Zn-Pb DEPOSITS IN THE CARIBOO SUBTERRANE, CENTRAL BRITISH COLUMBIA (93A/NW)

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INTRODUCTION

The Cariboo subterrane comprises dominantly Precambrian to Early Mesozoic clastic and carbonate rocks that were deposited along the western margin of North America (Struik, 1988). It correlates with parts of the Cassiar Platform and Selwyn Basin of the Yukon and northern British Columbia, and with Proterozoic and Paleozoic rocks in the Selkirk and Purcell Mountains of southern British Columbia. These rocks include both basinal and platformal sediments with demonstrated stratigraphic ties to North America. They contain numerous mineral deposits, including a variety of veins, Pb-Zn and W skarns, and carbonate and sediment-hosted massive sulphide occurrences. These massive sulphide deposits are the focus of this paper.

This paper overviews known Zn-Pb massive sulphide deposits of the Cariboo subterrane in the Likely-Barkerville area (Figure 1), focusing on the Maybe (MINFILE no. 093A 110) prospect. The paper is part of a regional study of both volcanogenic and sediment-hosted massive sulphide deposits in adjacent Kootenay terrane and correlative Yukon-Tanana terranes (Nelson *et al.*, 1997). A companion paper (Höy and Ferri, 1998) overviews the geology of the Barkerville subterrane, compares it to the other parts of the Kootenay terrane, and describes, classifies and compares contained massive sulphide deposits.

MASSIVE SULPHIDE DEPOSITS

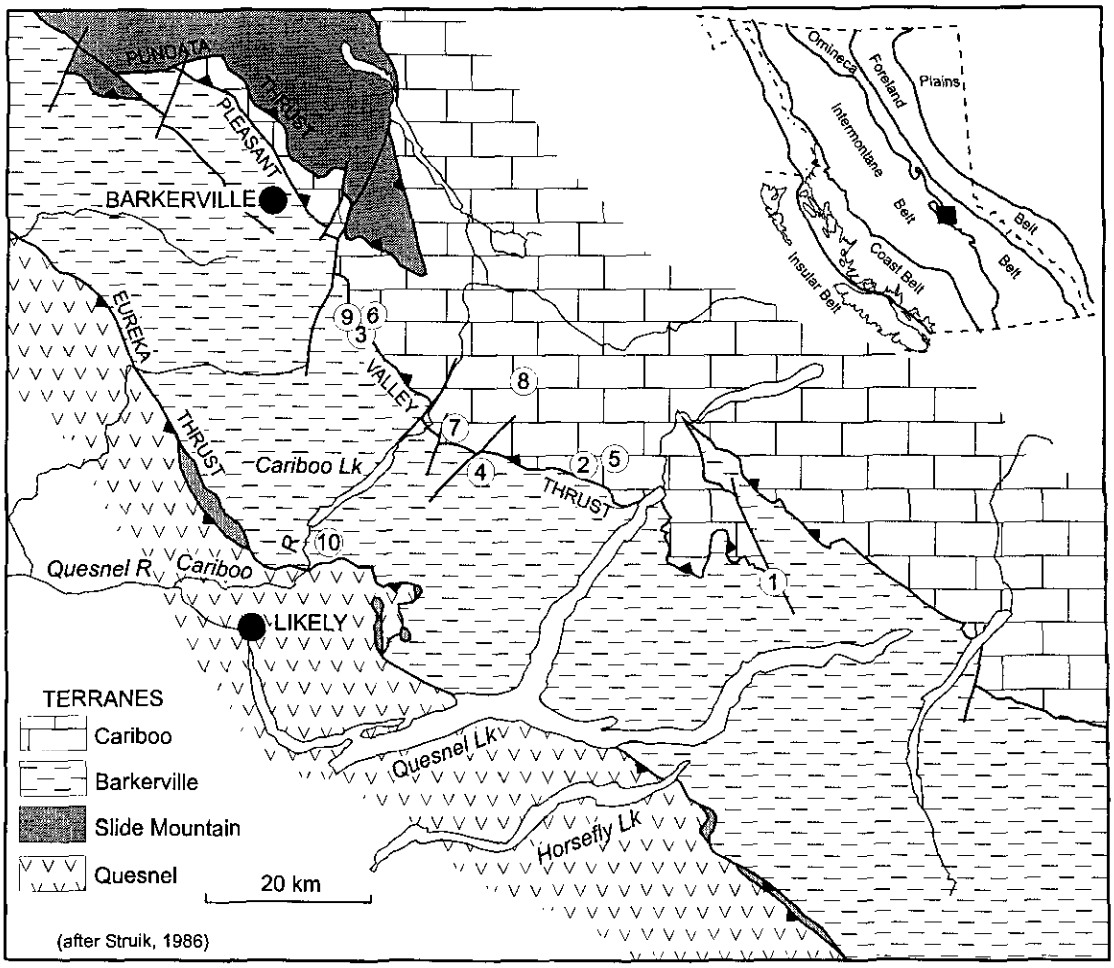
Massive sulphide deposits in miogeoclinal rocks correlative with those in the Cariboo subterrane include stratiform sediment hosted deposits and carbonate replacement deposits. Sediment hosted deposits (sedex deposits) are concentrated during periods of extensional tectonics, typified by marine transgressions, pronounced facies changes from shallow to deeper water, and locally with mafic volcanism. Carbonate-replacement deposits are also commonly controlled by tectonics, localized near regional unconformities and along major structural breaks.

