32. INVESTIGATION OF BASE METAL MINERALIZATION IN PROTEROZOIC METASEDIMENTS, MELVILLE PENINSULA, DISTRICT OF FRANKLIN

Project 750051

E.M. Cameron
Resource Geophysics and Geochemistry Division

Cameron, E.M., Investigation of base metal mineralization in Proterozoic metasediments, Melville Peninsula, District of Franklin; in Current Research, Part A, Geol. Surv. Can., Paper 79-1A, p. 187-196, 1979.

Abstract

In 1977 a National Geochemical Reconnaissance survey that consisted of sampling lake sediments and waters was carried out over the southern part of Melville Peninsula, District of Franklin. Among the more interesting features of the data were extensive, strong and coincident Zn and Ni anomalies. These are principally associated with paragneiss of the lower Proterozoic Penrhyn Group and occur throughout the outcrop area of this group.

A brief study of a number of the anomalous areas was made in August, 1978. This relied principally on sampling of surface waters, which were then analyzed in a field laboratory, to identify, more precisely, mineralized ground.

This work has shown that there is widespread Zn- and Ni-bearing mineralization in sulphidic, and often graphitic, paragneiss and schist. These metals are present as sphalerite and pentlandite. Lesser amounts of Cu also occur and Pb, Ag and Au were found locally. Recent oxidation of the base metal sulphides has been intense and has removed all but traces of these minerals from the surface. This makes evaluation of the mineralization difficult, but no bodies of obvious economic interest were seen in the limited area examined.

The extent of the anomalies suggests that there was a major influx of base metals into this Proterozoic basin, which forms part of the Foxe Fold Belt. The rocks of the belt on Melville Peninsula and Baffin Island appear to have been deposited in an intracratonic rift. Intracratonic rift basins were the locus for important sediment-hosted base metal mineralization during the Proterozoic. There is some evidence to suggest that Zn, where present in such basins, has the most extensive primary distribution of any of the base metals. The identification of Zn-rich strata may, therefore, provide the key for more detailed exploration for base metal targets within the Foxe Fold Belt.

Introduction

In 1977 a National Geochemical Reconnaissance lake sediment and water survey was carried out in 30 000 km^2 of Melville Peninsula (Geological Survey of Canada, 1978a, 1978b). This region (Fig. 32.1) is underlain by Archean rocks, mainly granites and granitic gneisses, and by lower Proterozoic (Aphebian) metasediments, the Penrhyn Group.

Collectively, the Melville Peninsula lake sediments contain high levels of a number of elements, compared to sample sets previously collected from other large regions of the Shield. This may be illustrated by comparing median and 95 percentile data for this region with similar data for the Nonacho Belt (Hornbrook et al., 1976a, 1976b, 1976c). The latter region, bounded by latitudes 60° and 63° and by longitudes 108° and 110°, has a broadly similar geological setting of an Aphebian metasedimentary belt enclosed within Archean granitic rocks. The comparison (Table 32.1) shows that, at the median level, Mn, Fe, Co, Ni, Cu, Zn, Pb and U are greater in the Melville samples by a factor ranging from 1.6 to 6.5. Of these, Mn, Fe and U are not notably enriched at the 95 percentile level in the Melville samples, but Co, Ni, Zn, Pb, plus Ag and As are. The 95 percentile provides a measure of element levels reached by the more anomalous samples in each area.

To examine more closely the distribution of selected elements in the Melville samples, the data have been grouped in terms of the dominant lithology of the lake catchment area (Table 32.2). The latter information was derived from detailed (1:50 000) geological maps. For all elements listed in this table the median concentrations are reasonably similar for all lithologies. For some of the elements, the 95 percentiles are also reasonably similar from rock type to rock type. In these cases the ratio of the 95 percentile to the median is mostly in the range 2 to 3. Other elements show exceptions to this, notably Zn and Ni in lake sediments associated with paragneiss and Ni with metaquartzites. These have 95 percentile/median ratios in the range of 5 to 8, indicating that strong anomalies exist, relative to regional background. These are the most obvious targets for detailed investigation.

Some qualification should be given of the above discussion. Firstly, the detailed geological mapping used to construct Table 32.2, mainly covers the Proterozoic fold belt. Elsewhere in the geochemical survey area interesting anomalies that are not reflected in this table occur in the Archean. Secondly, subtle geochemical anomalies may often disclose mineralized targets. For instance, lake sediment anomalies may be weaker in the alkaline surface environment of carbonate terrane.

On the basis of the data given in Table 32.2 it was decided to investigate the Zn and Ni anomalies associated with paragneiss of the Penrhyn Group. Zn and Ni anomalies are associated with this lithology throughout the Penrhyn Group, but field work was largely confined to map area 46N/1, reasonably close to the base at Repulse Bay, with lesser amounts of work carried out in areas 46O/2 and 46O/4. Field work was carried out over a period of two weeks during August, 1978.

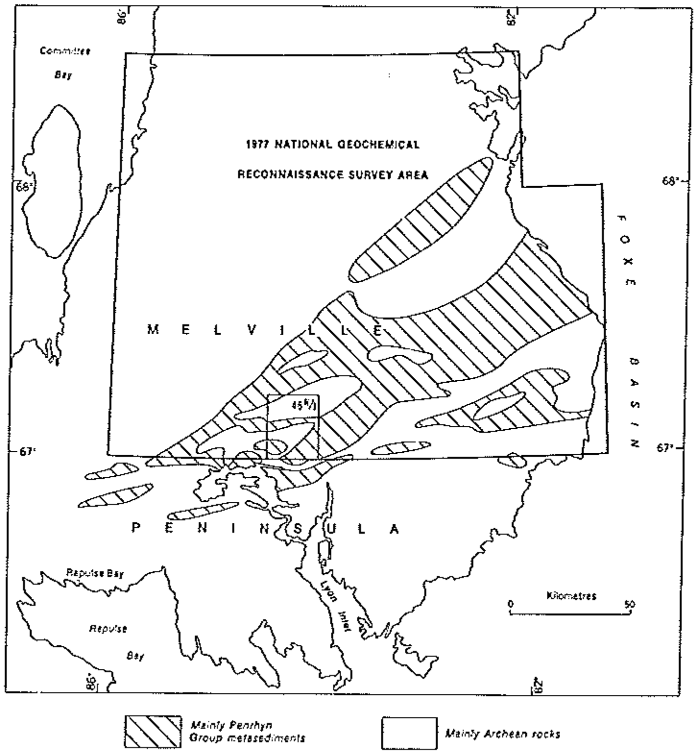


Figure 32.1. *Location map, Melville Peninsula.*

Geology

The first comprehensive account of the geology of the region was by Heywood (1967). Using this as a framework, much detailed mapping has since been carried out by the Geological Survey of Canada. The Proterozoic rocks, which form part of the Foxe Fold Belt (Jackson and Taylor, 1972), have been mapped by T. Gordon, J.R. Henderson, I. Hutcheon, A.N. LeCheminant, A.V. Okulitch and J.E. Reesor. This work has been described in a series of 1:50 000 maps and in reports by Reesor, 1972, 1974; Reesor et al., 1975; and Okulitch et al., 1977, 1978. The following summary of the geology is based on these maps and reports and refers principally to that part of the fold belt near longitude 84°.

