Stratigraphic and Lithological Constraints of Late Cretaceous Volcanic Rocks in the TREK Project Area, Central British Columbia (NTS 093E)

R.S. Kim, Mineral Deposit Research Unit, University of British Columbia, Vancouver, BC, rsykim@eos.ubc.ca

C.J.R. Hart, Mineral Deposit Research Unit, University of British Columbia, Vancouver, BC

J.J. Angen, Mineral Deposit Research Unit, University of British Columbia, Vancouver, BC

J.M. Logan, Consulting Geologist, Victoria, BC

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Introduction

The TREK (**T**argeting **R**esources for **E**xploration and **K**nowledge) project aims to facilitate mineral exploration in the northern Interior Plateau in central British Columbia by using a multidisciplinary approach to improve geological confidence and knowledge (Clifford and Hart, 2014). The TREK area is considered to have high mineral exploration potential with numerous epithermal and porphyry deposits documented in the region, including New Gold Inc.'s Blackwater Au-Ag epithermal deposit. The hostrocks for the Blackwater orebody, and other epithermal occurrences in the region, are interpreted to be Late Cretaceous Kasalka Group volcanic rocks (Christie et al., 2014; Looby, 2015); consequently this volcanic rock package is highly prospective. However, extensive Eocene and Neogene magmatism, along with glacial till, obscure older bedrock exposure, leading to considerable uncertainty in the distribution of the Kasalka Group across central BC.

Fieldwork conducted in 2015 focused on the correlation of geophysical signatures to rock units and structures in the TREK area, as well as their relationships to mineral occurrences in the region (Angen et al., 2016). Comparisons to the Late Cretaceous Kasalka Group type section, defined by MacIntyre (1977, 1985, 1988) in the Tahtsa and Whitesail Lake areas (NTS 093E), will be made to better define the regional distribution of Late Cretaceous volcanic rocks throughout central BC. This project is a joint initiative between the Mineral Deposit Research Unit (MDRU) at the University of British Columbia (UBC) and Geoscience BC to characterize the Kasalka Group and to distinguish Late Cretaceous volcanic rocks from visually comparable Jurassic and Eocene volcanic suites in the area. The results from new regional 1:20 000 scale bedrock mapping, aided by high-resolution geophysical surveys (Angen et al., 2015), along with geochronological and geochemical analysis of field samples, will enable easier identification of the Kasalka Group rocks, thereby aiding in future exploration targeting initiatives within the TREK project area.

Keywords: *Kasalka Group, stratigraphy, TREK, volcanic, Late Cretaceous, mineral exploration*

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Regional Geology

Tectonic Framework

British Columbia consists predominantly of several tectonic blocks that accreted onto the western margin of ancestral North America during the Mesozoic Era (Monger, 1977). Much of central BC is underlain by the Intermontane Belt that comprises the amalgamated Stikine, Cache Creek and Quesnel terranes (Monger and Price, 2002). The Stikine and Quesnel terranes formed as volcanic-oceanic island arcs that may have been part of the same Late Triassic arc that enclosed the Cache Creek terrane during accretion onto the continental margin (Mihalynuk et al., 1994). The underlying units in the study area are Late Triassic to Middle Jurassic arc volcanic rocks of the Stikine terrane and their erosional products. Overlap basinal assemblages of the Bowser Lake Group record marine deposition from the Late Jurassic until the mid-Cretaceous, with subsequent deposition of the Skeena Group in the Early Cretaceous (Riddell, 2011). Continental volcanic arcs formed episodically through the Late Cretaceous to the Eocene and produced the Kasalka, Ootsa Lake and Endako groups of volcanic strata (Evenchick, 1991). The younger rocks exposed in central BC are dominantly the extensive Eocene Endako Group and basalt flows of the Neogene Chilcotin Group (Bevier et al., 1983).