EoCambrian to Early Cambrian time is marked, locally, by rifting, volcanism and submergence along the ancestral continental margin. Sedex deposits occur in a variety of rock types in British Columbia including the Bend in platformal carbonate rocks (Leask, 1982), Cottonbelt and other Shuswap deposits in high grade metamorphic rocks of the Monashee Complex (Fyles, 1970; Höy, 1987) and Lucky Coon and Mosquito King in a metasedimentary / metavolcanic succession of the Eagle Bay Assemblage (Schiarizza and Preto, 1987). As well, carbonate-replacement deposits characterize Early Cambrian platformal carbonates in the Kootenay Arc; those in Middle Cambrian rocks, including Monarch and Kicking Horse in the Rocky Mountains, occur at a platform margin.

A marine transgression in Middle Ordovician time, also marked locally by mafic volcanism, is associated with sedex deposits in Road River Group rocks of the Gataga District (McIntyre, 1991). In southern British Columbia, a few small carbonate-hosted Pb-Zn occurrences, such as Hawk Creek (082N 021), may be in Ordovican rocks.

In Middle Devonian to Early Mississippian time, opening of the Slide Mountain ocean to the west is believed to have occured in response to arc volcanism along the distal continental margin, remnants of which are found in the Eagle Bay Assemblage of the Kootenay terrane (Ferri, 1997). Continental margin rocks are characterized by extensional tectonics, isolated rift basins, minor volcanism and major unconformities, an event referred to as the "Little Diastrophism" by Struik (1980). These rocks host numerous large sedex deposits, including Pb-Zn-barite deposits in the Ketchika trough and Selwyn basin in northern British Columbia and Yukon.

Known massive to semi-massive sulphide deposits in the Cariboo subterrane include a number of carbonate-hosted Zn-Pb deposits (Figure 1). They are in



Property		Commodities	Host	Deposit type(s)	Terrane
1.	Green Ice (093A 082)	Zn	Snowshoe Gp limestone	disseminated/ vein	Barkerville
2.	Mae (093A 083)	Cu-Zn-Pb	Downie calc silicate	stratabound?	Barkerville
3.	Peter Gulch (093A 093)	Pb-Zn	Snowshoe Gp limestone	vein/ replacement	Barkerville
4.	Ace (new) (093A 142)	Cu-Au-Ag-Zn-(Pb)	Downie "phyllite"	volcanogenic massive sulphide	Barkerville
5.	Al (093A 065)	Pb-Zn-(Cu)	Cunningham limestone	replacement Zn-Pb	Cariboo
6.	Vic (093A 070)	Pb-Zn-barite	Midas Fm limestone	stratiform (sedex?)	Cariboo
7.	Maybe (093A 110)	Pb-Zn-Ag	Black Stuart Gp black pelite unit	replacement/ vein	Cariboo
8	Comin Throu Bear (093A 158)	Pb-Zn-barite	Mural Fm limestone	replacement	Cariboo
9.	Cunningham Creek area	Pb-Zn	Hardscrabble Mtn limestone	stratiform (sedex?)	Barkerville
10.	Big Gulp (new) (093A 143)	Cu-Zn-(Ag-Au)	Downie phyllite	volcanogenic massive sulphide	Barkerville

Figure 1. Map of the Cariboo and Barkerville subterranes (after Struik, 1988), with location of stratabound Zn-Pb occurrences.

carbonate rocks that range in age from Late Proterozoic to Middle Devonian. The Maybe and Comin Throu Bear (093A 148) prospects are interpreted to be carbonate replacement deposits above a Late Silurian to Early Devonian unconformity. Numerous small concordant sulphide deposits in dark calcareous shales in the Cunningham Creek area have been interpreted to be in the Eocambrian Midas Formation (e.g., Longe, 1977). However, they may be in the Barkerville subterrane which hosts correlative? barite occurrences in the Devonian Hardscrabble Mountain succession (Struik,1988).

