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MINERALOGICAL EVALUATION OF PROXIMAL–DISTAL FEATURES IN NEW BRUNSWICK MASSIVE-SULFIDE DEPOSITS

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ABSTRACT

Massive-sulfide deposits in the Bathurst–Newcastle district of New Brunswick are predominantly Zn>Pb>Cu stratiform lenses, but some have Zn subordinate to either of the other metals, and one Cu (only) deposit is known. A few deposits which have underlying stringer mineralization associated with their stratiform lenses are examples of combined primary subsurface replacement and on-surface deposition of proximal-type massive-sulfide ores. Comparison of metal values, metal zonation, gangue minerals and footwall alteration of these proximal-type ores and other Bathurst-district deposits suggests that many stratiform lenses have proximal-type features even though associated stringer mineralization and footwall alteration have not been detected. Detailed studies of Caribou, a stratiform deposit with a chloritic footwall but no known alteration pipe, have revealed its silicate gangue to be similar to that within Archean proximal-type ores. A contrast is that siderite predominates and calcite is uncommon at Caribou and in nearly all other Bathurst-area massive lenses. Mineral and metal zonation is present in most deposits in the camp. Pyrrhotite, where present, is concentrated in the stratigraphically lower sulfide assemblages; pyrrhotite distribution is not correlative with the mapped sub-zones of greenschist-facies regional metamorphism. A tentative classification of most of the Bathurst-area deposits is made with reference to their established or assumed displacement from feeder conduits (proximal *versus* distal) and position of sulfide crystallization (autochthonous *versus* allochthonous).

SOMMAIRE

Les gisements de sulfures massifs du district de Bathurst–Newcastle (Nouveau-Brunswick) sont généralement des lentilles stratiformes ayant Zn > Pb > Cu; dans certains d'entre eux le Zn est subordonné aux deux autres métaux, et on ne connait qu'un seul gisement de Cu (sans Pb ni Zn). Quelques gisements montrent une minéralisation sous-jacente en veinules associée aux lentilles stratiformes: ce sont des exemples d'une combinaison de remplacement primaire sous la surface et précipitation de sulfures massifs du type proximal en surface. La comparaison de ces minerais du type proximal avec ceux d'autres gisements du district de Bathurst, à divers points de vue (concentration des métaux et leur zonation, minéraux de la gangue, altération de l'éponte inférieure), montre que plusieurs lentilles stratiformes possèdent des caractères du type proximal quoique ni la minéralisation en veinules ni l'altération de l'éponte inférieure n'y soient observées. Le gisement de Caribou, étudié en détail, est stratiforme sur éponte inférieure chloritique, mais sans cheminée d'altération; la gangue silicatée du minerai y est semblable à celle des minerais archéens de type proximal. Par contre, la sidérite prédomine et la calcite est rare à Caribou et dans la plupart des autres lentilles massives de la région de Bathurst. On trouve des minéraux et des métaux zonés dans la plupart des gisements du camp. Si la pyrrhotine est présente, on la trouve concentrée dans les assemblages de sulfures stratigraphiquement plus bas; sa distribution ne semble pas liée aux sous-zones cartographiées du facies métamorphique schiste-vert. Une classification préliminaire de la plupart des gisements de la région de Bathurst repose sur la distance (prouvée ou postulée) du gîte aux conduits alimenteurs (type proximal ou distal) et sur le site de la cristallisation des sulfures (gîte autochtone ou allochtone).

(Traduit par la Rédaction)

INTRODUCTION

It is generally accepted that stratiform massive-sulfide deposits in volcanic terranes are coeval with their enclosing submarine volcanic rocks and were deposited either near or at the rock-water interface (Large 1977). Present-day discussions are largely focused on specific aspects of this genetic model and are concerned with details such as the original depth of the rock–water interface, the degree of involvement of nonmagmatic fluids, and the processes which have led to vertical zonation of the ore metals.

In considering the evolution of massive-sulfide deposits, Large (1977) summarized many of their physical and chemical features and interpreted their genesis in terms of two different, but closely related, geological environments. Each environment reflects the relative proximity of the sulfide deposits to the conduits

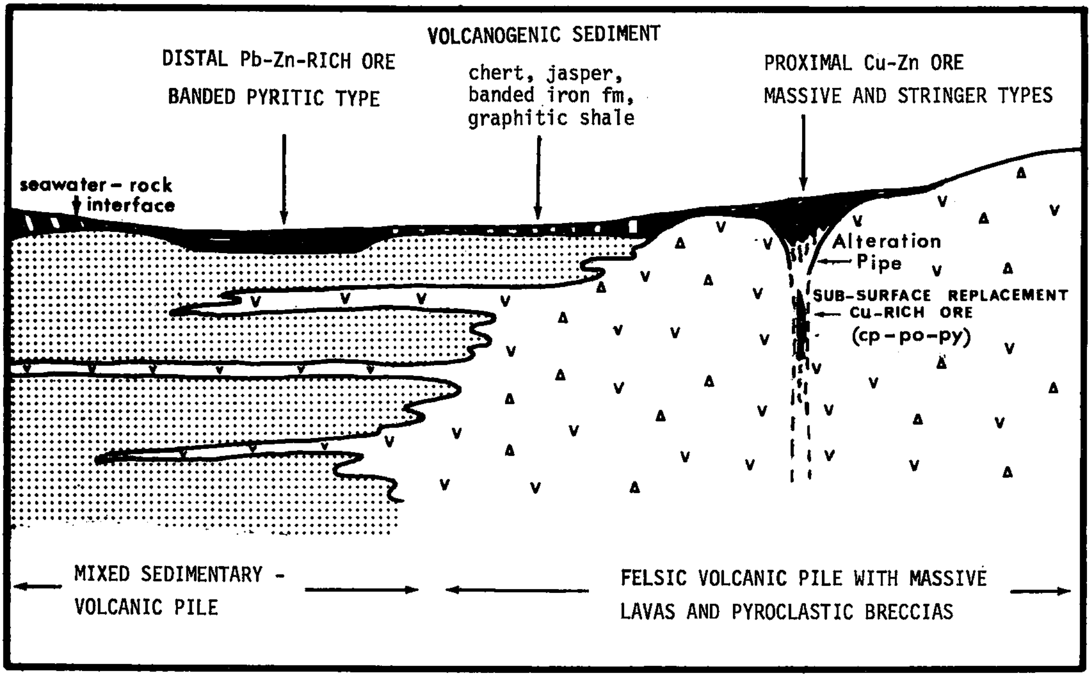

FIG. 1. Schematic representation of the geological setting of proximal and distal ores according to Large (1977).

from which the metal-bearing hydrothermal solutions are thought to have escaped. Thus "proximal" deposits, which form at or very near the conduits, are distinguished from "distal" deposits which form at an appreciable distance from the conduits (Fig. 1). The traits of each ore type are compared here with features found in massive sulfide deposits in the Bathurst–Newcastle district of northern New Brunswick. These deposits are being investigated as part of an extensive CANMET program in which the ultimate objective is to improve the unsatisfactorily low metal-recoveries from these ores: up to a third of the lead, zinc, copper and silver are lost to tailings. Detailed metallographic studies in progress are intended to provide basic documentation of the character of the sulfide ores in individual deposits and an assessment of whether the sulfides and textures show patterns of variation on a district-wide scale. Such patterns, if demonstrated, could be due either to primary mineralization or to the effects of superimposed regional metamorphism. For example, the average copper content of deposits south of the biotite isograd (Fig. 2) is higher than that of deposits to the north, and presumably reflects a primary mineralization control. A pyrrhotite–chalcopyrite association is common in massive sulfide deposits and is characteristic of Large's (1977) proximal ores. On the other hand, Helmstaedt (1973a,b) has stated that southern deposits in the Bathurst–Newcastle district are more pyrrhotite-rich as a result of regional metamorphic creation of this mineral. Thus, although these deposits are grossly similar, they do have appreciable variations, and some of these may reflect the proximal *versus* distal origins of individual deposits.

Large (1977) specified several criteria that distinguish proximal from distal ores. Although others have also used these terms, in some cases differently (Plimer 1978, 1979; Large 1979), the objective of the present paper is to evaluate New Brunswick deposits in order to make direct comparisons only with Large's (1977) criteria. The intent is to summarize and possibly add to the information on these deposits rather than to appraise the classification. Field work for the metallographic studies was done in 1976 and 1978, and 22 of the deposits were sampled. Nearly all of the sulfide occurrences lack significant outcrop, but extensive drill-core collections are accessible and voluminous records of assessment work for many properties are on file at the Bathurst office of the New Brunswick Mineral Resources Branch. As well, excellent one-page summaries of the geology of the deposits are in the unpublished report by Williams (1978).

