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THE SETTING OF EPIGENETIC, STRUCTURALLY CONTROLLED, POLYMETALLIC (Cu–Ag ± Pb ± Au ± Zn) MINERALIZATION AT THE BRIDAL VEIL ZONE (NTS 2D/15), GANDER LAKE SUBZONE, NEWFOUNDLAND

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ABSTRACT

The Bridal Veil and associated mineralized zones immediately north of Gander Lake in the Gander Lake Subzone (NTS 2D/15) host chlorite- to biotite-grade psammite, less common semipelite and rare pelite of the Jonathon's Pond Formation, Gander Group. Bedding dips shallowly to the west-northwest and is parallel to a composite, regional S_{1-2} transposition foliation. The Jonathon's Pond Formation hosts layer-parallel, metagabbro sills or dykes consisting of chlorite– albite–actinolite–magnetite schist. The Bridal Veil and Abbotts Ridge zones are ≤5 m thick, intensely silicified and quartz-veined, and are shallowly northwest-dipping, subparallel psammite horizons, separated by ~900 m across strike. Preferential silicification of psammite was coincident with at least three generations of quartz veins, one pre-(V_1) and two syn-D_3 deformation (V_{2a} and V_{2b}). Narrow (≤5 cm), remnant muscovite ± biotite semipelite horizons in quartz-veined and altered psammite contain sinuous, millimetre-scale septae and blebs of chalcopyrite ± galena ± sphalerite in quartz, and minor accompanying chlorite, albite and sericite. Chalcopyrite is variably altered to goethite. Assay and lithogeochemical samples of the silicified zones have variable metal concentrations, up to 8.9% Cu, 19.5% Pb, 218 ppm Ag and 723 ppb Au, and are also characterized by variably anomalous Bi, Sb, Mo and Sn. Silver is likely associated with galena whereas gold may accompany Bi-tellurides. The youngest, rectilinear, sulphide-poor quartz veins form conjugate Riedel shears and contain anomalous concentrations of the same metals as second-generation veins associated with mineralization in the psammite. Collectively, the two metal-carrying quartz vein generations (V_{2a} and V_{2b}) developed in a biotite-grade, west-southwest-striking (~260°), steeply dipping (~85°) dextral, reverse, oblique shear zone, are of inferred Acadian (Middle Devonian) age. Bridal Veil is an epigenetic, shear zone-hosted Cu–Ag ± Pb ± Au mineralized zone with granitophile metal associations suggestive of local fluid input from a magmatic source.

INTRODUCTION

The Bridal Veil mineralized zone (NTS map area 2D/15; UTM 682308E, 5418249N; NAD27 Zone 21) is located 10 km southeast of Gander, in the north-central part of the northeast Gander Lake Subzone of the Newfoundland Appalachians (Williams *et al.*, 1988; Figures 1 and 2). The area of interest is underlain by metasedimentary rocks of the Gander Group (Kennedy and McGonigal, 1972; Pajari and Currie, 1978; Blackwood, 1982; O'Neill and Blackwood, 1989; O'Neill, 1991a, b; O'Neill and Colman-Sadd, 1993) and is covered in thick glacial deposits (Batterson, 2000; Brushett, 2012). Other than base-metal, chromite, asbestos and minor gold exploration along its western margin in the mid-1950s (Figure 2; *see* Blackwood, 1982; O'Neill and Colman-Sadd, 1993), the northeast Gander Lake Subzone has received little exploration attention despite its geological similarities to the polymetallic (W–Mo–Ag–Au–Sb–Cu–Bi–In) mineralized and lithological correlatives in the Gander Zone of New Brunswick (*e.g.*, Seal *et al.*, 1987; McLeod, 1990; McLeod and McCutcheon, 2001; Thorne and McLeod, 2003; Park *et al.*, 2008). Initial gold discoveries in the region (*see* Figure 2) stemmed from regional 1:50 000-scale mapping in the 1980s and early 1990s (*e.g.*, Blackwood *et al.*, 1984; O'Neill and Knight, 1988; O'Neill and Colman-Sadd, 1993), and the release of regional lake-sediment geochemical data (Davenport *et al.*, 1988; Davenport and Nolan, 1989). Gold exploration has been cyclical and sporadic, with the interval 1992–1997 seeing modest exploration on known mineralized zones (*e.g.*, the Wing Pond gold showing: Graham and St. Hilaire, 1995; Greene *et al.*, 1995; Greene, 1996a, b). Renewed interest in

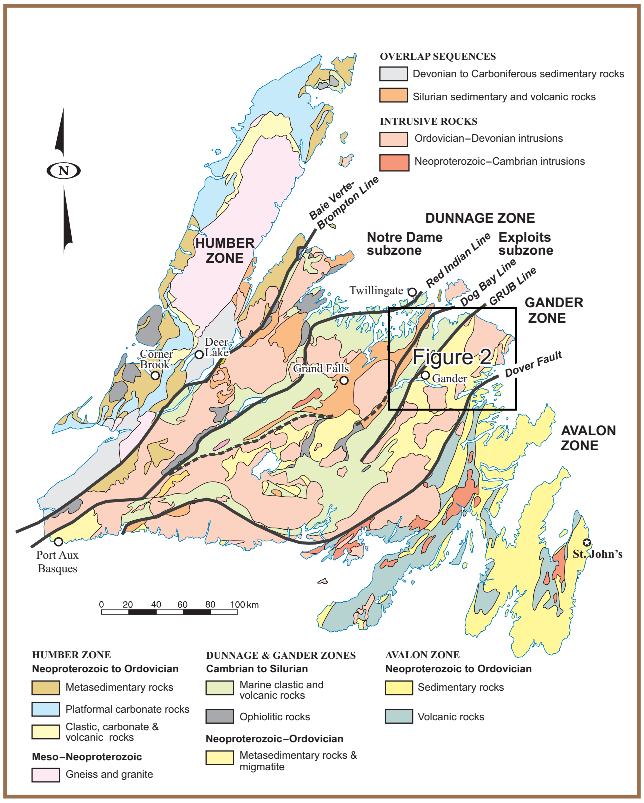


Figure 1. *Simplified geological map of the Island of Newfoundland. The Bridal Veil zone (inset Figure 2) is indicated with respect to major geological terranes and tectonic boundaries (after Colman-Sadd* et al.*, 1990).*

exploration for gold in the Gander Lake Subzone in the early 2000s was likely spurred by increasing gold prices. The Bridal Veil and associated mineralized zones (Woodman and Guinchard, 2000), as well as the Au–As–Sb ± Ag-bearing quartz veins of the Startrack property near Benton (*e.g.*, McVeigh, 2002), were discovered during this resurgence.

This contribution focuses on the Bridal Veil zone, the along-strike mineralization at Hidden Outcrop and the adjacent Abbotts Ridge zone (Figures 2 and 3). All are hosted by greenschist-facies, polydeformed psammitic and semipelitic metasedimentary rocks of the Jonathan's Pond Formation (JPF), one of two major lithostratigraphic units of the areally extensive Gander Group (O'Neill and Blackwood, 1989; O'Neill, 1991a; O'Neill and Colman-Sadd, 1993). The silica-rich, Bridal Veil zone is visible on Google Earth™, and is exposed 520 m north of the Trans-Canada Highway (TCH), 10.3 km to the southeast of Gander (Figure 2). The Abbotts Ridge zone consists of a similar style of mineralization, outcrops approximately 900 m to the north of Bridal Veil, and is easily accessible from the Newfoundland Trailway. Field, structural and petrographic observations, complemented by energy dispersive electron microbeam spectrometric, MLA (Mineral Liberation Analysis) X-ray mapping of mineralization, as well as robust lithogeochemical data for selected rocks in, and around, the Bridal Veil and Abbotts Ridge zones are discussed. These data constrain the nature and origin of the host rocks and their contained polymetallic mineralization. For clarity, the term psammite is used here to describe quartz-feldspar-rich, fine- to medium-grained sandstone; semipelite is used for finer grained rocks, originally consisting of fine-grained sandstone and siltstone beds, and pelite refers to rocks originating as siltstone–mudstone (Robertson, 1999). All ages herein are consistent with the International Commission on Stratigraphy International Chronostratigraphic Chart (ICS, 2018).

REGIONAL SETTING AND HISTORICAL WORK

From west to east, northeastern Newfoundland is underlain by rocks of the Exploits Subzone of the Dunnage Zone, and the Gander and Avalon zones (Figures 1 and 2). The Exploits Subzone is dominated by marine, clastic sedimentary rocks of the Davidsville Group, unconformably overlying ophiolite assemblage rocks of the Gander River Complex. The latter structurally overlies the metasedimentary rock-dominated sequences of the Gander Lake Subzone to the southeast (Williams *et al.*, 1988). The eastern boundary of the northeast Gander Lake Subzone with Neoproterozoic sedimentary–volcanic assemblages of the Avalon Zone is the northeast-striking and steeply dipping, brittle–ductile Dover Fault zone (Figure 2; Blackwood and Kennedy, 1975).

The Gander Lake Subzone has received significantly less government, academic and industry attention than much of the remainder of Newfoundland, largely as a result of two factors. These are:

1) the region is topographically low, has many bogs, a thick cover of glacial till, and limited bedrock exposure (*e.g.*, Batterson, 2000; Brushett, 2011, 2012, 2013), and;

2) most of the northeast Gander Lake Subzone is underlain by relatively shallow dipping metasedimentary rocks cut by granitoid intrusions, and hence the structural, cross-sectional relief of much of the subzone is relatively limited (*e.g.*, Hanmer, 1981).

Much of the early exploration, academic and government studies in the northeast Gander Lake Subzone and environs have been extensively summarized by Blackwood (1982) and O'Neill and Colman-Sadd (1993) and are only briefly outlined herein. The earliest modern investigations of the rocks consisted of 1:250 000-scale mapping (Jenness, 1954, 1958, 1963; Williams, 1962; Anderson and Williams,

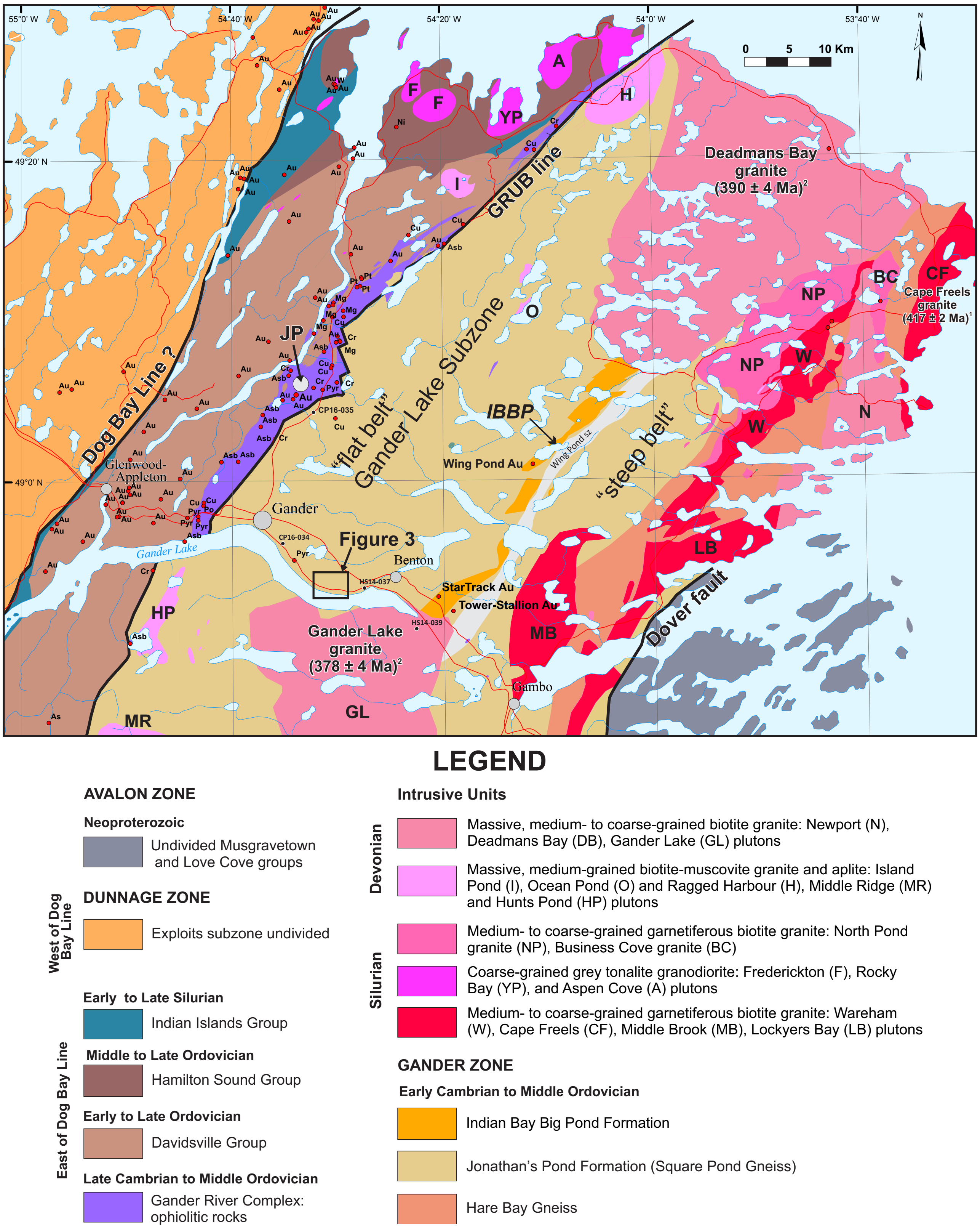


Figure 2. *Geological map of northeastern Newfoundland outlining the Bridal Veil–Abbotts Ridge study area (inset Figure 3) in the northeast Gander Lake Subzone (modified after Colman-Sadd* et al.*, 1990; O'Neill and Colman-Sadd, 1993); includes additions from Tucker (1990) and Kellett* et al. *(2014). JP = Jonathan's Pond gold prospect.*

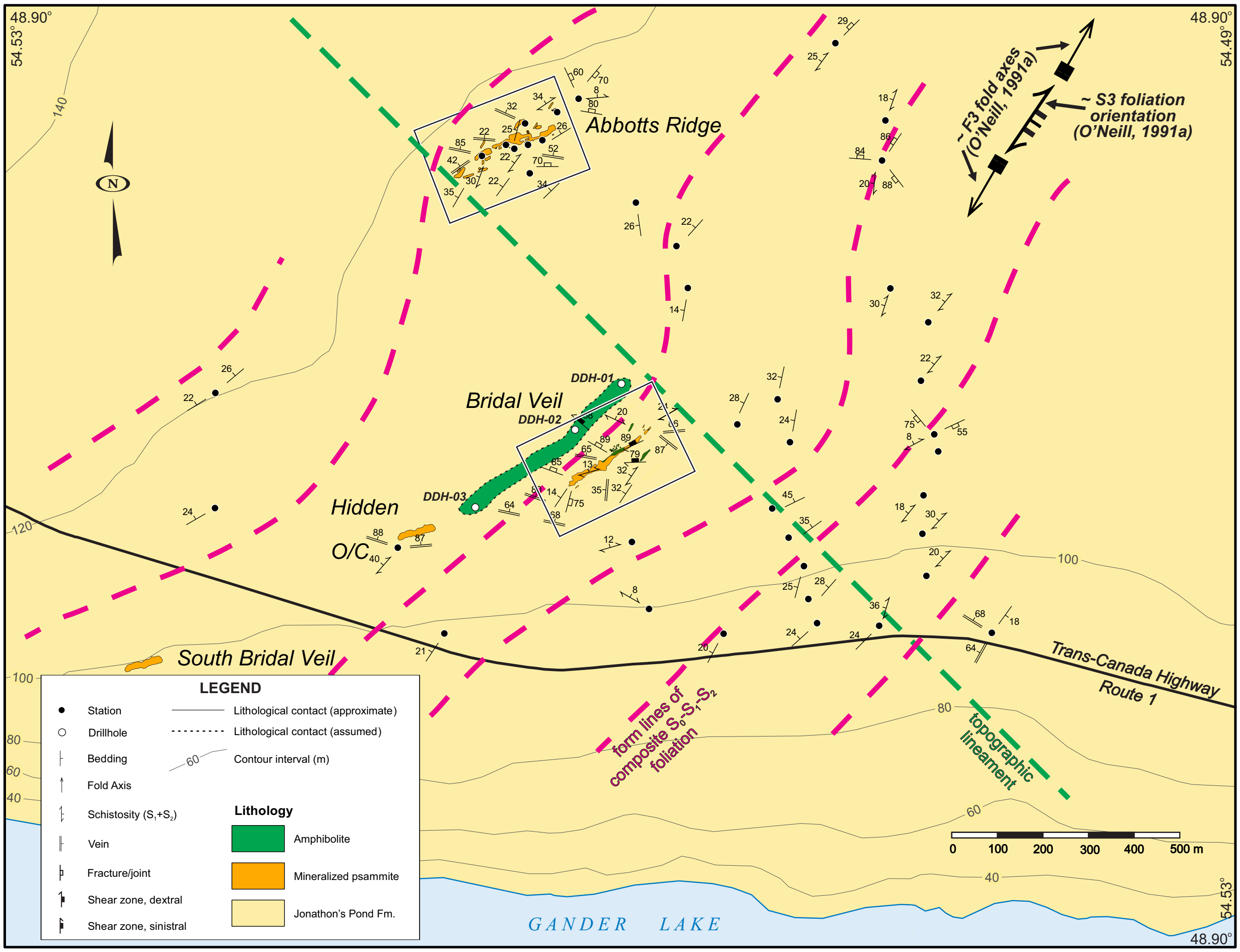


Figure 3. *Simplified geological map of the Bridal Veil area (O'Neill, 1991a; O'Neill and Colman-Sadd, 1993; Woodman and Guinchard, 2000;* this study*). The small rectangular boxes represent the areas included in the detailed geological maps of W. Jacobs (*in *Woodman and Guinchard, 2000).*

1970), and definition and characterization of lithostratigraphic units, paleontology, geochemistry and geochronology (*e.g.*, Lowden, 1960; Eastler, 1969; Kennedy and McGonigal, 1972; McGonigal, 1973; Dickson, 1974; Bell *et al.*, 1977; Pajari and Currie, 1978; Strong and Dickson, 1978; Stouge, 1980). Systematic 1:50 000-scale geological mapping began in the late 1970s to early 1980s (*e.g.*, Blackwood, 1980, 1981, 1982; Jayasinghe, 1978). Hanmer (1981) proposed a regional, geodynamic synthesis for the northeastern Gander Zone, based largely on structural analyses, and interpreted the area as representing a paired Devonian, ductile sinistral shear zone in the east and a ductile sinistral thrust zone in the northwest. Integrated magnetic, gravity and geochemical studies (Miller and Weir, 1982; Miller, 1988) outlined two probable thrust panels of ultramafic to mafic Exploits Zone-like rocks that extended from Gander Lake, north-northeast to the Gander River Complex, near the Gander Bay coast, and led to the proposal that these units had been transported eastward over the northeastern Gander Lake Subzone in the Ordovician.

Much of the northeast Gander Lake Subzone was last mapped at 1:50 000 scale in the late 1980s and early 1990s (O'Neill, 1987, 1990a, b, c, 1991a, b, 1993; O'Neill and Knight, 1988; O'Neill and Colman-Sadd, 1993), broadly coincident with the geophysical work of Miller and Weir (1982) and Miller (1988). Other than sporadic mineral exploration work, little academic or government studies have since been undertaken in the Gander Lake Subzone. The few published studies (*e.g.*, Holdsworth, 1991, 1994; D'Lemos and Holdsworth, 1995; D'Lemos *et al.*, 1997; Kellett *et al.*, 2014, 2016) have focused on the eastern boundary of the Gander Lake Subzone near the Dover Fault where the features, produced during Ganderia and Avalonia collision, are best preserved and interpreted. Neodymium isotopic investigations have been undertaken on several granitic intrusions and gneissic rocks in the northeast Gander Lake Subzone (D'Lemos and Holdsworth, 1995; Kerr *et al.*, 1995). A number of undergraduate and graduate dissertations have provided new geochronological and petrochemical constraints on the rocks of the subzone (*e.g.*, *see* Buchanan and Bennett, 2009; Langille, 2012).