The Penrhyn Group rests unconformably on an Archean basement composed mainly of granitoid gneiss and foliated granite. The basal Penrhyn consists of a thin orthoquartzite and a thin rusty schist. A possible metaregolith and an amphibolite have been recognized in places. These are succeeded by marble and biotite-quartz-feldspar paragneiss and schist. Above this is calc-silicate gneiss with marble, schist and paragneiss. At the highest observed levels are biotite-quartz-plagioclase schist and quartzite. Much of this sequence appears to be sulphidic, giving rise to rusty weathering rocks. In the lower part of the succession sulphidic, graphitic metasediments are common. Folding and metamorphism has made it difficult to determine stratigraphic thicknesses.

Two major episodes of folding of the Penrhyn rocks along east-northeast axes have produced broad, doubly plunging anticlinal zones of basement with narrow, tight synclinal in folds of Penrhyn Group rocks.

The Penrhyn Group has been metamorphosed to upper amphibolite grade. Foliated pretectonic or syntectonic granitic rocks, including abundant pegmatites, intrude the Penrhyn Group. Migmatites developed in the paragneiss suggest that the granites were, in part, derived from the metasediments. Metamorphism of the Penrhyn ended at about 1700 Ma and the metasediments were intruded by massive, posttectonic granites with an age of approximately 1600 Ma.

Exploration activity

The only major search for base metals in the area was by Aquitaine Company of Canada Ltd. during 1970-1972. The company carried out airborne electromagnetic and magnetic surveys, then ground follow-up comprising geological, V.L.F., magnetic and geochemical soil surveys. Shallow drilling was carried out at one location (the DUC claim group). A description of the work is given in assessment reports available from the Department of Indian and Northern Affairs, Ottawa.

Numerous targets were identified, principally within the graphitic and sulphidic Penrhyn metasediments, but disappointing results were obtained from surface outcrops and drilling on the DUC zone. This drilling showed that the graphitic biotite paragneiss had abundant pyrrhotite and pyrite, with inconspicuous sphalerite and minor chalcopyrite. Analysis indicated that the principal base metal is Zn with lesser Ni, Cu and Mo. For instance, the richest section of core analyzed, 44-48 feet from DUC Number 2, contained 8% Zn, 1850 ppm Ni, 700 ppm Cu, 295 ppm Mo and 75 ppm Pb.

Clearly, the Penrhyn Group is difficult terrane for base metal exploration. The widespread distribution of graphite and pyrrhotite causes a multitude of geophysical targets with Zn-sulphide mineralization being, in itself, a nonconductor. Soil geochemistry is not an appropriate exploration method for mineralization whose principal components are Zn and Ni. These elements are generally not retained in the permafrost soils overlying mineralization, unless buffered by carbonate minerals. Indeed it has been shown (Cameron, 1977a, 1977b) that mobile base metals may actually be at their lowest level in the soils overlying the higher grades of mineralization, because of the acidic conditions caused by sulphide oxidation.

Approach to follow-up of lake sediment anomalies

The approach taken to follow-up is determined by the mobility in the surface environment of the northern Shield of the elements found in base metal mineralization. The order, from most to least mobile, has been estimated as: Zn=Ni >Cu, >Fe,>As,>Ag,>Pb,>Hg,>Au (Cameron, 1977a, 1977b). The elements with the greatest mobilities, such as Zn, are removed from surface rocks, and soils. They are carried away in the drainage waters and eventually precipitate in the sediments of the lakes. For example, in following up a Zn anomaly in lake sediments, this element is measured in waters collected up-drainage from the anomaly. Once the source has been defined within a few hundred metres, soils may be collected and analyzed for the less mobile elements present in the mineralization. If immobile elements are absent in the mineralization, pinpointing the target is more difficult, but may be done by sampling seeps and pools of surface water.

The initial step in Melville Peninsula field investigations was to carry out detailed sampling of lake waters over Penrhyn Group rocks. This was done over all such terrane in map area 46N/1 (Fig. 32.1) and in parts of 46O/2 and 46O/4. The waters were obtained using a helicopter-borne sampling system (Cameron, 1978). This allows rapid rates of collection, in this case 30-40 lakes per hour, using a Bell 206-B helicopter. On the basis of analyses for "total" heavy metals in a field laboratory, more detailed water and soil sampling was then carried out.

Analysis

In the field laboratory the waters were analyzed for "total" heavy metals, pH and conductivity. The heavy metal test, which principally measures Zn, is the dithizone method using Bloom's buffer. The detection limit of 1 ppb was more than adequate for the relatively high threshold (compared to other northern waters) of 10 ppb Zn.

Table 32.1

Comparison of lake sediment data from National Geochemical Reconnaissance operations in Nonacho Area, N.W.T. (2688 samples) and Melville Peninsula, N.W.T. (2185 samples)

ELEMENT	MEDIAN (PPM)			95% PERCENTILE (PPM)		
	NONACHO	MELVILLE	RATIO MELVILLE/ NONACHO	NONACHO	MELVILLE	RATIO MELVILLE/ NONACHO
Mn	260	415.	1.6	1680.	1400.	0.8
Fe	1.35%	4.0%	3.0	6.8%	9.4%	1.4
Co	6.	17.	2.8	14.	38.	2.7
Ni	8.	52.	6.5	25.	126.	5.0
Cu	26.	82.	3.2	74.	196.	2.6
Zn	90.	148.	1.6	178.	325.	1.8
As	2.	1.5	0.7	5.	14.5	2.9
Mo	5.	4.	0.8	17.	13.	0.8
Ag	<0.2	<0.2	-	<0.2	0.5	>2.5
Hg	40.	40.	1.0	100.	80.	0.8
Pb	3.	17.	5.7	9.	46.	5.1
U	8.6	18.4	2.1	50.3	58.7	1.2
L.O.I.	36.9%	10.4%	0.3	67.2%	29.0%	0.4

Table 32.2

Lake sediment data for selected elements in terms of dominant lithology of lake drainage basins based on 1:50 000 geological maps of N.T.S. sheets
46N 1, 2, 3, 4, 7, 8, 9; 46O 1-16; 46P 3-6, 11-13; 47A 3

		ARCHEAN	APHEBIAN			
		GRANITE/ GNEISS	PARAGNEISS	QUARTZITE	MARBLE	GRANITE
NUMBER OF SAMPLES		510	197	48	206	82
Fe %	MEDIAN	4.70	3.60	3.90	3.75	3.90
	95 PERCENTILE	10.00	9.80	11.60	8.50	8.95
	RATIO 95/M	2.1	2.7	3.0	2.3	2.3
Ni ppm	MEDIAN	52.	58.	65.	58.	54.
	95 PERCENTILE	100.	290.	510.	200.	168.
	RATIO 95/M	1.9	5.0	7.8	3.4	3.1
Cu ppm	MEDIAN	92.	72.	84.	70.	66.
	95 PERCENTILE	190.	174.	295.	154.	166.
	RATIO 95/M	2.1	2.4	3.5	2.2	2.5
Zn ppm	MEDIAN	174.	158.	132.	168.	136.
	95 PERCENTILE	300.	1200.	345.	725.	615.
	RATIO 95/M	1.7	7.6	2.6	4.3	4.5
Pb ppm	MEDIAN	23.	14.	14.	16.	20.
	95 PERCENTILE	50.	43.	57.	56.	57.
	RATIO 95/M	2.2	3.1	4.1	3.5	2.85
U ppm	MEDIAN	20.3	19.1	21.1	21.3	27.4
	95 PERCENTILE	57.0	58.0	98.2	65.1	75.1
	RATIO 95/M	2.8	3.0	4.7	3.1	2.7

