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Revisiting the Stratigraphy of the Alkalic Stuhini Group in the Galore Creek Area, Northwestern British Columbia (Parts of NTS 104G/03, 04)

R.J. Johnston[1], **The University of British Columbia, Vancouver, British Columbia, rjohnston@eoas.ubc.ca**

L.A. Kennedy, The University of British Columbia, Vancouver, British Columbia

K.A. Hickey, The University of British Columbia, Vancouver, British Columbia

B.I. van Straaten, British Columbia Geological Survey, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, Victoria, British Columbia

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Introduction

The Galore Creek alkalic porphyry Cu-Au-Ag deposit is one of several large porphyry systems in the prolific Golden Triangle of northwestern British Columbia (BC; Nelson and van Straaten, 2020; Figure 1), and it is the most silica-undersaturated alkalic porphyry system globally (Lang et al., 1995). Galore Creek is located within the Stikine island-arc terrane, in which volcano-sedimentary rocks of the Devonian–Permian Stikine assemblage are overlain by the Upper Triassic Stuhini Group and the Lower to Middle Jurassic Hazelton Group. At Galore Creek, porphyry-style alteration and mineralization is hosted in, and broadly coeval with, an alkalic volcanic sequence, cut by alkalic intrusive rocks (Enns et al., 1995; Schwab et al., 2008; Byrne and Tosdal, 2014; Micko et al., 2014). The alkalic volcanic rocks are part of the Stuhini Group, and orthoclase-phyric alkalic volcanic rocks have been dated at 210.27 ±0.19 Ma (van Straaten et al., 2023). The alkalic intrusions, typically orthoclase and/or feldspathoid phyric, are part of the Galore plutonic suite and have been dated between 210 and 208 Ma (Mortensen et al., 1995; Logan and Mihalynuk, 2014).

Across the Golden Triangle, the Stuhini Group is defined by thick mafic to intermediate volcanic rocks and well-stratified clastic sedimentary rocks (Logan and Koyanagi, 1994; Logan et al., 2000). These rock types are present throughout the Galore Creek area but at rare locations within the Golden Triangle (e.g., this study area) they are overlain by a distinctive alkalic volcanic sequence.

Within the Galore Creek deposit area, Enns et al. (1995), Micko (2010) and Micko et al. (2014) recognize lower augite-phyric volcanic rocks overlain by pseudoleucite-bearing volcanic rocks and/or orthoclase-bearing volcanic rocks. Subsequently, Johnston et al. (2023) and van Straaten et al.'s (2023) work at sites surrounding the deposit identified the upper alkalic sequence overlying the lower intermediate to mafic volcano-sedimentary succession. Herein, the stratigraphy described by Johnston et al. (2023) is revisited and updated based on new field, petrographic and scanning electron microscope (SEM) data.

Methods

Two field seasons of approximately 60 days each were conducted at Galore Creek in 2022 and 2023. Research focused on mapping deformation, stratigraphy and key crosscutting relationships. Several dozen thin sections from 2022 and 2023 samples were examined with an optical microscope at The University of British Columbia (UBC) in 2023. The SEM analyses were also completed at UBC (Vancouver, BC) in 2023.

Stuhini Group Stratigraphy

The study area lies immediately west of the Galore Creek deposit area, and coincides with a large, 3 by 11 km, broadly north-south deformation corridor (termed here the Butte ridge deformation corridor) defined by folded and variably foliated volcano-sedimentary rocks of the Stuhini Group (Johnston et al., 2023; Figure 1). The fold axes in the volcano-sedimentary rocks plunge to the south-southwest. The foliation (primarily an axial-planar cleavage) dips to the west to southwest. Ductile penetrative strain of this intensity is rare outside this deformation corridor. Stratigraphic superposition was determined by detailed structural mapping of the deformation corridor, with a focus placed on recording way-up indicators, faults and folds. The Galore Creek region has been affected by several generations of faults, which juxtapose stratigraphy, alteration and earlier deformation features. Major sets of faults include north- and east-directed thrust faults, broadly north-