The northeast Gander Lake Subzone (Williams *et al.*, 1988) is underlain mainly by a central area of relatively "flat-lying" turbiditic metasedimentary rocks of the Gander Group (*e.g.*, Hanmer, 1981; O'Neill and Colman-Sadd, 1993). These units are structurally bound to the west by the north-northeast-trending Gander River Complex (GRC; Figures 1 and 2), a relatively narrow belt (≤8 km) of structurally imbricated peridotite, gabbro, basalt, trondhjemite and marine sedimentary rocks collectively considered to represent a dismembered, Cambro-Ordovician ophiolite complex (O'Neill and Blackwood, 1989; O'Neill, 1990a, b). The GRC is undated, but it is unconformably overlain and imbricated with rocks of the Weirs Pond Formation (O'Neill and Blackwood, 1989; O'Neill, 1991a, b), part of the basal Davidsville Group that contains brachiopod fragments, indicative of a Floian to Dapingian (Middle Ordovician) age (Jenness, 1963; McKerrow and Cocks, 1977). These are slightly older than, but overlapping in age with, late Dapingian to early Darriwilian conodonts extracted from limestone of the Weirs Pond Formation near Weirs Pond (Stouge, 1980). Therefore, the ophiolitic rocks are inferred (Blackwood, 1982; Colman-Sadd *et al.*, 1992) to have been emplaced eastwards over the Ganderian margin during the Floian, *ca.* 475–470 Ma Penobscott orogeny (Neuman, 1967; Zagorevski *et al.*, 2010; van Staal and Barr, 2012). The ophiolitic GRC is therefore older than *ca.* 475 Ma.

Regional mapping, geochemical, structural, metamorphic and geochronological studies (O'Neill, 1987; O'Neill and Knight, 1988; O'Neill and Lux, 1989; O'Neill, 1991a; O'Neill and Colman-Sadd, 1993) have clarified many issues relating to northeast Gander Lake Subzone geology. O'Neill and Knight (1988) and O'Neill and Colman-Sadd (1993) redefined the Gander Group as consisting of two distinct metasedimentary packages:

1) the JPF comprises interbedded arenitic sandstone and semipelite, and;

2) the overlying Indian Bay–Big Pond Formation (IBBPF) typically comprises fine-grained pelitic metasedimentary rocks, but locally intercalated with pebble to cobble conglomerate, maroon siltstone and basaltic lavas (Wonderly and Neuman, 1984; O'Neill and Knight, 1988; O'Neill and Colman-Sadd, 1993).

Mapping in the northwestern part of the Gander Lake Subzone near Gander Bay (Currie, 1997) outlined the calcareous Cluff Pond pelite, a unit inferred to represent the top of the Gander Group in that area. A detailed examination and documentation of this unit, however, has not yet been completed. The age of the JPF is poorly constrained. A JPF psammite yielded a single detrital zircon age of *ca.* 550 Ma, whereas six titanite grains, of possible/probable detrital origin, yielded individual U–Pb ages that cluster around *ca.* 540 Ma (T. Krogh, personal communication, 1988; cited in O'Neill, 1991a). The JPF was interpreted as a sequence of Cambro-Ordovician, deep-water turbidites deposited along the west-facing, extended Gander margin and the eastern margin of Iapetus Ocean (Blackwood, 1982; O'Neill, 1991a; O'Neill and Colman-Sadd, 1993). The IBBPF is younger than the JPF, and exhibits paleontological and lithological characteristics typical of rocks of the eastern Exploits Subzone (Wonderly and Neuman, 1984; Boyce, 1987; O'Neill and Knight, 1988). An argillaceous tuff, exposed on the shore of Indian Bay Big Pond, yielded late Floian brachiopods, trilobites and bryozoans (Wonderly and Neuman, 1984); corroborated subsequently by identification of the trilobite *Anamitella* (Boyce, 1987). The IBBPF is presently considered to be allochthonous upon rocks of the JPF, based on the contrasting radiometric and paleontological data, as well as contrasting metamorphic grade and structural grain (Wonderly and Neuman, *op. cit.*; O'Neill and Colman-Sadd, 1993).

O'Neill (1991a) recognized and defined the Wing Pond shear zone, a south-southwest-trending, 3- to 6-km-wide high-strain zone separating the eastern margin of the IBBPF from JPF rocks of the "steep belt" lying to the east (Figure 2). Within the Wing Pond shear zone, rocks typically have steeper and more intensely developed phyllonitic fabrics relative to those of the IBBPF to the west and the JPF to the east (O'Neill and Colman-Sadd, 1993). The shear zone broadly coincides with the trace of the eastern geophysical anomaly zone (Miller and Weir, 1982; Miller, 1988).

East of the Wing Pond shear zone, rocks of the JPF progressively increase in metamorphic grade to upper amphibolite, locally, to granulite facies, and the regional southwest-striking schistocity is steeper ("steep belt"). Farther east, the higher grade metamorphic rocks transition into the Hare Bay Gneiss (Blackwood, 1978; O'Neill and Colman-Sadd, 1993; Holdsworth, 1994; D'Lemos *et al.*, 1997; Langille, 2012). The Gander Group metasedimentary rocks and Hare Bay Gneiss are intruded by a series of dominantly granitic (*s.s.*), syntectonic Late Silurian to Middle Devonian plutons (*e.g.*, Middle Brook, Lockyers Bay and Cape Freels plutons; Figure 2), as well as posttectonic, Middle Devonian intrusions (*e.g.*, Deadmans Bay, Lumsden and Gander Lake plutons; Langille, 2012; Kellett *et al.*, 2014; G.R. Dunning, personal communication, 2018; Figure 2). The former plutons are variably deformed, whereas the latter intrusions are typically massive.

MINERAL EXPLORATION

Early mineral exploration was generally confined to the evaluations of the base-metal, chromite, as well as the asbestos and gold potential of the GRC (Figure 2; *see* Blackwood, 1982; O'Neill, 1990a; O'Neill and Colman-Sadd, 1993). The release of regional lake-sediment and water-chemical surveys (Davenport *et al.*, 1988; Davenport and Nolan, 1989) and the bedrock and mineral-inventory mapping of O'Neill and Knight (1988), O'Neill (1990a) and O'Neill and Colman-Sadd (1993) prompted gold exploration in the area. The first discovery of gold in the broader region was within quartz-veined and altered gabbro of the GRC (Blackwood, 1982), 4 km northwest of Jonathan's Pond (Figure 2). The earliest reported gold mineralization within the northeast Gander Lake Subzone, (*s.s.*), was the Wing Pond gold showing (Figure 2; O'Neill and Knight, 1988). It consists of a series of quartz veins and breccias that cut variably iron-carbonate-altered and silicified metasedimentary rocks of the Indian Bay–Big Pond Formation that yield anomalous Au–As–Sb–Pb and Ag values (Graham, 1991; Greene, 1996a, b; Morgan, 2012). Noranda Exploration Ltd. staked the Wing Pond gold showing immediately after the public release of mineralization data of the new gold showing; however, no exploration work was recorded. The discovery of the Wing Pond mineralization prompted more exploration and staking along much of the strike extent of the Indian Bay–Big Pond Formation (Dimmell and Jacobs, 1989; Graham, 1991, 1992; Graham and St. Hilaire, 1995; Greene *et al.*, 1995; Greene, 1996a, b). Follow-up on a coincident Au–As–Sb lake-sediment anomaly (Davenport *et al.*, 1988), led to discovery of quartz-vein-related Au–As–Sb–Ag mineralization at the Tower property (Graves, 1990), southeast of the community of Benton (since termed the Stallion-trend, McVeigh, 2002). O'Neill and Colman-Sadd (1993) reported assay sample results for mineralized rocks of the Gander Lake area, including a sulphidic quartz vein (sample 89-37, O'Neill and Colman-Sadd, 1993) obtained from what is herein termed the Abbott's Ridge zone. This sample yielded 92 ppb Au, 47 ppm Ag, 3.5 ppm As and 0.8 ppm Sb, and is one of a number of such examples from mineralized zones in the Gander Lake area, which contain comparable Au–As–Ag–Sb metal associations, and locally include anomalous tungsten and molybdenum (O'Neill and Colman-Sadd, 1993).

Since 1990, much of the exploration work in the northeastern Gander Lake Subzone has focused on gold. At the turn of the millennium, following the dot-com bubble and accompanying an increase in the price of bullion, gold exploration resumed and resulted in a number of new discoveries (*e.g.*, Startrack Trend, McVeigh, 2002; Squires, 2005) as well as further exploration of known showings (*e.g.*, Stallion Trend, McVeigh, 2002, 2003; Sparkes and Hoffe, 2004; Mullen, 2004). The Bridal Veil and Abbotts Ridge mineralized zones were initially staked and explored in 2000, and have been intermittently investigated since (Woodman and Guinchard, 2000; Woodman, 2002, 2003, 2005, 2006, 2007; Guinchard, 2010, 2011, 2012, 2013). Work on the Bridal Veil–Abbotts Ridge zones has included: detailed geological mapping (W. Jacobs *in* Woodman and Guinchard, 2000); extensive, but poorly documented grab-sample collection; detailed ground magnetic studies including Induced Polarity gradient, multi-dipole and VLF-EM grids (Woodman, 2002, 2003; Guinchard, 2011, 2012); and structural analysis (C. Buchanan *in* Woodman, 2007). Three shallow (75.3, 14.35 and 43.6 m) diamond-drill holes, two vertical and one steeply inclined (80°), were collared to the north of the Bridal Veil zone in an effort to intersect the mineralized psammite at depth (Figure 3; Woodman, 2003; Guinchard, 2012). These three holes penetrated a thick unit of fine-grained mafic schist (sill?) cut by quartz veins and quartz-flooded zones accompanied by epidote–chlorite–adularia alteration, and sporadic, elevated Cu (<9154 ppm), Pb (<8700 ppm), Ag (<5.1 ppm) and weakly anomalous Au (<74 ppb) (Guinchard, 2012).

GEOLOGY OF THE BRIDAL VEIL–ABBOTS RIDGE AREAS

Twelve days, over two summers (2014 and 2016), were spent examining and sampling regional outcrops in the Gander Lake Subzone focusing on the area hosting the Bridal Veil and Abbots Ridge mineralized zones (Figure 3). The map area is characterized by undulating, gentle topography descending toward Gander Lake, and exhibits low, northeast-trending ridges separating wide, sparsely tuckamore-covered peatland. Exposure is poor (<<5%), typically confined to the northeast-trending ridges. The study area (Figure 3) is underlain entirely by rocks of the JPF of the Gander Group (O'Neill and Knight, 1988; O'Neill, 1991a; O'Neill and Colman-Sadd, 1993). The JPF in the map area typically consists of thick-bedded (20 cm to 2 m), fine- to medium-grained psammite and less common, thinner layers, and septae of semipelite and pelite (*e.g.*, Plate 1A, B). Thick pelitic layers (>50 cm) are typically rare. Bedding-parallel quartz veins are variably developed, but locally common. The metasedimentary rocks preserve a compositional-layering (bedding) and parallel foliation defined by micaceous folia (Plate 1C, D). Examination of the JPF in regional quarries, however, indicates that thicker intervals (~<5 m) of fine-grained semipelite to pelite may be more common than suspected, and are therefore not well represented in regional, till-blanketed outcrops.

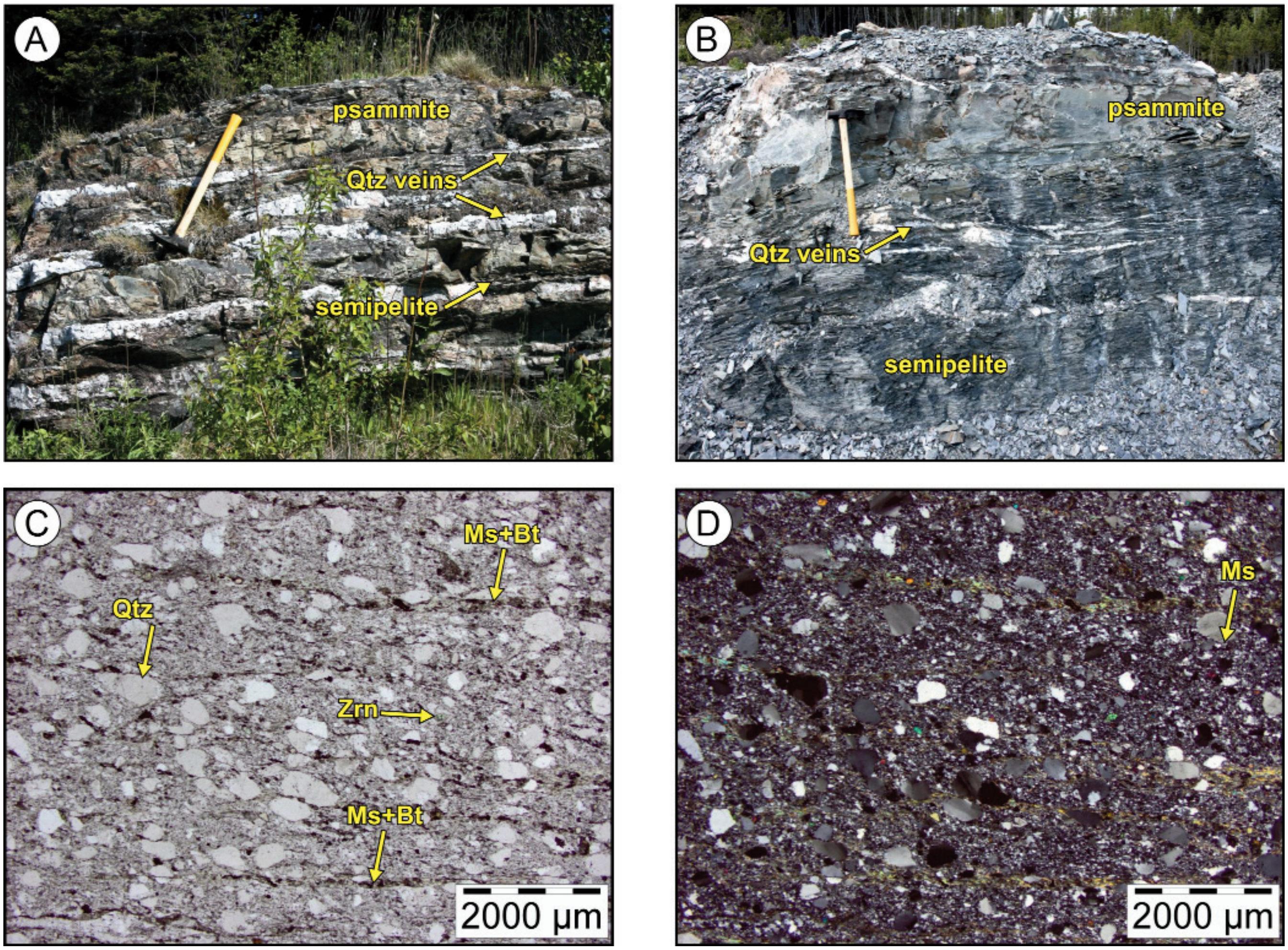


Plate 1. *Field photographs of representative JPF rocks in the greater study area. A) Typical, medium-bedded, fine-grained psammite with thin semipelitic interbeds cut by numerous bedding-parallel quartz veins. Geotul is 57 cm long; B) Photograph of interlayered 25-cm-thick psammite horizon in thick-bedded semipelite cut by layer-parallel, V_1 quartz veins. Geotul is 57 cm long; C) Plane-polarized photomicrograph of the schistose, biotite + muscovite-bearing, fine-grained psammite of the JPF; D) Crossed-polar photomicrograph of the same psammite sample. Key: Qtz–quartz; Ms–muscovite; Bt–biotite; Zrn–zircon.*

The metasedimentary rocks are locally interlayered with broadly bedding-parallel sheets of fine- to medium-grained mafic schists interpreted (O'Neill, 1990, 1991a; *this study*) as either sill-like intrusions parallel to primary layering, or as mafic dykes that have been rotated into bedding-parallel sheets. At Bridal Veil, mafic schist sheets (Plate 2A, B) occur directly above and below the mineralized psammite. A mafic schist to the northwest of the zone (structurally above) has an amphibole–chlorite mineral foliation parallel to the regional fabric in the adjacent metasedimentary rocks, is intensely quartz-veined, silicified and altered, with magnetite being largely destroyed; thus, this unit clearly predates alteration and mineralization (Plate 2C). Immediately southeast of the mineralized psammite, the mafic-schist horizon is poorly exposed, but is largely unaltered and lacks quartz veins. Amphibolitic schist and mafic rocks have not been identified in the vicinity of the Abbotts Ridge zone. Both mafic horizons at Bridal Veil are fine-grained, albite–chlorite–actinolite–magnetite schists that have been metamorphosed to greenschist facies, contain rare biotite porphyroblasts, and preserve a single foliation defined by chlorite–actinolite and quartzofeldspathic folia (Plate 2D, E).

Although the metasedimentary and mafic schists of the JPF are the only lithostratigraphic units identified in the immediate Bridal Veil–Abbotts Ridge study area (Figure 3), the Devonian non-foliated Gander Lake granite (*ca.* 378 ± 4 Ma; Kellett *et al.*, 2014; *see* Figure 2) is exposed along the southeastern shore of Gander Lake and along the TCH at the eastern end of the lake. Bedrock exposures along the TCH,

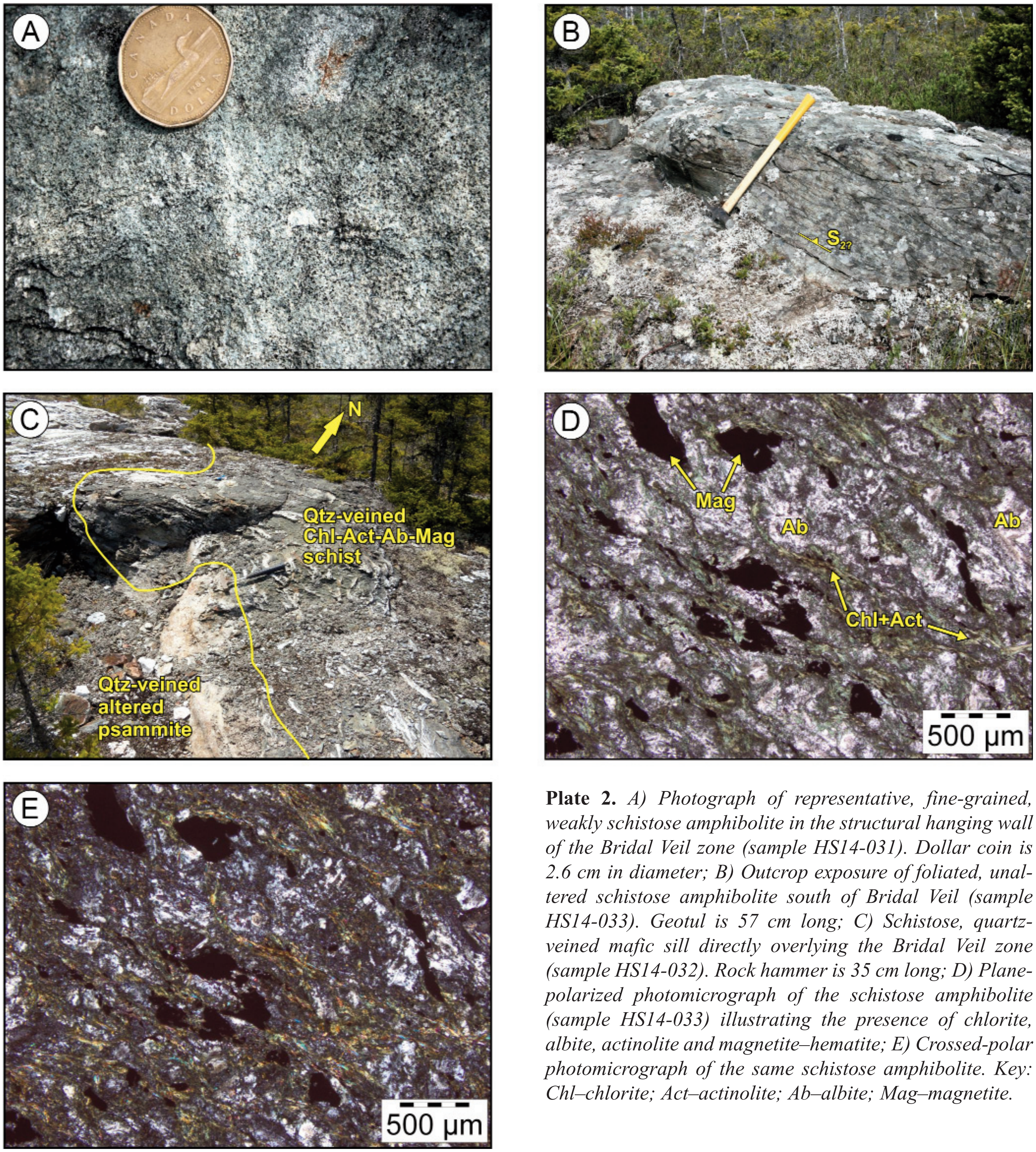


Plate 2. *A) Photograph of representative, fine-grained, weakly schistose amphibolite in the structural hanging wall of the Bridal Veil zone (sample HS14-031). Dollar coin is 2.6 cm in diameter; B) Outcrop exposure of foliated, unaltered schistose amphibolite south of Bridal Veil (sample HS14-033). Geotul is 57 cm long; C) Schistose, quartz-veined mafic sill directly overlying the Bridal Veil zone (sample HS14-032). Rock hammer is 35 cm long; D) Plane-polarized photomicrograph of the schistose amphibolite (sample HS14-033) illustrating the presence of chlorite, albite, actinolite and magnetite–hematite; E) Crossed-polar photomicrograph of the same schistose amphibolite. Key: Chl–chlorite; Act–actinolite; Ab–albite; Mag–magnetite.*

between Bridal Veil and Benton (Figure 2), locally contain quartz–microcline ± biotite ± muscovite pegmatoidal patches and veins (*e.g.*, Plate 3A, B). Variably chloritized and chlorite-veined, weakly potassium-feldspar–porphyritic, medium-grained muscovite–biotite monzogranite (Plate 3C, D) is exposed in a small stream on the northeastern side of Gander Lake, 3.8 km east of the Bridal Veil zone (Figure 2, sample HS14-37).

