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STRUCTURALLY CONTROLLED OROGENIC GOLD MINERALIZATION IN THE GLOVER ISLAND AND GRAND LAKE AREA, WESTERN NEWFOUNDLAND (NTS MAP AREAS 12A/12 AND 13)

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ABSTRACT

The Glover Island–Grand Lake area is host to a number of significant gold occurrences including the Lunch Pond South East deposit on Glover Island. These occurrences are hosted in volcanic and sedimentary rocks of the Cambro-Ordovician Glover Group, close to the Baie Verte Brompton Line–Cabot Fault Zone (BCZ) separating the Humber and Dunnage lithotectonic zones in western Newfoundland.

Gold occurrences on Glover Island are divided into two main types based on host lithology: conglomerate-, and volcanic-hosted. Conglomerate-hosted mineralization occurs in strongly deformed and altered polymictic conglomerates of the Basal Conglomerate Member, Kettle Pond Formation. Gold mineralization is restricted to massive quartz veins in the hinges of F_2 *folds, and associated with broad (10s of metres) alteration halos with pervasive carbonate–sericite–chlorite ± fuchsite alteration of the surrounding conglomerates. Volcanic-hosted occurrences are in felsic to mafic volcanic rocks of the Kettle Pond Formation, and are typically located close to* D_2 *thrusts. Mineralization most commonly occurs in brecciated and strongly altered felsic tuffs and rhyolites (quartz–albite–sericite–carbonate–pyrite–chlorite alteration); although locally, mineralization also occurs in quartz–chlorite–carbonate altered mafic tuffs. A number of gold occurrences have also been recorded east of Grand Lake, associated with sheared and brecciated volcanic rocks of the Kettle Pond and Tuckamore formations.*

*Detailed drillcore logging and field mapping, combined with lithogeochemical data and short wavelength infrared (SWIR) spectrometry, suggest that all gold occurrences in the study area are related to a single mineralization event. Variations in the style of mineralization and associated alteration are controlled by host-rock rheology and chemistry. The strong structural control on gold mineralization and its association with greenschist-facies metamorphism is typical of orogenic-type gold mineralization and similar to other deposits along the BCZ (*e.g.*, Stog'er Tight, Pine Cove, Baie Verte Peninsula).*

INTRODUCTION

This report presents the results of a study investigating gold mineralization on Glover Island and the adjacent rocks immediately to the east of Grand Lake (NTS map areas 12A/12 and 13). Grand Lake is the largest lake in Newfoundland, and Glover Island is a large (39 x 5 km) island situated at the southern end of the lake, approximately 30 km southeast of Corner Brook. The area of interest is located at the boundary between two lithotectonic zones in Newfoundland, the Humber and Dunnage zones, which are separated by a crustal-scale lithotectonic boundary known as the Baie Verte Brompton Line–Cabot Fault Zone (BCZ; Figure 1). To the east of the BCZ, Cambrian to Ordovician volcanic and ophiolitic rocks of the Grand Lake Complex and overlying Glover Group predominate (Figure 2; Knapp, 1982; Cawood and van Gool, 1998; Szybinski *et al.*, 2006). These may have formed in a narrow tract of ocean volcanic arcs between the Laurentian continental margin and the Dashwoods microcontinent (Waldron and van Staal, 2001; van Staal *et al.*, 2007), and represent the southern extension of the Baie Verte Oceanic Tract (BVOT) of the Baie Verte Peninsula (van Staal *et al.*, 2007).

The potential of the Glover Island and Grand Lake area to host significant orogenic gold deposits has been recognized since the 1980s (Barbour and French, 1993). Exploration from the 1980s to 2012 has identified numerous gold showings and prospects (Figures 2 and 3), including the Lunch Pond South East (LPSE) deposit, which has a NI 43-101 Indicated Mineral Resource of 58 200 oz. gold and an additional Inferred Mineral Resource of 120 600 oz. (Puritch and Barry, 2017). In 2019, the Geological Survey of Newfoundland and Labrador (GSNL) initiated a multi-year

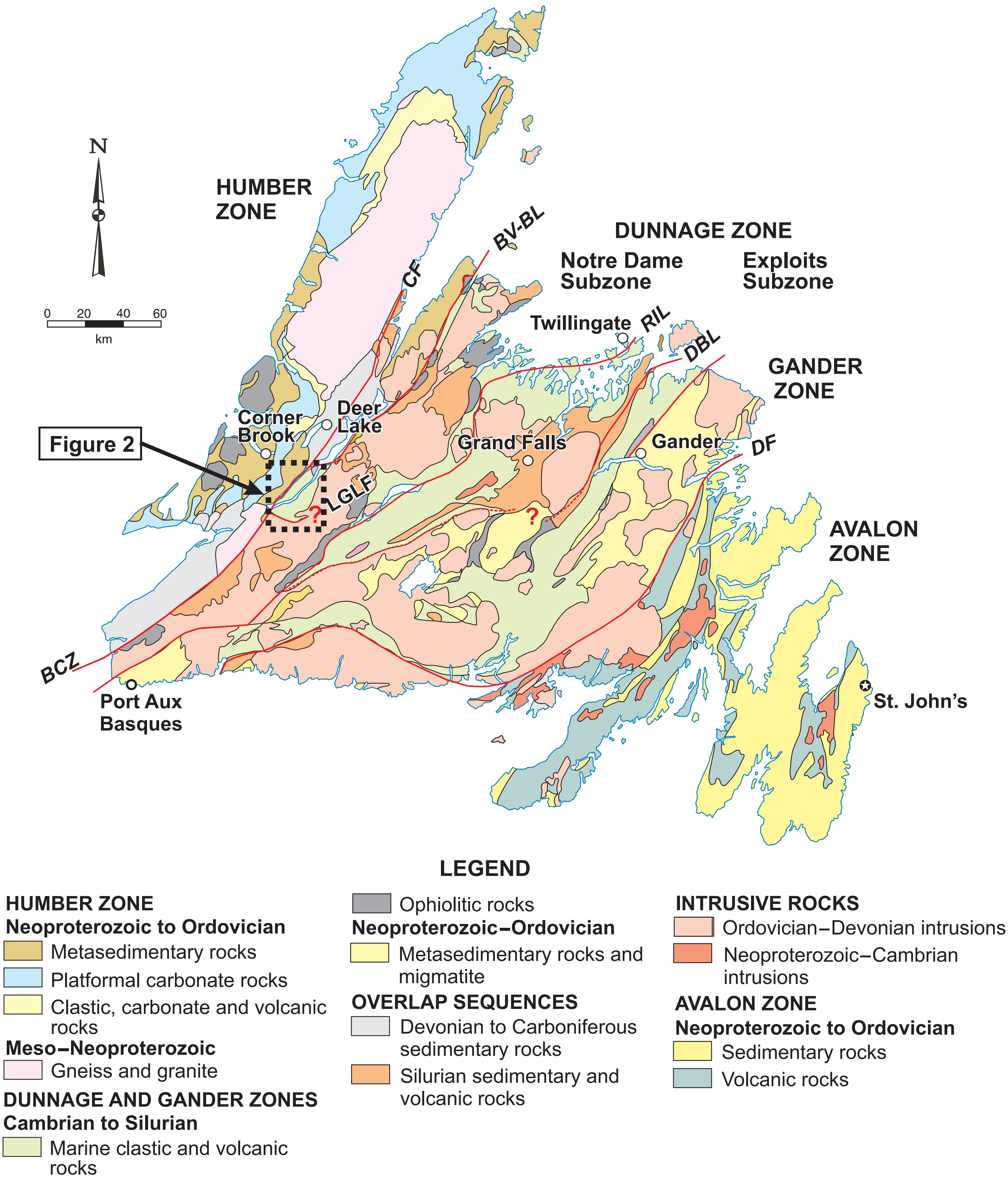

Figure 1. *Simplified geological map of the Island of Newfoundland, showing location of the study area with respect to major lithotectonic zones and large-scale crustal structures (adapted from Colman-Sadd* et al.*, 1990). BCZ: Baie Verte Brompton Line–Cabot Fault Zone; BV-BL: Baie Verte-Brompton Line; CF: Cabot Fault; DBL: Dog Bay Line; DF: Dover Fault; LGLF: Little Grand Lake Fault; RIL: Red Indian Line.*

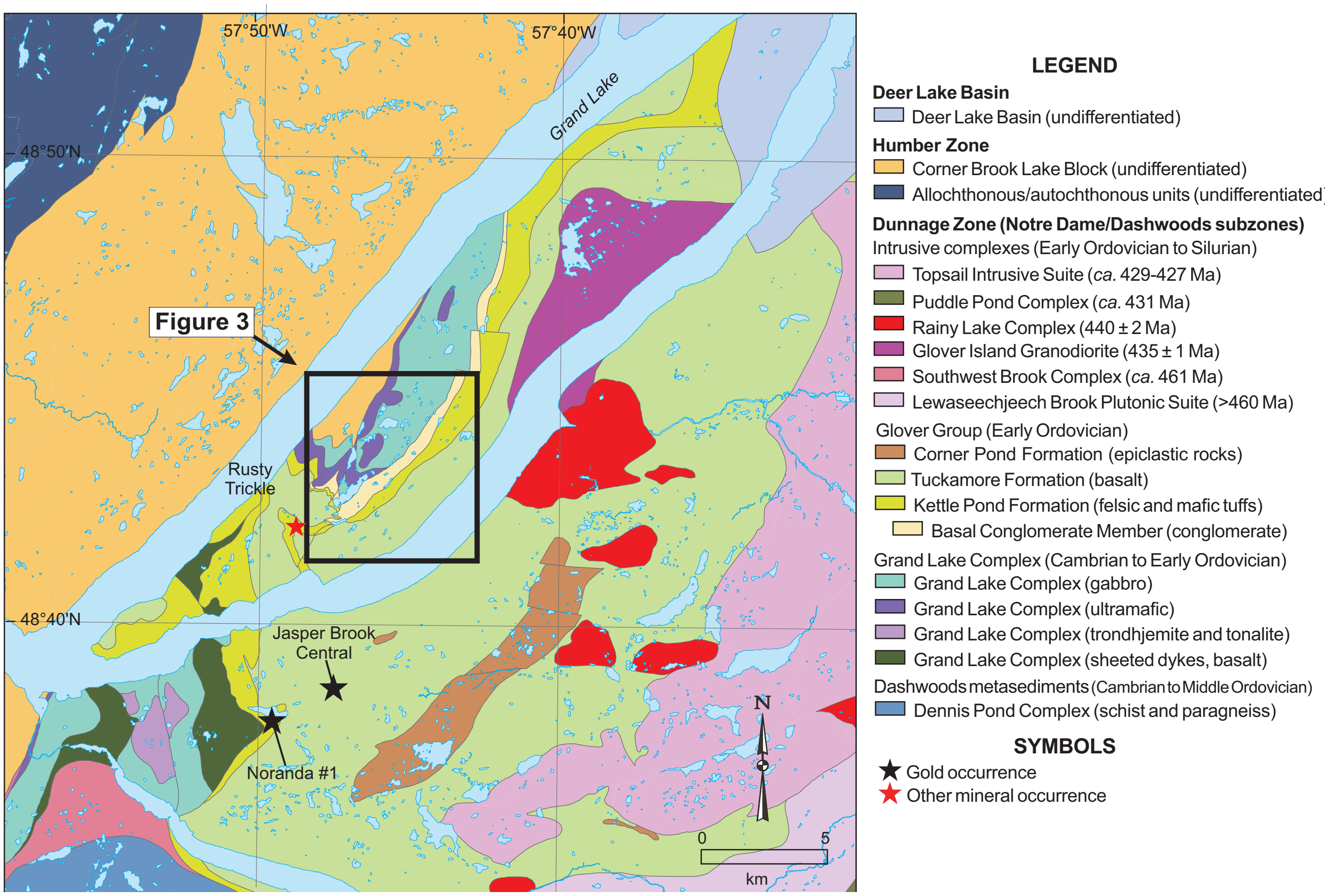

Figure 2. *Geological map of the Glover Island and Grand Lake area, compiled from published geological maps (Whalen and Currie, 1988; Whalen, 1993; Cawood and van Gool; 1998; Szybinski* et al.*, 2006) and detailed geological maps in industry assessment reports (Coates* et al.*, 1992; Barbour* et al.*, 2012).*

study to investigate the mineral potential of the Glover Island and Grand Lake area, and facilitate correlations with the rocks of the Baie Verte Peninsula, host to numerous economic orogenic gold and base-metal deposits (*e.g.*, Pine Cove, Rambler, Ming Mine, Stog'er Tight, Nugget Pond; *cf.* Evans, 1996). This contribution focuses on the gold potential, and builds on detailed descriptions of the gold occurrences reported in Barbour and French (1993) and Barbour *et al.* (2012). It includes detailed descriptions of known occurrences based on field mapping, relogging of historical drillcore, petrography, lithogeochemical data of selected outcrop and drillcore samples and, short wavelength infrared (SWIR) data. These data are used to classify and better understand the genesis of these orogenic gold occurrences, and can be used in mineral exploration, as well as in comprehensive land-access and land-use reviews.

PREVIOUS WORK

The first geological mapping in the Glover Island–Grand Lake area was completed by Riley (1957) as part of a regional-scale mapping project of the Red Indian Lake area. Knapp (1982) completed a Ph.D. thesis on the Glover Island/Grand Lake area, and identified and described most of the map units shown in Figure 2. More detailed regional mapping by the Geological Survey of Canada resulted in the publication of geological maps of NTS map areas 12A/12 and 13 (*see* Whalen and Currie, 1988; Whalen, 1993; Cawood and van Gool, 1998; Szybinski *et al.*, 2006).

