

The Nahlin suite is named after extensive exposures on Nahlin Mountain (~120 km to the south; Terry, 1977; McGoldrick et al., 2018; Zagorevski et al., 2021). It is exposed throughout the Atlin terrane and is generally interpreted as the mantle section of an ophiolite, although it locally includes minor ultramafic cumulates (Ash, 1994, 2004; Zagorevski et al., 2021). The Nahlin suite is characterized by voluminous harzburgite, dunite, sparse orthopyroxenite, rare lherzolite and rare clinopyroxenite. Harzburgite typically appears knobby on account of resistant, 1-2 cm orthopyroxene pseudomorphs (10-40%) in an olivine pseudomorph groundmass. Dunite lacks the knobby weathering surface and tends to weather a lighter, dun to olive. It is locally characterized by whisps of chromite.

Harzburgite is commonly interlayered with dunite and orthopyroxenite and deformed at high temperatures, as indicated by elongated orthopyroxene porphyroclasts and annealed olivine. Dunite and orthopyroxenite commonly form discordant dikes, channels, and pods. Nahlin suite peridotites are variably altered and range regionally from fresh (few percent serpentine), to serpentinite and/or listwanite (e.g., Terry, 1977; McGoldrick et al., 2018; Zagorevski et al., 2021). Orthopyroxenite may display chocolate tablet-like surfaces where host peridotite was serpentinized leading to volume gain in the host, and extension of the orthopyroxenite.

In some localities, especially near the contact with the Nakina suite and in the Lincoln complex (see below), Nahlin suite harzburgite displays a strong, macroscopically continuous foliation. This foliation is likely inherited from foliated serpentinite that was subsequently contact metamorphosed, obscuring primary textural relationships. Such contact metamorphism is common in the study area due to extensive intrusion by the Three Sisters (Middle Jurassic) and Surprise Lake (Late Cretaceous) suites.

4.4.2. Nakina suite

The Nakina suite is named after exposures of mafic volcanic and hypabyssal rocks in the Nakina area (~90 km to the south). The Nakina suite is spatially associated with the Nahlin suite and ranges from medium-grained gabbro to very fine-grained, flinty, flow-banded to foliated basalt. Nakina suite fine-grained gabbros appear to be intrusive into peridotites of the Nahlin suite, where they form dikes and pods with chilled margins in the peridotite, although some contacts appear to be tectonic. The transition from the Nahlin suite to the Nakina suite is characterized by intrusive and structural interleaving of the gabbro/basalt and peridotite. The main exposures of the Nakina suite occur in the Mount Barham area and on Marble Dome. In these areas, the Nakina suite consists of massive to almost flow-banded basalts and minor fine-grained gabbro. Clear contact relationships in the basalt/gabbro unit are rare but suggest that these are predominantly hypabyssal intrusions with very few true extrusive equivalents. Primary volcanic textures were not observed, except at rare exposures east of Mount Barham, where screens of pillow basalt are exposed on steep slopes (Fig. 12).

In the Mount Barham area, Nakina suite mafic hypabyssal bodies also intrude chert, suggesting that the chert is part of the ophiolite cover deposited synchronous with extension. Similar relationships were observed to the south of the study area, where Nakina suite gabbro and basalt intrude into Late Permian radiolarian chert (Zagorevski et al., 2021).

4.4.3. Lincoln complex

Northeast of Marble Dome, peridotite, gabbro, basalt, chert, limestone and fine-grained siliciclastic rocks are interleaved on a decameter scale. In this area, competent gabbro and peridotite are structurally juxtaposed with recrystallized marble and polydeformed siliciclastic rocks and chert, in part comprising a mixed siliceous and amphibolite mylonite. Overall, the interleaving of the disparate rock types suggests juxtaposition in a tectonic melange-like zone. Excellent exposures of these rocks occur to the east of Lincoln Lake and Lincoln Creek and these rocks are herein referred to as the Lincoln complex.