Two previously unreported mafic dykes cut the bedding and regional bedding-parallel cleavage. The first, an approximately 1-m-wide dyke (CP16-034) that strikes 165° and

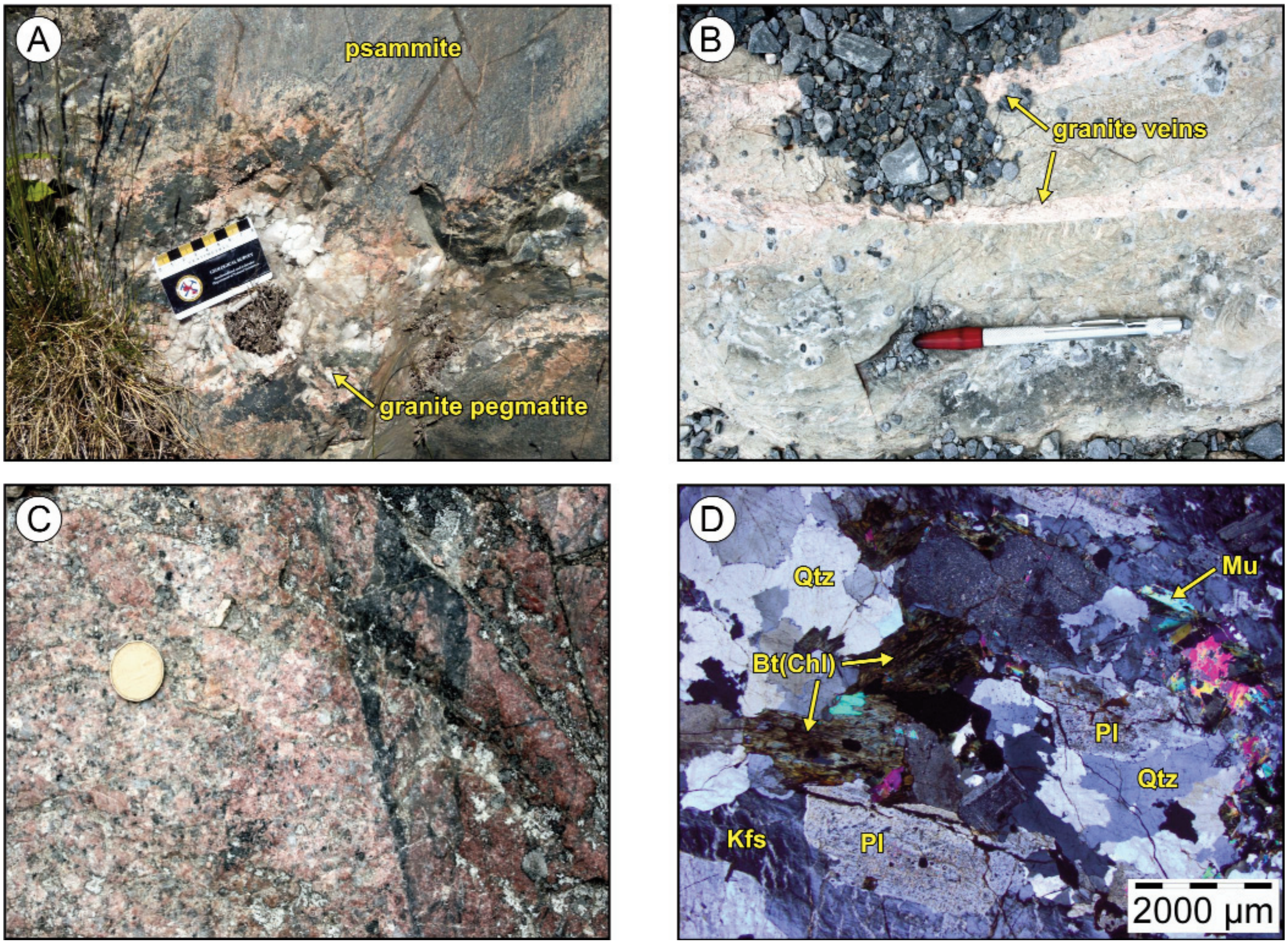


Plate 3. *Photographs documenting evidence of the proximity of the Gander Lake granite. A) Granitic pegmatite patches in biotitic psammite of the JPF (station HS14-26); B) Two- to three- cm-wide fine-grained granite veins cut biotitic psammite of the JPF; C) Photograph of medium-grained, locally chloritic muscovite–biotite monzogranite of the Gander Lake granite (sample HS14-37); D) Crossed-polar photomicrograph of the biotite–muscovite monzogranite sample HS14-37. Key: Qtz–quartz; Ms–muscovite; Bt–biotite; Chl–chlorite; Pl–plagioclase; Kfs–potassium feldspar.*

dips 70° to the west cuts strongly deformed (275/12) interbedded psammite and semipelite of the JPF in a large quarry east of Gander (Figure 2). The dyke is a fine- to medium-grained gabbro, has variably preserved anhedral clinopyroxene intergrown with variably sausuritized plagioclase laths and less common anhedral ilmenite–magnetite grains (Plate 4A, B). The second dyke (CP16-035) was noted in the quarry immediately north of Jonathan's Pond, near the western margin of the northeast Gander Lake Subzone (Figure 2). This dyke is narrow (<30 cm), has an orientation of 170/85, and is a fine-grained, plagioclase porphyritic basaltic dyke with seriate texture. Plagioclase phenocrysts range from a maximum of ~1 mm in diameter down to tiny microlites, all set in a black to opaque, glassy groundmass. Larger plagioclase phenocrysts commonly exhibit sieve-textured core zones (Plate 4C, D).

CHARACTERISTICS OF MINERALIZATION

Mineralization at the Bridal Veil and Abbotts Ridge zones consists mostly of chalcopyrite, and is hosted by thick (<5 m) layers of fine- to medium-grained psammite (Plates 5 and 6), locally containing thin (typically <15 cm thick) semipelite interlayers. These psammite-dominated horizons are, locally, strongly silicified and are cut by numerous, tightly spaced quartz veins. Silica alteration and quartz veining are more extensive at Bridal Veil than at Abbotts Ridge (*cf.* Plates 5 and 6), obscuring protoliths of the host rocks at the former. At Bridal Veil, the intensely silicified, chalcopyrite-mineralized host rocks, may have originally contained more extensive semipelite, but are now represented by a rock consisting mostly of silica along with minor sericite and sulphide

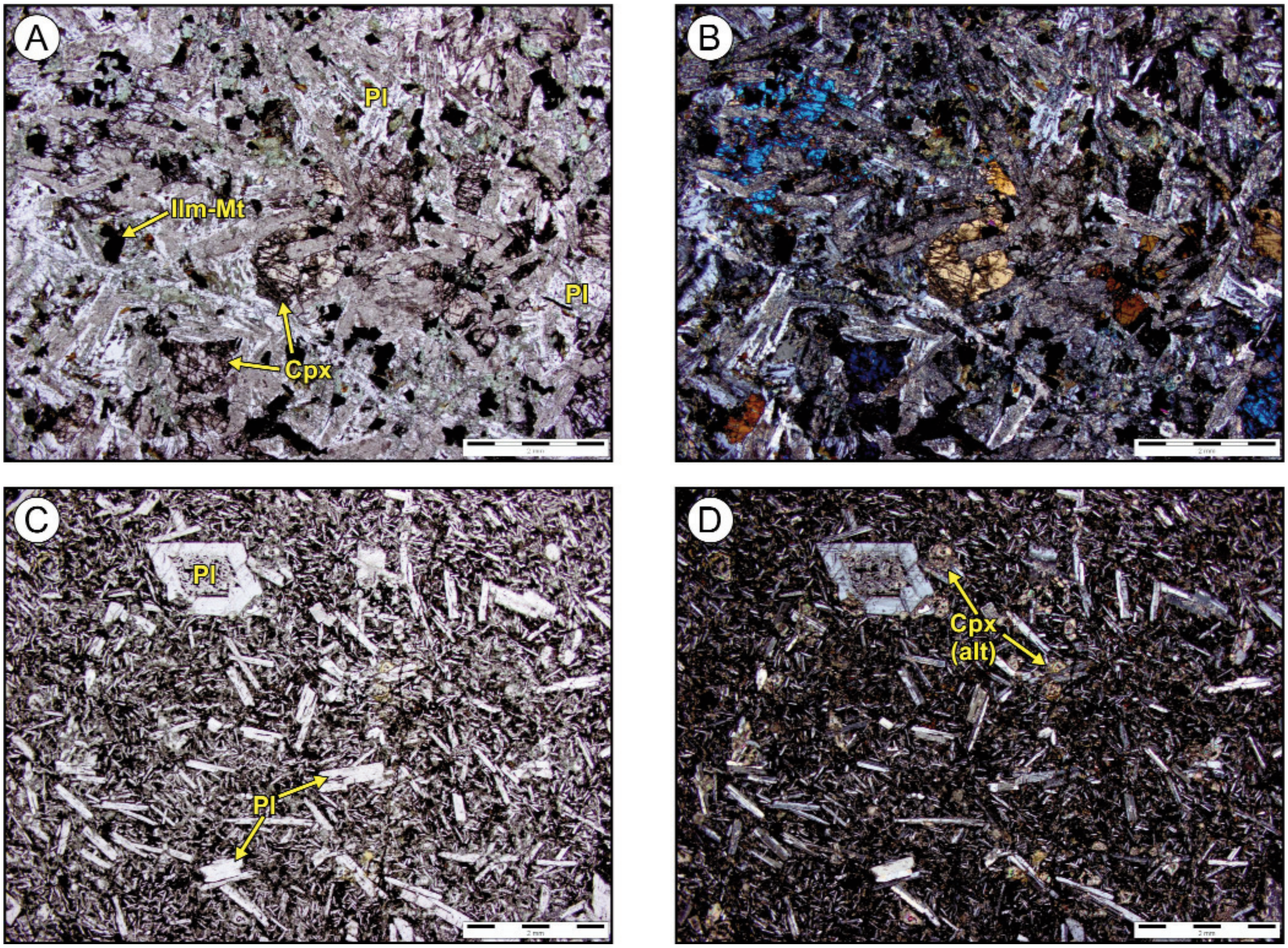


Plate 4. *Photomicrographs of the two young mafic dykes. A) Plane-polarized photomicrograph of the medium-grained gabbroic dyke (sample CP16-034); B) Crossed-polar photomicrograph of dyke sample CP16-034; C) Plane-polarized photomicrograph of the fine-grained basaltic dyke (sample CP16-035); D) Crossed-polar photomicrograph of dyke sample CP16-035. Key: Cpx–clinopyroxene; Pl–plagioclase; Ilm–ilmenite; Mt–magnetite.*

minerals (Plate 5). Mineralization at Abbotts Ridge is typically confined to bedding-parallel, vein-like ribbons of granular chalcopyrite and quartz in thick layers of semipelite, interlayered with the silicified psammite (Plate 6).

Silicified and mineralized host rocks are cut by a complex network of at least three generations of quartz veins (Plates 5 and 6: Qtz 1–3). Chalcopyrite mineralization occurs both in silicified psammite and in two generations of crosscutting discrete quartz veins. Adjacent to many of these veins, sparse, green, and translucent sericite is abundant in remnant wall-rock fragments floating in the quartz stockwork. Minor albite and Fe-chlorite also form sparse alteration phases and, with sericite, typically form curvilinear trails in a matrix of fine-grained, recrystallized sutured quartz, and outline the main foliation in the altered hostrock (Figure 4). The silicified rocks are cut, broadly parallel to the remnant foliation, by coarse-grained, mosaic and sutured, irregular quartz veins, which, both contain and have margin-parallel, sinuous chalcopyrite blebs accompanied by chlorite–sericite and goethite. Anomalous copper and other metals (*see* below) are found in singly veined and silicified hostrock, in multi-veined and silicified hostrock and, in late, rectilinear crosscutting quartz veins. Samples with the most elevated metal concentrations are composed of silicified, multiple quartz-veined psammite with chalcopyrite ± pyrite ± galena ± bismuth telluride-bearing bands, lenses and septae (Plate 6C; Figure 4), and display sericite + Fe–chlorite + albite ± goethite alteration (Figure 4). An increase in the abundance of chalcopyrite appears to correlate with an increase in the proportion of pelite and semipelite lenses in the psammite, such as that at Abbotts Ridge (Plate 6B). Thus, Cu assay values at Abbotts Ridge are generally comparable to those at Bridal Veil, despite the lower intensity of silicification in the former. Semipelite layers and lenses in the hostrock may have provided a more reactive, Fe–S-bear-

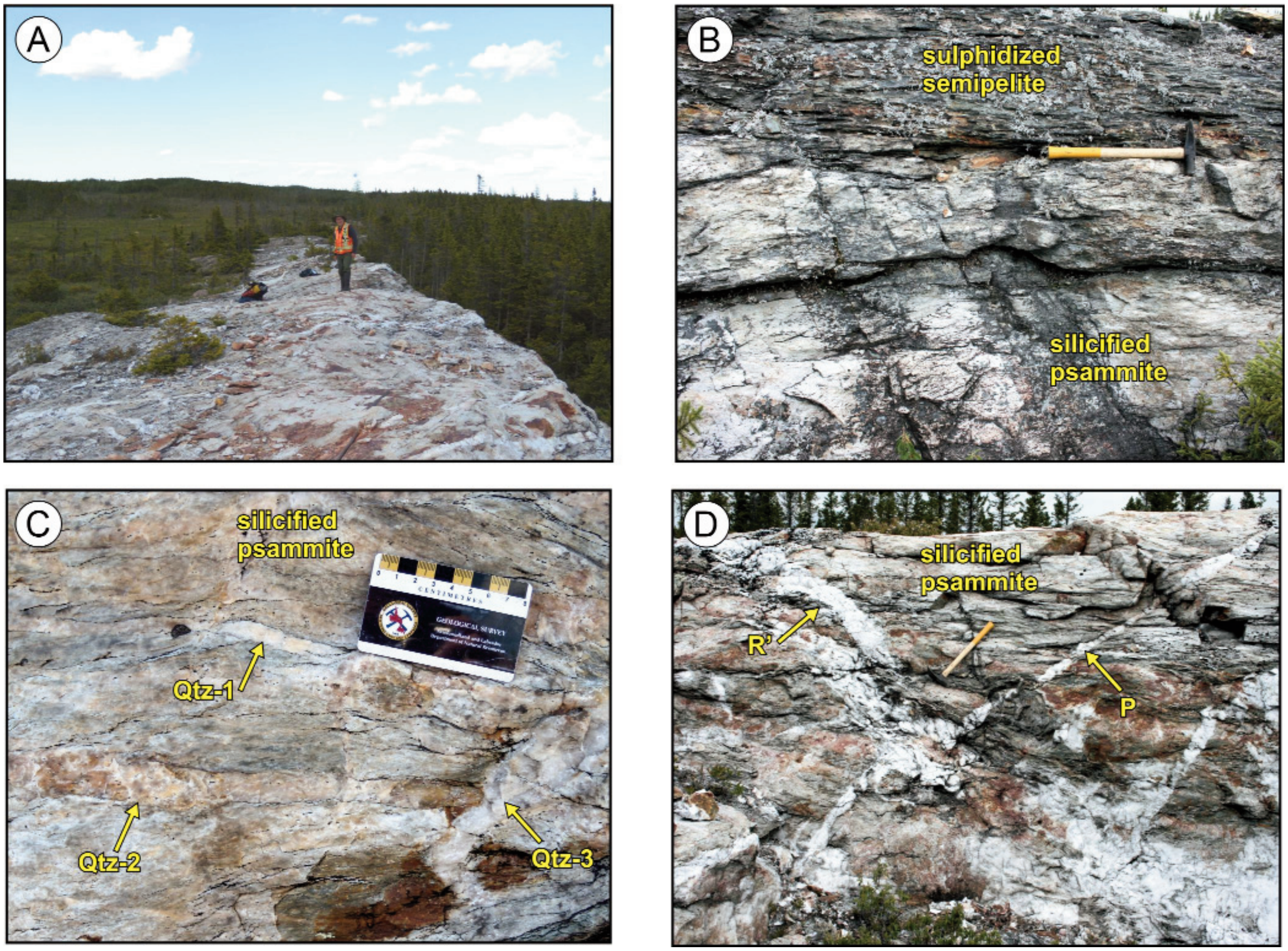


Plate 5. *Representative photographs of the mineralized horizon at Bridal Veil. A) Looking northeast along strike at the rusty, silicified and quartz-veined mineralized zone – W. Guinchard for scale; B) Moderate silicified psammite interlayered with rusty semipelite at the northeast termination of the Bridal Veil zone. Geotul is 48 cm in length; C) A vertical surface of the mineralized zone, looking northwest, and outlining the three distinct generations of quartz veins. Labelled veins correspond to those discussed in the text (V_1, V_{2a} and V_{2b} veins, respectively); D) A vertical surface of the mineralized horizon, looking northwest, and outlining the rectilinear set of R' and P (V_{2b}) veins. Geotul is 48 cm long.*

ing setting for the reduction of the mineralizing fluids that accompanied emplacement of the quartz vein array (Plate 6B, C). The youngest, rectilinear quartz veins (Plates 5D, 6D and Figure 5) are generally sulphide-poor, and contain <5% chalcopyrite + pyrite ± galena with minor sericite + albite + chlorite + goethite (Figure 5), particularly along their contacts with the altered host rock.

STRUCTURAL ANALYSIS OF THE BRIDAL VEIL AREA

Rocks of the northeast Gander Lake Subzone are polydeformed, gently inclined and lack any mappable marker horizons. Although rare, F_1 folds were identified on the wave-washed exposures along the shores of Gander Lake (Blackwood, 1982; O'Neill and Colman-Sadd, 1993), forming isoclinal, commonly rootless folds of bedding and, locally, bedding-parallel amphibolite layers and lenses (*see* Plate 2; O'Neill and Colman-Sadd, 1993). The structural grain of the northeast Gander Lake Subzone, however, is defined by second generation F_2 sub-recumbent to recumbent isoclines and a composite, axial planar S_1–S_2 transposition fabric that formed during regional D_2 deformation (O'Neill, 1991a; O'Neill and Colman-Sadd, 1993; C. Buchanan *in* Woodman, 2007). During later regional D_3 deeformation, the F_2 folds and S_2 fabric were refolded by open-to-closed, northeast-plunging F_3 folds (*see* O'Neill, 1991a).

