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METALLOGENIC STUDIES: ROBERTS ARM AND CUTWELL GROUPS, NOTRE DAME BAY, NEWFOUNDLAND[1]

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ABSTRACT

Metallogenic studies within the northern part of the Buchans - Robert's Arm belt focused on mineral occurrences hosted by the Roberts Arm and Cutwell groups. These studies indicate that the two groups contain two distinct classes of mineralization: 1) syngenetic, mafic and felsic volcanic-hosted sulphide mineralization, and 2) epigenetic, structurally controlled, disseminated and vein-hosted gold and base-metal mineralization. Felsic volcanic-hosted sulphide mineralization is mainly restricted to Pilley's Island. However, there is potential for similar felsic volcanic-hosted sulphide mineralization to exist to the east of the community of Robert's Arm and in the Handcamp area. Within the Roberts Arm Group, outside of the Pilley's Island area, the volcanogenic sulphide mineralization appears to be restricted to pyrite – chalcopyrite stockwork zones within tholeiitic pillow lava of the Crescent Lake terrane.

Volcanogenic sulphide mineralization within the Cutwell Group consists of sphalerite – galena –chalcopyrite (± Ag and Au) rich massive lenses, pods, disseminations and stringers. This mineralization is typically hosted by felsic volcanic rocks of the Long Tickle Formation.

The epigenetic mineralization is widespread and appears to be structurally rather then lithologically controlled. The mineralization occurs as sulphide-bearing quartz veins, sulphide veinlets, and disseminated sulphides associated with silicification and sericitization. Three of the epigenetic occurrences (Handcamp, Shamrock and Chignic) contain significant concentrations of gold.

INTRODUCTION

The Buchans - Robert's Arm belt has a long and colourful mining and mineral exploration history with past-producing mines located at Buchans, Gull Pond and Pilley's Island. The belt is highly prospective for both polymetallic base-metal and gold mineralization, and this is reflected in the current levels of mineral exploration. To aid this exploration effort, the Department of Natural Resources initiated a comprehensive multidisciplinary project consisting of office-based regional-data compilation and synthesis, regional surficial geological mapping and till geochemistry, and regional bedrock geological mapping and metallogenic studies. The results of the metallogenic studies, which focused on mineralization within the Roberts Arm and Cutwell groups (Figure 1), is presented here. Volcanogenic sulphide mineralization associated with felsic volcanic rocks at Pilley's Island were not included in this study. This work included, where necessary, detailed mapping, re-logging of diamond-drill core and sampling. A detailed study of the Lochinvar volcanogenic sulphide deposit was also included in this project, the results of which are presented in Froude *et al.* (*this volume*).

Access to the area is provided by the Trans-Canada and Robert's Arm highways and by numerous forest access roads; mineral occurrences in coastal areas are best reached by boat. The western part of the Roberts Arm Group is characterized by a gently undulating topography covered by extensive heavily forested areas and old cutover. In the east, the Roberts Arm and Cutwell groups are quite rugged and mostly covered by scrub spruce. Coastal sections are generally well exposed, but inland, extensive glacial till results in a paucity of bedrock exposure.

REGIONAL SETTING

The Roberts Arm and Cutwell groups lie within the Notre Dame Subzone (Williams *et al.*, 1988) of the Dunnage tectonostratigraphic zone (Williams, 1979). The geological evolution of the region is subdivided into three broad geological environments: 1) Cambro-Ordovician ophiolitic

[1] Buchans – Robert's Arm multidisciplinary project: Metallogenic studies

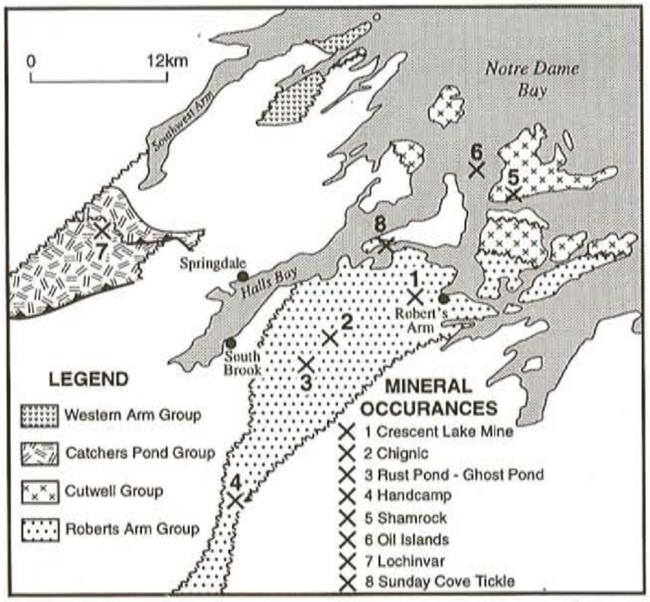

Figure 1. *Map showing the locations of the Roberts Arm, Cutwell and Catchers Pond groups and the mineral occurrences discussed in the text.*

rocks of the Lushs Bight Group, which formed in a supra-subduction zone tectonic environment, 2) Ordovician tholeiitic and calc-alkaline volcanic and volcaniclastic rocks, which includes the Roberts Arm, Cutwell and Catchers Pond groups, which formed in a series of island-arcs and back-arc basins, and 3) post-accretion, Silurian, subaerial volcanic and fluviatile sedimentary rocks of the Springdale Group, which were deposited in successor basins and unconformably overlie the Ordovician and older sequences.

PREVIOUS WORK

Exploration activity within the study area dates back to the late 1860s when Philip Cleary staked claims at Pilley's Island (Martin, 1983). Mining began in 1878 with the discovery of the Crescent Lake deposit and the Pilley's Island pyrite mine opened in 1887 and operated intermittently until 1908. Later, significant base-metal and gold mineralization was discovered at the Handcamp property in 1928 (Corlett, 1930). The Robert's Arm area was included in the extensive Brinex/Brinco exploration concession granted by the Newfoundland Government in the early 1950s and a number of exploration companies were active in the area under joint-venture agreements with Brinex; these included New Jersey Zinc Exploration Company Limited, Cominco Limited, Texasgulf Canada Limited, Falconbridge Nickel Mines Limited and Noranda Exploration Company Limited. The Brinex concession has since reverted back to the Crown. Exploration companies presently active in the area include Eastern Goldfields Limited, Phelps Dodge Corporation, Grubstake Management Limited and Celtic Minerals Limited.

The first recorded government surveys within the region were undertaken in the late 1800s by the Newfoundland Geological Survey. At that time, the mineral occurrences in the Robert's Arm – Crescent Lake area were examined and the early mining activity was described by Murray and Howley (1881, 1918). Espenshade (1937) also included detailed descriptions of the mineral occurrences as part of regional geological mapping of the Pilley's Island area. Many of the mineral occurrences within the study area were examined in detail as part of a regional inventory of the copper resources of Newfoundland (Douglas *et al.*, 1940).

The Roberts Arm and Cutwell groups were included in regional 1:250 000-scale mapping by the Geological Survey of Canada (Neale *et al.*, 1960; Williams, 1962). The Roberts Arm Group was mapped at a scale of 1:50 000 by the Geological Survey of Canada (Bostock, 1978, 1988). Similar scale mapping of the Cutwell Group was undertaken by Memorial University graduate students (Kean, 1973; Szybinski, 1995). Detailed descriptions of the mineral occurrences were also included in the reports that accompanied the 1:50 000-scale mapping.

Regional 1:50 000-scale mapping of the Roberts Arm Group as part of the present multidisciplinary project has resulted in a new stratigraphic and structural interpretation for the area (Kerr, *this volume*). The group can be subdivided into four calc-alkaline basalt-dominated terranes that are structrally overlain by the tholeiitic basalt-dominated Crescent Lake terrane. The calc-alkaline terranes in ascending structural order include: 1) the Boot Harbour terrane, which contains abundant submarine felsic volcanic rocks, 2) the Pilley's Island terrane, which contains fragmental felsic volcanic rocks interpreted to have been erupted into shallow water, 3) the Mud Pond terrane, which consists of strongly hematized and epoditized pillow lava, and 4) the Triton terrane, which consists of fresh pillow basalt and abundant mafic intrusive rocks.

The five terranes are separated by a series of variably steepened, south- to southeast-dipping, north-directed thrust faults. The distribution of the calc-alkaline terranes is interpreted to represent the disrupted lower limb of a northward-overturned anticlinal nappe structure (Kerr, *this volume*). Silurian sedimentary rocks of the Springdale Group unconformably overlie a number of the calc-alkaline terranes indicating pre-Middle Silurian imbrication (Kerr, *op. cit.*). Subsequent deformation is interpreted to be of a mainly brittle nature related to movement along major structures such as the Lobster Cove Fault.

