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CARBONATE-HOSTED Zn MINERALIZATION IN THE HARE BAY AND PISTOLET BAY AREAS, GREAT NORTHERN PENINSULA, NEWFOUNDLAND

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ABSTRACT

The Hare Bay and Pistolet Bay areas of the Great Northern Peninsula are host to numerous carbonate-hosted Zn deposits and occurrences, several of which were examined during the summer 2016 field season. These mineral occurrences are hosted in the Ordovician St. George Group and the Cambrian Port au Port Group. This report presents geological and petrographic descriptions of the best known deposits and occurrences in the area, including the Round Pond Deposit, Salmon River prospect and Twin Ponds prospect.

Two types of Zn mineralization have been recorded from the studied occurrences. Crackle breccia, a type of collapse breccia, has been recorded in trenches and outcrops at the Round Pond Deposit (grab samples up to 24.46 wt. % Zn) and Twin Pond prospect (grab samples up to 11.96 wt. % Zn). Mineralization consists of sphalerite (and saddle dolomite) cementing angular fragments of host rocks, and minor galena and pyrite were also, locally, recorded. Pseudobreccias, formed by the selective replacement of fabrics in the host rocks, have been recorded at the Salmon River prospect, as well as stratigraphically below the crackle breccias at the Round Pond Deposit and the Twin Ponds prospect. This mineralization style is characterized by disseminated sphalerite occurring in secondary dolomite and quartz-orthoclase-dolomite cements. Assay data from pseudobreccia grab samples from the Salmon River prospect have returned up to 20.04 wt. % Zn. Non-mineralized pseudobreccias are also common, occurring in a linear belt stretching for more than 60 km from Cape St. Norman in the north to the Salmon River area in the south. Further studies into the source of mineralizing fluids and controls on the deposition of sulphide minerals are being conducted as part of a B.Sc. (Hons.) project at Memorial University.

INTRODUCTION

Carbonate-hosted Zn (± Pb) mineralization has been documented to occur throughout the Great Northern Peninsula (GNP), Newfoundland, including that at the Daniels Harbour Deposit. Most mineralization, including the Daniels Harbour Deposit and the deposits and occurrences described in this study are considered to represent Mississippi Valley-Type (MVT) deposits. These deposits are characterized by Zn–Pb mineralization occurring in platform carbonate sequences. Mineralization processes generally involve low-temperature basinal brines, and are generally associated with the development of pseudobreccias (selective replacement of host limestones and dolomites) and collapse breccias.

Exploration for MVT deposits on the GNP has been intermittent since the discovery of the Daniels Harbour Deposit in the early 1960s. Previous exploration has identified a number of Zn occurrences in the Hare Bay and Pistolet Bay areas (NTS map sheets 02M/12, 12P/01, 12P/08, 12P/09). These occurrences are hosted in carbonate rocks of the St. George and Port au Port groups, and occur, in a linear belt stretching for more than 60 km, from Cape St. Norman in the north to the Salmon River area west of Main Brook in the south (Figure 1). The largest known deposit is the Round Pond Deposit (non NI-43-101 resource of 400 000 tons @ 2% Zn; Born, 1983), with other significant occurrences at Salmon River and Twin Ponds prospects. Although MVT deposits typically occur in large districts (100's km^2) with multiple deposits, previous exploration has failed to identify any other deposits as large as the Daniels Harbour Deposit. The deposit type represents a difficult exploration target as the deposits lack significant alteration of the host rocks and they are not easily detected by geophysical methods. All known occurrences in the Hare Bay/Pistolet Bay area were identified based on soil anomalies, and the potential remains for the discovery of blind deposits (not outcropping at the surface) in this area.

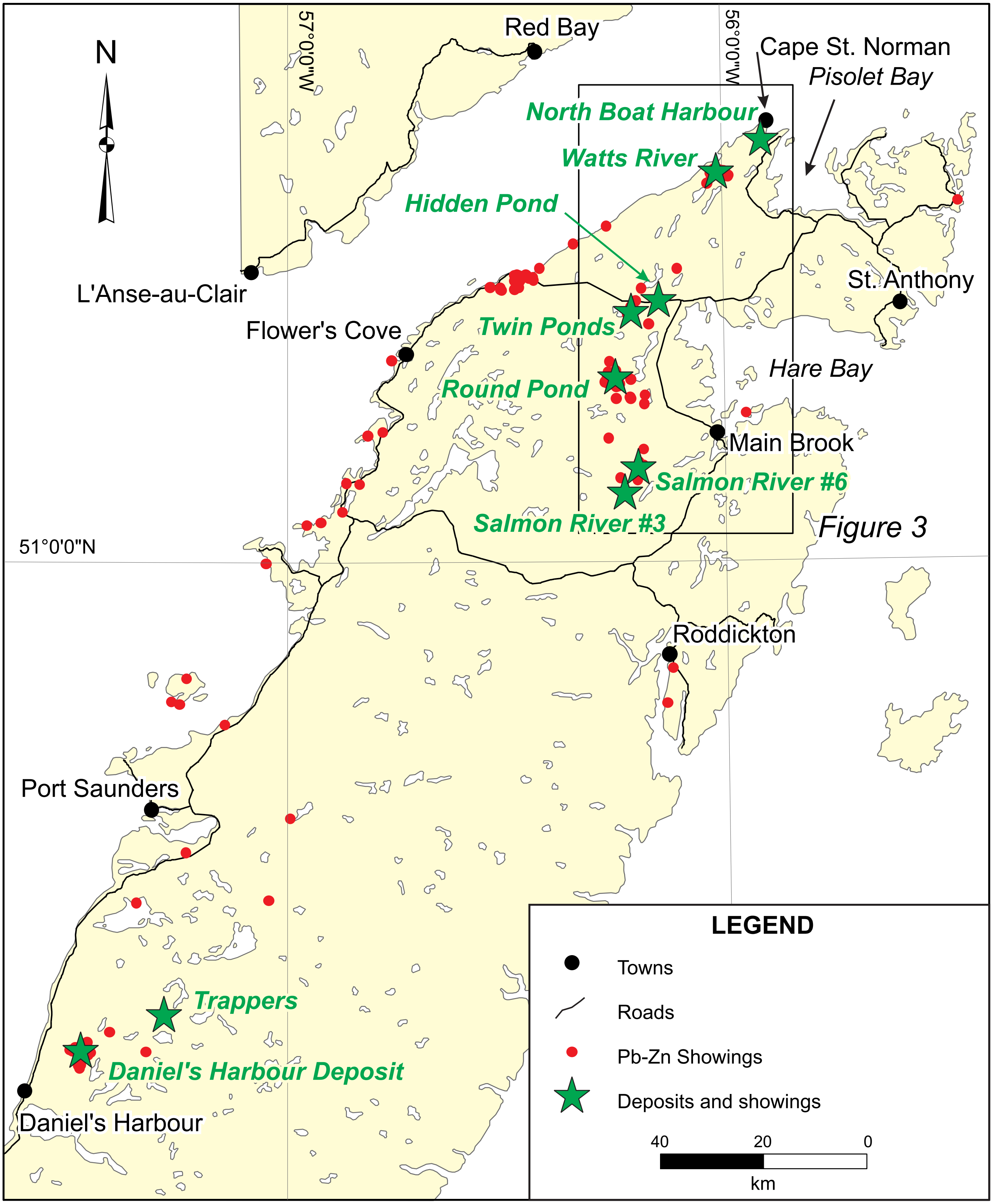

Figure 1. *Map of the Great Northern Peninsula and southeastern Labrador, showing main towns, location of known Zn occurrences and deposits (taken from MODS database).*

This report describes the main deposits and occurrences in the Hare Bay/Pistolet Bay area, and includes petrographic descriptions of the mineralization and assay data from known occurrences. It will form part of a larger research project into the source of mineralizing fluids and controls on deposition of sulphide minerals in carbonate platforms on the GNP, and aims to develop a genetic model for the deposits and occurrences in the region.

PREVIOUS WORK AND HISTORY OF EXPLORATION

The first regional-mapping programs in the study area included reconnaissance mapping in the 1860s (described in Logan, 1863, and Murray and Howley, 1881), followed by mapping in the Hare Bay area by Cooper (1937). Bostock *et al.* (1976) mapped the Strait of Belle Isle area (including the study area) at a scale of 1:125 000. The Geological Survey of Newfoundland and Labrador conducted a multi-year mapping project on the GNP in the late 1970s and 1980s, which included the production of a series of 1:50 000-scale maps of the Salmon River (Knight *et al.*, 1982), Eddies Cove (Knight *et al.*, 1986), Big Brook (Knight and Edwards, 1986a) and Raleigh (Knight and Edwards, 1986b) map sheets (NTS map sheets 02M/12, 12P/01, 12P/08, 12P/09).

Most studies of MVT mineralization on the GNP have focused on the nature and timing of mineralization at the Daniels Harbour Deposit and surrounding area (Lane, 1984, 1990; Nakai *et al.*, 1993; Pan and Symons, 1993), and on the relationship between the Daniels Harbour Deposit and other MVT-style deposits in the Appalachians (Kesler and van der Pluijm, 1990; Kesler *et al.*, 1996; Bradley and Leach, 2003). Little work has been conducted on Zn mineralization outside of the Daniels Harbour area. Saunders *et al.* (1992) briefly described the setting and petrography of more than 40 Pb–Zn occurrences in western Newfoundland, including all known occurrences in the study area, and subdivided these occurrences into three types based on the style of mineralization and the host-rock composition. Type-1 occurrences consist of open-space filling/replacement mineralization associated with secondary white dolomite (Saunders *et al.*, 1992), and include the Daniels Harbour Deposit and all other occurrences discussed in the current study. Saunders *et al.* (1992) also reported fluid inclusion and microprobe data from selected occurrences, and Swinden *et al.* (1988) reported lead isotope data from a number of occurrences in western Newfoundland (including two occurrences discussed below).

