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PRELIMINARY INVESTIGATIONS INTO THE DISTRIBUTION OF VMS-STYLE MINERALIZATION WITHIN THE CENTRAL PORTION OF THE BUCHANS–ROBERTS ARM (VOLCANIC) BELT, CENTRAL NEWFOUNDLAND

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ABSTRACT

*The central portion of the Buchans–Roberts Arm (volcanic) belt represents a highly prospective region with respect to the development of volcanogenic massive sulphide (VMS) mineralization. Here, volcanic and related volcanosedimentary rocks of the Roberts Arm Group are host to several base-metal deposits (*e.g.*, Gullbridge, Southwest Shaft and Lake Bond) and numerous other prospects. These occurrences have been the subject of significant mineral exploration, beginning in the early 1900s, along with a number of academic studies, but have received minimal investigation in recent years.*

The following report highlights preliminary observations from the first year of a multi-year study aimed at investigating the nature and timing of VMS-style mineralization within the region. Several discrete zones of alteration have been identified within the preserved tectonostratigraphy, potentially representing multiple episodes of hydrothermal activity of different ages. Ongoing examinations of these zones will focus on characterizing their alteration and related mineralization in an attempt to highlight areas of potential economic interest.

INTRODUCTION

The Buchans−Roberts Arm (volcanic) belt of central Newfoundland is host to numerous examples of volcanogenic massive sulphide (VMS) mineralization, and hosts several notable deposits, namely Buchans, Lake Bond, Gullbridge and Pilley's Island (Swinden, 1991). These deposits are inferred to have formed within a mature volcanic island-arc complex that developed within the Cambro-Ordovician Iapetus Ocean (Evans *et al.*, 1992). The Buchans−Roberts Arm belt (also referred to as *the belt*) represents an informal term, initially used to segregate it from other lithotectonic belts in the Norte Dame Subzone of the Dunnage Zone (*e.g.*, Swinden *et al.*, 1997). The belt was initially composed of the Early–Middle Ordovician Buchans, Roberts Arm, Cottrells Cove and Chanceport groups, and was later expanded to include the Red Indian Line Group (Rogers *et al.*, 2005).

The current study area is centred on the former Gullbridge mine and spans some 35 km, extending from the Handcamp prospect in the north to the Skull Hill Brook prospect in the south (Figure 1). The central portion of the belt is covered by recently completed geological mapping and detailed airborne geophysical surveys, providing a comprehensive geological database that will be utilized in ongoing deposit-level studies. This region has been the focus of extensive mineral exploration since the early 1900s, which is demonstrated by the more than 350 drillholes that are distributed throughout the region. The following summary is based on information from mineral assessment files, academic studies, and field observations made while examining the various base-metal occurrences in the region during the 2017 field season.

PREVIOUS WORK

GULLBRIDGE AND SOUTHWEST SHAFT DEPOSITS

The Gullbridge deposit was discovered in 1905 along the western shore of Great Gull Lake (Upadhyay, 1970). Since that time, the surrounding region has been one of the primary focal points of mineral exploration within the central portion of the Buchans−Roberts Arm belt (for a tabulated summary of previous work, *see* Delaney and Akkerman, 2007). Early mineral exploration at the Gullbridge deposit as well as at the smaller Southwest Shaft deposit, was first conducted by the Reid Newfoundland Company Ltd. and the Great Gull Lake Copper Company Ltd. in 1918 (Hatch

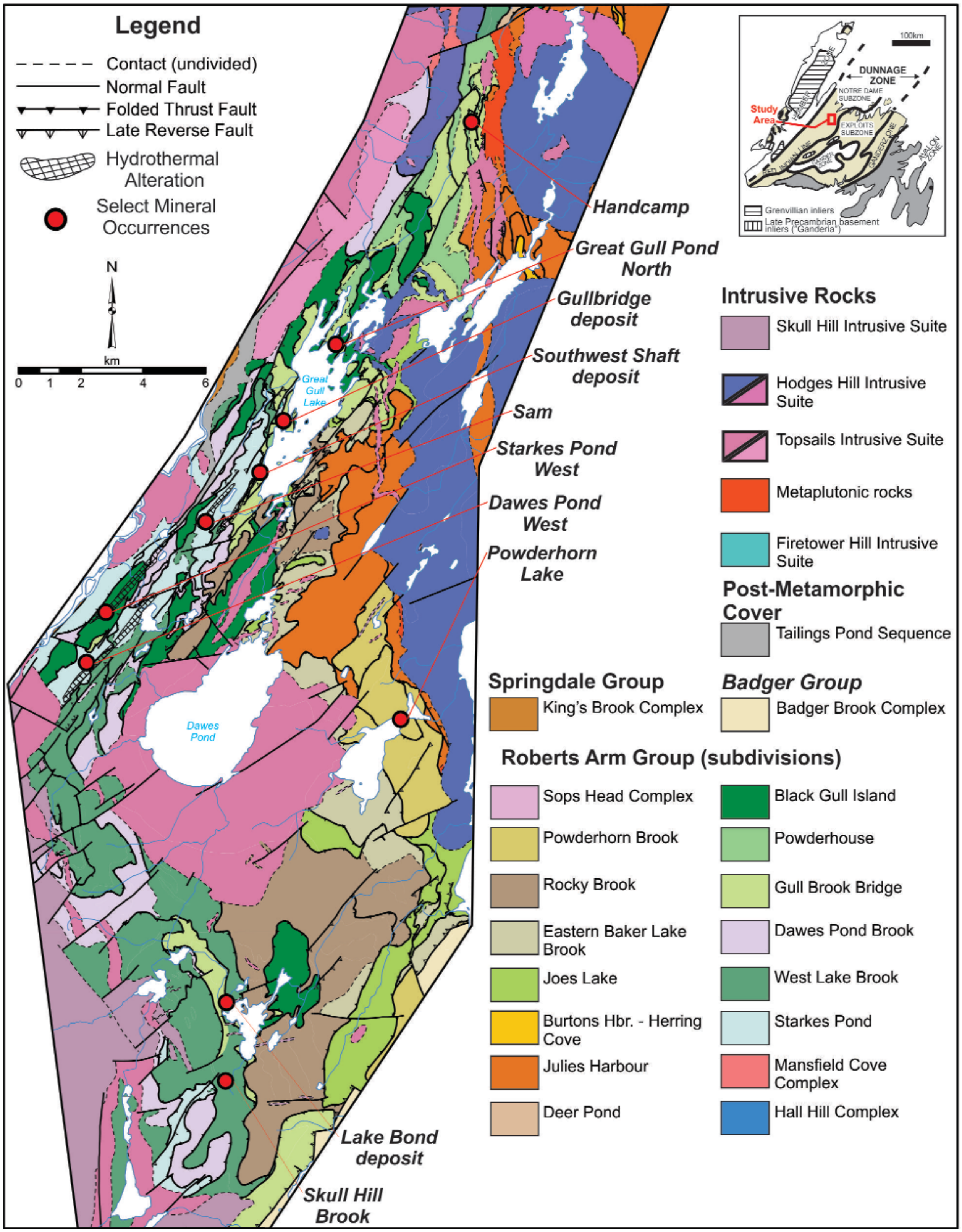

Figure 1. *Simplified regional geology map of the central portion of the Buchans–Roberts Arm (volcanic) belt, outlining select sulphide occurrences within the study area along with the distribution of related alteration zones; modified from O'Brien (2009, 2016a, b).*