CARIBOO SUBTERRANE

The Cariboo subterrane includes: the Late Proterozoic Kaza Group, a succession of dominantly impure quartzites, phyllites and conglomerates; the overlying Late Proterozoic to Early Paleozoic Cariboo Group; and the Early to Late Paleozoic Black Stuart Group (Struik, 1988). Much of the Barkerville-Likely area underlain by the Cariboo subterrane has been mapped by Sutherland Brown (1963), Campbell *et al.* (1973) and Struik (*op. cit.*). Debate concerning the internal stratigraphy, paleotectonic environment and regional correlations of the Cariboo Group, as discussed in Struik (1988), is beyond the scope of this paper; as such, the most recent nomenclature of Struik is used.

Middle Pennsylvanian		ALEX ALLEN FORMATION	
Early Mississippian	BLACK STUART GROUP	GREENBERRY FORMATION	
late Devonian to Early Miss.		GUYET FORMATION	
			←unconformity
Middle to Late Devonian		WAVERLY FORMATION	
Mississippian & younger		sandstone unit	
Devonian		black pelite unit	* Maybe
Early Dev. & Late Silurian		chert-carbonate unit	* Comin Throu Bear
			unconformity
Upper Ordovician		black pelite unit	
Early Cambrian	CARIBOO GROUP	DOME CREEK FORMATION	
		MURAL FORMATION	
		MIDAS FORMATION	* Vic
PROTEROZOIC		YANKS PEAK FORMATION	
		YANKEE BELLE FORMATION	
		CUNNINGHAM FORMATION	* Al
		ISAAC FORMATION	
	KAZA GROUP		

Figure 2. Table of formations for the Cariboo and Black Stuart Group, Cariboo subterrane (*after* Struik, 1988), showing position of stratabound Zn-Pb occurrences.

The Cariboo and Black Stuart successions are illustrated in Figure 2. The Cariboo Group includes phyllite, slate, limestone and minor quartzite of the Isaac, Cunningham and Yankee Bell formations, quartzites of the Yanks Peak Formation and limestone of the Lower Cambrian Mural Formation. These correlate with the North American Windermere Group, Hamill Group and Badshot Formation respectively in southern British Columbia. Conformably overlying slate and shale of the Dome Creek Formation may correlate with similar lithologies in the Chancellor Group of the southern Rocky Mountains (see Struik, 1986) and perhaps with the base of the Index Formation of the Lardeau Group in the Kootenay terrane.

The Black Stuart Group unconformably overlies the Cariboo Group (Struik, 1986, 1988); it ranges in age from Late Ordovician to Mississippian. A discontinuous chert and dolostone breccia unit, host to Comin Throu Bear mineralization, commonly defines the base of the group. It is overlain by dark shales, slate, cherty argillite, phyllite and minor limestone of the "black pelite unit", host to the Maybe prospect. A thin succession of mafic volcaniclastics, the Waverly Formation, and a prominent Devono-Missisissippan (?) conglomeratic facies, the Guyet Formation, occur near the top of the Black Stuart Group.

MAYBE (093A 110)

The Maybe prospect is one of a number of stratabound Zn-Pb occurrences in Early Paleozoic platformal carbonates of the Cariboo subterrane. It is located 5 kilometres northeast of the confluence of the Cariboo and Little Rivers and 35 kilometres northeast of the town of Likely (Figure 1). The deposit occurs on the steep eastern slopes of the Cariboo River, at elevations ranging from just over 1000 metres to 1400 metres. Most of the area has been recently logged, and exposures of mineralization are largely restricted to logging roads. Access is provided by a road that leaves the Likely-Barkerville (8400) road at km 21.2, then crosses the Little River.

Exploration History

Exposures of Pb-Zn mineralization, discovered in 1986 on new outcrops created by logging roads, were drilled in 1987 by Gibraltar Mines Ltd. Twenty N.Q. holes, totaling 3,044 metres, intersected "numerous" lead-zinc horizons and associated veinlets and mineralized quartz veins (Bysouth, 1988). Three main