EXPLORATION HISTORY

Exploration for lead and zinc mineralization on the GNP intensified in the mid-1960s, spurred by the discovery of the Daniels Harbour zinc deposit. In 1963, Leitch Gold Mines conducted reconnaissance silt and soil geochemical surveys and prospecting in the Hare Bay area (Pegg, 1964; Born, 1983), but no significant mineralization was found and the concession reverted back to the Crown in 1966 (Cajka, 1969).

Commodore Mining Ltd. and Cominco conducted regional mapping, prospecting and geochemical surveys in the Hare Bay area in 1967-68, which identified a number of zinc showings in rocks similar to those hosting the Daniels Harbour Deposit (Cajka, 1969; Cook and Rhodes, 1970). In 1970, Cominco conducted a detailed soil-geochemical survey in the area around Round Pond, and follow up drilling intersected mineralized zones (with visible sphalerite) in 59 of 82 short diamond-drill holes. These mineralized zones returned grades up to 6.4% Zn over 3 m, outlining a potential zinc deposit 600 m north of Round Pond (Round Pond Deposit). Further drilling in 1971 attempted to identify a possible extension of the mineralized zone to the northeast but was unsuccessful (Rhodes and Young, 1971).

In 1975, Round Pond and surrounding areas were explored by a number of companies, including Noranda, Kerr Addison Mines Ltd. and Phillips Management. Drilling by Noranda in the Round Pond area intersected significant mineralization in two drillholes, containing 1.23% Zn over 3 m in one drillhole, and 0.95% Zn over 1.5 m in the other. This was interpreted as the northeast extension of the Round Pond Deposit (MacDonald, 1975). Kerr Addison's claims were to the southeast of Round Pond and were explored using soil geochemistry and follow up diamond drilling on identified anomalies. Drilling yielded poor results, only intersecting trace to minor sphalerite (Constable, 1976). Phillips Management's claim area was approximately 600 m south of Noranda's, and in 1975 they drilled 24 holes for a total depth of 299.2 m to test what is now referred to as the 'Phillip's Zone'. The drilling outlined a non NI-43-101 compliant resource estimate of 98 266 tons at 1.5% Zn (Hutchings *et al.*, 1975). Narex Ore Search Consultants staked the Round Pond property in 1982, performing geochemical sampling, prospecting, and diamond drilling of a total of 640 m of core in 1983. The drilling outlined a mineralized zone measuring 250 m long by 50 m wide and 11.3 m thick containing a non NI-43-101 compliant estimate of 400 000 tons of ore grading 2% Zn (Born, 1983). Narex dropped its claims in the Round Pond area in 1982, and exploration in the area has since been limited and sporadic. Recent exploration work consisted of compilation of previous work and drilling proposals by Royal Roads and Buchans Minerals Corporation (White, 2007; Moore and Butler, 2009, 2010).

In 1976, Shell conducted exploration to the north and south of the Round Pond prospect. They identified two main mineralized zones: one at Twin Ponds and another in the Salmon River region (Figure 1). The two areas were mapped and prospected, followed by testing with a grid-based soil-geochemical survey, trenching, pitting and eventually diamond drilling. Although trenching identified significant zinc mineralization at both locations, drilling yielded poor results, with only one hole from the Twin Ponds prospect containing visible zinc mineralization that assayed 0.81% Zn over less than 1 m (Cant and van Ingen, 1976a; Dean, 1977).

Other prospective areas identified near Watts River, Hidden Pond and North Boat Harbour (Figure 1) were also explored in the 1970s and 1980s. Numerous soil-geochemical anomalies and minor sphalerite in outcrop were identified. Trenching at North Boat Harbour identified significant zinc mineralization (grab samples up to 8.14% Zn; Cant and van Ingen, 1976b). Follow-up drilling on these anomalies only identified low-grade (<1% Zn) mineralization over short intervals, but drilling did recognize significant thicknesses of collapse breccia favourable to mineralization (Laforme, 1980; Burton, 1980; Leslie, 1981).

GEOLOGICAL SETTING

The Humber Zone is the westernmost of five tectonostratigraphic zones in the Canadian Appalachians (Williams, 1979), and is composed of autochthonous platform rocks, allochthonous deep-water sediments, ophiolitic rocks, and Grenvillian basement rocks. These record a complex history of rifting, passive margin sedimentation, and development of a foreland basin during the opening, and subsequent closure, of the Iapetus Ocean.

The autochthonous rocks were deposited on Grenville basement during the latest Neoproterozoic (~615 Ma) and Early Ordovician (~470 Ma). Significant rifting, associated with the opening of the Iapetus Ocean, began during the Neoproterozoic to Early Cambrian (Waldron and van Staal, 2001), and is first recorded in western Newfoundland by the Neoproterozoic, fault-bounded, terrestrial clastic and volcanic rocks of the Bradore and Forteau formations (Kamo *et al.*, 1989; van Staal and Barr, 2012; Figure 2). These are unconformably overlain by clastic rocks of the Hawke Bay Formation and a thick (~1.5 km) Cambrian to lower Ordovician carbonate platform succession (Port au Port and St. George groups; Figure 2), deposited on a passive margin to the south of Laurentia (James *et al.*, 1989).

The Taconic Orogeny, initiated at around 490 Ma (Waldron *et al.*, 1998), began with the formation of an east-dipping subduction zone. Subsequent subduction, involving the Laurentian shelf sediments, led to the development of a peripheral bulge and the formation of the St. George Unconformity at the top of the St. George Group (Knight *et al.*, 1991). Progressive loading led to the formation of a marine foreland basin and the deposition of the Table Head Group (468 Ma, Hiscott, 1978; Malo *et al.*, 2001; van Staal and Barr, 2012). The shallow to deep subtidal carbonates and shales of the Table Head Group were subsequently buried by muddy flysch of the Goose Tickle Group (James *et al.*, 1989; Figure 2).

Thrusting associated with the late stages of the Taconic Orogeny induced the obduction of oceanic crust and lithosphere onto the Laurentian margin (Waldron and Stockmal, 1994; Waldron *et al.*, 1998; van Staal and Barr, 2012). This thin-skinned thrusting emplaced allochthonous rocks of the Humber Arm Allochthon (HAA) and the Hare Bay Allochthon (HBA) onto the Laurentian margin rocks (Cawood and Williams, 1988; Waldron *et al.*, 1998). The HAA contains Neoproterozoic to Middle Ordovician deep-water sediments of the Cow Head and Curling groups (James *et al.*, 1989), as well as mafic volcanics and felsic intrusive units of the Little Port complex and Skinner Cove Volcanics (Williams, 1975; James *et al.*, 1989), and ophiolite sequences, that overly the deep water sediments (Waldron *et al.*, 1998). The HBA is located on the GNP, and is composed of the Maiden Point Formation deep-water sediments, Cape Onion Formation volcanic rocks and St. Anthony Complex volcanic rocks and peridotite (Williams and Smyth, 1983; James *et al.*, 1989).

Evidence for Late Silurian to Early Devonian deformation is preserved on the Port Au Port Peninsula where Silurian rocks are deformed, but the overlying Mississippian rocks are flat lying and undeformed (Waldron and Stockmal, 1994). This orogenic event, termed the Acadian Orogeny, inducted the reactivation of thrust faults in the Humber Zone, including the Parsons Pond Thrust and the Round Head Thrust (Waldron *et al.*, 1998). Thrusting was thick skinned in these two major faults, as well as in the minor Long Range Thrust (Waldron and Stockmal, 1994; Stockmal *et al.*, 1998), and was responsible for the uplift of the Grenvillian basement rocks that form the core of the Long Range Mountains and the platform rocks.