and Bancroft, 1924; Healing, 1980); this included the construction of shallow exploration shafts at each of the deposits. Follow-up work in the 1920s largely focused on the Gullbridge deposit through intermittent drilling and geophysical surveys. In the early 1950s, the Gullbridge deposit was acquired by Gullbridge Mines Ltd. (controlled by Falconbridge Nickel Mines Ltd.). The company conducted additional detailed drilling of the deposit in addition to regional drilling along the prospective Gullbridge trend (Hudson *et al.*, 1953). In 1955, Gullbridge Mines Ltd. was acquired by Maritimes Mining Corp., who conducted further underground development of the deposit and brought the mine into production in 1967. However, the mine was closed in 1972 due to high operating costs and the low price of copper; total production during this time was approximately 3 million tons of ore, with an average grade of 1.1% Cu (Upadhyay and Smitheringale, 1972). Reserves for the Gullbridge deposit are estimated at 100 000 tonnes grading 2.0% Cu (Wardle, 2007), whereas the Southwest Shaft deposit is reported to contain approximately 90 000 tonnes of ore at a grade of 1–2% Cu (O'Sullivan, 1985); note that these reserves are historical in nature and are not NI 43-101 compliant.

The area surrounding the Gullbridge deposit was further investigated by Rio Canex Ltd. (later renamed to Rio Algom) in the early 1980s, through the use of various geochemical and geophysical surveys (Bucknell and Bonham, 1983). Due to the structural complexity of the area hosting the mineralization, the company conducted a structural and stratigraphic analysis of the property, which introduced major revisions to the stratigraphy of the mine area in addition to a re-interpretation of the geology of the deposit (Pope and Calon, 1993). The new interpretations of the geology and related mineralization formed the basis for a drilling program in the early 1990s, targeting both the Gullbridge and Southwest Shaft deposits; however, the program was only met with limited success (Lenters and Sears, 1990a, b; Pudifin *et al.*, 1991; Pudifin and Watson, 1992).

In the early 2000s, Gallery Resources Ltd. carried out drilling at the north end of Great Gull Lake (Great Gull Pond North prospect; Figure 1), targeting anomalous zinc values reported from drilling conducted by Sturgeon River Mines Ltd. (1957). Gallery intersected a zone of anomalous zinc and lead mineralization, traceable over 300 m along strike, and locally assaying up to 1.82% Zn over 2 m (French and Wells, 2000). The company also carried out exploration on the Southwest Shaft deposit in the form of ground geophysical surveys and drilling. This drilling confirmed historical intersections of narrow, high-grade, copper mineralization (*e.g.*, 7.0% Cu over 1.2 m) in the area of the deposit and also identified localized zones of zinc enrichment (*e.g.*, DDH SW-11; 1.77% Zn over 1 m; French and Wells, 2001).

Prior to 2010, Copper Hill Resources conducted a compilation study of all previous exploration in the area surrounding the Gullbridge deposit (*cf.* Delaney and Akkerman, 2007). As a follow-up, the company conducted ground and airborne geophysical surveys in the region, but focused its main exploration efforts farther east in the area of the Powderhorn Lake prospect (*see* below).

STARKES POND WEST AND DAWES POND WEST PROSPECTS

The first reported work conducted in the area of the Starkes Pond and Dawes Pond prospects was by Falconbridge Nickel Mines Ltd. in the early 1950s (Coleman, 1951). However, it was not until the mid- to late-1960s, when a Cu–Zn soil anomaly was identified in the area of the Starkes Pond West prospect, that it became the focus of targeted exploration (Figure 1; British Newfoundland Exploration Ltd. (Brinex), 1969). The anomaly was further investigated by Noranda in the early 1970s through additional geochemical and geophysical surveys (Dean, 1973). In the late 1970s, Brinex discovered a zone of pyritic alteration to the southeast of the Starkes Pond West prospect while conducting regional exploration, which resulted in the discovery of the Dawes Pond West prospect (Figure 1; Busch, 1978). In 1980, Brinex conducted follow-up drilling of both the Starkes Pond West and Dawes Pond West prospects, drilling a single hole at each location. No mineralization was intersected at the Starkes Pond West occurrence, but the hole drilled at the Dawes Pond West prospect intersected anomalous zinc mineralization, returning up to 0.25% Zn over 4.57 m (McHale, 1982).

Falconbridge further tested both prospects in the early 1990s with additional geophysical surveys, and they drilled four holes at the Starkes Pond West prospect, targeting IP anomalies. A narrow zone of exhalative massive sulphide mineralization was reported from the drilling, with the best intersection returning 5.60% Zn and 1.65% Cu over 0.91 m (Hudson, 1990). In the late 1990s, GT Exploration Ltd. conducted regional exploration in the area and drilled two holes at the Dawes Pond West prospect. The drilling intersected altered felsic volcanic rocks displaying localized zinc enrichment assaying up to 0.29% Zn over 14.2 m (Harris *et al.*, 1999).

LAKE BOND DEPOSIT

Mineralization was first noted in the area of the Lake Bond deposit in 1954 by the Reid Newfoundland Company Ltd. (Lynch, 1954). The discovery was followed-up with trenching and drilling carried out by New Jersey Zinc Exploration Company Ltd. through a joint venture with Brinex in the mid-1950s (Hannah, 1955; Hannah and

Newman, 1957); however, the joint venture was terminated and work was discontinued in the early 1960s. Drilling highlights from this early work produced values of up to 11.91% Zn and 0.83% Cu over 6.1 m (DDH 56-27; Hannah and Newman, 1957). In the late 1970s, Consolidated Morrison Exploration Ltd. investigated the area through additional trenching and limited drilling. They calculated a preliminary reserve for the deposit (non-NI 43-101 compliant), identifying a resource of 1.2 Mt grading 2.12% Zn and 0.31% Cu (Harris, 1976, 1977).

In the late 1980s, Macree Resources Inc. conducted additional geophysical surveys and drilling on the Lake Bond deposit, but discontinued work on the property in 1990. Then, in 1992, Noranda Exploration Company Ltd. commenced exploration in the area, conducting geophysical and geochemical surveys, along with limited trenching and drilling, but they discontinued work the following year. Results indicated that the Lake Bond alteration zone had a strike length of 1.4 km, and a vertical depth of 300 m, with the mineralized sequence having a maximum thickness of approximately 150 m (Collins, 1992). The best results obtained by Noranda included 2.73% Zn over 16.3 m, 3.40% Zn over 4.1 m and 2.24% Zn over 9.9 m (DDH LB-92-01). Additionally, local silicified zones were noted to contain anomalous precious-metal mineralization, assaying up to 5.77 g/t Ag and 0.40 g/t Au over 5.1 m (Collins, 1992). In the late 1990s, First Labrador Acquisitions Inc. conducted a ground gravity survey, identifying a well-defined anomaly measuring 125–175 m wide and trending for 850 m along strike, located to the northeast of the main deposit. The southern end of this anomaly was tested with seven drillholes, from which the best intersection returned 1.0% Zn over 4.6 m (DDH LA97-05; Frew *et al.*, 1998). The most recent work conducted on the Lake Bond deposit was by Prominex Resources Corp. in 2012, which included a detailed review of the previous exploration conducted on the deposit (Agnerian, 2012). The company carried out prospecting and soil sampling along strike to the northeast of the deposit, but no further work was reported.