Late Cretaceous Volcanic Rocks

Late Cretaceous volcanic rocks in the TREK project area are closely associated with several mineral deposits and occurrences, including hostrocks to the Blackwater deposit, with its epithermal style Au-Ag mineralization (Christie et

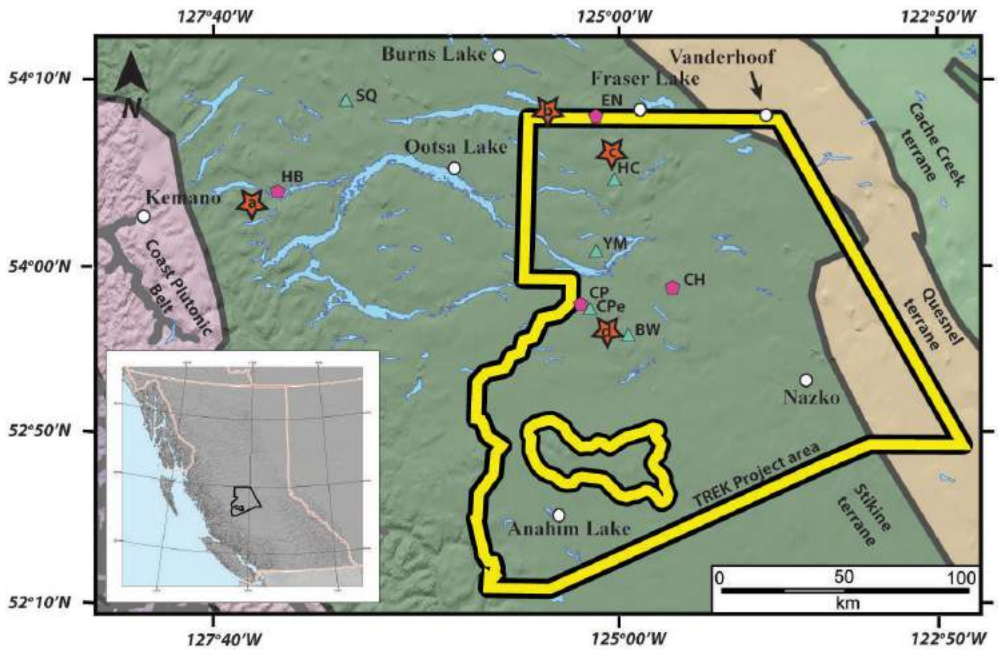

Figure 1. The TREK project area, central British Columbia, modified from Colpron et al. (2007). Stars indicate the locations of stratigraphic sections (See Figure 2) that are based on mapping of Late Cretaceous Kasalka Group rocks. Green triangles indicate locations of epithermal mineralization hosted in Late Cretaceous volcanic packages: BW, Blackwater; CPe, Capoose; HC, Holy Cross; SQ, Silver Queen; YM, Yellow Moose. Pink pentagons indicate porphyry deposits in the region. Jurassic: EN, Endako; Cretaceous: CP, Capoose; HB, Huckleberry; Eocene: CH, Chu.

al., 2014; Looby, 2015). Similar mineralization styles occur in Late Cretaceous felsic dikes and sills of the Capoose epithermal prospect (Figure 1), 27 km northwest of Blackwater (Andrew, 1988; Bordet et al., 2011). The Newton epithermal deposit, located ~175 km southeast of Blackwater in the Chilcotin Plateau, is hosted in Late Cretaceous felsic fragmental volcanic rocks (McClenaghan, 2013) and represents the most southerly known occurrence of Late Cretaceous epithermal mineralization in central BC. Late Cretaceous rocks of the Tip Top Hill (known informally as Brian Boru) Formation also host the Silver Queen epithermal Au-Ag-Zn-Pb deposit (Leitch et al., 1991) south of the town of Houston (Figure 1). The Huckleberry mine is a Cu-Mo porphyry deposit, hosted in the Late Cretaceous Bulkley intrusive suite and located approximately 120 km southwest of Houston, BC (MacIntyre, 1985; Ferbey and Levson, 2000; Diakow, 2006).