ST. GEORGE GROUP

The autochthonous St. George Group consists of a ~500 to 600 m succession of subtidal and peritidal carbonate rocks deposited as part of a broad, low-energy platform, during the Early to Middle Ordovician. The St. George Group is subdivided, in ascending order, into the Watts Bight, Boat Harbour, Catoche and Aguathuna formations (Figure 2; Knight and James, 1987). These represent sedimentation in a series of subtidal and peritidal environments and have been subdivided into two megacycles of Tremadocian and Arenigian age, reflecting changes in depositional environments in response to eustatic sea-level fluctuations and local tectonics (Knight and James, 1987). A significant unconformity separates the St. George Group and the overlying Table

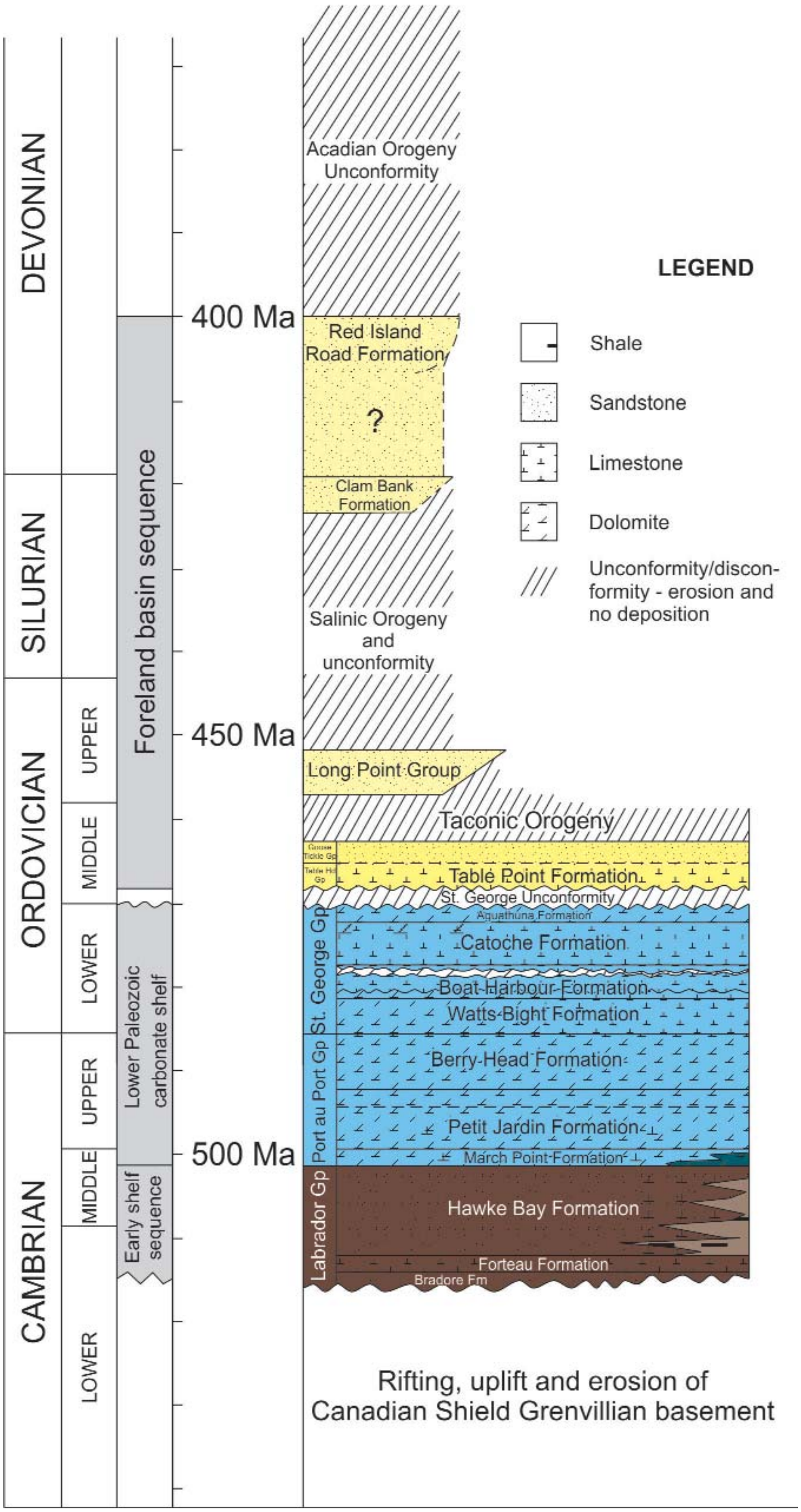

Figure 2. *Simplified stratigraphy of autochthonous Lower Paleozoic sequences in western Newfoundland (adapted from Hinchey* et al.*, 2015).*

Head Group, termed the St. George unconformity (Knight *et al.*, 1991).

The Watts Bight Formation is a 73- to 89-m-thick succession of muddy, bioturbated dolostone and dolomitized limestone (Knight and James, 1987). This formation defines the boundary between the underlying Port Au Port Group and the St. George Group. The upper boundary of the Watts Bight Formation and the overlying Boat Harbour Formation is conformable.

The Boat Harbour Formation is a 120- to 156-m-thick sequence of interbedded dark-grey dolomitic limestone, buff to light-grey dolostone, and crystalline limestone (Knight *et al.*, 1986; Knight and James, 1987). Chert-chalcedony and quartz sand grains, as well as crackle breccias containing chert and dolomite fragments in a white spar dolomite matrix, occur throughout the unit (Knight and James, 1987; Lane, 1990). The unit is extensively dolomitized, related to two disconformities (lower unnamed and upper Boat Harbour disconformity; Azmy *et al.*, 2009), and often displays replacement textures with relic dark-grey dolomite and porous white dolomitic cement (Knight and James, 1987; Lane, 1990; Moore and Butler, 2009).

Conformably overlying the Boat Harbour Formation is the Catoche Formation, which is up to 160 m thick on the Port au Choix Peninsula (Knight *et al.*, 2007). The Catoche Formation is subdivided into a lower limestone dominantly composed of well-bedded, fossiliferous, bioturbated grey limestone, a Middle dolostone, and an upper member called the Costa Bay Member, which is extensively dolomitized in some areas (Knight and James, 1987; Lane, 1990; Knight *et al.*, 2007).

The contact between the Catoche Formation and the overlying Aguathuna Formation is generally conformable; however, the contact in the vicinity of the River of Ponds Lake is disconformable (Knight and James, 1987). The Aguathuna Formation is a succession of green-grey to pale-grey, generally microcrystalline dolostone, limestone and shale, and common chert (Knight and James, 1987). The formation has a highly variable thickness, largely due to variable erosion at the St. George Unconformity (Knight *et al.*, 1991).

ZINC MINERALIZATION ON THE GREAT NORTHERN PENINSULA

Numerous carbonate-hosted Zn (± Pb) occurrences have been documented on the GNP, with 126 individual occurrences recorded in the MODS database. Most of these occurrences are hosted in St. George Group and the underlying Port au Port Group. They are subdivided into a number of distinct mineral occurrence types (Saunders *et al.*, 1992). The most economically important type is open-space filling/replacement mineralization associated with secondary white dolomite (Saunders *et al.*, 1992), which is classified as MVT mineralization (Lane, 1990). The MVT deposits are characterized by epigenetic, stratabound Zn (± Pb) mineralization in limestone and dolomite, occurring as pore fillings or replacements of the host rock associated with low-temperature fluid migration. The deposition of sulphide requires interaction with a reducing agent, generally organic material or natural gas, being present at the deposition site.

The largest known Zn deposit on the GNP is the Daniels Harbour Deposit, where ~7 Mt with an average grade of 7.8% Zn was mined between 1975 and 1990 (Lane, 1990). The Daniels Harbour Deposit occurs in the upper Catoche Formation (Costa Bay Member) of the St. George Group (Lane, 1990), and the nature and genesis of the mineralization has been described in detail (Lane, 1990). At Daniels Harbour, the limestone of the Costa Bay Member is extensively dolomitized often forming secondary replacement textures where grey to tan dolomite is replaced *in situ* by white sparry dolomite (known locally as pseudobreccias; Lane, 1984). These pseudobreccias are host to most of the sulphide mineralization at Daniels Harbour (Lane, 1990). More than 15 ore bodies are documented in the mine area, all having a northeast to east trend. The ore bodies are described as being pencil shaped by Lane (1990), with varying dimensions, grade and tonnage. Two ore bodies in particular, the L and T zones, were responsible for more than 5.5 Mt of ore grading 8% Zn, with the remaining approximate 2 Mt being mined in other ore bodies.

This study focuses on other, lesser known occurrences in the Hare Bay and Pistolet Bay areas of the GNP, which were visited by the authors in the summer of 2016. This work forms part of an ongoing B.Sc. (Hons.) project by R. King at Memorial University, and will be used to develop a genetic model for these occurrences and determine future exploration potential. The following is a geological and petrographic description of three main prospects and deposits visited in 2016: the Round Pond Deposit, Salmon River prospect and Twin Ponds prospect. Other occurrences visited in the study area will also be briefly discussed.

ROUND POND DEPOSIT

The Round Pond Deposit is located approximately 15 km west of Hare Bay (Figures 1 and 3) and is accessible by helicopter or ATV. Two main mineralized zones occur in the Round Pond area, the Main Zone to the northeast and the Phillips Zone to the south (Figure 4A), with a number of other sphalerite showings recorded in the vicinity of these zones (Knight *et al.*, 1986). All occurrences are hosted by the Boat Harbour Formation, which consists of a basal dolomite-chert breccia overlain by a sequence of bioturbated micritic limestones, laminated limestones and dolostones and secondary dolomite (Knight, 1980).

Two main types of mineralization have been reported from the Round Pond Deposit. Surface outcrops in the Main Zone trench (Plate 1A), located to the northeast of Round Pond (Figure 4A), consist mainly of angular fragments of tan, fine-grained dolomite in a white, coarse-grained dolomitic cement (approximately 20% white spar), known as 'crackle breccia' (Figure 5; Plate 1B, C). Mineralization in the crackle breccia is dominated by coarse-grained sphalerite, and minor galena, occurring as 1- to 5-mm-thick rims on dolomite clasts, assay data for surface samples from the Main Zone trench ranging from 1.96 to 15.34 wt. % Zn (Figure 5; Table 1). Crackle breccia also occurs in the Phillips Zone, and a grab sample from a small outcrop located directly south of Round Pond returned 24.46 wt. % Zn (Table 1). Subcrop and boulders having poor- to well-developed crackle breccia were also recorded in the Round Pond area, particularly to the north and southeast of the Main Zone trench.

