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METALLOGENY OF THE RAMAH GROUP: DISCOVERY OF A NEW Pb–Zn EXPLORATION TARGET, NORTHERN LABRADOR [1]

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ABSTRACT

The ca. 2000 Ma Ramah Group is a relatively undeformed cover sequence developed on the Archean crust of the Nain craton, northern Labrador. The group is a 1.7-km-thick sequence of sedimentary rocks exposed over a distance of almost 75 km. A series of mafic to ultramafic sills occurs in the stratigraphically higher levels of the group. Base-metal geochemical anomalies are spread over this group and a lower unit contains a mixed pyrite–chert horizon.

A variety of sulphide mineral occurrences were found or re-examined in the Ramah Group during mapping in 1993; these include; (i) the syngenetic Nullataktok Formation pyrite–chert bed, (ii) minor syngenetic sulphide mineralization in gabbroic to diabasic sills, (iii) diagenetic pyrite concretions in the Nullataktok and Typhoon Peak formations slate/shales, (iv) epigenetic galena–sphalerite and pyrite mineralization filling secondary porosity in the Reddick Bight Formation dolomite, (v) vein-hosted chalcopyrite–pyrite, galena or sphalerite occurrences in basement, Rowsell Harbour Formation, Nullataktok Formation, Warspite Formation and diabase–gabbro sills, and (vi) late pyrrhotite, nickel sulphide and nickel arsenide mineralization mobilized from diabase sills.

The Reddick Bight Formation occurrences resemble MVT-style mineralization. Their continuity over greater than 75 km outcrop of the Ramah Group indicates that they represent an important new exploration target in the Ramah Group. In fact, they are the first documented examples of large-scale Pb–Zn sulphide mineralization from the Lower Proterozoic supracrustal rocks of northern Labrador.

INTRODUCTION

The ca. 2000 Ma Ramah Group unconformably overlies Archean gneiss of the Nain Province (Taylor, 1979) in northern Labrador (Figure 1). This 1.7-km-thick unit (Morgan, 1975; Knight and Morgan, 1976) consists of six formations (after Knight and Morgan, 1981), *viz.*; 1) the basal Rowsell Harbour Formation, predominantly quartzite with minor phyllite, shale and a solitary, thin, volcanic member; 2) the Reddick Bight Formation, a succession of sandstone, laminate and quartzite members, with an upper 3- to 10-m-thick dolomite member; 3) the Nullataktok Formation, with a lower sequence of pyritiferous shale and mudstone that passes up into a distinctive sequence of massive pyrite (up to 3.3 m thick) and chert (4 to 17 m thick), and an upper mudstone sequence; 4) the Warspite Formation, dominantly dolomite and dolomitic sandstones–mudstones; 5) the Typhoon Peak Formation, dominantly slates and laminated sandstones–siltstones–limestones intruded by numerous diabasic to gabbroic sills; and 6) the Cameron Brook Formation, turbiditic sandstones and shales. Basement rocks consist of quartzofeldspathic gneisses of the Archean Nain Province (North Atlantic craton) (Bridgwater *et al.*, 1973; Collerson, 1983; Schiøtte *et al.*, 1989). The rocks are exposed in spectacular cliffs and mountains that rise to 1100 m above sea level. Outcrop exposure is generally good as there is no tree or soil cover, however, there is extensive scree and felsenmeer.

The general stratigraphy is illustrated on Figure 2. The chert and pyrite beds within the Nullataktok Formation and the dolostone member within the Reddick Bight Formation are conspicuous marker horizons that can be mapped with ease over a distance of 75 km from Nachvak to Saglek fiords.

The unit was originally mapped by Daly (1902) who termed it the Ramah Sedimentary Series. Coleman (1921) measured two sedimentary sections and noted the presence of a volcanic unit near the base of the group. Douglas (1953) produced detailed stratigraphic columns and cross-sections

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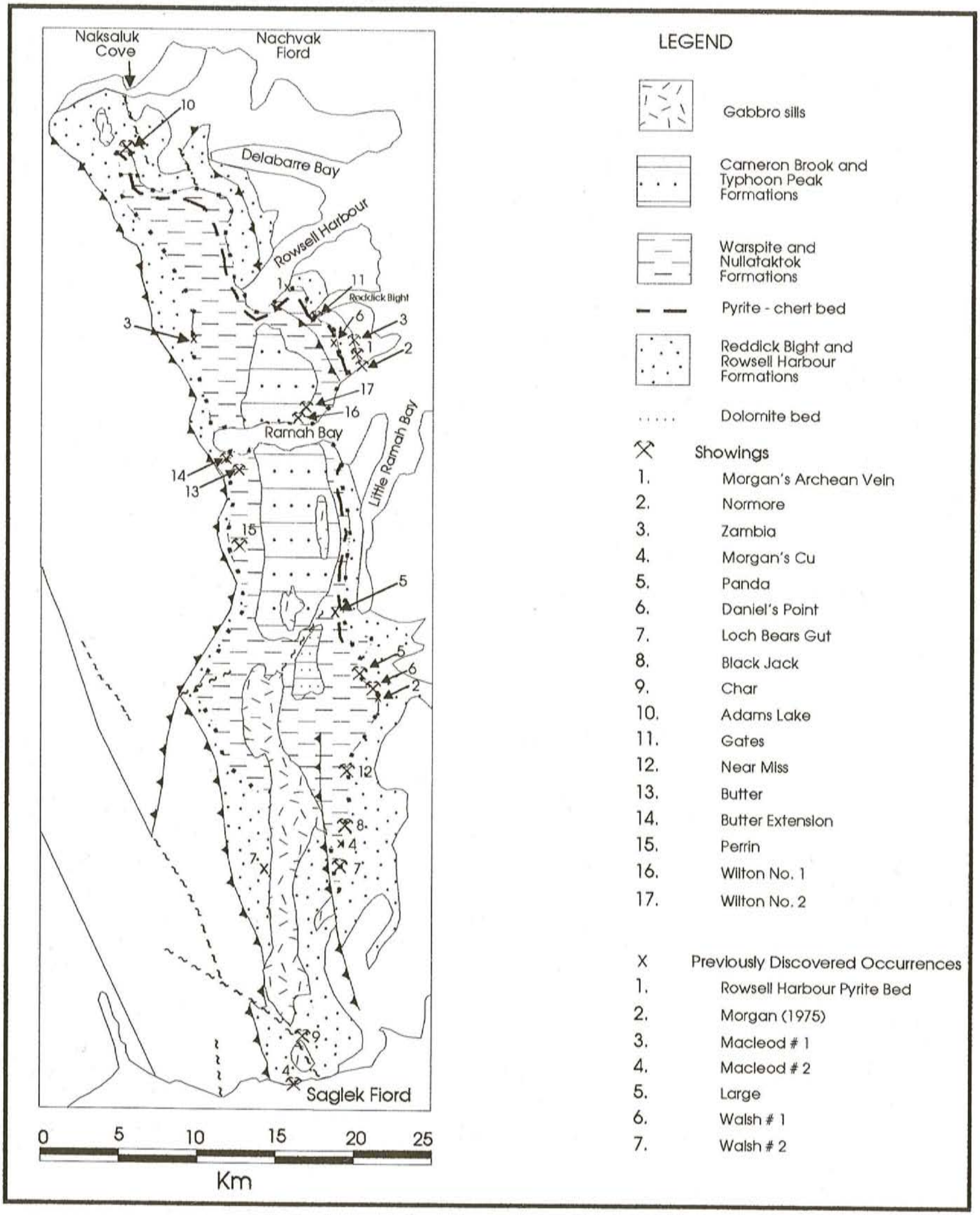

