Insights from Syn- to Postmineralization Dikes into the Origin of the Brucejack High-Grade Gold-Silver Epithermal Deposit, Northwestern British Columbia (NTS 104B)

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Introduction

Precious- and base-metal mineralization in low- and intermediate-sulphidation epithermal systems is commonly distal to igneous intrusions. For example, auriferous fluids in low-sulphidation systems may be transported along basin-bounding structures that are kilometres long (Sillitoe and Hedenquist, 2005). Nonetheless, magmas are believed to be the thermal drivers of large-scale hydrothermal systems, as well as the principal contributors of precious metals to the epithermal realm (Gammons and Williams-Jones, 1997; Heinrich et al., 2004). At the Brucejack epithermal Au-Ag deposit in the Golden Triangle of northwestern British Columbia (BC), the absence of a recognized source intrusion for the auriferous vein system poses a challenge to constraining the timing and origin of the mineralization. However, dikes that cut the volcanic and volcaniclastic rocks that host the ore are common and believed to be syn- to postmineralization. In this paper, a summary of the geochemical characteristics of these dikes is presented to gain insight into the magmatic evolution of the potential source of the bonanza-grade gold mineralization.

The Brucejack deposit, which is situated in the Sulphurets mineral district (Figure 1a, b), is characterized by high-grade gold mineralization in carbonate-quartz veins and has a mineral resource, including measured, indicated and inferred categories, of 303.3 t (10.7 million oz.) of gold and 1771.8 t (62.5 million oz.) of silver (Tetra Tech, 2020); locally, gold grades reach 41 000 g/t in 0.5 m drillcore intervals (Board et al., 2020). This hyperenrichment of the gold has been attributed to colloidal transportation and deposition (McLeish et al., 2021). Several important genetic questions, however, remain unanswered, including the source of the gold.

In many epithermal systems, the highest gold and silver concentrations occur in veins and breccias that are interpreted to form as a result of the mixing of hot, low-salinity magmatic fluids, including condensed or contracted vapours, with cooler, meteoric water (Williams-Jones and Heinrich, 2005; Tosdal et al., 2009). In some cases, spatial and temporal associations with intrusive centres and associated porphyry deposits have been recognized (Hayba et al., 1985; Arribas et al., 1995; Hedenquist, 1995), which suggests late-stage magmatic fluids played a role in the formation of epithermal mineralization (Heinrich et al., 2004). Despite the lack of a recognized source intrusion at the Brucejack deposit, syn- to postmineralization dikes are evidence of at least a spatial association between the mineralization and magmatism. The dikes intrude most major hydrothermal domains in the deposit, including both mineralized and barren stockworks (Board et al, 2020). Locally, they cut early bonanza-grade quartz-carbonate veins but are generally cut by mineralized carbonate veins (McLeish, 2022); typically, however, the dikes are unmineralized. They are metre-wide, intermediate to mafic in composition and have trace– and rare-earth–element compositions similar to those of the host volcanic rocks (e.g., volcaniclastic andesite; Tombe, 2015) and therefore, likely share a similar magmatic origin. As the closest expression of magmatism that may be genetically linked to gold, these dikes provide an opportunity to target and fingerprint the potential source of fluids and mineralization at Brucejack.

A detailed petrographic and geochemical study of a suite of intermediate to mafic dikes that have a close spatial and

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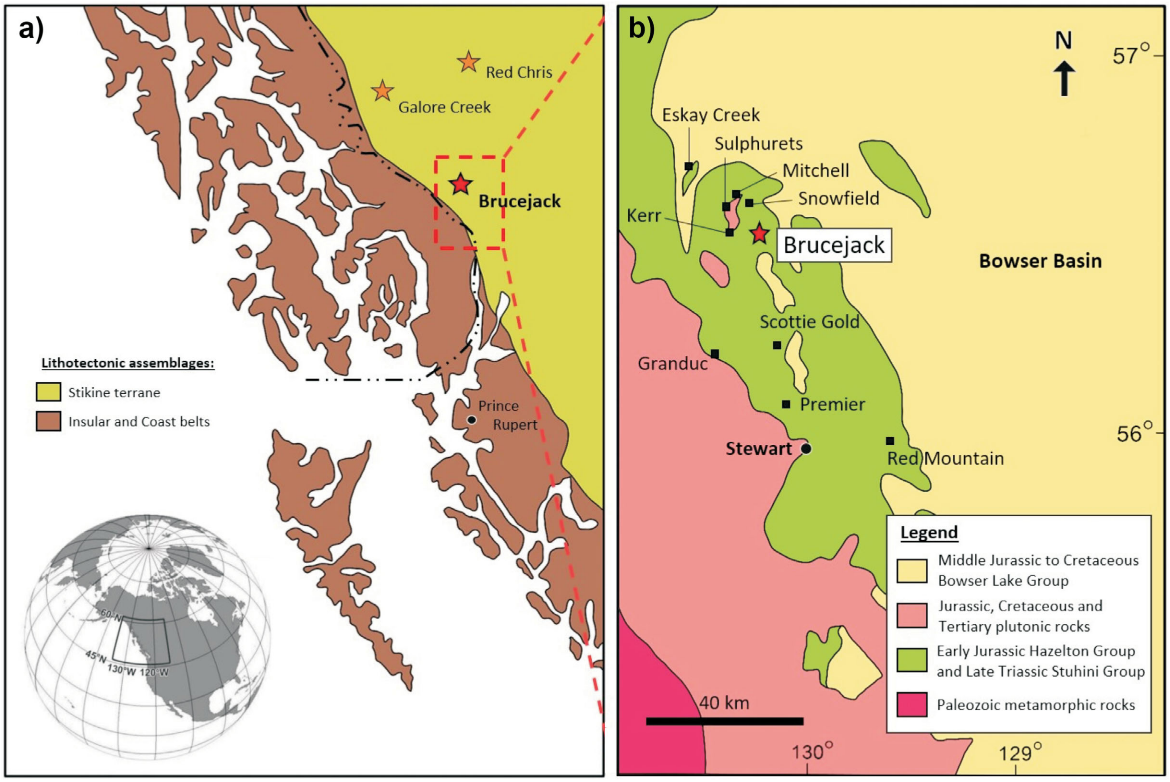

Figure 1. a) Regional geological setting of the Sulphurets mineral district in western Stikinia (modified from McLeish, 2013, with lithotectonic boundaries from Johnston, 2008). **b)** Select epithermal, volcanogenic massive-sulphide and porphyry-related deposits in the Brucejack mine area (modified from McLeish et al., 2018).

temporal association with the deposit was undertaken; the dikes are exposed in the mine and have been intersected in drillholes at depths >1 km beneath the main ore zones (Figure 2a, b).