Kasalka Group

The Kasalka Group was first defined in the Whitesail Lake map area (NTS 093E) by D.G. MacIntyre (1977). The type section is characterized by a basal conglomerate that unconformably overlies deformed Lower Cretaceous Skeena Group rocks and is therefore interpreted to be deposited during the Late Cretaceous (MacIntyre, 1977, 1985). The conglomerate is overlain by thick packages of andesitic flows and volcaniclastic rocks. The uppermost members of the Kasalka Group consist of felsic flows and fragmental units (MacIntyre, 1977, 1985). The descriptions originally made at the type section are also applied to volcanic rocks across the northern half of the TREK project area, which is dominated by andesitic flows with minor felsic components (Anderson et al., 1999, 2000).

The distribution of the felsic flows and fragmental units in the northern half of the TREK project area, indicates their probable formation proximal to an eruptive centre, such as a rhyolite dome or a caldera complex (Looby, 2015). In the area west of the Blackwater deposit, this felsic package was initially interpreted to belong to the Eocene Ootsa Lake Group (Diakow and Levson, 1997), an interpretation supported by the paucity of mineralization compared to the felsic rocks within the Blackwater deposit (R. Whiteaker, pers. comm., 2015). Improved exposure with recent logging activity made it possible to conduct detailed mapping and improve understanding of the stratigraphic relationships of various units in the area, and has resulted in this package being reassigned to the Late Cretaceous (R. Whiteaker, pers. comm., 2015). A capping unit of a variably quartz-bearing rhyolite lithic-ash tuff is common to the Blackwater deposit (Figure 2d). This resistant unit is found to crop out at higher elevations near Blackwater, and was interpreted as part of the Eocene Ootsa Lake Group (Diakow and Levson, 1997). However, lithological similarities to the Late Cretaceous G-Pluton (quartz-eye granite dated at 68.3 ±2 Ma; R. Whiteaker, pers. comm., 2015) sug-