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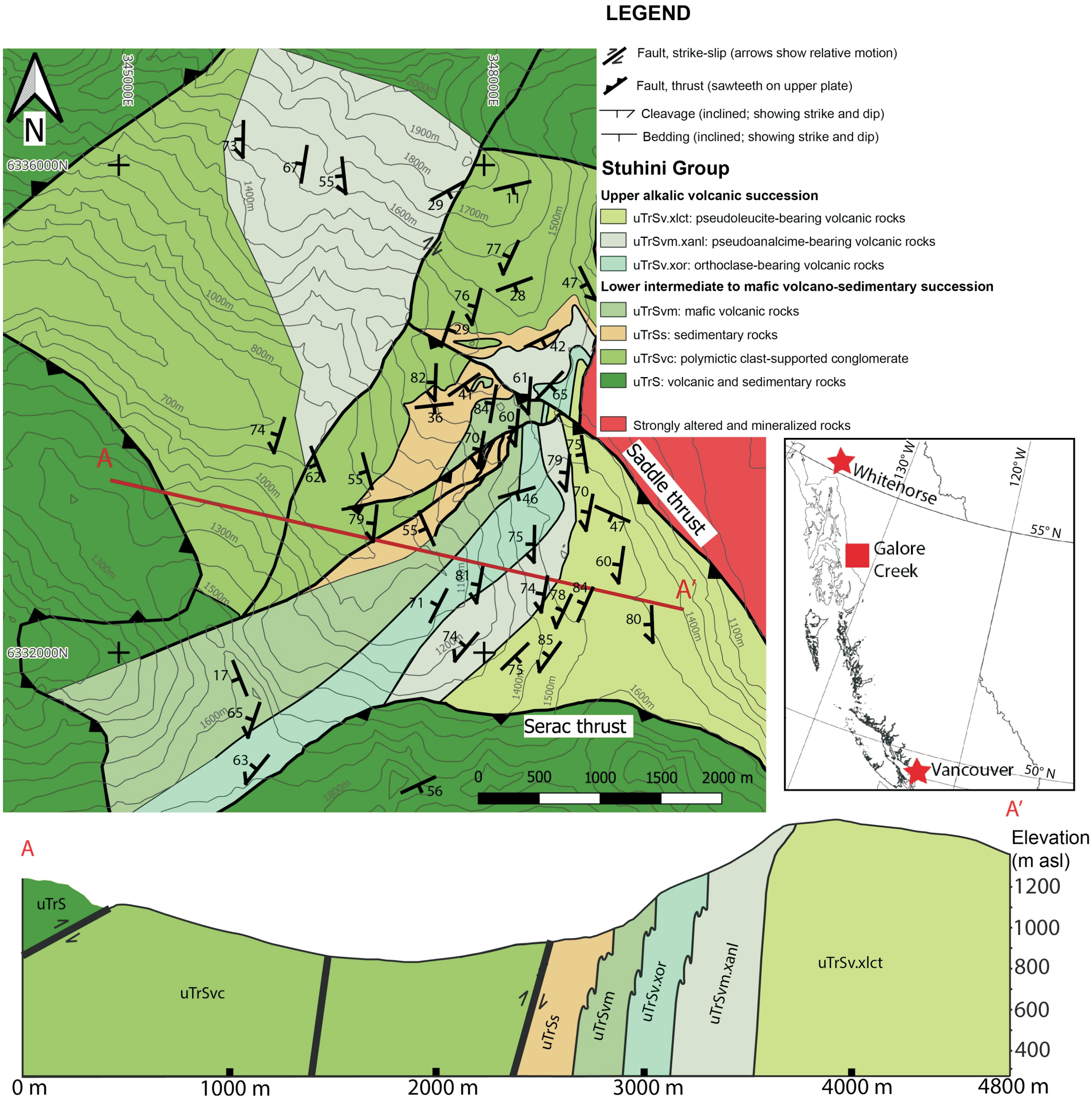

Figure 1. Map and cross-section of the Butte ridge deformation corridor west of Galore Creek, northwestern British Columbia (based on 2022 and 2023 field data). Elevation contours in m asl. All co-ordinates are in UTM Zone 9, NAD 83.

striking strike-slip faults and broadly north-striking normal faults.

Units of the Stuhini Group are described below from oldest to youngest.

Lower Intermediate to Mafic Volcano-Sedimentary Succession

Volcanic and Sedimentary Unit (uTrS)

Lower Stuhini Group rocks are exposed in the northern, western and southern portions of the study area (Figure 1). This unit is typically composed of thick (>10 m) packages of a) locally augite-bearing mafic volcanic rocks, b) 'pin-striped' sandstone and siltstone and c) polymictic pebble-boulder conglomerate.