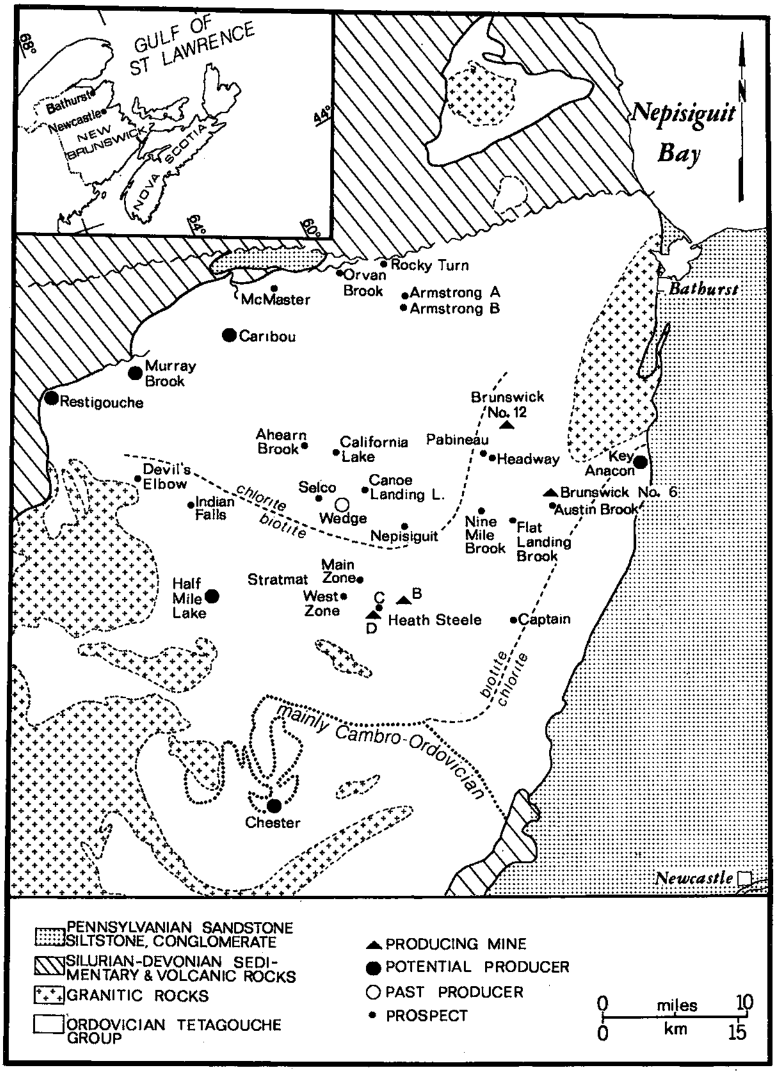

FIG. 2. General geology and principal sulfide occurrences in the Bathurst-Newcastle district, New Brunswick. Geology and boundaries of chlorite–biotite subzones of regional metamorphism compiled from Helmstaedt (1973b), Irrinki (1973), and Plate 73–10, New Brunswick Mineral Resources Branch. The Key Anacon deposit, in the eastern part of the district, is in the biotite subzone according to Saif *et al.* (1978). Potential producers are as indicated on Plate 73–10 of the New Brunswick Mineral Resources Branch. The Caribou deposit, shown as a potential producer, also had a supergene-enriched copper zone that has been mined out.

PROXIMAL AND DISTAL DEPOSITS

Hutchinson (1973) classified massive sulfide deposits into three major types (Table 1) with the following features as summarized by Large (1997):

1. The Cu–Zn type is exemplified by deposits in Canadian Archean greenstone belts. Chalcopyrite in these deposits is concentrated with pyrite–pyrrhotite±magnetite in the base of the massive-sulfide lens, or in an underlying discordant stringer zone. In the massive lens, the ratio pyrite/pyrrhotite increases upward and the top is characterized by pyrite–sphalerite,

TABLE 1. CHEMICAL AND CRYSTALLOGRAPHIC DATA FOR BENJAMINITE

Microprobe analysis:		Space group :	C2/m
		Unit cell :	a = 13.299(8) Å
	wt%		b = 4.070(8) Å
Ag	11.8(4)		c = 20.209(10) Å
Cu	1.6(2)		β = 103.32(5)°
Pb	3.8(6)	D(calc) :	6.64 resp. 6.76
Bi	63.4(8)	Z :	2
Sb	-	Radiation :	CuKα
S.	17.8(1)	Total number of reflections:	585
Total	98.4		

Derived formula $Cu_{0.54}Pb_{0.40}Ag_{2.36}Bi_{6.56}S_{12}$

Structural formula $Cu_{0.50}Pb_{0.40}Ag_{2.30}Bi_{6.80}S_{12}$

Provenance: Manhattan, Nevada, U.S.A. (ROM Toronto, M 13805)

generally without economically recoverable amounts of galena. Cu–Zn deposits are commonly overlain by, or change laterally to, pyritiferous cherty tuffs.

2. The Pb–Zn–Cu–Ag type has a similar metal zonation, but also has economic amounts of lead in the upper part of the lens. Deposits of this type are exemplified by Japanese kuroko ores and those in the Bathurst–Newcastle district. The upward succession in kuroko ores (Lambert & Sato 1975) is from (a) pyrite–chalcopyrite–quartz stockwork ore to (b) pyrite–chalcopyrite stratiform ore, to (c) sphalerite–galena–barite stratiform ore, commonly overlain by ferruginous chert with variable pyrite.

3. Cupriferous pyrite ores, such as the Cyprus deposits, consist of pyrite and chalcopyrite in poorly zoned massive lenses and in underlying discordant stringer zones. Only minor sphalerite is present in the lenses, and galena, pyrrhotite and magnetite are negligible. The sulfides generally occur in altered pillow lavas within mafic–ultramafic rocks of ophiolitic affinity. Felsic volcanic rocks are rare or absent, and the massive ores are commonly capped by pyrite-bearing ocherous mudstones.

Notable contrasts within examples of type 2 (Pb–Zn–Cu–Ag) ores are that pyrrhotite and magnetite are absent in kuroko deposits, but are common in those at Bathurst. Barite, on the other hand, is a major constituent of kuroko ores but does not occur in more than trace amounts in most Bathurst deposits. Therefore, differences between kuroko and Bathurst ores are major, and grouping these deposits into a single ore-type is arbitrary.

The three stratiform ore types listed above are commonly accompanied by underlying discordant zones of stockwork and disseminated sulfides. These sulfides occur in chloritic alteration pipes and silicified zones that mark the outlets for the metal-bearing hydrothermal solutions of proximal stratiform lenses. It has been implied (Stanton 1972, Large 1977) that distal massive-sulfide lenses are unaccompanied by zones of strong footwall-alteration and represent chemical sediments deposited in basins some distance from the hydrothermal vents. Distinctions between proximal and distal ores are summarized in Table 2.

TABLE 2. DIFFERENCES BETWEEN PROXIMAL AND DISTAL ORES*

	Proximal ores	Distal ores
Metal content	Cu-rich (with Au); Zn may be present in economic quantities. Pb generally low.	Pb-Zn rich;poor in Cu
Alteration	Underlain by a distinct alteration zone (pipe).	No distinct footwall alteration zone.
Iron sulfides and oxides†	py- and po-dominant sulfides. Mag often in footwall.	Py dominant, po absent. Mag may be in hanging wall.
Form	Pipe-like or mushroom-shaped, generally massive and cross-cutting. Banding only in hanging wall.	Well-banded, stratiform, and blanket-shaped.
Zoning	Good zoning. Cu is concentrated toward footwall. Zn/Cu ratio increases upward. Pb occurs in hanging wall of lode.	Generally lack distinct metal zoning.
Volcanic setting	Toward the top of a pile of massive pyroclastics, fragmental volcanics, and lavas.	Within a mixed sedimentary-volcanic pile.

*From Large (1977).
†These differences may be destroyed by high-grade metamorphism.

NEW BRUNSWICK DEPOSITS

Introduction

More than 30 massive-sulfide deposits occur in the sedimentary–volcanic complex of the Ordovician Tetagouche Group in the Bathurst–Newcastle district. Relatively few of the deposits have been exploited: former producers are the Wedge and Caribou, and current producers are Heath Steele, Brunswick No. 6 and Brunswick No. 12 (Fig. 2).