Methods of Investigation

To better understand the spatial links between gold mineralization and syn-, late- and postmineralization dikes, a detailed review of the nature and distribution of dikes in the mapped and modelled vein corridors, including those within the Valley of the Kings mine area as well as in near-mine exploration areas (e.g., the West and Gossan Hill zones; Figure 2a, b), was conducted. Drillcore intervals of representative dike intersections from the deep-drilling program were sampled for whole-rock lithogeochemical analysis and compositional comparison with dikes in the current mine workings.

Core samples from the deep drillholes were collected at 0.5 to 1.5 m intervals and analyzed at ALS-Geochemistry (Vancouver, BC) for gold, as well as for major- and selected minor- and trace-element contents, using analytical packages ME-ICP61 and Au-AA26 (ALS, 2022). Pulp duplicates of 356 samples from the deep drillholes, including all major dikes and other intrusive units (Figure 2a, b), were analyzed for a wider spectrum of trace elements (including the rare-earth elements [REEs], Nb and Th) using analytical package ME-MS81d™ (ALS, 2022). In addition to the deep-drillhole samples, 24 dike samples sourced from within, or from drillholes immediately adjacent to, the Valley of the Kings and historic West zone mine workings were also sampled and analyzed at ALS-Geochemistry for major- and selected minor- and trace-element contents using analytical packages ME-XRF26, ME-MS81™, ME-MS61™ and F-ele82™ (ALS, 2022). All samples were subjected to lithium-borate fusion followed by digestion with a multi-acid solution, including hydrofluoric acid, to ensure near-complete extraction of the elements. All the data were processed and interpreted using the ioGAS™ software distributed by REFLEX.

Geological Setting, Mine Geology and Mineralization

Gold mineralization at the Brucejack deposit is hosted in the Early Jurassic Hazelton Group, comprising complexly deformed island-arc volcanic and volcano-sedimentary rocks of the Stikine terrane (Stikinia); the gold occurs in east- to east-northeast-trending ca.183 Ma epithermal veins (Board et al., 2020). The deposit is located along the Eskay Creek–Stewart trend of the Golden Triangle, together with Late Triassic and Early Jurassic subalkalic to alkalic porphyry and VMS deposits (Nelson et al., 2018), including Red Chris, Galore Creek, Kerr-Sulphurets-