Figure 1. *Geological map of the Ramah Group, northern Labrador and locations of mineral occurrences (after Swinden et al., 1991). Geology from Morgan (1975) and some locations from MacLeod (1984, 1985) and Morgan (1975).*

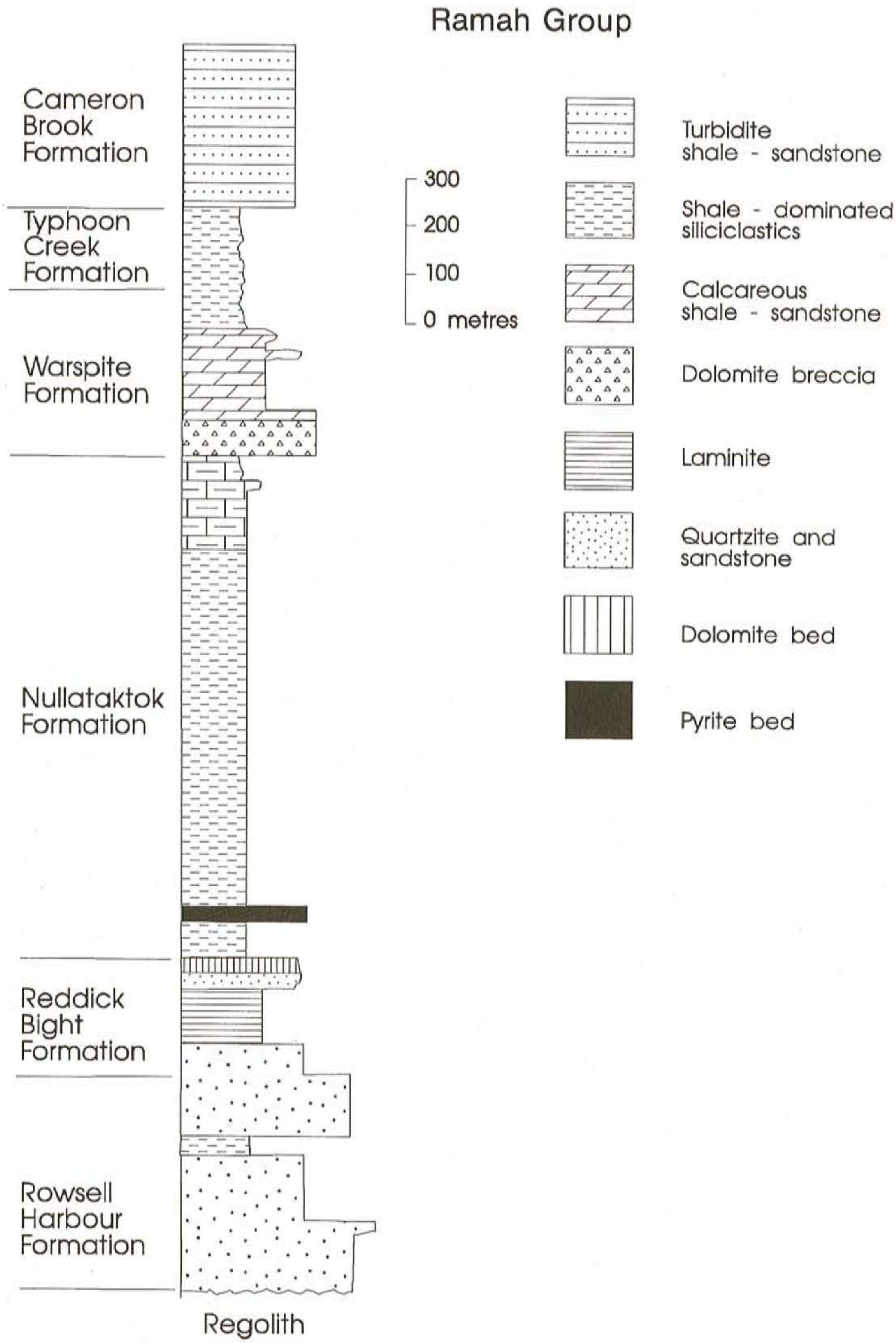

Figure 2. *Stratigraphic column for Ramah Group based on Knight and Morgan (1981) (after Swinden* et al., *1991).*

of the Ramah Group, studied Archean rocks that had been thrust over the Ramah Group north of Rowsell Harbour, and recognized several other west-dipping thrust faults.

Morgan (1975) carried out the most detailed mapping of the unit on a 1:50 000 scale. Smyth and Knight (1978) correlated the Ramah Group stratigraphy with that of the Mugford and Snyder groups. Knight and Morgan (1981) defined the stratigraphic nomenclature and suggested that the Ramah Group consists of two contrasting sequences, a lower shelf sequence (the Rowsell Harbour and Reddick Bight formations) and an upper basinal sequence (the four remaining formations). They also suggested that an intrabasinal high, the Reddick Arch, separated the depositional environment into north and south subbasins.

The group is exposed as a > 75-km-long and up to 16-km-wide, north- to north-northwest-trending, doubly plunging synclinorium (Knight and Morgan, 1981). The group lies in the Churchill Foreland Zone (Ermanovics *et al.*, 1989) of the Torngat Orogen (Hoffman, 1988). Calon and Jamison (1992) describe the Ramah Group as part of an east-verging fold-and-thrust belt on the Eastern Borderland of the Torngat Orogen.

The age of the Ramah Group has been defined as ca. 2000 Ma (Korstgard *et al.*, 1987) but has not been independently derived. Deposition of the Ramah Group predated greenschist- to granulite-facies metamorphism in the Churchill Foreland Zone (Ermanovics *et al.*, 1989). U–Pb zircon and monazite data (Bertrand *et al.*, 1990) indicate that this occurred before 1805 Ma. Bertrand *et al.* (1993) suggest that the Ramah Group was a platformal sequence deposited prior to subduction-related arc magmatism that they have dated (U–Pb zircon) at ca. 1881 Ma.