4.4.4. Relationships between Atlin terrane units

Primary relationships between Nahlin and Nakina suites are preserved in the Mount Barham area. Emplacement of the fine-grained Nakina suite sills into peridotites suggests that peridotite was exhumed to shallow depth, cooled, and serpentinized before gabbro was chilled against it. The very thin crustal section overlying the peridotite, including presence of chert within a few 100 m of the contact (Fig. 3 inset; Fig. 12), suggests that Penrose-style ophiolite stratigraphy was not developed. Rather, this ophiolite appears to have formed by tectonically accommodated extension in an ocean core complex where mantle was exhumed to just below the sea floor along an extensional detachment (e.g., Ildefonse et al., 2007). Similar relationships are present throughout the Atlin terrane, including north of the study area along the Alaska highway, where Bogatu et al. (2023) constrained the detachment to 249 to 245 Ma.

Zagorevski et al. (2021) interpreted that the Atlin terrane was obducted onto the Cache Creek terrane carbonate platform (exposed immediately west of the study area) in the Middle to Late Triassic. The contact between Paleozoic limestones and Atlin terrane ophiolites is generally poorly exposed or has not been previously investigated in detail. South of the study area, coherent crust to mantle ophiolite seems to transition to the Lincoln complex across a valley with no exposure. In this context, the Lincoln complex may represent a tectonic melange formed during emplacement of the ophiolite onto the Paleozoic carbonate platform, resulting in juxtaposition and interleaving of crust and mantle rock along the interface. Future discovery of high-pressure mineral assemblages would support this interpretation.

5. Mineral occurrences

Well-known mineralized systems within or immediately

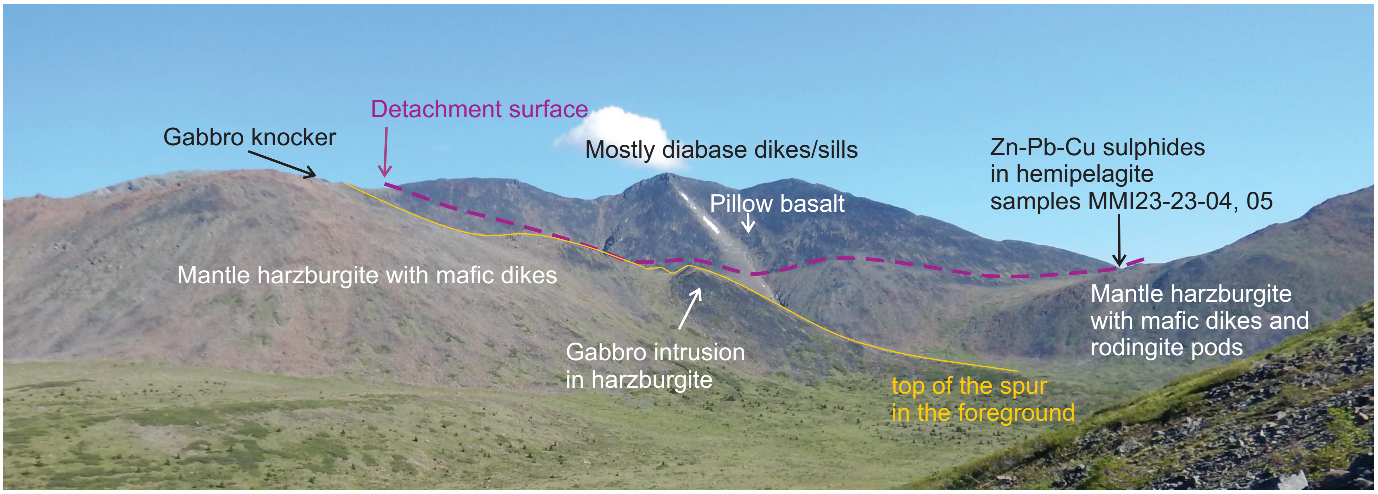

Fig. 12. View of the detachment surface near Mount Barham (dashed purple line). The mineralized (see below) hemipelagite sample collection site at the detachment is shown. This site was probably at a breakaway, where mantle was exposed on the seafloor.