The massive-sulfide deposits in the district are pyrite-rich, layered, stratiform lenses. Most, but not all, are stratigraphically near porphyroclastic metarhyolite schist ("augen schist", "Bathurst porphyry") which, according to Helmstaedt (1971, 1973b, 1978) is in the basal part of the middle volcanic sequence of the Tetagouche Group. Iron-formation also is commonly present at this stratigraphic position and is represented locally by a basal sulfide facies (massive-sulfide deposits) overlain by oxide, carbonate and silicate facies (Luff 1977). Most of the sulfide deposits are at the periphery of two rhyolitic volcanic centres, one in the northwestern part of the district, the other south of the Brunswick – Heath Steele area (Helmstaedt 1973b).

The massive-sulfide ores are fine-grained and commonly texturally complex, but typically contain few minerals: pyrite, sphalerite, galena, chalcopyrite and pyrrhotite account for more than 95% of the sulfides; with the addition of minor arsenopyrite, marcasite, tetrahedrite and bournonite, the total of sulfides accounted for is greater than 99.8% in nearly all deposits. Layering or bedding of the sulfides, evident both megascopically and microscopically, results from variations in mineral abundances (composition layering) and variations in grain sizes. Footwall beds of each stratiform lens almost always contain disseminated sulfides, predominantly pyrite at the majority of deposits. The disseminated pyritiferous footwalls are in some cases megascopically gradational to overlying massive zones averaging more than 70% sulfides by volume. Nevertheless, the contact between disseminated and massive sulfides is invariably sharply demarcated in thin sections. In contrast to the sulfide-rich nature of the basal rocks, contacts above the massive lenses are abrupt and significant disseminated mineralization is absent in hanging-wall rocks of most deposits.

In addition to concordant massive-sulfide lenses, a few of the New Brunswick deposits have a discordant pyrrhotite–pyrite–chalcopyrite assemblage which occurs as veins and brecciated sulfide masses underlying the stratiform bodies. The cross-cutting footwall assemblages are a characteristic feature of proximal ores (Table 2). Most of the thick stratiform sulfide lenses in New Brunswick have recognizable metal zonation from a copper-rich footwall to a Pb–Zn hanging wall. The distinct metal zonation is characteristic of proximal deposits whereas the richness in Pb–Zn is a feature typical of distal deposits (Table 2). Several of the Bathurst-area deposits have a sulfide–oxide mineralogy which places them in the proximal-ore category, whereas the majority of deposits has a sulfide-only mineralogy typical of that in distal ores.

Table 3 lists 31 massive sulfide deposits in the Bathurst area and classifies them with respect to some of the features referred to in Table 2. Sizes of many of the deposits are indicated by published ore-reserves as listed in Table 4. Of the properties included in Table 3 but not in Table 4, all except one have reserves well below 0.5 million tonnes. The exception, Nepisiguit, is also relatively small and of low grade.

All of the Bathurst-area massive-sulfide deposits occur in the Tetagouche Group, a volcanic-sedimentary sequence characteristic of the depositional environment for distal ores. For most deposits the host rock is either chlori-

TABLE 3. CHARACTERISTIC FEATURES OF SOME NEW BRUNSWICK MASSIVE SULFIDE DEPOSITS

Property (Fig. 2)	Metal Content	Fe Sulfides	Alteration	Interpreted Zoning
Armstrong A	Zn>Pb>Cu>Ag[1]	py	negligible	Zn-Pb over Cu - OVT[8]
Armstrong B	Zn Cu Pb	py-po	chloritic footwall	Zn-Pb(py) over Cu(po) - OVT
Rocky Turn	Zn Pb Cu	py	negligible	
Orvan Brook	Zn Pb Cu	py	negligible	
Orvan Brook South[2]	Zn Cu Pb	py-po	negligible	
McMaster	Cu[3]	py	local chloritic	
Caribou	Zn Pb Cu	py	local chloritic footwall	Zn-Pb over Cu
Murray Brook	Zn Pb Cu	py(po)[6]	---	
Restigouche	Zn Pb Cu	py	chloritic with stockwork sulfides[7]	Zn-Pb over Cu
Ahearn Brook	Zn Pb Cu	py	negligible	
California Lake	Zn Pb Cu	py	negligible	
Selco	Zn Pb Cu	py	---	
Wedge	Cu Zn Pb	py	bleached zone (McAllister 1960)	Zn-Pb over Cu
Canoe Landing Lake	Zn Pb Cu	py-po	negligible	py mainly over po
Nepisiguit	Zn Pb Cu	py-po	bleached zone (McAllister 1960)	
Brunswick No. 12	Zn Pb Cu	py-po	chloritic footwall	Zn-Pb(py) over Cu(po)
Pabineau	Zn Pb Cu	py-po	---	
Headway	Zn Pb Cu	py	---	
Key Anacon	Zn Pb Cu	py-po	local chloritic	py over po
Brunswick No. 6	Zn Pb Cu	py-po	chloritic footwall	Zn-Pb(py) over Cu(po)
Austin Brook	Zn Pb Cu	py-po	---	
Flat Landing Brook	Zn Pb Cu	py-po	---	
Nine Mile Brook	Pb Zn Cu[4]	py	---	Zn-Pb over Cu (Williams 1978)
Captain	Cu Zn Pb	py±po	chloritic (?)	Cu-Co zoning (Tupper et al. 1968)
Heath Steele B	Zn Pb Cu	py-po	local chloritic footwall	Zn-Pb(py) over Cu(po)
ACD	Zn Pb Cu	py-po	---	
Stratmat Main (East)	Zn Pb Cu	py-po	sericite-chlorite (Johnston 1959)	
West	Zn Pb Cu	py	---	
Devil's Elbow	Cu Zn Pb	py-po	chloritic	py over po
Half Mile Lake	Zn Pb Cu	py-po	chloritic footwall	Zn-Pb(py) over Cu(po) - OVT
Chester	Zn Pb Cu[5]	py-po	chloritic stringer zone	Zn-Pb(py) over Cu(po)

1. Ag is exceeded by Zn, Pb, and Cu in all deposits
2. About 600 m south of Orvan Brook (Fig. 2)
3. Combined Pb-Zn averages less than 0.1%
4. Deposit also contains abundant barite
5. Massive ore only; reserves mainly Cu-rich ore
6. Po-cp stringer mineralization 500 m west of massive zone
7. Rankin (1978); Rankin & Davies (in press)
8. Most of deposit is overturned

TABLE 4. RESERVES AND GRADES OF SOME MASSIVE SULFIDE DEPOSITS, BATHURST-NEWCASTLE AREA, NEW BRUNSWICK

Property	tonnes ($X10^3$)	%Zn	%Pb	%Cu	Ag g/tonne	Au g/tonne	Reference
Armstrong A	3,175	2.29	0.42	0.29	1.4		Boorman (1975)
Rocky Turn	200	7.00	1.50	0.30	78.9		Boorman (1975)
Orvan Brook	136	7.13	3.27	0.2	86.4	0.58	Annis *et al.* (1976)
McMaster	200			0.6			Boorman (1975)
Caribou	44,800	4.48	1.70	0.47	58.6	1.37	Cranstone & Whillans (1979)
Murray Brook	21,300	1.95	0.86	0.44	31.2	0.34	Rankin & Davies (in press)
Restigouche	2,360	6.8	5.5	0.3	103		Annis *et al.* (1976)
Wedge	——	1.75		3			Douglas (1965). Past producer.*
Canoe Landing L.	5,400	1.5	0.5	0.5	51	1.4	Worobec (1978)
Brunswick No. 12	97,129	9.22	3.77	0.31	98.4		Worobec (1978)
Headway	360	- 8.19 -		1.36	23.7		*Financial Post* (1972)
Key Anacon	1,686	7.43	3.03	0.2	91.5		Worobec (1978)
Brunswick No. 6	1,217	7.36	2.66	0.27	79.2		*Financial Post* (1978)
Austin Brook	~900	2.93	1.86		34		Boyle & Davies (1964)
Flat Landing Brook		Zn > Pb		<0.05	<30		*Northern Miner*, Mar. 3, 1977
Nine Mile Brook	133	1.0		0.42	87.1		Annis *et al.* (1976)
Captain	311			1.99	9.6	0.58	Captain Mines Ltd., Ann. Rep. 1970
Heath Steele B	21,315	4.24	1.55	1.17	61.0	0.7	Cranstone & Whillans (1979)
ACD	4,781	5.34	1.31	1.00	56.6	0.69	Cranstone & Whillans (1979)
Stratmat Main (East)	408	- 10 -		2.5			Annis *et al.* (1976)
West	2,040	6.29	2.44	0.59	31.9		*Northern Miner*, Dec. 15, 1977
Devil's Elbow	363			1.2			Annis *et al.* (1976)
Half Mile Lake	6,200 + 907	6.8	2.5	1.5 2.0			Cranstone & Whillans (1979)
Chester	11,800 + 1,450	 2.12	 0.83	0.77 0.63			disseminated zone open pit, massive — Annis *et al.* (1976)

*Produced 1.5 million tonnes grading 2.17% Cu (Williams 1978).

tic muscovite (metarhyolite) schist derived by metamorphism of felsic tuffs, or argillite near its contact with this schist. Several deposits occur at the contact between the schist and argillite or iron-formation. All deposits except that at Canoe Landing Lake have at least minor associated felsic metavolcanic rocks which variably represent pre- or post-sulfide volcanic activity.