In the 1950s, 1960s and 1970s, reconnaissance mineral-exploration programs in the Glover Island–Grand Lake area identified a number of mineral occurrences, and based on these results Hudson Bay Oil and Gas Company Limited conducted a regional exploration program from 1977 to 1979. This work focused on the VMS potential of the Glover Island–Grand Lake area, and included geological mapping and airborne geophysical surveys followed by detailed soil geochemistry, ground geophysical surveys and diamond drilling in select locations (Lassila, 1979a, b). Further prospecting identified a zone of stringer-style mineralization and alteration consistent with VMS mineralization at Rusty

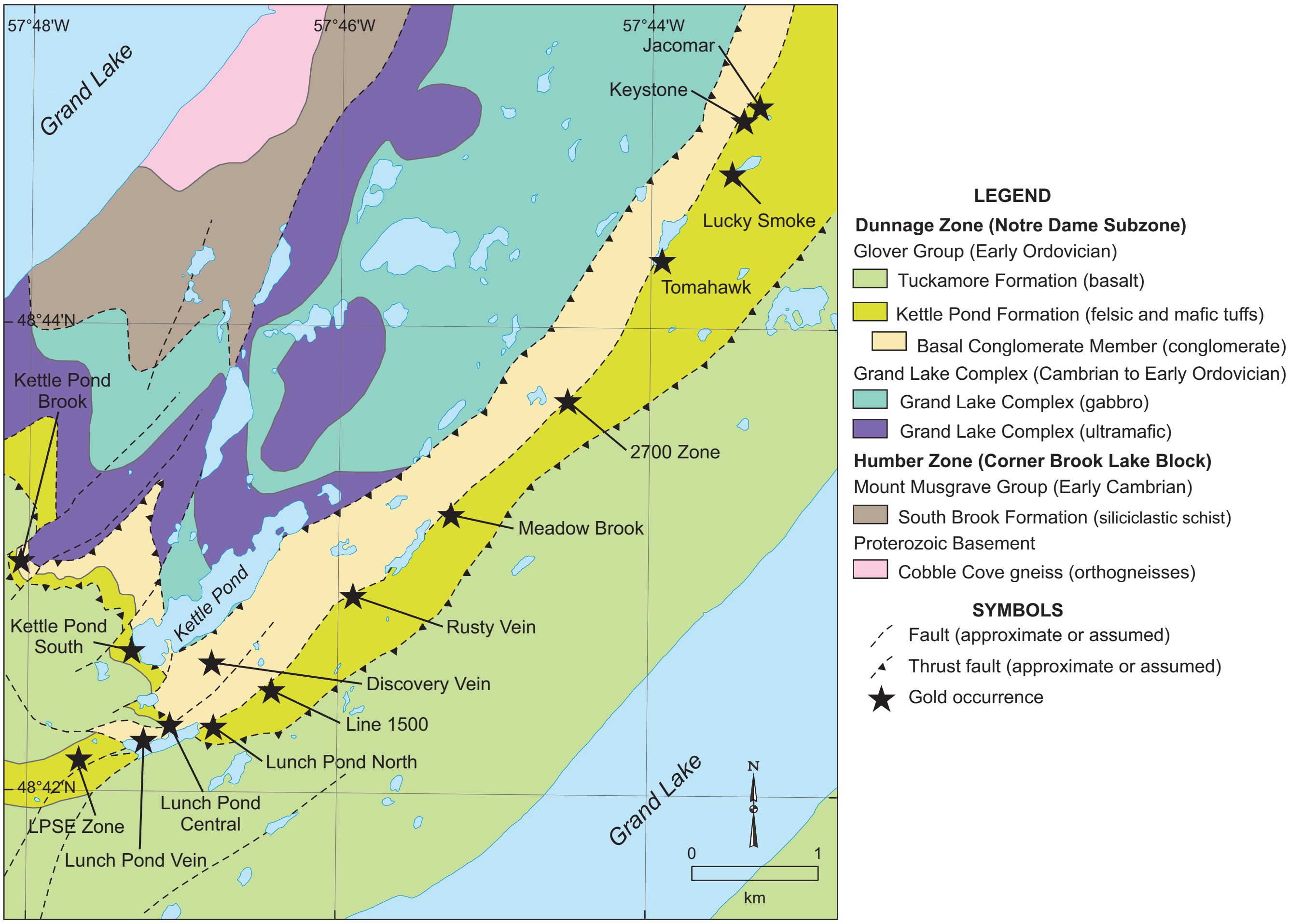

Figure 3. *Detailed geological map of Glover Island, showing the location of known gold occurrences. Compiled from Cawood and van Gool (1998), Szybinski* et al. *(2006) and Barbour* et al. *(2012).*

Trickle (Figure 3; Basha *et al.*, 2001), as well as numerous unsourced massive sulphide boulders at the north end of Glover Island and the Youngs Pond area (French, 1995).

Gold mineralization on Glover Island was first reported in the mid-1980s, and subsequent exploration led to the discovery of 15 gold occurrences in the Kettle Pond Formation close to the contact with the Grand Lake Complex, with a strike length of >7 km (Figure 3; Barbour *et al.*, 2012). Exploration by various companies from 1985 to 2008 included airborne and ground geophysics, prospecting, soil sampling, geological mapping and trenching (summarized by Barbour *et al.*, 2012). In addition, 81 diamond-drill holes were completed on 15 individual prospects. Gold mineralization was also identified in the Youngs Pond area to the east of Grand Lake, with two diamond-drill holes completed on the main showing (Deering, 1989). In 2011 and 2012, Mountain Lake Resources completed 41 drillholes (totalling 10 083.26 m) on the LPSE deposit (Barbour *et al.*, 2012). Based on this, Puritch and Barry (2017) reported a NI 43-101 Indicated Mineral Resource for the LPSE zone of 58 200 oz. gold (1.03 Mt at 1.76 g/t Au) with additional Inferred Mineral Resources of 120 600 oz. gold (2.08 Mt at 1.81 g/t Au).

GEOLOGICAL SETTING

The study area is located on the boundary between the Humber and western Dunnage zones of the Newfoundland Appalachians (Williams, 1979), with the boundary marked by the (BCZ), a major crustal-scale lithotectonic boundary in the Canadian Appalachians (Williams and St. Julien, 1982; Brem, 2007; Figure 1). On Glover Island, rocks of the Humber Zone are restricted to the west coast of the island (Figure 2), with strongly deformed schists of the South Brook Formation (Knapp, 1982; Cawood and van Gool, 1998) overlying basement gneisses of the Corner Brook Lake Complex (~1.5 Ga, Cawood *et al.*, 1996). These units form part of the Corner Brook Lake Block, an allochthonous terrane in the Humber Zone, which is believed to have been transported to its current location by significant (>400 km) orogen-parallel strike–slip motion after the Taconic Orogeny (Brem, 2007; Lin *et al.*, 2013).

The Notre Dame Subzone of the Dunnage Zone is located to the east of the BCZ, and represents a series of continental and oceanic arcs, back-arc basins and ophiolites of peri-Laurentian affinities (van Staal *et al.*, 2007). In the study area, the Notre Dame Subzone is subdivided into a sequence of ophiolite rocks known as the Grand Lake Complex, structurally overlain by oceanic to back-arc volcanic, volcaniclastic and sedimentary successions collectively grouped together as the Glover Group (Knapp, 1982; Cawood and van Gool, 1998; Szybinski *et al.*, 2006). van Staal *et al.* (2007) considered these units to represent the southern extension of the BVOT. The BVOT formed in the "Humber Seaway"; a narrow tract of oceanic arcs between the Laurentian continent and a small ribbon continent of Laurentian affinity (Dashwoods microcontinent; Waldron and van Staal, 2001; van Staal *et al.*, 2007). The southern boundary of the study area is marked by the Little Grand Lake Fault (LGLF, Figure 1), which juxtaposes the dominantly oceanic rocks of BVOT with continental arc rocks of the Notre Dame Arc (Dashwoods Subzone; Brem *et al.*, 2007; van Staal *et al.*, 2007).

On Glover Island, the Grand Lake Complex is strongly deformed and altered, and is in fault contact with the South Brook Formation (Corner Brook Lake Block) along BCZ. The base of the ophiolite complex is marked by a sequence of altered ultramafic units, including talc-schist, variably serpentinized peridotite, and wehrlite (Knapp, 1982; Cawood and van Gool, 1998). Ultramafic units are also recorded in discontinuous lenses (up to 1 km in length) in the lower gabbros (Cawood and van Gool, 1998). Gabbros predominate above the ultramafic unit, and have been subdivided into a lower, layered cumulate unit and an upper massive unit (Knapp, 1982; Cawood and van Gool, 1998). The upper sequence gabbros are intruded by numerous small trondhjemite bodies dated by Cawood *et al.* (1996) at 490 ± 4 Ma (U–Pb zircon). This portion of the Grand Lake Complex is interpreted to represent the base of an ophiolite complex (Knapp, 1982; Cawood and van Gool, 1998).

A sequence of relatively unaltered and undeformed sheeted dykes and pillow lavas, with lesser mafic tuffs and gabbros, occur on the southern end of Glover Island and in the southwestern Grand Lake area (Figure 2; Szybinski *et al.*, 2006). These have been intruded by numerous trondhjemite and tonalite intrusions. Geochemical analysis suggests that they represent the upper portion of the Grand Lake Complex on Glover Island (Knapp, 1982). This sequence was intruded by a number of felsic porphyries that are geochemically similar to felsic tuffs and rhyolites of the overlying Tuckamore Formation (Knapp, 1982).

The Glover Group is in fault contact with the Grand Lake Complex, but is interpreted to represent the cover sequence to the ophiolite (Knapp, 1982; Szybinski *et al.*, 1995, 2006; Cawood and van Gool, 1998). Cawood and van Gool (1998) interpreted the contact between the Grand Lake Complex and the Glover Group as structural rather than stratigraphic, with the contact zone referred to as the Kettle Pond Shear Zone, and grouped all units above the Kettle Pond Shear Zone together as the Glover Formation (Figure 4). However, recent geological mapping has defined three main formations in the Glover Group, namely the Kettle Pond, Tuckamore and Corner Pond formations (Figure 4; Szybinski *et al.*, 2006), and this classification is used here.

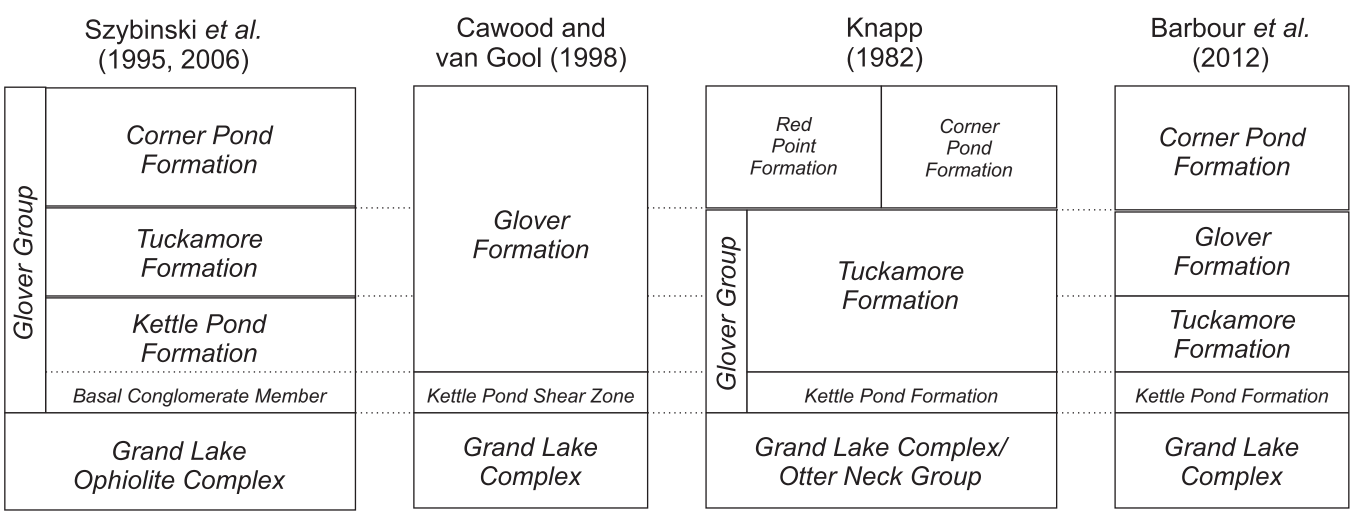

Figure 4. *Stratigraphic divisions of Cambro-Ordovician volcano-sedimentary rocks in Glover Island/Grand Lake area, based on government (Knapp, 1982; Szybinski* et al.*, 1995, 2006; Cawood and van Gool, 1998) and company (Barbour* et al.*, 2012) mapping.*

Of note, company geologists have used a modified version of this stratigraphy, with the upper part of the Kettle Pond Formation referred to as the "Tuckamore formation" and the overlying mafic dominated succession as the "Glover formation" (Figure 4; Barbour *et al.*, 2012).

The Kettle Pond Formation represents the stratigraphically lowest part of the Glover Group, and is divided into a lower conglomerate unit (Basal Conglomerate Member) overlain by felsic to mafic volcanic rocks (Szybinski *et al.*, 1995). The Basal Conglomerate Member outcrops extensively in central Glover Island but is not recorded elsewhere in the study area. It consists of strongly deformed clast-supported polymictic pebble to cobble conglomerate and matrix-rich polymictic conglomerates that grade upwards into arenaceous schists with rare clasts (Barbour *et al.*, 2012). Clast lithologies are highly variable, with gabbro, diabase, trondhjemite, basalt, rhyolite, quartz, jasper and rare orthoquartzite in a fine-grained felsic to mafic tuffaceous matrix (Knapp, 1982; Szybinski *et al.*, 1995; Barbour *et al.*, 2012). The abundance of gabbro and trondhjemite clasts indicates that they were largely derived from the Grand Lake Complex (Knapp, 1982).