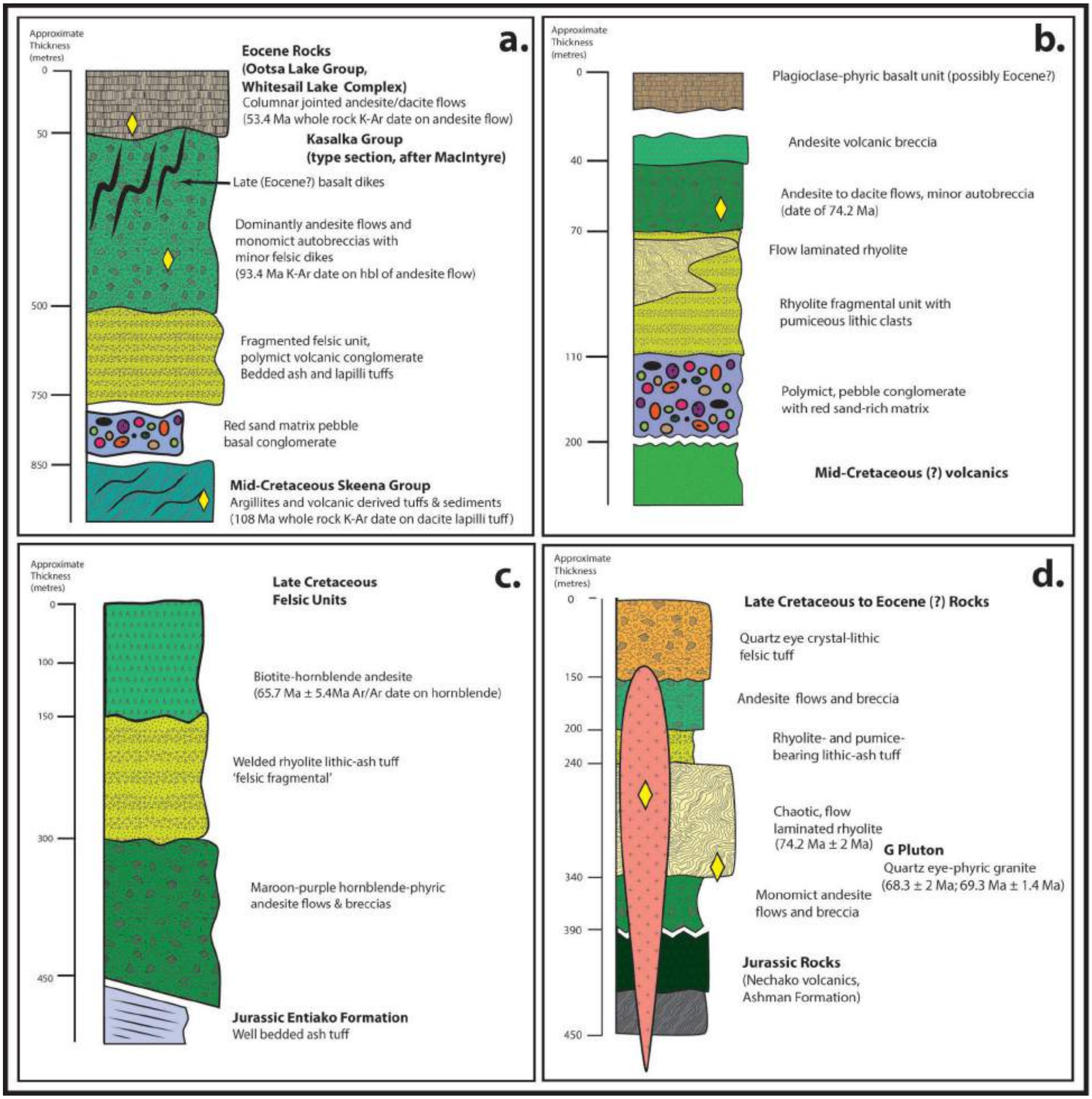

Figure 2. Stratigraphic schematics from the Kasalka type section and other localities in the study area: **a)** type section locality from the Kasalka Ranges (NTS 093E), K/Ar dates compiled in Diakow (2006), modified from MacIntyre (1985); **b)** stratigraphic schematic from Tchesinkut cell tower, north of Francois Lake, U/Pb date from Grainger (2000); **c)** stratigraphic schematic from the Cabin Lake area, in the northwest portion of the TREK project area, south of Francois Lake; Ar/Ar date from Friedman et al. (2001); **d)** stratigraphy west of Blackwater deposit, north of the access road, ages from R. Whiteaker (pers. comm., 2015).

gest that this unit was emplaced at a similar time as the intrusion. Felsic flows underlying this lithic-ash tuff are dated by New Gold Inc. as 74.2 ±2 Ma (R. Whiteaker, pers. comm., 2015) indicating that the underlying rocks also belong to Late Cretaceous stratigraphy.

Late Cretaceous stratigraphy is also observed near Cabin Lake (Figure 2c), where a felsic welded tuff unit underlies a capping sequence of a biotite hornblende andesite that was dated at 65.7 ±5.4 Ma (Friedman et al., 2001). This indicates the tuff must have been deposited prior to the biotite hornblende andesite.

Fieldwork

The fieldwork part of this project included the mapping of four localities (Figure 1). The first location (Figure 2b), was mapped as part of fieldwork conducted in 2014 and described in Kim et al. (2014). In 2015, three additional localities (Figure 2a, c, d) were mapped.

Continuous stratigraphic exposures of all units are rare in the project area. Late Cretaceous to Eocene stratigraphy is presented to correlate the lithological similarities observed at the regional scale. The Kasalka Group type section in the Tahtsa Lake area was sampled to facilitate geochemical and geochronological comparisons with examples of the Kasalka Group farther to the east.

Recent logging and forest fires have improved the surface exposure in the area allowing for detailed 1:20 000 scale mapping and studies of felsic rocks west of the Blackwater deposit. To supplement mapping, geochemical and geochronological samples were collected in the field, the results from which are anticipated to provide a comprehensive assessment of the Kasalka Group from the type section (Figure 3). This framework will then be used to compare the Late Cretaceous volcanic rocks in the TREK area to assess the similarities and/or differences between them.