Metal content

Of the 31 deposits, only three have a metal content significantly different from that of the Pb–Zn-rich distal ore type. The McMaster deposit, in the northern part of the district (Fig. 2), has an unequivocally proximal metal character. The sulfide zone (Fig. 3) consists of massive and disseminated pyrite–chalcopyrite that occur as a conformable lens in sericite–chlorite phyllite. The lens, about 100 m long and 5 m thick, contains several massive-sulfide sections that are not continuous from drillhole to drillhole. The sulfide zone averages about 0.6% Cu and has negligible Pb–Zn and Au–Ag. No stringer zone has been detected.

The Captain deposit, in the southeastern part of the district, is a lens of massive and disseminated pyrite–chalcopyrite. Although small amounts of galena and sphalerite are commonly visible in polished sections, overall Pb and Zn are apparently low enough that these metals are neither included in reserves nor were assayed. However, cobaltoan sulfides are present (Aletan 1960), and cobalt is included in some estimates of ore reserves (Annis *et al.* 1976).

The Devil's Elbow property (Fig. 4), in the western part of the district, is a conformable pyrrhotite–pyrite–chalcopyrite massive deposit with abundant accompanying disseminated mineralization. Sparse sphalerite is evident in some samples but, as is the case for the Captain deposit, Pb and Zn are low and were not assayed. Sulfide zoning from pyrite to pyrrho-

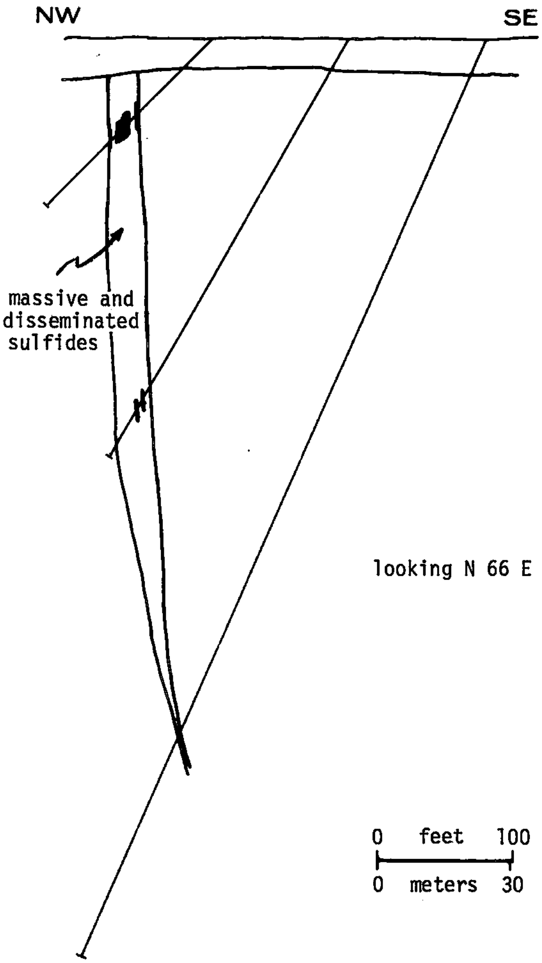

FIG. 3. Cross-section of the McMaster deposit, a conformable lens of massive and disseminated pyrite–chalcopyrite.

tite>pyrite is reversed in some drill cores and probably indicates complex folding with some beds overturned. The metal content, alteration and sulfide minerals in this deposit mark its character more clearly as proximal than is the case for Captain.

Alteration and form

Proximal ores are underlain by distinct visible alteration pipes and stockwork sulfides, whereas distal ores are not. New Brunswick deposits with well-defined discordant zones of alteration and mineralization beneath their massive-sulfide lenses are Brunswick No. 12 (Rutledge 1972, Luff 1977), Brunswick No. 6 (Rutledge 1972), Restigouche (Rankin 1978, Rankin & Davies, in press), and Chester. A footwall zone of pyrrhotite–chalcopyrite at the Heath Steele B deposit shows significant discordance (Williams 1978), and cross-cutting sulfides described by Vokes (1976) for Heath Steele ACD ores may possibly indicate the presence of stringer-type mineralization in these deposits. The Devil's Elbow mineralization is in intensely chloritized rocks; this alteration and the discordant veinlet form of some sulfides in the disseminated zone are considered here to indicate that the deposit has a proximal source. The Armstrong B deposit also has a disseminated and veinlet pyrrhotite–pyrite–chalcopyrite zone in chloritized rocks. The alteration zone is interpreted here to stratigraphically underlie the massive-sulfide body.

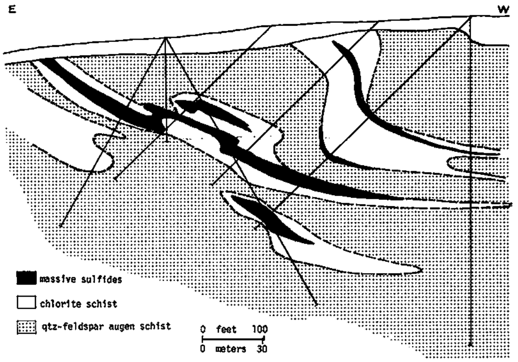

FIG. 4. Cross-section of the Devil's Elbow deposit (slightly modified from R. Theriault, unpublished property compilation map, New Brunswick Department of Natural Resources).

The Stratmat West and Captain deposits have certain features which make their proximal or distal classification uncertain. The Stratmat West deposit consists of four zones: Stratmat West A, Stratmat West B, Stratmat stringer zone, and Heath Steele N. Three of the zones consist of conformable, massive pyrite–sphalerite–galena–chalcopyrite. The Stratmat West stringer zone comprises disseminated pyrite–chalcopyrite which may represent stockwork-type stringer mineralization rather than a bedded deposit. That the Captain deposit also may have a metamorphosed stringer zone is more doubtful, but there is local discordance of sulfides, and the mineralized zone at depth does depart from its normal stratigraphic position (Fig. 5).

Among the properties mentioned above, the Chester deposit (Fig. 6) displays fairly well the pipe-like form and stringer mineralization that are definitive of proximal ores. The de-

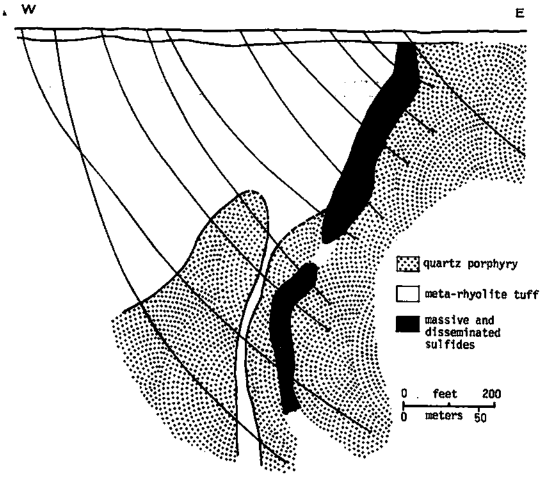

FIG. 5. Cross-section of the Captain deposit (after R. Theriault and D. A. Williams, unpublished, New Brunswick Department of Natural Resources).

formed Chester host rocks are metaquartzite and metarhyolite flows and tuffs that contain massive pyrite–chalcopyrite–galena–sphalerite; the extensive stringer zone of disseminated pyrrhotite–pyrite–chalcopyrite has abundant associated chloritic alteration.