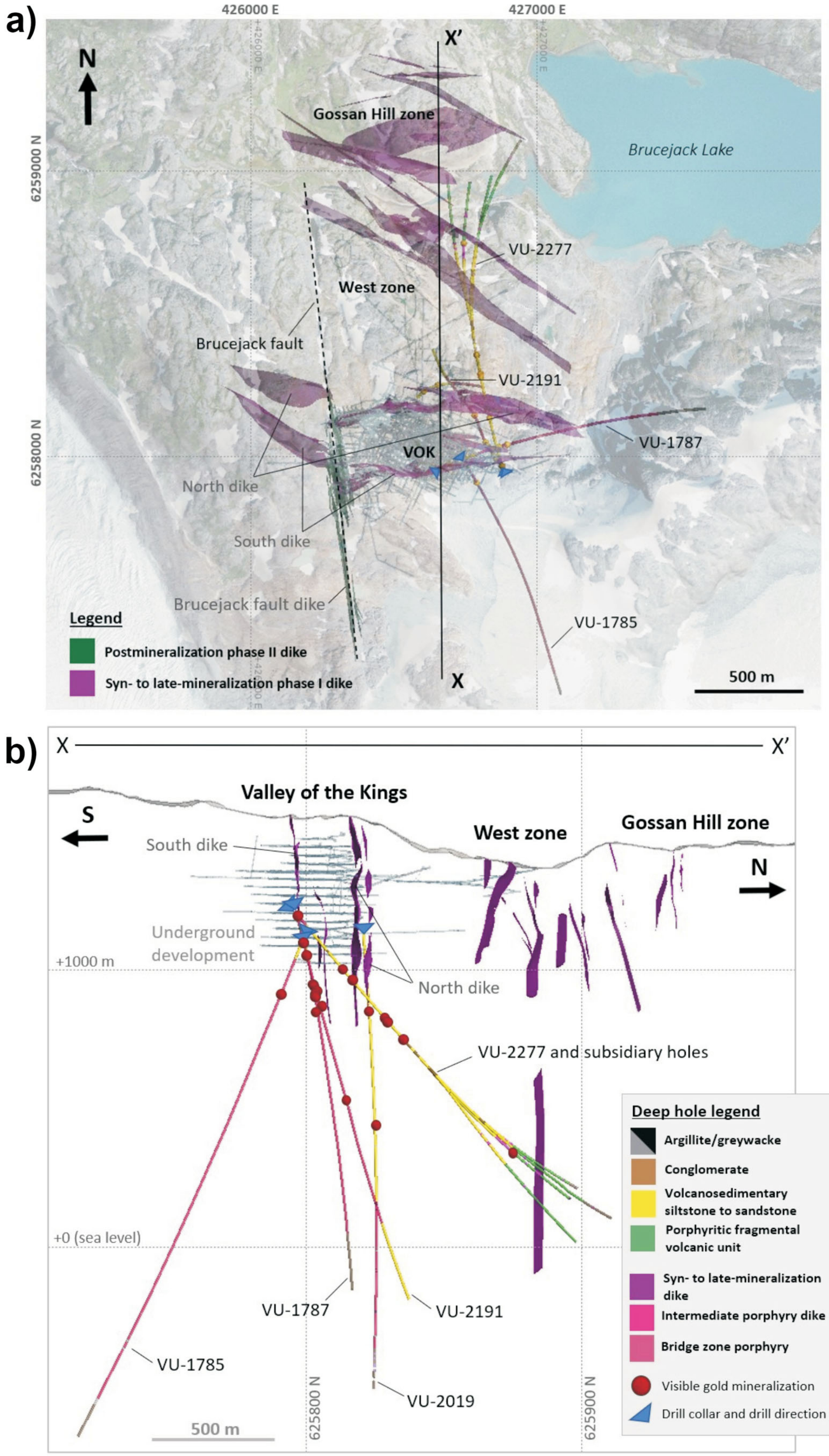

Figure 2. Valley of the Kings (VOK) zone and adjacent areas **a)** in plan view and **b)** in cross-section X-X', showing the extent of current mine development, the location and rock types of deep drillholes (e.g., VU-2277), the distribution of syn- to postmineralization dikes and intersections of bonanza-style gold in the deep holes.

Mitchell-Iron Cap and Eskay Creek. Stikinia is an allochthonous terrane, which evolved from an outboard intra-oceanic island-arc terrane within the peri-Laurentian realm during the mid-Paleozoic through to the initiation of end-on collision between the northern Stikinia microplate and the Yukon-Tanana terrane in the Late Triassic (212–200 Ma; Nelson et al, 2022). Closure of Stikinia against Quesnellia was initiated by counterclockwise rotation of the Stikinia arc and asymmetric advance of the Hazelton arc at ca. 189–185 Ma (Nixon et al., 2020). Ongoing accretion of Stikinia to the Laurentian margin and development of a back-arc tectonic regime occurred at ca. 185–178 Ma, which is coeval with the youngest lower Hazelton Group magmatism (Nelson et al., 2022).

The Valley of the Kings zone at Brucejack, which has been the focus of most of the current mine development, is located ~1 km southwest of Brucejack Lake (Figure 2a). The stratigraphy is characterized by a basal sequence of marine volcano-sedimentary rocks (ca. 195–194 Ma; Board et al., 2020; Nelson et al., 2022), including epiclastic volcanic sandstone, siltstone and mudstone, which are disconformably overlain by polymictic conglomerate comprising reworked, porphyritic intrusive and sedimentary pebbles to cobbles. The basal units were overlain by a transitional facies of fragmental andesite in a sandy matrix, which was succeeded by an upper andesitic volcanic sequence of agglomeratic latite flows and then by an uppermost andesitic to latitic potassium-feldspar–phyric crystal-tuff unit (Board et al. 2020; McLeish, 2022).

The Valley of the Kings zone experienced six stages of vein development (Tombe et al., 2018). Stage I and II veins are barren and consist of discontinuous pyrite-quartz-calcite stringers and translucent to white, microcrystalline quartz veinlets, respectively. Gold occurs predominantly in stage III to V quartz-carbonate-sericite veins, breccias and stockworks as electrum aggregates. Stage VI veins post-date mineralization and comprise quartz-calcite-chlorite tectonic-shear veins and/or tension gashes (Tombe et al., 2018). The auriferous veins crosscut most rock types (except postmineralization dikes), including all hydrothermally altered rock types and two generations of early foliation (Board et al., 2020).

The structures that focused the bonanza-grade quartz-carbonate stockworks were also exploited or locally cut by a generation of east-trending mafic dikes, here termed ‘phase I’ dikes, which have been interpreted as syn- to late mineralization, based on crosscutting relationships between the dikes and auriferous veins; phase I dikes cut, and are themselves cut, by auriferous veins (Tombe et al., 2018). Distinct from these dikes are a group of north-trending, postmineralization dikes, including the Brucejack fault dike (Figures 2a, 3e), which are referred to here as ‘phase II’ dikes; these dikes cut the auriferous veins and the phase I mafic dikes at high angles (Board et al., 2020). Drilling has demonstrated that intense phyllic alteration, bonanza-type gold mineralization, and the phase I and II dikes continue to at least 1300 m below the top of the present erosional surface in the Valley of the Kings zone (Figure 2b; McLeish, 2022), which exceeds the vertical extent (i.e., 50–700 m below the paleowater table) of most epithermal deposits (Hedenquist et al., 2000). In addition to the phase I and II dikes, five texturally and mineralogically distinct dikes have been encountered in deep exploration holes beneath the mine workings.

Spatial Distribution of Phase I and II Dikes in the Valley of the Kings Zone and Adjacent Areas

The syn- to late-mineralization phase I mafic dikes (i.e., North dike and South dike) respectively exploit two major east-trending, steeply dipping extensional and mineralized structures, the domain 13 and domain 20 faults (Figure 3a, b). These light green to milky green, aphanitic to fine-grained dikes, commonly metres to locally decimetres in width, exhibit moderate carbonate and chlorite alteration (Figure 3c, d). Calcite±chlorite–filled amygdules occur throughout the dikes, which have finely banded chilled margins. Phase I mafic dikes are porphyritic and are characterized by an aphanitic, magnetic groundmass that has been pervasively replaced by sericite and disseminated pyrite. Phenocrysts of hornblende and plagioclase have been replaced by sericite (Figures 3c, d, 4a). A 182.7 ±1.0 Ma U-Pb zircon age was obtained for North dike and is interpreted to provide a minimum age for the epithermal mineralization in the Valley of the Kings zone (Board et al., 2020).

In contrast, the postmineralization phase II dikes in the Valley of the Kings zone are dark grey to black, fine to medium grained, undeformed and relatively unaltered. They are characterized by poikilitic hornblende laths and fine-grained magnetite that is partly or fully enclosed by plagioclase oikocrysts (Figure 4b); these dikes exhibit weak propylitic alteration. The dikes are also steeply dipping, north-trending and occur proximal to, and along, the north-trending Brucejack fault, which crosscuts all hostrock types, gold mineralization and foliation (Board et al., 2020). Surface expressions of these dikes have been identified across the Valley of the Kings mine area and surrounding exploration areas, including metre-wide outcrops near the Gossan Hill zone (Figure 2a).