Drilling by Wayde Guinchard and Peter Rogers during the summer of 2016 intersected a zone of pseudobreccia at a depth of approximately 4.5 m. In one drillhole, pseudobreccia composed of grey dolomite and white dolomitic cement (approximately 10-15% white spar) was intersected between 4.65 and 4.8 m. Sulphide mineralization in the pseudobreccia is dominated by disseminated sphalerite and pyrite, and minor galena. An assay of a pseudobreccia core sample yielded 2.07 wt. % Zn. Although abundant pseudobreccia outcrops were found elsewhere in the Round Pond area, no visible sphalerite was recorded and samples returned less than 1400 ppm Zn.

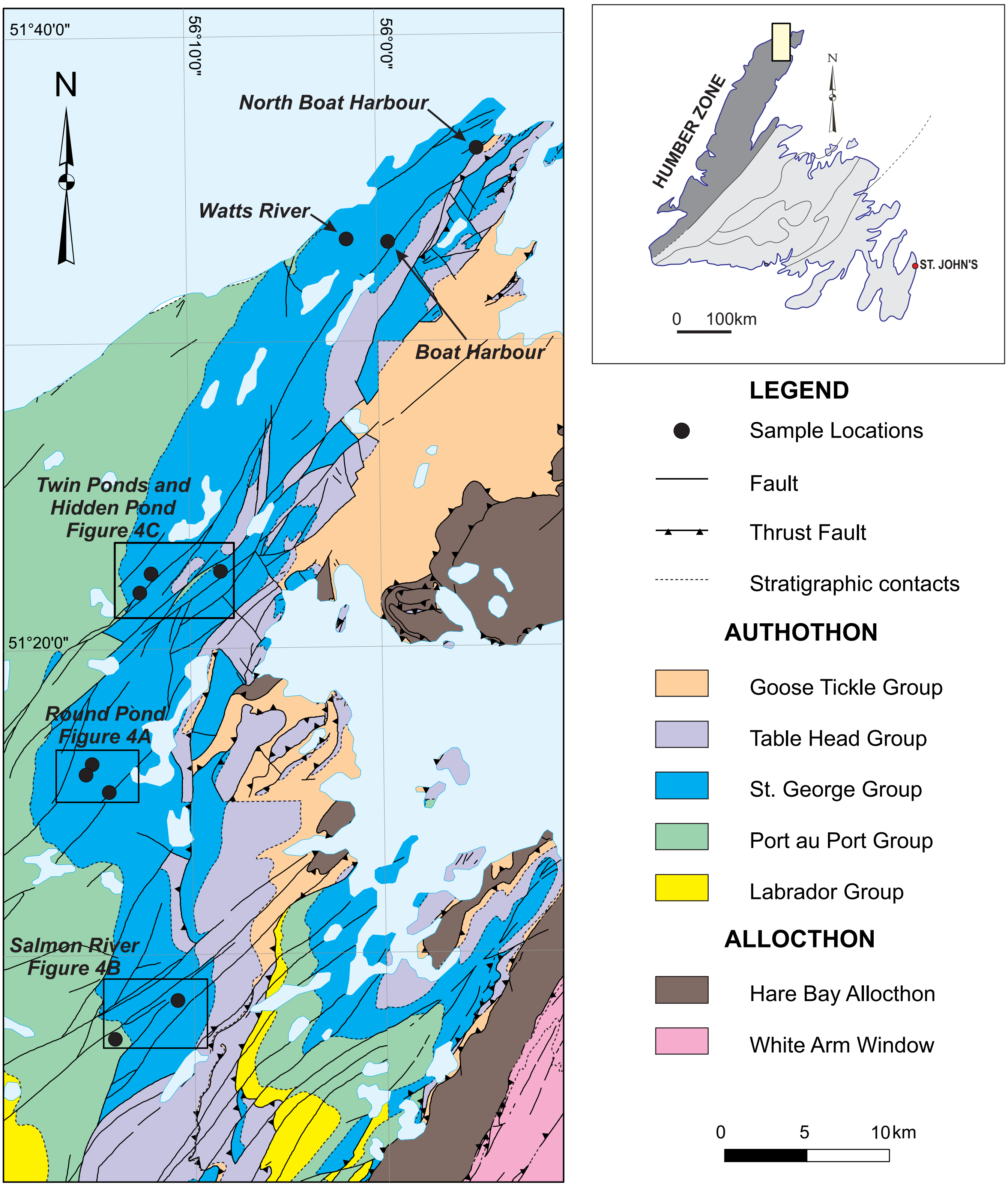

Figure 3. *Regional geological map of the Hare Bay and Pistolet Bay area outlining the distribution of known Zn deposits and showings (after Knight* et al.*, 1982, 1986; Knight and Edwards, 1986a, b).*

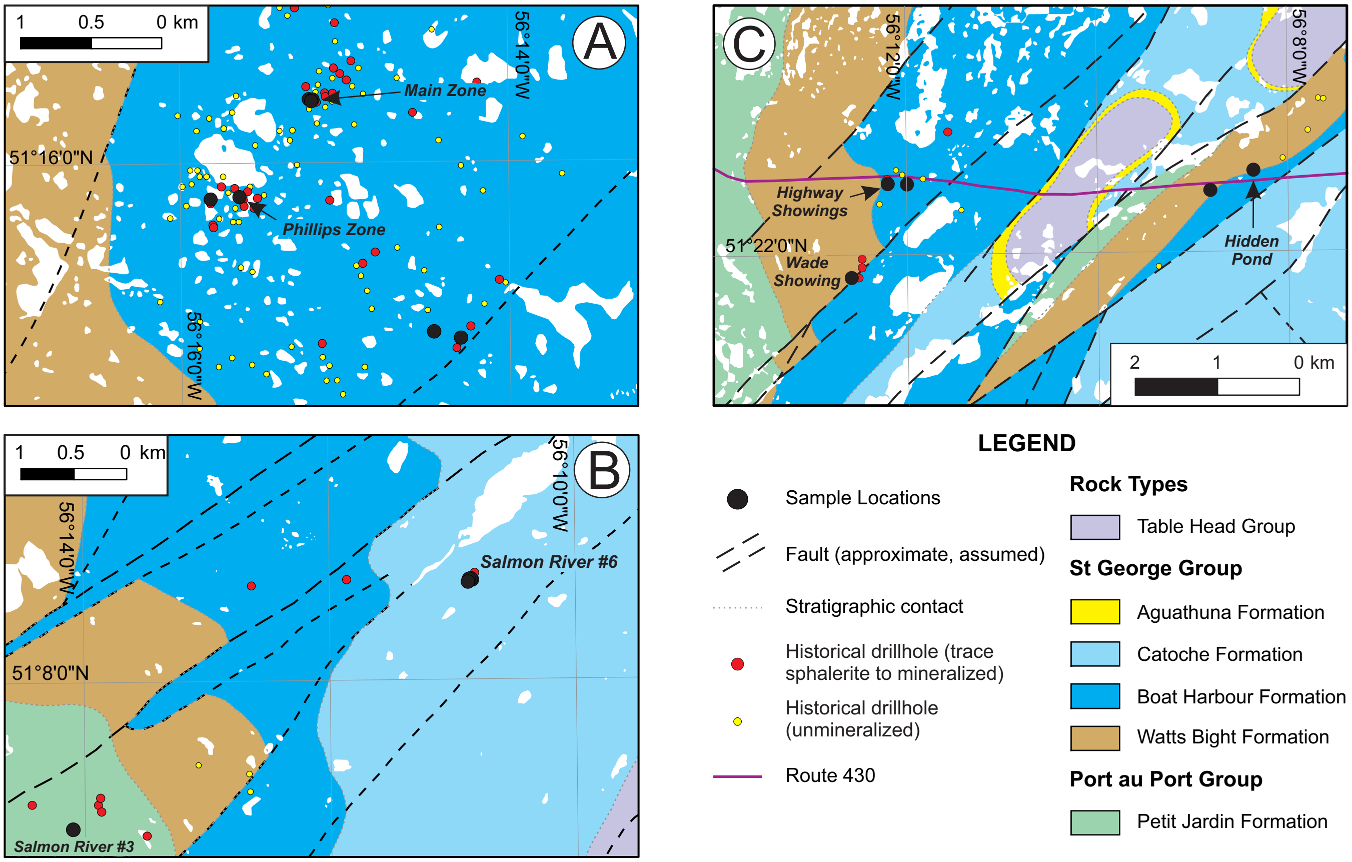

Figure 4. *Detailed geological maps of the (A) Round Pond, (B) Salmon River and (C) Twin Pond (Wade and Highway showings) and Hidden Pond areas, showing sample locations and historic drillholes. Modified from Knight* et al. *(1982, 1986).*

Petrography

Thin sections of crackle breccia all display early, coarse-grained sphalerite occurring as coatings on clasts of dolomite (Plate 1D). Galena occurs in varying modal abundances, sometimes being trace, but locally comprising approximately 5% of the sample. In all samples, galena occurs both within sphalerite crystals and in pore spaces between sphalerite crystals, indicating deposition late in the paragenetic sequence (Plate 1E, F). Pyrite has also been noted in samples, and occurs either as disseminated grains in the saddle dolomite cement or as grains within the dolomite clasts. The pyrite occurring within the dolomite clasts formed from early dolomitizing fluids in the host rock and predates the main sulphide mineralizing event, while pyrite in the cement postdates sphalerite and galena. All phases are cut by late fine quartz-orthoclase veins.