This study was carried out as part of a large-scale regional project examining the metallogenic potential of Lower Proterozoic supracrustal sequences developed on the Archean Nain craton in northern Labrador (Wilton and Phillips, 1992; Wilton *et al.*, 1993b). A preliminary report on the 1993 field work was presented by Wilton *et al.* (1993a).

PREVIOUS MINERAL EXPLORATION–EXPLOITATION

Maritime Archaic Indians made extensive use of the Nullataktok Formation chert horizon ca. 4000 years ago to fashion various implements (Gramly, 1978; Lazenby, 1980). The most extensive of the prehistoric workings are found in the centre of a cirque, located ~3 km southeast of the head of Reddick Bight, which forms the headwaters of what Gramly (1978) termed "Hilda's Creek". In this workshop the chert crops out on the floor of the cirque and scattered around the outcrop are very numerous naturally broken fragments and artifacts with various degrees of working (Plate 1). Gramly (*op. cit.*) estimates that there are over two million worked pieces of chert at this site.

At the beginning of the 20th century, mineral-exploration interest was drawn to the 3.3-m-thick outcrop of the Nullataktok Formation pyrite bed on the southeast side of Rowsell Harbour (Plate 2). Carlsson (1901) investigated the bed in a series of eight pits as a potential source of sulphur. Marsters (1902) conducted a thorough evaluation of the bed, which included the blasting of two drifts along the more promising pits. Both Carlsson (*op. cit.*) and Marsters (*op. cit.*) noted the presence of the prominent chert bed above the pyrite horizon. Assays of the pyrite revealed very low concentrations of base and precious metals.

Douglas and Milligan (*in* Douglas, 1953) re-sampled Marsters' (1902) trial pits and adits for Cu, Au and Ag but found that only the most easterly pit contained any Ag values (0.26 ppm), whereas the rest had no Ag or other metals. In a literature review on the pyrite bed at Rowsell Harbour, Fogwill (1966) postulated a syngenetic sedimentary origin for the bed that contrasted with the views of previous workers who preferred a replacement origin.

Blackwell (1976) reviewed the geology of the entire Ramah Group and completed detailed mapping and sampling of the pyrite horizon at Rowsell Harbour, Ramah Bay and Bears Gut. He found that the base-metal contents of the horizon were low and uneconomic, but that there seemed to be regional geochemical variations, which suggested deposition in separate sub-basins.

Morgan (1975) reported (1) the occurrence of quartz-vein hosted galena–sphalerite mineralization in the Archean basement on the north shore of Ramah Bay; (2) an occurrence of chalcopyrite in Rowsell Harbour Formation quartzite on the north shore of Saglek Fiord; and (3) sphalerite–galena–chalcopyrite mineralization in quartz veins cutting the Reddick Bight Formation dolomite member south of Little Ramah Bay. He also noted the presence of asbestos in an ultramafic sill in the Typhoon Peak Formation and several ultrabasic pods within the Archean gneiss east of the Ramah Group.

ESSO Minerals Ltd. (MacLeod, 1984) conducted stream-sediment surveys through the Ramah Group and defined three anomalous areas (A, B and C) and "one spurious anomalous area" (p. 17, MacLeod, *op cit.*–Area D). Area A extends for over 16.5 km along the western margin of the Ramah Group, north and south of the head of Ramah Bay, and was defined by seven samples with anomalous Cu, Zn and Ba. The largest anomaly was located 4 km north of the head of Ramah Bay (MacLeod, 1984).

Area B constitutes a 13-km-long belt of anomalous samples along the eastern margin of the Nullataktok Formation, from 3 km north to 10 km south of the head of Little Ramah Bay. The samples were anomalous in Pb with lesser Zn, Cu and Ba (MacLeod, 1984). The strongest anomaly (Pb and Zn) was defined 8 km south of the head of Little Ramah Bay and drained the area underlain by Morgan's (1975) sphalerite–galena–chalcopyrite occurrence to which MacLeod (1984) ascribed the anomaly.

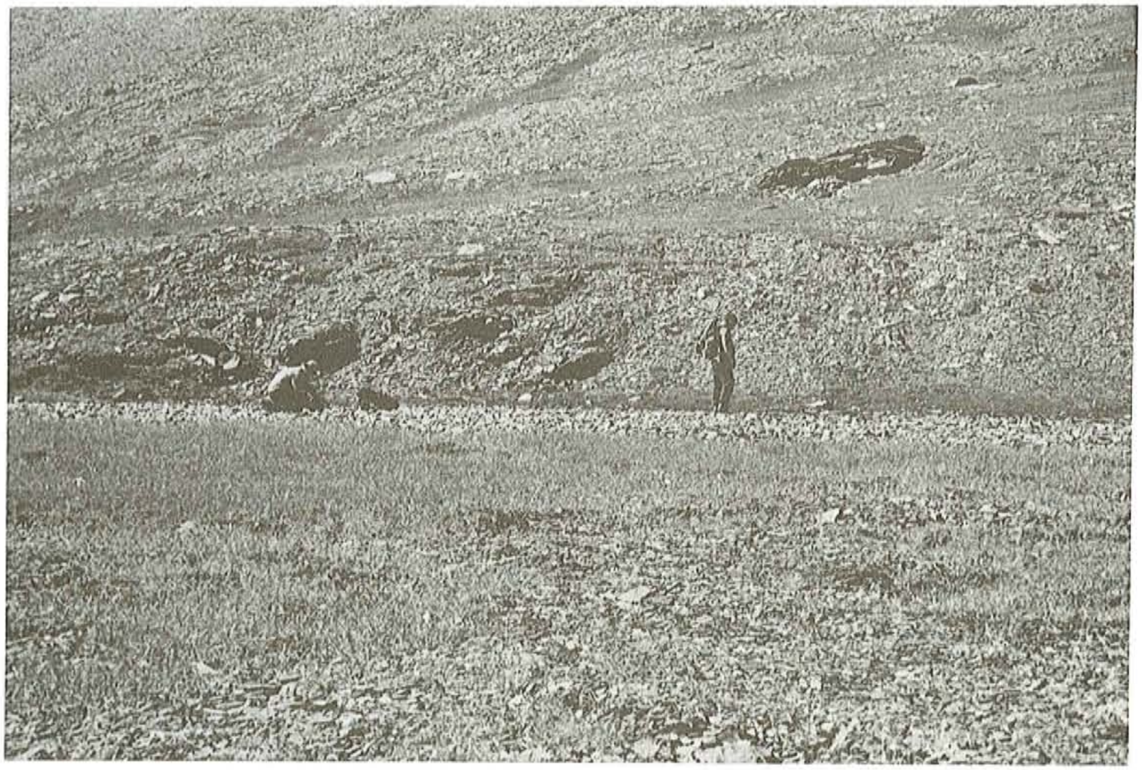

Plate 1. *Hilda ("Hilda's") Creek chert quarry site, chert outcrop is in middle background, chert debitage (worked and broken fragments) litter ground beneath Merlin and Andrew.*