MINERALIZATION

The results of this study indicate that two broad types or classes of mineralization are present within the volcanic sequences of the Roberts Arm and Cutwell groups. These classes comprise syngenetic volcanogenic sulphide mineralization, and epigenetic, disseminated and vein-hosted mineralization, which locally overprints the volcanogenic sulphide occurrences. These two classes of mineralization are discussed separately within each of the groups examined. Exploration case histories presented here are only brief summaries, and by no means should be considered complete.

ROBERTS ARM GROUP

Volcanogenic Sulphide Mineralization

Volcanogenic sulphide mineralization is not extensively developed within the Roberts Arm Group outside of the Pilley's Island terrane. Felsic volcanic rocks of both the Boot Harbour and Mud Pond terranes contain only minor sulphide occurrences related to volcanogenic processes. The majority of mineralization within these two terranes, particularly within the Mud Pond terrane, are epigenetic in origin. No significant mineral occurrences were noted within the Triton terrane.

Volcanogenic sulphide mineralization is preserved within tholeiitic rocks of the Crescent Lake terrane at Rust Pond - Ghost Pond. Base-metal sulphide mineralization is preserved within sericitic schists at the Handcamp prospect located in the southern Roberts Arm Group. However, it has not been determined whether this mineralization is associated with either calc-alkaline or tholeiitic volcanic rocks. These two groups of prospects were the only significant volcanogenic sulphide mineralization observed outside of the Pilley's Island terrane.

Rust Pond – Ghost Pond

Exploration History. The Rust Pond – Ghost Pond area (Figure 1) was included in the extensive Brinex concession granted by the Newfoundland Government in 1955. In 1959, a Brinex – New Jersey Zinc joint venture resulted in the discovery of mineralized boulders in the Ghost Pond area that assayed up to 6.55 percent Zn, 1.85 percent Pb and 0.80 percent Cu (McNamee, 1959).

In 1961, Brinex drilled five diamond-drill holes, two at Rust Pond and three at Round Pond (Figure 2). One of the holes drilled at Rust Pond intersected significant copper mineralization (Smajorie, 1961). Brinex drilled eight more holes at Rust Pond in 1962 but failed to intersect economically significant mineralization (Brinex, 1962).

Joint-venture agreements with Cominco (1964-1969) and Noranda (1972-1973) failed to delineate new targets. In 1975, a joint-venture agreement between Brinex and Texasgulf resulted in detailed geological, geochemical and geophysical surveys of the Rust Pond - Ghost Pond area (MacQuarrie, 1976). Three diamond-drill holes were drilled at Ghost Pond in 1977, only minor sulphide mineralization was intersected (Kelly, 1977).

The Brinex concession reverted to Crown land in 1980 and the area was subsequently staked by L. Murphy. Noranda Exploration Company Limited staked the area in 1989 and conducted prospecting, geochemical and geophysical surveys, linecutting and trenching (Andrews, 1990). This work resulted in the discovery of the Chignic gold prospect located at Fourth Pond (see discussion below).

Local Geology and Mineralization. The Rust Pond – Ghost Pond area is dominated by a sequence of variably deformed, strongly hematized and epidotized, locally variolitic pillow lava, pillow breccia and lesser intermediate pyroclastic rocks (Figure 2). Sporadic sulphide mineralization has been traced from Round Pond in the northeast to Rust Pond in the southwest over a strike length of 3.5 km (McNamee, 1959). The mineralization, as evident from drill core, is developed mainly within chloritized mafic volcanic rocks (pillow lava and pillow breccia). Breccia fragments are typically bleached and exhibit altered rims indicating post-depositional alteration. However, both southwest of Rust Pond and northeast of Round Pond, disseminated sulphide mineralization is developed within what appears to be strongly altered pyroclastic rocks, which MacQuarrie (1976) termed a dacitic breccia.

Drill core from Round Pond, Ghost Pond and Rust Pond exhibit stockwork-style stringer and disseminated pyrite and minor chalcopyrite associated with black chlorite. Brinex hole 61-5, drilled at Rust Pond, intersected 1.7 percent Cu over 11.4 ft (Smajorie, 1961). Subsequent drilling (Brinex, 1962) intersected similar mineralization, grading up to 2.93 percent Cu over 4 ft in hole 62-12. However, the drilling indicated that the mineralized zone had a strike length of less then 200 ft. The origin of the Zn-rich boulders discovered at Ghost Pond in 1959 has not been explained. Assay results from a grab sample of mineralized float collected at Ghost Pond are presented in Table 1.

Handcamp

Exploration History. Gold and base-metal mineralization was discovered at the Handcamp prospect (Figure 1) in 1928 by the Central Mineral Belt Syndicate (Corlett, 1930). The property is contained within a Fee Simple Grant owned by the Newfoundland Exploration Company, a company incorporated to take over the Central Mineral Belt Syndicate properties. The prospect has been extensively explored and the reader is referred to DeGrace (1976), Wilton (1984) and

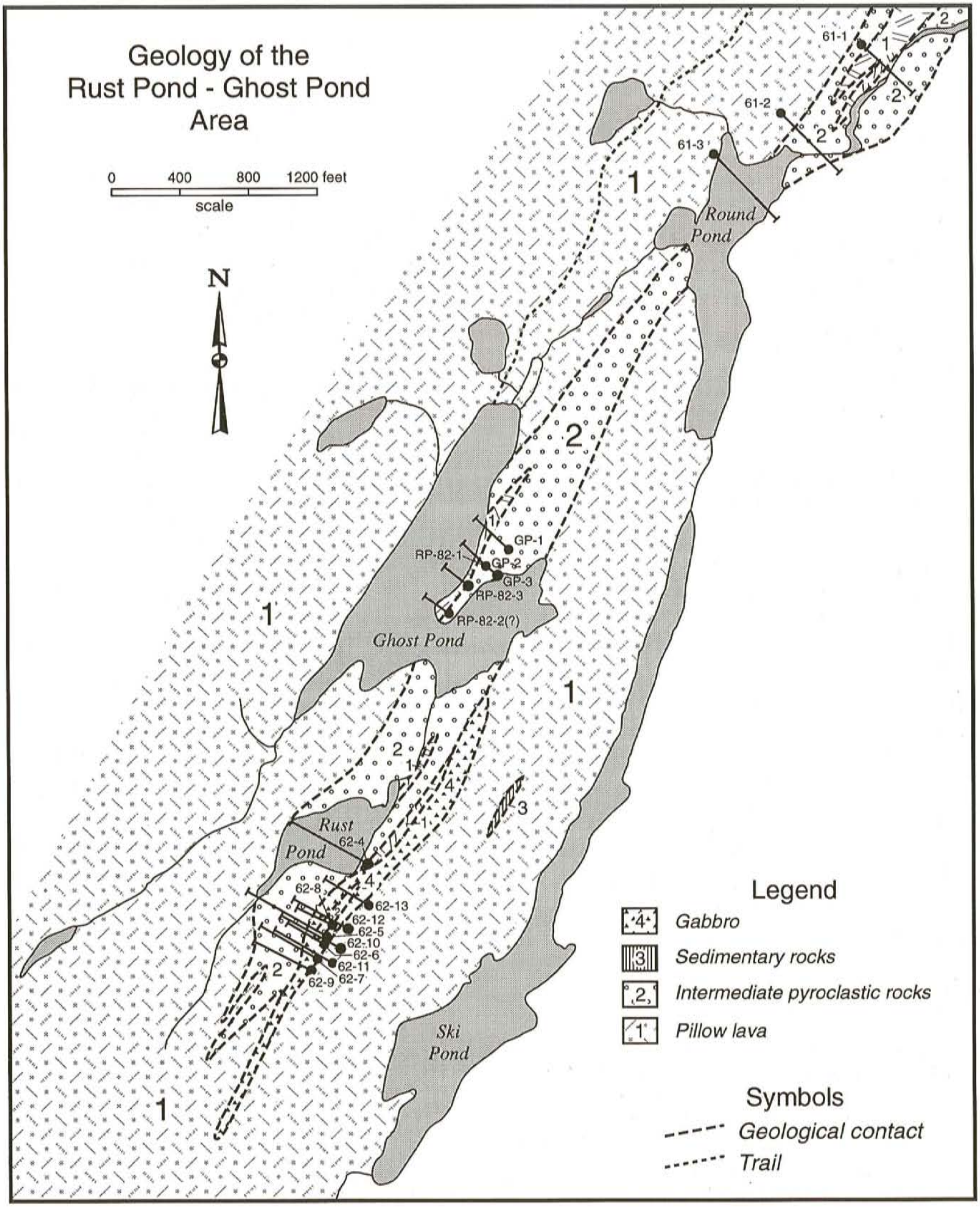

Figure 2. *Geological map of the Rust Pond – Ghost Pond area showing diamond-drill hole locations (modified from Fryer, 1982).*