Above the Basal Conglomerate Member, the Kettle Pond Formation consists of interlayered fine-grained mafic and felsic tuffs interspersed with thicker units of mafic volcanic rocks (Szybinski *et al.*, 1995; Barbour *et al.*, 2012). Quartz-feldspar crystal tuffs and aphanitic rhyolites are common to the southeast and northwest of Kettle Pond (Figure 3), and minor black shales, iron formation and massive sulphides are also recorded (Barbour *et al.*, 2012). Numerous porphyritic mafic sills and dykes intrude the stratigraphy. The upper contact of the Kettle Pond Formation is marked by the disappearance of felsic volcanic units (Szybinski *et al.*, 1995; Barbour *et al.*, 2012).

The Tuckamore Formation outcrops extensively on the east coast of Glover Island and to the east of Grand Lake (Figure 2). It is composed of a thick (<5 km) sequence of dominantly pillow basalts and plagioclase porphyritic flows, with minor red to purple shales, iron formation, massive sulphides and interstitial jasper (Knapp, 1982; Szybinski *et al.*, 2006). The uppermost unit in the Glover Group is the Corner Pond Formation and it unconformably overlies the Tuckamore Formation (Szybinski *et al.*, 2006). The Corner Pond Formation consists predominantly of felsic epiclastic (graded conglomerate to fine-grained siltstone) units with minor rhyolites, pillow basalts, shales, chert, and carbonate rocks. A black shale near the top of the Corner Pond Formation contains Laurentian graptolites spanning the *P. fruticosus* and *D. bifidus* biozones (Williams, 1989), indicating a mid-Floian (470 to 477.7 Ma) age (Loydell, 2012).

On the northeastern side of Glover Island, the Glover Group is intruded by the Llandovery Glover Island Granodiorite (440 ± 2 Ma; Cawood *et al.*, 1996), a moderately foliated, biotite granodiorite (Whalen *et al.*, 2006). The Glover Group is also intruded by gabbros and diorites that are included in the 435 ± 1 Ma Rainy Lake Complex (Whalen *et al.*, 2006), as well as a number of granite and granodiorite dykes and stocks of unknown affinity (Figure 2). The Glover Island Granodiorite and Rainy Lake Complex are arc-like intrusions and possibly related to the final stages of northwest-directed subduction of Ganderia below the Notre Dame Subzone (Whalen *et al.*, 2006). To the east of the study area, the Glover Group is intruded by voluminous within-plate (A-type) granitoids of the Topsails Intrusive Suite (427 ± 1 Ma; Whalen *et al.*, 2006).

On the northern end of Glover Island, Carboniferous sedimentary rocks of the Deer Lake Basin unconformably overlie the Glover Group (Cawood and van Gool, 1998).

Rocks of the Grand Lake Complex and Glover Group have experienced regional greenschist-facies metamorphism and four main deformational events have been recorded (Knapp, 1982; Szybinski *et al.*, 1995, 2006; Cawood and van Gool, 1998; Barbour *et al.*, 2012). The following summary is derived from Barbour *et al.* (2012). D_1 deformation is responsible for a regionally penetrative S_1 fabric with common mylonitization, which is strongly developed in the Grand Lake Complex and Tuckamore Formation on Glover Island, but decreases in intensity to the east. S_1 fabrics were subsequently folded during D_2 deformation, forming an asymmetric fold–thrust system with kilometre-scale F_2 fold nappes within D_2 thrust sheets. In the Kettle Pond area, spectacular mesoscopic F_2 folds with chevron, cuspate-lobate and ptygmatic styles are parasitic on decametre to kilometre scale F_2 folds (Barbour *et al.*, 2012). D_2 deformation also affected the Llandovery Glover Island Granodiorite, indicating that this deformation postdates *ca.* 440 Ma and may be associated with the Salinic Orogeny. D_3 deformation is recorded as a northwest–southeast oriented compressional event. F_3 folds vary greatly in style and orientation, and include the kilometre-scale Kettle Pond antiform–synform pair, located south and west of Kettle Pond (Figure 3). F_3 folds are also cut by north- to northeast-trending high-angle faults, interpreted as accommodation faults formed during D_3 deformation (Barbour *et al.*, 2012). D_4 deformation consists of brittle to brittle–ductile high-angle faults with subvertical or steeply plunging oblique-slip movements, which formed in an extensional environment, probably during the Carboniferous movement on the BCZ. D_4 faults commonly reactivated pre-existing thrusts or accommodation faults associated with earlier phases of deformation.

CHARACTERISTICS OF GOLD MINERALIZATION

A total of 15 gold occurrences have been reported from Glover Island, with a strike length of >7 km (Figure 3, Table 1). All occurrences are hosted in the Kettle Pond Formation and are divided into two types based on host lithology and style of mineralization: conglomerate-hosted, and volcanic-hosted gold mineralization. In addition, a number of gold occurrences are located in the Youngs Pond area to the east of Grand Lake (Figure 2), and are described separately.

CONGLOMERATE-HOSTED GOLD MINERALIZATION

Conglomerate-hosted gold occurrences on Glover Island are found in the Basal Conglomerate Member of the

Table 1. Summary of the known gold occurrences and significant gold mineralization reported from exploration work in the study area

Occurrence	Formation	Host Lithology	DDH	Drilling Highlights	Other Significant Mineralization
Glover Island					
Discovery Vein	Kettle Pond Formation (Basal Conglomerate Member)	Conglomerate	1	n/a	Channel sampling: 30.8 g/t Au over 1.7 m
Lunch Pond Vein	Kettle Pond Formation (Basal Conglomerate Member)	Conglomerate	3	0.73 g/t Au over 23.62 m	Channel sampling: 150 g/t Au over 1.5 m
Lunch Pond North Vein	Kettle Pond Formation (Basal Conglomerate Member)	Conglomerate	2	1.2 g/t Au over 7.9 m	Channel sampling 4.92 g/t Au over 0.7 m
Kettle Pond Brook	Kettle Pond Formation	Felsic tuff	1	n/a	Grab samples: 20 g/t Au
Kettle Pond South	Kettle Pond Formation	Felsic tuff, mafic tuff	11	4.8 g/t Au over 18.5 m	
Lunch Pond Central	Kettle Pond Formation	Felsic tuff	7	54.6 g/t Au over 1.22 m	
Lunch Pond South Extension	Kettle Pond Formation	Mafic tuff, rhyolite	76	1.74 g/t Au over 53.5 m, 1.67 g/t Au over 44.7 m	
Line 1500	Kettle Pond Formation	Felsic tuff	1	3.46 g/t Au over 1 m	Grab sample: 4.1 g/t Au
Rusty Vein	Kettle Pond Formation	Felsic tuff	3	1.79 g/t Au over 1.5 m	Channel sampling: 11.3 g/t Au over 2 m
Meadow Brook	Kettle Pond Formation	Felsic tuff	2	1.93 g/t Au over 0.4 m	Channel sampling: 3.08 g/t Au over 5.1 m
2700 Zone	Kettle Pond Formation	Felsic tuff	3	1.1 g/t Au over 20 m	Channel sampling: 1.47 g/t Au over 11.6 m
Tomahawk	Kettle Pond Formation	Felsic tuff	n/a	n/a	Channel sampling: 2.9 g/t Au over 2.3 m
Lucky Smoke	Kettle Pond Formation	Felsic tuff	8	10.18 g/t Au over 8 m, 0.95 g/t Au over 42.45 m	Channel sampling: 5.9 g/t Au over 9 m
Keystone	Kettle Pond Formation	Felsic tuff	1	1.65 g/t Au over 4 m	Channel sampling: 3.74 g/t Au over 4 m
Jacomar	Kettle Pond Formation	Felsic tuff	2	3.29 g/t Au over 1.1 m	Channel sampling: 8.96 g/t gold over 3 m
Youngs Pond					
Noranda #1	Kettle Pond Formation	Mafic tuff	n/a	n/a	Channel sampling: 1.82 g/t Au over 5.5 m
Jasper Brook Central	Tuckamore Formation	Basalt	n/a	n/a	Grab sample: 3 g/t Au

Kettle Pond Formation, and include the Lunch Pond, Lunch Pond North, and Discovery veins (Table 1). Mineralization occurs in decametre-scale massive white quartz veins up to 2 m wide (Plate 1A), which are located in the hinges of F_2 folds, and are highly irregular in thickness and strike length (Barbour *et al.*, 2012). Mineralized quartz veins are associated with pervasive carbonate–sericite–chlorite ± fuchsite alteration of the surrounding conglomerates (Plate 1B), with alteration locally extending for 10s of metres on either side of the quartz veins.

Pyrite occurs with chlorite in late fractures and clots that crosscut the massive quartz veins, with some larger aggregates of pyrite up to 30 cm long (Plate 1C). Trace amounts of chalcopyrite have been recorded in some samples, but no other sulphides have been identified. Free gold occurs as inclusions in pyrite or associated with chalcopyrite in fractures crosscutting pyrite grains (Plate 1D). Very high gold grades have been reported from these occurrences (*e.g.*, 150 g/t Au over a 1.5 m channel sample at the Lunch Pond Vein; French, 1990), but diamond drilling has failed to delineate the mineralization at depth, likely reflecting the discontinuous nature of the quartz veins.

VOLCANIC-HOSTED GOLD MINERALIZATION

On Glover Island, the volcanic rocks of the Kettle Pond Formation lie above the Basal Conglomerate Member and is host to numerous gold occurrences, including the LPSE deposit, Kettle Pond South prospect and Lucky Smoke prospect (Table 1; Figure 3). The host rocks of the occurrences include strongly deformed mafic and felsic volcanic rocks of the Kettle Pond Formation, with well-developed S_1 fabrics and local mylonitization.

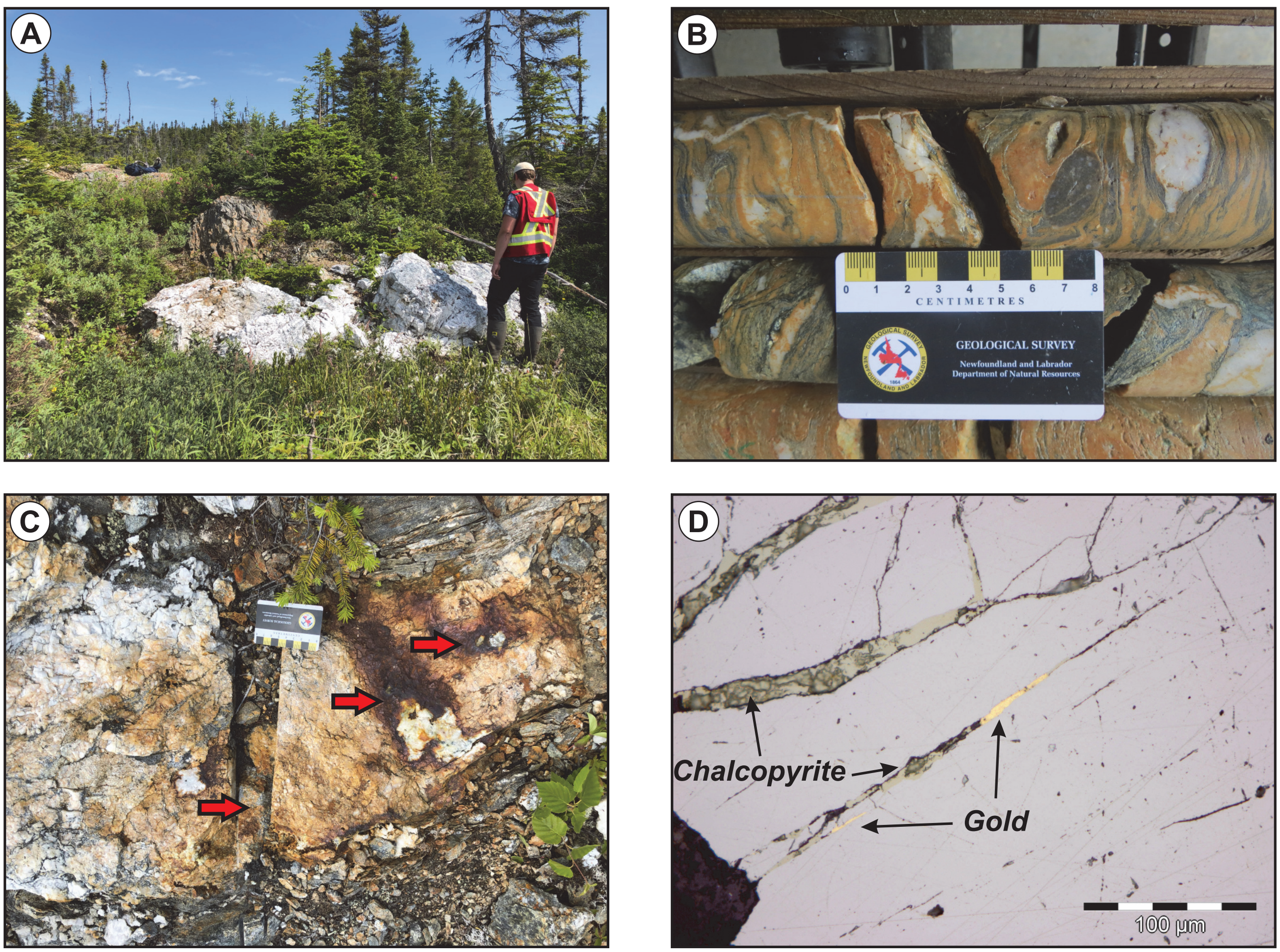

Plate 1. *Representative photographs and photomicrographs from conglomerate-hosted gold occurrences in the Kettle Pond Formation. A) Massive quartz vein in conglomerate at Lunch Pond showing; B) Strongly altered and deformed conglomerate from Lunch Pond North showing (drillhole LPN-2 @ 32.2 m); C) Large aggregate of pyrite in quartz vein, Lunch Pond showing. Red arrows show pyrite aggregates; D) Gold and chalcopyrite infilling late fracture in pyrite grain, Lunch Pond showing (reflected light, sample 19JC085A01).*

Gold mineralization occurs in rocks spatially adjacent to D_2 thrusts (Barbour *et al.*, 2012) and is associated with strong silicification and hydrothermal alteration, which overprints an earlier phase of regional chlorite ± epidote alteration in the host rocks. Gold grades are typically lower than in conglomerate-hosted occurrences, but mineralization is more laterally continuous, with significant thicknesses of mineralization (>1.5 g/t Au over >50 m) recorded in some occurrences (Table 1). Mineralization is subdivided into two main types based on the host lithology and associated alteration.