The Skull Hill Brook prospect, which is located approximately 3 km to the south of the Lake Bond deposit, was also investigated through the 1990s. The prospect was originally discovered by AVIP Resources in 1990 while drill testing an airborne EM anomaly (Gillis, 1990). The company intersected a zone of chloritic alteration and stringer pyrite hosting anomalous copper and zinc values; however no additional follow-up was conducted. The area was revisited by Celtic Minerals in 1999, who carried out ground geophysical surveys and drilling. This drilling intersected a subvertical stringer zone containing pyrrhotite, pyrite, chalcopyrite, and sphalerite mineralization. The best assay results obtained from this zone returned 0.51% Cu over 12.47 m (DDH LB-99-03) and 0.28% Zn and 0.14% Cu over 4.5 m (LB-99-02; Greene *et al.*, 2000).

POWDERHORN LAKE PROSPECT

Base-metal mineralization located along the western shoreline of Powderhorn Lake (Figure 1) was first noted by Kalliokoski (1955) during regional mapping of the area. However, the first documented mineral exploration of the prospect was not until the late 1990s (*cf.* Jacobs *et al.*, 1998). Prior to this, limited mineral exploration was conducted in the area of Powderhorn Lake, both as part of a joint venture between Brinex and New Jersey Zinc during the mid-1950s (*cf.* Hansuld, 1957; Bedford, 1957; Newman, 1957; Peters, 1958), and again by Noranda in the early 1970s (*cf.* Dean, 1973, 1974).These exploration programs targeted airborne geophysical anomalies located to the north and east of the lake and do not make reference to the sulphide occurrences along the western shoreline.

In the late 1990s, Canaco Resources Ltd. carried out exploration in the area, primarily focusing on magmatic sulphides developed to the east of Powderhorn Lake, but also conducted limited sampling of the sulphide occurrences along the western shoreline of the lake. From this program, grab samples containing semi-massive bands of sphalerite with lesser chalcopyrite produced assays of up to 3.4% Zn, 0.76% Cu, 0.56 oz/t Ag and 476 ppb Au (Jacobs *et al.*, 1998). However, Canaco terminated their option agreement on the property in 1998 before further follow-up could be conducted.

In 1999, Copper Hill Resources Inc. optioned the property and carried out prospecting and drilling to the northeast of the occurrences along the western shoreline, which produced intersections of up to 7.4% Zn and 0.19% Cu over 1 m (Wilton and Akkerman, 2000). Examination of this mineralization identified the potential for Zn–Cu ± Pb VMS-style mineralization (Wilton *et al.*, 2001a), and additional diamond drilling was carried out to test geophysical targets in the area. This drilling resulted in the intersection of sulphide mineralization, consisting of pyrrhotite, pyrite, sphalerite and lesser chalcopyrite, from which the best intersection returned 4.00% Zn, 0.14% Cu over 0.6 m (Wilton *et al.*, 2001b). Additional drilling was carried out by the company between 2006 and 2007, which intersected stringer-style mineralization, assaying up to 1.52% Zn over 5.7 m, including a higher grade interval of 3.50% Zn over 0.7 m (Delaney *et al.*, 2007). In 2008, an airborne gravity survey was completed over the property, which was followed up with drilling in 2009, targeting anomalies to the west of Powderhorn Lake, but the drilling failed to intersect any additional mineralization (Georghiou *et al.*, 2009).

HANDCAMP PROSPECT

The Handcamp prospect has been primarily targeted for its precious-metal mineralization, but is also host to appreciable base-metal enrichment. The prospect was discovered in 1928 by the Central Mineral Belt Syndicate (Corlett, 1930), who reported values of up to 3.78% Pb, 1.9% Zn and 0.75% Cu along with gold and silver mineralization. The prospect was first drilled by the Government of Newfoundland in 1941 (MacQuarrie, 1941), from which the highest assay returned 12.13 g/t Au (0.39 oz/t) and 15.24 g/t Ag (0.49 oz/t) over 2.1 m. Further drilling was conducted in the late 1950s by Orenada Mines Ltd. (Patterson, 1956), intersecting significant Zn–Pb–Cu–Ag–Au mineralization that returned assays of up to 2.35% Zn, 1.61% Pb, 0.06% Cu, 13.37 g/t Ag (0.43 oz/t) and 2.18 g/t Au (0.07 oz/t) over 1.5 m. Higher precious-metal mineralization was also reported, assaying up to 92.69 g/t Ag (2.98 oz/t) and 4.98 g/t Au (0.16 oz/t) over 0.8 m.

In the late 1960s, a limited amount of drilling by M.J. Boylen Engineering was conducted in the area south of the main Handcamp prospect, but only intersected weak mineralization (Brown, 1969). In the early 1970s, Emrex Mining Ltd. conducted ground geophysical surveys over the prospect, noting a zone of conductivity extending for 240 m that was coincident with the areas of historical trenching (Lea and Neilson, 1972), but no further work was completed. Falconbridge Nickel Mines Ltd. optioned the property from Newfoundland Exploration Company Ltd. in the late 1970s, and conducted a program of trenching and geological mapping, which produced channel samples of up to 2.6% Zn, 1.7% Pb, 0.37% Cu, 26.44 g/t Ag (0.85 oz/t) and 467 ppb Au (0.015 oz/t; de Ferriere, 1978). Follow-up drilling in 1980 produced gold intersections of up to 2.36 g/t Au (0.076 oz/t) over 0.3 m, whereas the best base-metal intersection returned 2.25% Zn, 1.90% Pb, 23.64 g/t Ag (0.76 oz/t) and 93 ppb Au (0.003 oz/t) over 2 m (Hinchey, 1980).

In the early 1980s, U.S. Borax Ltd. in partnership with Pacific Coast Mines Inc. began exploration in the area, conducting mapping, geophysical surveys and an extensive soil sampling program along the southwest-projected strike direction of the mineralized horizon of the Handcamp prospect (Burton, 1981). This was followed-up with drilling in 1983, which primarily focused on the area to the southwest of the main prospect, but failed to intersect any significant mineralization (Burton and Woolham, 1983). In the early 1990s, Rio Algom investigated the area along strike to the southwest of the Handcamp prospect, conducting soil and geophysical surveys over an area known to host mineralized boulders containing base-metal mineralization, but failed to identify any additional prospects (Pudifin and Muggridge, 1991).

In 2006, KAT Exploration Inc. optioned the Handcamp prospect and conducted work that included chip sampling of historical trenches, producing assays of up to 7.14 g/t Au over 8 m, along with higher grade, narrower zones of up to 15.72 g/t Au and 21.9 g/t Ag over 2 m (Stead, 2007); however, the option was terminated in 2007. Then in 2009, KAT Gold Holdings Corp. and KAT Exploration Inc. again optioned the property and conducted geochemical and geophysical surveys, trenching and drilling. Highlights from the trenching included tracing the alteration zone associated with the mineralization for upwards of 600 m along strike, from which assays of up to 2.63 g/t Au and 21.44 g/t Ag over 3.7 m were obtained (Pickett *et al.*, 2011). Follow-up drilling tested the alteration zone to a vertical depth of 185 m, with the best intersection returning up to 10. 8 g/t Au and 222.4 g/t Ag over 0.9 m within a broader interval of 3.15 g/t Au and 42.6 g/t Ag over 5.9 m (4.4 m estimated true width; Pickett *et al.*, 2011).