Numerous other dikes with variable orientation and composition (described below) were sampled from drillcore and outcrops adjacent to the mine areas, including veined syn- to late-mineralization dikes at Gossan Hill and relatively shallow-dipping dikes parallel to ore domains in the West zone (Figure 2b). Like the phase I mafic dikes in the Valley of the Kings zone, some of these dikes exploited

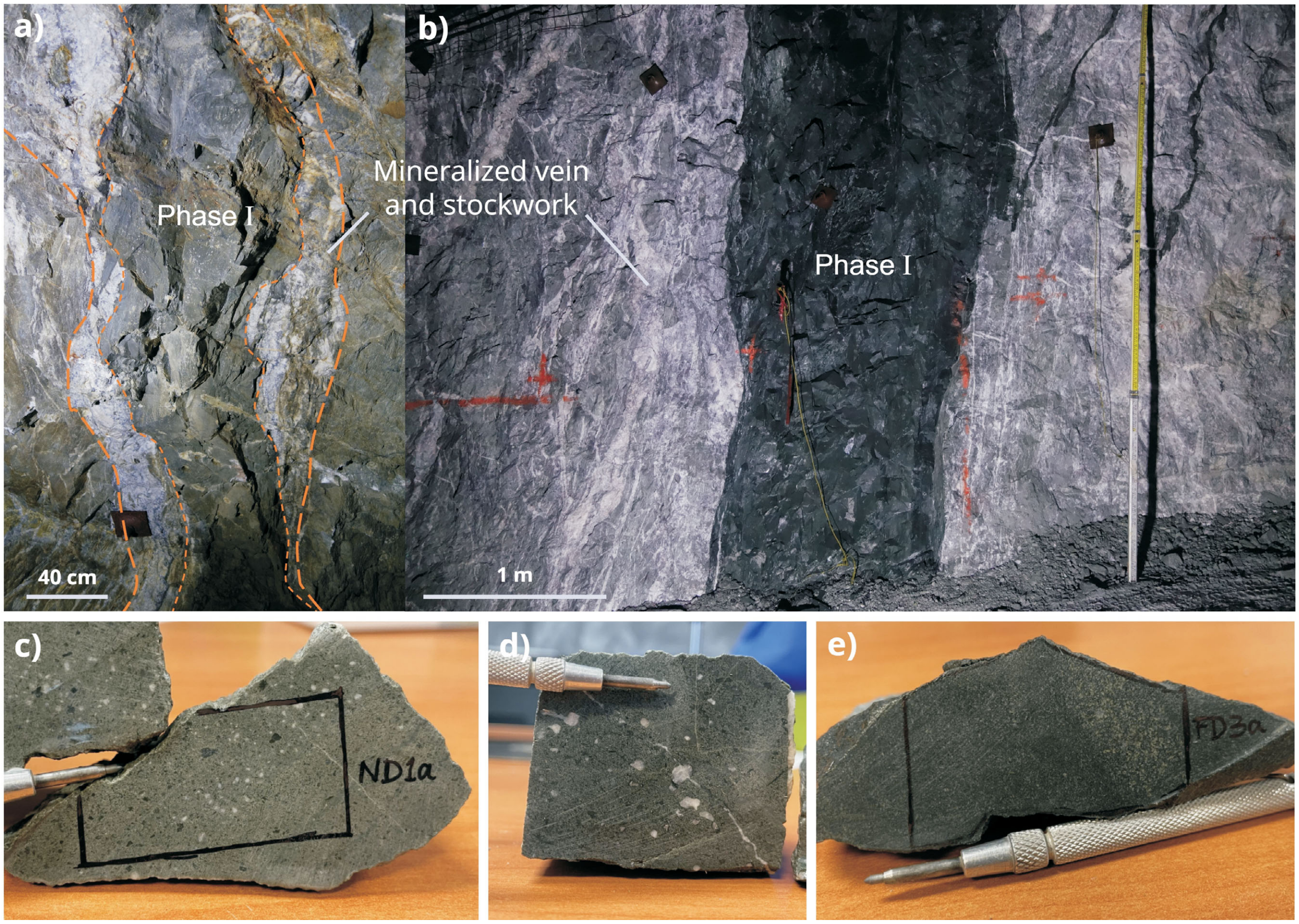

Figure 3. Representative photographs of mafic dikes showing the spatial relationships between mineralized quartz-carbonate stockworks and phase I mafic dikes underground in **a)** South dike and **b)** North dike, as well as in syn- to postmineralization dike hand samples from **c)** North dike phase I, **d)** South dike phase I and **e)** Brucejack fault dike phase II in the Valley of the Kings zone.

structural corridors similar to fault stockworks of mineralized domains 13 and 20, which host bonanza-grade gold and base-metal–sulphide mineralization.

The Vertical Extent of the Valley of the Kings Zone and Alteration

A deep-drilling program was conducted by Pretium Resources Inc. (acquired by Newcrest Mining Limited in 2022) between 2018 and 2020 to determine the vertical extent of gold mineralization beneath the Valley of the Kings zone and search for a potential magmatic source for the deposit. The dominant rock type in most of these holes is a variably altered (shallow phyllic alteration and deeper propylitic alteration) plagioclase- and hornblende-phyric porphyry, which is referred to by company geologists as the 'Bridge zone porphyry' because of its similarity to the main intrusive phase in the Bridge zone, a target of exploration near the Valley of the Kings zone. In drillholes VU-2277 and VU-2019 (Pretium Resources Inc., unpublished data, 2022), the main unit is a thick volcano-sedimentary package of sandy to silty sediments with local metre-thick interbeds of pebbly clast-supported oligomictic to polymictic conglomerates. The lowermost part of drillhole VU-2277 (Pretium Resources Inc., unpublished data, 2022) intersects a mafic, porphyritic fragmental volcanic unit that has an interval over 200 m long and is spatially associated with intermittent, metre-wide intermediate porphyry dikes (Figure 2b).