Table 1. Grab sample assay results

Sample	Rock Type	Cu %	Pb %	Zn %	Au ppb	Ag ppm	Ba ppm	As ppm	Sb ppm
CRESCENT LAKE									
DE-95-08	Quartz vein	4.84	<0.01	0.06	22	8.5	50	143.0	2.8
CRESCENT LAKE VEIN C									
DE-95-16B	Quartz vein	3.22	<0.01	0.07	29	14.6	290	5560.0	1730.0
DE-95-16C	Quartz vein	4.69	<0.01	0.15	51	23.4	520	9670.0	3340.0
CHIGNIC									
DE-95-18	Pyrite veinlet	na	na	<0.01	3540	2	50	615	6.0
GHOST POND									
DE-95-41	Altered volcanic rock (float)	0.16	<0.01	1.9	52	3	160	61.7	1.4
SHAMROCK									
DE-95-57A	Altered volcanic rock	0.26	0.32	6.26	170	4.7	28800	7.2	1.8
DE-95-58A	Altered volcanic rock	0.16	2.11	3.75	79	4.8	6230	124.0	14.7
DE-95-58B	Altered volcanic rock	0.16	2.48	5.74	98	6.1	7180	158.0	13.0
DE-95-71	Sulphide veinlet	0.05	0.39	4.82	32000	164.0	610	8.9	1.3
DE-95-84B	Quartz porphyry	na	na	<0.01	2	2	600	1.0	0.9
OIL ISLANDS									
DE-95-61A	Altered volcanic rock	na	na	2.63	66	11.0	2700	666.0	60.0
DE-95-62	Altered volcanic rock	na	na	4.17	100	21.0	430	1.7	4.7
HANDCAMP									
DE-95-100A	Red chert	na	na	<0.01	60	<2	6270	18.0	0.8
DE-95-100B	Red chert with magnetite	na	na	<0.01	5	<2	2700	27.0	0.9
DE-95-100C	Sericite schist (minor pyrite)	na	na	0.05	429	2	40200	44.0	3.8
DE-95-100D	Sericite schist (minor pyrite)	na	na	0.13	471	2	16100	56.4	4.0
DE-95-100G	Pyritic sericite schist	na	na	0.12	5730	16	42400	50.0	7.0
DE-95-100H	Pyritic sericite schist	na	na	na	53250	70.4	na	na	na
DE-95-100I	Pyritic sericite schist	na	na	0.25	3630	15	>99999	77.6	8.0
DE-95-100J	Sericite schist	na	na	0.01	252	<2	5290	47.0	3.1

Hudson and Swinden (1989) for comprehensive exploration summaries. A detailed geological mapping and petrological study of the prospect was undertaken by Hudson and Swinden (1989) for the Geological Survey of Canada.

A number of models have been proposed for the genesis of the mineralization at Handcamp. These include: 1) epigenetic - i) related to the emplacement of a nearby granodiorite (Corlett, 1930), ii) low-temperature replacement (Newfoundland Exploration Company Limited, 1940), and iii) shear-zone related (Neilson, 1972; Hudson and Swinden, 1989); 2) stratabound volcanogenic mineralization (DeGrace, 1976; Franc de Ferriere, 1978); and 3) hot-spring deposition (Burton, 1983).

The present study focused on detailed geological mapping of the stripped portion of the main mineralized zone. Samples were collected for assay and petrographic analyses.

Local Geology and Mineralization. The Handcamp prospect is located within a northeast-trending sequence of pillow basalt, pillow breccia, tuffs, massive flows, minor felsic volcanic rocks and interbedded chert and argillite (Hudson and Swinden, 1989; Figure 3). The mineralization is restricted to a less than 50-m-wide structurally complex, stratabound zone. Rock types within the zone include volcanic and volcaniclastic rocks, red and ferruginous chert and argillite, which have been variably altered to a quartz – sericite – pyrite – magnetite assemblage (Hudson and Swinden, 1989). In strongly deformed and possibly altered sections, the felsic volcanic rocks have been reduced to sericitic schists.

The best sulphide mineralization is associated with the sericitic schists where it occurs as patches, small lenses up to 15 to 20 cm thick, veinlets and disseminations (Hudson and Swinden, 1989). The mineralized zone has been traced in

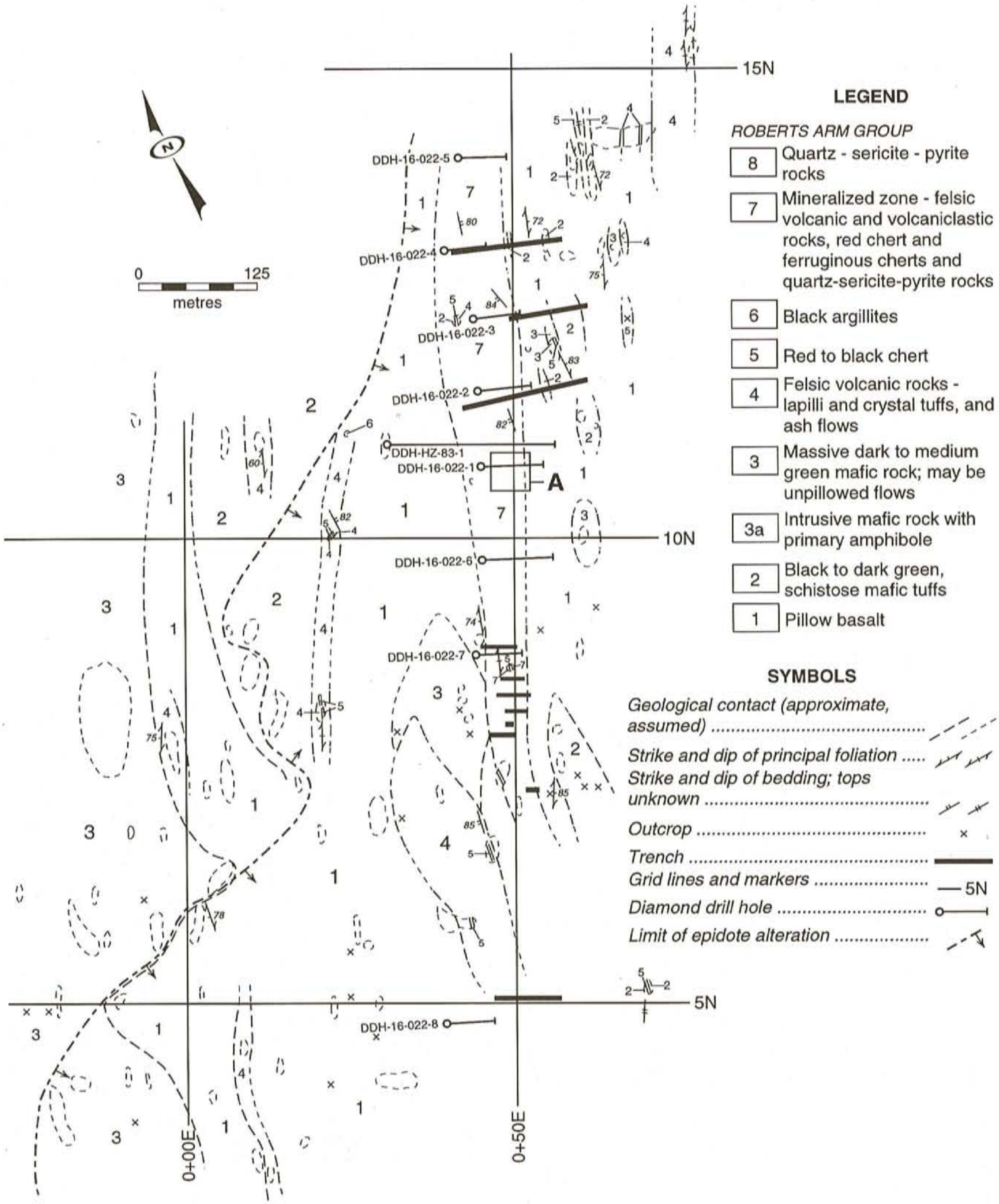

Figure 3. *Geological map of the Handcamp area showing trenches and Falconbridge diamond-drill holes (from Hudson and Swinden, 1989). Block A outlines the location of Figure 4.*

outcrop and through diamond drilling over a strike length of 1200 m and to a depth of <50 m.