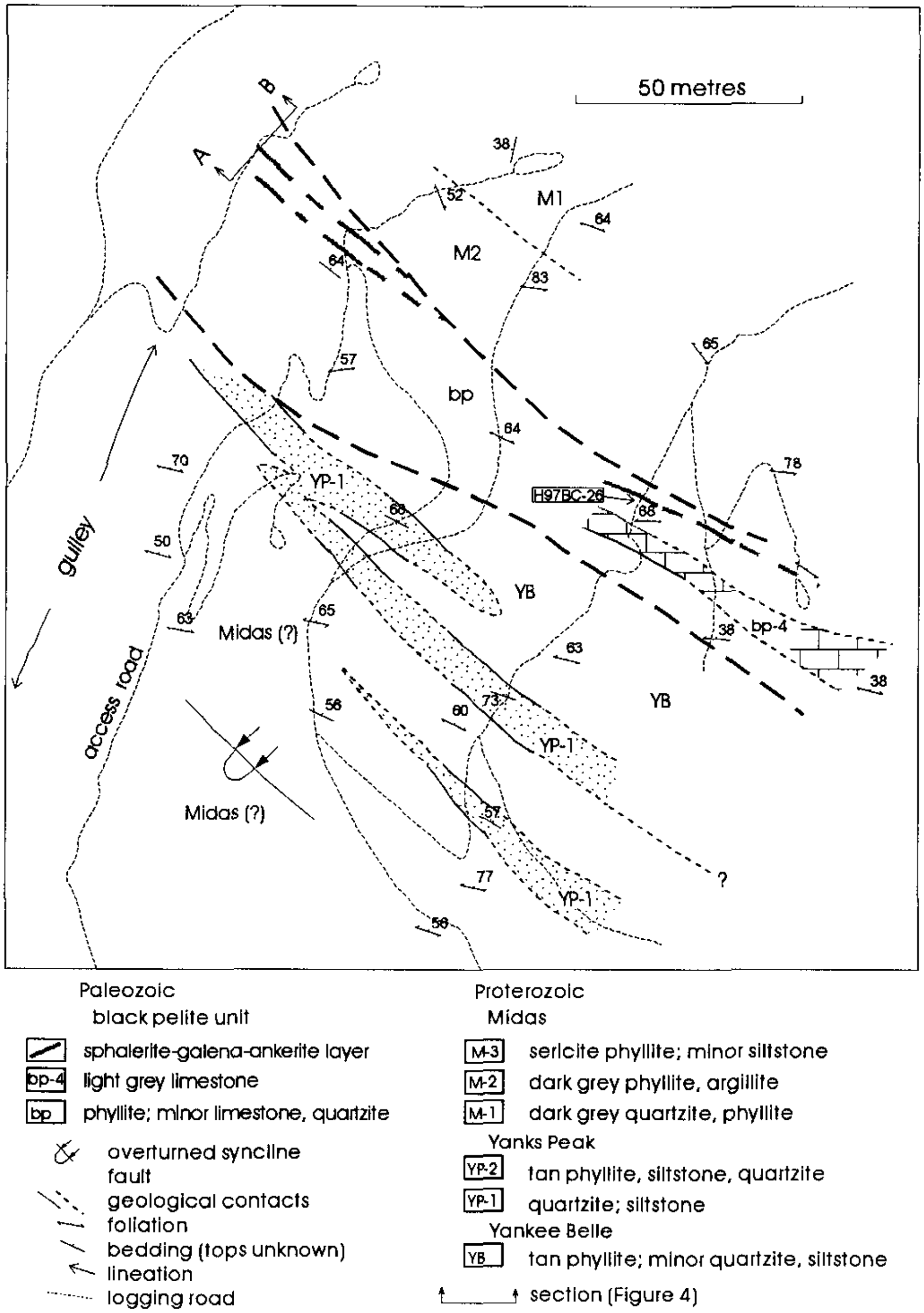


Figure 3. Geological map of the Maybe prospect, Cariboo subterrane (data sources: this report; Struik, 1988; Spencer, 1989).

mineralized layers were defined, with estimated geological reserves of 400 000 tonnes containing 4 percent combined lead and zinc.

Sable Resource Ltd. optioned the property in 1988 and undertook an exploration program of detailed geological mapping, trenching and limited geochemical soil surveys. This program concluded that the mineralization was dominated by fracture controlled veins, but that several of the showings were similar to "metamorphosed strata-bound lead-zinc carbonate-hosted occurrences" (Spencer, 1989).

The Maybe claim area has been acquired recently by Barker Minerals Ltd. Additional geological mapping and sampling has extended known mineralization and discovered higher grade massive sulphide zones. The recognition of anomalous values of antimony and mercury suggested to Roach (1997) that mineralization had similarities with an epithermal system. Test geophysical surveys concluded that the mineralization has a positive response to VLF-EM but no magnetic signature (Lammle, 1997).

Stratigraphy

The Maybe deposit area has been mapped at a scale of 1:50 000 by Struik (1988). The geology is dominated by northwest plunging, tight overturned folds that are cut by steeply dipping, northwest trending faults. A more detailed map, illustrated in Figure 3, attempts to adhere to the stratigraphic nomenclature of Struik (*op. cit.*). Several mineralized horizons are recognized within dark calcareous units of the Middle Devonian (?) black pelite unit; these are interpreted to be in an overturned north dipping succession, structurally overlain by dark siltstones and quartzites of the Eocambrian Midas Formation (Struik, *op. cit.*). Spencer (1989) places a fault rather than an inferred unconformity between these successions (*see* Figure 3) and, hence, the facing direction of the mineralized succession is not known.