The Restigouche deposit (Fig. 7) is intermediate between the demonstrably pipe-like form of Chester and the more typical New Brunswick deposit in which disseminated and stringer mineralization have a wide lateral extent and prevalent concordance. The Restigouche stockwork-sulfide zone underlying the massive lens has associated chloritic alteration and is interpreted by Rankin & Davies (in press) to thicken vertically beneath the central part of the lens. The stockwork consists of pyrite, sphalerite, galena and chalcopyrite, as does the lens, but Rankin & Davies report that chalcopyrite content noticeably increases with depth.

The remainder of the New Brunswick massive sulfide deposits are either more exactly concordant, or at least they do not have cross-cutting features of the kinds mentioned above. The deposits fall into two categories with respect to alteration and form: (a) stratiform lenses without stringer mineralization and without significant alteration of their enclosing host rocks, and (b) stratiform lenses with conspicuously altered footwall rocks. The two categories are gradational, but end members are nevertheless distinct. In the case of stratiform lenses without significant alteration, the massive sulfides rest on, and are overlain by, schistose country rocks in which alteration is either absent or is not readily apparent. The footwall rocks in these deposits are predominantly quartz–sericite phyllites or schists with disseminated sulfides and with variable, but generally very minor, chlorite. Although the amount of chlorite may increase slightly toward the massive-sulfide lens, quartz–sericite layers persist to the lens contact. Examples of this type of deposit in the northern part of the region are Armstrong A, Rocky Turn, Orvan Brook, and Canoe Landing Lake. The McMaster deposit is also

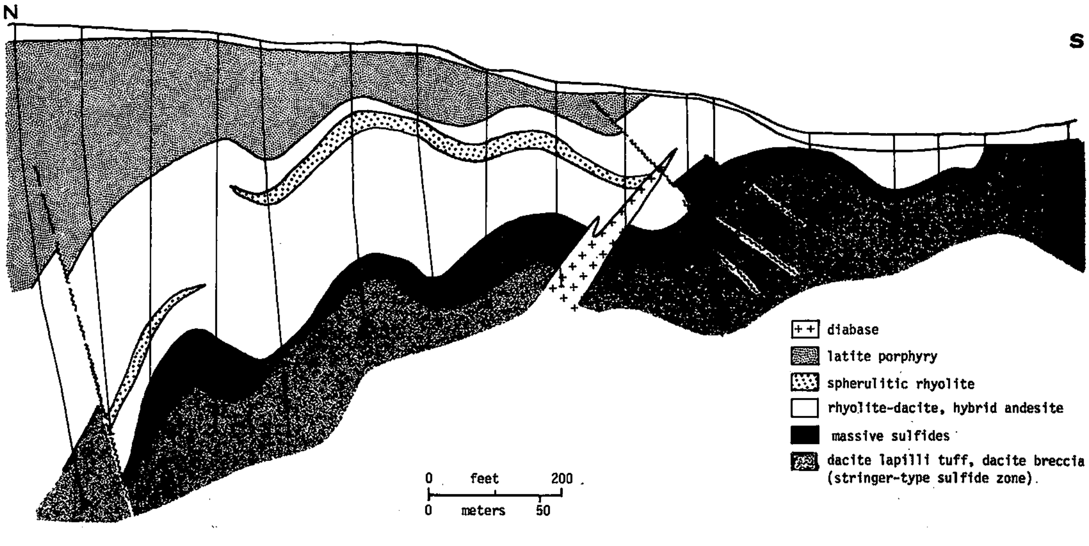

FIG. 6. Cross-section of the Restigouche deposit (after Rankin & Davies, in press).

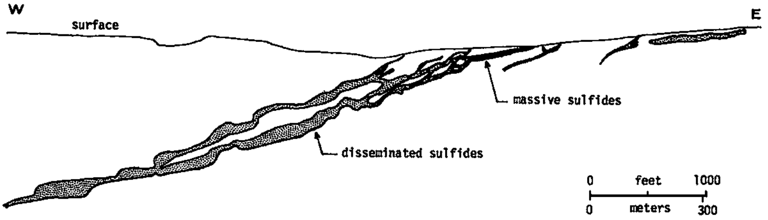

FIG. 7. Cross-section of the Chester deposit (assessment files, New Brunswick Department of Natural Resources).

considered to fit in this category; chlorite content in its host rocks increases near the sulfide lens, but seems to reflect primary lithological changes rather than alteration.

Aforementioned category (b) comprises stratiform lenses associated with apparently altered host rocks in which stringer-type mineralization is either inconspicuous, or its source is uncertain in that no distinct pipe-like zone has been detected. The alteration is predominantly along the stratigraphic footwalls of the massive lenses and is grossly concordant in that transecting parts are local rather than major features. Disseminated sulfides invariably occur in the footwall rocks and commonly increase in abundance toward the massive sulfide zone. In some cases the footwall disseminated sulfides are sufficiently abundant that the contact with massive-type mineralization is obscured megascopically. In contrast, hanging walls adjacent to the massive lenses lack alteration and have only minor intercalated sulfides or are barren.

Although the concordant alteration zones typically consist of megascopically massive, dark green chlorite, sericitic alteration also has been reported in the literature for a few deposits (Table 3; McAllister 1960, Williams 1978). Thus the same two silicate minerals that typify alteration in pipes associated with Archean massive sulfide deposits also characterize the alteration that accompanies several of the New Brunswick concordant deposits.

Discussion

The presence of apparently concordant chloritic alteration at some New Brunswick deposits and its absence at others raises the question of whether this type of alteration is merely a dispensable variation in what is assumed to be a distal-type environment. Alternative possibilities are that (a) the alteration is indicative of a proximal environment even though a pipe-like stinger-sulfide zone has not been located and large feeder orifices are not evident; (b) the chloritic zone represents a facies of iron-formation, with the local discordance reflecting lateral facies changes and possibly downward penetration and alteration of the floor of the depositional basin. The inference from alternative (a) is that feeder orifices, instead of being concentrated as a single large pipe, are defocused in multiple, much smaller orifices that effused relatively quiescently. Such a "multi-channel" model has nowhere been proven to be a legitimate means of venting for extensive massive sulfide ores; however, exactly the same concept seems to have been envisaged by Williams *et al.* (1975) in their reference to "meagre stockworks" underlying the San Antonio stratiform deposit of Rio Tinto, Spain. The model does seem to fit several New Brunswick deposits and has been invoked by Harley (1977) to explain the origin of the Half Mile Lake ores. If the multi-channel model is valid, the differences in form and alteration that separate proximal and distal ores (Table 2) become somewhat blurred.

Half Mile Lake deposit

The Half Mile Lake (Harley 1977) and Half Mile Lake North (Chandra & Williams 1976) deposits are contiguous parts of a sheet of massive sulfides with a strike length of about 2 km. According to Harley (1977), the Half Mile Lake deposit is an overturned sheet that averages less than 3 m in thickness and consists of several sulfide layers hosted by siltstone, argillite and wacke stratigraphically underlain by rhyolitic pyroclastic rocks. The principal sulfides in the massive zone are pyrite, pyrrhotite, sphalerite and galena; beneath these is an equally widespread Cu-rich stringer zone in which pyrrhotite predominates, with pyrite and chalcopyrite also common. The stringer zone averages between 3 to 5% sulfides and is "an irregularly shaped, broadly conformable but discontinuous sheet ranging between 30 and 120 m thick" (Harley 1977, p. 86). The massive and stringer zones, locally in direct contact, are generally separated by sediments that are up to 10 m thick and contain less than 2% sulfides. Although the stringer zone has a wide lateral extent, it is reported by Harley (1977) to be patchy, locally discordant, to have relatively restricted areas of ore-grade Cu-rich mineralization, and to have sulfide contents locally exceeding 10%.

Quartz stockworks are absent in the deposit and alteration in the sulfide zones is largely chloritic. According to Harley (1977), the hydrothermal solutions that gave rise to the Half Mile Lake sulfides derived their metals from the stratigraphically underlying rhyolitic pyroclastic rocks and rose through the accumulating and compacting sedimentary column.

Drill core from the adjacent Half Mile Lake North deposit examined by the present writer shows intense chloritization and abundant stringer-type mineralization. The sulfide stringers, predominantly pyrrhotite–chalcopyrite and less commonly pyrite, cut bedding and schistosity. Chloritic alteration is present as an almost complete replacement of finely laminated sediments that also are cut, in some cases vertically, by seams of massive chlorite up to 2 cm wide.