Hudson and Swinden (1989) interpreted the mineralization and alteration developed at the Handcamp prospect to be both synkinematic and postkinematic and not related to volcanogenic processes. However, the presence of small lenses of massive sphalerite and galena having significant concentrations of Ag and Au, the high concentrations of Ba associated with the mineralized zone and the spatial association of sulphide mineralization with altered felsic volcanic rocks, suggest a volcanogenic origin for the sulphide mineralization. It is proposed that this mineralization is related to volcanogenic processes but has been overprinted and remobilized by later shearing and CO_2-rich fluids as proposed by Hudson and Swinden (1989).

Epigenetic Mineralization

Vein-hosted and disseminated mineralization has long been recognized within the Roberts Arm Group. However, this mineralization has traditionally been interpreted to be the product of volcanogenic processes. Within the Boot Harbour and Mud Pond terranes, most of the alteration and mineralization appears to be either structurally controlled or related to intrusive rocks such as the Woodford's Arm pluton. Examples would include minor vein-hosted mineralization at Loon Pond and the extensive Sunday Cove Tickle alteration system. The base-metal sulphide-rich quartz veins at the Crescent Lake mine are clearly epigenetic and structurally controlled as is auriferous pyrite mineralization at the Chignic prospect. Gold mineralization at the Handcamp prospect is also considered to be epigenetic and structurally controlled.

Sunday Cove Tickle

Exploration History. The Sunday Cove Tickle area (Figure 1) was included in the extensive Brinex concession granted by the Newfoundland Government in 1955. The area has been included in a number of exploration programs but no economically significant mineralization has been noted.

Local Geology and Mineralization. The area on Sunday Cove Island south of the Lobster Cove Fault is underlain by a sequence of epidotized, locally variolitic, pillow lava and pillow breccia that have been intruded by numerous felsic and lesser diabase and gabbroic dykes. Many of these dykes are lithologically similar to the Woodford's Arm pluton. The trend of these dykes is quite variable. Deformation within the area is inhomogeneous with numerous small brittle faults and shear zones. In the vicinity of the Lobster Cove Fault, the pillow lavas are reduced to chlorite schists.

The alteration and pyrite mineralization is exposed in a series of roadcuts along the Miles Cove highway south of the Lobster Cove Fault. The alteration is restricted to a narrow zone (<100 m wide) that extends parallel to the highway for approximately 500 m. Within the zone, the pillow lava are typically rusty as are some of the felsic dykes. Alteration consisting of silicification and sericitization is variably developed throughout the zone. Disseminated and stringer pyrite is common. Pyrite is locally concentrated within the fault zones and along dyke margins suggesting that the mineralization is epigenetic. Minor disseminated chalcopyrite and sphalerite occur with the pyrite. Seven grab samples, collected by the author at various locations within the alteration zone, did not exhibit anomalous concentrations of either Zn, Au or Ag.

Handcamp

Exploration History. The exploration history is discussed in the section on volcanogenic sulphide mineralization within the Roberts Arm Group.

Local Geology and Mineralization. At the Handcamp prospect, base-metal mineralization is overprinted by a significant structurally controlled, disseminated style of gold mineralization. The mineralization and alteration are confined to a 50-m-wide zone of intense deformation (Figure 4). The rocks within the zone have been affected by a least three major episodes of deformation: D_1 - which is represented by a poorly preserved cleavage that trends 100° and dips 15° northeast; D_2 - which is represented by an S_2 cleavage that trends 028° and dips vertically and by F_2 Z folds, having axial planes that trend approximately 015° and plunge 15° northeast; and by narrow mylonitic zones that trend 150 to 185° and dip 80 to 85° west. The mylonitic zones cut all earlier deformation fabrics.

Alteration associated with the mineralization consists mainly of an assemblage of quartz – sericite – pyrite – magnetite developed within both the felsic volcanic and argillaceous sedimentary rocks (Hudson and Swinden, 1989). The abundant Ca – Mg – Fe silicate and carbonate minerals (epidote, wollastonite, calcite, grossularite, clinozoisite, tremolite) present at Handcamp were interpreted by Hudson and Swinden (1989) to suggest CO_2-rich fluids were in part responsible for the gold mineralization. However, these Ca – Mg – Fe silicate and carbonate minerals may be a regional phenomenon due to contact metamorphism related to the intrusion of the Twin Lakes Complex (Hudson and Swinden, 1989).

Gold concentrations appear to be sporadic with the highest concentrations typically associated with the pyritic – sericite schist. However, significant gold values have been reported locally from the red chert (Franc de Ferriere, 1978; Hudson and Swinden, 1989), where it is cut by small sulphide

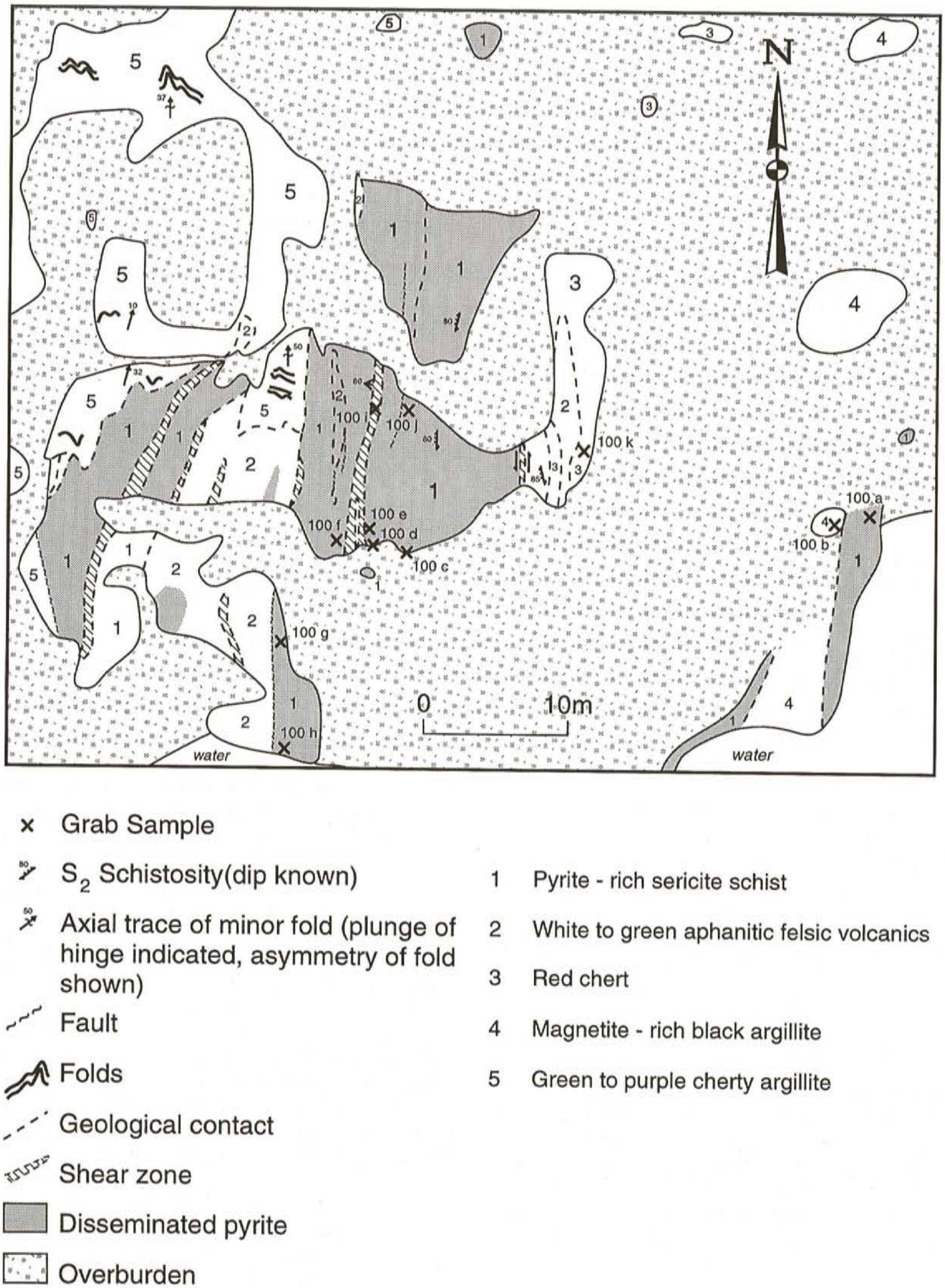

Figure 4. *Detailed geological map of a portion of the stripped area, Handcamp, showing grab sample locations.*

veinlets. Franc de Ferriere (1978) also reported that gold values in excess of 0.1 oz/t were obtained from white cherts. However, these white cherts are considered to be highly siliceous felsic volcanic rocks as they contain small euhedral feldspar phenocrysts. These rocks also commonly contain abundant disseminated pyrite. Grab samples from the sericite schist have assayed up to 158.9 g/t Au (Franc de Ferriere, 1978); samples collected from the red chert assayed up to 2.5 g/t Au (Hudson and Swinden, 1989). Assay results from grab samples collected from the main zone during this study are presented in Table 1.