Felsic Volcanic-hosted

The most extensive form of mineralization, found in all showings and prospects, were previously classified as felsite-hosted mineralization (Barbour and French, 1993). Mineralization occurs in strongly altered and intensely deformed aphanitic felsic tuffs (Plates 2A, B and 3A) and quartz-feldspar-porphyritic rhyolites (Plates 2C and 3B). These felsic units range in thickness from <1 to >30 m and are commonly intercalated with thin mafic tuffs. Mineralized felsic units are brecciated with multiple generations of quartz veins that crosscut S_1 fabrics (Plate 2B, C). Gold and associated sulphides are typically paragenetically late, with pyrite preferentially occurring on the margins of veins, in veinlets of pyrite and chlorite crosscutting earlier quartz veins or rarely disseminated in the wallrock. Discrete gold grains occur as inclusions in pyrite or infilling late fractures in the pyrite. Mineralized zones are surrounded by intense, proximal, quartz–albite–sericite–carbonate–pyrite–chlorite alteration (Plate 2B–D), with alteration decreasing to a distal chlorite ± carbonate ± sericite alteration that grades into the background regional metamorphic phases.

Mafic Volcanic-hosted

Gold mineralization at LPSE and Kettle Pond South is also locally hosted in strongly altered mafic tuffs. At LPSE, where this style of mineralization is most extensive, these tuffs lie in the hangingwall of a D_2 thrust, which brings altered volcanic rocks of the Kettle Pond Formation above relatively unaltered basalts of the Tuckamore Formation (Figure 5). Mineralization is associated with quartz veins that crosscut S_1 fabrics (Plate 2E), with sulphides precipitating at the margins of the quartz veins, in late-stage fractures or disseminated in the surrounding wallrock. Locally, intense silicification and brecciation imparts a distinctive ‘chicken-wire’ texture formed by thin seams of chlorite and pyrite (± carbonate ± albite) cementing silicified fragments (Plates 2F and 3C). Gold grains occur as inclusions within pyrite grains (Plate 3D) or as discrete grains associated with chalcopyrite. Strong chlorite–carbonate ± sericite alteration is recorded in mafic tuffs surrounding the mineralized zones.

YOUNGS POND OCCURRENCES

A number of gold occurrences have also been reported east of Grand Lake, including the Noranda #1 showing to the south of Youngs Pond and the Jasper Brook Central showing along Jasper Brook (Figure 2; Snow and Walker, 1988; Deering, 1989).

The most significant showing in the Youngs Pond area is Noranda #1, with assays returning 4.17 g/t Au over a 5.1 m chip sample (Deering, 1989). Mineralization is associated with quartz–carbonate veins that are hosted in strongly chlorite–carbonate–pyrite altered and sheared crystal lithic mafic tuffs of the Kettle Pond Formation (Plate 4A). Pyrite is disseminated in the wallrock around these veins, where it commonly pseudomorphs orthorhombic crystals (Plate 4B), or is found in thin veinlets that crosscut the mafic tuffs and are synchronous with the larger quartz–carbonate veins (Plate 4A, B). Petrographic analysis shows that gold and chalcopyrite occur as discrete grains or in late fractures in the pyrite.

A number of occurrences with anomalous Au (>100 ppb Au) in quartz–carbonate veins have been reported from Jasper Brook, to the northeast of Youngs Pond. These occurrences are hosted in brecciated and carbonate altered pillow lavas of the Tuckamore Formation, with gold grades of up to 3 g/t in grab samples. Gold mineralization associated with abundant arsenopyrite, and numerous galena–chalcopyrite bearing veins having anomalous gold grades, also occur in this area (Snow and Walker, 1988).

LITHOGEOCHEMISTRY

SAMPLING AND ANALYTICAL METHODS

Sixty samples were collected from trenches as well as drillcore stored at the Government of Newfoundland and Labrador Core Storage facility in Pasadena and at the Mountain Lake Resources camp on Glover Island. With the exception of two samples from the Noranda #1 showing, all samples were collected from known mineral occurrences on Glover Island. These samples include:

- Four mineralized quartz-vein samples from conglomerate-hosted occurrences in the Kettle Pond Formation;
- Eight samples of mineralized quartz veins and quartz breccias from volcanic-hosted occurrences in the Kettle Pond Formation;
- Fifteen aphanitic felsic tuffs, five quartz-feldspar-porphyritic rhyolites and sixteen mafic tuffs from the Kettle Pond Formation on Glover Island;
- Three samples of strongly altered and deformed mylonites from the Kettle Pond Formation;

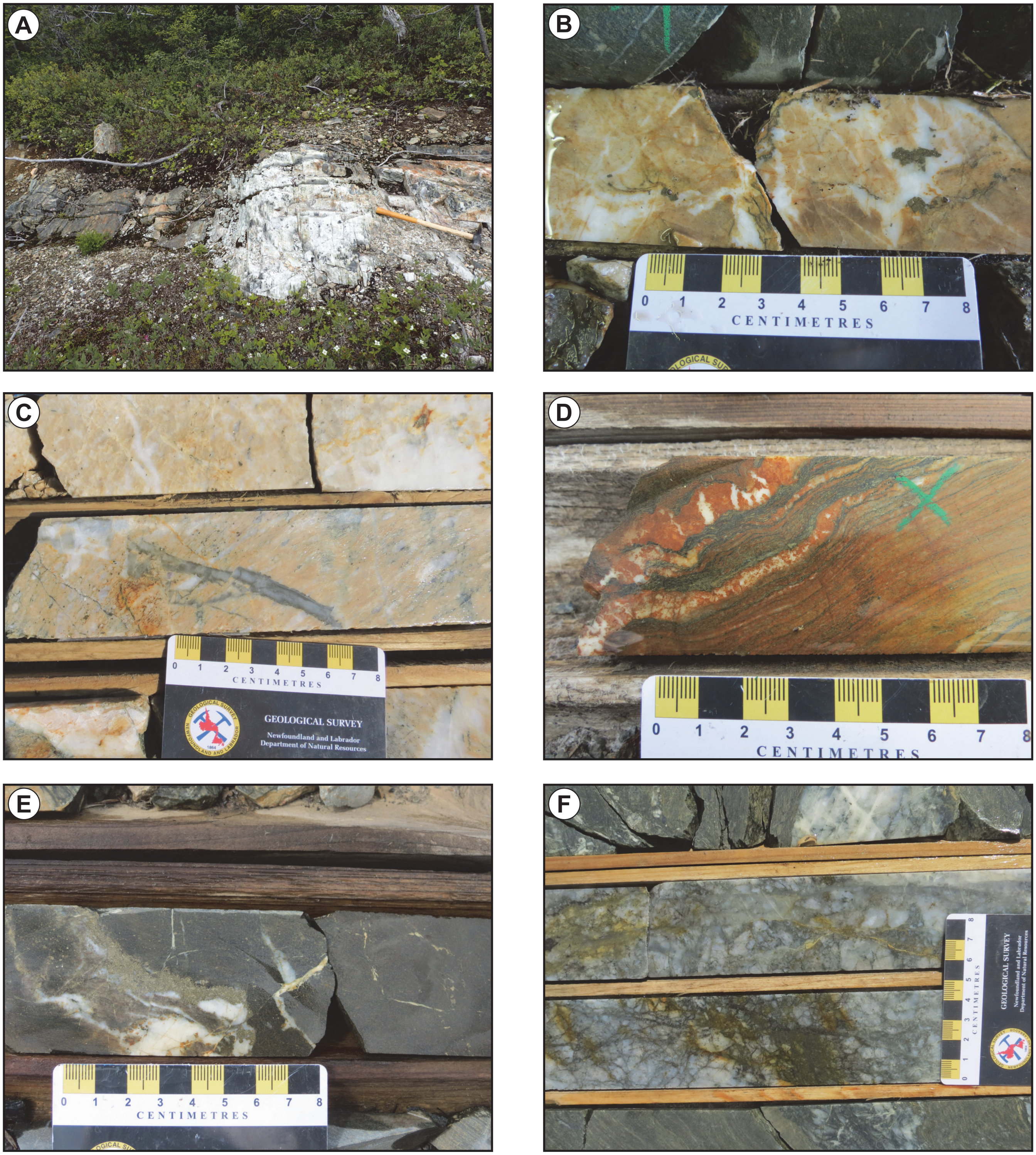

Plate 2. *Representative photographs from volcanic-hosted gold occurrences in the Kettle Pond Formation, Glover Island. A) Interbedded mafic tuffs (left) and strongly altered felsic tuffs (right) exposed in trench at Jacomar showing; B) Felsic tuff with intense quartz–albite alteration, crosscut by quartz–pyrite–chlorite veins (drillhole 2700-3 @ 27.7 m, 9.9 g/t Au); C) Altered and brecciated quartz-feldspar porphyry (drillhole LPSE-11-57 @ 116.5 m, 1.8 g/t Au); D) Altered mylonite with strong carbonate–sericite alteration (drillhole KPS-2 @ 31.9 m, 559 ppb Au); E) Quartz–pyrite–carbonate vein crosscutting chlorite altered mafic tuff (drillhole KPS-2 @ 57.5 m, 44.2 g/t Au); F) Silicified and brecciated mafic tuff with "chicken-wire" texture formed by thin seams of chlorite and pyrite (drillhole LPSE11-57 @ 405.2 m, 2.5g/t Au).*

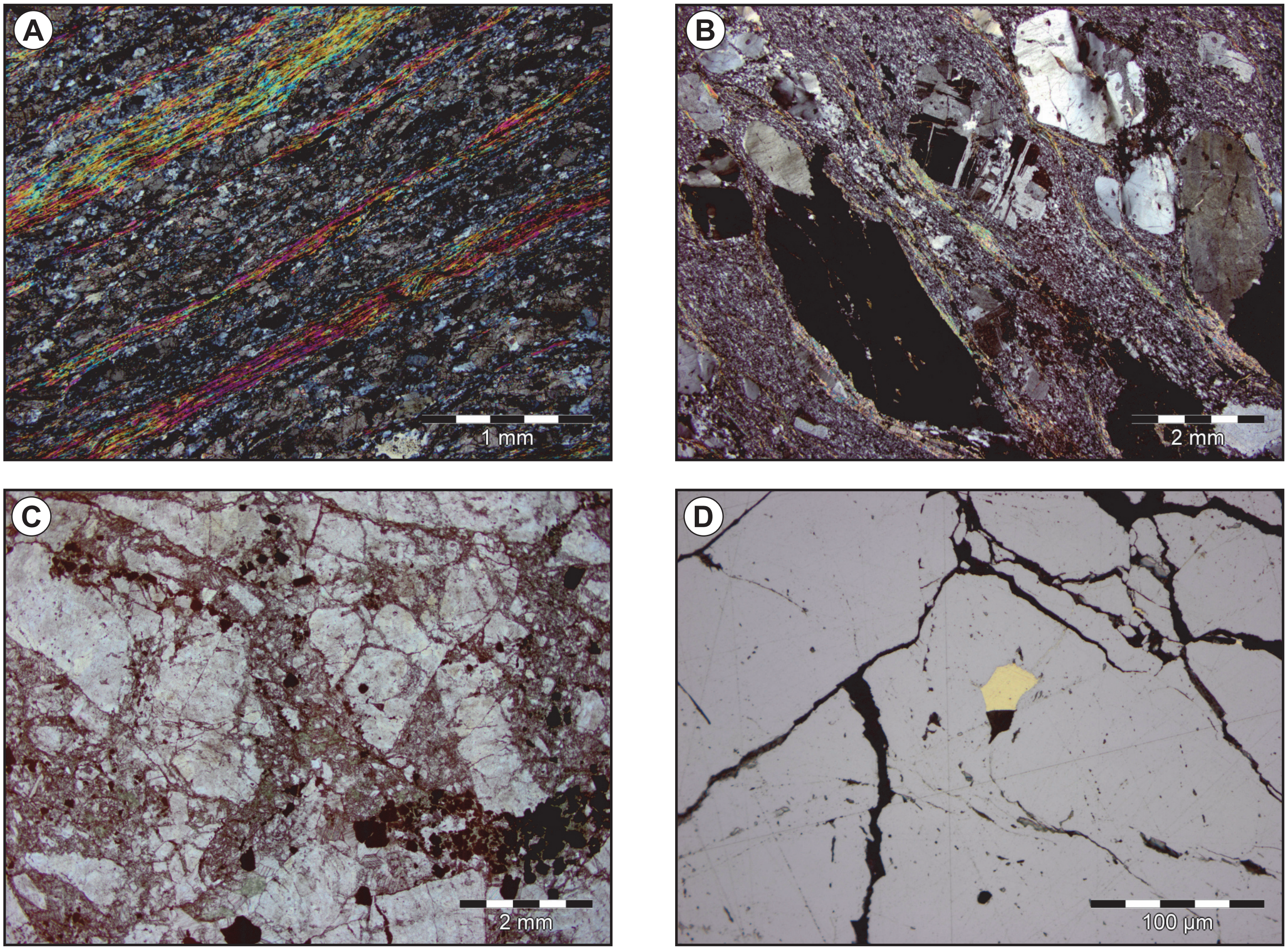

Plate 3. *Representative photomicrographs from volcanic-hosted gold occurrences in the Kettle Pond Formation, Glover Island. A) Mylonite with intense carbonate–albite–sericite alteration (cross-polarized light, drillhole KPS-2 @ 41.4 m); B) Quartz-feldspar porphyry with well-developed S_1 fabric (cross-polarized light, drillhole LPSE-11-57 @ 90 m); C) Brecciated quartz vein in mafic tuff, cemented by carbonate–albite–chlorite–pyrite (plane-polarized light, drillhole LPSE-1 @ 75.1 m); D) Gold grain in pyrite (drillhole KPS-2 @ 57.5 m).*

- Five samples of plagioclase-porphyritic mafic dykes and sills intruding the tuffs of the Kettle Pond Formation;
- Two samples of basalt from Tuckamore Formation; and
- Two samples of mineralized mafic tuff from the Noranda #1 showing in the Youngs Pond area.