Plate 2. *Rowsell Harbour pyrite and chert beds; the chert horizon is the resistant layer crossing plate near base of talus. The pyrite bed is well exposed beneath the chert to the left of the waterfall.*

Area C (MacLeod, 1984) consisted of two single anomalies of Ba (+Cu and Zn), and of Pb and Ba north of Saglek Fiord along the western margin of the Ramah Group. Area D is along the eastern edge of the Nullataktok Formation between Ramah Bay and Rowsell Harbour and was considered spurious on the basis that "weighted values are non anomalous" (p. 21, MacLeod, *op cit.*).

MacLeod (1984) also sampled various rocks in the Ramah Group and in particular the pyrite horizon. He suggested that the pyrite bed was probably an exhalative bed and that, although base-metal values were low, both the massive pyrite and Reddick Bight dolomite horizons might have some potential for hosting base-metal mineralization.

In a follow-up examination of the stream-sediment anomalies and more detailed evaluation of the lowermost portions of the Nullataktok Formation, ESSO Minerals Ltd geologists. (MacLeod, 1985) discovered small base-metal occurrences at the MacLeod #1 and #2, Large, Perrin and Walsh #1 and #2 Showings. MacLeod (1985) described (1) the MacLeod #1 and #2 occurrences as veinlets and disseminations, mainly of galena, in Reddick Bight dolomite, but with "no areal extent" (p. 16, MacLeod, *op. cit.*); (2) the Large occurrence as a chert (Nullataktok Formation) horizon with "minor brecciation and sphalerite–galena mineralization" (p. 40, MacLeod, *op. cit.*); (3) the Perrin occurrence as malachite and chalcopyrite in "an isolated quartz lense" (p. 16, MacLeod, *op. cit.*) within a gabbro sill; and (4) the Walsh #1 and #2 as sphalerite blebs in a chert breccia (Nullataktok Formation) and sphalerite in chloritic schist (Nullataktok Formation "volcanic unit" ?) float, respectively.

MacLeod (1985) considered that none of these occurrences had economic potential and proposed (p. 21, MacLeod, *op. cit.*) that "the geochemical anomalies detected last year can be explained by the presence of minor base metals at several locations in the Lower Nullataktok".

Based on the definition in a government survey (Geological Survey of Canada, 1987) of Pb, Zn, As and multi-element stream-sediment anomalies in areas draining the Ramah Group between Nachvak and Saglek fiords, Meyer and Dean (1988) carried out a follow-up lithogeochemical survey. They chip-sampled the Reddick Bight dolomite and Nullataktok chert and pyrite horizons, and noted the presence of pyrite together with ubiquitous quartz and carbonate veining in the dolomite.

In 1992, Falconbridge Nickel Mines Ltd. carried out a detailed examination of diabasic sills in the Typhoon Peak Formation for nickel and PGE potential (S. McLean, personal communication, 1993). The company currently holds a reserved area licence covering 440 claims over the Ramah Group between Ramah Bay and Saglek Fiord.

The present study was conducted in August 1993 from the MV Robert Bradford, a 55 foot longliner. The vessel served as a base from which a small inflatable boat was used to take crews ashore. The crews then conducted traverses through the Ramah Group, examining stratigraphy, re-examining and sampling known occurrences, and defining and sampling new mineral occurrences.

During this study, 21 new sulphide mineral occurrences, which range from indications to promising exploration targets, were found in the Ramah Group and underlying Archean basement. The most significant result of the 1993 field work was the discovery that sphalerite and/or galena are spread consistently throughout the 60 km outcrop of the Reddick Bight Formation dolomite (Wilton *et al.*, 1993a). Following release of the Wilton *et al.* (1993a) open-file report, numerous small claims were staked over showings and prospects described in the report.

METALLOGENY OF THE RAMAH GROUP AND ARCHEAN BASEMENT

ARCHEAN BASEMENT

The basement immediately below the Ramah Group consists of granitic gneiss, migmatite, granulite, mafic gneiss and metasediments (Knight and Morgan, 1976). Extensive regolithic weathering is developed in places on the Archean basement below the Ramah Group (Knight and Morgan, 1976, 1981).

These rocks were not examined in any detail for this study except on the northeast side of Ramah Bay, where Morgan (1975) reported a galena–sphalerite occurrence. At this locality, the contact between the Archean and the Rowsell Harbour quartzite is exposed in the bed of a small stream (Hilda's Creek) that flows south into Ramah Bay. The basement rock is predominantly a migmatitic metagranite. The contact with the Rowsell Harbour quartzite is difficult to discern as the two rocks have a strong resemblance.

Morgan's (1975) galena–sphalerite occurrence is incorrectly plotted on his published map; it actually occurs in the stream bed as opposed to 300 m north on the stream bank. The occurrence consists of a number of quartz vein/pods; the most significant is ~2 m long and up to 0.4 m wide. Intergrown with the quartz in the largest pod is massive galena (patches up to 40 by 12 cm) and sphalerite (Plate 3). The occurrences are open space fillings defined by intersection of primary and secondary fracture cleavage sets. The primary set trends approximately 154° and dips 83°E and the second trends 98° and dips 75°N. At the occurrence, the undeformed pods discontinuously distributed over a 10 m distance. Small galena-bearing quartz veins were found in the basement rocks 100 to 200 m east of the main occurrence.

This was the only occurrence examined within the Archean basement. Morgan (1975) reported ultramafic pods in the granitic gneisses; some of which contain asbestos.

The Rowsell Harbour Formation

This 350- to 470-m-thick unit (Knight and Morgan, 1981) is predominantly massive, coarse-grained quartz sandstone, or quartzite as designated by Morgan (1975). Excellent examples of trough crossbedding and ripple marks along bedding planes are typical (Plate 4). This unit also contains a thin, ≤ 10-m-thick, basaltic member, which is generally poorly exposed. The best exposures of the basalt found in this study are north of Morgan's Archean basement galena veins/pods, to the east of Bears Gut, and between Little Ramah Bay and Ramah Bay. At this latter outcrop, the basalt has well developed pillow forms with amygdules and glassy rims (Plate 5a). In the Bears Gut area, the basalt exhibits very deformed pillows (Plate 5b). Knight and Morgan (1981) suggest that the basalt is tholeiitic.