Mafic to intermediate dikes were encountered in all the deep holes and comprise both syn- to late-mineralization mafic–intermediate dikes and postmineralization mafic dikes, as well as other varieties of dikes (minor), which are described and classified below based on composition.

Results and Interpretation

Pervasive hydrothermal alteration and postmineralization metamorphism, up to subgreenschist facies (Board et al., 2020), have modified the primary compositions of the rocks in the Valley of the Kings zone and surrounding areas. As a result, mobile elements, such as potassium and sodium, cannot be used to assess the original compositions of most units. Therefore, relatively immobile elements (i.e.,

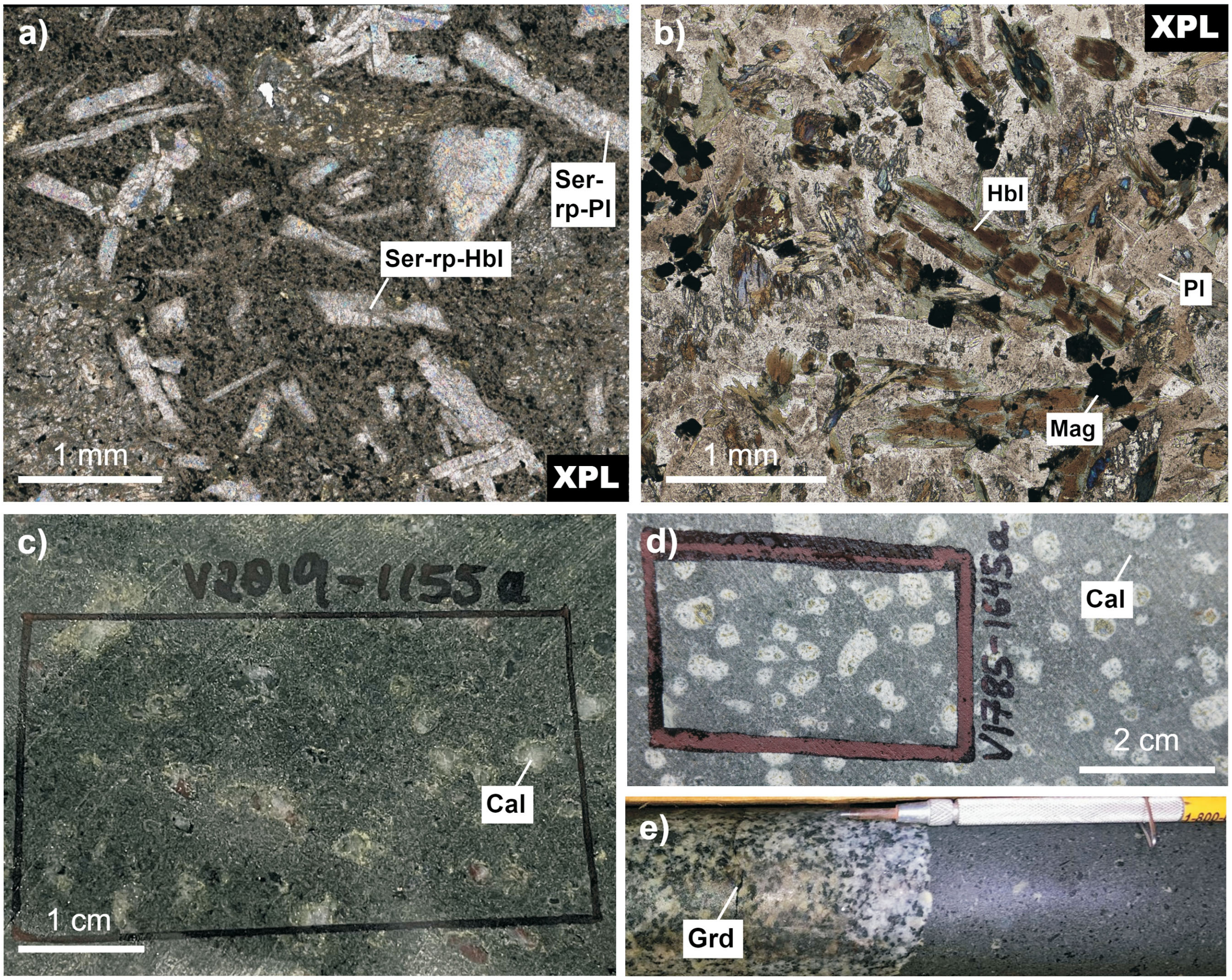

Figure 4. Photomicrographs of dikes from deep holes in the Brucejack deposit area and drillcore photographs of three texturally distinct intermediate to mafic dikes from Valley of the Kings mine workings: **a)** photomicrograph in cross-polarized light (XPL) of a syn- to late-mineralization phase I mafic dike containing sericite-replaced hornblende (Ser-rp-Hbl) and sericite-replaced plagioclase (Ser-rp-Pl) phenocrysts in a moderately sericitized groundmass; **b)** photomicrograph in cross-polarized light of a postmineralization phase II mafic dike containing large hornblende (Hbl) and plagioclase (Pl) phenocrysts that partly enclose smaller magnetite (Mag) euhedral crystals, which are also surrounded by groundmass; **c)** syn- to late-mineralization phase I mafic dike with calcite (Cal)-filled amygdule; **d)** relatively unaltered mafic dike with densely packed, calcite-(epidote)-filled vesicles; **e)** mafic to intermediate dike with a granodiorite (Grd) xenolith.

REEs and other high-field-strength elements [(HFSEs)] and their ratios were used to evaluate the primary geochemical characteristics of the dikes (Figure 5a, b). An immobile-element dataset of mine-hosted syn- to late-mineralization phase I dikes, including North and South dikes (Figure 2a, b), which are concordant with major mineralized domains, was evaluated and compared with a separate dataset for dikes intersected in the deep holes. Six types of texturally and geochemically distinct dikes were identified and are described below.