Thin sections of mineralized pseudobreccia contain fine- to medium-grained sphalerite occurring as disseminated grains within the saddle dolomite cement (Plate 1G, H). Pyrite is noted to have several habits: 1) as medium- to coarse-grained disseminations in the saddle dolomite cement (Plate 1G, H), 2) as fine disseminated grains in chert fragments found throughout the sample, and 3) as pyrite-rich veinlets cutting dolomite clasts. Minor galena occurs in the saddle dolomite cement as individual grains generally associated with sphalerite and as veinlets crosscutting sphalerite grains, indicating that galena precipitation was relatively late in the paragenetic sequence.

SALMON RIVER PROSPECT

A number of zinc occurrences were visited in the Salmon River area (Figures 3 and 4B), located approximately 12 km west of Main Brook and 15 km south along strike from the Round Pond Deposit, and accessible by woods roads. The main prospect in the Salmon River area is the Salmon River #6 prospect (also known as Frying Pan Pond Prospect), which is exposed in a series of trenches opened by Shell in 1976 (Figures 4B and 6; Plate 2A).

Mineralization at Salmon River #6 prospect occurs in the Catoche Formation, which in the area, is composed of dark-brown, thrombolytic, bioturbated, micritic limestones (Knight *et al.*, 1982; Saunders *et al.*, 1992). Dolomitization of the burrows is widespread in the area. Well-developed pseudobreccias have also been documented (Knight *et al.*,

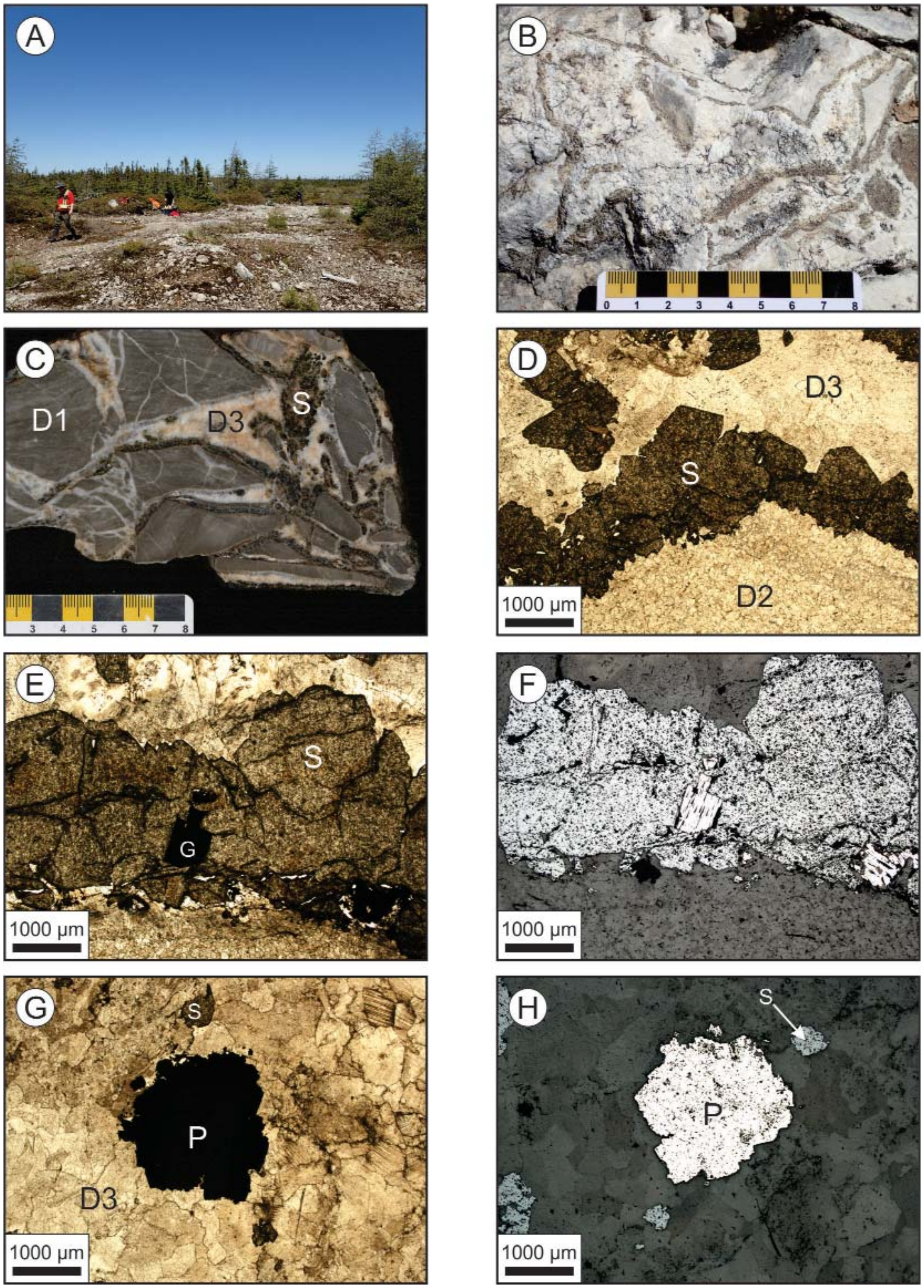

Plate 1. *Selected photographs and photomicrographs from Round Pond Deposit. A) Main Zone trench at Round Pond Deposit; B) Outcrop of crackle breccia in Main Zone trench; C) Crackle breccia with angular clast of early dolomite coated by sphalerite and saddle dolomite, sample 16JC026 A03; D) Photomicrograph of crackle breccia in sample 16JC029A01 (Phillips Zone), with euhedral sphalerite coating dolomite clast and late saddle dolomite filling pores (plane-polarized light); E) Photomicrograph of galena and sphalerite coating dolomite clast in sample 16JC026 A03 (plane-polarized light); F) Same view as shown in E in reflected light; G) Photomicrograph of pyrite and sphalerite crystals disseminated in saddle dolomite cement in pseudobreccia, sample 16JC026 A04 (plane-polarized light); H) Same view as shown in G in reflected light. D1 – fine-grained dolomite; D2 – medium-grained euhedral dolomite; D3 – saddle dolomite; G – galena; P–pyrite; S–sphalerite.*

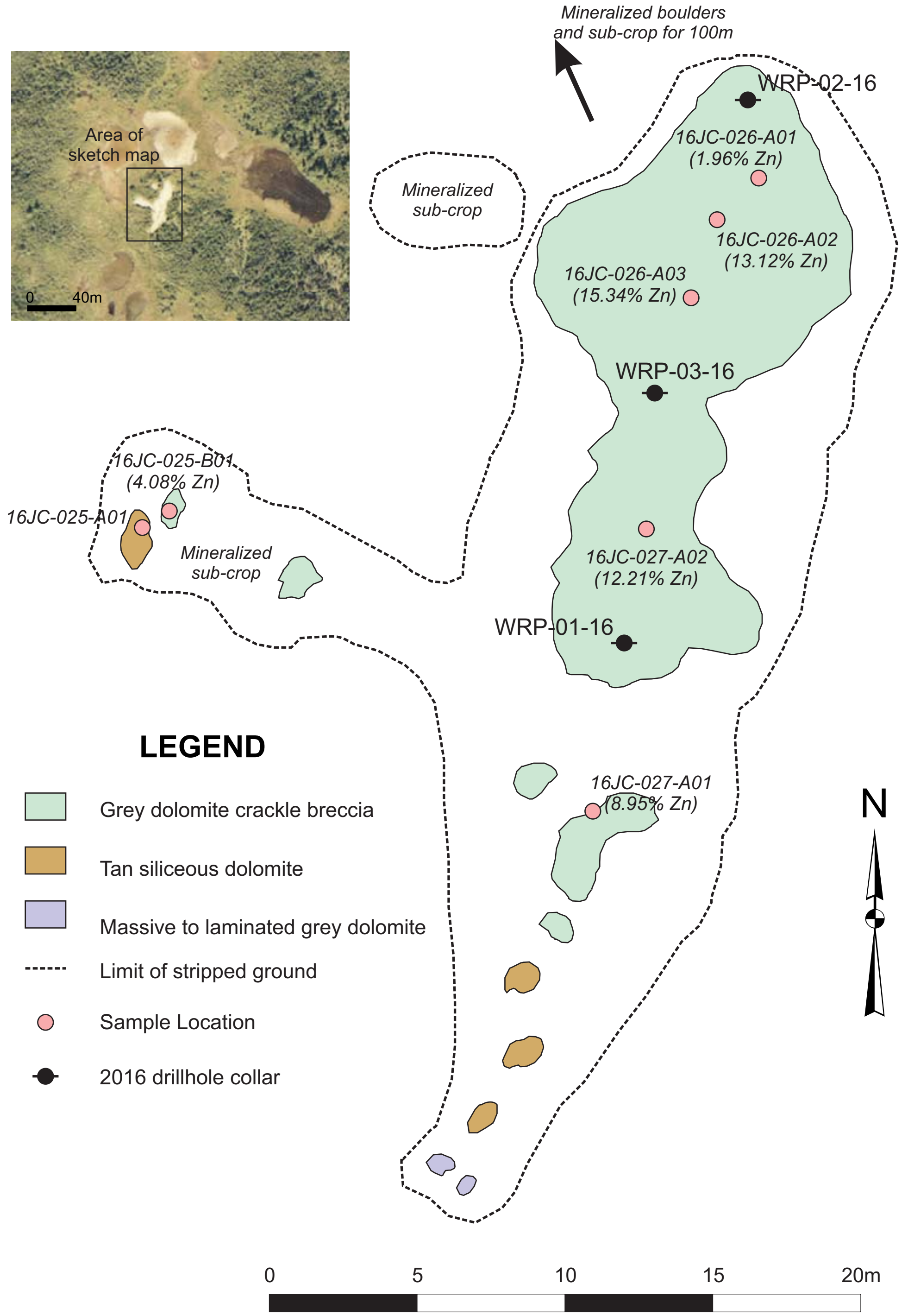

Figure 5. *Sketch map of the Main Zone trench at the Round Pond Deposit, showing the main rock types, sample locations (with assay data) and location of three drillholes drilled by prospectors in summer 2016.*