Two phases of deformation identified in the map area correlate with regional D_2 and D_3 deformational events

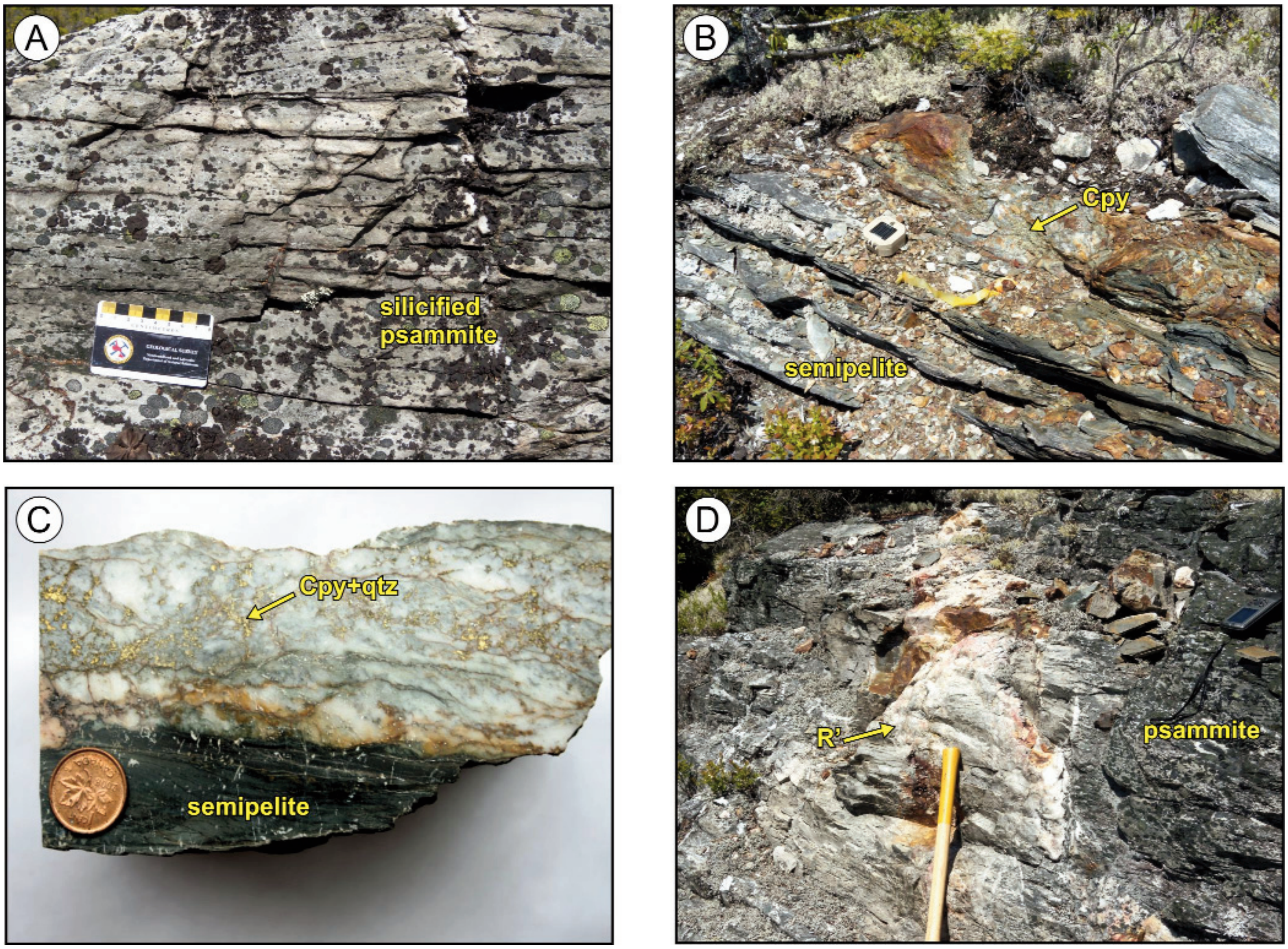
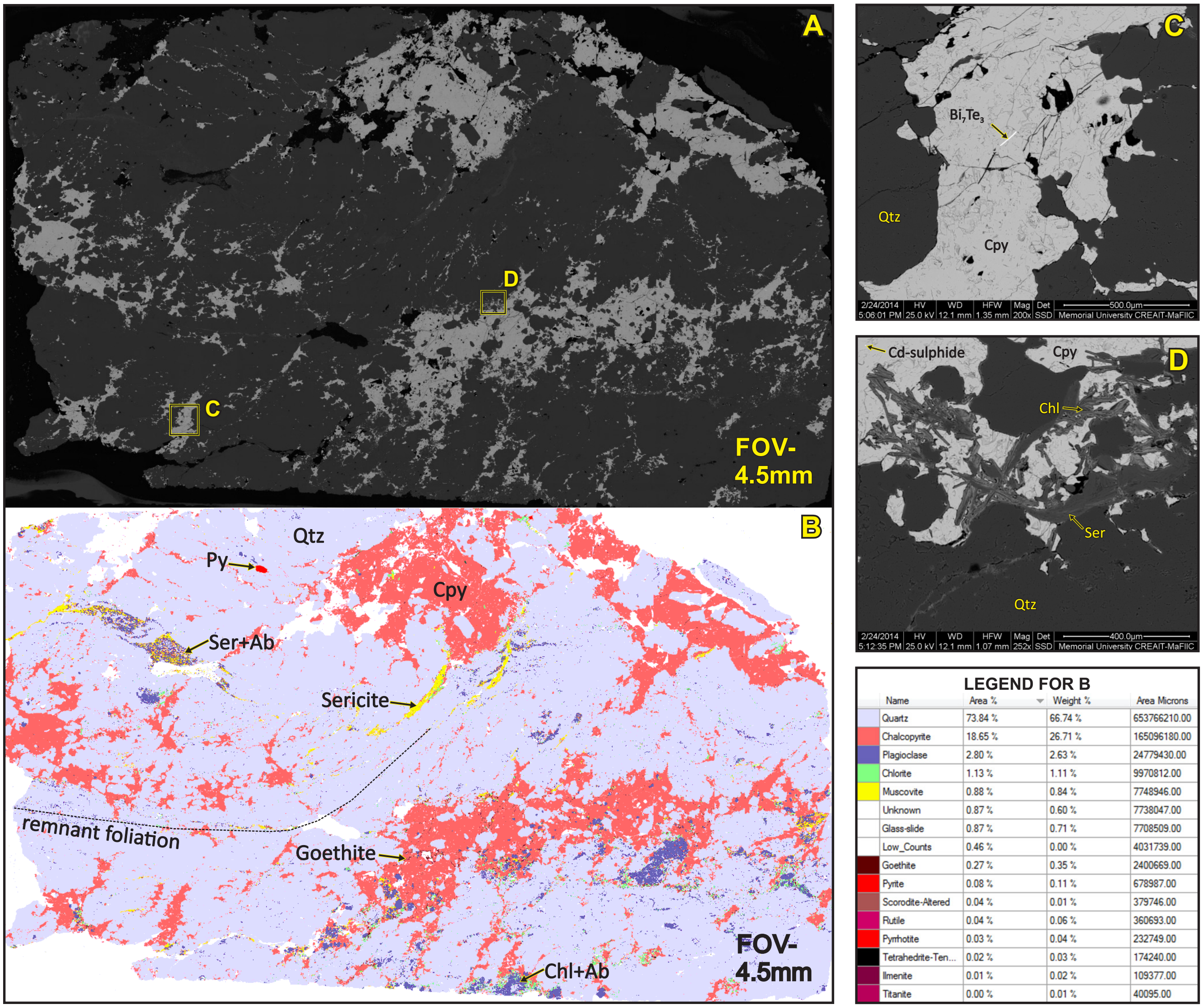


Plate 6. *Representative photographs of the host rocks at the Abbotts Ridge zone. A) Thin- to medium-bedded, fine-grained moderately silicified and sparsely quartz-veined psammite; B) Chalcopyrite-rich septae and bands in silicified semipelitic horizons. Brunton compass for scale; C) Slab photograph of chalcopyrite + quartz vein in semipelite. Canadian cent is 19 mm in diameter; D) Slightly irregular, R' Riedel shear fracture (V_{2b}) filled by a sulphidic quartz vein cuts, weakly altered and silicified psammite. Geotul is 48 cm long. Key: Qtz–quartz; Cpy–chalcopyrite.*

defined by previous workers, both characterized by northwest–southeast compression (*e.g.*, O'Neill, 1991a). Owing to a lack of exposure, the fold systems at Bridal Veil are poorly constrained. The geology is defined by a gently northwest-dipping, homoclinal panel of metasedimentary strata, amphibolitic schists, and an associated layer-parallel fabric, termed S_2 (Figure 6). The homocline is interpreted as a northwest-dipping F_3 limb imposed on a macroscale F_2 fold (Figure 7). Two quartz-vein generations are termed V_1 and V_2, the latter of which is subdivided into V_{2a} and V_{2b}. Below is a summary of the structural evolution of the Bridal Veil area with respect to the relative chronological development of observed structures including folds, faults, tectonic fabrics and veins, all of which may be related to mineralization.

V_1: EVOLUTION OF BEDDING-PARALLEL VEINS

The S_0/S_2 parallel veins are locally observed throughout the Bridal Veil property and are the oldest vein generation. These veins formed during flexural slip/flexural flow folding processes as indicated by bedding-parallel brittle–ductile shear zones (dextral and sinistral; Tanner, 1989; Huddleston *et al.*, 1996; Figures 7A, B and 8) and down-dip mineral lineations that lie orthogonal to F_2 fold axes noted by previous workers (*e.g.*, O'Neill *et al.*, 1991a). Shear zone kinematics were interpreted based on foliation asymmetries and sigma clasts (Figure 7C, D). Although mesoscopic hinges domains were not observed, the presence of both dextral and sinistral bedding-parallel shear zones suggest the presence of F_2 parasitic folds. During incremental bed-



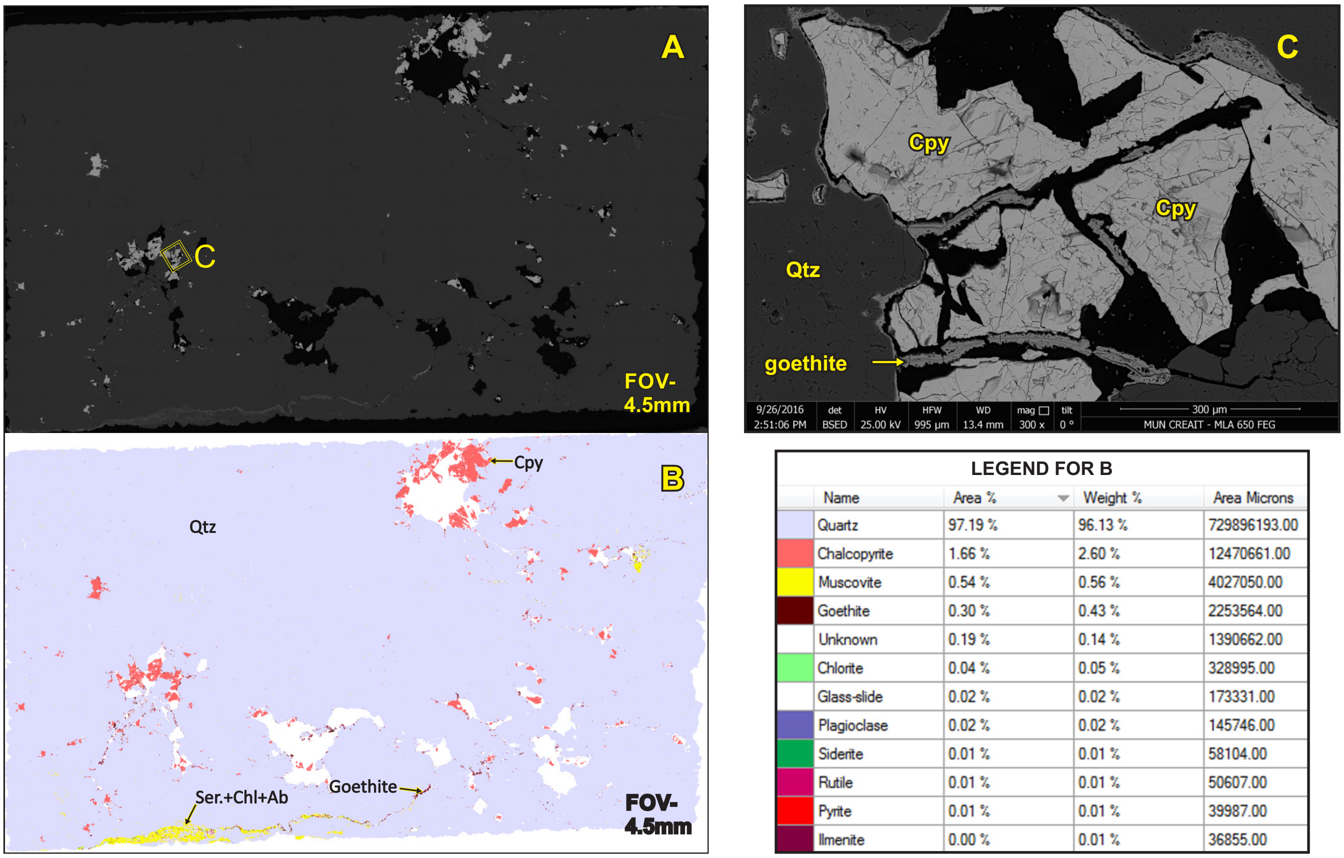
Name	Area %	Weight %	Area Microns
Quartz	73.84 %	66.74 %	653766210.00
Chalcopyrite	18.65 %	26.71 %	165096180.00
Plagioclase	2.80 %	2.63 %	24779430.00
Chlorite	1.13 %	1.11 %	9970812.00
Muscovite	0.88 %	0.84 %	7748946.00
Unknown	0.87 %	0.60 %	7738047.00
Glass-slide	0.87 %	0.71 %	7708509.00
Low_Counts	0.46 %	0.00 %	4031739.00
Goethite	0.27 %	0.35 %	2400669.00
Pyrite	0.08 %	0.11 %	678987.00
Scorodite-Altered	0.04 %	0.01 %	379746.00
Rutile	0.04 %	0.06 %	360693.00
Pyrrhotite	0.03 %	0.04 %	232749.00
Tetrahedrite-Ten...	0.02 %	0.03 %	174240.00
Ilmenite	0.01 %	0.02 %	109377.00
Titanite	0.00 %	0.01 %	40095.00

Figure 4. *Electron microprobe Mineral Liberation Analysis (MLA) imagery for a mineralized silicified psammite (sample BV13-001; 682554E, 5418133N) from the Bridal Veil zone. A) Backscattered secondary electron (BSE) image of thin section showing the locations of images C and D; B) MLA false-colour image of the mineralogy of the thin section (colour legend at right); C) BSE image of bismuth telluride inclusion in chalcopyrite intergrown with quartz; D) BSE image of cadmium sulphide inclusion in chalcopyrite intergrown with quartz, sericite and chlorite. Key: Qtz–quartz; Chl–chlorite; Ser–sericite; Cpy–chalcopyrite; Py–pyrite; Ab–albite.*

ding-parallel shear, an increase in fluid pressure in the hydrothermal system reduced the effect of normal stresses acting on the shear plane causing oblique dilation sub-perpendicular to the bedding/cleavage plane thereby permitting vein emplacement (Jessell *et al.*, 1994). Dilation and permeability cause fluid pressure to drop, leading to stress restoration of the system and shearing and lineation development (a cyclical process: Jessell *et al.*, 1994).

V_{2a} AND $_{2b}$: VEINS ASSOCIATED WITH STEEPLY DIPPING SHEAR ZONES

The second phase of veining includes stockworks formed in dextral, east-northeast-striking and steeply dipping, brittle–ductile shear zones formed during regional D_3 deformation. The shear zones host mineralization in two fundamentally different vein arrays; (V_{2a}) veins occur as *en echelon* straight and sigmoidal tension gashes, and (V_{2b})



LEGEND FOR B

Name	Area %	Weight %	Area Microns
Quartz	97.19 %	96.13 %	729896193.00
Chalcopyrite	1.66 %	2.60 %	12470661.00
Muscovite	0.54 %	0.56 %	4027050.00
Goethite	0.30 %	0.43 %	2253564.00
Unknown	0.19 %	0.14 %	1390662.00
Chlorite	0.04 %	0.05 %	328995.00
Glass-slide	0.02 %	0.02 %	173331.00
Plagioclase	0.02 %	0.02 %	145746.00
Siderite	0.01 %	0.01 %	58104.00
Rutile	0.01 %	0.01 %	50607.00
Pyrite	0.01 %	0.01 %	39987.00
Ilmenite	0.00 %	0.01 %	36855.00

Figure 5. *Electron microprobe Mineral Liberation Analysis (MLA) imagery for a mineralized rectilinear, R' mineralized quartz vein (sample HS14-010,* see *Sandeman and Peddle, 2020) cutting silicified psammite at the Abbotts Ridge zone. A) BSE image of the thin section showing the location of the image in C; B) MLA false-colour image of the thin section (colour legend at right); C) BSE image of goethite replacing chalcopyrite along internal fractures. Key: Qtz–quartz; Chl–chlorite; Ser–sericite; Cpy–chalcopyrite; Py–pyrite; Ab–albite.*

veins are hosted in Riedel shear fractures. Ambiguous cross-cutting relationships occur between these two vein systems and are, therefore, interpreted to be broadly coeval.

Mineralization at Bridal Veil is commonly associated with *en echelon* and straight sigmoidal tension gashes hosted within west-southwest-striking and steeply dipping dextral shear zones (average orientation 260/85, Figure 9). The evolution of shear zones of this nature is dependent on fluctuating hydrothermal fluid pressures within the system. High fluid pressures promote instantaneous extension forming straight tension gashes parallel to the trend of the maximum compressive stress. Fracturing and fluid migration decrease pressure, thereby re-instating ductile simple shear, which rotates the newly formed V_{2a} tension gashes clockwise (Craddock and Pluijm, 1988). The oldest veins of the system will have been strongly rotated, whereas the youngest veins will exhibit little-to-no rotation.

The geometric relationships between V_{2b} vein-filled fractures at the Bridal Veil and Abbots Ridge zones suggest that they form a Riedel-type shear system. Riedel shear fractures (R and R') form in specific orientations relative to a master fault zone and the principle stress axes. The R (synthetic shear) and R' (antithetic shear) shear fractures, together, form conjugate fracture sets defined by acute dihedral angles of ~60° and are bisected by the maximum compressive stress (σ1: Katz *et al.*, 2004). The P fractures (synthetic shear) form later in response to prolonged shearing and are commonly referred to as "compressive fractures", as they accommodate much of the compressive strain within the system (Katz *et al.*, 2004). At the metre scale, R, R' and P fractures are defined having mean orientations of 262/80, 318/75 and 050/86, respectively (Figure 10). The calculated average shear-zone orientation and slip vector for the Riedel Shear model is 246/88 and 17-246, respectively (Figure 10). The relationship between the average shear plane and slip vector suggests the Riedel Shear fractures formed in a dextral-reverse shear system (Figure 10). Moreover, the fractures and veins share a common intersection point (73-060), which may represent the plunge and trend of maximum fluid flow during formation of the shear zone (Figure 10). Ideally,

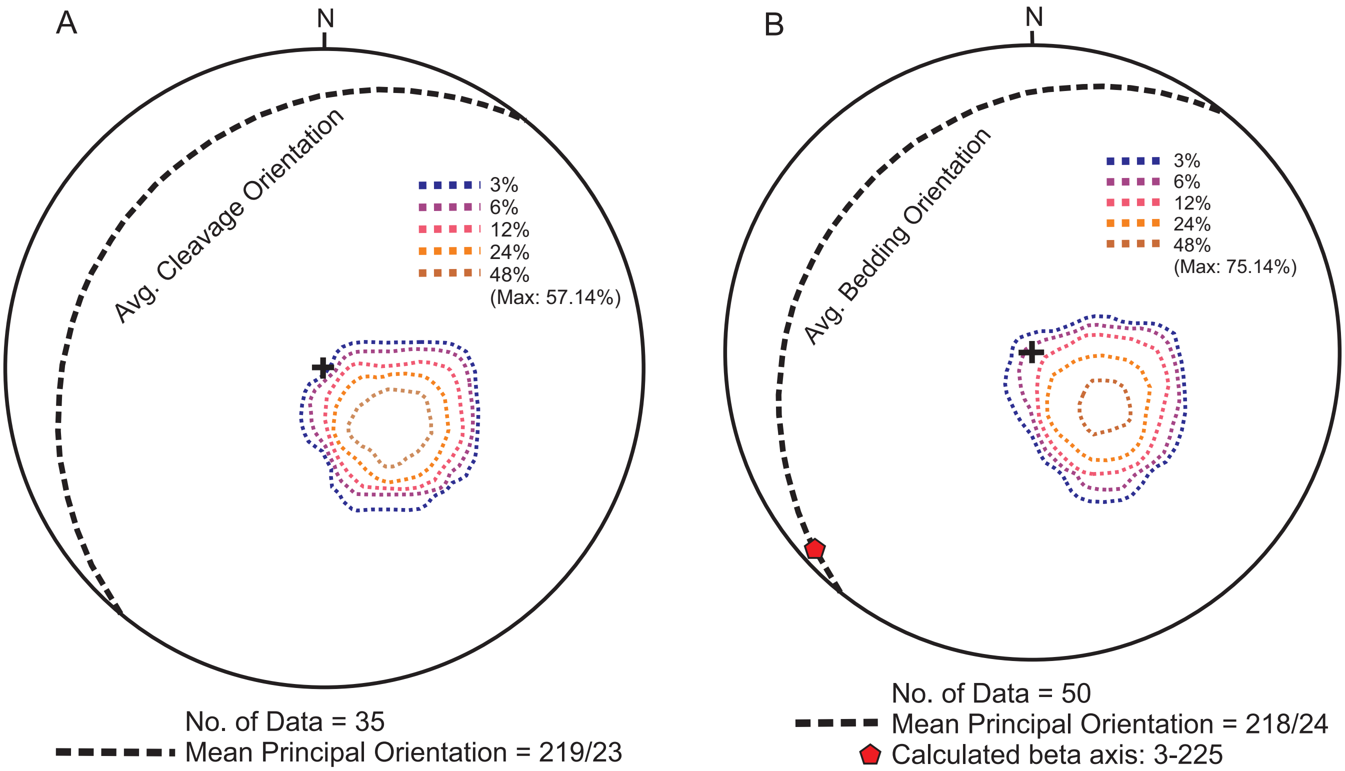


Figure 6. *A) Lower hemisphere, equal-area plot showing the average composite S_{1-2} orientation; B) Lower hemisphere, equal-area plot showing the average S_0 orientation at the Bridal Veil and Abbots Ridge zones. It represents a homoclinal section of a northwest-dipping F_3 fold limb.*

R, R', and P fractures in brittle-ductile shear zones should not undergo extension and promote vein development and, therefore, it is likely the fractures dilated later as tensile veins during high fluid pressures (Scholz, 1990). The similarity of V_{2b} vein orientations from the regional to the local scale (Bridal Veil and Abbotts Ridge zones) suggests that mesoscopic and regional-scale veining formed under similar stresses at different scales (Figure 10).