Syn- to Late-Mineralization Phase I Mafic Dikes

Metre-scale mafic dikes are common below the Brucejack deposit. They are aphanitic, green in colour, pervasively sericitized with local carbonate and chlorite alteration patches, and contain relics of hornblende and plagioclase, together with calcite-filled vesicles (Figure 4c). These dikes are similar to, and are considered to be, the deeper expression of the syn- to late-mineralization phase I mafic dikes in the mine, as they exhibit comparable mineralogy, textures, composition, alteration and relationships to veins (Figures 3–d, 4a, 5a). Both sets of dikes classify as subalkaline basalt (Figure 5a) and have higher V, Fe and Ti concentrations and lower Ba and Th than other dikes, except postmineralization mafic dikes.

Postmineralization Dikes

Most of the postmineralization dikes intersected in the deep holes are black to light grey, medium grained, relatively

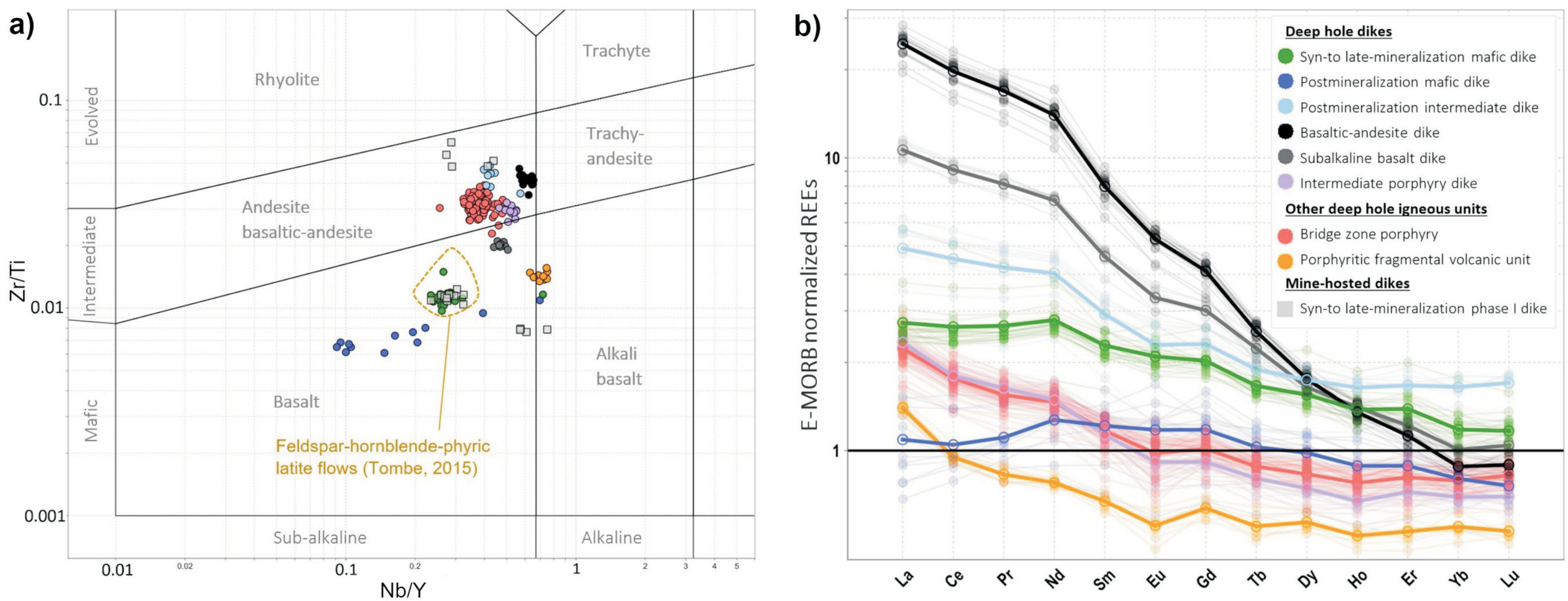

Figure 5. Geochemical characteristics of the dikes in the Brucejack deposit area: **a)** dike compositions on a volcanic-rock discrimination diagram of immobile-element ratios (Zr/Ti–Nb/Y; Pearce, 1996); **b)** dike REE profiles on a spider diagram normalized to enriched mid-ocean–ridge basalt (E-MORB; Sun and McDonough, 1989). Legend applies to both diagrams.

unaltered and undeformed. They can be divided into two geochemically distinct subclasses (corresponding to mafic and intermediate compositions) based on incompatible elements:

- Postmineralization mafic dikes that are typically dark grey to black, fine to medium grained, locally amygdaloidal and have a weakly sericite(-carbonate-chlorite)–altered groundmass, locally containing sericitized plagioclase phenocrysts; geochemically, they are characterized by elevated Cr, Sc, V and Ti contents and classify as subalkalic, tholeiitic basalt (Figure 5a).
- Postmineralization intermediate dikes that are typically grey to dark grey and fine to medium grained, plagioclase-phyric and either unaltered or locally weakly sericitized; they have relatively elevated concentrations of REEs and HFSEs, including Nb, Zr and P, and classify as andesitic basalt (Figure 5a).

Basaltic-Andesite Dikes

Basaltic-andesite dikes are restricted to depths greater than, or equal to, ~2 km below the erosional surface. They are relatively unaltered, dark grey, porphyritic, amygdaloidal and contain occasional granodiorite xenoliths (Figure 4e). These rocks are characterized by high concentrations of Ba, Sr, P, light REEs and most HFSEs, including Zr, Th and Nb (Figure 5b). Based on their immobile-element ratios, samples of this unit have a borderline alkaline affinity (Figure 5a).

Subalkaline Basalt Dikes

Subalkaline basalt dikes intersected in the deep holes are restricted to depths between 1 and 1.6 km below the current erosional level (Figure 2b) and are geochemically distinct. They are relatively unaltered, very dark grey, aphanitic and show minor or no evidence of deformation. Calcite amygdules are common (Figure 4d) as is decimetre-wide layering, suggesting multiple injections of magma. These dikes are more mafic than the basaltic-andesite dikes, as shown by their high concentrations of Cr, Ti and Co. However, they have E-MORB–normalized REE profiles similar to the basaltic-andesite dikes, albeit with lower absolute-element concentrations (Figure 5b). The immobile-element ratios indicate that the dikes are subalkaline to borderline alkaline and basaltic (Figure 5a).