Late Proterozoic and Early Cambrian: Yankee Belle, Yanks Peak and Midas Formations

The Yankee Belle, Yanks Peak and Midas formations are exposed south of the Maybe deposit. These units have been mapped as the northern limb of an overturned, northwest plunging fold with Midas rocks in its core and Yanks Peak and Yankee Belle formations on its limb (Struik, 1988). The discontinous nature of orthoquartzites in this footwall succession (Figure 3) may be due to structural complexity such as interfolding between Yanks Peak and Yankee Belle formations or, less likely, to rapid lateral facies changes in Yanks Peak.

The Late Proterozoic Yankee Belle Formation (Sutherland Brown, 1963) includes phyllite, calcareous phyllite, argillite and minor limestone and quartzite. In the Maybe deposit area, it comprises tan coloured phyllite with minor phyllitic siltstone and very minor grey to dark grey phyllite. The contact with the structurally underlying Yanks Peak is sharp, placed the base of a white orthoquartzite.

The Yanks Peak is dominated by quartzite with minor interlayered siltstone, phyllite and argillite. It is inferred to be tightly folded along the north limb of a syncline, structurally beneath the Yankee Belle Formation (Figure 3). It comprises ridge-forming, thick-bedded white to tan orthoquartzite, interlayered with thinner bedded impure quartzites and tan to medium grey phyllite and silty phyllite. A thin, discontinous green chlorite phyllite within the Yanks Peak may be a mafic tuff unit.

The Midas Formation is exposed south of the Yanks Peak and in the structural hangingwall north of the deposit (Figure 3). The more northern exposures are dominated by dark grey phyllite, slate, and graphitic argillite, interlayered with dark, fine-grained quartzite. These quartzites may be argillaceous and are commonly cut by numerous 2-3 cm quartz veins. Sericite phyllites are less common. Rare grey to greenish phyllite units, less than a metre thick, containing dispersed ankerite and minor mariposite, may be thin mafic tuff layers.

Paleozoic: Black pelite unit

The black pelite unit is interpreted by Struik (1988) to be inverted, and to unconformably overlie the Midas Formation in the deposit area. Alternatively, as suggested above, a fault may separate these units, as mineralized layers in the younger black pelite unit appear to be truncated along this contact; however, it is possible that the contact is locally fault reactivated. The Midas and black pelite unit are differentiated by the abundant limey units in the latter.

The black pelite unit comprises dark grey phyllite, fissile graphitic phyllite and interlayered limestone. The limestone is typically streaked light and dark grey, although locally a tan to pale grey limestone occurs. Minor pale green chloritic phyllite may have a volcanic origin. Lead-zinc mineralization is hosted by tan, siliceous carbonate units, interlayered with medium grey to tan calcareous and sericitic phyllite.

The black pelite unit, as defined by Struik (1988), includes both graptolitic slates of Ordovician age and dark phyllite and argillite that overlies an Early Devonian chert-carbonate unit. Its age in the deposit area is not known; however, the abundance of included dark limestone suggests a Middle Devonian or younger age rather than an Ordovician age (L.C. Struik, personal communication, 1997).

Mineralization

The Maybe prospect comprises at least three thin, continuous layers of dominantly ankerite, dolomite and quartz that contain streaky sphalerite, galena and minor pyrite. These layers are within dark grey limey intervals in the more typical dark phyllite of the black pelite unit. Drill intersections, illustrated in Figure 4, indicate that mineralized layers commonly have a higher grade core, up to one metre thick, of locally semimassive sphalerite and galena, with dispersed and vein mineralization extending two to three metres on either side.

Figure 5 is a detailed section through one of the mineralized intervals exposed at surface (*see* Figure 3). The stratigraphic top is not known, but based on regional work by Struik (1988), the section may be inverted. Two thin carbonate layers, separated by sericite phyllite, host sulphides.

The host carbonate layers comprise dominantly brown weathering, grey ankerite and quartz, with minor sericite, dolomite, calcite, trace fuchsite and locally actinolite. These minerals are typically sheared or foliated or, less commonly, brecciated with dolomite or ankerite clasts in a granular ankerite-quartz groundmass.

Sulphide minerals include dark brown sphalerite and galena, with minor pyrite and trace chalcopyrite and pyrrhotite. Sphalerite and galena are commonly streaked parallel to layering (and foliation) and/or disseminated in the carbonate matrix. Less commonly, they occur in both early sheared quartz-carbonate veinlets and late, discontinuous, post-shearing veins. However, most of the late veins are barren or contain only pyrite.