REGIONAL GEOLOGY

The geology of the central portion of the Buchans–Roberts Arm belt has been discussed by Swinden (1991), Dickson (2000) and O'Brien (2007), and the following summary is largely derived from these sources. The Buchans–Roberts Arm (volcanic) belt forms part of the larger Notre Dame Arc (*cf.* Swinden *et al.*, 1997; van Staal *et al.*, 1998) and is inferred to have been accreted to older oceanic rocks of the Dunnage Zone along the Laurentian continental margin during the Taconic Orogeny (Cawood *et al.*, 1995; Kusky *et al.*, 1997; Draut and Clift, 2002; Lissenburg *et al.*, 2005). Early interpretations of stratigraphic relationships within the central portion of the Buchans–Roberts Arm belt inferred a westward younging of the overall succession (*cf.* Kalliokoski, 1955; Swinden and Sacks, 1986). However, reinterpretations of this region now recognize the complex structural nature of the succession, within which stratigraphic units are locally repeated (*cf.* Pope *et al.*, 1991; Pope and Calon, 1993; O'Brien, 2007). This structural reinterpretation of the region by Pope and Calon (1993) noted that although the stratigraphy within individual structural panels young's westward, the overall stacking of these structural panels of older on top of younger panels results in an eastward younging of units within the region.

O'Brien (2007) subdivided the rocks occurring in the central portion of the Buchans–Roberts Arm belt into four main fault-bounded structural tracts, namely the Gullbridge, Baker Brook, Burnt Pond and the Powderhorn Lake tracts. This tectonic subdivision was further expanded to include the South Brook and Catamaran Brook structural tracts by O'Brien (2008). The Gullbridge tract is composed of altered greenschists, mineralized mafic flows and/or felsic pyroclastic rocks, iron formation, and volcaniclastic turbidites.

Rocks included within the South Brook tract include pillowed tholeiitic basalt and gabbro sills along with lesser clastic limestone and red siltstone. Volcanosedimentary rocks of the Baker Brook tract are characterized by thinning-upward and fining-upward epiclastic turbidites, which structurally overlie and underlie gossanous basalt and associated felsic pyroclastic rocks. The Catamaran Brook tract consists of calc-alkaline and tholeiitic basalt and related volcaniclastic rocks, gabbro, wacke and pyritic black shale and chert. Rocks of the Burnt Pond tract are characterized by regionally metamorphosed metasedimentary schist along with higher grade migmatite and gneissic intrusive rocks. Finally, the metamorphic rocks of the Powderhorn Lake tract are composed of variably altered metavolcanic and overlying metasedimentary rocks that are regionally metamorphosed to upper amphibolite facies.

LOCAL GEOLOGY AND MINERALIZATION

The following provides summaries of the general characteristics of the occurrences, and related alteration zones, within the central portion of the Buchans–Roberts Arm belt. Unit subdivisions utilized in the following section follow those outlined by O'Brien (2016a, b) and the various structural tracts used to group regional alteration zones are taken from O'Brien (2008).

GULLBRIDGE AND SOUTHWEST SHAFT DEPOSITS

The VMS-style mineralization at both the Gullbridge and Southwest Shaft deposits occur within the regional Gullbridge structural tract and are primarily hosted within altered pillow basalt (Gull Brook Bridge division of O'Brien, 2016a, b). However, the associated alteration also extends into the structurally overlying felsic volcanic rocks (*see* below). To the west of the Gullbridge deposit, rocks of the Gull Brook Bridge division are structurally overlain by felsic volcanic rocks of the Starkes Pond division (O'Brien, 2016a, b). The main mineralized zones occur proximal to this structural contact. Although the mineralization and alteration are largely conformable to the regional stratigraphy, detailed studies indicate that the alteration locally transects stratigraphic contacts (Upadhyay and Smitheringale, 1972; Pope *et al.*, 1991). The alteration zone can be traced intermittently along strike for about 4.5 km, extending from the area of the Gullbridge deposit in the north to areas south of the Southwest Shaft deposit, where it is locally noted to crosscut stratigraphy, resulting in alteration of the structurally overlying felsic volcanic rocks (Pope *et al.*, 1991).

The Gullbridge deposit is interpreted to represent stockwork-style mineralization, with the main ore body forming two overlapping, steeply westward-dipping, tabular lenses extending 430 m along strike (Upadhyay and Smitheringale, 1972; Pope *et al.*, 1991). The main ore body, which extends to approximately 210 m depth and varies in thickness from 30 to 75 m, primarily consists of pyrite, pyrrhotite and chalcopyrite (Plate 1A; Upadhyay and Smitheringale, 1972). The mineralization is contained within a zone of cordierite–andalusite–chlorite schist, which is, in turn, enveloped by a zone of cordierite–anthophyllite alteration. Gullbridge ore is associated with a Mg-rich stockwork that has been structurally disrupted and thermally metamorphosed due to the regional plutonic activity, which has resulted in the cordierite-, andalusite- and anthophyllite-bearing alteration assemblages (Upadhyay and Smitheringale, 1972; Pope *et al.*, 1991). Geochemically, Healing (1980) characterized the alteration zone extending from Gullbridge to the Southwest Shaft deposit as displaying relative enrichments in Mg, Fe, S and K and depletions of Na and Ca. Iron formation is noted to structurally overlie the mineralized zones at the Gullbridge–Southwest Shaft deposits. This unit displays copper enrichment in the vicinity of the Gullbridge deposit, and gold enrichment is also noted to the immediate south of the ore body (Swinden, 1975).

The Southwest Shaft deposit, which is located 2.3 km along strike to the southwest of the Gullbridge deposit, occurs within a similar structural setting as the Gullbridge deposit, and is primarily hosted within volcaniclastic rocks and interbedded felsic tuffs inferred to overlie basaltic rocks (Gull Brook Bridge division; O'Brien 2016b). These rocks are structurally overlain to the west by felsic volcanic rocks of the Starkes Pond division (O'Brien, 2016b). The associated alteration zone averages 200 m in width and contains similar mineral assemblages to that developed within the Gullbridge area, aside from the development of significant anthophyllite (Healing, 1980). Sulphide mineralization consists of pyrite, pyrrhotite and chalcopyrite occurring as fine-grained disseminations and stringers (Plate 1B; Pope *et al.*, 1991). Narrow high-grade intersections of semi-massive sulphide have been reported from the deposit, such as 7.0% Cu and 30.10 g/t Ag and 550 ppb Au over 1.2 m, in addition to discrete zones of zinc enrichment (up to 1.77% over 1 m) associated with laminated chert horizons (French and Wells, 2001). Anomalous gold enrichment (up to 590 ppb) is also noted in samples collected from the ore dump at the Southwest Shaft deposit by Swinden (1988). The Gullbridge–Southwest Shaft alteration zone is traceable along strike for upwards of 2 km to the southwest of the Southwest Shaft deposit, and is characterized by the occurrence of stratiform horizons of pyritic alteration in association with chert beds intercalated with mafic and felsic tuffaceous units (Plate 1C). Exploration drilling by Falconbridge in the 1950s at the southern end of the Gullbridge–Southwest Shaft alteration zone returned anomalous miner-