All samples selected for lithogeochemical analysis were prepared at the GSNL geochemistry laboratory in St. John's, from where major-element, trace-element and rare-earth-element (REE) analyses were carried out; the analytical methods are described in Finch *et al.* (2018). Additional analyses for trace elements including Au, Cd, Sb and As were conducted by Maxxam Analytics (now Bureau Veritas) using Instrumental Neutron Activation Analysis (INAA). Analytical duplicates were inserted at a frequency of one in 20, with the duplicate selected at random. In addition, a selection of reference standards was analyzed, also at a frequency of one in 20 (Conliffe, unpublished data, 2021).

ALTERATION

All rock units sampled for lithogeochemical analysis have been variably affected by regional metamorphism/alteration or hydrothermal alteration associated with mineralization. During hydrothermal alteration, most major elements (except Al, Ti) and low-field-strength elements (LFSE; *e.g.*, Cs, Rb, Ba, Sr) are likely to have been mobile (MacLean, 1988; MacLean and Barrett, 1993). Therefore, lithogeochemical data for igneous rock types associated with felsic volcanic-hosted and mafic volcanic-hosted mineralization on Glover Island, and from the Noranda #1 showing at Youngs Pond, are plotted on a series of alteration discrimination diagrams to determine the nature and intensity of alteration associated with gold mineralization.

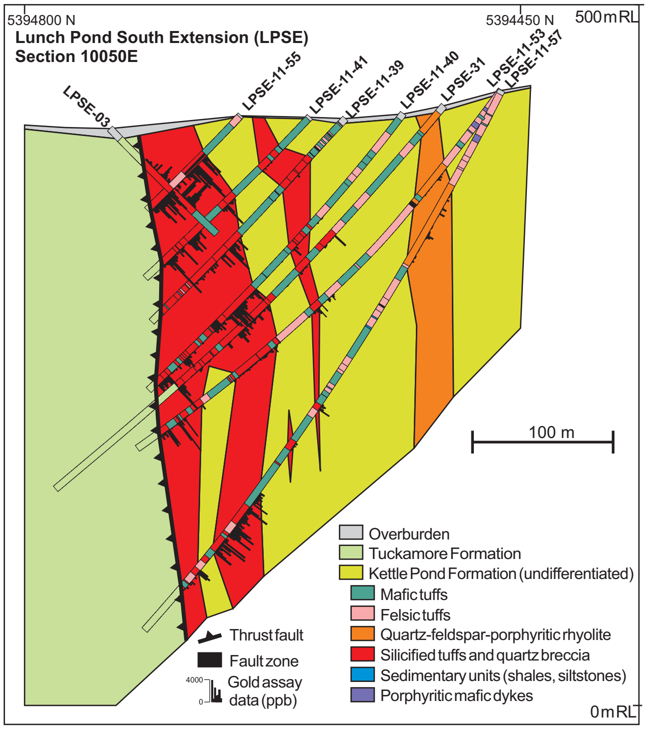

Figure 5. *Schematic cross-section through the Lunch Pond South East (LPSE) deposit with drillholes projected onto a common plane, illustrating the distribution of the main lithological units, faults and gold mineralization. Adapted from Barbour* et al. *(2012).*

The geochemical data are plotted on an alteration box plot in Figure 6A (Large *et al.*, 2001). This diagram uses two common alteration indices; the chlorite–carbonate–pyrite index values (CCPI; $100*(MgO+Fe_2O_3)/(MgO+Fe_2O_3+K_2O+Na_2O)$; Large *et al.*, 2001) and Hashimoto alteration index values (AI; $100*(MgO+K_2O)/(MgO+K_2O+CaO+Na_2O)$; Ishikawa *et al.*, 1976). Although this diagram was originally developed to classify alteration associated with VMS deposits (Large *et al.*, 2001), it is also applicable in determining alteration styles in other deposit types (*e.g.*, orogenic gold deposits; MacDonald and Piercey, 2019). Felsic rocks from hydrothermal alteration zones in the study area typically have low AI values (<20) and plot outside the least altered box, close to the albite node (Figure 6A). This suggests that albitization is an important alteration process associated with gold mineralization. Two samples of aphanitic felsic tuffs have higher AI values (32 to 42) and plot in the least altered field. These drillcore samples were located >20 m away from gold mineralization, and are interpreted to represent least altered felsic tuffs. Mafic tuffs and crosscutting porphyritic mafic dykes of the Kettle Pond Formation have high CCPI values (73 to 87) and low to moderate AI values (22 to 59). These samples plot within the least altered field for basaltic and andesitic rocks on the alteration box plot (Figure 6A; Large *et al.*, 2001), irrespective of the intensity of regional metamorphism or hydrothermal (chlorite–carbonate) alteration.

A similar distribution is evident on a Spitz-Darling plot of Al_2O_3/Na_2O *vs.* Na_2O, which shows that hydrothermally altered felsic rocks generally have elevated Na_2O contents (>5% Na_2O) compared to those in the least altered field

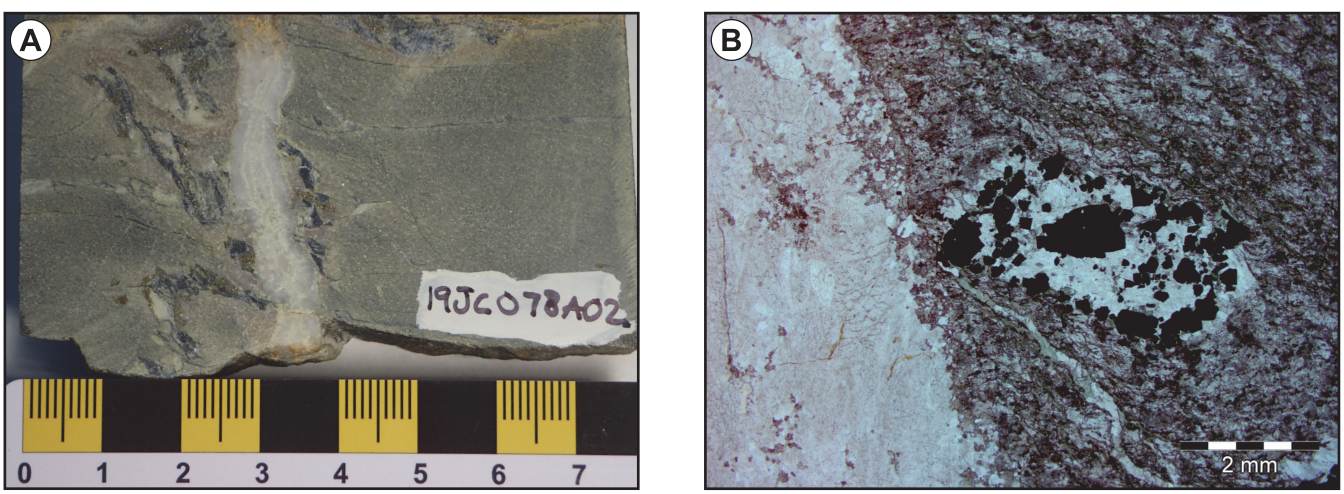

Plate 4. *Representative photograph and photomicrograph from Noranda #1 showing in the Youngs Pond area. A) Altered mafic tuff with barren quartz–carbonate vein and synchronous quartz–pyrite–chlorite veinlets in altered wallrock (sample 19JC078A02); B) Photomicrograph of chlorite altered mafic tuff crosscut by barren quartz–carbonate vein and with pyrite pseudomorphing orthorhombic crystal in wallrock (plane polarized light, sample 19JC078A02).*

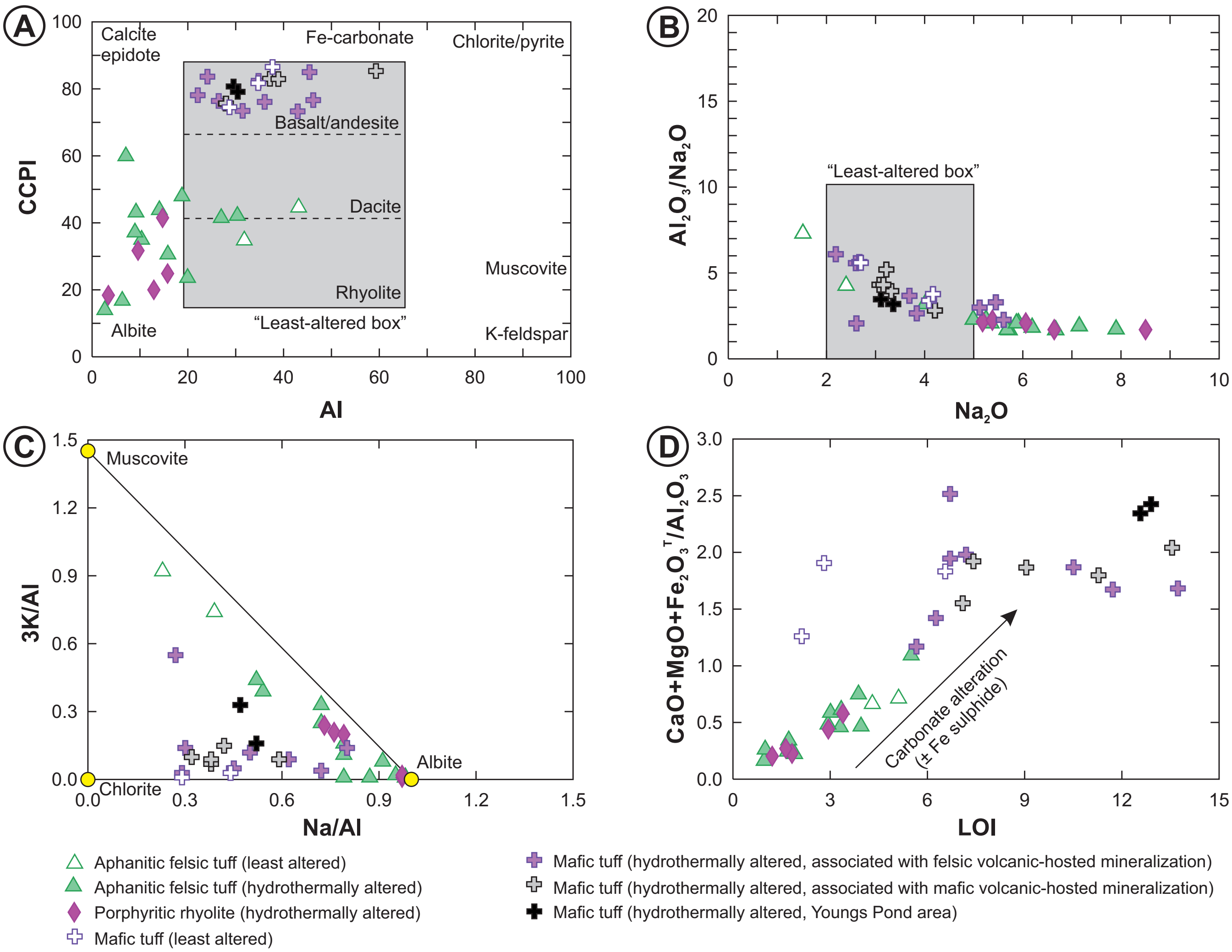

Figure 6. *Mobile-element plots for geochemical samples from the Kettle Pond and Tuckamore formations. A) Alteration box-plot (from Large* et al*., 2001) with chlorite–carbonate–pyrite index (CCPI; Large* et al*., 2001)* vs. *Hashimoto alteration index (AI; Ishikawa* et al*., 1976); B)* Na_2O vs. Al_2O_3/Na_2O *plot with designations for least altered samples (modified from Spitz and Darling, 1978); C) 3K/Al (sericite saturation index)* vs. *Na/Al (albite saturation index); D)* $CaO + MgO + Fe_2O_3^T/Al_2O_3$ vs. *LOI plot (adapted from MacDonald and Piercey, 2019).*

(Figure 6B). Mafic tuffs generally plot within the least altered field (Figure 6B).

Alkali-metal concentrations were also calculated using albite (Na/Al) and sericite (3K/Al) saturation indices (Kishida and Kerrich, 1987; Figure 6C). These data show that the hydrothermally altered felsic rocks plot close to the albite node, with least altered felsic tuff plotting closer to the muscovite node. Mafic tuff and porphyritic dykes in the Kettle Pond Formation have low–moderate albite saturation indices and low sericite saturation indices (Figure 6C).

On a plot of $(CaO+MgO+Fe_2O_3)/Al_2O_3$ *vs.* LOI, which monitors carbonate (± Fe sulphide alteration; MacDonald and Piercey, 2019), hydrothermally altered felsic tuffs have low $(CaO+MgO+Fe_2O_3)/Al_2O_3$ and LOI values (Figure 6D). Mafic tuff and porphyritic dykes have higher $(CaO+MgO+Fe_2O_3)/Al_2O_3$ values, and hydrothermally altered samples show a strong positive correlation between $(CaO+MgO+Fe_2O_3)/Al_2O_3$ and LOI (Figure 6D).

Overall, the data indicates that albitization is the dominant alteration type in mineralized felsic rocks in the Kettle Pond Formation, with minor carbonate and sericite alteration. Alteration associated with gold mineralization in mafic tuffs on Glover Island and at Youngs Pond is characterized by strong chlorite–carbonate alteration.