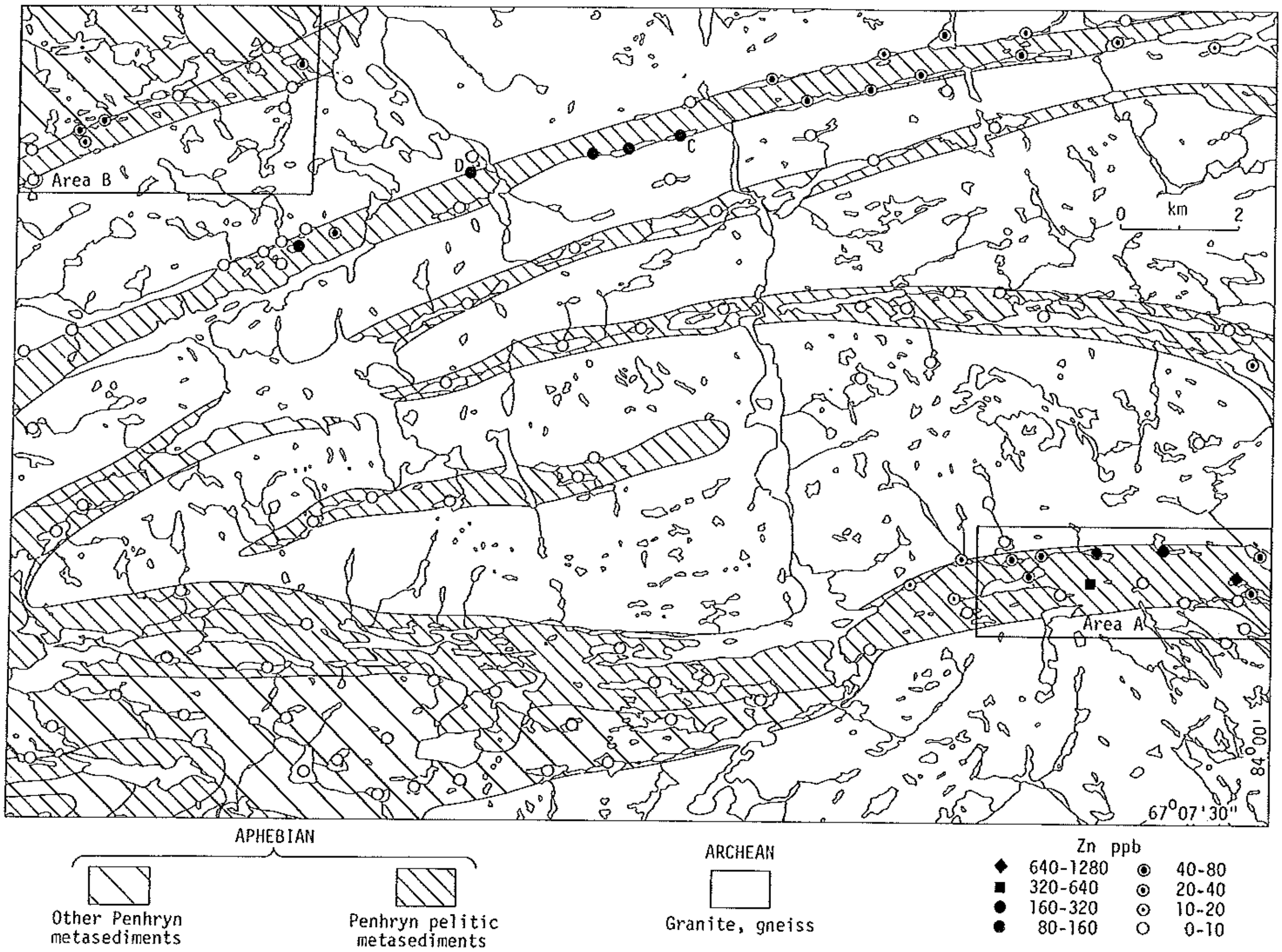


Figure 32.2. *Zinc in lake waters, north half, N.T.S. Sheet 46N/1. Geology after Reesor et al., 1976.*

The waters were reanalyzed in Ottawa for Zn, Cu and Ni. This was done by direct aspiration into an atomic absorption spectrometer for waters with >10 ppb of the element. Waters with less than this amount were treated with A.P.D.C.-M.I.B.K., to chelate and extract the heavy metals. This provided a detection limit of 1 ppb for each of the three elements. Following previous practice (Cameron, 1978), samples were not acidified or filtered, but analysis, in Ottawa, was completed within a month of sampling. Only the Ottawa analyses are reported in this paper.

Soil samples were sieved to minus 80- mesh, then extracted with a hot mixture of 1 part concentrated HCl to 3 parts concentrated HNO_3. Rocks were extracted by heating with HF, taken to dryness, then again heated with a mixture of 2 parts concentrated $HClO_4$ and 5 parts concentrated HNO_3. The soil and rock extracts were then analyzed by atomic absorption spectrometry for Zn, Cu, Fe, Mn, Ni, Pb and Ag using background correction for the latter three elements. Soil samples to be analyzed for Au were pre-concentrated by fire assay method, then extracted and measured by atomic absorption spectrometry.

Results

To illustrate the results, data for Zn in lake waters from the northern half of map area 46N/1 are shown in Figure 32.2 and the histograms of Zn, Cu, Ni, pH and specific conductivity for these waters are given in Figure 32.3. A correlation matrix for the same samples is listed in Table 32.3. These illustrations show that the most common type of lake water is weakly acidic, has a low content of total dissolved solids, and contains less than 2.5 ppb of each of the three base metals. These are typical northern Shield waters from unmineralized terrane, similar to those described from the northern part of the Slave Geological Province (Cameron, 1978).

As well as these "unmineralized" waters there are waters with anomalous levels of one or more base metals, and commonly with an acidic pH. These waters owe their distinctive composition to the present day oxidation of nearby base metal mineralization. They show a strong positive correlation between the elements Zn and Cu and Ni and between these variables and water acidity. Specific conductivity has a U-shaped distribution when plotted against pH. Higher conductivities occur in the acidic waters and also in the weakly alkaline waters. This results in weaker correlation between the base metals and specific conductivity than between these metals and pH.

The mineralized lake waters overlying the Penrhyn Group are much more anomalous in Zn than are similar waters from the northern part of the Slave Province (Cameron, 1978). In the latter region, lake waters with high contents of Zn (i.e. 40 ppb or more) are rare. These are

Table 32.3

Correlation matrix for 113 lake water samples, north half of N.T.S. Sheet 46N/1

	Log Zn	Log Cu	Log Ni	pH
Log Zn				
Log Cu	.79**			
Log Ni	.83**	.60**		
pH	-.69**	-.51**	-.80**	
Spec. Cond.	.25*	.41**	.15	.12

**Indicates significant correlation at 99.9% level
*at 99.5% level

usually found close (<2 km) to exposed massive sulphide bodies. The 95 percentile for Zn in a 1218 sample lake water survey from the northern Slave Province was only 2.8 ppb. By contrast, the data shown in Figures 32.2 and 32.3 have a 95 percentile of 193 ppb and waters with 40 ppb or more are relatively common. The markedly anomalous nature of Zn in many lake sediments collected over the Penrhyn Group discussed in the Introduction, may thus be related to a high flux of dissolved Zn passing into the lake systems.