Petrographic study (Payne, 1997) confirms that many sulphides and carbonates are foliated or strained. Sphalerite and galena are intimately intergrown and typically concentrated in thin, discontinuous lamellae that parallel foliation. They also occur as extremely fine inclusions in ankerite. Some sphalerite grains contain fine inclusions of chalcopyrite or pyrrhotite. Galena and sphalerite may also occur as coarser, recrystallized grains with ankerite and quartz.

Galena can also occur as inclusions in pyrite, replacement of ankerite, and rarely in late veinlets that

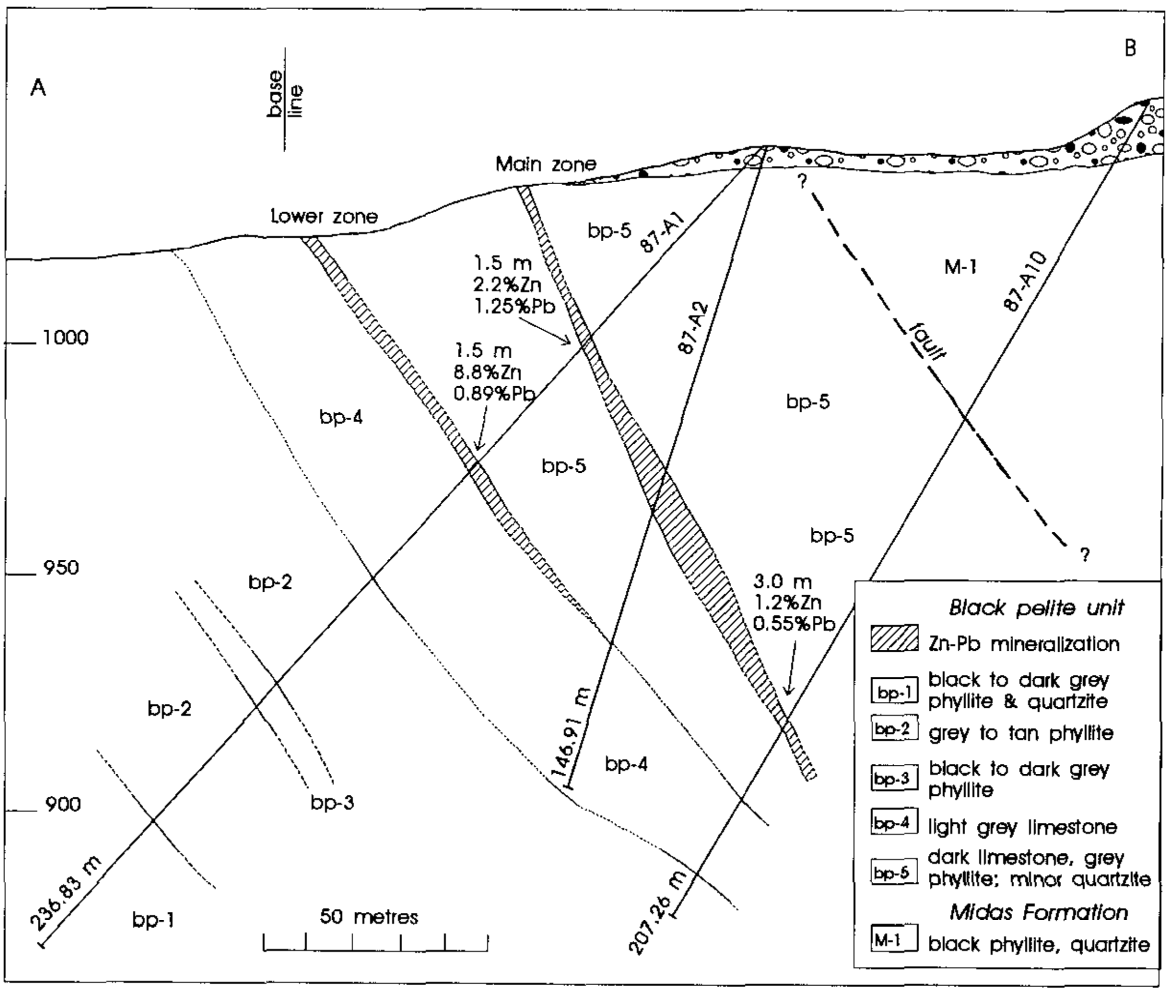


Figure 4. Vertical section throught the Maybe prospect, based on drilling by Gibraltar Mines Ltd. (Bysouth, 1988); *see* Figure 3 for location.

cut foliation. Pyrite is commonly late, occuring as euhedral grains and in late veins. Dendritic hematite and limonite form late veinlets and irregular alteration patches.

Analyses of a number of hand samples of the mineralized layers are given in Table 1. Lead and zinc values are highly variable, with selected massive sulphide samples containing greater than 10 per cent combined lead and zinc. Silver content is variable, but commonly 15 to 30 ppm. Gold values are low, with a maximum obtained value of 109 ppb. Roach (1997) reports anomalous mercury, with samples typically containing more than 2-3 ppm (Table 1). Antimony and selenium are also anomalous.