Volcanic-Clast–Bearing Conglomerate Unit (uTrSvc)

This unit (Figure 2) comprises polymictic pebble to boulder conglomerate and decimetre to metre thick sandstone beds. The conglomerate is clast supported, with distinct white-weathering intermediate volcanic clasts with feldspar and amphibole phenocrysts, and mafic volcanic clasts with augite phenocrysts up to 3 mm in size. Locally, where augite-bearing mafic volcanic clasts are absent, the conglomerate is matrix supported with pebble- to boulder-sized clasts of white-weathering intermediate volcanic rock set in a chloritized sandstone-siltstone matrix (Figure 3a). This unit is widespread across the northern and western extents of the study area (Figure 1).

Sedimentary Unit (uTrSs)

A sedimentary unit (uTrSs) conformably overlies and is often interbedded with unit uTrSvc (Figure 2). It is composed of well-stratified siltstone, sandstone (Figure 3b) and locally limestone. Sandstone contains abundant feldspar and quartz grains in a fine-grained chloritized matrix. The unit is exposed in the central part of the study area.

Mafic Volcanic Unit (uTrSvm)

The mafic volcanic unit (uTrSvm) is composed of augite-bearing mafic volcanic, volcaniclastic and reworked mafic volcanic rocks (Figures 2, 3c, d). Augite crystals are typically <2 mm in diameter. Augite is sparse in this unit and typically composes <10% of the rock by volume. Within the Butte ridge deformation corridor, the unit is mainly composed of reworked volcanic rocks. This contrasts with augite-phyric volcanic clasts in the volcanic and sedimentary unit (uTrS) and the volcanic-clast–bearing conglomerate unit (uTrSvc), which typically contain more abundant and coarser augite crystals. The groundmass of this unit has been metamorphosed and is dominated by actinolite, with minor chlorite and biotite, and plagioclase is present locally (Figure 3c, d). The primary composition of the protolith groundmass is unclear. This unit is exposed in the western portion of the study area.

Upper Alkalic Volcanic Succession

Orthoclase-Phyric Volcanic Unit (uTrSv.xor)

The orthoclase-phyric volcanic unit (uTrSv.xor) contains tuff, crystal tuff, volcanic breccia and reworked volcanic rocks. All contain coarse orthoclase crystals (typically 5 mm in length). The groundmass composition is highly variable between lithofacies, but in the Butte ridge deformation corridor the unit is dominated by a chlorite-carbonate-biotite-white mica groundmass (Figure 3e, f). The SEM analysis shows that white mica contains both paragonite and muscovite. This unit is exposed as a broadly west-trending band north of the Saddle thrust, and a southwest-trending unit south of the Saddle thrust.

Feldspathoid-Bearing Mafic Volcanic Unit (uTrSvm.xanl)

The augite-pseudoanalcime–phyric volcanic unit (uTrSvm.xanl) encompasses a wide range of lithofacies, including crystal tuff, lesser volcanic breccia and minor sedimentary rocks derived from this unit.

The volcanic rocks contain 10–50% white-weathering trapezohedronal pseudoanalcime (3–7 mm) crystals and 10–30% augite (2–4 mm) crystals (Figure 4a). Pseudoanalcime refers to analcime crystals that have been pseudomorphed into clusters of albite (Figure 4b). The albite clusters commonly form concentrically around the core of each crystal. In general, the groundmass is similar to that of unit uTrSvm and contains abundant actinolite and chlorite, with local plagioclase and biotite, however, groundmass composition is highly variable and is dependent on the lithofacies and augite abundance. This unit is widespread across the Galore Creek area, and within the study area it can be found north and south of the Saddle thrust.

Coarse Feldspathoid-Phyric Volcanic Unit (uTrSv.xlct)

The coarse feldspathoid-phyric volcanic unit (uTrSv.xlct) is composed of tuff, crystal tuff, volcanic breccia, conglomerate derived from feldspathoid-bearing units, and local sandstone and siltstone.