The gold mineralization at Handcamp was interpreted by Hudson and Swinden (1989) to have formed through shear-related hydrothermal activity. The present study supports this conclusion, but it appears that the gold mineralizing event was superimposed upon pre-existing volcanogenic sulphide mineralization.

The Handcamp prospect typically contains high concentrations of Ag. Grab samples typically assay up to 14.6 ppm Ag (Franc de Ferriere, 1978) and a grab sample collected during this study assayed 2.07 oz/t Ag. These high Ag concentrations are not typical of Newfoundland mesothermal gold occurrences (Evans, *in press*). Some base-metal sulphide-rich quartz veins such as the Road Showing within the Victoria Lake Group do contain significant Ag concentrations, but these are typically very small occurrences. The high Ag concentrations at Handcamp may reflect remobilization of Ag associated with earlier volcanogenic sulphide mineralization.

Shearing, folding and mylonite development make delineation of a continuous mineralized zone difficult. Exploration in the past focused on a stratigraphic control rather than a structural control for the mineralization. Both folding and shearing of the felsic volcanic and argillaceous sedimentary rocks appear to control the distribution of the gold. Future exploration should focus on delineating the plunge of the F_2 folds.

Chignic

Exploration History. Noranda Exploration Company Limited discovered gold mineralization at the Chignic prospect (Figure 1) in 1989 (Andrews, 1990) as part of regional exploration of the Rust Pond – Ghost Pond area (see previous discussion). Further prospecting, geochemical and geophysical surveys and trenching were undertaken in the Chignic area in 1990 (Andrews, 1991).

Local Geology and Mineralization. The area is underlain by pillow basalt, felsic fragmental rocks and deformed red chert. The red chert, which host the gold mineralization, occurs as a small shear-zone-bounded lens within variably deformed felsic fragmental rocks. The chert lens is approximately 5 to 7 m wide and 20 m long. The lens trends east – west and appears to dip steeply to the south. The chert is highly fractured and cut by numerous pyrite and quartz veinlets and clots. Two sets of specularite-coated fractures, which strike 135° and 90°, dip 35° east, and vertically respectively, also cut the chert. Grab samples assayed up to 19.4 g/t Au and chip sampling across the lens returned an average grade of 3.18 g/t Au over 3.0 m (Andrews, 1990). A grab sample collected from the red chert assayed 3.54 g/t Au (Table 1).

Crescent Lake

Exploration History. Copper mineralization was discovered at Crescent Lake (Figure 1) in 1878, and mining was initiated by the Betts Cove Mining Company. Between 1879 and 1881, the mine produced approximately 1260 tons of ore grading 28 percent Cu (Espenshade, 1937). The mine was reactivated by the Reid Newfoundland Company and 2000 tons grading 12 percent Cu were produced between 1924 and 1925. Approximately 4430 tons grading 0.92 percent Cu and 0.35 oz/t Ag remained in the mine dumps (Bruce, 1951), but this material was removed in 1974 for wharf construction.

In 1970, Brinex drilled six diamond-drill holes totalling 1567 feet in the vicinity of the Crescent Lake mine (Glenn, 1971). Two of the holes intersected narrow widths of low-grade copper mineralization within silicified volcanic rocks.

Local Geology and Mineralization. The area surrounding the Crescent Lake mine is underlain by variably epidotized - hematized pillow lava and pillow breccia and minor cherty argillaceous sedimentary rocks of the Mud Pond terrane (Figure 5). Minor gabbroic and diorite dykes cut the pillow lava sequence. A large gabbroic intrusion referred to as the West Cleary intrusion is located approximately 1 km to the northwest. Numerous mineralized quartz veins, including the old West Cleary mine, cluster along the margin of this intrusion.

Deformation within the area is inhomogeneous. Numerous small brittle faults and several major fault systems are developed near the old mine (Figure 6). One significant fault is exposed in a roadcut adjacent to the mine site. This is a low-angle reverse fault, which forms the structural hanging-wall contact to the mineralization. The fault zone was found to outcrop at several locations near the old mine workings.

Mineralization at the Crescent Lake mine consists of chalcopyrite - pyrite, minor sphalerite and galena-bearing extensional quartz veins developed within variably chloritized pillow lava and breccia. The veins exhibit multiple vein generations and locally contain angular wall-rock fragments.

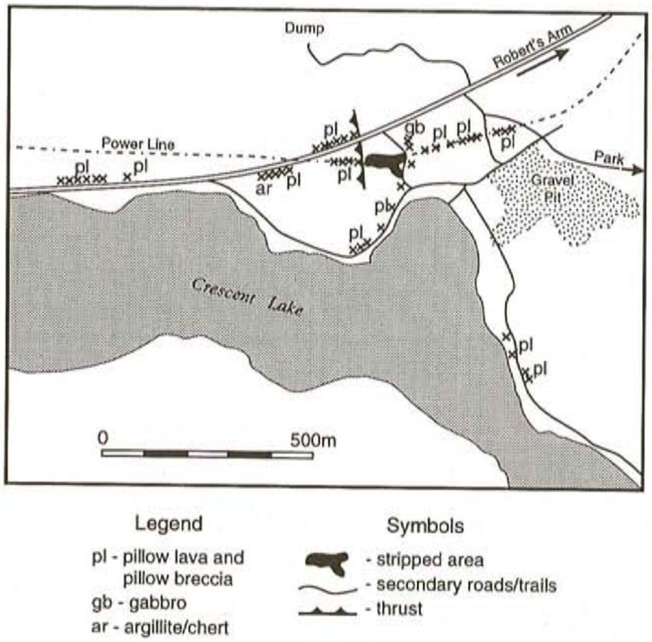

Figure 5. *Geological map of the Crescent Lake area, the location of the mine is designated by the stripped area.*

The quartz vein(s) strike 46 to 92° and dip 30 to 40° to the south (Bruce, 1951). The vein systems are reported to be up to 5 m in width (Swinden, 1990) The alteration and mineralization appear to be localized within the footwall of the shallow westward-dipping fault zone described above (Figure 7). Grab samples collected from the Crescent Lake mine dump and the nearby Crescent Lake Vein C assayed up to 4.84 percent Cu and 23.4 g/t Ag (Table 1).

Based on petrographic and fluid inclusion analyses, Waldie (1989) indicated that the Crescent Lake quartz veins and related alteration probably formed deep within a volcanogenic hydrothermal system. However, given the preservation of the veins, the brittle nature of the vein formation (i.e., multiple vein generations and angular wall-rock fragments) and the lack of a strong deformation fabric within the chloritized pillow lava, indicate that the vein system is epigenetic and not related to volcanogenic processes. Black chloritic alteration associated with volcanogenic sulphide mineralization in north central Newfoundland is typically preserved as chlorite-schist zones (see Kean *et al.*, 1995).

CUTWELL GROUP

Volcanogenic Sulphide Mineralization

Rocks of the Cutwell Group are host to two significant volcanogenic sulphide occurrences – the Shamrock prospect located on the southwest coast of Long Island and the Oil Islands prospect (Figure 1). Both prospects occur within andesitic to dacitic tuffaceous rocks of the Long Tickle Formation immediately north of the Lobster Cove Fault (Kean, 1973).

Shamrock Prospect

Exploration History. The volcanogenic sulphide mineralization at the Shamrock prospect was discovered during a Brinco - Getty joint-venture exploration program in 1980 (McHale and McHale, 1981a). A mineralized zone up to 60 m in width, developed over a strike length of 450 m, was outlined. The area was trenched and tested with 8 diamond-drill holes (McHale, 1988). Significant concentrations of gold were identified from both surface trenches and in diamond-drill core (McHale, 1988, 1990).