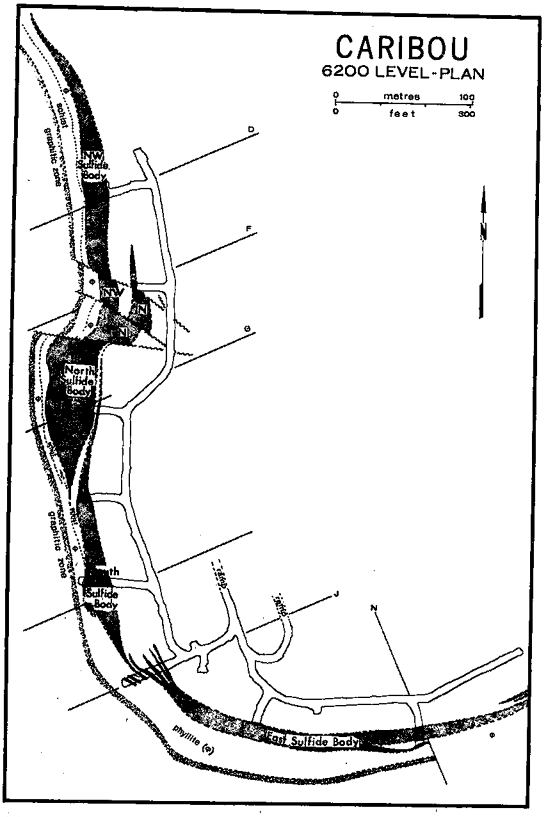

FIG. 8. Configuration of the major massive sulfide bodies of the Caribou deposit. The 6200 level is 1200 ft. (366 m) above sea level (from Anaconda Canada Exploration Limited).

The Half Mile Lake deposit seems to straddle the proximal–distal distinctions listed in Table 2. Specifically, the deposit is rich in Cu as well as Pb–Zn; distinct footwall alteration is present, though it is not in a pipe; sulfides are predominantly pyrrhotite and pyrite, but the stringer and massive zones are mainly blanket-shaped; good metal and mineral zoning are present, but the deposit is in a mixed sedimentary–volcanic environment.

The blanket-like form the Half Mile Lake deposit is such an overwhelmingly dominant feature that it possibly induces a bias to classify the deposit as distal. If in fact distal, nearly all of the criteria in Table 2 are not meaningful. Indeed, an argument put forth to this writer is that proximal deposits *must* have an associated pipe-like stringer and alteration zone. However, this restricted definition merely evades the genetic problem by confining feeder zones to a particular shape. Are there other traits that mark pipe-associated deposits as unique? The sulfide minerals are not distinctive; the possibility that gangue minerals might be was investigated as detailed below.

CARIBOU DEPOSIT

Introduction

Stanton (1972) and Large (1977) have reported that chlorite and carbonate gangue minerals associated with proximal-type ores are conspicuously more iron-rich than those in the banded, distal-type ores. Iron-rich chlorite and quartz are the common silicates in stringer-sulfide zones and the associated proximal massive-sulfide lenses may contain chlorite, talc, dolomite, calcite, siderite, stilpnomelane, quartz, sericite and minor amounts of other gangue minerals. For the Orchan No. 3 orebody, Québec, Large (1977) determined that the gangue minerals have an upward and outward stratigraphic zonation as follows:

Hanging wall		
	quartz	SiO_2
Zn ores	calcite	$CaCO_3$
	talc	$Mg_{5.0}Fe_{1.7}Al_{0.1}Si_8O_{20}(OH)_5$
Cu ore	stilpnomelane	$Mg_{1.6}Fe_{4.6}Al_{1.0}Si_8O_{20}(OH)_7$
	chlorite	$Mg_{5.2}Fe_{4.8}Al_{4.6}Si_{5.3}O_{20}(OH)_{16}$
Foot wall		

The Caribou deposit (Fig. 2) is an excellent example of a massive Pb–Zn–Cu–Ag deposit in which hydrothermal vents or sulfide-stringer zones have not been detected beneath the now-upright sulfide lenses (Roscoe 1971). However, concordant chloritic and pyritic zones underlie parts of the North and South Sulfide lenses (Fig. 8). These alteration zones, the adjacent unaltered footwall rocks and the gangue minerals of all of the Caribou lenses were examined in order to establish the variations among the lenses, and to compare the results with data known for proximal-type ores.

Caribou mineralogy

The main sulfides throughout the Caribou deposit are pyrite, sphalerite, galena, and chalcopyrite. Magnetite is common in all of the massive-sulfide lenses, but is absent in their underlying disseminated-sulfide zones.

In the Caribou East Sulfide Body (Fig. 8), the principal silicate–carbonate gangue minerals in the densest parts of the massive-sulfide zone (sulfides $>85\%$ by vol.) are siderite and stilpnomelane. Minor minerals are chlorite, minnesotaite and chamosite or greenalite. Quartz is absent in the stratigraphic centre of the lens, but is a minor mineral in its upper third. Where sulfide abundance in the zone locally drops to less than 75% by volume, quartz is the principal gangue-mineral. The base of the lens directly overlies quartz–sericite±chlorite phyllite containing disseminated sulfides. Thus the massive-sulfide zone with its predominance of a siderite-stilpnomelane gangue and absence of sericite, is sharply demarcated from the footwall quartz–sericite phyllite.

The densest, sulfide-rich massive zone of the South Sulfide Body has a siderite–stilpnomelane gangue with negligible quartz. Sparse minnesotaite, chamosite, greenalite and chlorite occur in the lower half of the lens; only one occurrence of talc has been observed and it is near the hanging wall. The base of the sulfide lens has a footwall of massive chlorite 10 to 20 cm thick that contains up to 50% disseminated sulfides and little else; quartz is absent. Abundant disseminated sulfides persist stratigraphically below the chloritic zone and are contained in quartz–sericite phyllite.

The gangue mineralogy of the North and Northwest sulfide bodies is more complex. Siderite, ankerite and minnesotaite are the most abundant gangue in the main part of the North Body and calcite, chamosite, talc and stilpnomelane are minor. A crude zonation is present in that calcite, ankerite and talc are restricted to the stratigraphic upper half of the massive zone. Quartz is negligible in most of the lens, but is locally common in some samples from the upper half and at the footwall contact. The basal contact is massive chlorite with disseminated sulfides.

In the largest of the faulted segments of the North Body, the principal gangue minerals are siderite and quartz in the stratigraphic upper half, and chamosite–siderite±stilpnomelane in the lower half. The northwestern, terminal part of the lens has siderite and quartz as the principal gangue.

In the main part of the Northwest Sulfide Body, siderite and talc are the chief gangue minerals. Minor stilpnomelane occurs in the upper third of the lens and chamosite in the lower third. Quartz is absent from most samples and is otherwise sporadically distributed. In the faulted segment adjacent to the North Body, ankerite and talc predominate and quartz is an abundant part of the non-sulfide assemblage. The basal contact of the Northwest Sulfide Body is quartz–sericite phyllite.

The silicate and carbonate assemblages in all of the Caribou lenses are strikingly similar to the gangue present in Archean proximal-type deposits. A major difference is that siderite, although apparently rare in Archean deposits (Franklin *et al.* 1975), is the principal carbonate, not only at Caribou, but in most ores in the Bathurst camp. Calcite constitutes an important gangue mineral in very few Bathurst-area massive sulfide lenses (*e.g.*, at Canoe Landing Lake), and its absence from the great majority of these ores contrasts markedly with its prevalance in Precambrian deposits.

The results of the Caribou study indicate that part of the footwall of the South Sulfide Body is chloritized in a zone only a few cm thick. Nevertheless, drillhole intersections indicate that the chloritic zone persists in the deep parts of the now-upright lens. Microprobe analyses of chlorites in one cross-section through the central part of the South Body gave MgO values of <10 wt. % for samples from sericitic and graphitic footwall schists, about 13% for the chloritized zone, and about 16% for chlorite in sericitic schist at the hanging-wall contact. Two samples from the northern part of the sulfide lens also were analyzed: chlorite from the footwall chloritic zone gave $<10\%$ MgO, whereas analysis of a 2 mm-thick massive chlorite layer representing the absolute hanging-wall contact of the massive-sulfide zone gave 16.5% MgO.

A similar but more substantial chloritic zone, at least 3 to 4 m thick, underlies the southern half of the North Sulfide Body. Microprobe analysis of a single chloritic footwall sample from near the thickest part of the North lens gave $<10\%$ MgO. Thus, although the chlorite analyses are few, the results do seem to trend towards a stratigraphically upward enrichment in MgO. Whether this trend is consistent, and whether the MgO values are a potentially useful discriminator between alteration *versus* sedimentation is not yet known [see, for example, the diverse MgO values obtained by Roberts & Reardon (1978) for chlorite in the Mattagami-mine alteration zone, and other chlorite analyses reported by Soler (1974) and Schermerhorn (1978)].