1982). In the trenches at Salmon River #6 prospect, the pseudobreccias are grey dolomitic clasts having a white dolomite cement (approximately 5–10% white spar), and several samples also containing a late-stage, fine-grained black cement composed of quartz, feldspar and dolomite (Plate 2B). Zinc mineralization is sporadic, with approximately 10% of the pseudobreccia samples containing significant sphalerite. Some samples contain up to 20% sphalerite in the form of euhedral, coarse crystalline red sphalerite in white dolomitic cement and fine-grained yellow sphalerite occurring within the black cement. Grab samples of sphalerite-rich pseudobreccias have Zn contents ranging from

Table 1. Samples of crackle breccia and pseudobreccia taken during this study, including sample locations and assay data

	Sample	Location	Type	UTMEast	UTMNorth	UTMZone	Zn (wt. %)	Zn (ppm)
Round Pond	16JC025B01	Main Zone	crackle breccia	552075.6	5679974.4	21, NAD27	4.08	
	16JC026A01	Main Zone	crackle breccia	552102.3	5679972.5	21, NAD27	1.96	
	16JC026A02	Main Zone	crackle breccia	552102.3	5679972.5	21, NAD27	13.12	
	16JC026A03	Main Zone	crackle breccia	552102.3	5679972.5	21, NAD27	15.34	
	16JC026A04	Main Zone	pseudobreccia	552102.3	5679972.5	21, NAD27	2.07	
	16JC027A01	Main Zone	crackle breccia	552093.0	5679959.2	21, NAD27	8.95	
	16JC027A02	Main Zone	crackle breccia	552093.0	5679959.2	21, NAD27	12.21	
	16JC027A03	Main Zone	crackle breccia	552093.0	5679959.2	21, NAD27	4.82	
	16JC027B01	Main Zone	crackle breccia	552093.0	5679959.2	21, NAD27		490
	16JC028A01	Phillips Zone	pseudobreccia	551380.3	5679145.0	21, NAD27		1372
	16JC029A01	Phillips Zone	crackle breccia	551584.1	5679279.1	21, NAD27	24.46	
	16JC034A01	South Round Pond	pseudobreccia	552963.3	5678329.4	21, NAD27		679
	16JC035B01	South Round Pond	pseudobreccia	553037.7	5678309.7	21, NAD27		30
	16JC036A01	South Round Pond	pseudobreccia	553154.8	5678285.6	21, NAD27		47
	16JC036B01	South Round Pond	crackle breccia	553154.8	5678285.6	21, NAD27		17
Salmon River	16JC042A01	Salmon River #6	pseudobreccia	557318.9	5665690.4	21, NAD27		63
	16JC042B01	Salmon River #6	pseudobreccia	557318.9	5665690.4	21, NAD27	1.75	
	16JC043A01	Salmon River #6	pseudobreccia	557307.0	5665702.6	21, NAD27	18.52	
	16JC044A01	Salmon River #6	pseudobreccia	557290.3	5665698.1	21, NAD27	1.73	
	16JC045A01	Salmon River #6	pseudobreccia	557282.9	5665670.2	21, NAD27	8.47	
	16JC045A02	Salmon River #6	pseudobreccia	557282.9	5665670.2	21, NAD27	20.04	
	16JC045A03	Salmon River #6	pseudobreccia	557282.9	5665670.2	21, NAD27	10.49	
	16JC045A04	Salmon River #6	pseudobreccia	557282.9	5665670.2	21, NAD27	16.27	
	16JC051A01	Salmon River #3	pseudobreccia	553540.9	5663322.2	21, NAD27		7131
Twin Ponds	16JC017A01	Highway	crackle breccia	555684.2	5691532.8	21, NAD27	7.25	
	16JC017A02	Highway	crackle breccia	555684.2	5691532.8	21, NAD27	6.73	
	16JC017A03	Highway	crackle breccia	555684.2	5691532.8	21, NAD27	11.96	
	16JC018A01	Wade Showing	crackle breccia	555013.1	5690391.2	21, NAD27	5.65	
Other Occurrences	16JC019A02	Hidden Pond	crackle breccia	559903.9	5691711.6	21, NAD27		25
	16JC040A01	Hidden Pond	crackle breccia	559379.9	5691464.2	21, NAD27		13
	16JC038A01	North Boat Harbour	crackle breccia	575408.0	5717391.8	21, NAD27		9709
	16JC037A01	Boat Harbour	pseudobreccia	570033.6	5711718.4	21, NAD27		38
	16JC023C01	Watts River	pseudobreccia	567527.1	5711868.3	21, NAD27		11

10.49 to 20.04 wt. % (Figure 6), whereas a sample of pseudobreccia with less than 5% visible sphalerite returned 1.75 wt. % Zn. One trench also contained subhedral, coarse crystalline, green sphalerite within white dolomite cement. Assays of pseudobreccia containing green sphalerite yielded 1.75% Zn.

The zinc occurrence at the Salmon River #3 prospect is located approximately 4.5 km southwest of the Salmon River #6 prospect (Figure 4). Mineralization is hosted in a thin (<1 m) pseudobreccia bed in the Port au Port Group (undivided Berry Head and Petit Jardin formations). The pseudobreccia is composed of tan- to light-grey dolomitic clasts with white dolomite cement (approximately 10-15% white spar). Pyrite occurs as anhedral grains and clusters up to 1 cm in the white dolomite cement (Plate 2G). Sphalerite is present as several different colours including: yellow, yellow-orange, red-brown, and black. It mainly occurs as fine- to medium-grained crystals at the margins of dolomitic clasts, or as individual grains in the white dolomite matrix. Some phases (black and red-brown sphalerite) are intergrown with clusters of pyrite in the white dolomitic matrix. Locally, the red phase of sphalerite occurs as subhedral to euhedral crystals ranging up to 5 mm in width in the dolomite cement.

Petrography

Thin sections of samples from Salmon River #6 prospect contain three generations of dolomite: 1) early