Geochemistry

Whole-rock lithogeochemistry data were acquired from selected samples collected during the 2014 field season and are presented here (Figure 4). These data are plotted against previously published data (MacIntyre, 1985, 2001) in order to compare rock type and affinity. Geochemical data from the Kasalka Group and other Late Cretaceous volcanic packages indicate two main compositions: mafic to intermediate and felsic end members.

Geochemistry data from rocks in the Kasalka Group type section will be compared to new data to be obtained from rocks observed within the TREK area and collected in 2015. This comparison is expected to provide insights into the composition of, and distinctive element signatures from, each constituent unit.

Geochronology

Previous geochronological studies of Cretaceous and Jurassic rocks in the area were conducted in conjunction with the Nechako NATMAP project (Friedman and Armstrong, 1995; Friedman et al., 2001; Grainger et al., 2001; Struik and MacIntyre, 2001) and ages were largely obtained from K-Ar dating on whole rock, hornblende and/or biotite, in addition to U/Pb geochronology on zircons (Grainger, 2000; Friedman et al., 2001; Ferbey and Diakow, 2012; Christie et al., 2014; Looby, 2015; R. Whiteaker, pers. comm., 2015).

Published geochronological ages for the Kasalka Group show a broad distribution (Figure 5). MacIntyre (1988) reports ages ranging from 105 to 75 Ma suggesting that the Kasalka Group ranges from mid- to Late Cretaceous in age. Friedman et al. (2001) report Late Cretaceous ages ranging from 68.1 to 65.7 Ma for andesitic rocks that were previously mapped as Jurassic and Eocene in the Fawnie Range. At the Blackwater deposit, Late Cretaceous ages ranging from 72 to 70 Ma (Looby, 2015) and also 74.2 Ma (R. Whiteaker, pers. comm., 2015) are reported for felsic flow units.

A total of 20 samples were collected during the 2014 and 2015 field seasons for U-Pb dating on zircons using laser-ablation, multiple-collector inductively coupled plasma–mass spectrometry (LA-MC-ICP-MS) with another 11 samples collected for $^{40}Ar/^{39}Ar$ dating. The results will contribute to this project's aim to constrain the timing of Late Cretaceous volcanism in the TREK project area, and more specifically to define the age of the Kasalka Group volcanic suite.

Discussion

The volcanic rocks and suites in the northern and western TREK project area presented herein were documented in the field over the 2014–2015 field seasons. Late Cretaceous volcanic packages across the TREK project area are predominantly intermediate to felsic, coherent and fragmental packages.

The compilation of stratigraphic successions across the northern TREK area and at the Kasalka Group type sections show broad similarities in rock units. Figure 2 shows the general trend across each section of a middle felsic unit being under- and overlain by andesite breccias and flows. This package of felsic and intermediate rocks is also shown to overlie Jurassic Ashman Formation and mid-Cretaceous Skeena Group volcano-sedimentary packages. The basal conglomerate described in the Kasalka Group type section is not continuous, possibly the result of paleotopography.

The Kasalka Group rocks have been dated previously by a variety of methods (K-Ar on whole rock, biotite, hornblende; $^{40}Ar/^{39}Ar$ on hornblende; U-Pb on zircon. More recent geochronology results from zircon show the age range