In 1986, Tillicum Resources Limited channel sampled the large roadcut north of the Long Island ferry terminal and identified several gold and base-metal-rich zones (McHale, 1988).

Local Geology and Mineralization. The Shamrock prospect is hosted by hornfelsed, variably deformed and altered volcanic rocks of the Long Tickle Formation. These rocks are best exposed in the long roadcut north of the ferry terminal. The roadcut exposes a sequence of tuffaceous andesitic rocks that pass westward into altered (silicified) possibly flow-banded dacitic rocks. The sequence is cut by numerous quartz-feldspar porphyry dykes and lesser gabbroic dykes. At the western end of roadcut, the dacitic rocks are intruded by gabbroic rocks of the Long Island pluton.

Within the roadcut, base-metal mineralization consists of remobilized (i.e., crosscutting) veinlets and patches of sphalerite, galena, minor chalcopyrite (Ag, ± Au) and barite. Channel sample results indicate that all the volcanic rocks exposed in the roadcut are anomalous with respect to zinc and copper with several 2-m-wide zones assaying in excess of 10 000 ppm Zn and up to 3479 ppm Cu (McHale, 1987). Grab samples collected from the roadcut during this study assayed up to 6.26 percent Zn and 2.48 percent Pb (Table 1). The base-metal sulphide mineralization has been traced within the altered felsic volcanic rocks over a strike length of approximately 800 m (McHale, 1987).

Oil Islands

Exploration History. The Oil Islands prospect was discovered prior to 1937 (Espenshade, 1937). A filled, inclined shaft located on the beach just above the high tide mark probably dates from this early exploration activity. Between 1979 and 1982, Brinex conducted detailed geological mapping, geophysical surveys and tested the prospect with 10 diamond-

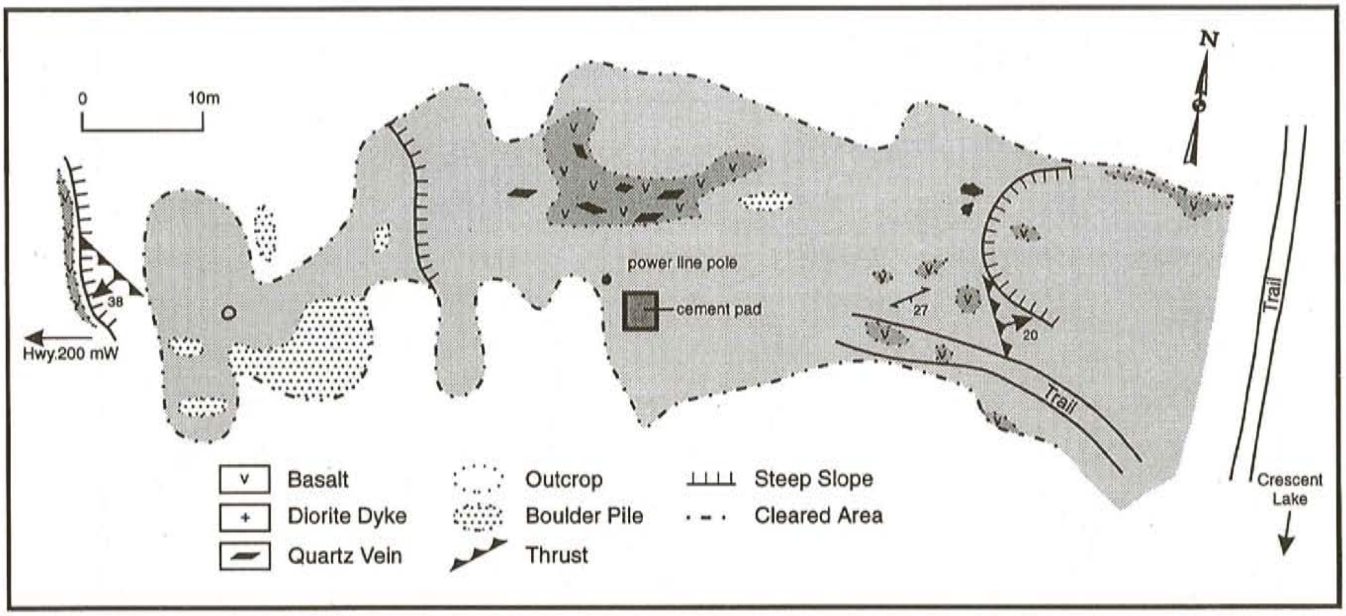

Figure 6. *Geological map of the stripped area, Crescent Lake mine (modified from Swinden, 1990).*

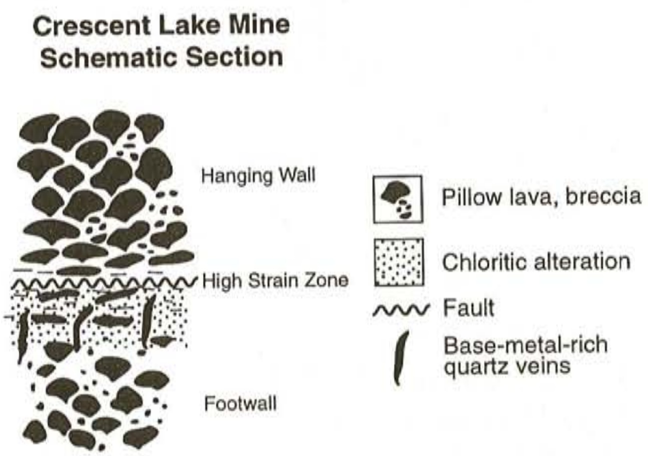

Figure 7. *Schematic section through the Crescent Lake mine. Quartz-vein-hosted mineralization is restricted to the footwall of the high-strain zone.*

drill holes (Harper, 1979; McHale and McHale, 1981b, 1983). This work indicated that volcanogenic sulphide mineralization occurs as narrow lenses within altered felsic pyroclastic rocks.

In 1988 and 1989, James Wade Engineering Limited conducted prospecting, soil sampling and geological mapping of the Oil Islands prospect for Epoch Capital Corporation (Paltser and Scott, 1988; Chataway, 1990). The property was subsequently staked by Roland Butler and is presently being examined by Phelps Dodge Corporation.

Local Geology and Mineralization. The Oil Islands prospect occurs within variably sericitized and silicified felsic (dacitic) pyroclastic rocks, which are included within the Long Tickle Formation of the Cutwell Group (Figure 8). The felsic pyroclastic rocks dip approximately 30 to 35° to the west and are in fault contact with a structurally overlying sequence of andesitic pyroclastic rocks (Figure 9). The felsic rocks are structurally underlain by a distinctive marker horizon termed the 'black feldspar porphyry', which is tentatively assigned to the Seal Cove Complex. At surface, the contact between the felsic rocks and the porphyry is a mylonite zone, but in drillcore this fault is difficult to identify. Red chert and magnetite-iron formation are preserved locally within the footwall to the fault. Conformably beneath the 'black porphyry' is a sequence of sedimentary rocks consisting of argillite, limey sandstone and limestone breccia that have been correlated with the Parsons Point Formation.

Mineralized host rocks exposed near the old shaft contain angular lithic fragments and appear to be only weakly deformed. Deformation within all rock units increases down dip with lithic fragments becoming quite attenuated. Rocks exposed on the south side of the islands are hornfelsed.

The felsic volcanic-hosted mineralized zone outcrops at two separate locations along the northeastern and southeastern shores of the island (Figure 8). The sulphides occur as coarse veinlets, stringers and small pods associated with variable silicification and sericitization. Assay results from diamond-drilling include up to 3.02 percent Zn and 1.51 percent Pb over 3 m and 6.41 percent Zn over 1.03 m (McHale and McHale, 1983). Grab samples collected from near the old shaft assayed up to 4.17 percent Zn (Table 1). Large pods or blocks of barite also occur throughout the altered sequence.