Roscoe (1971) reported that muscovite at Caribou progressively increased in Na_2O content from footwall to hanging-wall rocks. Roscoe's trend, based on X-ray diffraction studies, was not substantiated by microprobe analyses in the present investigation: most of the microprobe determinations gave Na = <0.1 wt. % (limit of detection) and the highest value, 1.2% Na_2O, was obtained from a sample of the graphitic footwall.

The preceding results do not unequivocally resolve the question of whether the footwall chloritized zone represents alteration or sedimentation, though the lack of a pronounced discontinuity in chlorite MgO values seems to favor the latter origin. Nevertheless, alteration related to an undetected nearby feeder vent or to a series of small, less conspicuous vents cannot be dismissed perfunctorily. If a nearby source is assumed, at least some of the features of the chloritic and sulfide zones should be comparable with alteration–mineralization features characteristic of classical proximal-type stringer zones and lenses.

The absence of breccias in the local volcanic setting, and the lack of severe disruption or intense veining in the strata at the Caribou site suggest that ore-solution venting or deposition occurred under generally quiescent conditions. Nevertheless, one would expect the North Body chloritized zone to have some stratigraphic discordance, and the near-footwall sulfides to be above-average in copper grade.

Examination of drill cores indicates that the North Body chloritic zone most probably was formed by replacement of the footwall phyllite. Discordance is evident in that the replaced zone is variable in thickness and terminates laterally against chlorite-poor, sericitic phyllite. In the most completely replaced part of the chloritic unit, the rock consists only of disseminated pyrite in a dense mass of chlorite with granules of residual rutile along the former bedding. In some places the footwall rocks have not been massively replaced, but instead are cut by discordant chlorite seams and pyrite stringers with chlorite margins. The above features are localized in that they do not occur beneath all of the massive-sulfide lenses, and are also restricted laterally beneath an individual lens. Although such localization suggests that a specific nearby source rather than blanketing, ponded hot brine was responsible for alteration, it has not been demonstrated that the chlorite–pyrite stringers originated by upward-moving rather than downward-moving solutions. Moreover, none of the drillholes at Caribou contains pyrite–chlorite stringers in a zone that has clearly pierced the graphitic footwall.

With respect to metal ratios, assay data kindly provided by Anaconda Company show that the North Body has copper grades substantially above average, and that copper is richest in the lowermost part of the massive sulfide lens. Metal zonation is well-developed, with Cu/Pb+Zn locally ~ 1 in the footwall and progressing to Cu/Pb+Zn = <0.1 in the hanging wall.

Discussion and interpretation

Evaluation of the North Body in terms of the proximal *versus* distal characteristics in Table 2 leads to mixed results. The massive sulfide zone is basically a Pb–Zn lens, but Pb:Cu is only in the neighborhood of 2:1 and so the lens is not Cu-poor. No alteration that is distinctly pipe-like is known to underlie the lens; the footwall chloritic alteration is conspicuous, but is of uncertain origin. The sulfide assemblage is pyrite-dominant and thus characteristically distal; magnetite, on the other hand, is more common in the footwall half than in the hanging-wall half of the lens. However, the most pronounced changes in magnetite content are lateral rather than vertical (*i.e.*, along the lens strike rather than in an upward stratigraphic sense). The North Body occurs within a mixed sedimentary–volcanic pile but has distinct metal zoning: Cu is concentrated toward the footwall, and Zn/Cu increases upward. Pb occurs throughout the lens, but is most abundant in the hanging wall.

If the assumption is made that the Caribou North Sulfide Body is a proximal lens, there are further implications concerning the partly overlapping adjacent lenses. The Caribou South

Body (Fig. 8) has only a minor, though persistent, chloritic footwall, but no well-defined copper zone. The East Body, however, lacks both the chloritic alteration and a copper zone, and also differs in that high-grade Pb–Zn values extend throughout from footwall to hanging wall. Thus, for the Caribou deposit as a whole, the Cu-rich footwall pinches out toward the south and east, whereas high-grade Pb–Zn thickens. Along the same trend, silver content of the lenses is highest in the East Body, where the bulk of the element occurs in tetrahedrite (Jambor & Laflamme 1978). Silver, antimony and bismuth in solid solution in galena decrease from the South to the East Body; Sb/Bi values in galena increase from the South Body to the East Body, a trend which corresponds to decreasing temperatures of formation according to the data of Malakhov (1968). All these systematic changes suggest not only that the individual lenses had a common source, but that either the source of the hydrothermal fluids or their focal point of deposition was in the vicinity of the North Sulfide Body.

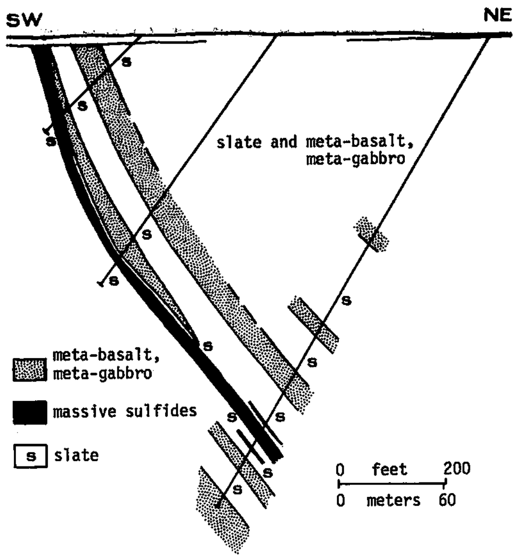

FIG. 9. Cross-section of the Canoe Landing Lake deposit (assessment files, New Brunswick Department of Natural Resources, and D. A. Williams, unpublished).

Despite their variations in metal contents and minor minerals, all of the Caribou sulfide lenses are strikingly similar in their major gangue and sulfide minerals and in the textures of these assemblages. These overriding gross similarities are interpreted to indicate that sulfide deposition occurred from ore-forming solutions that blanketed a depression encompassing the whole of the Caribou site. Within this major environment, precipitation of different proportions of the major elements and minerals could have been largely dependent on a progressive change in physical-chemical conditions with increasing distance from the focus of the system, provided that the focus was the main-vent site. Local variations in the depositional environment are indicated by the presence of resedimented sulfides, especially in footwall samples. (Unlike the excellent examples of resedimented sulfides at Canoe Landing Lake (see Fig. 9), those at Caribou are unaccompanied by lithic fragments). Reworking of the initially deposited sulfides may reflect topographic undulations that could have led to local ponding and eventual overlap of the sulfide bodies. Clastic deposition of sulfides indicates that the system was agitated rather than static, and that deposition–crystallization–erosion of some sulfides occurred before others were precipitated. From these features it is inferred that the system was a progressively evolving one in contrast to a situation in which quiescent precipitation occurred from a static, dense, hot brine. Within the evolving system, however, the fundamental conditions of deposition must not have differed radically from lens to lens. In essence, therefore, Caribou is an on-surface, banded, pyritic type 2 (Pb–Zn–Cu–Ag) deposit that conforms extremely well to Large's (1977) idea of a near-vent stratiform ore.

GENETIC IMPLICATIONS

Features characteristic of both proximal and distal ores are present not only at Caribou, but also in other New Brunswick deposits (Table 3). Most of the deposits are Pb–Zn–rich, and some of these have substantial amounts of associated Cu. Stringer–type mineralization underlies massive lenses in a few cases, but both types can be copper-rich. Massive lenses are generally zoned and copper-rich near the footwall. The proximal–distal genetic model is accepted as conceptually valid, but the criteria in Table 2 do not provide a convenient basis for distinction among most New Brunswick deposits. This kind of overlap in Type 2 (Pb–Zn–Cu–Ag) deposits was recognized by Large (1977). He suggested that in Archean deposits, for example, the lower massive Cu–Zn ores probably formed by subsurface replacement of rocks at the top of the hydrothermal pipe, whereas the banded upper Zn–rich ore probably deposited on the sea floor around the vent. The banded pyritic Pb–Zn–Cu ores of principal concern here "...range over the proximal–distal classification and generally result from direct precipitation onto the sea floor" (Large 1977, p. 554). Banded massive lenses, for which a sublens replacement zone has not been detected, therefore do not necessarily represent deposition in a low-temperature distal environment.