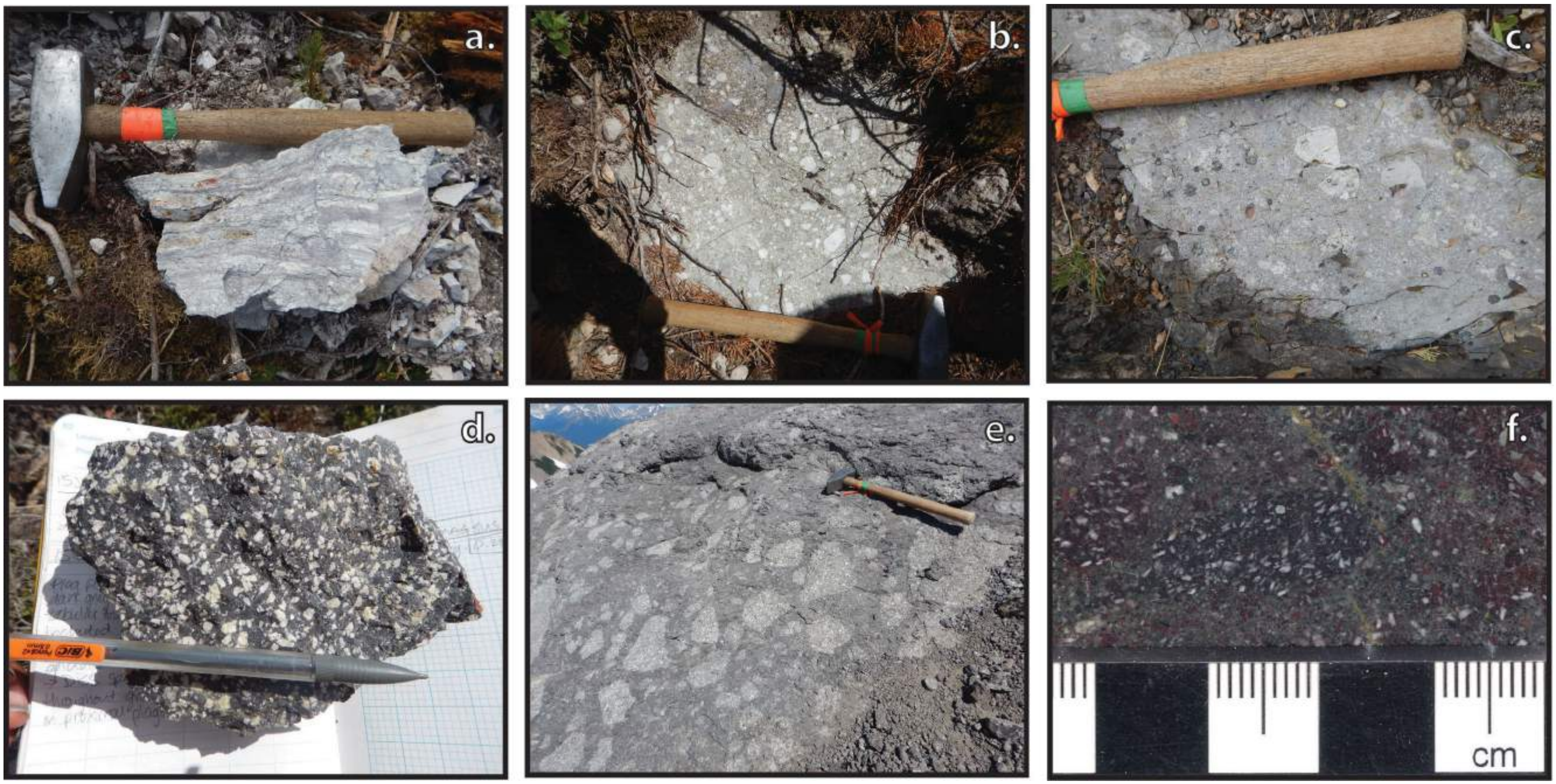

Figure 3. Examples of lithological units of the Kasalka Group: **a)** flow-banded rhyolite west of Blackwater; **b)** ‘felsic fragmental’, flow-banded rhyolite clast-dominated unit at Blackwater; **c)** andesitic volcanic breccia dominated by felsic clasts; **d)** plagioclase-phyric andesite; **e)** monomict, andesitic volcanic breccia from Kasalka type section; **f)** polymict, plagioclase-hornblende–phyric andesite breccia sampled from north of the Yellow Moose showing.