IGNEOUS LITHOGEOCHEMISTRY

Elements thought to be immobile in hydrothermal fluids, such as Al, Ti, high-field-strength elements (HFSE; *e.g.*, Zr, Y, Nb) and the REEs (*e.g.*, MacLean, 1988; MacLean and Barrett, 1993) are used to infer the primary magmatic and tectonic affinities of igneous rock types. Felsic and mafic volcanic rocks of the Kettle Pond Formation (including late-stage porphyritic dykes) and basalts of the overlying Tuckamore Formation all have subalkaline Nb/Y ratios, and the bimodal nature of magmatism is clearly illustrated on the Zr/TiO_2 – Nb/Y plot (Figure 7; after Pearce, 1996).

Aphanitic felsic tuff and quartz-feldspar-porphyritic rhyolite of the Kettle Pond Formation have high Zr/Ti ratios and plot in the field for rhyolites + dacites (Figure 7). These felsic rocks have strong negative Nb and Ti anomalies, weak light rare-earth-element (LREE) enrichment (La/Ybcn = 1.2 to 2.0; Figure 8A: cn denotes chondrite normalized) and low Zr/Y ratios (>4; Figure 9A), and plot on the boundary between Type FIIIa and Type FIV rhyolites on the La/Ybcn–Ybcn diagram of Hart *et al.* (2004; Figure 9B). These data are consistent with the classification of these felsic rocks as tholeiitic rhyolites, interpreted to have formed by shallow partial melting of mafic material, often associated with development of intra-oceanic, island arcs on oceanic crust (Hart *et al.*, 2004; Piercey, 2011).

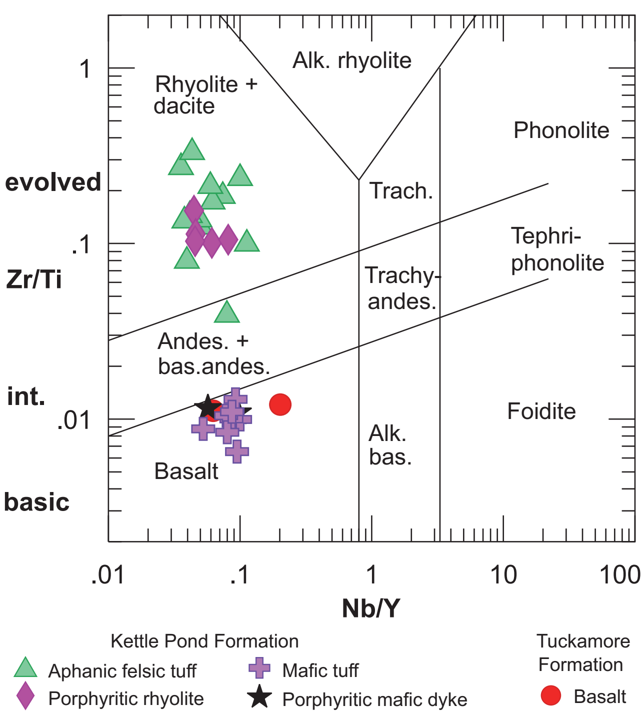

Figure 7. *Zr/Ti vs. Nb/Y rock discrimination diagram of Pearce (1996), modified after Winchester and Floyd (1977).*

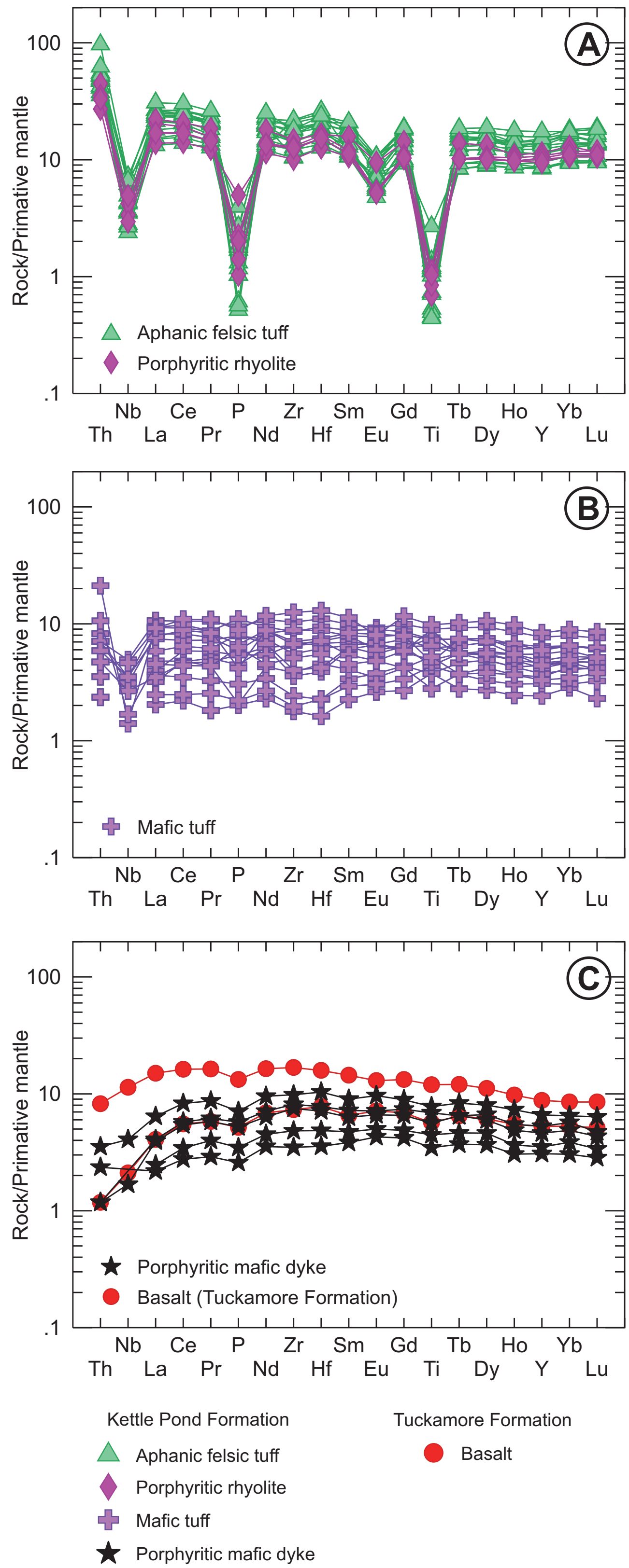

Figure 8. *Primitive-mantle-normalized extended trace-element plot for lithogeochemical samples (normalizing values from Sun and McDonough, 1989).*

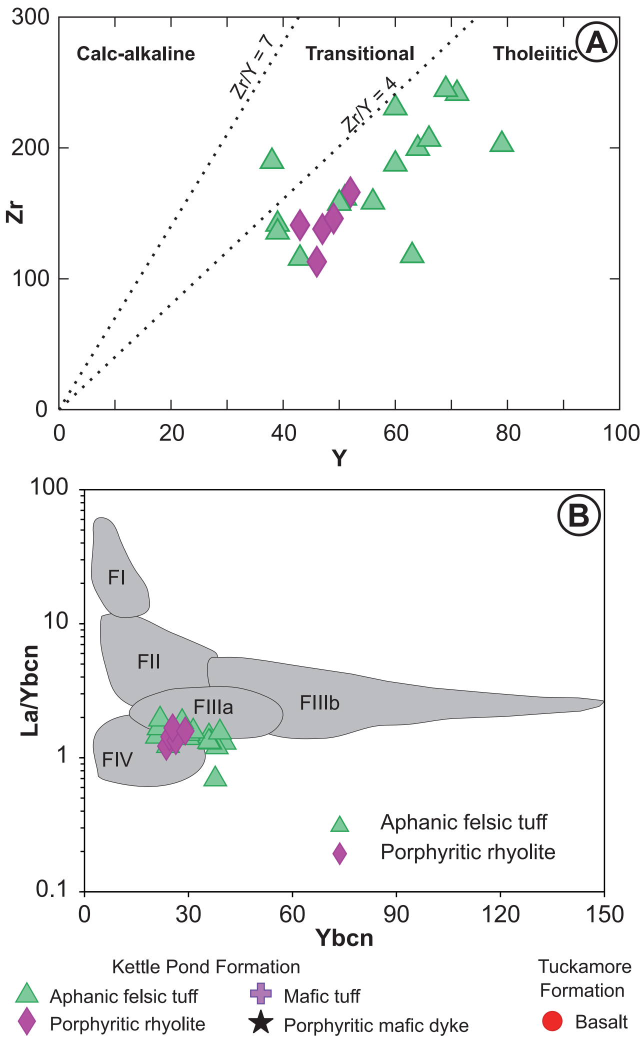

Figure 9. *Trace-element data for felsic rocks plotted on selected discrimination diagrams. A) Zr–Y plot illustrating the tholeiitic character of felsic rocks (modified from Barrett and MacLean, 1999); B) La/Ybcn–Ybcn showing felsic rocks have FIIIa and FIV affinities (from Lesher* et al.*, 1986b; Hart* et al.*, 2004).*

Mafic tuff in the Kettle Pond Formation plot in the basalt field on the Zr/TiO_2 *vs.* Nb/Y plot (Pearce, 1996; Figure 7). On extended trace-element plots, these samples typically have weak negative Nb anomalies or Nb contents below detection limit, have flat to slightly high rare-earth-element (HREE)-enriched profiles (Figure 8B), and have patterns similar to island-arc tholeiites (Piercey, 2011). Mafic tuffs also plot in, or close to, fields for volcanic arc-basalts on lithotectonic discrimination diagrams (*e.g.*, Th *vs.* Zr/117 *vs.* Nb/16; Figure 10).

Porphyritic dykes and sills, in the Kettle Pond Formation, and basalt from the Tuckamore Formation also plot in the basalt field on the Zr/TiO_2 *vs.* Nb/Y plot (Pearce,

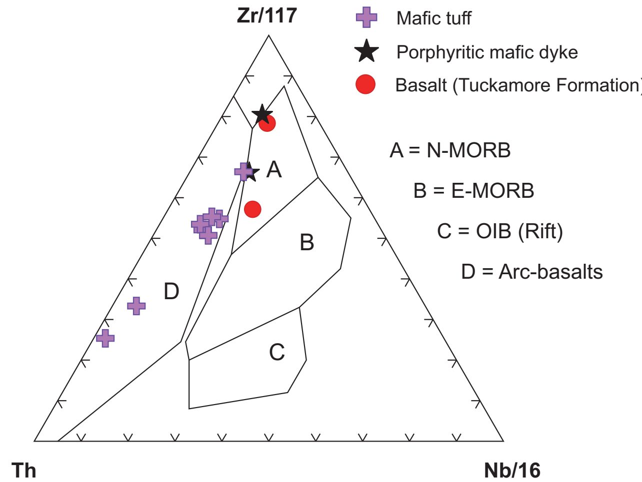

Figure 10. *Trace-element data for mafic rocks plotted on Th–Zr–Nb plot (Wood, 1980)*

1996; Figure 7). However, they do not display negative Nb anomalies on extended trace-element diagrams (Figure 8C), and have MORB-type affinities on lithotectonic discrimination diagrams (Figure 10). The geochemical similarities between the porphyritic dykes and sills intruding the Kettle Pond Formation, and basalts of the overlying Tuckamore Formation indicates that the dykes and sills were likely feeders for the overlying MORB-type basalts.

METAL ASSOCIATIONS

Gold contents of mineralized samples range from >5 up to 44 200 ppb, with the higher values reflecting the “nugget effect” caused by particles of free gold identified during petrographic studies. Concentrations of metals (*e.g.*, Ag, Co, Cu, Ni, Pb, Zn) and semi-metals (*e.g.*, As, Sb) are generally low; with some samples showing relative enrichment in As (up to 73 ppm) and Ag (up to 3 g/t). Gold abundances show a strong correlation with Ag and S contents (Figure 11A, B), with Pearson correlation coefficient values of 0.81 and 0.91, respectively. Gold also shows a positive correlation with As, but with fairly low total As abundances (<40 ppm). Samples from volcanic-hosted occurrences on Glover Island, however, have lower As values than those from occurrences in the Youngs Pond area (<80 ppm; Figure 11C). Other pathfinder elements commonly associated with gold mineralization elsewhere show no correlation with gold contents (*e.g.*, Sb, Figure 11D).