adjacent the study area include porphyry and skarn mineralization related to the Surprise Lake plutonic suite evolved granite (Late Cretaceous), and polymetallic veins associated with the Three Sisters plutonic suite (Middle Jurassic) and related lamprophyre dikes. Identified here for the first time is mineralization at a preserved intraoceanic detachment within the Atlin terrane, perhaps a distal equivalent of modern ultramafic associated massive sulphide deposits forming today in analogous extensional seafloor settings.

5.1. Porphyries related to evolved granites

The Surprise Lake batholith and surrounding contact aureole contain several molybdenum and granophile mineral occurrences (Mo, ±W, Sn, Au; e.g., Aitken, 1959; Ballantyne and Littlejohn, 1982; Ray et al., 2000; Smith and Arehart, 2009; Zagorevski et al., 2017). Currently, the most significant known mineralization is contained within the Ruby Creek deposit (formerly named Adanac), immediately south of the study area (Fig. 3, inset). It contains Measured and Indicated resources of 369,398,000 tonnes grading 0.053% Mo (Ristorcelli et al., 2022; MINFILE 104N 052). Molybdenite mineralization occurs in extensively quartz veined zones along with introduction of potassium as indicated by intergrowth of muscovite with molybdenite (Fig. 13). In addition to this syn-magmatic-hydrothermal mineralization in the Mount Leonard stock, potential has also been identified in post-intrusion hydrothermal systems related to a continued enhanced heat flow generated by radioactive decay of elements concentrated in the highly evolved granite (e.g., Ballantyne and Littlejohn, 1982). Such late mineralizing systems include argillic alteration locally observed north of Zenazie Creek and around fracture zones near Mount Weir (~15 km south of Lincoln Lake) together with magnetite-sphalerite veins (Ballantyne and Littlejohn, 1982).

Farther to northeast, the Gladys Lake stock and ring dike complex (G on Figs. 2, 3) display many of the characteristics of the Mount Leonard stock. This includes polyphase pegmatitic to aplitic intrusions and extensive quartz veining, and limited molybdenite mineralization (Pinsent, 2005).