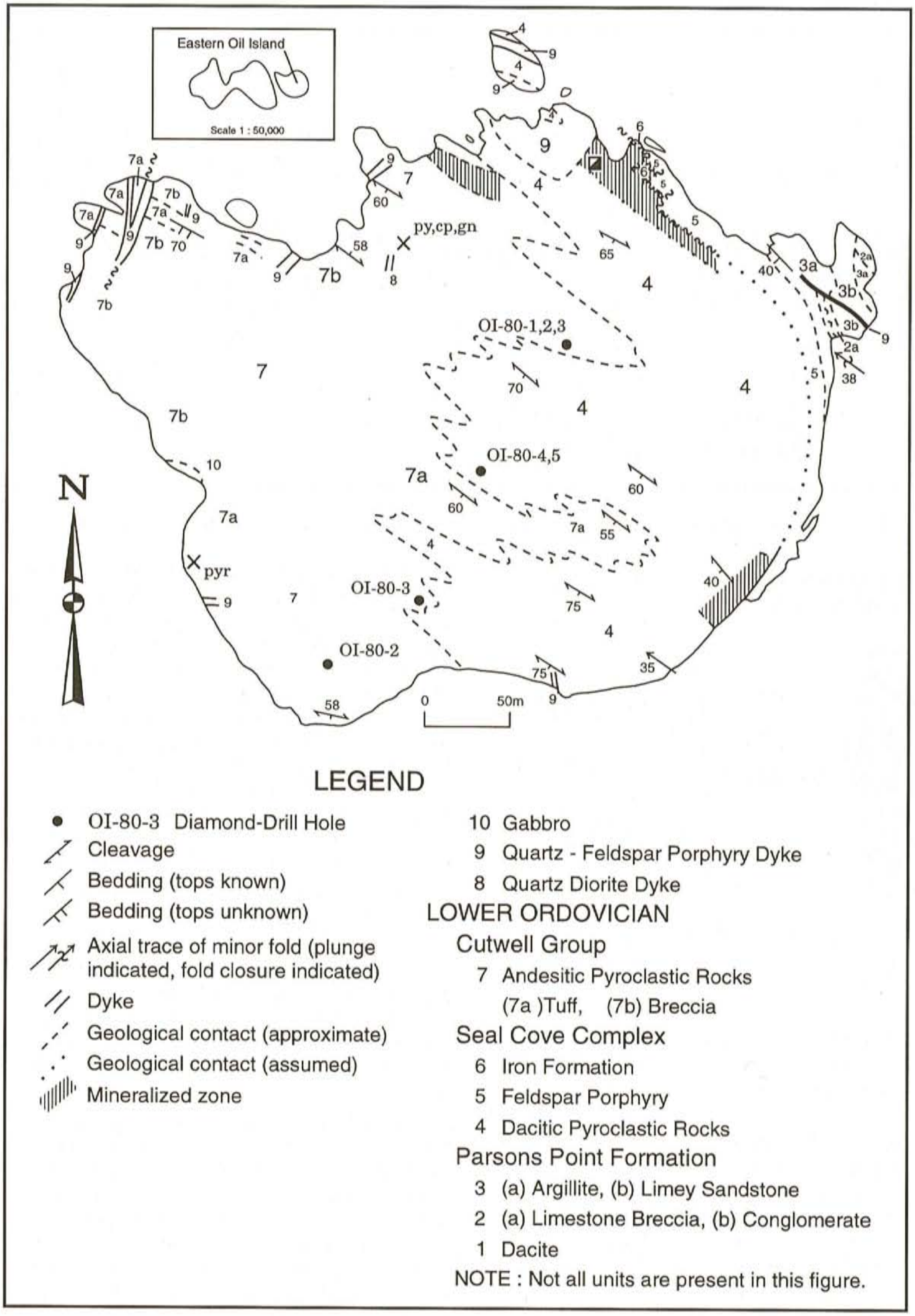

Figure 8. *Geological map of eastern Oil Island illustrating mineralized zones and diamond-drill hole locations.*

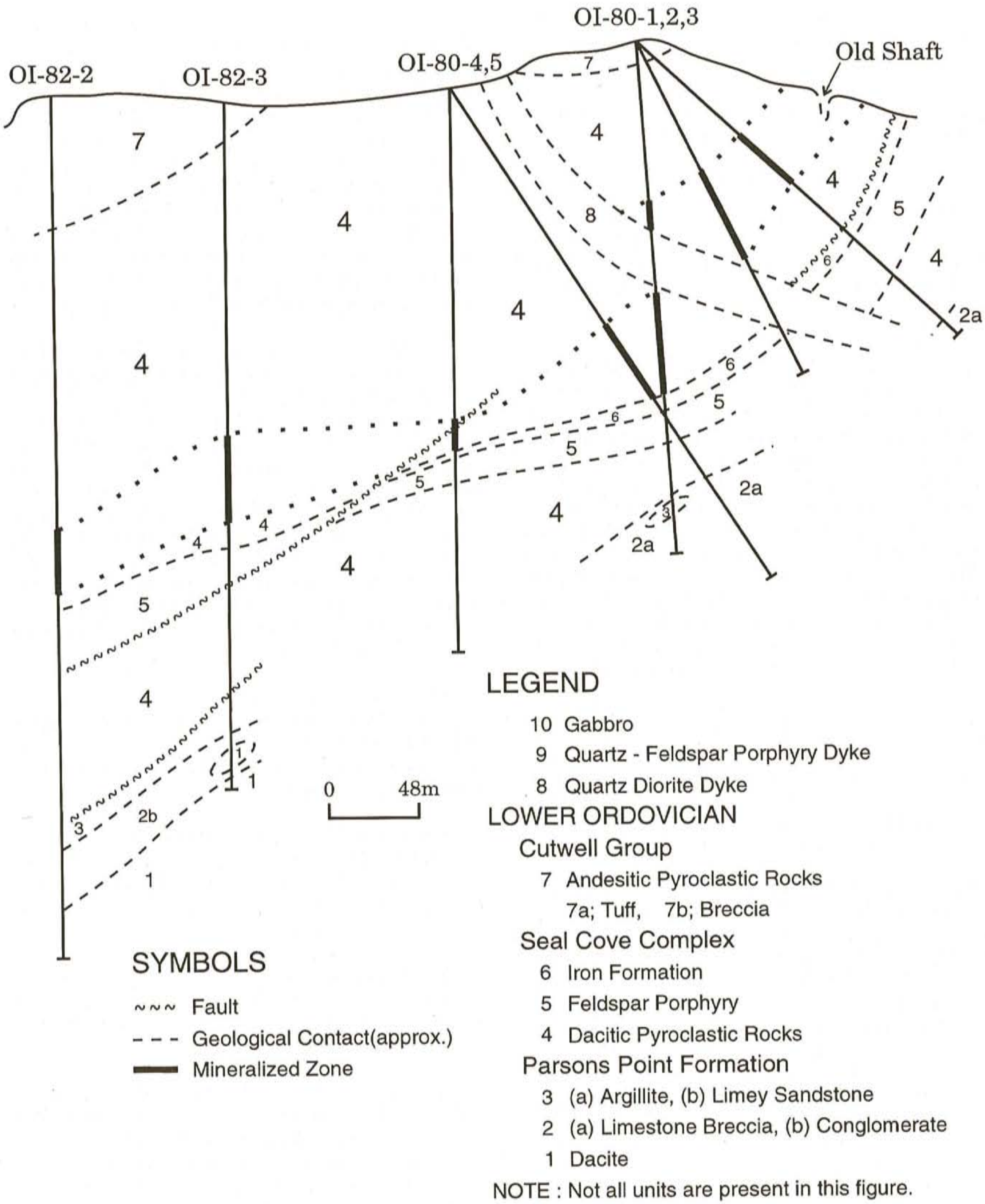

Figure 9. *Diamond-drill section through eastern Oil Island (modified from McHale and McHale, 1983).*

Three weakly mineralized zones occur within andesitic tuffaceous rocks to the west of the dacite – andesite contact (Figure 8). The sulphides occur mainly as disseminations and small veinlets consisting of pyrite with lesser chalcopyrite and galena. The relationship between the felsic-hosted and andesite-hosted mineralization is not known.

Epigenetic Mineralization

Mineralized shear zones and sulphide-bearing quartz veins are widespread within the Cutwell Group. However, the Shamrock prospect contains the only known epigenetic structurally controlled gold mineralization within the group.

Shamrock

Exploration History. The reader is referred to the previous section for a more detailed summary of exploration at the Shamrock prospect. During the Brinex (1980 to 1983) exploration program, a limited number of diamond-drill core samples were analyzed for gold. The results of these analyses indicated significant concentrations of the precious metal (McHale, 1988) making the prospect a potential gold exploration target. The property was subsequently optioned to Westfield Minerals Limited and a trenching and channel sampling program was undertaken in 1986 and 1987. Old trenches were resampled and the diamond-drill core was reanalyzed for gold (McHale, 1988). Results from the trenching were not encouraging, but the reanalyses of the drill core confirmed the presence of significant concentrations of gold.