For Ni, suitable comparative data are sparse, but this element is also believed to be strongly anomalous in many of the waters collected from above Penrhyn Group rocks. For Cu, the differences from previous data sets are less marked.

The 10 ppb level for Zn is a convenient threshold (Fig. 32.3) for distinguishing anomalous waters. In the northern half of map area 46N/1 such waters are confined to three principal areas (Fig. 32.2): the two most northerly infolds of Penrhyn rocks and the easternmost portion of the southern infold. The airborne surveys carried out by Aquitaine Company of Canada Ltd. found conductive zones throughout all areas of Penrhyn rocks exposed within map area 46N/1. Gossanous soils and outcrop are also ubiquitous in those parts of this area that are underlain by the Penrhyn Group. But there is no apparent correlation between the relative distinctiveness of gossanous zones and the geochemical results. For the area shown in Figure 32.2, the most extensive and colourful gossans are in the western half of the most southerly Penrhyn infold. This area has low contents of base metals in lake waters.

For two of the more anomalous areas shown in Figure 32.2 more detailed information is given below.

Area A (Fig. 32.4)

This area is underlain by a steeply dipping infold of Penrhyn metasediments, enclosed by Archean granitic rocks. There is a thin border of metaquartzites along the flanks of the infold. Within this is paragneiss with some marble beds. The Proterozoic succession appears to have been derived from a miogeoclinal-type succession containing shale, silt, quartzite and carbonate. Pegmatites are common and generally lie parallel to the strike of the metasediments.

The zone of base metal enrichment, as indicated by the water data, has a stratigraphic trend. Samples from lakes within the Archean or from the marginal zone of the infold, have background levels of base metals (Fig. 32.4). It is the central, more pelitic, metasediments that contain the highest content of base metals. Within this zone, the mineralization is widely distributed. This is apparent from the large number of lakes and ponds with anomalous waters, many of which have a local drainage basin.

The Penrhyn rocks within the mineralized area are well exposed. Most have a rusty weathering surface, the product of the oxidation of sulphides. In most cases, the amount of sulphide present in rock samples, or likely to have been present prior to oxidation, is small. But there are also zones where sulphide has been a major or a dominant component. When exposed, these zones appear as limonitic rock, with residual iron sulphides. Pyrite is most resistant to weathering and is commonly seen as prominent crystals standing out from the weathered surface. Pyrrhotite is less commonly found in surface exposures. Only trace amounts of sphalerite, chalcopyrite and pentlandite were observed.

It is inferred that sulphide zones underlie marshy depressions that contain mineralized seeps. The soils of the depressions are unusually soft, with a high water content and the principal vegetation is a black moss. The mineralized nature of the waters may be immediately determined in the field by their low pH and high conductivity. On analysis they show a strongly anomalous base metal content. Two such seeps are shown in Figure 32.4 and may be identified by their Zn contents of 2204 ppb and 2245 ppb. The waters also contain substantial levels of Ni and Cu. By comparison, the principal seep above the Agricola Lake massive sulphide body in the Slave Province (Cameron, 1978, Fig. 5) was measured as 1080 ppb Zn, 867 ppb Cu, 23 ppb Ni, pH 3.4.

Soil samples were also taken from these seep areas (Table 32.4). Sample 784041 is adjacent to the seep containing 2204 ppb Zn (Fig. 32.4). The low pH of this residual soil sample indicates that any anomalous levels of Zn, Ni or Cu

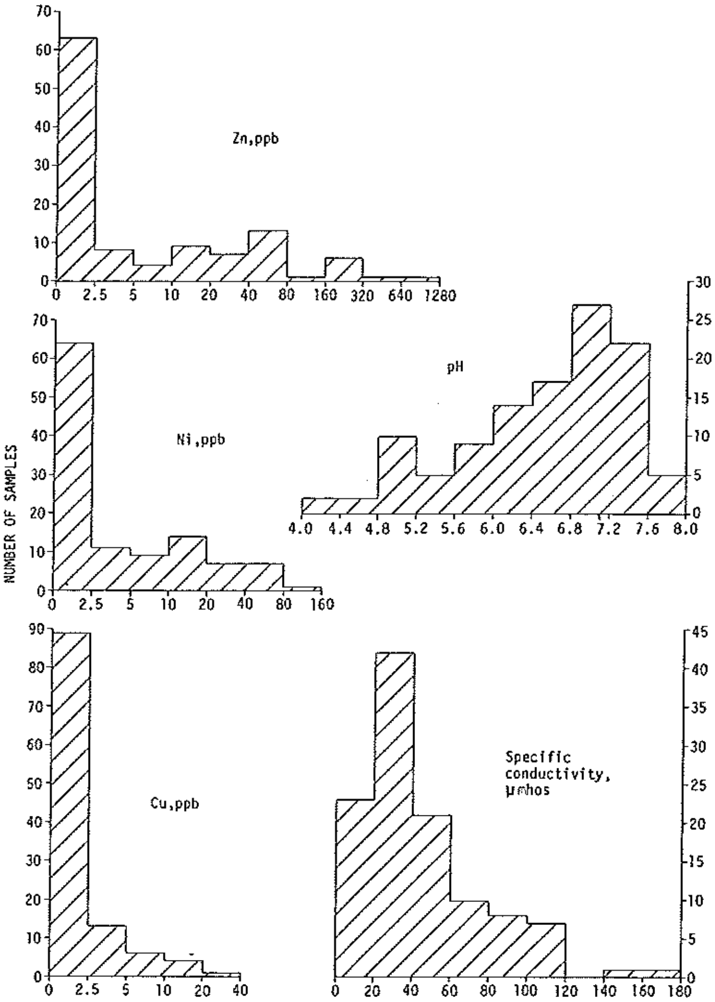


Figure 32.3. Histograms for Zn, Ni, Cu, pH and specific conductivity. Lake waters from north half, N.T.S. Sheet 46N/1.