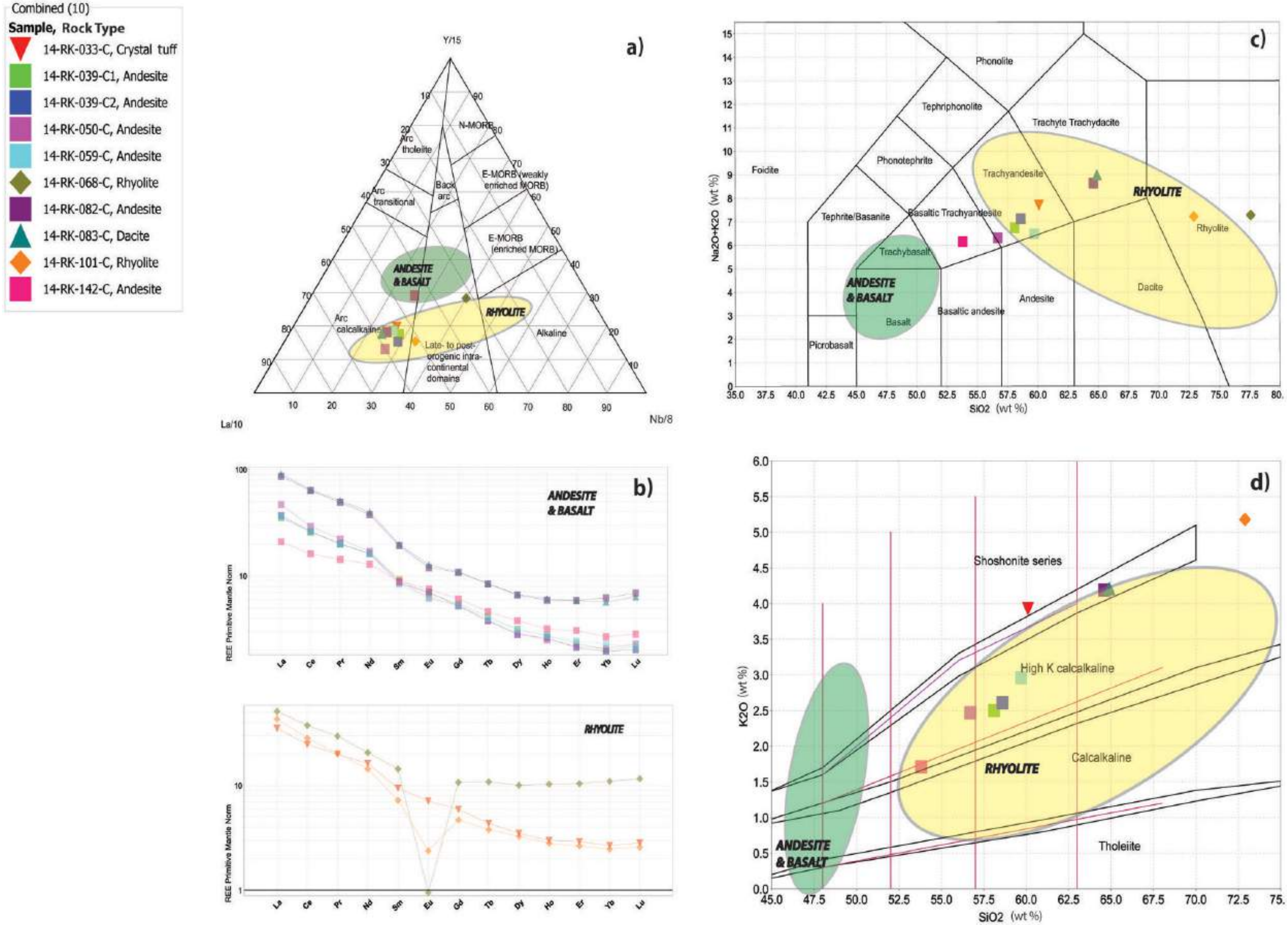

Figure 4. Compilation of geochemistry data collected from Late Cretaceous volcanic rocks across the Stikine terrane; samples collected in the 2014 field season. Ellipses represent Kasalka Group geochemistry data (MacIntyre, 1977, 1985, 2001): **a)** tectonic classification ternary plot, after Cabanis and Lecolle (1989); **b)** primitive mantle-normalized rare-earth element (REE) pattern (Sun and McDonough, 1989) for andesite and basaltic samples (top) and for rhyolite and crystal tuff samples (bottom); **c)** total alkali/silica (TAS) classification for volcanic rocks; **d)** Percillo-Taylor plot of K_2O vs. SiO_2.