The volcanic rocks contain 20–50% coarse, flattened and stretched feldspathoid phenocrysts (1 to >3 cm). Broken feldspathoid crystals are common and suggest an extrusive origin. In the field, two textural varieties of the rocks were observed: 1) black- or green-zoned crystals set in a white-weathering groundmass (Figure 4c, d) and 2) white-weathering crystals set in a dark grey to black aphanitic groundmass (Figure 4e, f). Petrographic observations and SEM analysis of the first textural variety indicate that the dark crystals have both orthoclase-dominated and muscovite-dominated zones. These crystals are set in a

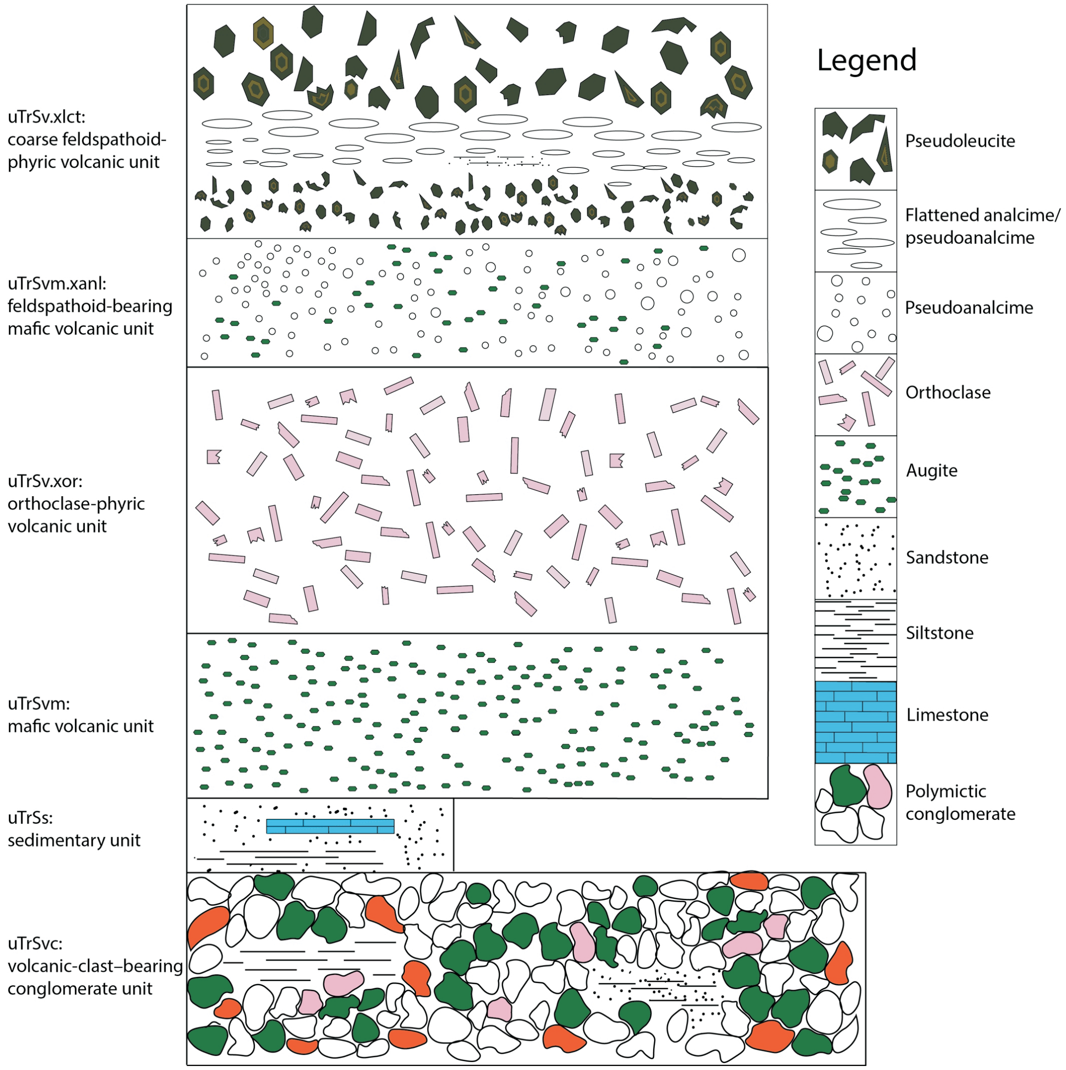

Figure 2. Stratigraphic column of the Butte ridge deformation corridor, showing the lower intermediate to mafic volcanic and sedimentary calcalkalic sequence and upper alkalic volcanic stratigraphy, derived from Johnston et al. (2023) and van Straaten et al. (2023). Relative thickness of the units is indicated.