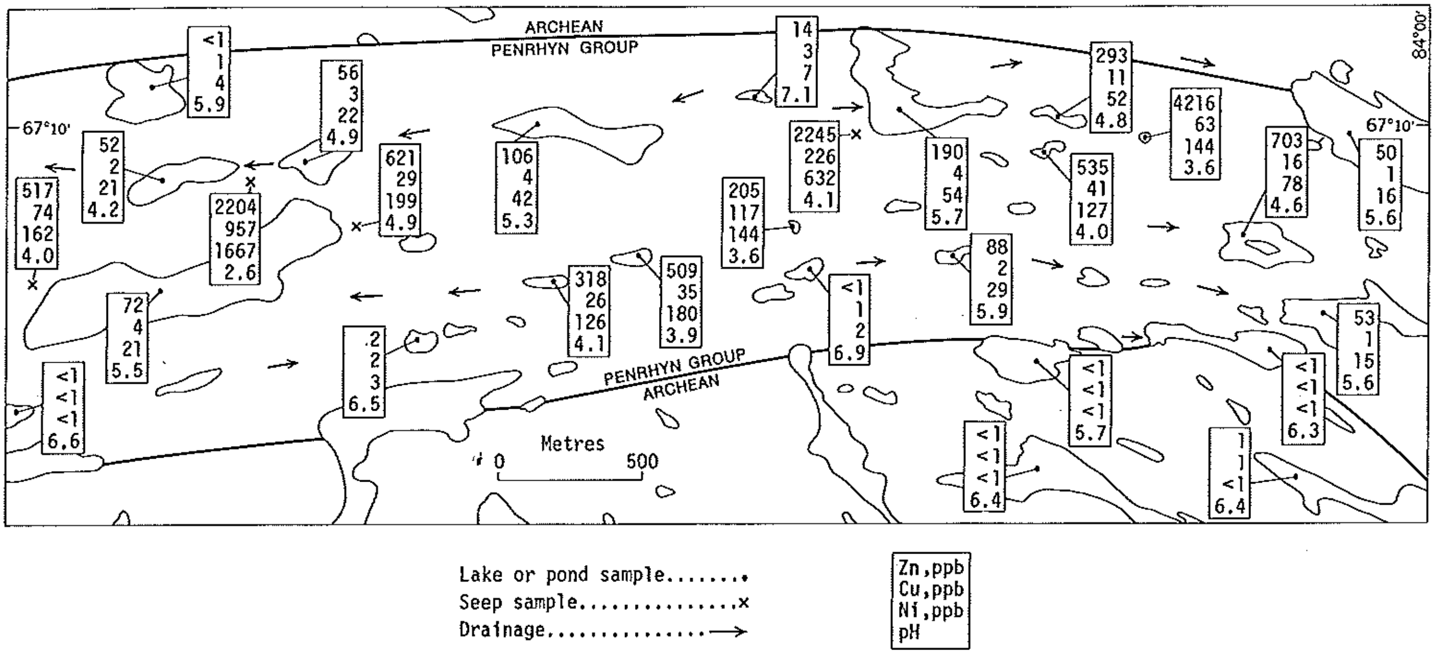


Figure 32.4. Lake and pond water analyses, Area A (see Fig. 32.2). Geology after Reesor et al., 1976.

present in the parent material would not have been retained in the soils. This is confirmed by the actual data for these elements. But also, the soil does not contain anomalous levels of the immobile elements Pb, Ag and Au. This implies that these are not present in the Zn-, Ni- and Cu-bearing mineralization from which the seep waters were derived.

Soil sample 784056 (Table 32.4) was taken near the pond measuring 4216 ppb Zn (Fig. 32.4). It is similar to the soil described above, but at this location the mineralization does appear to contain Ag and Au.

In summary, the area of Penrhyn metasediments shown in Figure 32.4 contains several zones in which sulphides, including base metal sulphides, are believed to have been a major or dominant component. At the surface they appear as limonitic rocks, with residual iron sulphides, or as topographic depressions containing base metal-rich seep waters. Water and soil analyses indicate that Zn is the dominant base metal in the mineralization and is accompanied by lesser amounts of Ni and Cu. The elements Ag and Au are present in one zone. Because of soil or blockfield cover no attempt was made to estimate the dimensions of the zones, but it is doubtful if any exceed a maximum length of 100 m and width of 10 m. For all zones observed, long dimensions are parallel to the strike of the metasedimentary rocks.

Area B (Fig. 32.5)

This area is principally underlain by steeply dipping Penrhyn Group metasediments. Relief is low and much of the area drains to the north through a chain of three larger lakes in the northwest quadrant of the area. The central lake of this chain was sampled during the 1977 geochemical reconnaissance and was the only lake sampled within the area shown in Figure 32.5. The sediment sample from this lake (773008, Table 32.4) is strongly anomalous in a number of elements.

The detailed lake water sampling shows that waters from Archean terrane and over much of the Penrhyn contain background concentrations of base metals. But the waters are strongly anomalous, particularly in Zn, along the part of the Penrhyn succession composed of paragneiss and schist. These mineralized waters flow into the chain of three lakes noted above and cause their waters to be moderately anomalous. The strongly anomalous nature of lake sediment sample 773008 undoubtedly derives from this source. It is a good example of a lake sediment anomaly displaced from source. The data listed in Figure 32.5 illustrate the complementary nature of lake sediment reconnaissance and lake water follow-up.

A soil sampling traverse was made across strike, near the apparent source of the base metals (Fig. 32.6). Much of this traverse is over ground that slopes gently to the north and is underlain by paragneiss and schist. In places these rocks are graphitic and sulphidic. The paragneiss appears to have been derived from a succession containing a good deal of quartzite. At the northern end of this traverse is a contact with marble. Along and to the south of this contact is low ground carpeted by black moss and the site of a seep.

The soils along the part of the traverse that overlies the paragneiss/schist are acidic, in the range pH 2.8-4.2. Any anomalous levels of Zn and Ni in the rocks would not have survived in these acid soils. But the single soil sample taken over the marble has a slightly alkaline pH and with this, strongly anomalous levels of Zn and Ni. Surface waters were taken from the north and the south sides of the seep area. Sample 783314 (Table 32.5) was taken at 5 m along traverse 77 (Fig. 32.6) and sample 783316 at 15 m. Sample 783316 is acidic and very strongly anomalous in Zn and Ni. Sample 783314 is faintly alkaline and, while still significantly anomalous in Zn and Ni, is less so than the other sample. In the pool of water from which sample 783314 was collected there is a light coloured, flocculent precipitate.

Table 32.4

Soil and lake sediment analyses (ppm)

SAMPLE		Zn	Ni	Cu	Pb	Ag	Au
Soil	784014	435	48	740	15600	12.1	0.16
Soil	784041	35	9	59	15	0.8	0.01
Soil	784056	170	4	275	45	11.8	0.23
Lake Sediment	773008	3400	530	295	39	0.1	-

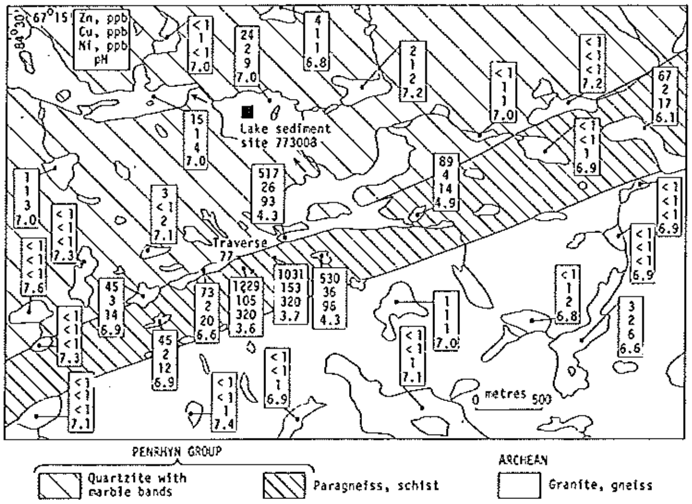


Figure 32.5. Lake water analyses, Area B (see Fig. 32.2). Geology after Reesor et al., 1976.

These water data complement the soil data. Over the paragneiss, the oxidation of sulphides has created an acidic environment in which Zn and Ni are released into surface waters. At the contact with the marbles, the slightly alkaline environment allowed these elements to remain in the soils and/or to precipitate from the surface waters.

The seep area near the paragneiss/marble contact is believed to overlie the maximum development of base metal mineralization at this locality. This is suggested by the extreme values of Zn and Ni in sample 783316. The maximum width of this seep zone is 15 m and the feature can be traced for several hundred metres.