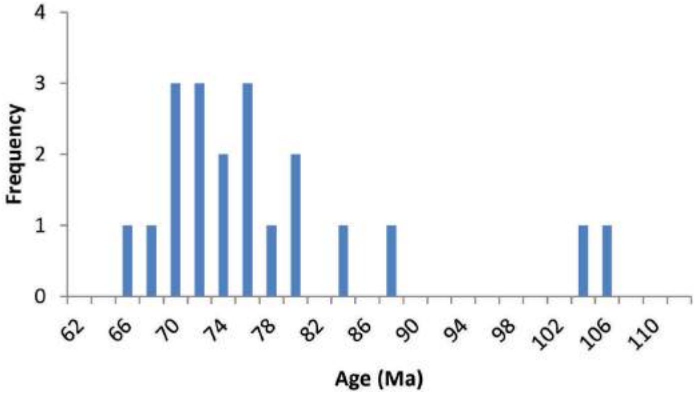

Figure 5. Compiled histogram of published ages for Kasalka Group and similar volcanic suites. Dating methods include K-Ar on whole rock, biotite and hornblende (MacIntyre, 1985; Leitch et al., 1991; Diakow et al., 1997; Friedman et al., 2001), and U/Pb on zircon (Grainger, 2000; Friedman et al., 2001; Ferbey and Diakow, 2012; McClenaghan, 2013; Looby, 2015).

for felsic components of the Kasalka Group to be from ca. 74 to 70 Ma (Friedman et al., 2001; Ferbey and Diakow, 2012; Looby, 2015; R. Whiteaker, pers. comm., 2015). Although the age ranges of these recent dates narrow the timing constraints, correlation to the units and their respective timing is sparse. The rocks mapped as the Kasalka Group in the TREK area may represent a different pulse of volcanism compared to the Kasalka Group type section.

The susceptibility of zircon inheritance in volcanic rocks may have affected the reported dates of older data, so this study will utilize cathodoluminescence imaging and LA-MC-ICP-MS to target both zircon populations and parts of zircon grains that represent the latest stages of growth to enhance the geochronological dataset. Dating using K-Ar methods is also prevalent for rocks associated with the Kasalka Group, particularly at the type section (MacIntyre 1977, 1985; Diakow, 2006). These methods have been proven to be unreliable in some cases, and this study will attempt to re-date these units using more robust methods, including $^{40}Ar/^{39}Ar$ and U-Pb on mineral grains.

Whole rock lithogeochemistry signatures for each unit of the Kasalka Group may provide further contrast when identifying rocks from the Jurassic, Late Cretaceous and Eocene. Rocks of the Late Cretaceous may be difficult to define based solely on whole-rock geochemistry, as indicated by Grainger (2000) who determined that geochemistry data from Kasalka Group rocks are identical to those from Eocene Ootsa Lake Group rocks. The focus of trace-element geochemistry on selected minerals such as hornblende and zircon, in addition to petrographic and geochronological analysis, may allow for a clearer distinction between visually similar units of Eocene, Cretaceous and Jurassic ages. The observations and analyses of samples collected at the Kasalka Group type section are anticipated to provide a geochemical footprint to compare against the Late Cretaceous volcanic packages farther west in the TREK area. Magnetic-susceptibility measurements taken in the field will also be compared to existing regional geophysical studies to further characterize various volcanic rocks in the study area. At the time of writing the authors await results for lithogeochemical and geochronology data for samples collected in the 2015 field season.

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