fine-grained orthoclase and white mica groundmass or matrix (Figure 4d). The crystals in this textural variety are interpreted to be pseudoleucite. Petrographic observations and SEM analysis of the second textural variety show that albite ± white mica have pseudomorphed coarse feldspathoid crystals. Relict analcime is often present (Figure 4e, f). The coarse crystals in this textural variety are interpreted to be pseudoanalcime. The contacts between these textural varieties are irregular and cannot always be visually distinguished in the field. This unit is found as a very thick package in the southeastern part of the study area.

Discussion

The lower calcalkalic stratigraphy seen in the study area is similar to what constitutes the Stuhini Group regionally. Thick packages of augite-bearing mafic volcanic rocks, interbedded sandstone, siltstone and conglomerate are all common in the Stuhini Group (Logan and Koyanagi, 1994; Logan et al., 2000). Similar augite-bearing mafic volcanic clasts are seen within the volcanic-clast–bearing conglomerate unit (uTrSvc) and the volcanic and sedimentary unit (uTrS). These lower units are overlain by a sedimentary unit (uTrSs) and mafic volcanic unit (uTrSvm), the latter containing distinctly smaller and fewer augite crystals than the lower units.

The upper alkalic succession in the study area represents an unusual package of alkalic silica-saturated and silica-undersaturated rocks not commonly documented elsewhere in the Stuhini Group. The stratigraphic sequence is increasingly alkalic, with orthoclase-phyric volcanic rocks (unit uTrSv.xor) grading into silica-undersaturated, feldspathoid-bearing mafic volcanic rocks (unit uTrSvm.xanl), and finally grading into the uppermost coarse feldspathoid-