From the water data it is clear that some Cu accompanies the Zn and Ni in the mineralization. The soils along this traverse show low values for other metals: <5-41 ppm Pb, 0.5-2.5 ppm Ag and <5-5 ppb Au. On a similar soil traverse 200 m to the west, one sample contains 20 ppm Ag, indicating that significant amounts of this metal may be present locally.

Other areas

Several other localities were examined in similar fashion to areas A and B. These are located in other parts of map area 46N/1 and in map areas 46O/2 and 46O/4. At all of these localities, the source of anomalous levels of base metals in lake sediments and waters is similar to that found in areas A and B: Zn-rich mineralized zones in sulphidic and frequently graphitic Penrhyn metasediments. The only additional feature found in these areas that supplements the information given above is a soil sample (784014, Table 32.4) rich in Pb, Ag and Au collected near a Zn, Ni, Cu-rich seep (sample 783123, Table 32.5). The U.T.M. co-ordinates of this sample are 376600 E, 7456650 N, Zone 17. This indicates that Pb may also be present locally in the mineralization.

Examination of sulphides

Preliminary mineralogical examination has been carried out of polished sections of sulphide-rich paragneiss. One is an outcrop sample from area A, close to soil sample 784056. The U.T.M. co-ordinates are: 629000E, 7429000N, Zone 16. The other samples are core from the DUC 7 and DUC 8 drillholes. The U.T.M. co-ordinates of both holes are: 407900E, 7487850N, Zone 17. Sulphide minerals occur in the samples as veins or coarse segregations.

The major sulphide present is pyrrhotite. All samples contain lesser and variable amounts of sphalerite, pentlandite, chalcopyrite and pyrite. The latter commonly occurs as veins in pyrrhotite, while pentlandite occurs as blebs exsolved within pyrrhotite. Some chalcopyrite is present as blebs exsolved within sphalerite. Grains that have been tentatively identified as silver pentlandite occur in many of the samples. They are often present within chalcopyrite. Microprobe analyses indicate that Ni is held as a solid solution impurity in pyrrhotite and pyrite. The most readily oxidized sulphide mineral is pyrrhotite. The alteration of pyrrhotite is illustrated in Figure 32.7, a polished section of the outcrop sample.

Interpretation of results

The results presented above show that sulphide lenses containing base metals are an important feature of paragneiss and schist of the Penrhyn Group. The units in which they occur have a generally sulphidic character and are variably graphitic. The apparent disposition of individual lenses and the trend of geochemical anomalies along strike suggest that the mineralization is stratiform. Surface water analysis indicates that Zn is the most abundant base metal with lesser amounts of Ni and minor Cu. This order of abundance is confirmed by examination of the limited amount of sulphide material available.

The Zn and Ni anomalies in lake sediments and waters are stronger and more extensive than have been measured over mineralized Archean greenstone belts in the northern Shield. This might suggest that the total amount of these metals, present as sulphides, is greater in the Penrhyn Group than in a similar volume of rock from a greenstone belt. But before this conclusion is reached some consideration must be given to whether the Penrhyn mineralization is more susceptible to weathering. Pyrrhotite is abundant and is readily oxidized, thus contributing to the acidity of the surface environment; the graphitic gneiss, being fissile, readily allows water infiltration; and the presence of the conductor, graphite, may facilitate electrochemical reactions. This question can only be answered by examining unweathered drill core of the mineralized zones and their host rocks.

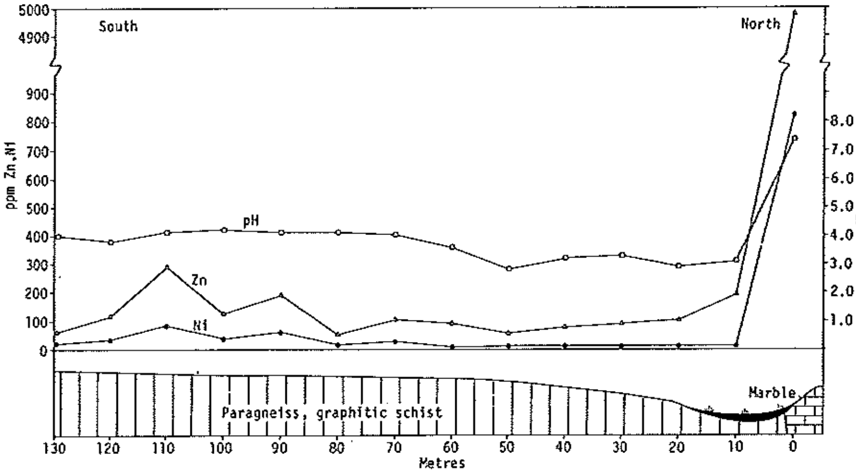
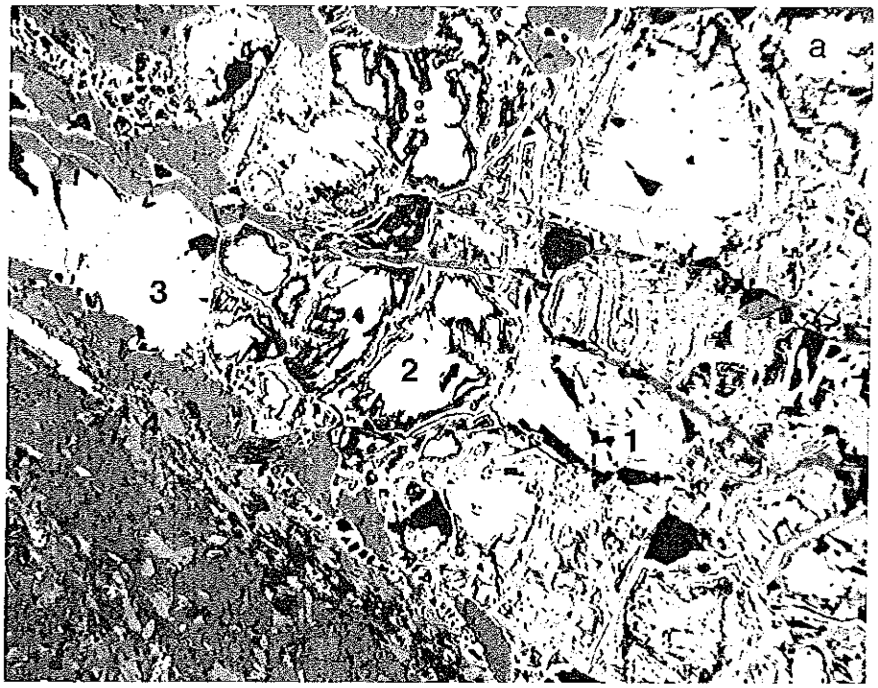


Figure 32.6. Soil traverse 77. For location see Figure 32.5.