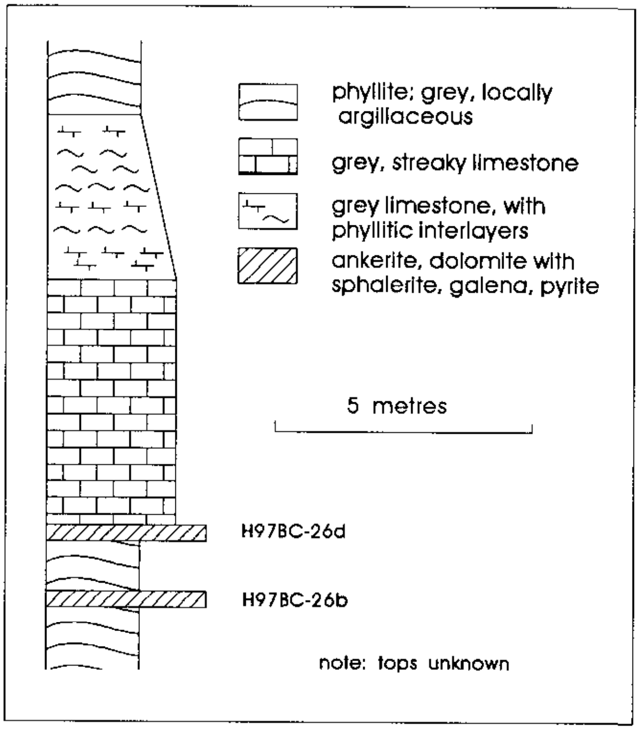


Figure 5. Schematic section through a mineralized interval of the Maybe prospect; *see* Figure 3 for location.

Discussion

The origin of mineralization at the Maybe occurrence is difficult to determine due to metamorphism and deformation. Sulphide and gangue textures suggest a paragenetic sequence of early intergrowth of sphalerite, galena, ankerite and possibly pyrite; chalcopyrite may be due to exsolution from sphalerite. This mineralization is clearly prekinematic. Syn to post kinematic mineralization includes pyrite overgrowths, and possibly layer-parallel ankerite-sulphide veining. Late, post-kinematic mineralization includes pyrite, as well as discordant quartz-dolomite veins that contain minor pyrite and rare sphalerite and galena.

TABLE 1
ASSAYS OF SELECTED SAMPLES OF MINERALIZED LAYERS FROM THE MAYBE PROSPECT;
SEE FIGURES 3 AND 5 FOR LOCATIONS

Sample	Description	Sourc	Cu	Pb	Zn	Ag	Au	Ni	Co	Mn	As	Sb	Cr	Se	Hg
			ppm	%	%	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppb
4009	massive sulphide	1	58	4.64	>10	22.3	25	9	11	2273	1.4	21.2	258	9.1	3185
4012	calcareous chert	1	59	1.4	3.46	8.7	19	9	3	638	2.3	17.9	64	0.5	2590
4013	calcareous chert	1	73	4.51	5.24	25.4	49	22	4	832	2.4	61.4	93	1.6	2340
4081	massive sulphide	1	99	2.36	>10	53	59	33	36	2213	3.7	61.2	192	24.6	9260
4139	qz-carb. stockwork	1	233	1.25	4.54	11.6	12	28	6	3259	177	14	41	2.6	1060
4164	massive sulphide	1	136	3.47	>10	117.2	83	10	59	2266	8	154	<1	0.4	99999
H97BC-26b	semi-masssive sulphide	2	56	2.85	9.95	25.8	87	7	4	595	< 5	18	72		
H97BC-26d	semi-masssive sulphide	2	69	3.33	9.15	28.1	109	12	6	586	< 5	14	73		
H97BC-48a	semi-masssive sulphide/vei	2	78	1.15	>10	8	82	10	6	1642	25	18	101		
H97BC-48b	semi-masssive sulphide/vei	2	140	3.4	>10	19.9	44	11	10	1800	20	14	79		
H97BC-50	semi-masssive sulphide/vei	2	90	3.31	>10	33.7	34	10	11	2713	8	17	93		
H97BC-71b	brecciated sulphides/veins	2	112	2.36	>10	16.1	24	7	16	3404	26	16	84		
H97BC-84	diss. to massive sulphide	2	37	0.87	1.21	4.6		38	12	2372	5	< 5	76		
H97BC-103a	massive sulphide	2	182	3.44	>10	43.3		16	13	1199	11	47	189		
H97BC-103b	massive sulphide	2	24	0.41	>10	< .5		6	8	1247	11	< 5	42		
H97BC-110	semi-massive sulphide	2	77	2.54	4.3	18.6		14	2	834	< 5	15	60		

Notes: Analyses of samples of Roach (1997) are by ICP, Acme Analytical Laboratories, Vancouver
Analyses of samples from this report are by MIC, Acme Analytical Laboratories, Vancouver
Source: 1. Roach, 1977; 2. this report

The restriction of all mineralization to specific carbonate horizons within the black pelite unit, the recognition that considerable mineralization is prekinematic, and the pseudolayered nature of this mineralization suggest a syngenetic origin. However, comparisons with other carbonate-hosted Zn-Pb deposits, the dominant ankeritic host, chemistry and abundant vein mineralization suggest that Maybe is a replacement deposit.