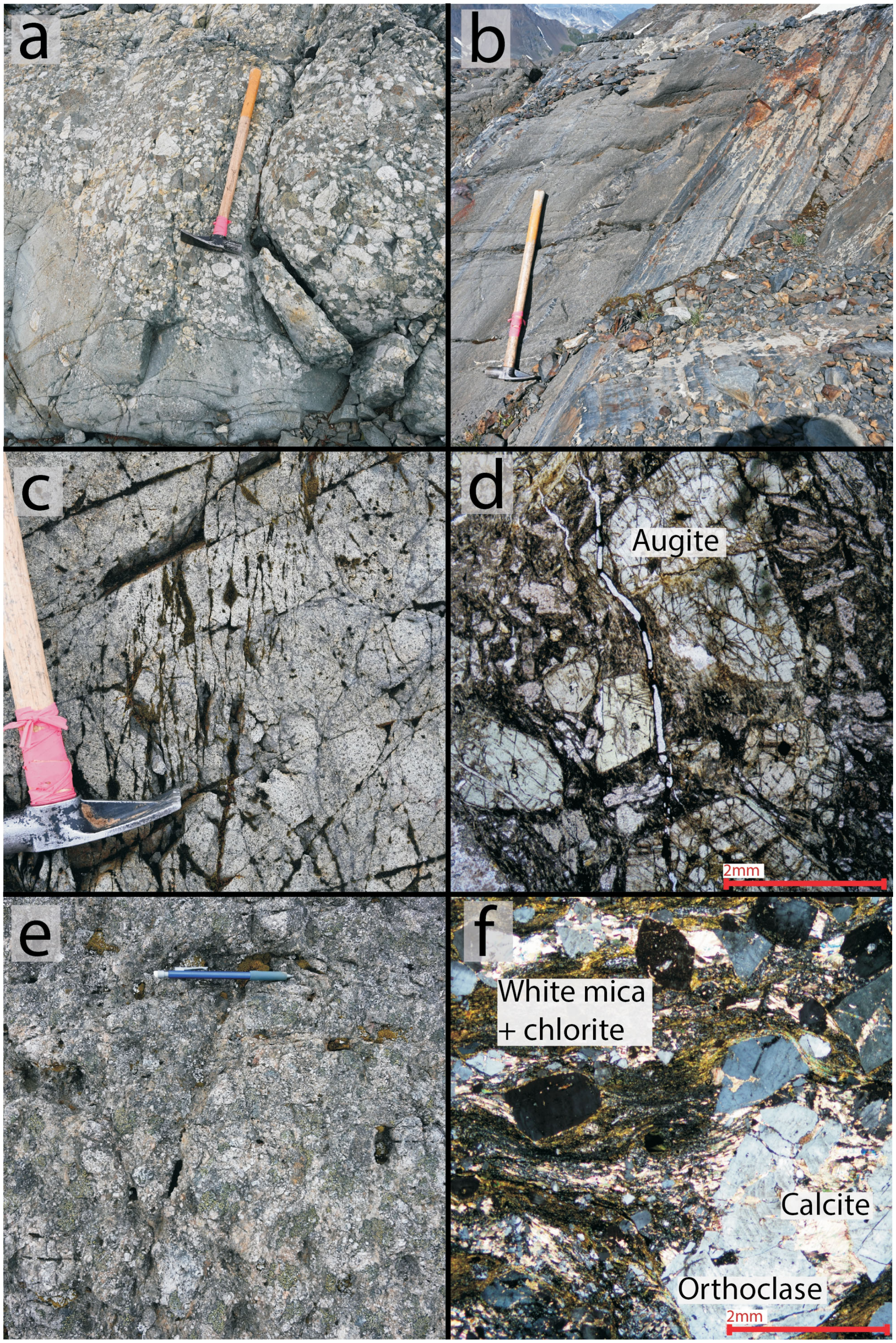

Figure 3. Photographs and photomicrographs of the lower intermediate to mafic volcanic and sedimentary succession of the Stuhini Group: a) field photograph of interbedded sandstone and polymictic conglomerate (unit uTrSvc); b) field photograph of interbedded sandstone and siltstone (unit uTrSs); c) field photograph of augite-phyric mafic volcanic rocks (unit uTrSvm); d) photomicrograph showing coarse augite crystals in a micaceous groundmass (unit uTrSvm); e) field photograph of orthoclase-bearing volcanic rocks (unit uTrSv.xor); f) photomicrograph of unit uTrSv.xor showing coarse orthoclase crystals set into a white mica–rich groundmass.