LITHOGEOCHEMISTRY

ANALYTICAL METHODS

Twenty one lithogeochemical samples were obtained from the Abbotts Ridge and Bridal Veil mineralized zones, as well as from the surrounding sedimentary rocks of the Gander Group, mafic schists and dykes and, the Gander Lake granite. Four samples were analyzed as rock duplicates, representing a second aliquot of the crushed rock, whereas four others were chosen as laboratory duplicates. The samples include: two unaltered psammites of the JPF; one quartz-veined and two unaltered mafic schists; two post-D_2 mafic dykes; four from west- to northwest-trending (set 3: R' and P shear fractures; Plate 4D), weakly sulphidic quartz-veins; seven silicified and mineralized psammites; one barren quartz-vein breccia containing fine-grained psammite fragments and; two from the Gander Lake granite. The Gander Lake granite analyses are supplemented by five samples from the Geoatlas (http://geoatlas.gov.nl.ca/Default.htm), for which additional incompatible trace-element data have been determined using inductively coupled plasma-mass spectrometry (ICP-MS).

Samples were analyzed for their major, trace, and rare-earth element (REE) contents (*see* Sandeman and Peddle, 2020 at the Department of Natural Resources, Government of Newfoundland and Labrador, Geochemical Laboratory (Howley Building, Higgins Line) using methods outlined in Finch *et al.* (2018). Gold, Cd, Bi, As and Sb contents were determined *via* Instrumental Neutron Activation Analysis (INAA) at Bureau Veritas Laboratories using their standard techniques (http://www.bvlabs.com/). These new data are supplemented by, and compared to, previously published data for the Bridal Veil area, available in mineral-exploration industry assessment reports (Woodman and Guinchard, 2000; Woodman, 2002, 2003; 2005; 2006; 2007; Guinchard, 2010, 2011, 2012; 2013).

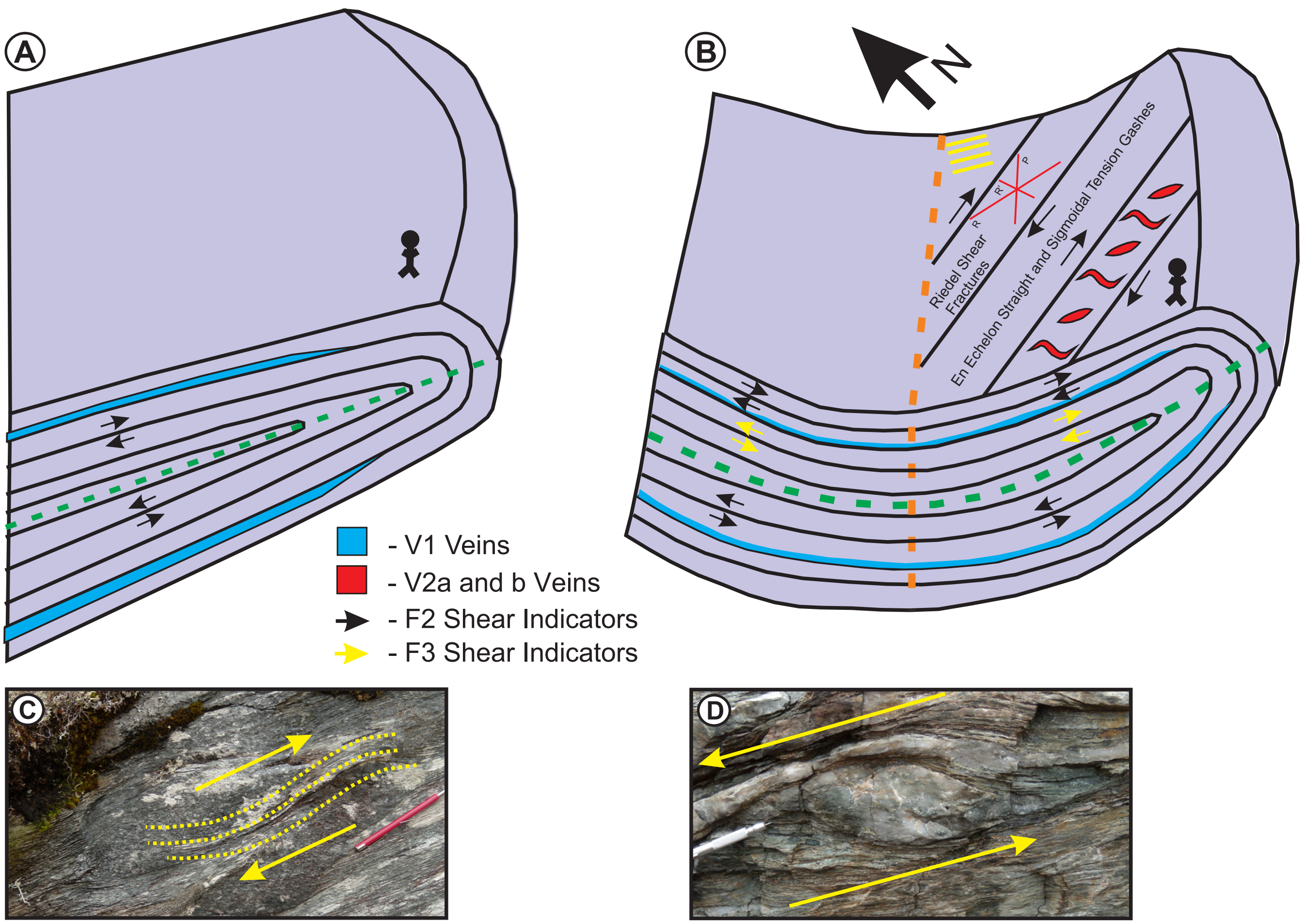


Figure 7. *A) Block diagram showing the relationship between the V_1 vein systems in a F_2 fold geometry. Here, V_1 veins formed during D_2 deformation along layer-parallel shear zones through flexural slip/flow mechanisms and parallel to both S_0 and S_2; B) Block diagram showing the relationship between V_1 and V_2 veins in the northwest-dipping limb of the overprinting F_3 fold system. In this model, early V_1 veins that formed during D_2 were later cut by V_{2a} and V_{2b} veins during progressive D_3 deformation; C) Foliation asymmetries located in a bedding-parallel brittle–ductile shear zone indicating dextral shear-sense suggesting an upper limb domain of a recumbent F_2 fold; D) Sigma clast located in a bedding-parallel brittle–ductile shear zone indicating sinistral shear-sense suggesting a lower limb domain of a recumbent F_2 fold. Pen magnet is 13.5 cm long. Stick figure indicates observer's viewpoint.*

ELEMENT ASSOCIATIONS IN MINERALIZATION

Clear identification of the host lithology and the sampling of specific quartz-vein generations are hindered by localized intense silicification, sericitization, albitization and chloritization, and the emplacement of a network of at least three generations of quartz veins. Altered and mineralized samples show significant variability in their compositions, although altered samples have multi-element patterns broadly comparable to their unaltered equivalents, albeit at lower concentrations because of silica dilution. This suggests that many elements may have been mobile and significantly diluted during alteration. The metal associations and their relationships with the loss-on-ignition (LOI) values, along with fluid-mobile elements, are important for the interpretation of the mineralized rocks. However, the immobile major and trace elements, along with the high-field strength (HFSE) and rare-earth (REE) elements, show more consistent values and systematic behaviour for all fresh rock samples, and are important in the interpretation of protoliths.

Lithogeochemical results from this study along with exploration industry ICP and fire-assay data, are plotted in log-log plots (Figures 11 and 12). The data indicate that gold (Au), silver (Ag), lead (Pb), bismuth (Bi) and, sporadically, molybdenum (Mo) and tellurium (Te) correlate with copper (Cu, Figure 11). Figure 12A–D demonstrate broad correlation of Bi, Au and Pb with Ag (Figure 12A–C), and that Bi correlates with Au (Figure 12D). Quartz-veined and silici-

Figure 8. *Lower hemisphere, equal-area plot showing the orientations of mineral fibre packages (green crosses), mineral stretching lineation (orange star) and the predicted F_2 fold axis trend (red pentagon) noted by O'Neill (1991a). The trend of the fold axis lies perpendicular to measured lineation's observed on the surface of bedding-parallel veins indicating that strain was partitioned through flexural slip during their formation.*

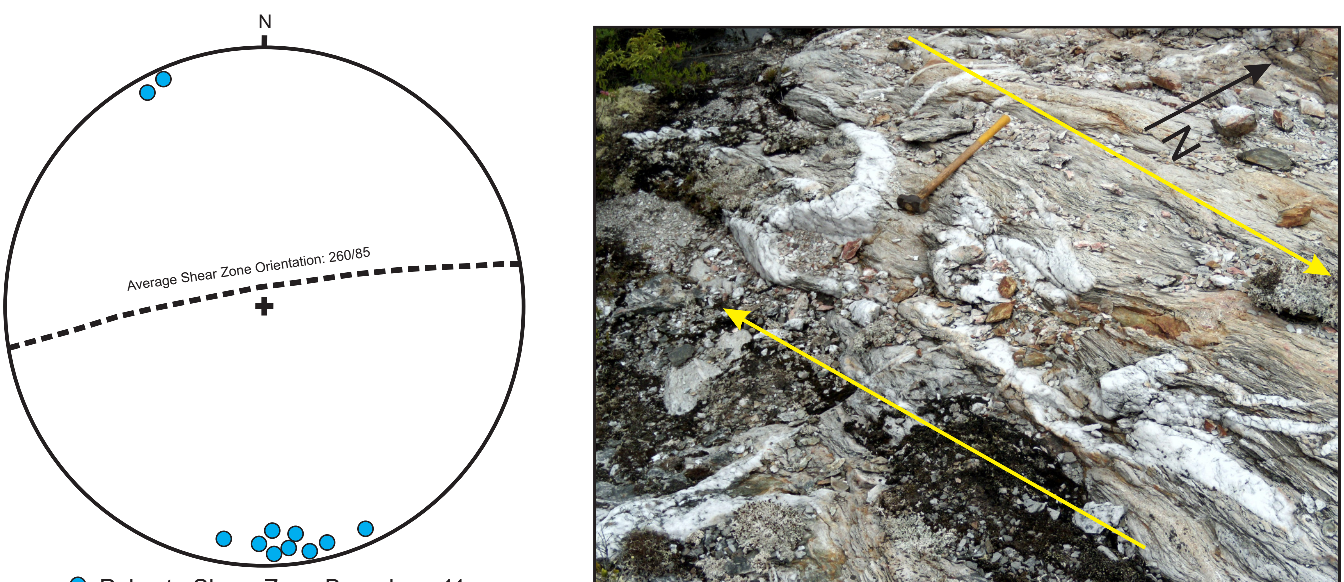


Figure 9. *Lower hemisphere, equal-area plot showing the poles to shear planes bounding straight and sigmoidal* en echelon *tension gashes located at the Bridal Veil and Abbotts Ridge zones. The average shear zone orientation is 260/85.*

fied psammite of the JPF, at the Bridal Veil and Abbotts Ridge zones, exhibit the highest Cu (<33 297 ppm), Pb (<8530 ppm), Ag (<218 ppm), Au (<723 ppb) and Bi (<285 ppm) assay results. Collectively, the metal variations are similar in the distinct P and R' (V_{2b}) rectilinear veins, as well as in the altered psammite cut by the quartz vein sets. The weakly sulphidic margins of the late rectilinear R' and P quartz veins also yielded high concentrations of these elements, but typically at slightly lower levels (*see* Figures 11 and 12; *see* Sandeman and Peddle, 2020), indicating that the greater the sulphide mineral abundance, the higher the concentration of metals.

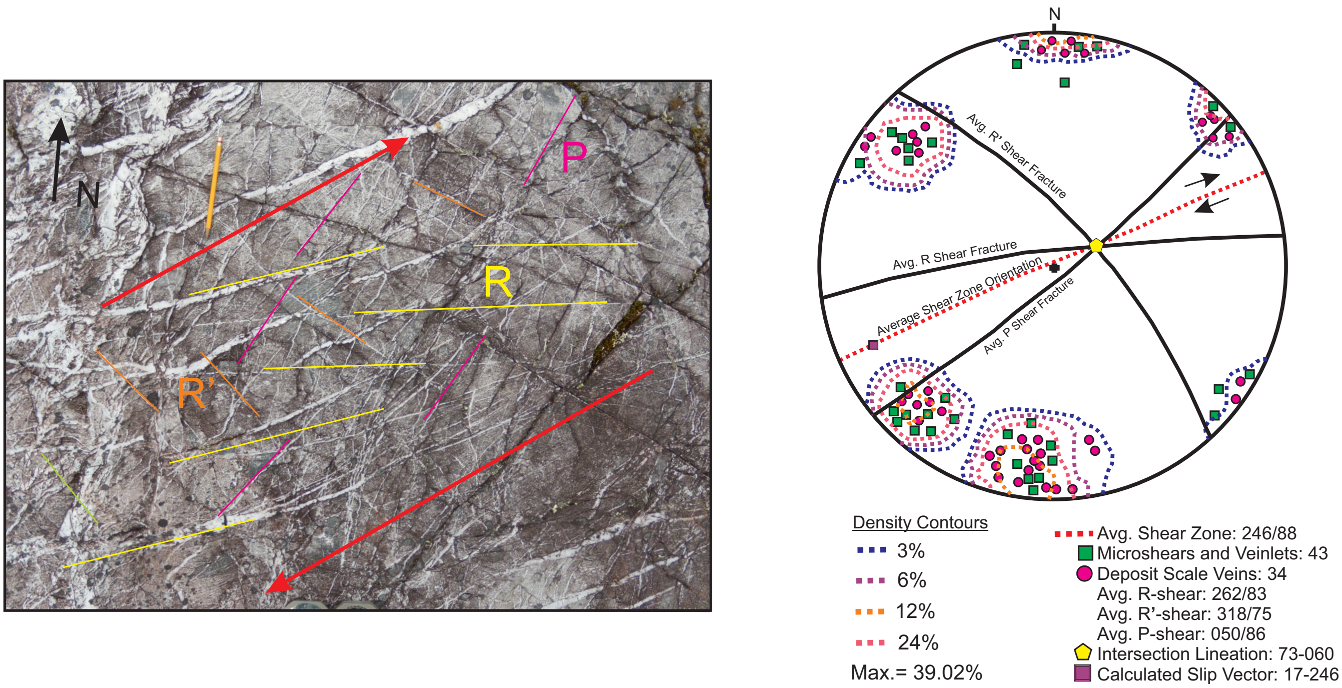


Figure 10. *Lower hemisphere, equal-area plot showing the orientations of veins along micro- and deposit-scale Riedel Shear fractures including R, R' and P shear fractures. The similar orientations of both micro- and deposit-scale fractures indicate they formed in the same shear system but at different scales. The geometric relationships between the shear fractures and the calculated average shear zone orientation show they formed in a dextral-reverse shear zone. All fractures lie in the fault zone at a common intersection point that may represent the orientation of maximum fluid flow during fracture and vein development.*

JONATHAN'S POND FORMATION (JPF)

Two samples of unaltered psammite from the JPF are compared to altered equivalents from the mineralized zones and to the partial lithogeochemical analyses for other rock samples of the formation (O'Neill, 1991a). The two unaltered samples have comparable elevated SiO_2, moderate K_2O/Na_2O and $Fe_2O_3^T/MgO$, but have slightly elevated TiO_2 relative to the published data (Figure 13A–C). The data suggest that the psammite of the JPF originated as clastic detritus deposited in a passive to active continental margin (Bhatia, 1983; Bhatia and Crook, 1986). The trace-element variations (*e.g.*, Th–Sc–La) of the two psammite samples (Figure 13D–F) indicate that the detritus was likely derived through erosion of an upper crustal continental source terrane with minor input from more primitive oceanic material (Bhatia and Crook, 1986; Kasanzu *et al.*, 2008).

Mafic Schist

Samples of metamorphosed, but unaltered chlorite–actinolite–albite schist (HS14-031, HS14-033) exhibit low SiO_2 abundances (47.21–48.67 wt. %) and elevated MgO (5.01–7.40 wt. %), FeO^T (10.83–15.09 wt. %) and TiO_2 (1.73–2.83 wt. %), characteristic of basaltic and gabbroic rocks (*see* Sandeman and Peddle, 2020). The altered schist shows massive SiO_2 addition and dilution of most other elements. The unaltered schists exhibit low Nb/Y, typical of subalkaline basalt (Pearce, 1996). They are transitional, tholeiitic basalts in terms of their Th/Yb *vs.* Zr/Y (Figure 14A; Ross and Bédard, 2009), and exhibit moderate TiO_2 values at moderate V contents, similar to that of back-arc basin and continental basalts (Figure 14B; Shervais, 1982). Their incompatible trace-element abundances and ratios are also characteristic of volcanic-arc tholeiites or back-arc-basin basalts (Figure 14C, D; Cabanis and Lecolle, 1989; Pearce, 2008). Whereas their Nb/Yb ratios are typical of normal mid-ocean ridge basalt (N-MORB), their elevated Th/Yb ratios, relative to the mantle array, indicate that their parental mantle-derived magmas are contaminated by subduction-related fluids and/or assimilated lithosphere. They are weakly light-REE-enriched (La/Yb_{CN} = 1.44–1.45), lack negative Eu anomalies, and exhibit variable, minor spikes at Rb and Sr, and modest negative Nb, P and Ti anomalies (Figure 14E, F). The mafic schists are lithogeochemically distinct from the mafic volcanic rocks of the ophiolitic Gander River Complex (Figure 14; *see* O'Neill, 1991a). The quartz-veined sample of mafic schist has strongly elevated SiO_2 (84.33 wt. %), low abundances of all other major elements and weakly elevated Au (6 ppb), Ag (0.2 ppm), Pb (240 ppm), W (73 ppm), Mo (6 ppm) and Cu (257 ppm). The multi-element pattern for the sample of quartz-veined mafic

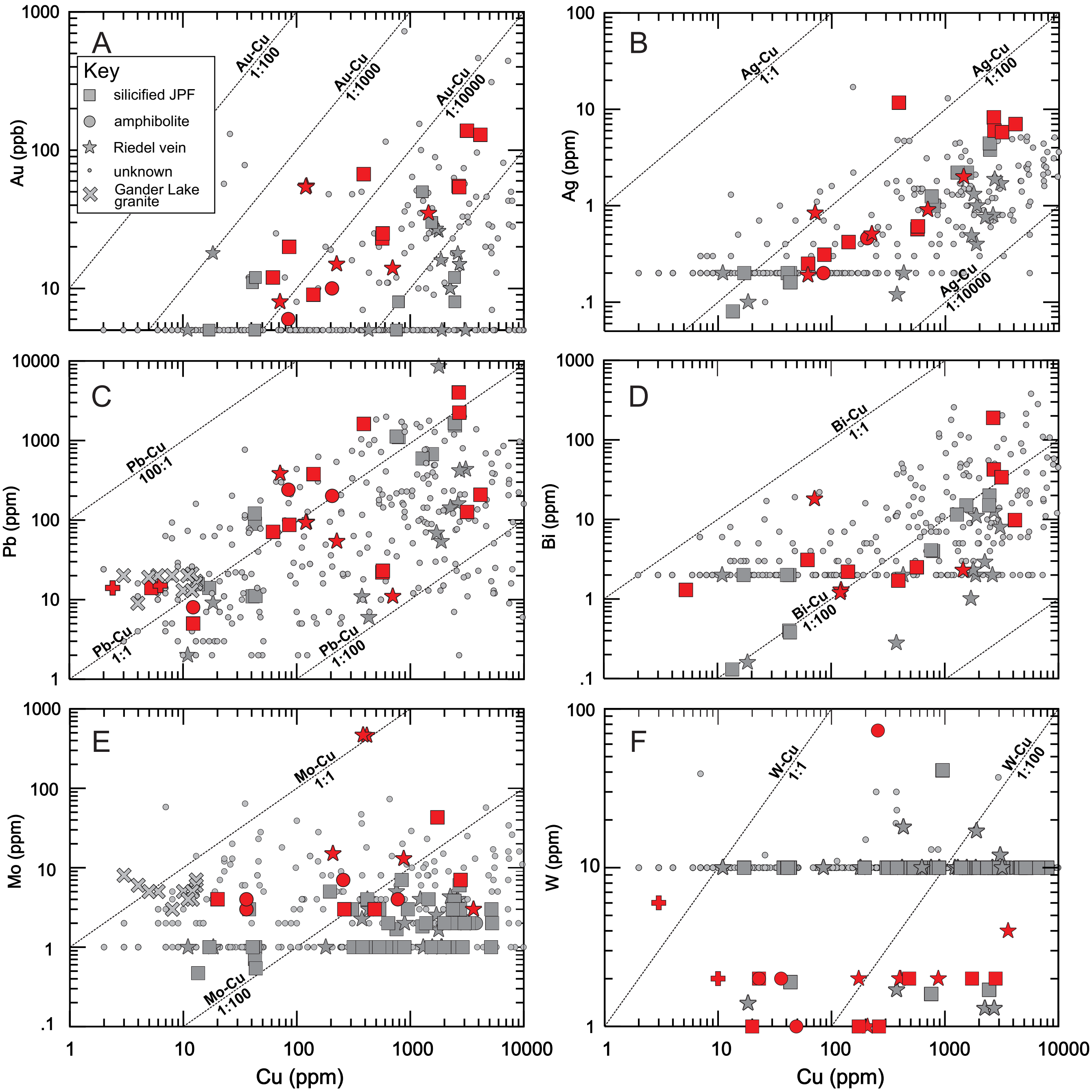


Figure 11. *Log-log plots for mineralized and unmineralized samples collected from the Bridal Veil area. A) Au* vs. *Cu; B) Ag* vs. *Cu; C) Pb* vs. *Cu; D) Bi* vs. *Cu; E) Mo* vs. *Cu and F) W* vs. *Cu. Grey symbols are samples from mineral-exploration industry assessment reports (*see *text). Key: Dashed lines represent lines of constant element/element ratios.*

schist displays minor enrichment in the elements Ba, Rb and Th and depletion of Sr and the heavy- and middle-REEs. Niobium, Zr, Hf and the light-REE concentrations in the altered and veined sample are comparable to those in the unaltered mafic schist. The reason for the decoupling of the REE is unclear, but may be a function of the composition of the fluids responsible for alteration.