The quartzite hosts a 1.5-m-wide quartz vein with chalcopyrite, pyrite and malachite at the Normore Showing (Wilton *et al.*, 1993a), 200 m to the south-southwest of the Morgan (1975) basement galena occurrence. The Normore vein brecciated the host quartzite but is itself undeformed. There is minor sericite associated with the vein and the host quartzite contains abundant disseminated pyrite marginal to the vein.

The Zambia occurrence (Wilton *et al.*, 1993b) is located within a 10-m-thick exposure of the basalt member, 1 km north of Morgan's Archean galena occurrence. Mineralization consists of chalcopyrite blebs scattered through the middle part of the altered, amygdaloidal, basalt member where it is enriched in feldspar phenocrysts. Outcrop length is <15 m before becoming obscured by overburden.

Morgan's (1975) chalcopyrite showing on the north shore of Saglek Fiord consists of chalcopyrite and malachite fractures, up to 5 cm wide and 20 cm long, in Rowsell Harbour Formation quartzite.

South of Nachvak Fiord and inland from Naksaluk Cove, exposures of the quartzite exhibit a green colour along

Plate 3. *Morgan's (1975) galena–sphalerite vein/pod in Archean basement, north of Ramah Bay. The pod extends from the upper middle of the plate (above pen scale) down to the lower left-hand corner. Galena is present just above the pen and sphalerite occurs in lower left-hand embayed region. Note the primary set of fractures trending across upper portion of plate and secondary fractures parallel to pen.*

Plate 4. *Ripple marks in Rowsell Harbour Formation, Reddick Bight.*

bedding and joint planes that strongly resembles fuchsite (Cr-rich mica). Further work is in progress on samples of these green rocks, of quartzite from other locations in the unit, and of a hematitic conglomerate found at Naksaluk Cove to ascertain heavy-mineral detrital compositions.

The Reddick Bight Formation

This unit is up to 143 m thick consisting of a lower sequence of quartzites, sandstones, shales, laminites and a mud flow underlying an upper 4- to 17-m-thick dolomite member (Knight and Morgan, 1981). The dolomite is distinctive by virtue of its unique yellow colour and relatively resistant nature. Near the MacLeod #1 Showing, the lower quartzite grades up into the dolomite and contains dolomitic pods.

Attention was drawn to the dolomite member because of the presence of a secondary porosity as evidenced by large irregular voids filled with quartz and secondary dolomite, and locally calcite (Plate 6). In some cases, the void-fillings also contained significant sphalerite, galena and pyrite (Plate 7).

Wherever the secondary porosity is developed, graphite is present within the quartz cores, but base-metal sulphide mineralization is not always present. Carbon isotope analyses define $\delta^{13}C$ (relative to PDB) of -21.14 to -31.63 ‰ (Table 1) for samples of the graphite. Carbon, hydrogen and nitrogen (CHN) analyses indicate C contents of 51.6 to 75.8 wt percent (Table 1). Taken together, these data indicate that the graphite had a biological origin, most likely as some sort of bitumen.

Detailed descriptions of individual showings or occurrences are given in Wilton *et al.* (1993a), and for the sake of brevity only the most spectacular and/or distinctive examples of the base-metal sulphide mineralization from this unit are described here. Showing names are those assigned by Wilton *et al.* (1993a).

Panda Showing

This showing is contained within a >2.5-km-long continuous exposure of the dolomite member of the Reddick Bight Formation that is sandwiched between black quartzite and the overlying Nullataktok Formation chert horizon. Scattered throughout the >2.5 km exposure, the dolomite exhibits excellent secondary porosity together with minor sphalerite and galena and synsedimentary structures such as folding and autobrecciation.

At the showing, a >30 m length of dolomite contains sphalerite and galena intergrown with quartz, dolomite and calcite in secondary porosity spaces. The best mineralization occurs in the lower portions of the dolomite wherein sphalerite and galena locally account for up to 5 percent of the rock (Plate 8). Individual sphalerite patches vary up to 5 cm across.

A

B

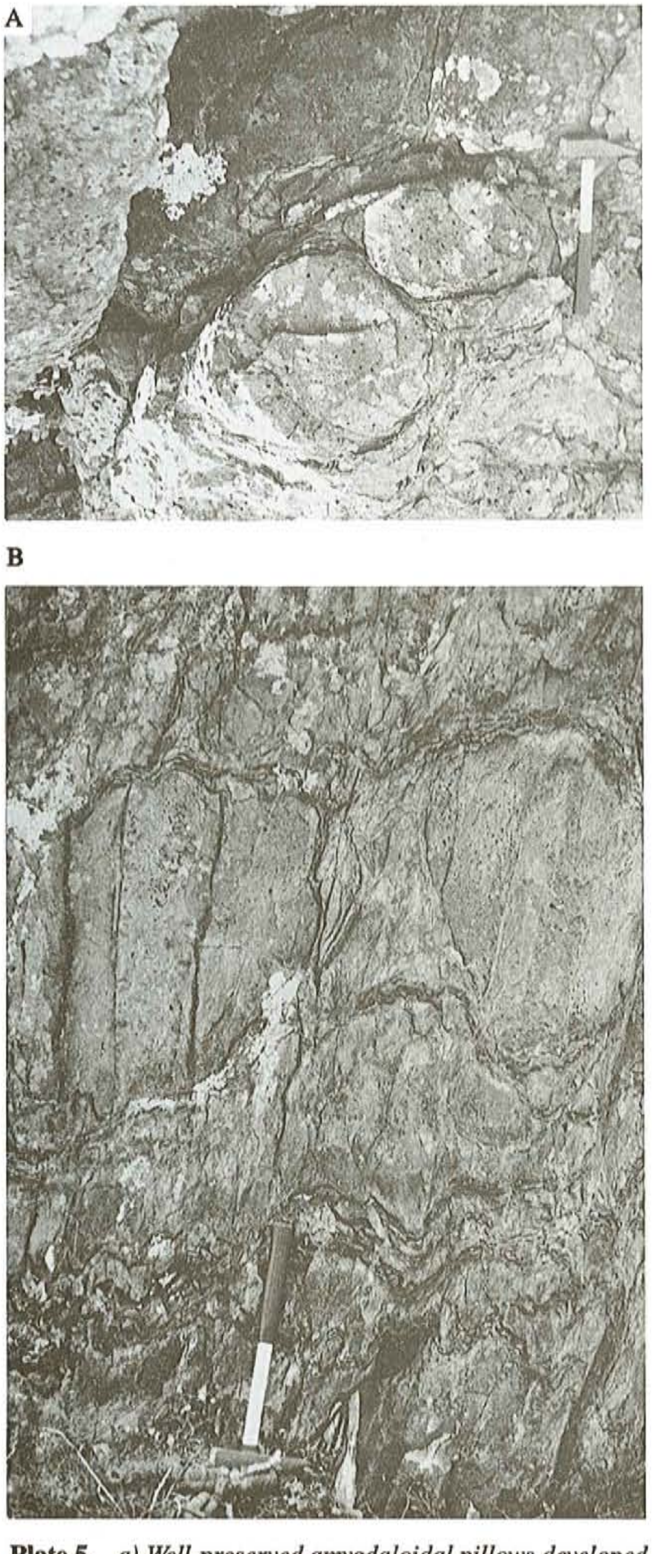

Plate 5. *a) Well-preserved amygdaloidal pillows developed in the Rowsell Harbour Formation basalt member. b) Highly deformed pillow lava in the Rowsell Harbour Formation basalt member; west of Bears Gut.*