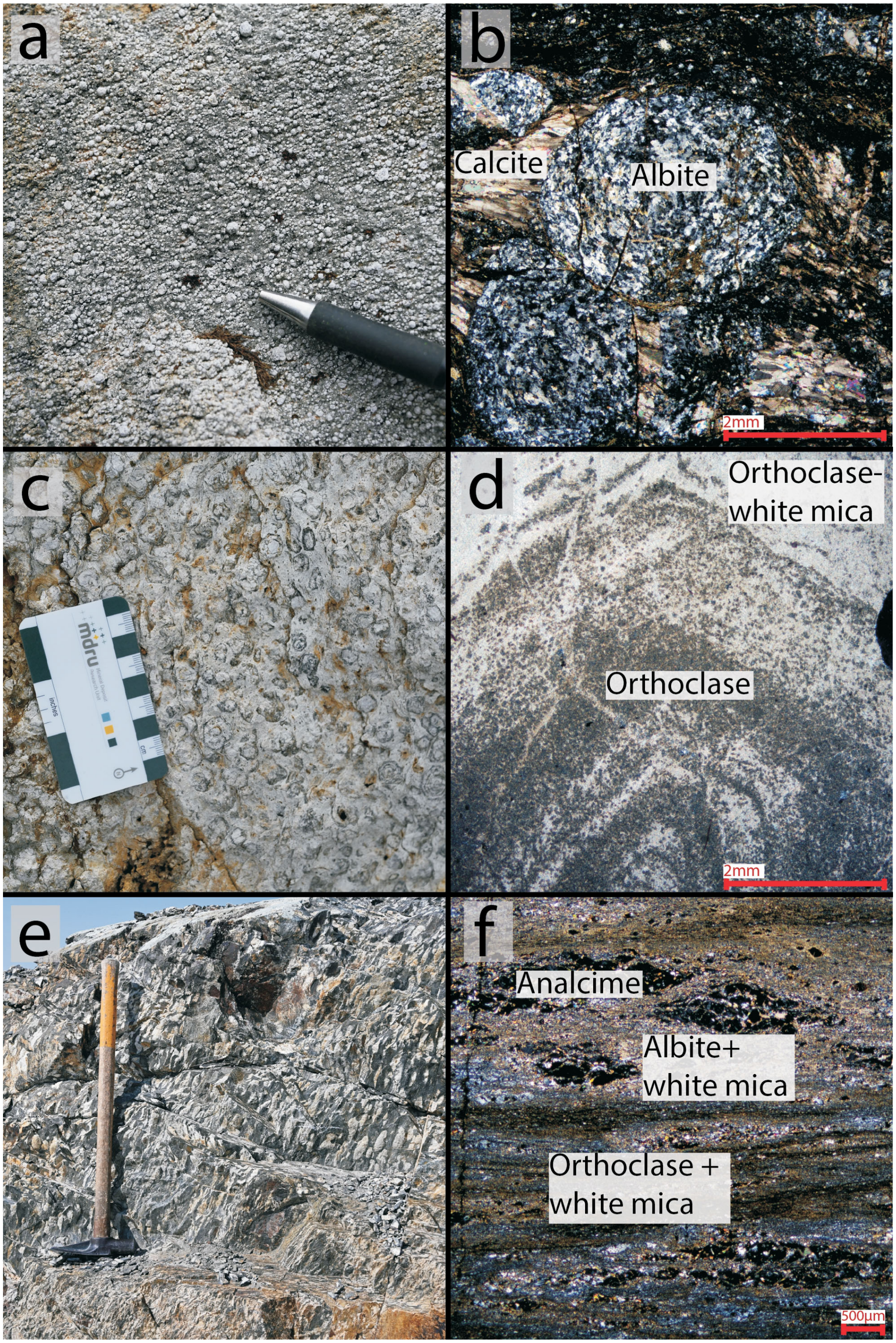

Figure 4. Photographs and photomicrographs of the upper alkalic volcanic succession of the Stuhini Group: a) field photograph of the feldspathoid-bearing mafic volcanic unit (uTrSvm.xanl); b) photomicrograph of the feldspathoid-bearing mafic volcanic unit (uTrSvm.xanl); c) field photograph of pseudoleucite crystals in the coarse feldspathoid-phyric volcanic unit (uTrSv.xlct), note the zonation in the crystals; d) photomicrograph of pseudoleucite crystals showing alternating orthoclase- and white mica–bearing zones (unit uTrSv.xlct); e) field photograph of stretched pseudoanalcime/analcime crystals in the coarse feldspathoid-phyric volcanic unit (uTrSv.xlct); f) photomicrograph of relict analcime (isometric minerals) in pseudoanalcime crystals, hosted in the coarse feldspathoid-phyric volcanic unit (uTrSv.xlct).

phyric volcanic unit (uTrSv.xlct). Due to the level of erosion, it is unknown if the coarse feldspathoid-phyric volcanic unit represents the final phase of deposition.

The feldspathoid-bearing rocks present at this site are not common in alkalic porphyry systems globally. This unusual composition has been attributed to a late pulse of Stuhini magmatism (Nelson and van Straaten, 2020).

Future Work

The stratigraphic observations presented here will be integrated with data and observations from the BC Geological Survey and Galore Creek Mining Corporation. Additional microanalytical work on the upper alkalic volcanic units will be conducted to provide a more complete geological history. Lithogeochemical analysis of rocks and corresponding petrographic samples will be compared for the purposes of estimating a metamorphic history of the deformed and undeformed rocks.

Conclusions

The upper alkalic volcanic sequence in the study area has only rarely been documented elsewhere in the Stuhini Group. In the study area, the volcanic stratigraphy of the Stuhini Group becomes increasingly alkalic upward, with the uppermost unit of coarse feldspathoid-phyric volcanic rocks being the most silica-undersaturated unit.

This work provides a revised stratigraphy for the Stuhini Group in the Galore Creek area. Regional explorers should be mindful of the unusual alkalic stratigraphy when exploring for Galore Creek–type porphyry systems in the region. Porphyry-style mineralization at Galore Creek is typically hosted in the upper alkalic stratigraphy (Enns et al., 1995; Schwab et al., 2008; Micko et al., 2014) and alkalic stratigraphy elsewhere may indicate the presence of similar alkalic intrusions that were responsible for mineralization.

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