SHORT-WAVELENGTH-INFRARED SPECTROSCOPY

ANALYTICAL METHODS

Hyperspectral data was collected from drillcore samples from five occurrences on Glover Island (Kettle Pond

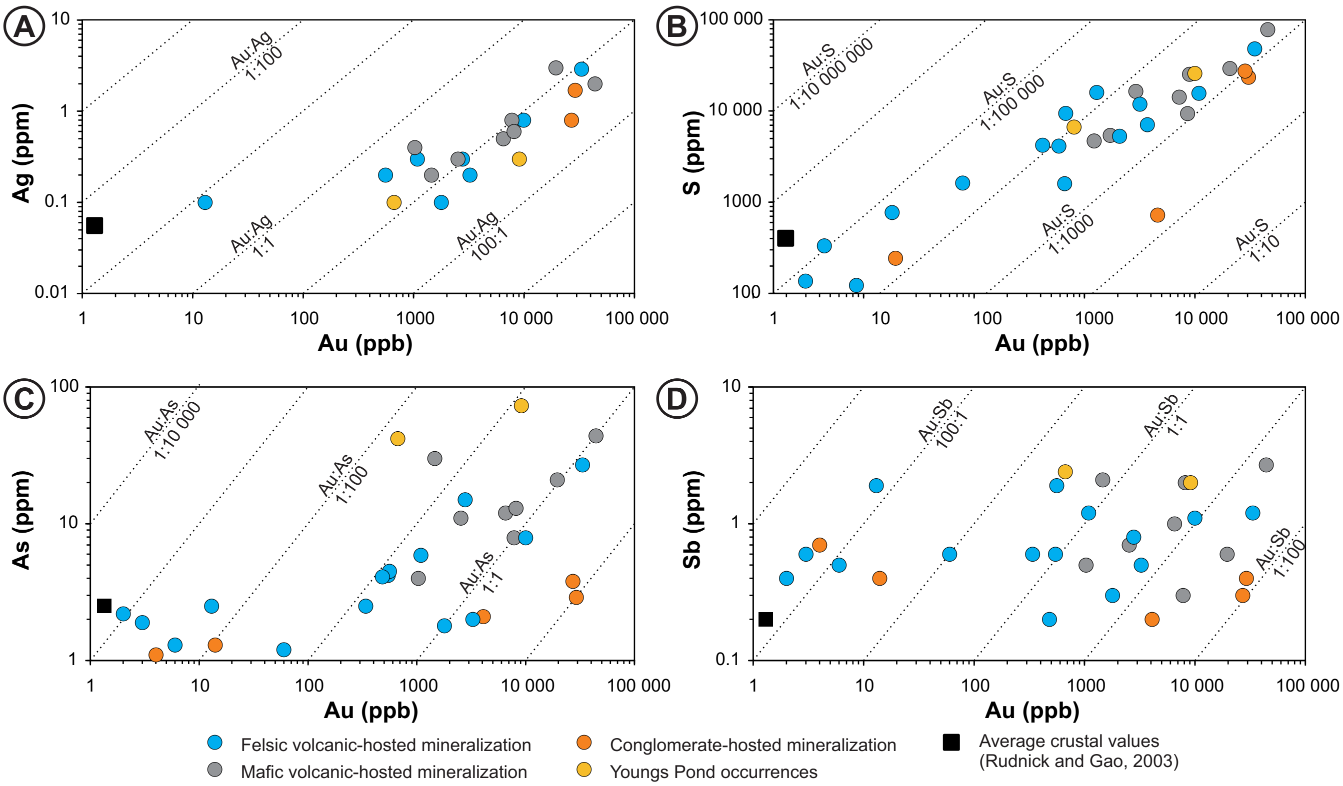

Figure 11. *Log-log plots showing correlations between gold and selected trace elements. A) Ag* vs. *Au; B) S* vs. *Au; C) As* vs. *Au; D) Sb* vs. *Au. Large open squares are average crustal values, from Rudnick and Gao (2003).*

South, Lunch Pond North, LPSE, Meadow Brook Zone and 2700 Zone), as well as cut representative samples from the Jacomar, Lucky Smoke, Tomahawk, Discovery Vein and Noranda #1 occurrences. In total, 367 hyperspectral measurements were recorded using visible/infrared reflectance spectrometry (VIRS) collected on, and exported from, a TerraSpec® Pro spectrometer. These samples have been subdivided based on the degree of visible alteration and type of mineralization. Spectral measurements were recorded for each geochemical sample (multiple measurements to record intra-sample variations), at downhole intervals of 2 m outside of the zone of observable hydrothermal alteration, and from 0.5 to 1 m in zones of moderate to strong observable alteration. The TerraSpec® Pro spectrometer was optimized every 30 minutes using a white standard reference material to reduce instrument drift.

Spectral data was processed using the TSG™ Pro software program (*see* Kerr *et al.*, 2011 for complete details). Eleven spectra that were classified as being dark, containing a signal-to-noise ratio below a defined threshold or with no identifiable features, have been removed. The software facilitates estimation of the relative proportions of the two most abundant mineral phases within each sample (Min 1 and Min 2) by comparing the spectra to a spectral library in the TSG™ database. The location and depth of characteristic absorption features of SWIR-active alteration minerals was also calculated. These include the Al-OH absorption wavelength of white micas (2190–2225 nm) and the Fe-OH absorption wavelength of chlorite (2245–2265 nm), which are commonly used to track hydrothermal alteration associated with mineralization (*e.g.*, Jones *et al.*, 2005; Yang *et al.*, 2011; Laakso *et al.*, 2016; Wang *et al.*, 2017; Lypaczewski *et al.*, 2019; Sparkes, 2019; Cloutier and Piercey, 2020; Pawlukiewicz, 2020).

RESULTS

The position of the Al-OH absorption wavelength at ~2200 nm is a function of the octahedral Al content (Al^{VI}) in white mica (Post and Noble, 1993; Swayze *et al.*, 2014), with the wavelength progressively increasing from ~2190 nm in Al-rich white micas (muscovite–paragonite) to ~2220 nm in Al-poor and Fe- and Mg-rich white micas (phengite). The hyperspectral data from this study shows clear variations in white mica chemistry between samples with little or no observable hydrothermal alteration (regional metamorphism/alteration) and those with moderate to strong hydrothermal alteration associated with gold mineralization (hydrothermal alteration). Regional metamorphism/alteration samples have white mica with average Al-OH absorption wavelengths of 2216 ± 6 nm (Figure 12A), indicative of

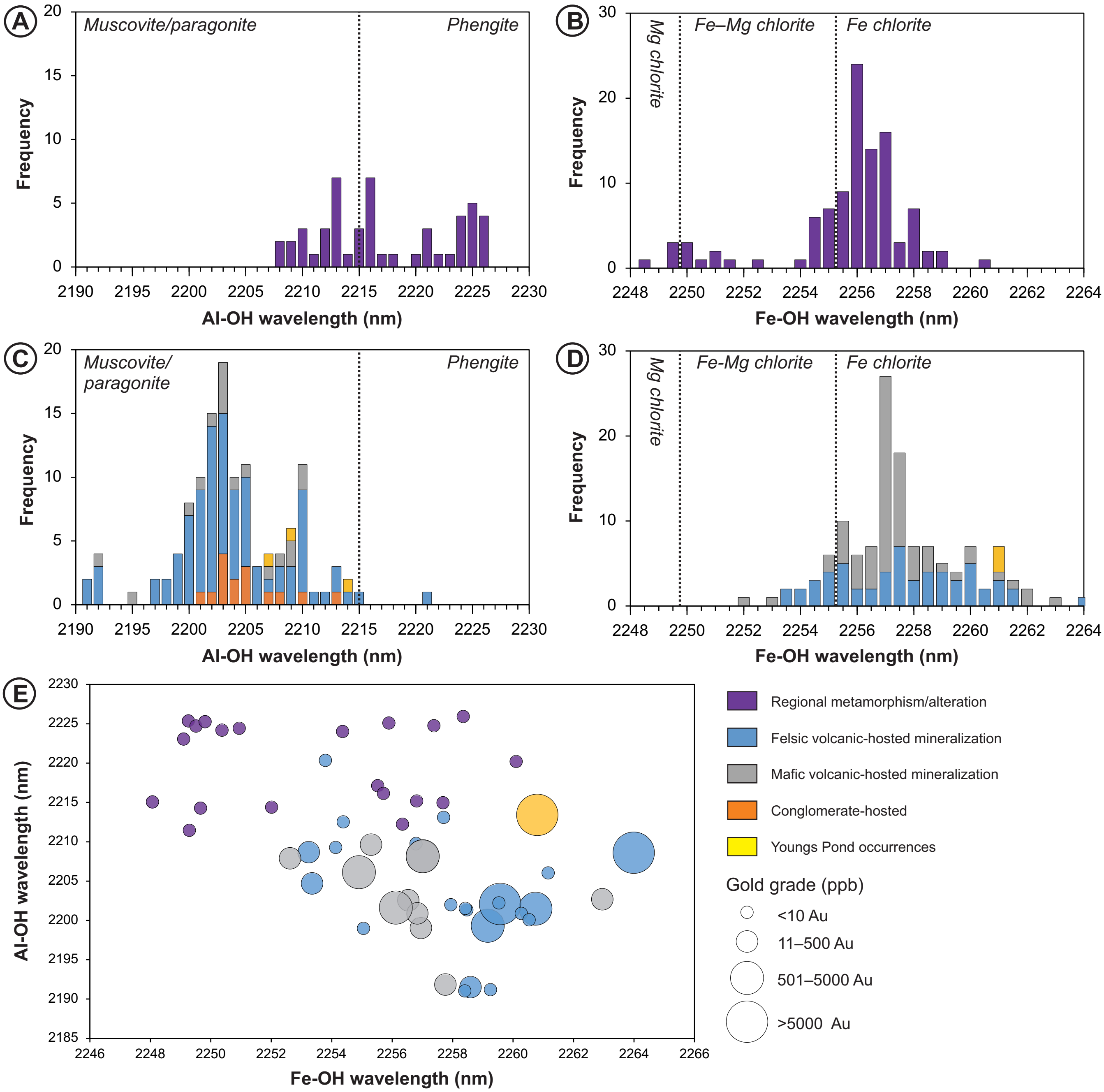

Figure 12. *SWIR data from drillcore and outcrop samples. Mineral species thresholds from Cloutier and Piercey (2020).*

phengitic white mica associated with regional alteration on Glover Island. White micas in samples from hydrothermally altered zones have lower Al-OH absorption wavelengths of 2207 ± 5 nm (Figure 12C), and predominantly plot within the field defined for muscovite or paragonite. The position of the Al-OH absorption feature in short wavelength is unable to determine the relative substitution of K+ and Na+ between muscovite (K-rich end member) and paragonite (Na-rich end member) in white micas (Martínez-Alonso *et al.*, 2002; Wang *et al.*, 2017). However, the low K_2O and high NaO content of mineralized samples, coupled with the evidence for strong sodic alteration in felsic units, suggests that paragonite is an important mineral associated with hydrothermal alteration and gold mineralization.

The Fe-OH absorption wavelength at ~2250 nm is strongly controlled by the Al^{VI} content and Mg# of chlorite (Lypaczewski and Rivard, 2018), with a progressive increase in the wavelength position from Mg-rich chlorite (<2250 nm) to Fe-rich chlorite (>2255 nm). Hyperspectral data from regional metamorphism/alteration samples show a wide range in Fe-OH absorption wavelength positions from 2248 to 2260 nm (average wavelength of 2255 ± 2 nm), with most samples containing Fe-Mg- and Fe-chlorite (Figure 12B). Hydrothermally altered samples show a slight shift to more Fe-rich chlorite (Figure 12D), with Fe-OH absorption wavelengths of 2251 to 2264 nm (average wavelength of 2257 ± 2 nm).

These overall trends in absorption features between regionally metamorphosed and hydrothermally altered samples are also evident in individual occurrences, and can give key insights into hydrothermal processes associated with gold mineralization. Figures 13 and 14 show schematic lithological logs from drillholes at Kettle Pond South (KPS-2) and Lunch Pond North (LPN-2), as well as gold assay and hyperspectral data. At Kettle Pond South, both felsic- and mafic-volcanic-hosted mineralization occur within the same drillholes, and analysis of white mica Al-OH absorption wavelengths show a systematic decrease from ~2220 nm in unaltered mafic tuff to ~2200 nm in altered and mineralized mafic and felsic tuff (Figure 13). The similarities in white mica composition between the two mineralization types indicates that they represent the same mineralizing event, and variations in the style of mineralization is controlled by the physical and chemical characteristics of the host lithology. Similarly, altered conglomerates in the Basal Conglomerate Member of the Kettle Pond Formation, at the Lunch Pond North occurrence, show a distinct decrease in white mica Al-OH absorption wavelength over ~40 m (Figure 14). However, gold mineralization is confined to thin (<50 cm) zones with abundant quartz–carbonate–pyrite veining. This suggests that mineralizing fluids were responsible for widespread alteration of the conglomerates, and mineralization precipitated in narrow zones where changes in physiochemical conditions facilitated gold precipitation. At Kettle Pond South and Lunch Pond North, a progressive decrease in white mica Al-OH wavelength with proximity to mineralized zones is evident for approximately 5–10 m outside the zones of visible alteration of the host rock types (Figures 13 and 14). This suggests that hyperspectral analysis may be useful in vectoring towards mineralization in these orogenic gold deposits.