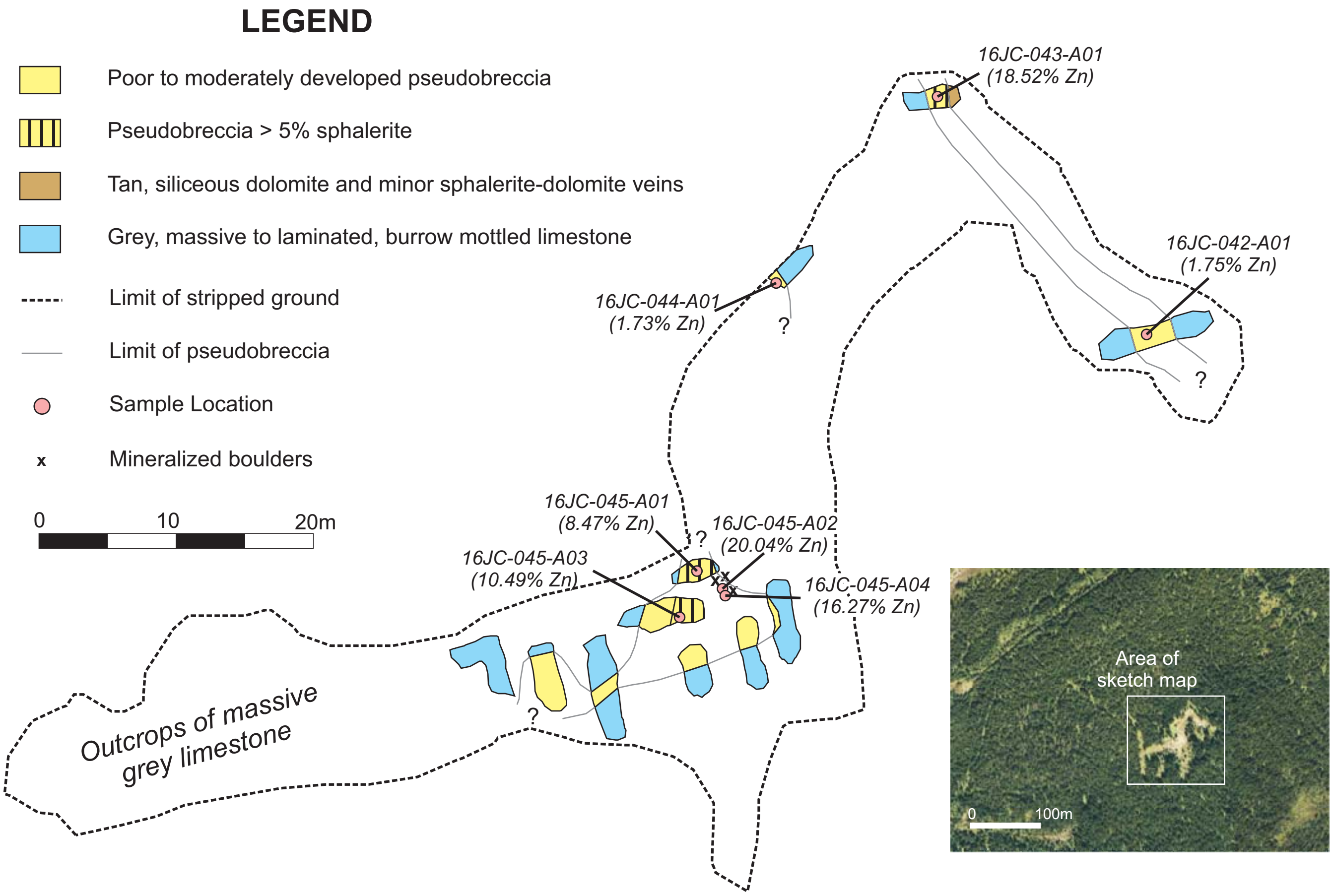

Figure 6. *Sketch map of the trenches at Salmon River #6, showing the main rock types and sample locations (with assay data).*

fine-grained, dolomitized clasts of host rock, 2) medium-grained, euhedral dolomite crystals, and 3) a late coarse-grained saddle dolomite. Late-stage calcite also fills vugs, and late black cement is present in some samples, consisting of fine-grained orthoclase, quartz and dolomite. Sphalerite is found in two main associations: 1) as relatively coarse-grained, euhedral, and commonly zoned crystals occurring at the margins of vugs in saddle dolomite that contain late infillings of calcite (Plate 2C, D), or 2) as medium-grained, anhedral crystals in the quartz-orthoclase-dolomite cement (Plate 2E, F). Sphalerite also locally occurs as megacrystic, anhedral masses within fine- to medium-grained saddle dolomite. Two generations of pyrite are observed in samples: 1) early subhedral grains within sphalerite and dolomite clasts, and 2) disseminated grains within saddle dolomite and the quartz-orthoclase-dolomite cement.

A thin section of a sample taken at the Salmon River #3 prospect contains two generations of dolomite: 1) early fine- to medium-grained dolomitized host rock clasts and, 2) late coarse-grained saddle dolomite cement. Quartz and orthoclase occur as a late infill of pore spaces in saddle dolomite and at the edges of dolomite clasts. Sphalerite occurs as fine- to coarse-grained, subhedral grains in the saddle dolomite cement and commonly contains alternating orange-brown to tan zones. Two generations of pyrite are present, consisting of early, disseminated grains occurring in fine-grained dolomite clasts and late coarse-grained, subhedral crystals in the saddle dolomite cement that are associated with sphalerite (Plate 2H).

TWIN PONDS PROSPECT

The mineral occurrences at Twin Ponds are located approximately 6 km southwest of the St. Anthony Airport, and approximately 12 km north along strike from the Round Pond Deposit (Figures 3 and 4C). Mineralization was observed at two main locations in the Twin Ponds area (Figure 4C), in an exploration trench (also known as the Wade showing; trench map in Cant and Ingen, 1976a; Plate 3A) and in roadside outcrops along Route 430. Mineralization at the Wade showing is hosted in fine- to medium-grained grey to cream dolostone of the Watts Bight Formation (Saunders *et al.*, 1992), while outcrops along the highway are hosted in the overlying Boat Harbour Formation (similar to the Round Pond Deposit). In addition, roadside outcrops also indicate

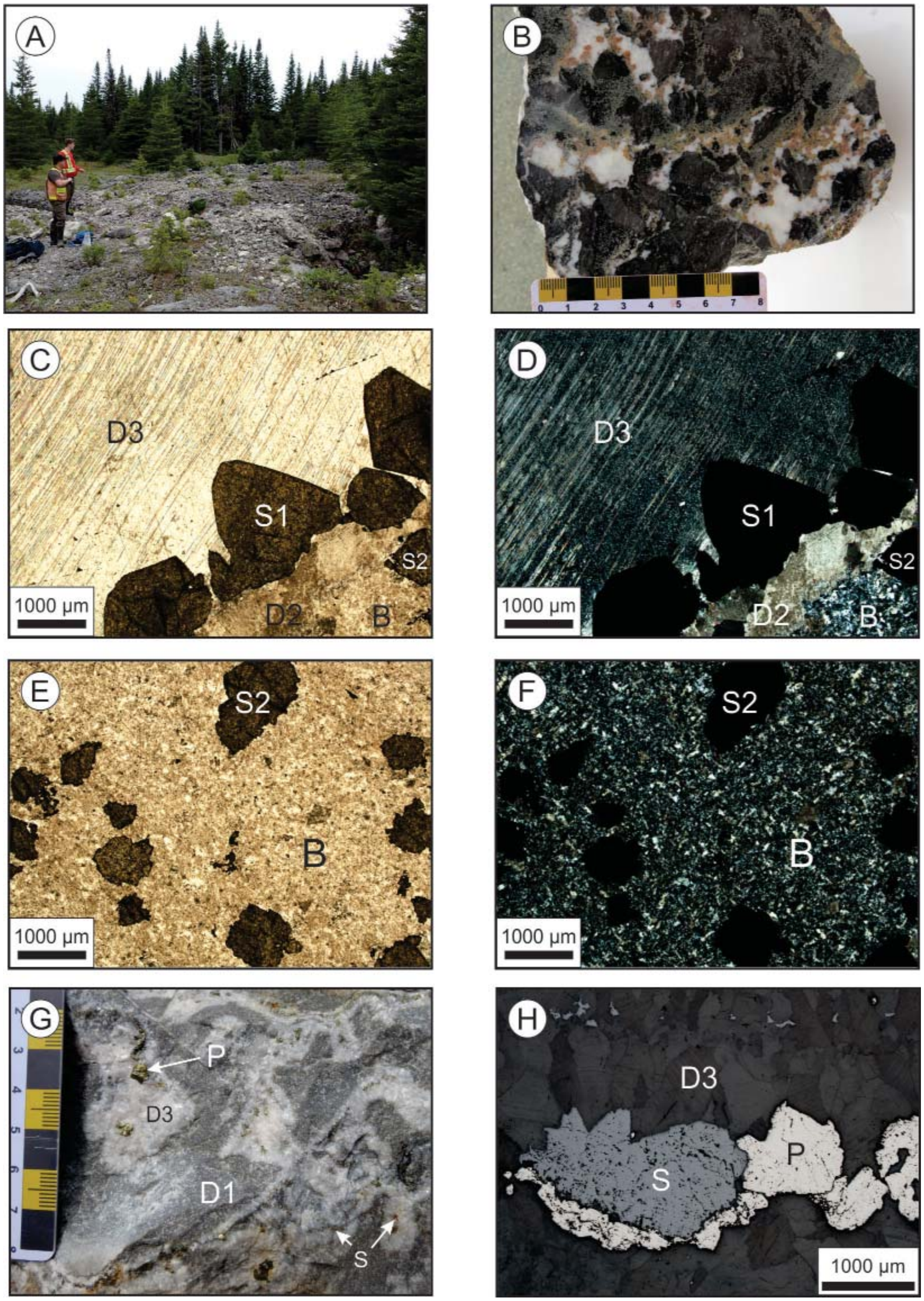

Plate 2. *Selected photographs and photomicrographs from Salmon River area. A) Stripped ground and trenches at Salmon River #6 prospect; B) Sample 16JC45 A04, with euhedral red sphalerite associated with white dolomite cement and yellow sphalerite in black cement; C) Photomicrograph of euhedral sphalerite lining a vug filled with saddle dolomite (plane-polarized light, sample 16JC045 A01); D) Same view as in C but in cross-polarized light; E) Photomicrograph of anhedral sphalerite in fine-grained quartz, orthoclase and dolomite cement (plane-polarized light, sample 16JC045 A01); F) Same view as in E but in cross-polarized light; G) Sample from Salmon River #3, with euhedral pyrite and minor sphalerite in saddle dolomite of pseudobreccia (sample 16JC051 A01); H) Photomicrograph of coarse-grained sphalerite and pyrite in saddle dolomite cement (reflected light). B – black cement with quartz, orthoclase and dolomite; D1 – fine-grained dolomite; D2 – medium-grained euhedral dolomite; D3 – saddle dolomite; S1 – red sphalerite; S2 – yellow sphalerite; S – sphalerite; P – pyrite.*

that moderately developed pseudobreccias (with 15-20% white dolomite spars) with less than 1% yellow sphalerite occur stratigraphically below the crackle breccias.

The mineralization style is similar to that exposed in the Main Zone trench at Round Pond with well-developed crackle breccia. The crackle breccia is composed of angular, tan-grey dolomite and grey chert clasts in coarse-grained, white dolomite cement with abundant vugs. Fine-grained dark-green to black sphalerite occurs as 1-mm-thick coatings on dolomite and chert clasts (Plate 3B), as grains in the dolomite cement and rarely as coarse-grained crystals lining vugs. Assay data from a sample at the Wade showing returned 5.65 wt. % Zn, while three grab samples from the roadside outcrops returned from 6.73 to 11.96 wt. % Zn (Table 1).