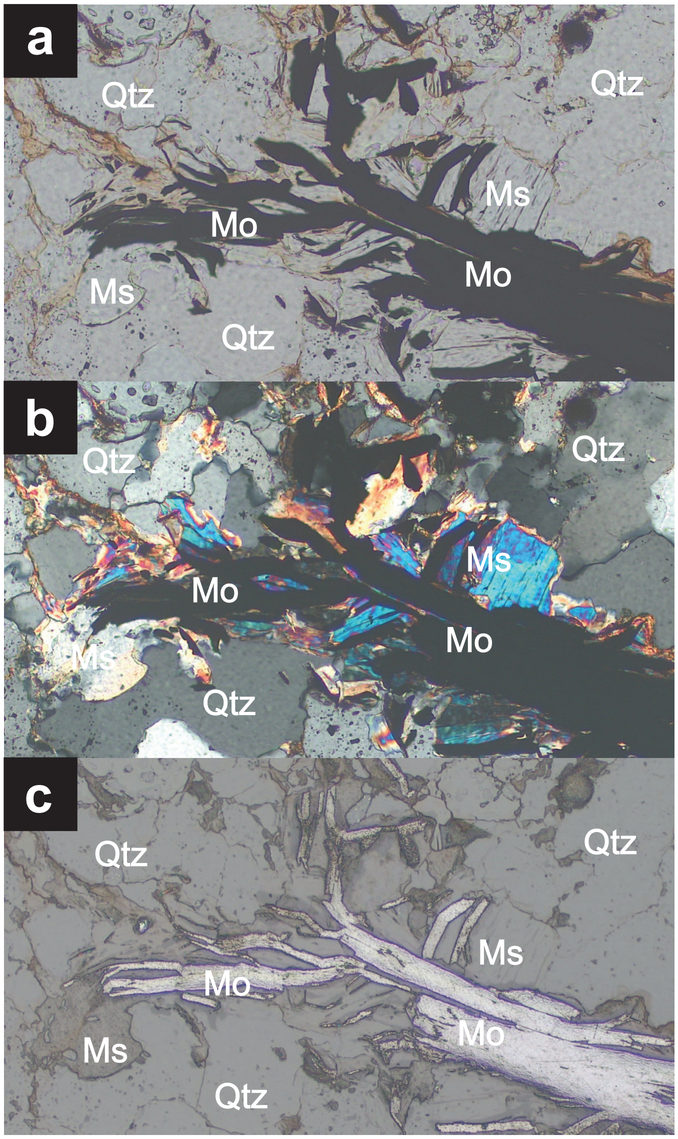

Fig. 13. Representative molybdenite mineralization in intensely quartz veined zone (Qtz) from a surface exposure of the Ruby Creek deposit. In all instances molybdenite (Mo) is mantled by muscovite (Ms). Plane polarized **(a)**, cross polarized **(b)** and reflected light **(c)** views in photomicrographs with long dimensions representing ~1 mm (Sample 23ZE1475b1, location in Table 1 and on Figure 3).

5.2. Skarn sulphide mineralization

The most extensive zone of skarn mineralization known in the Gladys Lake area is the Sunrise occurrence (MINFILE 104N 012; locality S on Fig. 3). There, magnetite-sphalerite-galena-chalcopyrite lenses tens of metres long and metres in thickness formed near the intrusive contact of the Surprise Lake batholith and Paleozoic Cache Creek terrane marble. Indications of mineralization extend along a 500 m strike length of the contact zone (Devine, 2020).

5.3. Lode gold veins

Most of the historic lode gold exploration in the Atlin district was focused on listwanite alteration (quartz-carbonate-chrome mica) of mafic and ultramafic rocks. Evaluation of mineral grains (especially thorite) intergrown with gold recovered from placer operations south of the Surprise Lake batholith suggests a genetic relationship with the highly evolved, U-Th rich phases of the batholith (Sack and Mihalynuk, 2004). Coarse gold is demonstrably intergrown with chert-argillite in bedrock below producing placer gravels (Mihalynuk et al., 2017), suggesting that listwanite is not the singular major source of lode gold. Most of the placer gold mining has taken place on the south margin of the Surprise Lake batholith, with lesser placer operations in the Gladys Lake area. Considering that the Surprise Lake batholith intrudes the same rock types along its south and northern contacts, there may be similar lode gold potential in the Gladys Lake area, especially near known placer deposits.

No anomalous gold values were recovered from the Surprise Lake batholith-related samples. All of the anomalous gold analyses (and As ±Au, Pb and Cu) were from the Three Sisters suite (Table 1), which is not known for Au potential. More focused mapping and sampling is required to assess the lode gold potential of the Gladys Lake area.

5.4. Ultramafic-associated massive sulphide (UAMS)

Ultramafic-associated massive sulphide (UAMS) deposits are polymetallic (Cu-Zn-Pb-Ni-Co) sulphide accumulations on or adjacent to sea floor detachment faults (Mihalynuk et al., 2019). The most extensively explored modern UAMS near the Mid Atlantic Ridge comprise some of the highest grade Cu-Zn deposits globally with combined Cu+Zn grades averaging 20% (Cherkashev et al., 2013). Typically, UAMS have low preservation potential because they must survive oxidizing bottom waters (e.g. Murton et al., 2019) and subduction or obduction to become part of an accretionary orogen. Atlin terrane preserves a rare example of a fossil intraoceanic detachment zone on land that can be traced along strike for hundreds of km (Fig. 2; Zagorevski et al., 2015, 2016, 2021; Corriveau, 2018; Bogatu et al., 2023). As such, it has potential for UAMS mineralization.