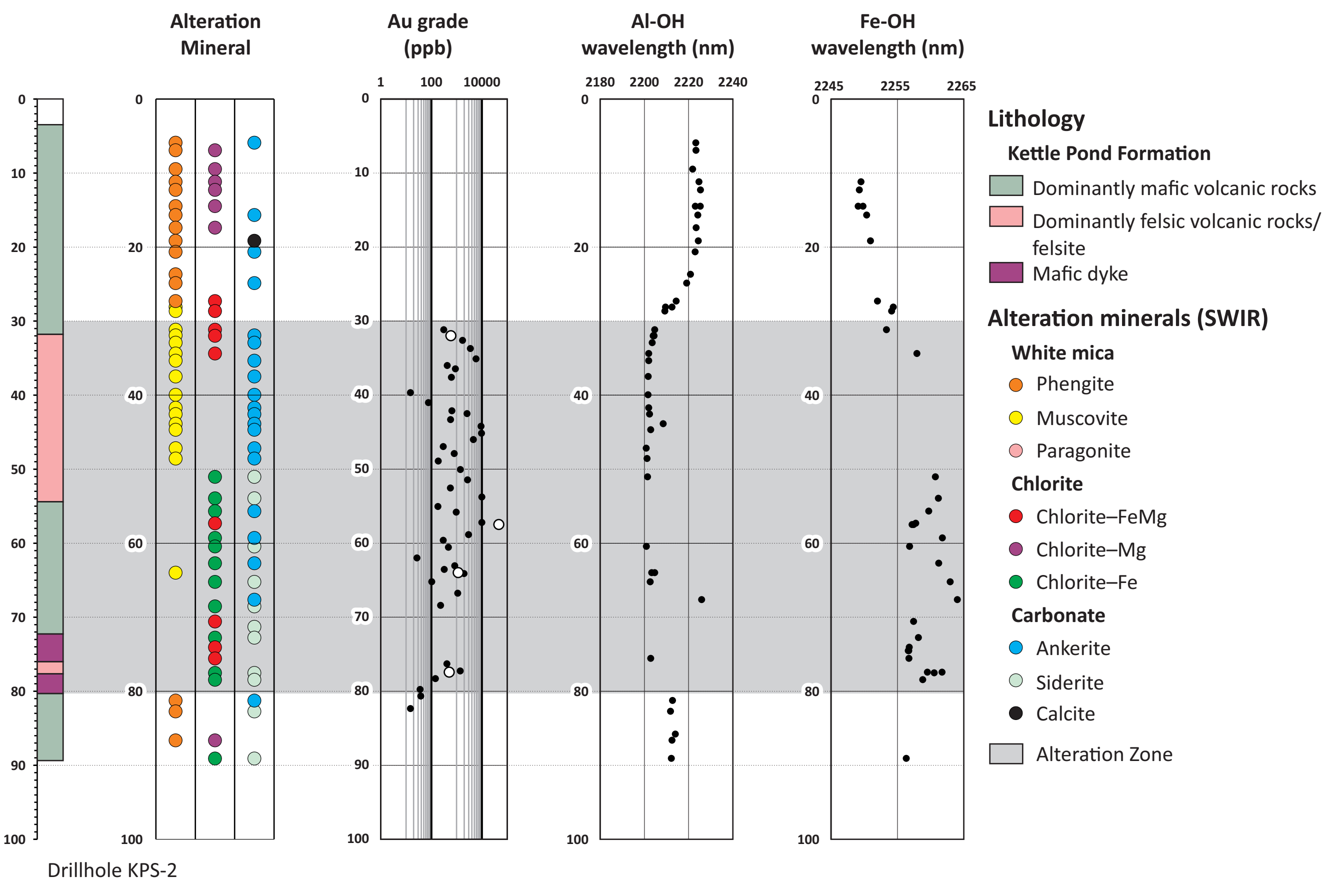

Figure 13. *Strip log for drillhole KPS-2 (Kettle Pond South prospect), showing lithology, Au grades from company assay data (French* et al.*, 1993; filled symbols) and this study (open symbols), alteration minerals as determined from spectral data and key absorption features for white micas (Al-OH) and chlorite (Fe-OH).*

SWIR analysis shows proximal alteration zones are associated with shorter wavelength white mica (muscovite–paragonite) and a slight shift to more Fe-rich chlorite, irrespective of the host rock types or style of mineralization (Figure 12). Although comparisons with other orogenic gold deposits are complicated by variations in the host rocks and the physiochemical composition of the mineralizing fluids, a number of other studies have identified similar trends of decreasing Al-OH absorption wavelengths in white mica proximal to mineralization. Hyperspectral analysis of gabbros associated with the Argyle gold deposit on the Baie Verte Peninsula documented a shift from distal phengitic mica (>2208 nm) to proximal muscovite mica (<2200 nm) close to mineralization (Pawlukiewicz, 2020). Wang *et al.* (2017) reported on similar trends from the Sunrise Dam deposit in Western Australia, with gold mineralization associated with a shift from phengite to muscovite and paragonite. In contrast, the opposite trend has been reported from the Canadian Malartic deposit (Lypaczewski *et al.*, 2019) and the Kanowna Belle deposit in Australia (Wang *et al.*, 2017), with a shift from distal muscovite (<2205 nm) to proximal phengite (>2205 nm). Wang *et al.* (2017) attributed these contrasting signatures to variations in the chemical composition of the mineralizing fluids, with a shift towards shorter wavelengths (similar to this study) associated with reduced, acidic and Fe-rich hydrothermal fluids. Further work is required to better understand the relationship between hyperspectral absorption features, hydrothermal fluid composition and gold precipitation in orogenic gold systems, and to determine the applicability of these findings in mineral exploration.

SUMMARY

Gold occurrences in the Glover Island–Grand Lake area are hosted in volcanic and sedimentary rocks of the Cambro-Ordovician Glover Group, close to the BCZ, a major crustal structure separating the Humber and western Dunnage lithotectonic zones of the Canadian Appalachians.

In the Basal Conglomerate Member of the Kettle Pond Formation, high-grade (up to 150 g/t Au over 1.5 m) conglomerate-hosted gold mineralization occurs in quartz veins in the hinges of regional F_2 folds. Although these mineral-

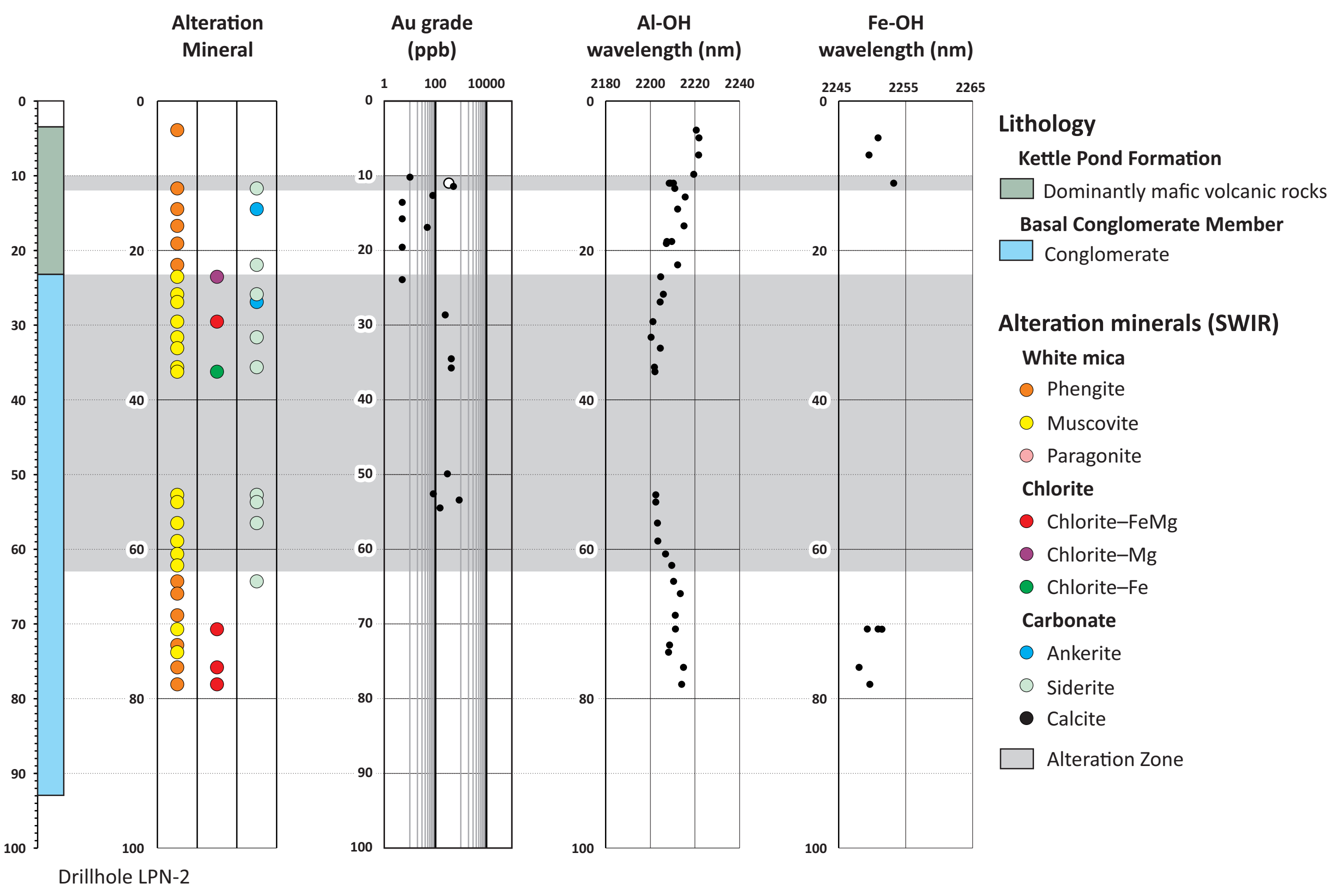

Figure 14. *Strip log for drillhole LPN-2 (Lunch Pond North showing), showing lithology, Au grades from company assay data (French* et al.*, 1993; filled symbols) and this study (open symbols), alteration minerals as determined from spectral data and key absorption features for white micas (Al-OH) and chlorite (Fe-OH).*

ized quartz veins are discontinuous, hydrothermal alteration of the surrounding conglomerates is extensive, up to 40 m from the veins, and is accompanied by characteristic changes in white mica chemistry (as recorded by SWIR analysis). This suggests that gold-bearing hydrothermal fluids were responsible for widespread alteration, but gold mineralization was restricted to the quartz veins in the hinges of F_2 folds and altered conglomerates are unmineralized. Gold occurs in late pyrite-filled fractures that crosscut these quartz veins, suggesting that gold mineralization postdates formation of the quartz veins, and rapid changes in pressure and associated physiochemical fluid conditions during fracturing of the competent quartz veins facilitated precipitation of gold from solution (*e.g.*, Gaboury, 2019).

On Glover Island, volcanic-hosted gold mineralization in the Kettle Pond Formation is spatially related to D_2 thrusts. These occurrences are characterized by lower gold grades, but mineralization occurs over significant thicknesses and is more laterally continuous than in conglomerate-hosted occurrences (*e.g.*, LSPE deposit with 1.74 g/t Au over 53.5 m; Table 1). Mineralization is hosted by strongly altered and deformed felsic to mafic tuffs, with a well-developed S_1 schistosity and the local development of mylonitic fabrics. Gold mineralization postdates the development of the S_1 fabrics, and the hydrothermal alteration mineral assemblages related to gold mineralization are strongly controlled by host rock types. In aphanitic felsic tuff and quartz-feldspar-porphyritic-rhyolite, proximal alteration zones are marked by intense quartz–albite–sericite–carbonate ± chlorite alteration, with mafic volcanic-hosted mineralization characterized by strong chlorite–carbonate ± sericite alteration.

The distribution of volcanic-hosted gold occurrences in the Kettle Pond Formation on Glover Island appears to be largely controlled by variations in host rock rheology and chemistry. Felsic volcanic-hosted gold mineralization predominates and is found in all showings and prospects. Felsic units are significantly more faulted and brecciated than the mafic tuffs, which commonly show evidence of ductile deformation. This brittle deformation of felsic rocks enhanced permeability and enabled gold-bearing hydrothermal fluids to flow through these units. Gold precipitation was likely related to rapid pressure changes during brittle deformation and associated changes in fluid pH (*e.g.*, Gaboury, 2019). Mafic volcanic-hosted gold mineralization has only been recorded in the three largest known occurrences: LPSE, Kettle Pond South and Lucky Smoke. These mafic tuffs also show evidence of brittle deformation, and these occurrences may represent enhanced hydrothermal fluid flow in areas of structural complexity. Sulphides and associated gold mineralization occurs in quartz veins and zones of intense silicification and disseminated in the wallrocks proximal to quartz veins. The abundance of disseminated sulphides in the wallrocks suggests that wallrock sulphidation was an important process in gold precipitation in these mafic volcanic rocks, and this may be responsible for the formation of the largest gold occurrences on Glover Island (*e.g.*, LPSE deposit).

Despite the variations in the styles of mineralization and alteration, largely controlled by host rock lithology and rheology, it is interpreted that gold occurrences on Glover Island are related to a single hydrothermal event. All known occurrences are hosted in greenschist-facies rocks and are related to second or third order structures proximal to a major crustal structure (BCZ). Such a setting is typical of orogenic gold deposits (Goldfarb *et al.*, 2005; Dubé and Gosselin, 2007), and gold occurrences in the study area are similar to other deposits proximal to the BCZ (*e.g.*, Stog'er Tight, Pine Cove deposits, Baie Verte Peninsula). Conglomerate-hosted occurrences postdate formation of quartz veins in the hinges of D_2 folds, and Barbour *et al.* (2012) illustrated that silicified quartz breccias in the volcanic-hosted occurrences were not folded during D_2 deformation but during D_3 deformation. This indicates that gold mineralization on Glover Island occurred syn- to post-D_2 but pre-D_3 deformation, and may be related to the latest stages of the Silurian Salinic orogeny. Similar structural relationships between orogenic gold mineralization and late Salinic deformation have been reported from the Baie Verte Peninsula close to the BCZ (Castonguay *et al.*, 2009), and geochronology indicates that gold mineralization at Baie Verte occurred at *ca.* 420 Ma (Ramezani *et al.*, 2000; Kerr and Selby, 2012).

Gold occurrences in the Youngs Pond area are hosted in mafic tuffs of the Kettle Pond Formation and pillow basalts of the overlying Tuckamore Formation. The host rocks have been strongly sheared and fractured, which is related to a north-northeast-trending fault that may have acted as a conduit for hydrothermal fluid flow (Snow and Walker, 1988; Deering, 1989). At the Noranda #1 showing, mineralization is associated with quartz-carbonate veining and strong chlorite–carbonate–pyrite alteration of the wallrock. Gold is associated with disseminated pyrite in the altered wallrock, indicating wallrock sulphidation was an important control on gold precipitation. Although the relationship between gold mineralization and deformation is less well constrained at Youngs Pond compared to Glover Island, it is possible that mineralization is related to the same hydrothermal event that led to gold deposition on Glover Island.

The structurally controlled, orogenic-style gold mineralization on Glover Island is demonstrated to be related to hydrothermal fluid flow along second and third order structures of the BCZ, likely during the later stages of the

Silurian Salinic orogeny. Further investigations should include $^{40}Ar/^{39}Ar$ geochronology of white mica alteration to determine the precise timing of gold mineralization. SWIR analysis has shown potential to identify distal white mica alteration outside the zone of visible alteration. High-resolution hyperspectral imagery at a range of wavelengths would provide more detailed mineralogy and mineral chemistry related to proximal and distal alteration processes, which could be useful as a vectoring tool for the discovery of new occurrences as have been previously shown in other orogenic gold systems (*e.g.*, Canadian Malarctic; Lypaczewski *et al.*, 2019).

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