Most of the Bathurst-area deposits fall into the distal category of Table 2 in terms of metal content, but many of these are proximal in terms of iron sulfides and oxides. Indeed, a significant aspect of Large's (1977) proposed chemical evolution of massive sulfide deposits is that pyrrhotite is assumed to be primary and cogenetic with its associated sulfides. In contrast, many writers seem to have assumed that pyrrhotite in stratiform lenses is secondary and has been derived by metamorphic alteration of pyrite. The theory of metamorphic genesis of pyrrhotite also has been applied to the Bathurst-area deposits: according to Helmstaedt (1973a, b), the passage from the chlorite subzone to the biotite subzone of greenschist-facies regional metamorphism (Fig. 2) marks the transition from non-pyrrhotite to pyrrhotite-bearing deposits.

The present writer's study has not substantiated Helmstaedt's proposed sulfide isograd. Deposits in the biotite subfacies of greenschist metamorphism are predominantly pyrrhotite-bearing, but this mineral is also an abundant component of massive sulfide lenses at Armstrong B, at Canoe Landing Lake and near Orvan Brook, all of which are in the chlorite subfacies. A common denominator for pyrrhotite-bearing deposits, regardless of their location in the district, is that pyrrhotite is either concentrated in or occurs exclusively near the stratigraphic footwalls of the lenses. The consistent change from a pyrrhotite–pyrite footwall to a pyritic hanging-wall is readily explicable only if primary rather than metamorphic genesis for the bulk of the pyrrhotite is assumed.

Pipe-like alteration, or discordant stringer-type mineralization, has been delineated at a few of the New Brunswick deposits, and distinct footwall alteration has been recognized at several others. Prominent chloritic zones are conspicuous at several deposits where significant discordance of sulfides has not been proved. Similar chloritic rocks underlie massive sulfides elsewhere and have been recognized as alteration zones of diverse origins (Anderson & Nash 1972, Griffitts *et al.* 1972, Schermerhorn 1978).

Mineralogical studies of the Bathurst-district deposits indicate that many of the stratiform lenses are similar to those at Caribou, whereas a few others have a much higher proportion of gangue minerals. Stratiform lenses that have a several-metres thickness of completely massive sulfide are tentatively concluded here to reflect *in situ* (autochthonous) crystallization in either proximal or distal environments. Massiveness in this case refers to material with at least 90% opaque minerals, *i.e.*, extremely low percentages of silicate and carbonate gangue. Although transportation, deposition, and especially metal zonation of such sulfide-rich material seem unlikely in a distal environment, it has been experimentally demonstrated (Turner & Gustafson 1978) that hot saline solutions, representing ore-bearing brine, are capable of coherent flow. Stratiform deposits with relatively low sulfide percentages (<50% by volume) may reflect distal deposition, a rapid influx of diluents, or only gradual discharge of proximal ore-forming fluids; in all cases the vented fluids seem to have been modified by temperature drop, substantial dilution, or an equivalent variable whose effect has been to neutralize differences between the ore fluid and its surroundings. The low-sulfide ores accumulate in an environment compatible with the formation of the enclosing, commonly intercalated country rocks. Thus the trend may be for autochthonous ores to have a unique gangue, but for low-sulfide and allochthonous ores to have a matrix mineralogically similar to that of their intimately associated host rocks.

Classification of Bathurst-area deposits

A difficulty in classifying proximal and distal stratiform deposits is related to the usage of these terms. Plimer (1978), for example, has subdivided individual kuroko deposits into proximal and distal parts: the chalcopyrite-rich "keiko" footwall ore is regarded as proximal whereas the overlying lead–zinc–barite (kuroko proper) ore is considered as distal. Large (1979) has suggested that most stratiform deposits form in the immediate vicinity of the fumarolic centres from which the ore-bearing solutions emanate, and he has advocated that the terms proximal and distal be used "in their strict sedimentological sense which implies mechanical transport and redeposition of lithified sulphides" (Large 1979, p. 124). In his discussion of Iberian pyritic bodies, Schermerhorn (1978) stated that some of the ore "...is in place or almost in place – that is, autochthonous; the widespread occurrence of internal sedimen-

TABLE 5. HOST ROCKS AND TENTATIVE CLASSIFICATION OF BATHURST-NEWCASTLE MASSIVE SULFIDE DEPOSITS

Deposit	Host Rocks	Classification
Armstrong A	sericite-chlorite schist	distal-autochthonous
Armstrong B	sericite-chlorite schist	proximal-autochthonous
Rocky Turn	sericite-chlorite schist	distal-autochthonous
Orvan Brook	sericite schist	distal-mainly autochthonous
Orvan Brook South	phyllite	distal-autochthonous
McMaster	phyllite	distal-allochthonous
Caribou	phyllite, sericite schist	proximal-mainly autochthonous
Murray Brook	meta-siltstone (Rankin & Davies, in press)	proximal-allochthonous
Restigouche	sericite-chlorite schist	proximal-autochthonous
Ahearne Brook	felsic meta-tuff, slate	distal-autochthonous
California Lake	slate (Williams 1978)	distal- (?)
Selco	meta-rhyolite tuff (Williams 1978)	--------
Wedge	slate	proximal-autochthonous
Canoe Landing Lake	slate	distal-allochthonous
Nepisiguit	slate (Williams 1978)	--------
Brunswick No. 12	meta-sediments, sericite-chlorite schist	proximal-autochthonous
Pabineau	meta-rhyolite (Williams 1978)	--------
Headway	sericite-chlorite schist	--------
Key Anacon	felsic meta-tuff, iron-formation	proximal-allochthonous
Brunswick No. 6	meta-sediments, iron-formation	proximal-autochthonous
Austin Brook	iron-fm., ser.-chlor. schist (Boyle & Davies 1964)	distal-autochthonous
Flat Landing Brook	iron-fm., rholite breccia, tuffs (P. Gummer)*	proximal-allochthonous(?)
Nine Mile Brook	rhyolite, argillite, iron-formation	distal-allochthonous
Captain	quartz porphyry	proximal-autochthonous
Heath Steele B	chlorite schist, iron-formation	proximal-autochthonous**
ACD	chlorite schist	proximal(?)-autochthonous
Stratmat	sericitic and chloritic schists	--------
Devil's Elbow	chlorite schist	proximal-autochthonous
Half Mile Lake	sericite-chlorite schist	proximal-autochthonous
Chester	sericite-chlorite schist	proximal-autochthonous

*Oral comm. 1979 **McBride (1976) has concluded that the source area was west of the present deposit

tary structures, especially thin bedding, suggests, however, that most pyritite in this province has moved downslope on the submarine volcanoes to be redeposited at varying distances from the source. Such ore is allochthonous – ranging from proximal to distal deposits – and may be classified as exhalative–resedimented" (Schermerhorn 1978, p. 163).

Much of the present study has focused on alteration and sulfide and gangue mineralogy of the Bathurst-area deposits in an attempt to determine whether these might provide indications that a deposit was formed near its hydrothermal fumarolic centre. Even with the identification of such a centre, a simple classification of a deposit is difficult because parts of it also generally show well-developed thin bedding and local deposition of sulfide clasts. These sedimentary features need not indicate movement downslope on submarine volcanoes, but instead may represent sedimentary deposition and local reworking of sulfides accumulated around conduits that are in a relatively subdued terrain distant from submarine volcanoes. The resultant sulfide deposit may overlie its feeders, and in this sense the sulfides have moved very little.

Table 5 gives a tentative classification of most of the Bathurst-area stratiform deposits with reference to their established or assumed displacement from feeder conduits. The two basic terms, proximal and distal, refer to this displacement and are qualified as follows:

proximal–autochthonous: overlaps hydrothermal conduits; basically, both the stringer and the stratiform sulfides have formed in place; clastic sulfides occur only locally and are at the contact or below the massive lens;

proximal–allochthonous: sulfide clasts widespread, commonly coarse, and are in the lower part of the massive zone as well as in footwall rocks; vent peripheral to stratiform sulfides, indicating significant downslope movement;

distal–autochthonous: distant from hydrothermal conduits, but sulfides mainly crystallized *in situ*, as for example, from transported brine;

distal–allochthonous: distant from hydrothermal conduits and abundant evidence of transportation of particulate sulfides, commonly fine-grained, through much of the sulfide zone.

Host rocks do not enter into the above classification. Proximal-autochthonous ores, such as those of the kuroko and Cyprus deposits, form in volcanic environments that range from acidic to basic. Other deposits, such as the Sullivan mine, British Columbia, seem to have formed by the same genetic processes despite being sedimentary-hosted.

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