Metallogenic Considerations

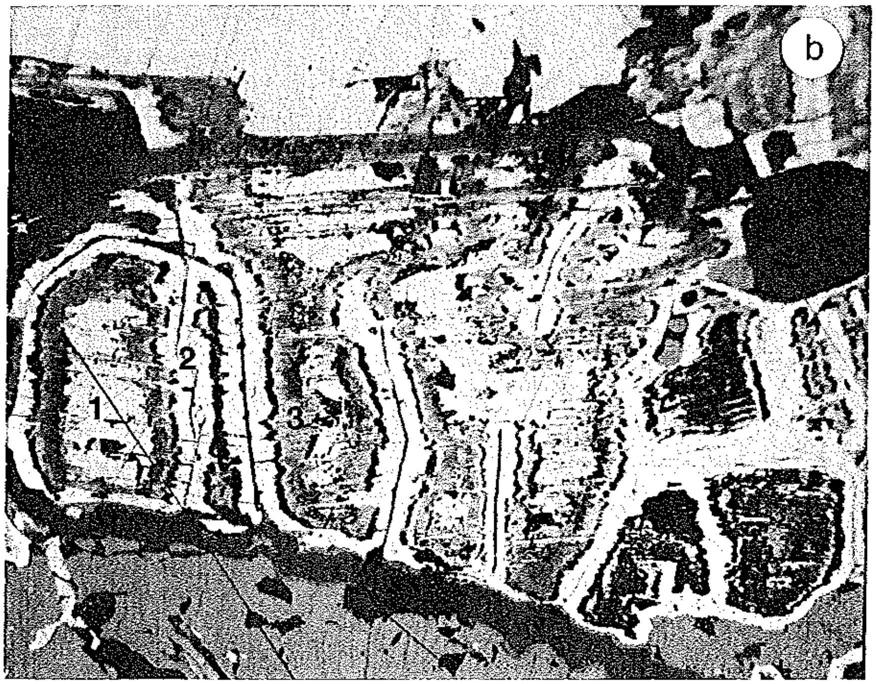
Many of the major sediment-hosted stratiform base metal deposits of the world are of Proterozoic age. The development of plate tectonic concepts has allowed the distribution of these deposits in time and space to be better understood. In particular, they are known to be associated with intracratonic and cratonic margin rifts (Burke and Dewey, 1973; Vokes, 1973; Dunnet, 1976; Sawkins, 1976a, 1976b; Raybould, 1978). The rifts may have allowed metal from a deep source to reach the surface or, alternatively, allowed the escape of heat to provide the driving force for near-surface redistribution of metals. The deposits occur in miogeoclinal sedimentary sequences and there is often some development of basaltic lavas, characteristic of a tensional environment.

One of the most striking examples of the clustering of stratiform deposits around a plume-generated triple rift junction is at Mount Isa, Australia (Dunnet, 1976). These deposits occur near the intersection of the Paradise aulocogen with the geosyncline that developed along the margin of the Proterozoic craton. Known Cu deposits are restricted to a zone at the craton boundary marked by a thick sequence of flood basalts and which is above the hypothetical position of the mantle plume. The Pb-Zn deposits have a wider geographic range. To the north, the McArthur Zn-Pb-Ag deposit occurs in the Batten Trough, a rift similar to the Paradise aulocogen, with a thickened platformal sequence of sediments, but removed from the craton boundary. Other important Proterozoic stratiform deposits in a broadly similar environment include Sullivan, British Columbia (Kanasewich et al., 1968; Burke and Dewey, 1973); the Copperbelt of Zambia and Zaire (Burke and Dewey, 1973; Raybould, 1978); and Whitepine, Michigan (Sawkins, 1976b).



a. General view, 2.2 x 1.7 mm

1. *Sphalerite with exsolved chalcopyrite*
2. *Pyrrhotite remnant and alteration products*
3. *Pyrite*
4. *Graphite in matrix*



b. Detail of pyrrhotite weathering 0.55 x 0.43 mm

1. *Pyrrhotite remnant*
2. *Marcasite*
3. *Intermediate phase (Einaudi, 1971; Fleet, 1978)*

Figure 32.7. Textures in partially oxidized sample of sulphide-bearing paragneiss.

Table 32.5

Surface water analyses
(metals in ppb; specific conductivity as µmhos)

SAMPLE	Zn	Ni	Cu	pH	Specific Conductivity
783123	3280	706	353	2.8	837
783314	461	217	8	7.7	440
783316	11030	2540	500	3.1	1170

The rocks of the Foxe Fold Belt on Melville Peninsula and Baffin Island appear to have been deposited within an intracratonic rift trough. The miogeoclinal-type succession rests on Archean basement and similar Archean rocks flank the belt on either side. There is an apparent thinning of the succession and a narrowing of the belt westwards. On Baffin Island, the succession – here comprising the Piling Group (Jackson and Taylor, 1972) – is essentially similar to that of the Penrhyn Group. Quartzite, at the base, is succeeded by marble and this by deeply weathered, rusty, graphitic and sulphidic gneiss, up to 300 m thick. This, in turn, is overlain by a thick sequence of metagreywacke and metasiltstone. Important differences from the Penrhyn are a 60 m thick zone of oxide-facies iron formation at the same stratigraphic level as the rusty gneiss and also metabasalt, up to 760 m thick, in the basal part of the metagreywacke unit. That portion of the fold belt on Baffin Island may have lain closer to the cratonic margin or mantle plume. Mapping on Baffin Island, presently being carried out by G.D. Jackson and W.C. Morgan, should provide important evidence on the tectonic setting of the belt.

The work of Lambert and Scott (1973) and Lambert (1976) on the Middle Proterozoic McArthur Zn-Pb-Ag deposit of Australia has given valuable insight into the extensive regional distribution of metals in a mineralized shale unit. The deposit occurs near the base of a 500 m section of pyritic, carbonaceous and tuffaceous shale. The 200 million ton deposit, grading 10% Zn, 4% Pb, 45 ppm Ag, extends over 1.5 km^2 with an average thickness of 55 m. At this horizon base metal mineralization is regionally widespread, but consists mainly of Zn. Thus the W-Fold prospect, 8 km distant, contains 2-3% Zn but only minor galena. Pyritic shales as far as 20 km from the deposit may contain 0.5% Zn and 0.1% Pb. Silver has a very limited dispersion halo around the deposit. Nickel is low in both ore and host shale. Pyrite is abundant throughout the shale member and reaches 20-30% Fe near the deposit.

Conclusions

The Zn and Ni lake sediment anomalies outlined during the 1977 geochemical reconnaissance of the Penrhyn Group have been related to base metal-bearing, stratiform mineralization in sulphidic paragneiss and schist. Zinc is the principal base metal and is accompanied by lesser amounts of Ni and minor Cu. These elements are present as sphalerite, pentlandite and chalcopyrite. Also occurring locally are Pb, Ag and Au. Because of intensive surface oxidation, all but traces of the base metal sulphides have been removed from the surface exposures examined.

The markedly anomalous nature of the Zn and Ni lake sediment anomalies is directly related to the high flux of these metals entering the lake basins in solution. This, in turn, may imply a particularly high total content of Zn and Ni in sulphide form in the paragneiss, compared to, say, an equivalent volume of rock in a mineralized Archean greenstone belt. However, an alternative explanation is that the Penrhyn mineralization is more susceptible to weathering. An answer to this question, providing perspective on the economic significance of the mineralization, can only be obtained by subsurface sampling.

There can be no doubt however, about the extensive nature of the base metal mineralization within the Penrhyn basin. Although the follow-up work was carried out over a limited area, the coincidence of strong Zn and Ni lake sediment anomalies over paragneiss throughout the Penrhyn basin implies that introduction of base metals was a regional phenomenon.