Eastern Goldfields Limited conducted detailed prospecting, trenching, geological, geophysical and geochemical surveys from 1989 to 1991. This work identified a number of significant gold soil anomalies, the most significant of which were stripped in 1990. The source of this gold was not resolved (McHale, 1991).

Local Geology and Mineralization. At the Shamrock prospect, gold is associated with narrow structurally controlled sulphide-bearing quartz veins, exposed in the roadcut north of the ferry terminal, and narrow sericitic shear zones within quartz porphyry dykes (Figure 10) as is exposed in the large stripped area north of the highway. The gold mineralization is interpreted to be structurally controlled and overprints the earlier volcanogenic sulphide mineralization (McHale, 1991). Gold concentrations are quite sporadic. The best diamond-drill sections assayed up to 7.8 g/t Au and 13.5 g/t Ag over 1.2 m (McHale, 1990). A grab sample collected from the roadcut assayed 32 g/t Au and 4.82 percent Zn (Table 1).

SUMMARY

Results of metallogenic work within the northern portion of the Buchans – Robert's Arm belt (Roberts Arm and Cutwell groups) indicate that two styles or classes of mineralization are widely developed. These styles or classes consist of 1) volcanogenic sulphide mineralization hosted by both mafic and felsic volcanic rocks, and 2) epigenetic, structurally controlled vein and disseminated sulphide and gold mineralization hosted by a variety of rock types. Volcanogenic sulphide mineralization within the Roberts Arm Group occurs as pyrite – chalcopyrite stockwork within tholeiitic basalts and as small massive lenses and veinlets of sphalerite – galena – chalcopyrite – barite ± Ag and Au developed within sericite schist. Massive lenses and veinlets of sphalerite – galena – chalcopyrite – barite ± Ag and Au are preserved within dacitic felsic rocks of the Cutwell Group.

Exploration potential for volcanogenic sulphide mineralization within the Roberts Arm Group appears to be greatest within the felsic volcanic rocks of the Pilley's Island terrane. These rocks are typically more fragmental than felsic rocks preserved elsewhere in the Roberts Arm Group (Bostock, 1978; Kerr, *this volume*) and are interpreted to have erupted into relatively shallow water, conditions that promoted explosive volcanic activity. The fragmental nature of the felsic rocks together with abundant fracturing produced by the explosive activity would have enhanced fluid flow promoting alteration and sulphide deposition. Rocks similar to the those exposed on Pilley's Island are interpreted to underlie the Flat Rock Tickle area south of Tilley Cove and north of the Little Harbour thrust.

Felsic volcanic rocks within the Boot Harbour terrane are interpreted to have formed under deep submarine conditions and exhibit little evidence for explosive volcanic activity. Alteration and mineralization related to this volcanic activity is only weakly developed.

Felsic volcanic rocks in the Handcamp area are also potential hosts for volcanogenic sulphide mineralization. The tectonic setting of the volcanic rocks within the Handcamp area has been difficult to ascertain. Geochemical analyses of pillow lava from the area are in progress.

Exploration potential within the Cutwell Group is considered to be excellent. However, continued exploration at the Oil Islands is hampered by the small areal extent of the islands.

Volcanogenic sphalerite associated with the Bull Road deposit on Pilley's Island is typically black, fine grained and similar to sphalerite from the Buchans mines in the Buchans Group. However, sphalerites from Handcamp, Shamrock and the Oil Islands are a very light, honey colour. Similar light-coloured sphalerite is also present at the Lochinvar volcanogenic sulphide deposit within the Catchers Pond Group (Froude *et al., this volume*). The Fe-poor sphalerite

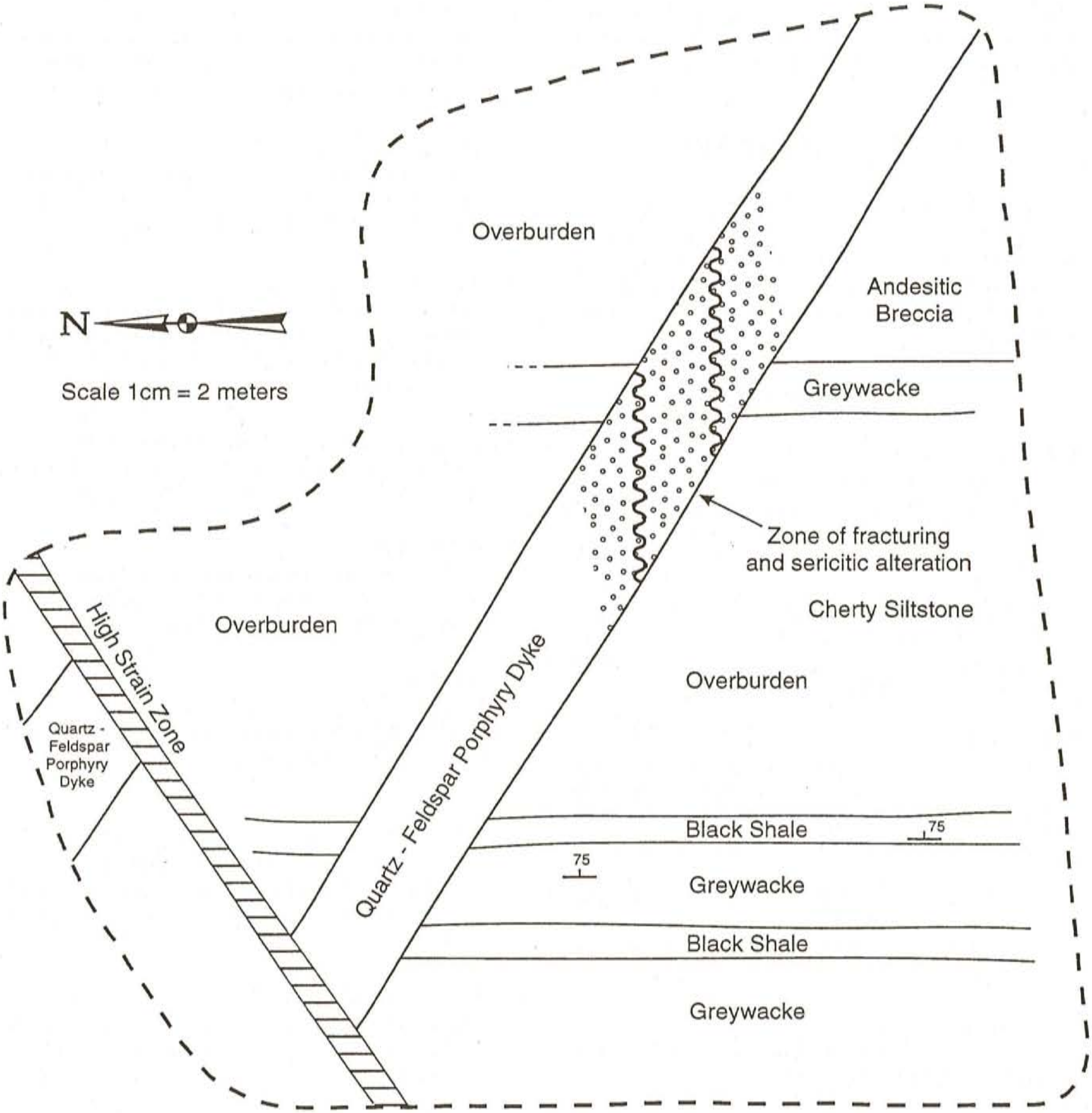

Figure 10. *Simplified geological map of a portion of the large stripped area, Shamrock gold prospect. Zone of sericitic alteration within the quartz-feldspar porphyry dyke is slightly anomalous with respect to Au.*

may indicate a lack of iron-rich rocks in the source area, and may suggest a fundamental difference between volcanic rocks both within the Roberts Arm Group and between the Roberts Arm Group and the Catchers Pond and Cutwell groups.

Epigenetic mineralization within the study area occurs in a variety of rock types that includes pillow lava, dacitic and andesitic tuffaceous rocks, chert, argillite and gabbroic and felsic dykes. The mineralization can occur as large sulphide-bearing quartz veins (Crescent Lake), as small, structurally controlled sulphide-rich veinlets (Chignic) or as zones of disseminated sulphide mineralization associated with sericitization and silicification (Handcamp). The vein-hosted occurrences in some cases contain significant concentrations of gold. The epigenetic mineralization often overprints earlier volcanogenic mineralization.

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