In the Mount Barham area, fine-grained, metalliferous sedimentary rocks are exposed in low, rubbly outcrops across an area of about 10 m^2 separated by ~300 m from outcrops of peridotite and ~40 m from outcrops of basalt (including hypabyssal gabbro). Contacts between the three units are covered, but projection of the detachment surface places it immediately below the metalliferous sedimentary rocks (Fig. 12) which display significant Au-Zn-Pb ±Cu enrichment (Table 1). In outcrop, chalcopyrite and galena are visible as fine disseminations, whisps, and blebs elongated up to about 2 cm along bedding and 0.5 cm across. Sphalerite is not easily distinguished from the rock matrix but in polished section is widely disseminated and contains inclusions of chalcopyrite (Fig. 14).

It is possible that mineralization is related to the nearby Surprise Lake suite intrusions (see Fig. 3). However, comparison between the Ruby Creek deposit and mineralization near Mount Barham (red text versus grey highlight of Table 1) show significant differences in almost all elements (notably Nb, Mn, Sb, Ge, and Pd). Iron contents are 17.2% and 9.5% with corresponding S of 0.4 and 0.2%, indicating that most Fe is contained in oxides (see Fig. 14). Overall, together with the trace element profile, this may be an indicator of distal UAMS mineralization in the Atlin terrane.

6. Summary

Framework geological mapping and sampling in the Gladys Lake area revises the mapping of Aitken (1959) that predates plate tectonics and widespread recognition of ophiolitic sequences (Dilek, 2003). It builds upon the work of Zagorevski et al. (2021) who clarified relationships between the underlying terranes, separating upper plate Atlin terrane from lower plate Cache Creek terrane. That work also documented widespread ocean floor extension in the upper plate and deposition of overlap successions. During mapping, mineralization in fine-grained strata was discovered above one of the detachment surfaces exposed near Mount Barham. Analyses confirmed that it is strongly elevated in numerous metals, particularly Ag, Zn, and Pb. The preferred working hypothesis is that the mineralized rocks are distal precipitates of hydrothermal plumes at ultramafic-associated massive sulphide fields. Given that these extensional ocean crustal sections have been identified for more than 400 km along strike, and that modern