Petrography

Samples contain two generations of dolomite occurring as fine-grained dolomite clasts and coarse-grained saddle dolomite cement. Chert clasts and quartz grains occur throughout the samples, with many chert clasts containing abundant disseminated pyrite (Plate 3C). Sphalerite occurs as individual fine- to medium-grained, subhedral crystals (Plate 3D) and as clusters of crystals that commonly exhibit alternating tan and yellow-orange zones. Both dolomitic clasts and saddle dolomite are commonly crosscut by veinlets of quartz and minor orthoclase.

OTHER OCCURRENCES

Several other Zn occurrences were visited during the field season, including the Hidden Pond and North Boat

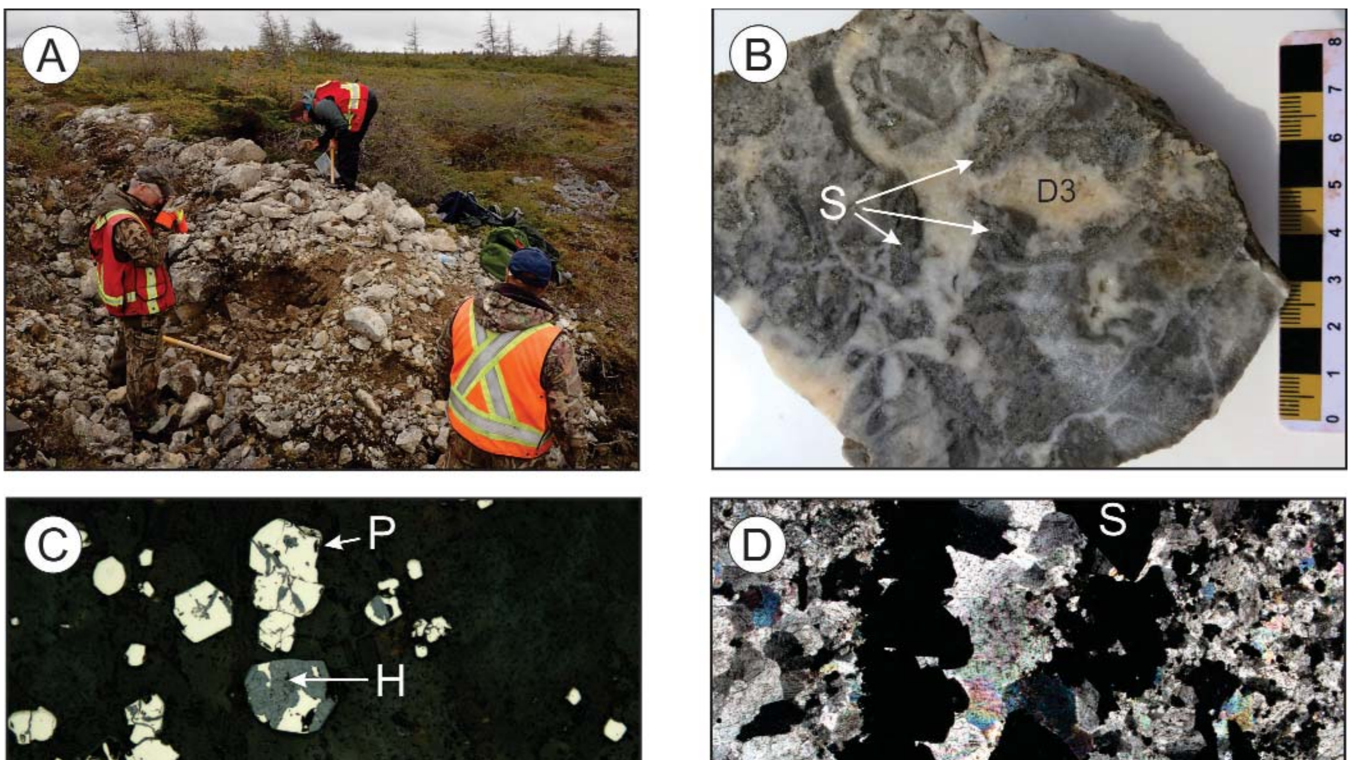

Plate 3. *Selected photographs and photomicrographs from Twin Ponds area. A) Trench at Wade showing, Twin Ponds prospect; B) Crackle breccia with black sphalerite and white saddle dolomite filling open space (sample 16JC018 A01); C) Photomicrograph of pyrite partially replaced by hematite in chert fragment (reflected light, sample 16JC017 A03); D) Photomicrograph of euhedral sphalerite and saddle dolomite filling open space in crackle breccia (cross-polarized light, sample 16JC018 A01). D3 – saddle dolomite; H – hematite; P – pyrite; S – sphalerite.*

Harbour occurrences (Figure 1). The Hidden Pond occurrence is located approximately 4 km west along Route 430 from the St. Anthony Airport, occurring in a quarry to the north of the road. The occurrence is hosted in the Watts Bight Formation, directly below the contact with the Boat Harbour Formation (Saunders *et al.*, 1992). Samples from this area contain poorly developed crackle breccia composed of dark-grey dolomite clasts and white dolomite cement. Samples from 1 km farther east, along Route 430, contain moderately well-developed crackle breccia composed of dark-grey chert and dolomite fragments having white dolomite cement. Fine-grained pyrite is disseminated throughout the crackle breccias. Minor sphalerite mineralization has been reported in previous studies (Saunders *et al.*, 1992).

Thin sections of samples from the quarry at Hidden Pond contain two types of dolomite occurring as fine-grained dolomite clasts and medium-grained dolomite cement. Abundant chert fragments are present throughout the sample. Minor fine- to medium-grained pyrite, partially altered to hematite, is present.

The North Boat Harbour occurrence is located approximately 32 km northeast of the Twin Ponds prospect, with the main showing located 500 m southeast of the town of Wild Bight. The area was stripped and trenched by Shell in 1975. The occurrence is hosted in well-developed pseudobreccias of the Catoche Formation. Mineralization is generally low grade, with grab samples from this study yielding less than 1 wt. % Zn, and historical trenching indicating 0.45 to 0.65% Zn over 3 m (Cant and van Ingen, 1976b). Petrographic study illustrates that the pseudobreccia is composed of fine-grained dolomite clasts with coarse-grained saddle dolomite cement. Sphalerite occurs in vugs and interstices between dolomite crystals, and is often heavily weathered and replaced by an unknown light-blue zinc oxide.

Numerous sphalerite showings have been reported in the limestone barrens between the North Boat Harbour and the Twin Ponds prospects, where the St. George Group is well exposed. Fieldwork during this study indicated that pseudobreccias are extensively developed over this area, but no new mineral occurrences were found.

CONCLUSIONS AND FUTURE RESEARCH

Carbonate-hosted Zn (± Pb) mineralization is common on the GNP, with the best known deposit being the former Daniels Harbour Deposit. Mineral occurrences are hosted in the platform carbonates of the St. George and Port au Port groups, with most mineralization occurring in dolomitized carbonates of the Catoche, Boat Harbour and Watts Bight formations (St. George Group). The two main mineralization styles include pseudobreccia, and crackle breccia. Pseudobreccias form by the selective replacement of the carbonate host rock by secondary white dolomite ± sulphides (Lane, 1984), while crackle breccias consist of angular fragments of the host rock cemented by secondary dolomite ± sulphides.

The largest known deposit in the Hare Bay/Pistolet Bay area is the Round Pond Deposit, which has an estimated non 43-101 compliant resource of 400 000 tons of ore, grading at 2% Zn in two main zones (Born, 1983). Mineralization in both zones is mainly associated with crackle breccia (grab samples grading up to 24.46 wt. % Zn), although mineralized pseudobreccia with 2.07 wt. % Zn was also recorded at depth below the Main Zone trench. Significant Zn occurrences have also been described from the Salmon River and Twin Ponds areas. Mineralization at the Salmon River prospect is mainly hosted in well-developed pseudobreccias, while the mineralization at the Twin Ponds prospect is very similar to the Round Pond Deposit. The documentation of well-developed pseudobreccias having numerous sphalerite showings over a strike length of more than 60 km from Salmon River to North Boat Harbour highlights the exploration potential of this area.

Petrographic analysis indicates that sphalerite is the main ore mineral, and minor galena is recorded at the Round Pond Deposit. Multiple generations of sphalerite mineralization have been recorded at the Salmon River prospect. The presence of quartz-orthoclase veins and quartz-orthoclase-dolomite cements in all occurrences indicate that high-temperature hydrothermal fluids were important in at least some stages of the mineralization. Ongoing research on these occurrences includes whole-rock geochemistry, electron microprobe analysis and sulphur and lead isotope analysis (bulk analysis and SIMS), as part of an ongoing B.Sc. (Hons.) project by R. King at Memorial University. These data will provide information on the nature of the mineralizing fluids and sulphide precipitation mechanisms. It will be used to develop a genetic deposit model to assist in determining what factors control deposit location and size. The results will be compared with data from the Daniels Harbour Deposit in an attempt to define whether these occurrences represent manifestations of the same mineralizing event, which could impact regional mineral exploration.

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