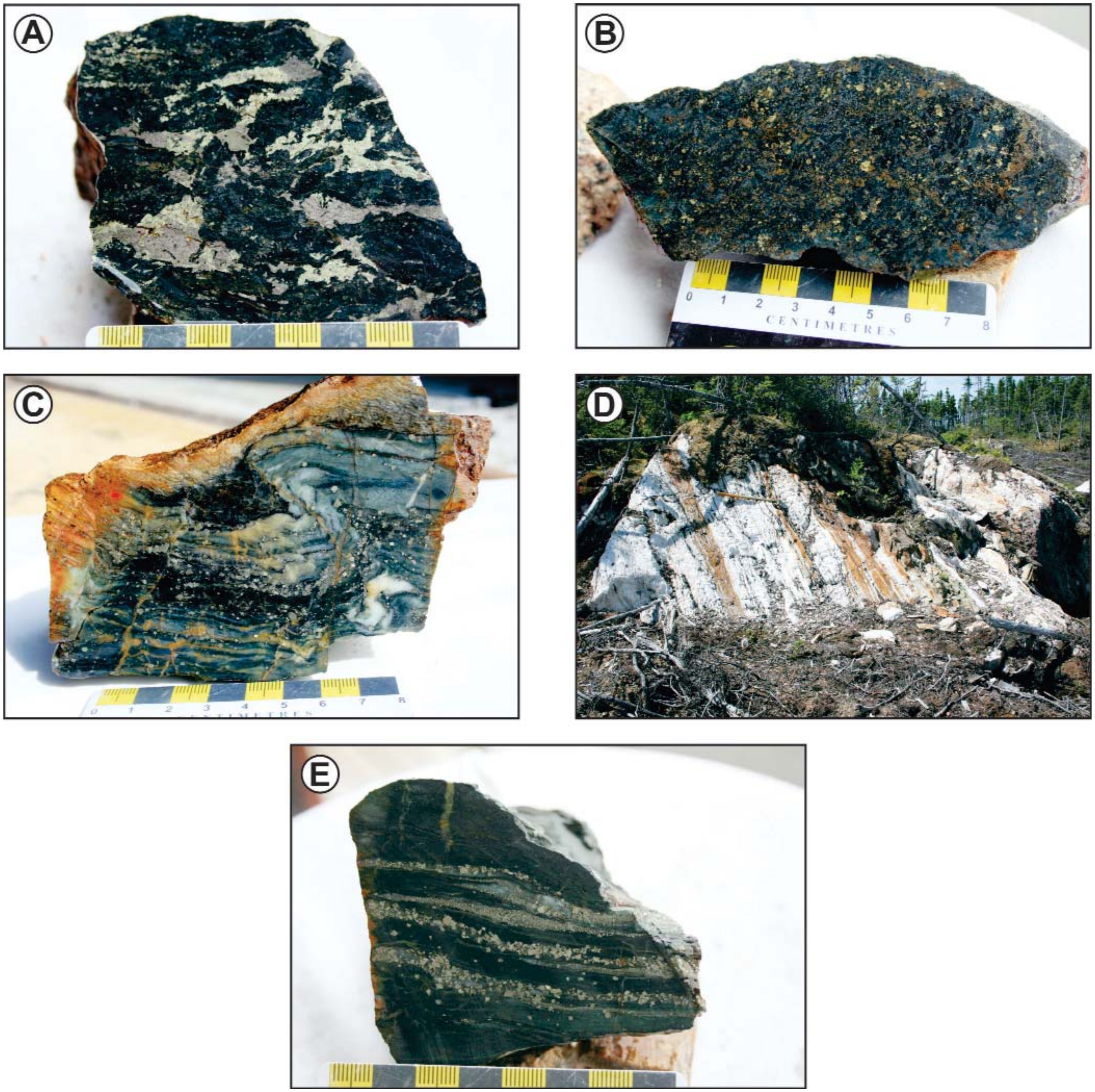

Plate 1. *A) Representative sample of sulphide mineralization from the Gullbridge deposit, obtained from ore dump, containing pyrrhotite–chalcopyrite within a cordierite–chlorite-rich groundmass (UTM 561579E/5449721N; NAD 83, Zone 21); B) Representative sample of outcropping sulphide mineralization containing disseminated pyrite–pyrrhotite–chalcopyrite in a cordierite–chlorite-rich groundmass; Southwest Shaft deposit (UTM 560568E/5447577N; NAD 83, Zone 21); C) Interbedded felsic tuff and chert containing recrystallized syn-depositional pyrite; sample collected approximately 700 m southwest of the Southwest Shaft deposit (UTM 560204E/5446979N; NAD 83, Zone 21); D) Western Alteration Zone, illustrating the stratiform nature of the pyritic alteration interbedded with the felsic tuff and discontinuous chert beds (UTM 559131E/5446537N; NAD 83, Zone 21); E) Representative sample of alteration outlining the stratiform nature of the pyritic alteration (UTM 559091E/5446469N; NAD 83, Zone 21).*

alization assaying up to 1.43% Cu, 10.58 g/t Ag (0.34 oz/t) and 311 ppb Au (0.01 oz/t) over 0.76 m (DDH GB-108; Hudson *et al.*, 1953; Bucknell and Bonham, 1983).

Located to the west of the Gullbridge–Southwest Shaft alteration zone is a second zone of stratiform pyritic alteration, termed the Western Alteration Zone by Swinden (1988), hosted entirely within the felsic volcanic sequence of the Starkes Pond division (Figure 1). This zone is traceable for approximately 2 km along strike and is host to the Sam prospect, as well as several other occurrences of pyritic alteration (Plate 1D, E). Texturally, this alteration resembles that from the southern extension of the Gullbridge–Southwest Shaft zone and is locally noted to host anomalous (230 ppb) gold (Swinden, 1988). Trenching at the southern end of the Western Alteration Zone by GT Exploration, targeting a soil anomaly containing anomalous values of zinc, exposed altered felsic and mafic tuffs hosting sphalerite and chalcopyrite from which a grab sample assayed 2.02% Zn, 0.41% Pb and 358 ppm Cu (Harris *et al.*, 1997). A drillhole in this same area, drilled by Rio Algom in the early 1990s, intersected anomalous copper (up to 0.46% over 1 m), but did not return any significant values of zinc (DDH GB-152; Pudifin and Watson, 1992).

Plate 2. *Moderately magnetic mafic epiclastic rocks containing locally interbedded centimetre-scale beds of iron formation and rare veinlets of magnetite and weakly developed stringer pyrite alteration. Note the unit is locally affected by east–west faulting displaying metre-scale dextral offset (along trend of rock hammer); Starkes Pond West prospect (UTM 556149E/ 5443395N; NAD 83, Zone 21).*

STARKES POND WEST PROSPECT

The Starkes Pond West alteration zone represents the western-most occurrence of VMS-related mineralization developed within the region (Figure 1). Alteration is primarily hosted within the Black Gull Island division of the South Brook structural tract (O’Brien, 2008, 2016b). The zone displays a spatial association with a prominent magnetic high on airborne geophysical surveys, and with local outcrops consisting of moderately magnetic basalt and related mafic epiclastic rocks, and rare centimetre-scale beds of iron formation along with local veinlets of magnetite and stringer pyrite (Plate 2).