MAFIC DYKES

Two samples of unaltered, fresh mafic dykes cutting the JPF (CP16-034 and CP16-035) exhibit low SiO_2 abundances (45.9–51.3 wt. %) and elevated MgO (5.73–8.06 wt. %), FeO^T (9.48–14.07 wt. %) and TiO_2 (1.38–2.52 wt. %), characteristic of basaltic and gabbroic rocks (*see* Sandeman and

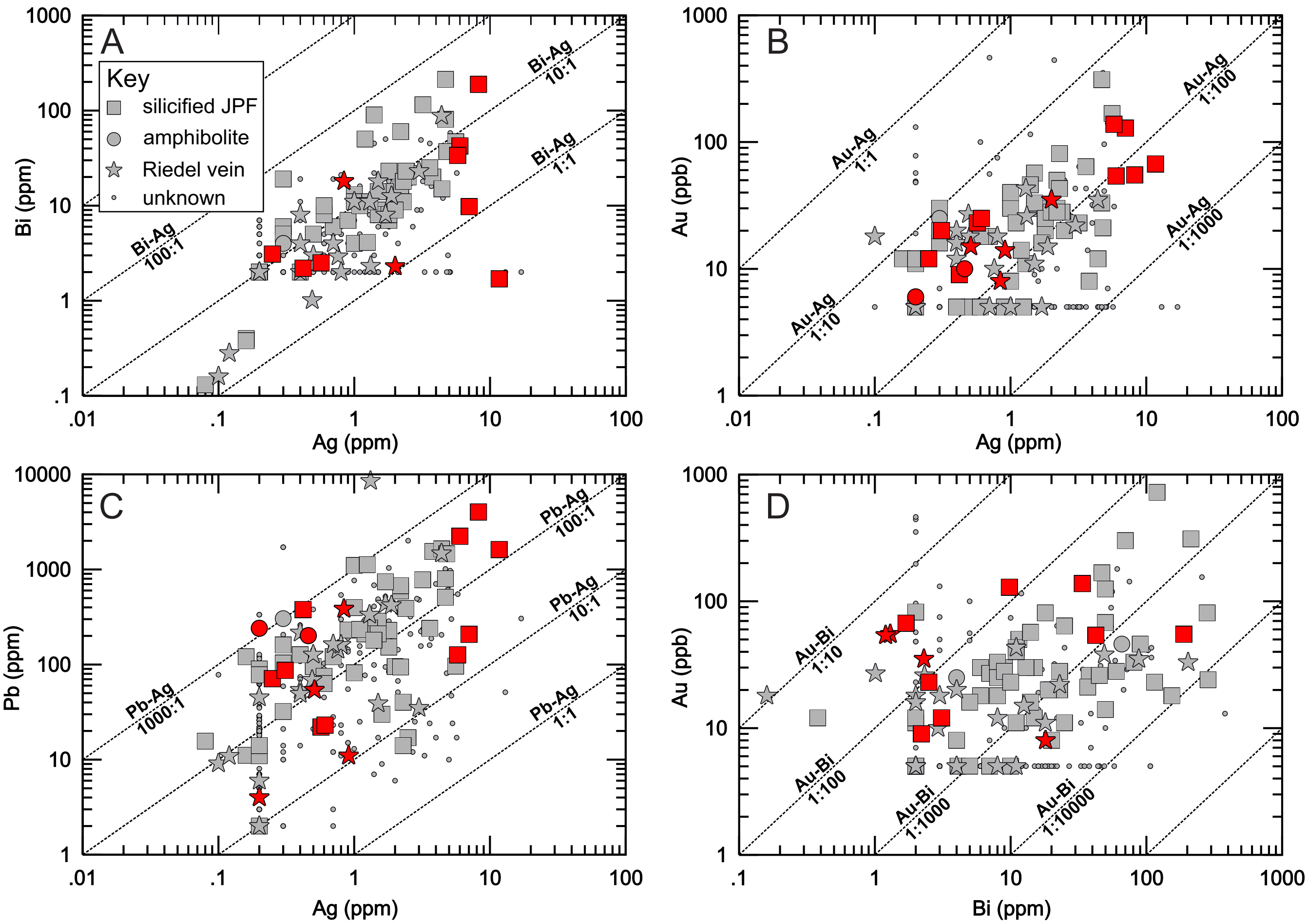


Figure 12. *Log-log plots for mineralized and unmineralized samples collected from the Bridal Veil area continued. A) Bi* vs. *Ag; B) Au* vs. *Ag; C) Pb* vs. *Ag; D) Au* vs. *Bi. Key: Grey symbols are samples from mineral exploration-industry assessment reports (*see *text). Key: Dashed lines represent lines of constant element/element ratios.*

Peddle, 2020). The dykes exhibit low Nb/Y, typical of sub-alkaline basalt (Pearce, 1996), are calc-alkaline in terms of their Th/Yb *vs.* Zr/Y (Figure 14A; Ross and Bédard, 2009), and exhibit moderate TiO_2 at moderate vanadium contents, similar to back-arc basin and continental basalts (Figure 14B; Shervais, 1982). The dykes have incompatible trace-element abundances and ratios similar to continental basalts (Figure 14C, D; Cabanis and Lecolle, 1989; Pearce, 2008). They have Nb/Yb typical of enriched mid-ocean ridge basalt (E-MORB), but their elevated Th/Yb relative to the mantle array indicate that their parental mantle-derived magmas were contaminated by subduction-related fluids and/or assimilated lithosphere. Relative to the mafic schists, they are more strongly light-REE-enriched (La/Yb_{CN} =5.07–5.50) and have lower Th/Nb ratios (1.13–1.30 *vs.* 1.97–2.01). The dykes exhibit minor Nb and Ti troughs but lack Sr and P anomalies and are also distinct from the mafic rocks of the ophiolitic Gander River Complex (Figure 14; *see* O'Neill, 1991a).

GANDER LAKE GRANITE

The two samples of the Gander Lake granite (HS14-037 and HS14-039) along with a selection of 5 re-analyzed samples (GEOATLAS: https://geoatlas.gov.nl.ca/Default.htm), provide previously unavailable, high precision, incompatible trace-element abundances for this unit (*see* Kerr *et al.*, 1995; Dickson and Kerr, 2007; Kellett *et al.*, 2014). The samples include a medium-grained marginal phase of the intrusion exposed on the north side of Gander Lake, and a coarser grained representative from the Crown Ridge resource road southeast of the lake (Figure 2). These are monzogranitic (Figure 15A) and weakly peraluminous, with A/CNK values ranging from 1.0 to 1.2 (A/CNK = molecular $Al_2O_3/CaO+Na_2O+K_2O$: Shand, 1943; Figure 15B), consistent with the presence of common biotite and lesser muscovite as the aluminous phases other than feldspar. Rubidium, Y and Nb relationships indicate that the Gander Lake granite overlaps the syn-collisional, volcanic-arc and

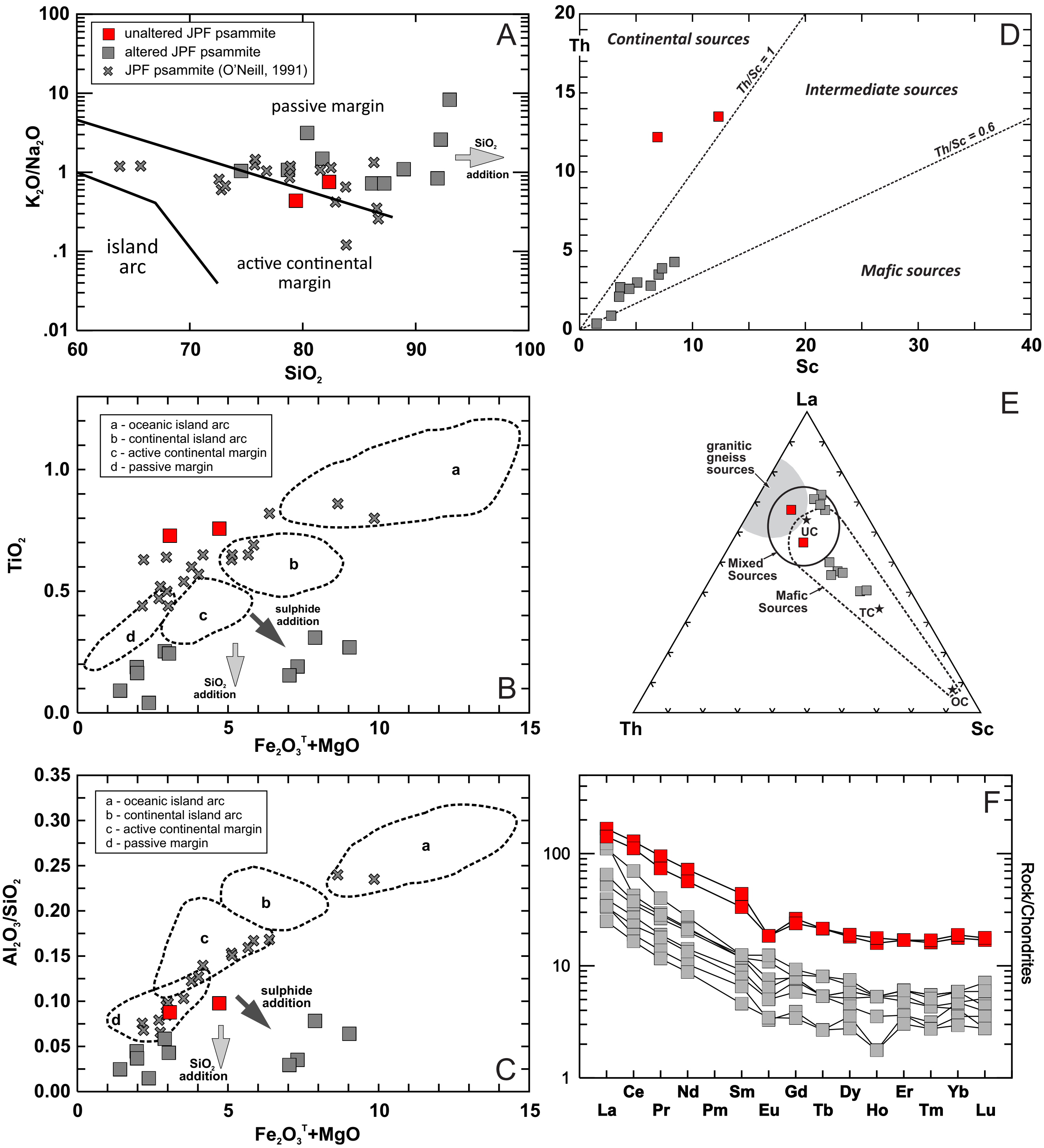


Figure 13. *Selected major- and trace-element diagrams for altered and unaltered psammite of the Bridal Veil area compared to published data for sandstone of the JPF (grey crosses: O'Neill, 1991a). A–C) Major-element paleotectonic discrimination diagrams (after Bhatia, 1983); D) Th* vs. *Sc plot (after McLennan* et al., *1980); E) Th–La–Sc ternary plot (Bhatia and Crook, 1986). Key: UC=upper crust; TC=transitional crust; OC=oceanic crust; F) Rare-earth-element plot (after Sun and McDonough, 1989) of the unaltered and altered psammite.*

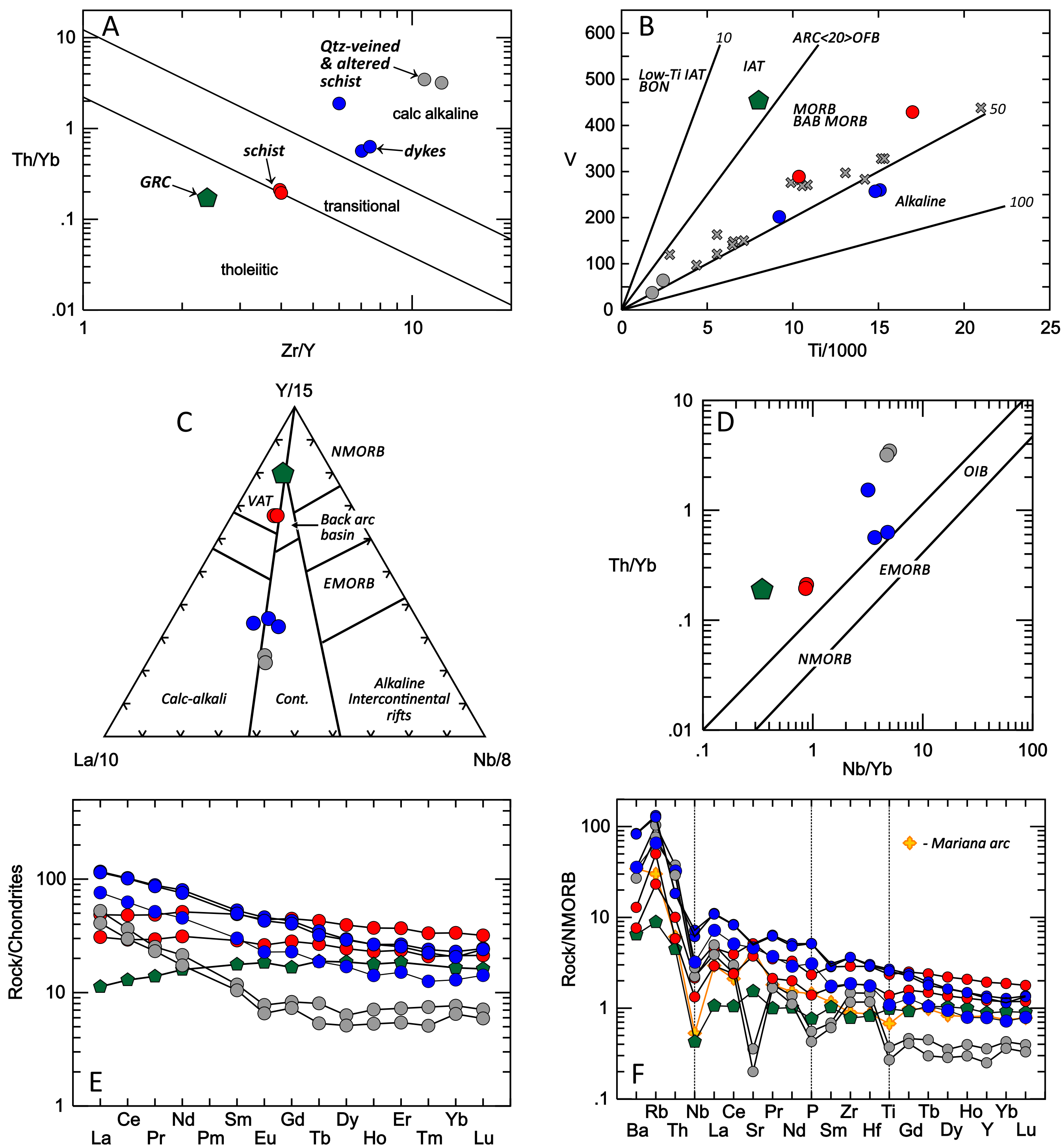


Figure 14. *Lithogeochemistry of the unaltered and altered Bridal Veil mafic schist (gabbro sills) and the two samples of young mafic dykes. Altered samples are not discussed further. A) Th/Yb* vs. *Zr/Y plot (Ross and Bédard, 2009); B) V* vs. *Ti/1000 plot (Shervais, 1982); grey crosses are analyses from the Weirs Pond map area (O'Neill, 1991a); C) La–Y–Nb plot (Cabanis and Lecolle, 1989); D) Th/Yb* vs. *Nb/Yb discrimination diagram (Pearce, 2008); E) Rare-earth-element diagram; F) Multi-element diagram. Key: N=N-MORB; E=E-MORB; OIB=ocean island basalt (Sun and McDonough, 1989). Shown for comparison is a basaltic sample from the Gander River Complex (GRC: O'Neill, 1991a) and a representative basalt from the Mariana arc (Elliott* et al., *1997).*

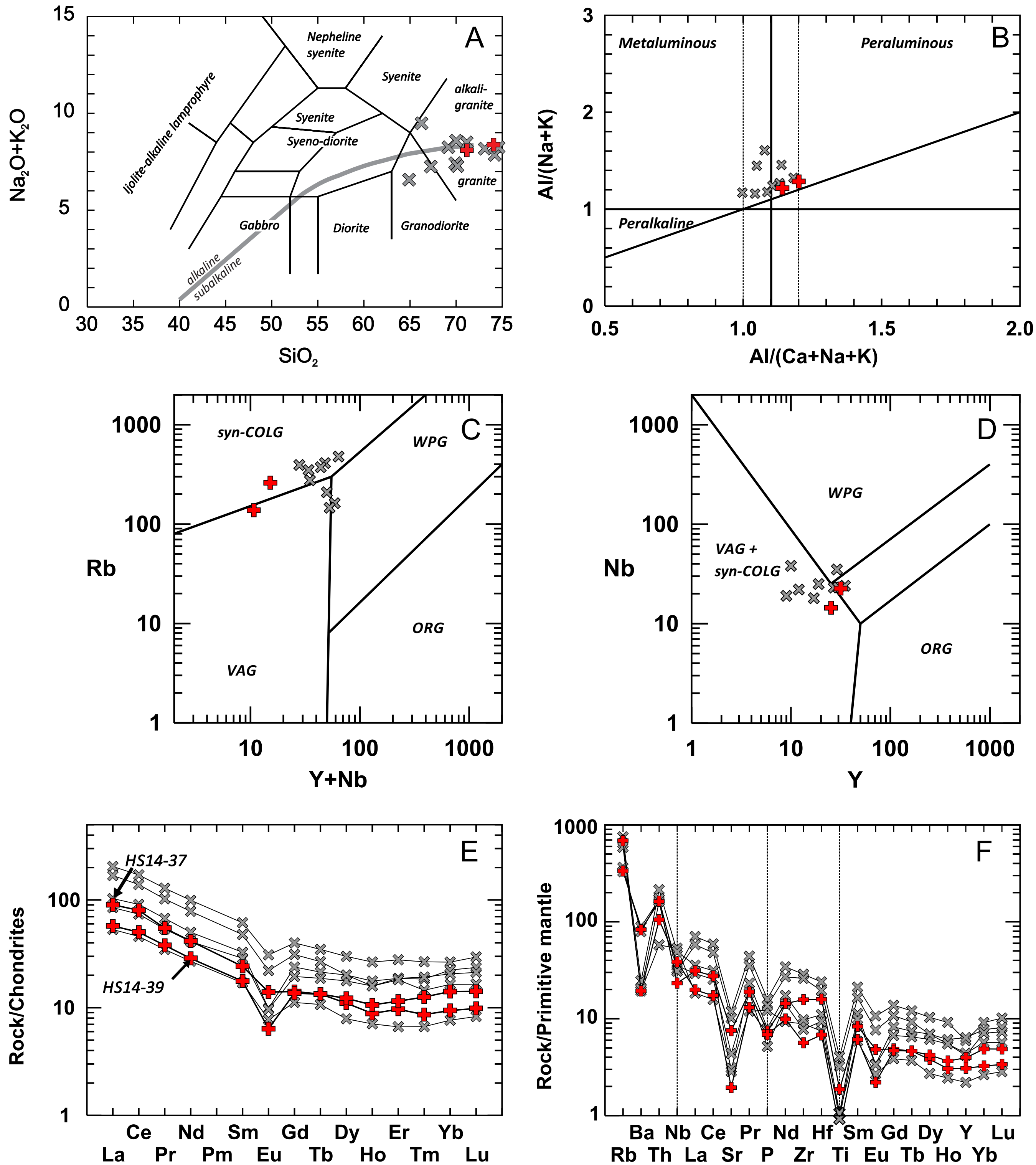


Figure 15. *Lithogeochemistry of two samples of the Gander Lake granite (red crosses) compared to selected samples available on the Geoatlas (grey crosses). A) Total alkalies* vs. *SiO_2 (after Wilson, 1989); B) Alkalinity* vs. *alumina saturation index (after Maniar and Piccoli, 1989); C, D) Trace-element paleotectonic discrimination diagrams for granitoids (Pearce* et al.*, 1984); E) Rare-earth-element plot (after Sun and McDonough, 1989) of the Gander Lake granite; F) Multi-element diagram (normalized to primitive mantle; after Sun and McDonough, 1989).*

within-plate granite fields, and likely represents a post-collisional intrusion (Figure 15C, D; Pearce *et al.*, 1984). The marginal phase exhibits greater light-REE enrichment (La/Yb_{CN}- 9.39 *vs.* 4.05), smaller negative Eu, Ba, Sr and Ti anomalies, and a slightly more prominent Nb trough (higher Th/Nb and Th/La ratios) than the coarser grained central phase. The samples of Gander Lake granite are only very weakly anomalous in W (d.l. to 7 ppm), Sn (d.l. to 6 ppm), Mo (d.l. to 8 ppm) and F (110–1080 ppm) (*see* Sandeman and Peddle, 2020).