The Foxe Fold Belt appears to have been the site of an intracratonic rift. Such features were the focus of stratiform mineralization during the Proterozoic. Of particular interest in this respect are basaltic volcanic rocks, typical of tensional regimes, on Baffin Island. They occur in close stratigraphic proximity to sulphidic gneiss that is possibly correlative with the mineralized rocks on Melville Peninsula.

Study of Middle Proterozoic shale-hosted Zn-Pb-Ag mineralization in the Batten Trough of Australia, an intracratonic rift, has shown that Zn has the widest primary distribution. The Pb and Ag occur in significant concentrations only at the McArthur deposit. Therefore, by analogy, the presence of Zn-rich stratigraphic horizons within the Penrhyn Group, and the possible occurrence of similar rocks on Baffin Island, may provide a key for more detailed exploration for base metals in the Foxe Fold Belt.

While the surface oxidation of the base metal sulphides presents obvious difficulties in studying the mineralization, it has created extensive secondary dispersion halos in surface waters and lake sediments. The sampling of surface waters by helicopter and their analysis for Zn in a field laboratory is a rapid and effective means of outlining mineralized ground for more detailed investigation.

Acknowledgments

The writer was very ably assisted in the field and office by Paul MacKay. The analytical work was performed under the direction of Ms. Gwendy Hall. Larry Cotter was the helicopter pilot. The mineralogical studies were carried out by Gordon Pringle, A.G. Plant and D.M. Watson, while Greig Lund provided the statistical data. Dr. A.V. Okulitch kindly arranged for fuel to be supplied and provided the base map for Figure 1. The field work was carried out in the company of Dr. Yvon Maurice, who investigated uranium anomalies in the same general area. Dr. Maurice also kindly provided critical comment on this paper. I am most grateful to all these persons for their generous contribution to the work.

References

Burke, K. and Dewey, J.F.
1973: Plume-generated triple junctions: key indicators in applying plate tectonics to old rocks; Journal of Geology, v. 81, p. 406-433.

Cameron, E.M.
1977a: Geochemical dispersion in mineralized soils of a permafrost environment; Journal of Geochemical Exploration, v. 7, p. 301-326.

1977b: Geochemical dispersion in lake waters and sediments from massive sulphide mineralization, Agricola Lake area, N.W.T.; Journal of Geochemical Exploration, v. 7, p. 327-348.

1978: Hydrogeochemical methods for base metal exploration in the northern Canadian Shield; Journal of Geochemical Exploration, v. 10.

Dunnet, D.
1976: Some aspects of the Panantarctic cratonic margin in Australia; Philosophical Transactions of the Royal Society of London, A280, p. 641-654.

Einaude, M.T.
1971: The intermediate product of pyrrhotite alteration; American Mineralogist, v. 56, p. 1297-1302.

Fleet, M.E.
1978: Pyrrhotite-marcasite transformation; Canadian Mineralogist, v. 16, p. 31-35.

Geological Survey of Canada
1978a: National Geochemical Reconnaissance release, regional lake sediment and water geochemical reconnaissance data, Melville Peninsula, N.W.T. NGR 32A-1977 or 32B-1977, NTS 46N and part of 47B; Geological Survey of Canada, Open File 521A or 521B.

1978b: National Geochemical Reconnaissance release, regional lake sediment and water geochemical reconnaissance data, Melville Peninsula, N.W.T. NGR 33A-1977 or 33B-1977, NTS 46O, P and part of 47A; Geological Survey of Canada, Open File 522A or 522B.

Heywood, W.W.
1967: Geological notes, northeastern District of Keewatin and southern Melville Peninsula, District of Franklin, Northwest Territories (Parts of 46, 47, 56, 57); Geological Survey of Canada, Paper 66-40.

Hornbrook, E.H.W., Garrett, R.G., and Lynch, J.J.
1967a: Regional lake sediment geochemical reconnaissance data, Nonacho Belt, N.W.T. (NTS 75C); Geological Survey of Canada, Open File 324.

1976b: Regional lake sediment geochemical reconnaissance data, Nonacho Belt, N.W.T. (NTS 75F); Geological Survey of Canada, Open File 325.

1976c: Regional lake sediment geochemical reconnaissance data, Nonacho Belt, N.W.T. (NTS 75K); Geological Survey of Canada, Open File 326.

Jackson, G.D. and Taylor, F.C.
1972: Correlation of major Aphebian rock units in the northeastern Canadian Shield; Canadian Journal of Earth Sciences, v. 9, p. 1650-1669.

Kanasewich, E.R., Clowes, R.M., and McCloughan, C.M.
1968: A buried Precambrian rift in western Canada; Tectonophysics, v. 8, p. 513-527.

Lambert, I.B.
1976: The McArthur zinc-lead-silver deposit: features, metallogenesis and comparisons with some other stratiform ores; in Handbook of Strata-Bound and Stratiform Ore Deposits, Editor K.H. Wolf, v. 6, p. 535-585, Elsevier, Amsterdam.

Lambert, I.B. and Scott, K.M.
1973: Implications of geochemical investigations of sedimentary rocks within and around the McArthur zinc-lead-silver deposit, Northern Territory; Journal of Geochemical Exploration, v. 2, p. 307-330.

Okulitch, A.V., Gordon, T., Henderson, J.R., Reesor, J.E., and Hutcheon, I.E.
1977: Geology of the Barrow River map area, Melville Peninsula, District of Franklin; in Report of Activities, Part A, Geological Survey of Canada, Paper 77-1A, p. 213-215.

Okulitch, A.V., Gordon, T., Henderson, J.R., Hutcheon, I.E., and Turay, M.
1978: Geology of the Barrow River and Hall Lake map-areas, Melville Peninsula, District of Franklin; in Current Research, Part A, Geological Survey of Canada, Paper 78-1A, p. 159-161.

Raybould, J.G.
1978: Tectonic controls on Proterozoic stratiform copper mineralization; Transactions of the Institute of Mining and Metallurgy, Sect. B, v. 87, p. 79-86.

Reesor, J.E.
1972: Penrhyn Group metamorphic complex, Melville Peninsula, District of Franklin; in Report of Activities, Part A, Geological Survey of Canada, Paper 72-1A, p. 106-107.

1974: Penrhyn Group metamorphic complex, Melville Peninsula, District of Franklin; in Report of Activities, Part A, Geological Survey of Canada, Paper 74-1A, p. 153.

Reesor, J.E., LeCheminant, A.N., and Henderson, J.R.
1975: Geology of the Penrhyn Group metamorphic complex, Melville Peninsula, District of Franklin; in Report of Activities, Part A, Geological Survey of Canada, Paper 75-1A, p. 349-351.

Reesor, J.E., LeCheminant, A.N., Henderson, J.R., Hutcheon, I.E., and Miller, A.
1976: 1:50 000 geological map, NTS Sheet 46N/1; Geological Survey of Canada, Open File 307.

Sawkins, F.J.
1976a: Widespread continental rifting; some considerations of timing and mechanism; Geology, v. 4, p. 427-430.

1976b: Massive sulphide deposits in relation to geotectonics; in D.F. Strong (Ed.) Metallogeny and Plate Tectonics; Geological Association of Canada, Special Paper 14, p. 221-242.

Vokes, F.M.
1973: Metallogeny possibly related to continental break-up in southwest Scandinavia; in D.H. Tarling and S.K. Runcorn (Eds.), Implications of Continental Drift to the Earth Sciences, v. 1, Academic Press, London, p. 573-579.