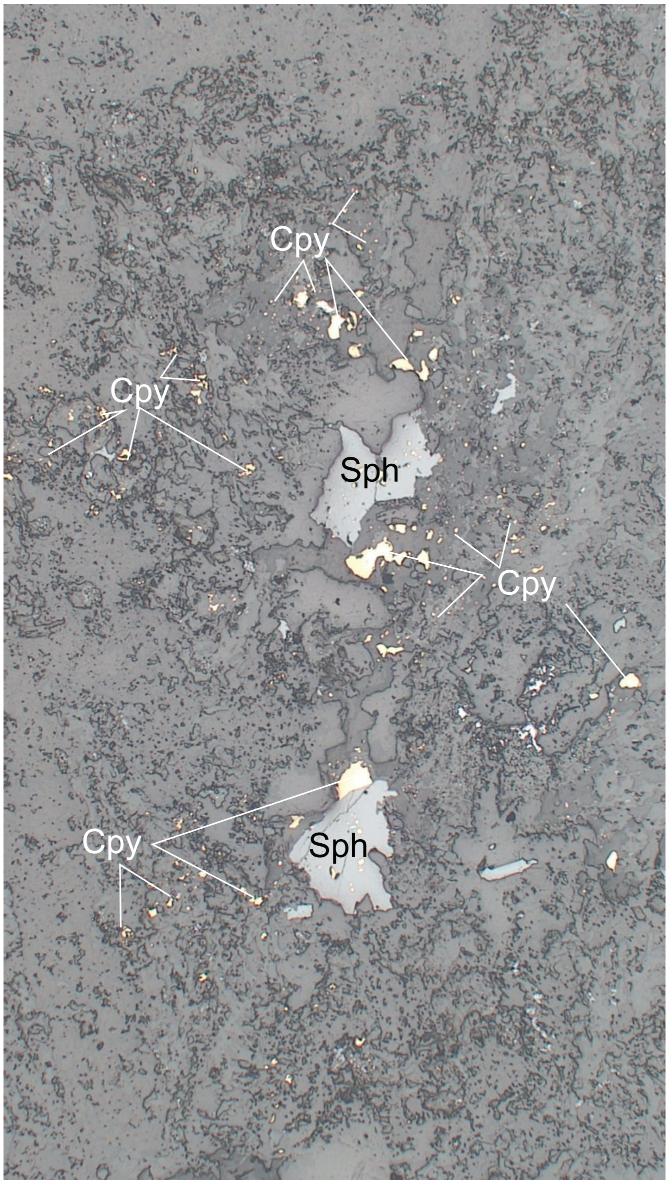

Fig. 14. Sphalerite (Sph) with inclusions of chalcopyrite and abundant scattered chalcopyrite (Cpy) in the matrix of fine-grained sedimentary rocks resting atop an interpreted mantle extensional fault in the Mount Barham area. Galena is present outside of the field of view. Chemical analysis of this sample returned 0.08% Cu, 0.4% Zn, 0.7% Pb, and 31 g/t Ag. Long dimension of photomicrograph represents 3.8 mm (Sample MMI23-23-05, location in Table 1 and on Figure 3).

Table 1. Geochemical analyses of selected samples from the Gladys Lake area. See Campbell et al. (2024) for full suite of samples, descriptions, and all elements analyzed.

Statnum	Unit and rock type	Latitude	Longitude	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppb	Ni ppm	Co ppm	Mn ppm	Fe %	As ppm	U ppm	Au ppb
23ZE1298XY	LKS quartz eye porphyry	59.71175	-133.403944	253.5	7.8	4.8	11.4	28	1.6	0.8	158.0	0.9	1.0	22.9	0.2
23ZE1475b1	LKSg quartz veined granite	59.75268	-133.318717	>2000	5.9	8.9	10.5	329	3.0	0.5	97.0	0.9	4.2	18.2	73.6
MMI23-07-19	MJTgd quartz eye porphyry dike MJTd	59.92192	-133.802976	5.1	8.7	18.2	27.1	80	9.1	6.7	629.0	2.1	488.8	9.0	235.1
MMI23-08-15	biotite>hornblende quartz diorite MJTgt	59.87746	-133.343889	3.3	45.7	0.9	43.4	57	19.8	13.2	258.0	2.4	1.5	2.6	1.7
MMI23-08-25	fine- to medium-grained tonalite MJTgd	59.87638	-133.362252	2.2	102.1	146.2	1356.9	2823	1.6	1.0	64.0	2.7	3.1	14.6	0.5
MMI23-12-32	clay atlered cut by dikes & veins MJTgd	59.79794	-133.575532	7.4	293.4	285.8	497.3	9491	11.5	5.9	205.0	5.2	1177.4	12.7	79
MMI23-12-32	clay atlered cut by dikes & veins MJTd	59.79794	-133.575532	6.4	274.4	265.7	476.0	9189	11.1	5.9	198.0	5.1	1123.3	12.4	74.2
MMI23-20-02	80cm banded vein in quartz diorite	59.75044	-133.804428	4.6	28.5	8.8	17.8	199	16.9	7.8	311.0	1.7	2764.4	0.3	110.7
MMI23-23-04	PTrN distal exhalite?	59.75239	-133.317854	0.3	115.0	>10000	5994.2	41656	32.2	14.1	>10000	17.2	89.4	0.2	0.5
MMI23-23-05	PTrN distal exhalite?	59.75242	-133.317981	2.0	814.8	7283.9	4494.3	31354	32.5	27.0	6719.0	9.5	180.2	0.2	<0.2
MMI23-23-08	PTrN sufide-rich pod in foliated gabbro	59.75295	-133.324153	0.7	164.7	16.5	52.3	346	27.1	23.9	277.0	3.4	0.6	<0.1	1.6
RCA23-12-20	MJTgd quartz-flooded breccia	59.79802	-133.575732	44.6	1162.4	3850.9	647.9	19668	12.4	3.7	59.0	2.7	>10000	0.7	198.7