The upper part of the dolomite bed tends to contain galena and pyrite with no sphalerite. Graphite is a common accessory mineral associated with the secondary dolomite.

Plate 6. *Secondary porosity developed in Reddick Bight Formation dolomite member. Large quartz-filled open space filling is in middle of plate and extends to upper right-hand edge, surrounding the quartz core are rims of darker coloured secondary dolomite.*

Plate 7. *Secondary porosity in Reddick Bight Formation dolomite member, near the Panda Showing. Small amounts of sphalerite occur in open space fillings above hammer head.*

Table 1. CHN ANALYSES (wt. percent) and $\delta^{13}C$(‰)

Sample	%C	%H	%N	^{13}C
W93-26B	75.8	0.51	0.88	-28.22
W93-26B	65.9	0.30	0.77	-28.22
W93-44A	51.6	0.00	0.74	-31.63
W93-44A	54.9	0.00	0.77	-31.63
W93-44A	59.9	0.00	0.89	-31.63
W93-39D	---	---	---	-21.14

---- = not analyzed

Three grab samples from this showing returned assays ranging up to 15.6 percent Zn and 1 percent Pb (Wilton *et*

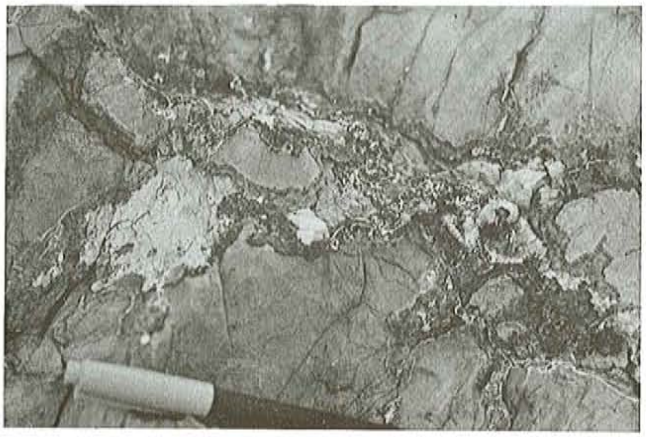

Plate 8. *Open space fillings in dolomite filled with central cores of calcite and quartz (white) surrounded by sphalerite and galena (black) and secondary dolomite.*

al., 1993a). Silver ranges from 0.4 to 1.4 g/t, and Cd from 330 to 370 ppm.

Daniel's Point Showing

This showing lies within the same ridge of dolomite as the Panda Showing and consists of a zone of increased secondary porosity and galena–sphalerite mineralization in the host dolomite. Morgan (1975) reported another showing 0.5 km and 60 m higher to the east-southeast of this occurrence on the same ridge. Morgan (p. 37) reported his occurrence as "thin veins of carbonate and quartz containing disseminated galena with minor sphalerite and chalcopyrite" in 10 m thick "replacement dolomite". Although Morgan's showing was not actually sampled, it is apparently the same as the Panda and Daniel's Point showings.

Loch Bears Gut Showing

This showing occurs within a stream bed 400 m south of the MacLeod # 2 Showing. Dolomite in the stream bed exhibits a secondary porosity filled with calcite, dolomite and/or quartz. Toward the stratigraphic top, within the stream bed, the dolomite changes from the typical light-yellow colour to a grey–black facies that contains sphalerite–galena–pyrite veins. These veins are almost pure sulphide and are subparallel to bedding but with vertical vein connections. The veins pinch and swell into pods up to 6 by 15 cm. The veins disappear laterally into the stream on either side and the entire dolomite bed is overlain by a thrust plane of friable, pyritiferous, Nullataktok Formation slate.

A galena-rich vein contained 3.3 percent Pb, 0.8 percent Zn and 7.2 g/t Ag. A sphalerite-rich vein assayed at 0.4 percent Pb, 12.6 percent Zn and 3.1 g/t Ag (Wilton *et al.*, 1993a).

Black Jack Showing

This occurrence is present within the basal part of the Reddick Bight Formation dolomite member. The main showing is a 1.45 by 0.4 by >0.45 m area composed predominantly of sphalerite and minor galena, with an outer quartz gangue surface (Plate 9); the outcrop is obscured by till and felsenmeer cover. The straw-brown-coloured dolomite host-rock exhibits well-developed secondary porosity, a coarse grain size, and extensive quartz veining. Other veins proximal to the showing appear to be composed of quartz, dolomite and calcite, with no base metals. Two grab samples from this showing assayed at 31.0 percent Zn, 14.9 g/t Ag and 17.8 percent Zn, 14.9 percent Pb, 40 g/t Ag (Wilton *et al.*, 1993a).

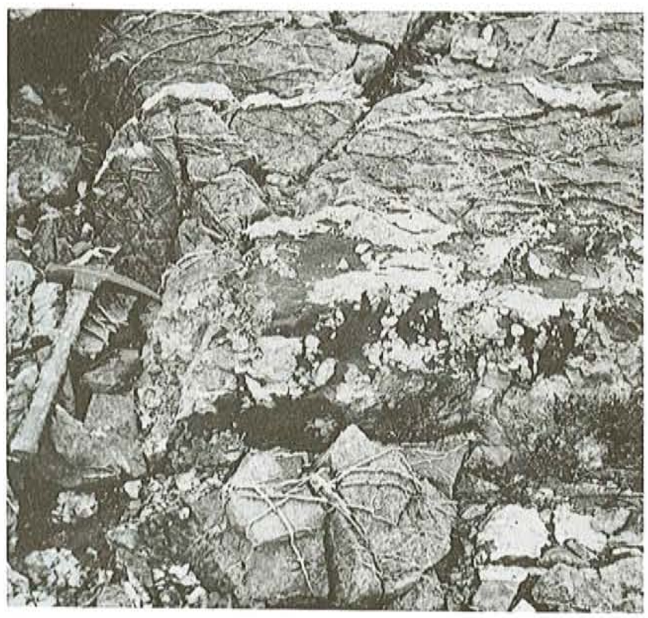

Plate 9. *Large pod of sphalerite (dark) and quartz (white) to right of hammer and extending to right-hand side at the Black Jack Showing.*

The Black Jack Showing is part of a zone of galena and sphalerite mineralization localized to the subcrop/outcrop surface exposure of the Reddick Bight dolomite member; that extends north–south along strike for at least 1 km. Other occurrences within this area can be classified into two subtypes of lead–zinc mineralization, *viz.* coatings and rims on small (0.5 to 1 cm thick) quartz veins, or, central masses in relatively thick (10 cm) vertical quartz/dolomite veins. The thicker veins display excellent growth textures of quartz and fine-grained secondary dolomite.