Intermediate Porphyry Dikes and Bridge Zone Porphyry

The intermediate porphyry dikes and the mineralized Bridge zone porphyry have indistinguishable trace-element compositions; both classify as subalkaline intermediate intrusions (Figure 5a). Both the Bridge zone porphyry and the intermediate porphyry dikes are characterized by relatively high concentrations of Th (3.12–5.04 ppm), whereas those of Ti, P and REEs (ΣTREE: 55–86 ppm) are low. They have Zr, Nb and REE concentrations and La/Yb ratios ([La/Yb]N: 3.88–7.65) similar to those of the syn- to late-mineralization mafic dikes.

Porphyritic Fragmental Volcanic Unit

The porphyritic fragmental volcanic unit classifies as an alkali basalt and is characterized by low concentrations of REEs (ΣTREE: 40–45 ppm), with slightly enriched light REEs and almost flat middle and heavy REE profiles (Figure 5b).

Discussion

The REE concentrations of all intermediate- to mafic-dike generations (except deep postmineralization mafic dikes) are characterized by light and middle REE enrichment relative to E-MORB and other igneous units (i.e., the Bridge zone porphyry, the intermediate porphyry dikes and the porphyritic fragmental volcanic unit; Figures 2b, 5b). The postmineralization mafic dikes have profiles very similar to E-MORB, with slightly elevated middle REE concentrations (Figure 5b). All units are readily distinguished one from the other by their REE profiles as well as their La/Yb, Ti/Yb, Th/Yb and Nb/Yb ratios (Figures 5b, 6a, b).

Syn- to late-mineralization phase I mafic dikes exposed in the mine and intersected in drillholes below are closest in affinity to E-MORB in terms of their TiO_2/Yb, Th/Yb and Nb/Yb ratios (Figure 6a, b), which may indicate the incorporation of enriched lithosphere (Pearce, 2008). In addition, the high Nb/Yb (2.38–3.52) and low Ti/Yb (0.50–0.71) ratios suggest a low degree of partial melting (<5%) from a relatively shallow, low-temperature mantle source (2.0–2.5 GPa) that is atypical of subduction-related arc magmas (Pearce, 2008). These ratios, however, could reflect a higher degree of partial melting (10–13%) of a more deeply sourced alkalic magma (Pearce, 2008). As the Brucejack deposit is spatially and temporally linked to other alkaline systems in the Golden Triangle, consideration should be given to the possibility that the phase I-type dikes represent mafic alkalic intrusions related to postsubduction extension. More specifically, the phase I syn- to late-mineralization mafic dikes may provide further evidence of mafic alkalic magmatism related to Pliensbachian postcollisional back-arc extension in Stikinia and the ultimate demise of the Hazelton volcanic arc (Nelson et al., 2022).

Significantly, the phase I dikes have Zr/Ti and Nb/Y ratios that are indistinguishable from those of the broadly coeval (182.6 ±1.1 Ma; McLeish, 2022) mineralized andesitic to latitic potassium-feldspar–phyric crystal-tuff unit (Figure 5a). Indeed, based on their similar ages, these phase I-dike corridors are considered to be the feeder structures for the latite flows (Board et al, 2020), which are interpreted to have been mineralized soon after eruption, given that the