Statnum	Unit and rock type	Th ppm	Cd ppm	Sb ppm	Bi ppm	V ppm	Cr ppm	Mg %	Al %	Sc ppm	Ga ppm	Cs ppm	Nb ppm	Re ppb	Pd ppb
23ZE1298XY	LKS quartz eye porphyry	36.1	0.09	0.47	0.19	4	6.4	0.09	0.41	1	2.6	1.15	9.26	2	<10
23ZE1475b1	LKSg quartz veined granite	27	0.78	0.41	759.77	<1	15	0.02	0.77	0.9	4	4.55	20.72	26	<10
MMI23-07-19	MJTgd quartz eye porphyry dike MJTd	15.5	0.03	5.49	0.06	11	11.7	0.35	0.41	3.5	0.9	4.72	0.03	<1	<10
MMI23-08-15	biotite>hornblende quartz diorite MJTgt	7.9	0.05	0.28	0.44	118	87.1	1.06	0.93	3.9	3.8	4.23	0.45	<1	<10
MMI23-08-25	fine- to medium-grained tonalite MJTgd	30.2	0.75	0.22	5.17	3	7.5	0.02	0.49	0.9	3.2	5.29	1.2	<1	<10
MMI23-12-32	clay atlered cut by dikes & veins MJTgd	7.5	8.99	21.31	8.37	44	10.4	0.13	1.7	6.3	7.3	3.02	<0.02	<1	<10
MMI23-12-32	clay atlered cut by dikes & veins MJTd	7.2	8.42	19.38	8.31	44	8	0.12	1.77	6.2	7.2	3	<0.02	<1	<10
MMI23-20-02	80cm banded vein in quartz diorite	0.5	0.03	28.53	0.32	18	20.6	1.2	0.28	6.2	0.8	1.34	<0.02	<1	<10
MMI23-23-04	PTrN distal exhalite?	0.2	52.81	28.91	0.73	261	64.3	2.2	5.7	21.6	31.4	7.27	<0.02	<1	29
MMI23-23-05	PTrN distal exhalite?	0.1	71.75	16.37	0.66	208	61	2.16	4.23	18	21.8	8.64	<0.02	<1	*
MMI23-23-08	PTrN sufide-rich pod in foliated gabbro	<0.1	0.26	0.12	3.43	92	51.2	1.08	3.06	7	10	4.5	<0.02	<1	<10
RCA23-12-20	MJTgd quartz-flooded breccia	2	11.58	86.83	23.79	11	24.6	0.02	0.22	3.2	2.1	1.6	0.02	<1	<10

fields can develop grades that average 20% combined Cu+Zn, Atlin terrane extensional structures represent a significant untested mineral exploration opportunity. More complete inventory of extensional structures, paleogeographic analyses, and relations to adjacent arc terranes, Stikinia and Quesnellia, will be considerations during framework mapping planned for 2024.

Acknowledgments

Joseph English, and JoAnne Nelson reviewed and improved earlier versions of this paper. Fieldwork benefited from the enthusiastic and capable assistance of Taku River Tlingit First Nation Land Guardians, Emma Law and Izaiah Carlick. Evan Orovan helped with interpretation of unidirectional solidification textures in samples of Surprise Lake porphyry. The pilots and staff at Discovery Helicopters, Atlin, transported us safely to and from remote corners of the field area.

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