Outcrop exposure in the area of the aeromagnetic anomaly is poorly developed due to extensive overburden, but trenching has, locally, exposed mafic volcanic rocks hosting patchy chlorite–pyrite alteration. In addition, the zone has been tested with five drillholes, spanning some 800 m of strike length along the aeromagnetic anomaly, with one hole reported to have intersected a narrow zone of exhalative sulphides containing pyrite, sphalerite and chalcopyrite; assays from this interval returned 5.60% Zn and 1.65% Cu and 159 ppb Au over 0.91 m (DDH SP-90-01; Hudson, 1990). A second hole, located approximately 200 m to the south, is reported to have intersected a narrow zone of stringer sulphides within chloritized basalt that assayed 1.89% Zn and 0.81% Cu over 1.17 m (DDH SP-90-02; Butler and Hudson, 1990).

DAWES POND WEST PROSPECT

The Dawes Pond West alteration zone is located to the southwest of, and largely parallels, the Starkes Pond West alteration zone (Figure 1). This alteration zone is hosted entirely within the felsic volcanic rocks of the Starkes Pond division of the Gullbridge structural tract, and is situated roughly along strike to the southwest of the Western Alteration Zone (*see* above). Trenching in the area of the Dawes Pond West prospect by GT Exploration Ltd. in the late 1990s, targeting strong Pb–Zn soil anomalies associated with IP chargeability anomalies, exposed quartz–sericite–pyrite alteration hosted within felsic volcanic rocks. Channel sampling of the alteration zone returned weakly anomalous values of zinc (426 ppm) and copper (377 ppm; Harris *et al.*, 1997). The felsic volcanic rocks exposed in the area contain a strong penetrative fabric and well-developed crenulation in addition to variably developed chlorite–pyrite alteration (Plate 3A, B). The alteration zone has been drill-tested over a strike length of approximately 800 m with three drillholes. Results from this drilling returned weakly anomalous zinc mineralization, returning 0.29% Zn over 14.2 m (Harris *et al.*, 1999).

LAKE BOND DEPOSIT

Sulphide mineralization at the Lake Bond deposit is hosted by variably altered pillow basalt (Plate 4A) of the West Lake Brook division (O’Brien, 2009). These rocks are, in turn, structurally overlain to the west by rocks correlated with the Gull Brook Bridge division. Both units are region-

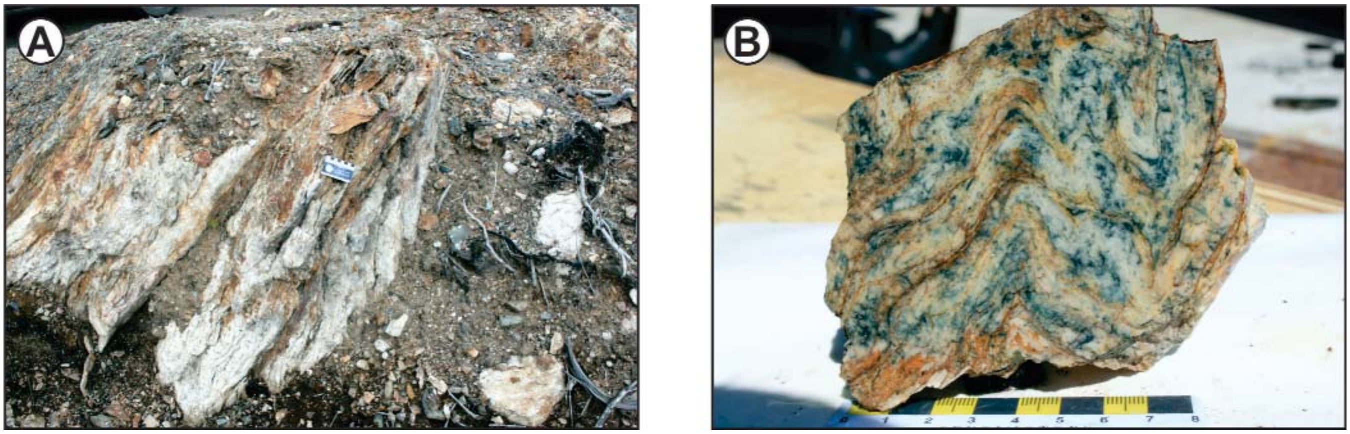

Plate 3. *A) Strongly foliated felsic volcanic rocks with variable pyritic alteration; Dawes Pond West prospect (UTM 555222E/ 5441730N; NAD 83, Zone 21); B) Foliated and crenulated chlorite–pyrite-altered felsic volcanic rock; Dawes Pond West prospect (UTM 555194E/5441870N; NAD 83, Zone 21).*

ally grouped within the Gullbridge structural tract of O'Brien (2008). Within the pillow basalt sequence, sulphide mineralization occurs as disseminations, stringers, veinlets and small pods, consisting of pyrite, sphalerite, lesser chalcopyrite and rare galena (Plate 4B; Swinden and Sacks, 1986; Swinden, 1988; Hudson and Swinden, 1990). The mineralized zone displays pervasive chloritic alteration and silicification. Epidote alteration, although not common in the immediate ore zone, is widespread in the surrounding area and is locally accompanied by pyrite ± chalcopyrite mineralization (Swinden and Sacks, 1986; Hudson and Swinden, 1990). At the north end of the mineralized zone, outcropping alteration appears to be structurally overlain by relatively unaltered mafic volcanic rocks, potentially representing units of the overlying Gull Brook Bridge division. The immediate footwall of this structural zone is host to the development of phengitic illite alteration accompanied by possible fuchsite and fine-grained disseminated pyrite (Plate 4C), which is similar to the style of alteration observed in the area of the Handcamp prospect (*see* below).

The mineralization developed at the Lake Bond deposit has been inferred to represent a volcanogenic style of mineralization (Harris, 1976; Swinden and Sacks, 1986; Swinden, 1988). However, Hudson and Swinden (1990) proposed an alternative style for at least part of the mineralization at the deposit. Observations based on petrological, mineralogical and structural evidence were used to suggest the presence of two generations of sulphide mineralization; the first being related to an early volcanogenic style of mineralization, which was subsequently overprinted by a later syn- to posttectonic, shear-hosted mineralizing event, similar to that proposed for the Handcamp prospect (*see* below; Hudson and Swinden, 1989). Hudson and Swinden (1990) noted that the first generation of sulphides within the Lake Bond deposit are largely composed of sphalerite and pyrite and with lesser chalcopyrite occurring as disseminations, stringers and pods. In contrast, the second generation of sulphide mineralization consists of sphalerite, chalcopyrite, pyrite, and trace galena along with anomalous enrichment in gold, arsenic, antimony and cadmium, occurring as veins that crosscut the dominant foliation.