DISCUSSION

Lithological, structural, petrographic and electron microprobe observations along with lithogeochemical data provide invaluable insight on the setting, character and age of the polymetallic mineralization at the Bridal Veil and Abbotts Ridge zones. Field observations indicate that the rocks of the area consist of polydeformed, interbedded, fine-grained sandstone and siltstone turbidites along with intercalated mafic schists of the JPF. The metasedimentary rocks exhibit shallow west-northwest-dipping bedding (218/24) with composite S_1–S_2 foliation surfaces. Mineralization is hosted by atypically thick (≤5 m), strongly silicified and quartz-veined, psammite, of the JPF. Mineralized zones consist of sinuous, discontinuous mm-scale septae and lenses of anhedral chalcopyrite and minor pyrite, galena and rare bismuth tellurides. Alteration of the host rocks consists predominantly of silicification and a complex array of at least three generations of quartz veins. Silicification is accompanied by sparse folia of green, translucent sericite, particularly in wallrock fragments in the quartz stockwork. Albite, Fe-chlorite, rutile and locally goethite also form sparse phases in the alteration assemblage and, with sericite, commonly form trails in mosaic quartz, thereby outlining the dominant (S_2) foliation in the rock. Metals in the mineralization include well correlated Cu, Ag, Pb, Au and Bi with minor local enrichment in Cd, W, Mo and Sn.

Structural analysis and field observations at the Bridal Veil and Abbotts Ridge zones define three vein systems hosted in a gently northwest-dipping F_3 fold limb including: 1) early V_1 barren, bedding-parallel flat veins and; 2) V_2 divided into V_{2a} and V_{2b} veins that include steeply dipping *en echelon* straight and sigmoidal tension gashes and, veins hosted in Riedel shear fractures. Although D_2 and D_3 deformational events are coaxial, it is likely that the initiation of bedding-parallel shear zones, the formation of V_1 veins and, the subsequent lineation development occurred under higher strain during F_2 recumbent folding relative to lower strain during subsequent open F_3 folding (Figure 7). Also, the compositional difference between V_1 and V_2 veins suggests they formed during separate events under contrasting geological conditions. The V_1 veins are barren, however, V_{2a} and V_{2b} veins have elevated levels of Cu, Pb, Ag, Au and sporadically Sb, Mo, Bi, suggesting that the mineralizing fluids may have contained a granite-related magmatic–hydrothermal component. The Lochkovian Gander Lake granite (378 ± 4 Ma, Kellett *et al.*, 2014) occurs a few kilometres to the east and may have provided heat and contributed metal-charged hydrothermal fluids to the system. If this hypothesis is correct, it suggests that the V_2 veins may have formed during the Devonian. Therefore, the steeply dipping and east-striking shear zones hosting V_2 veins are interpreted to have formed during D_3 (Figure 7).

Collectively, most examples of mineralization in this part of the Gander Lake Subzone, including indications, showings and prospects, are characterized by epigenetic, structurally controlled, shear-zone-hosted veins and vein breccia systems having a polymetallic, typically As–Sb–Au–Ag ± Cu ± Pb ± Zn ± Mo ± W ± Bi-bearing character.

IMPLICATIONS OF LITHOGEOCHEMISTRY

The sedimentary rocks of the JPF are composed of variably mature detritus eroded from a continental interior and may have been deposited in a passive, transitional to an active continental arc-margin setting as previously suggested (O'Neill, 1991a).

The mafic schists of the Bridal Veil area are interpreted as pre-D_2 gabbroic sills, and possibly transposed dykes, that now preserve a schistosity parallel to the bedding-S_1–S_2 surfaces in the metasedimentary rocks, and have therefore been subjected to the same deformation and metamorphism as the host metasedimentary rocks. The mafic schists are tholeiitic, volcanic arc or possibly back-arc-basin basalts derived from a fluid-fluxed asthenosphere. They have vanadium and titanium abundances broadly similar to the mafic schists from the Weir Pond map area (O'Neill, 1991a), however, they are distinct (*see* Figure 14) from the basaltic rocks of the Gander River Complex (O'Neill, 1991a). Their age and origin are not clear, however, they may represent sills and dykes that formed the magmatic conduits for the basaltic rocks of the Indian Bay Big Pond Formation (Figure 2; Wonderly and Neuman, 1984; O'Neill, 1991a; O'Neill and Colman-Sadd, 1993). This hypothesis has yet to be tested.

The Gander Lake granite is characterized by two feldspars, is subsolvus, contains phenocrysts of both biotite and muscovite and is weakly peraluminous (A/CNK >1<2). It has major- and trace-element characteristics compatible with formation in a posttectonic setting. Although the monzogranite is posttectonic, and does not contain anomalous concentrations of metals such as Cu, Pb, Ag and Au, upon intrusion and cooling it may have evolved hydrothermal fluids that carried granitophile metals regionally to brittle–ductile fault zones in the area.

Two examples of young, post-D_2 deformation mafic dykes are subalkaline, continental basalts in terms of their major- and trace-element characteristics and are distinct from the mafic schists. The dykes are large-ion lithophile, and light rare-earth-element-enriched basalts having modest Nb troughs, and are broadly similar, in composition, to the latest Silurian gabbroic rocks of the Mount Peyton intrusive suite (Sandeman *et al.*, 2017).

ISOTOPIC GEOCHRONOLOGICAL CONSTRAINTS ON THE TIMING OF MINERALIZATION

The isotopic constraints on rocks of the northeast Gander Lake Subzone are as follows:

1) the U–Pb analyses on zircon and titanite of the JPF yielded earliest Cambrian dates (*ca.* 540 Ma), interpreted as detrital ages (O'Neill and Colman-Sadd, 1993);

2) chemical Th–U total Pb isochron (CHIME) dating of metamorphic monazite from samples of the JPF (Buchanan and Bennett, 2009);

3) regional $^{40}Ar–^{39}Ar$ step-heating data for muscovite, biotite and hornblende (O'Neill and Lux, 1989; O'Neill and Colman-Sadd, 1993);

4) SHRIMP U–Pb ages on zircon and $^{40}Ar–^{39}Ar$ step-heating data for muscovite and biotite from the Gander Lake granite (Kellett *et al.*, 2014) and;

5) unpublished TIMS U–Pb ages for granitoid rocks of the northeast Gander Lake Subzone (Tucker, 1990; Langille, 2012; G. Dunning, MUN, unpublished data, 2019).

Perhaps the most enigmatic aspect of the northeastern Gander Lake Subzone geology is the timing and origin of the two documented, apparently distinct but broadly coaxial, early D_1 and D_2 deformation–metamorphic events. Miller and Weir (1982) and Miller (1988) proposed that the Ordovician thrust emplacement of the ophiolitic Gander River Complex was accompanied, farther east in the Gander Lake Subzone, by similar, broadly parallel, thrust ramps and wedges containing imbricated ultramafic, metasedimentary and mafic rocks. This hypothesis has never been adequately tested, however, the CHIME data (Buchanan and Bennett, 2009) lends support to such a proposal. The CHIME data yielded four distinct ages of monazite: 1) detrital monazite cores yielding Neoproterozoic to Early Cambrian ages; 2) metamorphic Ordovician monazite cores yielding ages ranging from 475 to 468 Ma; 3) Late Ordovician metamorphic monazite cores and rims yielding ages ranging from 460 to 450 Ma, and; 4) metamorphic monazite rims yielding Silurian ages of *ca.* 424 Ma (Buchanan and Bennett, 2009). These data suggest that the Gander Group metasedimentary rocks were subject to a significant regional orogenic event in the Middle Ordovician, prior to the Late Silurian to Middle Devonian orogenesis (Buchanan and Bennett, 2009).

The mineralization at Bridal Veil and Abbotts Ridge cuts the lithological units exposed in the map area and is therefore younger than the dominant D_2 deformation event, and its contemporaneous S_2 foliation. The only geochronological data directly related to the D_2 event include the youngest, *ca.* 424 Ma CHIME dates of monazite from metasedimentary rocks of the JPF (Buchanan and Bennett, 2009), and the single $^{40}Ar–^{39}Ar$ step-heating age for phyllonitic metamorphic muscovite in the Wing Pond shear zone (O'Neill and Colman-Sadd, 1993). The metamorphic muscovite from the Wing Pond shear zone (the interpreted surficial expression of the eastern, Indian Bay–Big Pond anomalous geophysical zone, Miller, 1988), yielded a well-defined Silurian $^{40}Ar–^{39}Ar$ plateau age (7 of 8 steps representing 98.4 % of the total argon released) of 428.9 ± 2.8 Ma (O'Neill and Colman-Sadd, 1993). This Silurian age is identical, within error, to the $^{40}Ar–^{39}Ar$ plateau age of 427 ± 7 Ma, determined for muscovite from a small, two-mica granite intrusion into the Davidsville Group, exposed west of the Gander River Complex (sample 269, O'Neill and Lux, 1989). These two $^{40}Ar–^{39}Ar$ cooling ages are significantly older than all of the other $^{40}Ar–^{39}Ar$ ages determined for the Gander Lake Subzone (400 to 385 Ma), and in particular, those determined on samples located in the metamorphic aureoles of the Gander Lake Subzone granitoid rocks (O'Neill and Lux, 1989; O'Neill and Colman-Sadd, 1993).

The Gander Lake granite, recently dated by the U–Pb SHRIMP method on zircon at 378 ± 4 Ma (Kellett *et al.*, 2014), is described as a "posttectonic" intrusion. However, this must imply posttectonic relative to recumbent isoclinal folding and development of the widespread and strong, bedding- and S_1-parallel, S_2 foliation. The penetrative S_2 foliation must therefore be older than 378 Ma, the age of the Gander Lake granite (Kellett *et al.*, *op. cit.*), and younger than *ca.* 470 Ma, the age of the Indian Bay Big Pond Formation (Wonderly and Neuman, 1984). On the basis of the Late Silurian monazite and $^{40}Ar–^{39}Ar$ cooling ages, the S_2 foliation may have formed at *ca.* 430–425 Ma in response to D_2 crustal thickening and accompanying propagation of Salinic, Ganderia–Laurentia collision-related thrust panels southeastward (present-day coordinates) over, and incorporating the rocks of the northeast Gander Lake Subzone. The latest regional deformation in the northeast Gander Lake

Subzone, D_3, produced open, doubly plunging southwest-trending folds of the gently inclined S_0–S_1–S_2 surfaces and is attributed to dextral, Middle Devonian collision of Avalonia with the trailing edge of Ganderia (O'Neill, 1991a; O'Neill and Colman-Sadd, 1993; van Staal and Barr, 2012). The development of the mineralization at Bridal Veil, associated with V_2, veining is inferred to have formed in dextral, strike-slip brittle ductile fault zones during regional D_3 deformation.

ORIGIN OF THE FLUIDS RESPONSIBLE FOR THE BRIDAL VEIL ZONE

The mineralization at Bridal Veil and Abbotts Ridge is polymetallic and, like many of the other examples of mineralization in the region, has metal associations somewhat atypical of orogenic gold systems. The Cu–Ag–Pb–Au ± Bi ± Mo ± W-bearing character of the Bridal Veil and Abbotts Ridge mineralized zones is very similar to metal associations observed in intrusion-related, or Carlin-style, of auriferous mineralization (Sillitoe and Thompson, 1998; Thompson *et al.*, 1999; Cline *et al.*, 2005; Hart, 2007; Muntean *et al.*, 2011). Such mineralized systems are typified by a diverse metal assemblage that includes many of the heavy, 'deleterious metal' suite such as As, Sb, Cd, Te, Se, and Pb. For this reason, it may be important to note the abundance of high-level (epizonal) and deeper, peraluminous to weakly peraluminous Devonian plutonic rocks in the region. These syn- to posttectonic granitoid intrusions may have acted as potential sources for metal-charged hydrothermal fluids that might then have become focused into discrete, silica-rich mineralized zones. Regional aeromagnetic data (GEOATLAS: https://geoatlas.gov.nl.ca/Default.htm) indicates that the Gander Lake granite is characterized by high magnetic susceptibility relative to the surrounding Gander Group sedimentary rocks. Significantly, a curvilinear magnetic high, termed the Soulis Pond metamorphic zone extends from the north shore of Gander Lake northeastward into Gander Group metasedimentary rocks (O'Neill and Colman-Sadd, 1993) and is characterized by rocks having metamorphic biotite porphyroblasts. This magnetic feature occurs farther north than the present mapped margin of the Gander Lake granite (O'Neill and Colman-Sadd, 1993). However, immediately south of the TCH along the north side of Gander Lake, biotite porphyroblastic semipelitic and psammitic schists of the JPF are locally cut by biotite–monzogranite veins and contain quartz + microcline pegmatoidal patches. Outcrops exposed along a small brook, 3.8 km east of Bridal Veil, and immediately south of the highway, consist of medium-grained, locally chloritic and hematitic subsolvus muscovite–biotite monzogranite. The Gander Lake granite may therefore extend at depth northeastward into the Bridal Veil–Benton–Soulis Pond corridor.

Exploration in the region might continue farther northeast (~080°), along strike, toward Soulis Pond as this corridor corresponds to:

1) the strike extension of the Bridal Veil and Abbotts Ridge zones;

2) the projection of the biotite-in isograd in plan view (O'Neill and Colman-Sadd, 1993);

3) an area with an abrupt transition from an aeromagnetic low to aeromagnetic high, as occurs near Bridal Veil (Woodman, 2002, 2003) and;

4) an area where mineral exploration companies have reported local, elevated values in Cu, Ag, Au and Pb in regional exploration plays.

This corridor is proximal to the margin of the Gander Lake granite, exhibits an anomalously elevated metamorphic grade with the formation of porphyroblastic biotite. It might be an area infiltrated by fluids released during regional and/or contact metamorphism, concomitant with the intrusion of granitic melts.

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REFERENCES

Anderson, F.D. and Williams, H.
1970: Geology of Gander Lake [2D] west half, Newfoundland. Geological Survey of Canada, "A" Series Map 1195A.

Batterson, M.J.
2000: Landforms and surficial geology of the Gander map sheet (NTS 2D/15), Newfoundland. Map 2000-19. Newfoundland and Labrador Geological Survey, Open File 2D/15/0350.

Bell, K., Blenkinsop, J. and Strong, D. F.
1977: The geochronology of some granitic bodies from eastern Newfoundland and its bearing on Appalachian evolution. Canadian Journal of Earth Sciences, Volume 14, pages 456-476.

Bhatia, M.R.
1983: Plate tectonics and geochemical composition of sandstones. Journal of Geology, Volume 91, pages 611-627.

Bhatia, M.R. and Crook, K.A.W.
1986: Trace element characteristics of graywackes and tectonic setting discrimination of sedimentary basins. Contributions to Mineralogy and Petrology, Volume 92, pages 181-193.

Blackwood, R.F.
1978: Northeastern Gander Zone, Newfoundland. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Report 78-1, pages 72-79.

1980: Geology of the Gander (west) area (2D/15), Newfoundland. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Report 80-1, pages 53-61.

1981: Geology of the west Gander rivers area, Newfoundland. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Report 81-1, pages 50-56.

1982: Geology of the Gander Lake (2D/15) and Gander River (2E/2) area. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Report 82-4, 56 pages.

Blackwood, R.F., Colman-Sadd, S.P., O'Brien, S., Hibbard, J., Meyer, J., Tomlin, S. and Green, R.
1984: Mineral Occurrence Map, Gander Lake, Newfoundland. Map 84-045. Scale: 1:250 000. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division. [GS# 002D/0271]

Blackwood, F. and Kennedy M.J.
1975: The Dover Fault: western boundary of the Avalon Zone in northeastern Newfoundland. Canadian Journal of Earth Sciences, Volume 12, pages 320-325.

Boyce, D.
1987: Cambrian-Ordovician trilobite biostratigraphy in central Newfoundland. *In* Current Research. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Report 87-1, pages 335-341.

Brushett, D.
2011: Quaternary geology of Weir's Pond and surrounding areas (NTS map areas 2D/15, 2E/01, 2E/02 and 2F/04). *In* Current Research. Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey, Report 11-1, pages 33-42.

2012: Till geochemistry of northeast Newfoundland (NTS map areas 2C/13, 2D/15, 2D/16, 2E/01, 2E/08, 2F/04 and 2F/05). Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey, Open File NFLD/3174, 167 pages.

2013: Surficial geology of the Weir's Pond map area (NTS 2E/01). Map 2013-05. Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey, Open File 2E/01/1733.

Buchanan, C. and Bennett, V.
2009: Implications of new geochronology for the tectonometamorphic history of the northern Gander Zone. St. John’s, NL, Annual CIMM/GSNL Open House, Poster Session.

Colman-Sadd, S.P., Hayes, J.P. and Knight, I.
1990: Geology of the Island of Newfoundland. Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Map 90-01.

Cabanis, B. and Lecolle, M.
1989: Le diagramme La/10-Y/15-Nb/8: un outil pour la discrimination des series volcaniques et la mise en evidence des processus de melange et/ou de contamination crustale. Comptes Rendus de l’Acadamie des Sciences, Series II, Volume 309, pages 2023-2029.

Colman-Sadd, S.P., Dunning, G.R. and Dec, T.
1992: Dunnage–Gander relationships and Ordovician orogeny in central Newfoundland: A sediment provenance and U/Pb age study. American Journal of Science, Volume 292, pages 317-355.

Cline, J.S., Hofstra, A.H., Munteau, J.L., Tosdal, R.M. and Hickey, K.A.
2005: Carlin-type gold deposits in Nevada: Critical geologic characteristics and viable models. Economic Geology, 100th Anniversary, Volume, pages 451-484.

Craddock, J.P. and van der Pluijm, B.
1988: Kinematic analysis of an *en echelon*-continuous vein complex. Journal of Structural Geology, Volume 10, pages 445-452.

Currie, K.L.
1997: Geology, Gander River–Gander Bay region, Newfoundland (2E east half). Geological Survey of Canada, Open File 3467, scale 1:100 000.

Davenport, P.H. and Nolan, L.W.
1989: Mapping the regional distribution of gold in Newfoundland using lake-sediment geochemistry. *In* Current Research. Government of Newfoundland and Labrador, Department of Mines, Geological Survey, Report 89-1, pages 259-266.

Davenport, P.H., Nolan, L.W. and Hayes, J.P.
1988: Gold and associated elements in lake sediment from regional surveys in the Gander Lake map area (NTS 2D). Government of Newfoundland and Labrador, Department of Mines, Mineral Development Division, Open File 002D/0175, 220 pages.

D'Lemos, R.S. and Holdsworth, R.E.
1995: Samarium-neodymium isotopic characteristics of the northeastern Gander Zone, Newfoundland Appalachians. *In* Current Perspectives in the Appalachian-Caledonian Orogen. *Edited by* J.P. Hibbard, C.R. van Staal and P.A. Cawood. Geological Association of Canada, Special Paper 41, pages 239-252.