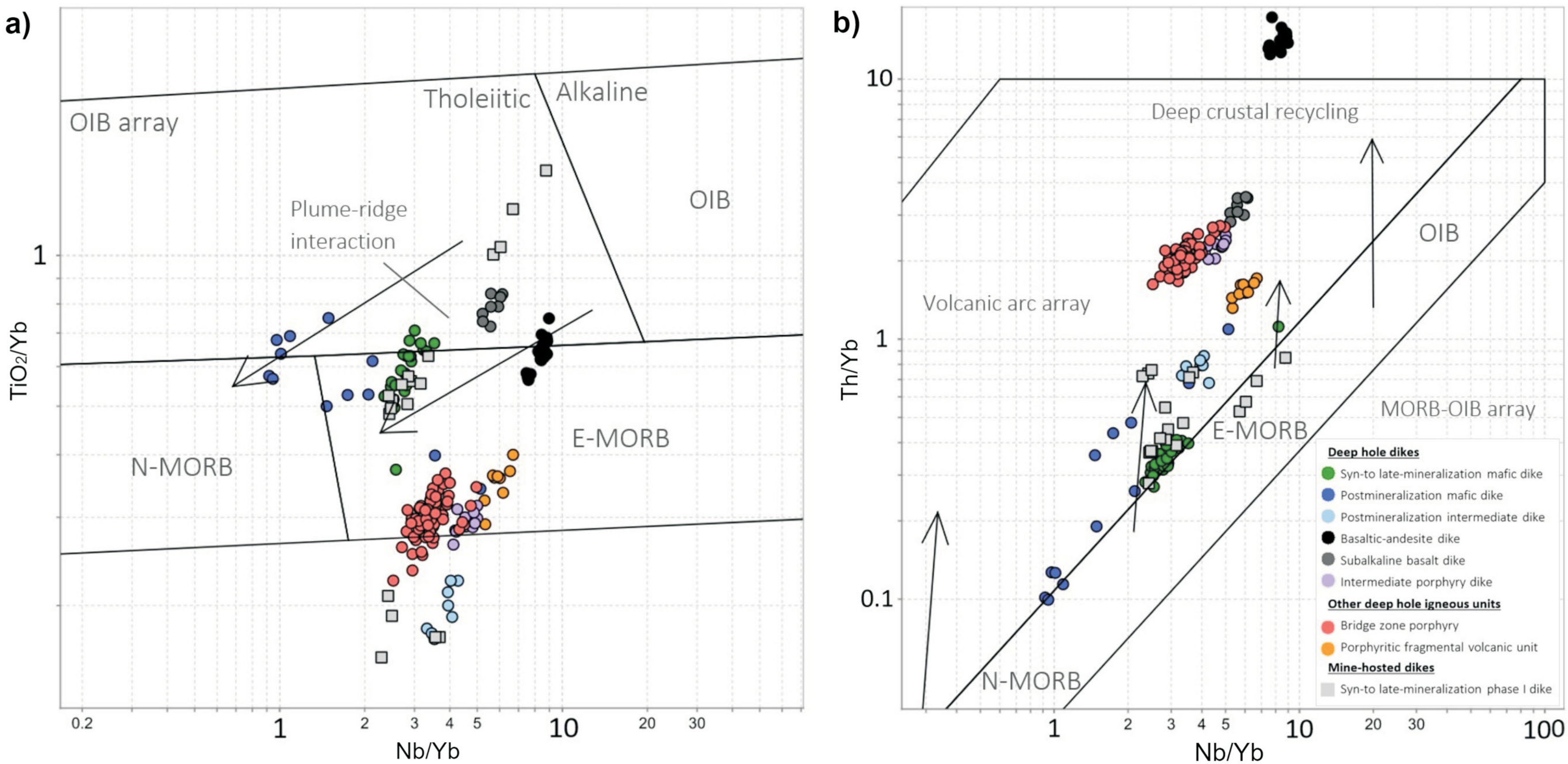

Figure 6. Immobile-element–ratio diagrams of dike compositions in the Brucejack deposit area designed to illustrate the effect of various petrogenetic processes (Pearce, 2008): **a)** TiO_2/Yb versus Nb/Yb; **b)** Th/Yb versus Nb/Yb (legend applies to both diagrams). Abbreviations: E-MORB, enriched mid-ocean–ridge basalt; N-MORB, normal (N-type) mid-ocean–ridge basalt; OIB, oceanic-island basalt.

dikes cut the early stage mineralized veins. Although the source of the syn- to late-mineralization mafic magmas remains uncertain, it seems likely that hydrothermal circulation associated with the gold mineralization may have been driven by an intrusion of this type at depth below the Valley of the Kings zone.

The postmineralization phase II mafic dikes display a primitive island-arc tholeiitic affiliation, as suggested by their E-MORB–like REE profiles (ΣTREE: 42–65 ppm; [La/Yb]N: 1.64–3.69) and their high Fe, Cr and Co contents. The Nb/Yb (0.92 5.13) and Th/Yb (0.10–1.09) ratios are highly variable and trend from N-MORB–like to continental-arc–like basaltic compositions (Figure 6b). This may signify a continental component in the ascending magmas. In contrast, the postmineralization intermediate dikes are relatively rich in REEs (ΣTREE: 142–214 ppm), especially the heavy REEs, whereas REE fractionation is subtle (Figure 5b). Given the relative enrichment in REEs and HSFEs in these dikes, they likely evolved from enriched mantle contaminated by crust (Pearce, 2008). As the age of the postmineralization intrusive event is still undetermined, the relationship between the mafic and intermediate subunits remains unclear.

The basaltic-andesite (BA) and subalkaline basalt dikes (SAB) have similar REE profiles, are relatively enriched in light and middle REEs, and are strongly fractionated. Basaltic rocks with very high (La/Yb)N ratios (BA: 42.8–58.3; SAB: 17.5–20.8) and no apparent depletion in Nb, Ta and Ti are commonly classified as alkaline (Weaver, 1991), although in Figure 5a they classify as subalkaline (the BA is borderline alkaline). Significant contributions by crustal components may have caused the high Th/Yb ratios (BA: 12.5–17.3; SAB: 2.82–3.52) of both dike types (Figure 6b). It is tentatively proposed that these magmas were sourced from a deep mantle after a low degree of partial melting and subsequently assimilated crustal material. From their similar geochemical signatures and close spatial association, it is further proposed that the BA and SAB dikes are genetically related and that the BA magma is probably an evolved product of the SAB magma.

Conclusions and Future Work

Six types of dikes were classified at the Brucejack deposit, based on their immobile-element (i.e., rare-earth elements, high-field-strength elements) concentrations and ratios and on their enriched mid-ocean–ridge basalt–normalized rare-earth element distributions. Discrimination diagrams suggest a geochemical affinity ranging from subalkaline basalt for the syn- to late-mineralization dikes to basaltic-andesite. Systematic differences in rare-earth element profiles (i.e., ΣREE, [La/Yb]N) and the concentrations of other high-field-strength elements suggest an enriched magma source that could possibly have been generated during rifting. The discrimination diagrams also suggest a genetic link between the syn- to late-mineralization mafic dikes intersected in deep drillholes and those occurring within high-grade mineralized corridors in the mine (Figure 5a).

Syn- to late-mineralization mafic dikes are characterized by moderate Ti/Yb and Nb/Yb ratios and may have been emplaced during back-arc rifting. Postmineralization structural events (e.g., the development of the Brucejack fault) are believed to have controlled emplacement of the postmineralization dikes, which experienced variable degrees of fractionation, leading to two subclasses (i.e., mafic and intermediate). Evidence of enrichment in immobile elements and strong rare-earth element fractionation in the basaltic-andesite and subalkaline basalt dikes suggest a deep mantle source and a high degree of crustal interaction.

Uranium-lead age determinations and a trace-element study of zircon and baddeleyite in the dikes will be used to further evaluate the magmatic evolution of the Brucejack area and gain additional insights into possible magmatic relationships with the gold mineralization. To assess the ages of the intrusive phases, zircon (and, if possible, baddeleyite) will be separated from all classes of intermediate to mafic dikes in the Brucejack area and will be evaluated by a cathodoluminescence imaging system coupled to a scanning electron microscope to distinguish primary magmatic zircon from possibly inherited zircon (Miller et al., 2007). Depending on the complexity of crystal growth and the morphology of the target grains, U-Pb age determinations will be conducted by either laser-ablation inductively coupled plasma–mass spectrometry or isotope dilution–thermal ionization mass spectrometry. The trace-element chemistry of the different growth phases of the target crystals will be evaluated from the results of laser-ablation inductively coupled plasma–mass spectrometry analyses. In addition, statistical analyses, including principal-component analysis, will be performed to assess the correlations between gold content and element concentrations attributable to alteration and magmatic processes.

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