POWDERHORN LAKE PROSPECT

The Powderhorn Lake area represents a distinctly different tectonic and geological setting relative to the other VMS-related occurrences developed farther to the west. The area surrounding Powderhorn Lake contains regional till anomalies of zinc, copper and gold as noted by Liverman *et al.* (2000). Locally, along the western shore of the lake, rusty-weathering gossan zones (Plate 4D) are hosted within felsic metavolcanic rocks of the Powderhorn Brook division of O'Brien (2016b), which is part of the Powderhorn Lake structural tract. Here, sulphide mineralization is hosted within variably altered quartz-crystal tuff (Plate 4E). The host rocks in this area represent regionally metamorphosed amphibolite-facies rocks that are inferred to represent the deepest exposed level of the Buchans–Roberts Arm belt in the region (Figure 1; O'Brien, 2007).

Exposures of the mineralized zone are limited to shoreline outcrops (Plate 4F), but an extensive zone of gossanous float is observed to the northwest of the lake, from which Dickson (2000) reported values of up to 0.57% Cu, 0.18% Zn, 0.05% Pb, 7.6 g/t Ag and 433 ppb Au. Drilling in the area of the mineralized float has intersected near-surface, stratiform zones of Zn–Cu ± Au mineralization, which has produced assays of up to 3.10% Zn, 0.19% Cu and 180 ppb Au over 0.4 m (Wilton *et al.*, 2001b). Sulphide mineralization from drill-

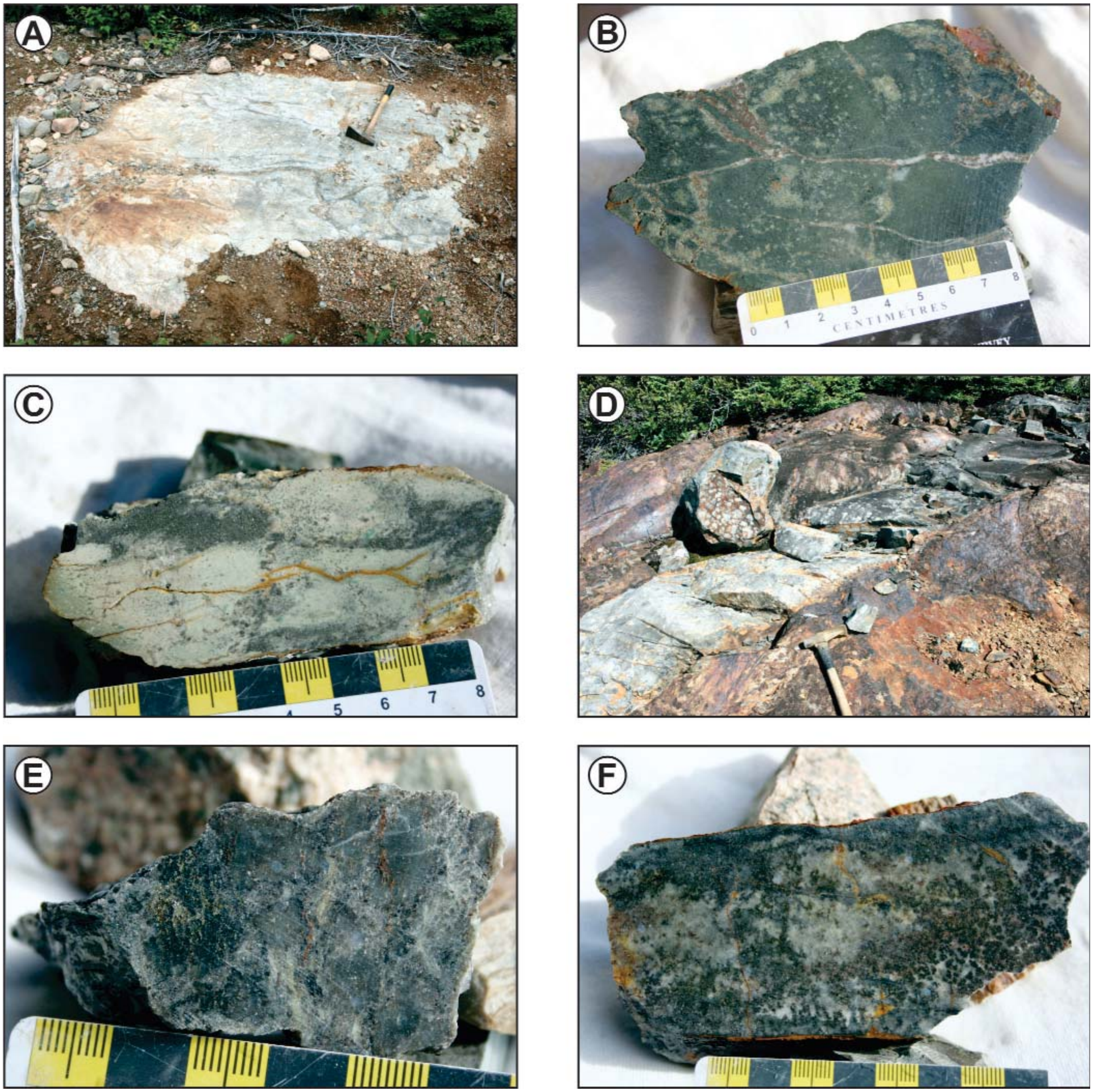

Plate 4. *A) Pillow basalt of the West Lake Brook division, displaying patchy pyritic alteration proximal to the Lake Bond deposit (UTM 559733E/5431490N; NAD 83, Zone 21); B) Disseminated and vein-hosted pyrite–sphalerite (reddish brown) mineralization within epidote-altered mafic volcanic rocks; Lake Bond deposit (UTM 559710E/5430804N; NAD 83, Zone 21); C) Phengitic illite alteration of the mafic volcanic rocks along with possible fuchsite in association with fine-grained disseminated pyrite alteration developed marginal to the main mineralized zone; Lake Bond deposit (UTM 559647E/5431169N; NAD 83, Zone 21); D) Zone of sulphide mineralization developed along western shoreline of Powderhorn Lake, locally cross-cut by post-mineralization, sulphide-bearing mafic dyke (UTM 565113E/5439817N; NAD 83, Zone 21); E) Representative sample of weakly altered quartz-crystal felsic tuff containing mm-scale rounded quartz grains and trace disseminated pyrite (UTM 565087E/5439842N; NAD 83, Zone 21); F) Intensely altered quartz-crystal tuff from the central portion of the Powderhorn Lake prospect, hosting fine-grained disseminated sulphides and locally containing relic mm-scale rounded quartz grains (UTM 565113E/5439817N; NAD 83, Zone 21).*

core is reported to occur as finely disseminated layers, ranging from 1 mm to 10 cm in width, consisting of pyrrhotite, pyrite, sphalerite and chalcopyrite. This zone of Zn-rich mineralization has been interpreted to represent a primary, syngenetic, volcanogenic style of mineralization, which has subsequently been hornfelsed during later plutonic activity (Wilton and Akkerman, 2000; Wilton *et al.*, 2001b).