Char Showing

This occurrence is the most southerly example of sulphide mineralization found in the Reddick Bight Formation dolomite member and was found in a stream outcrop. The dolomite outcrop and subcrop extend for over 100 m to the south and 20 m to the north of the occurrence, although no other examples of sulphide mineralization were found on surface. The dolomite is deformed and recrystallized in this area and the showing consists of very rusty, deformed quartz-vein zones (Plate 10). The rusty zones are friable and gossanous and contain pyrite with lesser galena. There is a

Plate 10. *Galena-bearing quartz–calcite vein (below hammer) cutting Reddick Bight Formation dolomite member; Char Showing.*

Plate 11. *Thrust fault contact between Reddick Bight Formation dolomite and Nullataktok Formation pyritiferous shale (black). In the plane of the fault, the shale gouge contains dolomite boulders (light).*

vague secondary porosity present in the dolomite, but it is poorly preserved.

Nullataktok Formation

According to Knight and Morgan's (1981) stratigraphic column, this unit is 595 m thick with a lower 12 to 20 m unit of pyritiferous shale, a 350-m-thick main facies of 'varicoloured mudstone' (p. 325, Knight and Morgan, *op. cit.*) and an upper 220- to 250-m-thick sequence of calcareous and dolomitic mudstone. The varicoloured mudstone member is split into two parts by the 8- to 20-m-thick pyrite–chert bed, which occurs 60 m above the base of the mudstone member (*ibid.*).

Knight and Morgan (1981) define the thickness of the basal pyrite bed as 50 to 57 cm and the upper chert bed as 4.5 to 17 m. They also found that the pyrite bed dies out to the north in the Naksulak Cove area, and this is also the region of greatest chert thickness. During this study, the pyrite bed was found to be up to 3.3 m thick in places, such as at Rowsell Harbour.

Knight and Morgan (1981) report that the contact between the Reddick Bight Formation dolomite member and the Nullataktok Formation is sharp and indicative of rapid environmental change. In some areas, however, the contact acted as the decollement for thrust faulting, as evidenced at the Loch Bears Gut and Large showings. In a stream bed, south of the head of Delabarre Bay, the contact is demarked by a thrust fault wherein blocks of the dolomite are caught up in tectonically disturbed Nullataktok Formation shales (Plate 11). The dolomite blocks are internally cut by numerous quartz veins indicative of fluid movement, pre- or syn-thrusting.

As described above, the pyrite bed was the initial focus of mineral exploration in the Ramah Group. MacLeod (1985) and Swinden *et al.* (1991) subsequently suggested that the exploration target should be enlarged to include the whole Nullataktok Formation as a possible Sedimentary Exhalative (SEDEX) environment. The lowermost pyritiferous shale contains abundant disseminated pyrite, especially south of Delabarre Bay where native sulphur from present-day bacterial oxidation covers the surface of strongly pyritiferous shale gouge. Pyrite nodules, up to 10 by 2.5 cm, are also common in this member.

The pyrite bed is best exposed at Rowsell Harbour. Elsewhere, the bed is variably deformed, particularly on the western limb of the Ramah Group where the sulphide consists of recrystallized pyrrhotite with round host-rock inclusions.

The pyrite bed constitutes the Nearmiss Showing in a river bed west of Bears Gut. Stratigraphy at this occurrence consists of a diabase sill, metamorphosed sedimentary rocks, chert and massive sulphide from top to bottom. The massive sulphide layer is gossanous with a maximum observed thickness of ~ 35 cm and consists mainly of pyrrhotite, minor chalcopyrite and rounded quartz blebs.

Assays of samples from the Near Miss Showing revealed Cu (0.08 percent), Ni (470 ppm) and Au (15 ppb) contents, which were higher than those for other samples analyzed by Wilton *et al.* (1993b). The assays were also different from those reported by others from the pyrite bed, supporting Blackwell's (1976) contention that the pyrite bed differs geochemically throughout the area. More likely however, trace-element contents at this occurrence may reflect the influence of the diabase sill.

Adams Lake Showing

This occurrence consists of chert float found about 10 m upstream from the top of the Reddick Bight Formation dolomite on the side of a steep cliff. No sign of the pyrite bed was observed in this area (also noted by Morgan, 1975, and Knight and Morgan, 1981), but the chert bed was easily located. Scree and felsenmeer cover the base of the chert bed, thus the presence of the pyrite bed may be obscured. The mineralization consists of massive sphalerite and pyrite within brecciated black and white chert.

The Reddick Bight dolomite has a lesser degree of secondary porosity here than as seen to the south. Because this occurrence is float of obviously local derivation, the relationship, if any, to the dolomite is not visible. Therefore, this occurrence may represent a completely different massive sulphide-type of mineralization or it might be part of the dolomite system.

Assay results for the float indicate up to 10.8 percent Zn, 0.1 percent Pb, 3 g/t Ag (Wilton *et al.*, 1993b). The Adams Lake float also contains anomalous values of As (73.6 ppm), Au (13 ppb), Cd (130 ppm) and Ni (51 ppm), therefore this area is clearly responsible for the stream-water and sediment anomalies reported by McConnell and Honorvar (1993).

Smaller occurrences in the chert bed include the Gates, Large and Walsh #1 showings. The Gates Showing consists of small patches of sphalerite along fractures in chert outcrops within the stream flowing into Reddick Bight. The Large Showing is a 3- to 5-m-thick zone of brecciated chert cemented by dolomite and overlain by Nullataktok Formation slate. The lower contact is not visible as the subcrop is buried by till but the dolomite bed is present in the sequence as it crops out below in the stream bed. Pyrite and lesser sphalerite are present in the secondary dolomite cement. At the Walsh #1 Showing, mineralization was found as float consisting of galena, sphalerite and pyrite in a brecciated and re-cemented chert.