D'Lemos, R. S., Schofield, D.I., Holdsworth, R.E. and King, T.R.
1997: Deep crustal and local rheological controls on the siting and reactivation of fault and shear zones, northeastern Newfoundland. Journal of the Geological Society, Volume 154, pages 117-121.

Dickson, W.L.
1974: The general geology and geochemistry of the granitoid rocks of the Northern Gander Lake Belt, Newfoundland. M.Sc. thesis, Memorial University, St. John's, Nfld. 167 pages.

Dickson, W.L. and Kerr, A.
2007: An updated database of historic geochemical data for granitoid plutonic suites of Newfoundland. Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey, Open File NFLD/2957.

Dimmell, P. and Jacobs, W.
1989: First year assessment report on geological and geochemical exploration for licence 3426 on claim block 6073, licence 3427 on claim block 6075 and licence 3479 on claim block 6281 in the Indian Bay Big Pond and Southern Pond areas, north-central Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2E/01/0686, 53 pages.

Eastler, T.E.
1969: Silurian geology of Change Islands and eastern Notre Dame Bay, Newfoundland. *In* North Atlantic Geology and Dontinental Drift. *Edited by* M. Kay. American Association of Petroleum Geologists, Memoir 12, pages 425-432.

Elliott, T., Plank, T., Zindler, A., White, W. and Bourdon, B.
1997: Element transport from slab to volcanic front at the Mariana arc. Journal of Geophysical Research, Volume 102, pages 14991-15019.

Finch, C., Roldan, R., Walsh, L., Kelly, J. and Amor, S.
2018: Analytical methods for chemical analysis of geological materials. Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey, Open File NFLD/3316, 67 pages.

Graham, D.
1991: First year assessment report on geological, geochemical and geophysical exploration for licence 3930 on claim block 6036 in the Little Wing Pond and Southern Pond areas, Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2E/01/0798, 56 pages.

1992: Second year assessment report on prospecting and geochemical exploration for the Wing Pond Project for licence 3930 on claim block 6036 in the Little Wing Pond and Southern Pond areas, Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2E/01/0832, 19 pages.

Graham, D.R. and St-Hilaire, C.
1995: First year assessment report on geochemical and geophysical exploration for licence 4459 on claim block 7584 and licence 4492 on claim block 7585 in the Wing Pond, Little Wing Pond and Southern Pond areas, Newfoundland, 2 reports. Newfoundland and Labrador Geological Survey, Assessment File NFLD/2577, 99 pages.

Graves, G.
1990: First year assessment report on geological and geochemical exploration for licence 3548 on claim blocks 15842-15843 in the Soulis Pond and Gander Lake areas, Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/16/0215, 43 pages.

Greene B.J.
1996a: Second year assessment report on diamond drilling exploration for licence 4512 on claim blocks 8291-8296 in the Wing Pond area, Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2E/01/1134, 62 pages.

1996b: Second year assessment report on geological and geochemical exploration for licence 4811 on claim blocks 7584-7587 in the Little Wing Pond area, Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File NFLD/2676, 31 pages.

Greene, B.J., Graham, D.R. and St-Hilaire, C.
1995: First year assessment report on geological, geochemical, geophysical and trenching exploration for licence 4510 on claim block 7586, licence 4511 on claim block 7585 and licence 4512 on claim blocks 8291-8296 in the Wing Pond, Southern Pond, Indian Bay Big Pond and Little Bear Cove Pond areas, Newfoundland, 2 reports. Newfoundland and Labrador Geological Survey, Assessment File NFLD/2592, 90 pages.

Guinchard, W.
2010: First year assessment report on prospecting and geochemical exploration for licence 15917M on claims in the Gander area, central Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/0803, 19 pages.

2011: First and second year assessment report on prospecting and geophysical exploration for licences 15917M, 17156M and 17870M on claims in the Gander area, central Newfoundland, 2 reports. Newfoundland and Labrador Geological Survey, Assessment File 2D/0843, 32 pages.

2012: Second and third year assessment report on compilation, prospecting and geophysical exploration for licences 15917M, 17156M and 17870M on claims in the Gander area, central Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/0849, 81 pages.

2013: Third year assessment report on prospecting and geochemical exploration for licence 17870M on claims in the Gander area, central Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/15/0875, 25 pages.

Hanmer, S.
1981: Tectonic significance of the northeastern Gander Zone, Newfoundland: An Acadian ductile shear zone. Canadian Journal of Earth Sciences, Volume 18, pages 120-135.

Hart, C.J.R.
2007: Reduced intrusion-related gold systems. *In* Mineral Deposits of Canada: A Synthesis of Major Deposit Types, District Metallogeny, the Evaluation of Geological Provinces, and Exploration Methods. *Edited by* W.D. Goodfellow. Geological Association of Canada, Mineral Deposits Division, Special Publication No. 5, pages 95-112.

Holdsworth, R.E.
1991: The geology and structure of the Gander–Avalon boundary zone in northeastern Newfoundland. Government of Newfoundland and Labrador, Department of Mines, Geological Survey, Report 91-1, pages 109-126.

1994: Structural evolution of the Gander-Avalon terrane boundary: A reactivated transpression zone in the NE Newfoundland Appalachians. Journal of the Geological Society, Volume 151, pages 629-646.

Hudleston, P.J., Treagus, S.H. and Lan, L.
1996: Flexural flow folding: Does it occur in nature? Geology, Volume 24, pages 203-206.

International Commission on Stratigraphy (ICS)
2018: International Chronostratigraphic Chart v 2018/8. http://www.stratigraphy.org/index.php/ics-chart-timescale

Jayasinghe, N.R.
1978: Wesleyville-Musgrave Harbour (east), Newfoundland. Map 78-070. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Report 78-8, 14 pages, enclosure (map). [GS# 002F/0013]

Jenness, S.E.
1954: Geology of the Gander River Ultrabasic Belt, Newfoundland. Unpublished Ph.D. thesis, Yale University, New Haven, USA.

1958: Geology of the Gander River Ultrabasic Belt, Newfoundland. Geological Survey of Newfoundland, Report 11, 58 pages.

1963: Terra Nova and Bonavista Bay map areas, Newfoundland. Geological Survey of Canada, Memoir 327, 184 pages.

Jessell, M.W., Willman, C.E. and Gray, D.R.
1994: Bedding parallel veins and their relationship to folding. Journal of Structural Geology, Volume 16, pages 753-767.

Kasanzu, C., Maboko, M.A.H. and Manya, S.
2008: Geochemistry of fine-grained clastic sedimentary rocks of the Neoproterozoic Ikorongo Group, NE

Tanzania: Implications for provenance and source rock weathering. Precambrian Research, Volume 164, pages 201-213.

Katz, Y., Weinberger, R. and Aydin, A.
2004: Geometry and kinematic evolution of Riedel shear structures, Capitol Reef National Park, Utah. Journal of Structural Geology, Volume 26, pages 491-501.

Kellett, D.A., Rogers, N., McNicoll, V., Kerr, A. and van Staal, C.
2014: New age data refine extent and duration of Paleozoic and Neoproterozoic plutonism at Ganderia–Avalonia boundary, Newfoundland. Canadian Journal of Earth Sciences, Volume 51, pages 943-974.

Kellett, D.A., Warren, C., Larsonc, K.P., Zwingmann, H., van Staal, C.R. and Rogers, N.
2016: Influence of deformation and fluids on Ar retention in white mica: Dating the Dover Fault, Newfoundland Appalachians. Lithos, Volume 254-255, pages 1-17.

Kennedy M.J. and McGonigal M.H.
1972: The Gander Lake and Davidsville Groups of northeastern Newfoundland: New data and geotectonic implications. Canadian Journal of Earth Sciences, Volume 9, pages 452-459.

Kerr, A., Jenner, G.A. and Fryer, B.J.
1995: Sm–Nd isotopic geochemistry of Precambrian to Paleozoic granitoid suites and the deep-crustal structure of the southeast margin of the Newfoundland. Canadian Journal of Earth Sciences Volume 32, pages 224-245.

Langille, A.E.
2012: A detailed petrographic, geochemical and geochronological study of the Hare Bay Gneiss, northeastern Newfoundland. Unpublished M.Sc. thesis, Memorial University of Newfoundland and Labrador, St. John's, 241 pages.

Lowden, J.A.
1960: Age determinations by the Geological Survey of Canada. Geological Survey of Canada, Paper 60-17.

Maniar, P.D. and Piccoli, P.M.
1989: Tectonic discrimination of granitoids. Geological Society of America Bulletin, Volume 101, pages 635-643.

McGonigal, M.H.
1973: The Gander and Davidsville groups: Major tectonostratigraphic units in the Gander Lake area, Newfoundland. Unpublished M.Sc. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 121 pages.

McKerrow, W.S. and Cocks L.R.M.
1977: The location of the Iapetus Ocean suture in Newfoundland. Canadian Journal of Earth Sciences, Volume 14, pages 488-495.

McLennan, S.M., Nance, W.B. and Taylor, S.R.
1980: Rare earth element–thorium correlations in sedimentary rocks, and the composition of the continental crust. Geochimica et Cosmochimica Acta, Volume 44, pages 1833-1839.

McLeod, M.J.
1990: Geology, geochemistry, and related mineral deposits of the Saint George batholith; Charlotte, Queens and Kings Counties, New Brunswick. New Brunswick Department of Natural Resources and Energy, Mineral Resource Report 5, 169 pages.

McLeod, M.J. and McCutcheon, S.R.
2001: Gold environments in New Brunswick. Atlantic Geology, Volume 36, pages 65-66.

McVeigh, G.
2002: Second year assessment report on prospecting, trenching and geochemical exploration for licences 6813M, 7309M, 7317M-7318M and 7327M on claims in the Benton area, central Newfoundland. New-foundland and Labrador Geological Survey, Assessment File 2D/16/0418, 60 pages.

2003: Third year assessment report on prospecting and geochemical exploration for licence 7179M on claims in the Gander Lake area, central Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/15/0453, 36 pages.

Miller, H.G.
1988: Geophysical interpretation of the geology of the northeast Gander Terrane, Newfoundland. Canadian Journal of Earth Sciences, Volume 25, pages 1161-1174.

Miller H.G. and Weir, H.C.
1982: The northwest portion of the Gander Zone - a geophysical interpretation. Canadian Journal of Earth Sciences, Volume 19, pages 1371-1381.

Morgan, J.
2012: Fourth year assessment report on geological, geochemical and trenching exploration for license 13808M

on claims in the Wing Pond area, east-central Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2E/01/1805, 61 pages.

Mullen, D.V.
2004: Fourth year supplementary report on diamond drilling exploration for licence 9834M on claims in the Benton area, central Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/16/0561, 285 pages.

Muntean, J.L., Cline, J.S., Simon, A.C. and Longo, A.A.
2011: Magmatic–hydrothermal origin of Nevada's Carlin-type gold deposits. Nature Geoscience, 19 pages. DOI: 10.1038/NGEO1064

Neuman, R.B.
1967: Bedrock geology of the Shin Pond and Stacyville quadrangles, Penobscot County, Maine. United States Geological Survey, Professional Paper 524-1.

O'Neill, P.
1987: Geology of the west half of the Weir's Pond (2E/1) map area. *In* Current Research. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Report 87-1, pages 271-282.

1990a: Geology of the Weir's Pond area, Newfoundland. Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Map 90-002.

1990b: Metamorphic geology and $^{40}Ar/^{39}Ar$ geochronology of the Weir's Pond area, Newfoundland. Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Map 90-003.

1990c: Geology of the Davidsville Group and Gander River Complex, NW Weir's Pond area. Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Map 90-004.

1991a: Geology of the Weir's Pond area, Newfoundland (NTS 2E/1). Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Report 91-03, 164 pages. [GS# 002E/01/0917a]

1991b: Geology of Davidsville Group and Gander River Complex, NW Weir's Pond area (NTS 2E/1). Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Report 91-03, enclosures (3 maps). [GS# 002E/01/0917b]

1993: Geology of the eastern Gander (NTS 2D/15) and western Gambo (NTS 2D/16) map areas, Newfoundland, Scale: 1:50 000. Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Map 93-015.

O'Neill, P. and Blackwood, F.
1989: A proposal for revised stratigraphic nomenclature of the Gander and Davidsville groups and the Gander River Ultrabasic Belt, of northeastern Newfoundland. *In* Current Research. Government of Newfoundland and Labrador, Department of Mines, Geological Survey, Report 89-01, pages 127-130.

O'Neill, P.P. and Colman-Sadd, S.P.
1993: Geology of the eastern Gander (NTS 2D/15) and western Gambo (NTS 2D/16) map areas, Newfoundland. Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Report 93-2, 53 pages.

O'Neill, P. and Knight, I.
1988: Geology of the east half of the Weirs Pond (2E/1) map area and its regional significance. *In* Current Research. Government of Newfoundland and Labrador, Department of Mines, Mineral Development Division, Report 88-01, pages 165-176.

O'Neill, P. and Lux, D.
1989: Tectonothermal history and $^{40}Ar–^{39}Ar$ geochronology of the northeastern Gander Zone, Weirs Pond area (2E/1). *In* Current Research. Government of Newfoundland and Labrador, Department of Mines, Geological Survey, Report 89-1, pages 131-139.

Park, A.F., Lentz, D.R. and Thorne, K.G.
2008: Deformation and structural controls on intrusion history and gold mineralization in the Clarence Stream shear zone, southwestern New Brunswick, Canada. Exploration and Mining Geology, Volume 17, No. 1/2, pages 51-66.

Pajari, E. and Currie, K.L.
1978: The Gander and Davidsville groups of northeastern Newfoundland: A re-examination. Canadian Journal of Earth Sciences, Volume 15, pages 708 -714.

Pearce, J.A.
1996: A User's Guide to Basalt Discrimination Diagrams. Geological Association of Canada, Short Course Notes, Volume 12, pages 79-113.

2008: Geochemical fingerprinting of oceanic basalts with applications to ophiolite classification and the search for Archean oceanic crust. Lithos, Volume 100, pages 14-48.

Pearce, J.A., Harris, N.B.W. and Tindle, A.G.
1984: Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. Journal of Petrology, Volume 25, pages 956-983.

Robertson, S.
1999: BGS Rock Classification Scheme. Volume 2. Classification of Metamorphic Rocks. British Geological Survey, Research Report, RR 99-02.

Ross P. and Bédard, J.H.
2009: Magmatic affinity of modern and ancient subalkaline volcanic rocks determined from trace-element discrimination diagrams. Canadian Journal of Earth Sciences, Volume 46, pages 823-839.

Sandeman, H.A.I. and Peddle, C.
2020: Description, location, structural and lithogeochemical data for rocks of the Bridal Veil and Abbotts Ridge zones, Northeast Gander Lake Subzone, Newfoundland. Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey, Open File 002D/15/0951.

Sandeman, H.A.I., Dunning, G.R., McCullough, C.K. and Peddle, C.
2017: U–Pb geochronology, petrogenetic relationships and intrusion-related precious-metal mineralization in the northern Mount Peyton intrusive suite: implications for the origin of the Mount Peyton Trend, central Newfoundland (NTS 2D/04). *In* Current Research. Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey, Report 17-1, pages 189-217.

Scholz, C.H.
1990: The Mechanics of Earthquakes and Faulting. Cambridge University Press.

Seal, R.H., Clark, A.H. and Morrissy, C.J.
1987: Stockwork tungsten (scheelite)-molybdenum mineralization, Lake George, southwestern New Brunswick. Economic Geology, Volume 82, pages 1259-1282.

Shand, S.J.
1943: Eruptive Rocks. Their Genesis, Composition, Classification, and Their Relation to Ore-Deposits with a Chapter on Meteorite. John Wiley and Sons, New York.

Shervais, J.W.
1982: Ti-V plots and the petrogenesis of modern ophiolitic lavas. Earth and Planetary Science Letters, Volume 59, pages 101-118.

Sillitoe, R.H. and Thompson, J.F.H.
1998: Intrusion-related vein gold deposits: types, tectono-magmatic settings and difficulties of distinction from orogenic gold deposits. Resource Geology, Volume 48, pages 237-250.

Sparkes, B.A. and Hoffe, C.K.
2004: Fourth year supplementary assessment report on geological, geochemical and trenching exploration for licence 9834M on claims in the Benton area, central Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/16/0562, 438 pages.

Squires, G.C.
2005: Gold and antimony occurrences of the Exploits Subzone and Gander Zone: A review of recent discoveries and their interpretation. *In* Current Research. Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey, Report 05-1, pages 223-237.

Stouge, S.
1980: Conodonts from the Davidsville Group, northeastern Newfoundland. Canadian Journal of Earth Sciences, Volume 17, pages 268-272.

Strong, D.F. and Dickson, W.L.
1978: Geochemistry of Paleozoic granitoid plutons from contrasting tectonic zones of northeast Newfoundland. Canadian Journal of Earth Sciences, Volume 15, pages 145-156.

Sun, S.S. and McDonough, W.F.
1989: Chemical and isotopic systematics of ocean basalts: Implications for mantle composition and processes. Geological Society of London, Special Publication 42, pages 313-345.

Tanner, P.W.G.
1989: The flexural-slip mechanism. Journal of Structural Geology, Volume 11, pages 635-655.

Thompson, J.F.H., Sillitoe, R.H., Baker, T., Lang, J.R. and Mortenson, J.K.
1999: Intrusion-related gold deposits associated with tungsten-tin provinces. Mineralium Deposita, Volume 34, pages 323-334.

Thorne, K.G. and McLeod, M.J.
2003: Gold deposits associated with felsic intrusions in southwestern New Brunswick–Field guidebook: New Brunswick Department of Natural Resources and Energy, Open File Report 2003-4, 83 pages.

Tucker, R.D.
1990: Report on geochronology in the central mobile belt, Newfoundland. Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Internal Collection, Company or Consultant Report, 1990, 5 pages, [NFLD/2127].

van Staal, C. and Barr, S.M.
2012: Lithospheric architecture and tectonic evolution of the Canadian Appalachians and associated Atlantic margin. Chapter 2 *In* Tectonic Styles in Canada: the Lithoprobe Perspective. *Edited by* J.A. Percival, F.A. Cook, and R.M. Clowes. Geological Association of Canada, Special Paper 49, pages. 41-95.

Williams, H.
1962: Botwood, west half, map-area, Newfoundland, 2E/W. Geological Survey of Canada, Paper 62-09, 21 pages.

Williams, H., Colman-Sadd, S.P. and Swinden, H.S.
1988: Tectonic-stratigraphic subdivisions of central Newfoundland. *In* Current Research, Part B. Eastern and Atlantic Canada, Geological Survey of Canada, Paper 88-1B, pages 91-98.

Wilson, M.
1989: Igneous Petrogenesis. Unwin and Hyman, London, 466 pages.

Wonderly, P.F. and Neuman, R.B.
1984: The Indian Bay Formation: fossiliferous Early Ordovician volcanogenic rocks in the northern Gander Terrane, Newfoundland, and their regional significance. Canadian Journal of Earth Sciences, Volume 21, pages 525-532.

Woodman, A.
2002: First and second year assessment report on prospecting and geochemical and geophysical exploration for licences 7216M, 7276M, 7460M-7462M, 7847M, 7862M-7863M, 7873M-7876M and 8247M on claims in the Gander area, central Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/0506, 65 pages.

2003: First year supplementary and second and third year assessment report on prospecting and geophysical and diamond drilling exploration for licences 7216M, 7461M-7462M, 7847M, 7873M and 8247M on claims in the Gander area, northeastern Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/0475, 47 pages.

2005: Fifth year assessment report on prospecting, geochemical exploration and re-analysis of diamond drill core for licence 9310M on claims in the Gander area, central Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/0652, 54 pages.

2006: Sixth year assessment report on prospecting and geochemical exploration for licence 9310M on claims in the Gander area, central Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/0661, 27 pages.

2007: Seventh year assessment report on compilation and geological exploration for licence 12954M on claims in the Gander area, central Newfoundland, 2 reports. Newfoundland and Labrador Geological Survey, Assessment File 002D/15/0678.

Woodman, A. and Guinchard, W.
2000: First year assessment report on geological and geochemical exploration for licences 7216M, 7276M and 7460M-7462M on claims in the Gander area, central Newfoundland, 2 reports. Newfoundland and Labrador Geological Survey, Assessment File 002D/0383.

Zagorevski, A., van Staal, C.R., N. Rogers, McNicoll, V.J. and Pollock, J.
2010: Middle Cambrian to Ordovician arc-backarc development on the leading edge of Ganderia, Newfoundland Appalachians. *In* From Rodinia to Pangea: The Lithotectonic Record of the Appalachian Region. *Edited by* R.P. Tollo, M.J. Bartholomew, J.P. Hibbard and P.M. Karabinos. Geological Society of America, Memoir 206, pages 1-30.