HANDCAMP PROSPECT

The Handcamp prospect forms a relatively narrow, structurally bound, linear alteration zone, traceable for up to 1.2 km along strike (Hudson and Swinden, 1989). This mineralized zone is hosted within mafic volcanic rocks of the Gull Brook Bridge division of O'Brien (2016a), occurring within the Gullbridge structural tract. Relatively unaltered, pillow basalt and associated iron formation are observed within the structural footwall of the prospect (Plate 5A), which is structurally juxtaposed with a rusty-weathering gossan zone (Plate 5B), which measures up to 50 m in width. This alteration zone dips steeply to the west and is structurally overlain by relatively unaltered pillow basalt, similar to that observed within the structural footwall. Within the main mineralized zone, relic beds of chert are also preserved (Plate 5B), but all other primary textures are obscured by the intense quartz–muscovite (± fuchsite) –pyrite–magnetite alteration, which forms the bulk of the mineralized zone (Plate 5C, D). Mineralization developed within this zone consists of pyrite, chalcopyrite, sphalerite, minor galena and irregularly distributed gold (Hudson and Swinden, 1989).

The nature of the mineralization at the Handcamp prospect has been the subject of some debate, with a variety

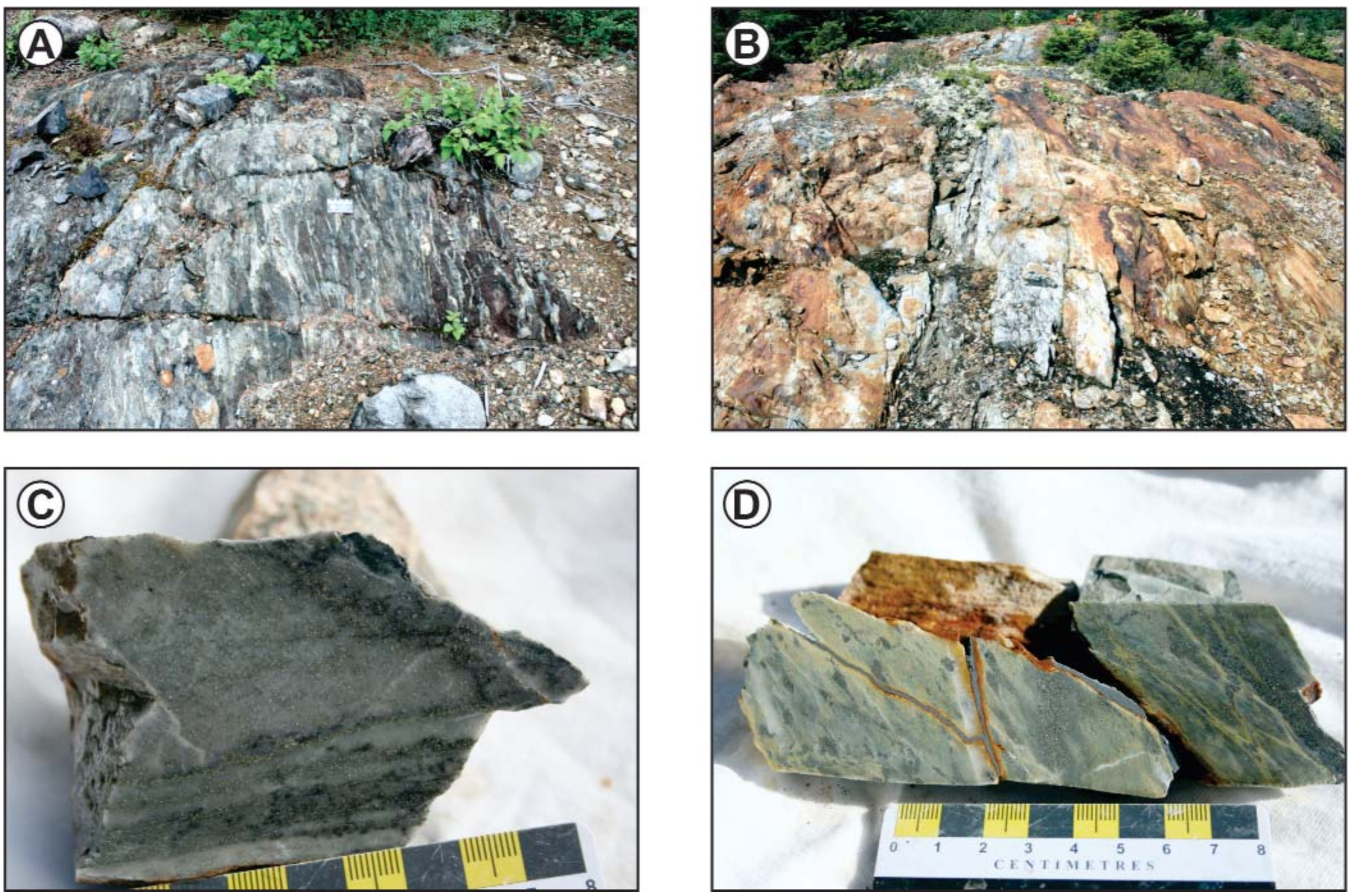

Plate 5. *Select photographs from the Handcamp prospect. A) Relatively unaltered pillow basalt developed within the footwall of the main mineralized zone (UTM 567615E/5459312N; NAD 83, Zone 21); B) Main zone of quartz–pyrite alteration containing a relic white chert bed within the central portion of the mineralized zone (UTM 567597E/5459301N; NAD 83, Zone 21); C) Cut sample of quartz–pyrite alteration displaying the fine-grained disseminated and locally banded nature of the predominantly pyritic sulphide mineralization (UTM 567597E/5459301N; NAD 83, Zone 21); D) Disseminated pyrite in association with muscovite (± fuchsite) white mica alteration; note that the grey material infilling the fractures is glue (UTM 567516E/5459085N; NAD 83, Zone 21).*

of genetic models being proposed, such as epigenetic (Corlett, 1930), shear-zone related (Lea and Neilson, 1972), stratabound volcanogenic (DeGrace, 1976), and epithermal styles of mineralization (Burton and Woolham, 1983). Hudson and Swinden (1989) reported on the Handcamp prospect and provided supporting evidence for the shear-related hydrothermal model for the mineralization, which included the association of arsenic and antimony enrichment and the abundance of Ca-rich minerals associated with gold mineralization.

DISCUSSION AND FUTURE WORK

Despite the structural complexity of the central portion of the Buchans–Roberts Arm (volcanic) belt, the various base-metal occurrences preserved within the region generally display a spatial association with regionally extensive alteration zones, some of which can be traced for several kilometres along strike. Given the variations in host lithology and structural setting of the various alteration zones, it is likely that more than one hydrothermal system is preserved within the tectonostratigraphy of the region, and that these systems could potentially be of distinctly different ages. The development of alteration zones and related mineralization in rocks grouped within correlative structural tracts on a regional scale points to the prospectivity of particular stratigraphic units within the preserved tectonostratigraphy. Future work in the region will focus on determining the ages and characteristics of various altered and mineralized zones hosted within distinctly different structural tracts to test whether these occurrences represent the structural repetition of related systems, or distinctly different mineralizing events.

In addition, the local presence of precious-metal enrichment associated with occurrences of base-metal mineralization has been inferred to represent a distinctly different mineralizing process (*e.g.*, shear-related), relative to the inferred volcanogenic origin of the base-metal mineralization. If such processes exist, the presence of similar styles of alteration and mineralization (*e.g.*, Handcamp prospect and Lake Bond deposit) distributed over wide geographical areas demonstrate that such systems were active on a regional scale and do not represent localized events. Determining the nature of precious-metal enrichment and its relationship with base-metal mineralization will be another focus of ongoing studies in the region.

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