Warspite Formation

The Warspite Formation is a 110- to 165-m-thick unit with lower, up to 90-m-thick, dolomitic beds and an upper sequence of argillite–mudstone–dolomite (Knight and Morgan, 1981). The brown-weathering lower dolomite is massive and compact, and, unlike the Reddick Bight Formation dolomite, contains no secondary porosity. Soft-sediment deformation features such as flame structures and synsedimentary faults are typical of laminated portions of the dolomite.

The only mineral occurrences found were quartz veins at the Wilton #1 and #2 showings, which contain malachite–chalcopyrite and galena, respectively. The sparse nature of mineralization is not surprising given the massive, impermeable nature of the dolomite in this unit. Plate 12 shows the vein at the Wilton #2 occurrence.

Typhoon Peak Formation

As described by Knight and Morgan (1981), this 85- to 130-m thick unit is poorly exposed as thin recessive units between voluminous diabasic to gabbroic sills. The formation consists of slates, with lesser sandstone and limestone (*ibid.*). Thin, ≤ 10-cm-thick, grey metavolcanic layers were found 3.5 km southwest of the head of Reddick Bight.

Plate 12. *Folded galena-bearing quartz vein at the Wilton #2 Showing.*

The slate, where exposed, is moderately pyritiferous with some pyrite cubes up to 5 cm across. Fibrous pressure shadows around large pyrite cubes and evidence of rotation of some cubes indicate that sulphide growth predated deformation.

Cameron Brook Formation

This 200-m-thick sequence of turbiditic greywackes (Knight and Morgan, 1981) was not examined during this study, however, Morgan (1975) reported pyrite and rusty-weathering zones.

Diabasic–Gabbroic Sills

These sills are generally diabasic, but a sill extending from near the Large Showing south to Loch Bears Gut Showing has an ultramafic core. The sills cut both the Nullataktok and Typhoon Peak formations. Some sills contain minor disseminations of pyrrhotite and pyrite (± chalcopyrite), which were apparently syngenetic, but no appreciable sulphide concentrations have yet been discovered. Epigenetic quartz-vein-hosted sulphide occurrences have been found in the sills, as described below.

Butter Showing

At this showing, the host rocks are Nullataktok slates and a 8-m-thick diabase sill. Mineralization consists of chalcopyrite, pyrrhotite, and pyrite (coated in most cases by a malachite) within quartz veins that cut the slate. The quartz veins vary in thickness from 30 to 60 cm and do not penetrate the slates for more than 30 cm. Assay values of 0.5 percent Cu, 3.1 g/t Ag, and 15 ppm Co have been reported by Wilton *et al.* (1993a).

Other vein occurrences include the Butter Extension, a 0.4-m-wide quartz vein with chalcopyrite and malachite staining cutting a diabase sill 250 m northwest of the Butter Showing, and the Perrin Showing, where a 1.5-m-wide quartz vein with up to 3 percent chalcopyrite cuts a diabase sill. South of Naksaluk Cove, diabase sills are cut by thin shears filled with brown-weathering dolomite and minor pyrite.

Near the Char Showing, a bed of Reddick Bight Formation dolomite, proximal to a sill, is cut by late fractures containing pyrrhotite, NiS_2 (vaesite) and complex nickel arsenides. Seemingly, this occurrence represents mobilization of components from the sill.

DISCUSSION

The historic target for exploration in the Ramah Group was the supposedly exhalative pyrite bed and associated chert horizon in the Nullataktok Formation. The principal rationale for this interest was the SEDEX-style depositional and tectonic environment of the formation and the presence of widespread base-metal anomalies as indicated by regional geochemical surveys. Results from previous and current examinations of these horizons have, however, been uniformly disappointing in terms of base-metal grades.

The 1993 field work has defined an important new exploration target for Pb and Zn mineralization in the form of the Reddick Bight Formation dolomite member where it exhibits secondary porosity. The recognition of the base-metal contents in that unit also explains the regional stream-sediment geochemical anomalies.

Wherever this unit was examined, at least traces of Zn–Pb sulphide were discovered; such evaluations being necessarily restricted to surface exposures. The dolomite horizon was examined solely on the limbs of the synclinorium and hence there may be structurally thickened mineralized zones in hinges. Also, in some areas, such as the east side of Little Ramah Bay, the dolomite is inaccessible in cliff faces.

Wilton *et al.'s* (1993a) preliminary genetic model for the origin of these dolomite-hosted showings is that they represent Lower Proterozoic Mississippi Valley Type occurrences (cf. Anderson and MacQueen, 1988). Such a model is supported by (1) the restriction of mineralization to a dolomite horizon, (2) the mineralogy of the sulphides, (3) the restriction of mineralization to zones of secondary porosity with secondary dolomite and calcite, (4) ubiquitous graphite, which presumably represents metamorphosed organic material (5) the geochemical composition of the sulphides with elevated Cd and nil Cu, (6) the lack of any visible relationship to magmatic rocks, and (7) textural relationships, including colloformal sphalerite.

In some of the occurrences, galena and sphalerite were remobilized into planar quartz veins, which suggests that initial sulphide deposition in the secondary porosity pre-dated deformation.

Although base-metal sulphide showings are predominantly concentrated in the Reddick Bight Formation dolomite, minor vein-hosted occurrences are present in the basement, Rowsell Harbour, Nullataktok and Warspite formations, and diabase sills. The relatively small size of these occurrences suggests that fluid flow was concentrated in the dolomite, but also that the hydrothermal fluids coursed through impermeable beds above and below the dolomite. Determining the ultimate origin of the fluids, whether they were derived from the basinal portions of the Ramah Group, the shelf portions of the Ramah Group, or even the basement, awaits the results of detailed geochemical and isotopic studies now underway.

CONCLUSIONS

Sulphide mineralization in the Ramah Group can be subdivided into four principle episodes:

1) syngenetic deposition of the Nullataktok Formation pyrite–chert bed together with concretionary deposition of pyrite in the Nullataktok and Typhoon Peak Formations slate–shales;

2) minor sulphide mineralization associated with gabbroic to diabasic sills; these sills may have geochemically modified the pyrite beds as at the Near Miss Showing;

3) epigenetic galena–sphalerite and pyrite mineralization filling secondary porosity in the Reddick Bight Formation dolomite and vein-hosted chalcopyrite-pyrite, galena or sphalerite occurrences in basement, Rowsell Harbour Formation, Nullataktok Formation, Warspite Formation and diabase–gabbro sill rocks, and

4) late pyrrhotite, nickel sulphide and nickel arsenide mobilization from diabase sills into Reddick Bight Formation dolomite.

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