The metal content of the Maybe deposit, with high Zn/Pb ratios, moderate silver content, and low gold, is similar to many carbonate-hosted Zn-Pb deposits, including those in the Early Cambrian platformal carbonates in the Kootenay Arc in southern British Columbia and the Irish deposits in Early Carboniferous rocks. However, in these deposits the dominant host is a fine-grained granular dolomite or, less commonly, silica in contrast to the ankeritic host of Maybe mineralization. A considerable portion of the mineralization in the Maybe occurs in sheared, foliation parallel veins; other includes later cross-cutting veins. It is possible that this vein mineralization records remobilized sulphides and gangue, as it is restricted to carbonate host.

In summary, Maybe is a carbonate-hosted Pb-Zn deposit and, as is common to many of these deposits, its origin remains enigmatic. Detailed work on the Irish deposits, often considered examples of syngenetic sulphide deposition in carbonate rocks, now suggests that they are largely structurally controlled diagenetic to epigenetic replacement mineralization (e.g., Hitzman, 1995). We suggest that mineralization of the Maybe prospect is also largely replacement/vein in origin. Its unusual characteristics are similar to some manto style deposits.

COMIN THROU BEAR (093A 148)

The Comin Throu Bear showings comprise galena and barite replacement of a Late Silurian to Early Devonian chert-dolostone breccia in the Black Stuart Group (Figure 2). The property is located at an elevation of approximately 1800 metres on Black Stuart Mountain, approximately 18 kilometres northeast of Cariboo Lake. Past work on the property includes mapping, trenching, sampling and diamond drilling totalling 465.6 metres in 16 holes (Reed *et al.*, 1981). The property was not visited this past summer, and these descriptions are summarized from assessment reports.

The showings occur in fine grained clastic dolostone that overlies the Mural Formation. The dolostone is recessive weathering due to high pyrite content. It contains lenses of limestone and two showings of coarse-grained barite and galena. It is underlain by a grey weathering limestone of the Mural Formation, and overlain gradationally by a dolostone breccia that grades upwards to chert-dolostone breccia. The breccia is highly variable both vertically and laterally, and records an unconformity within the basal Black Stuart Group (Struik, 1988). It is overlain by black slates of the Black Stuart Formation.

Mineralization has been located in two areas (Reed *et al.*, 1981), separated by a strike length of approximately 1200 metres. Five of eleven trenches in the eastern "Area B" expose coarse-grained barite with interstitial galena, with widths up to eight metres. Mineralization is at the contact of dolostone and overlying laminated grey limestone. Trenching at the western "Area A" exposes a similar zone 15 cm thick.

Reed *et al.* (1981) suggest that these occurrences are early (diagenetic?) carbonate replacement and possible open-space fill deposits. Alteration includes early dolomitization, concentrated in breccias and clastic units, followed by silicification, then sulphide deposition. The simple mineralogy, textures, brecciation and stratigraphic control, suggest similarities with Mississippi Valley type deposits.

SUMMARY AND DISCUSSION

The Cariboo subterrane comprises Late Proterozoic to Paleozoic basinal to platformal successions that were deposited on the North American continental margin. Massive sulphide deposits in these and correlative rocks include both syngenetic sediment-hosted and replacement carbonate-hosted lead-zinc ± barite mineralization. These types of mineralization are typically concentrated during periods of extensional tectonics; sedex deposits form in rift-controlled basins and carbonate replacement deposits occur along structural breaks commonly at or above unconformities or along platformal margins.

Known massive sulphide deposits in the Cariboo subterrane are within carbonate successions that immediately overlie a Late Silurian to Early Devonian unconformity, locally marked by conglomerate and breccia facies and removal of underlying stratigraphy. They include the stratabound Maybe and Comin Throu Bear prospects, both interpreted to be replacement deposits. Maybe is unusual because it has an ankeritic host and a geochemical signature that includes anomalous trace element concentrations such as mercury, antimony and selenium.

Exploration for new sulphide discoveries in the Cariboo subterrane should focus on recognized stratigraphic intervals that host deposits in correlative rocks elsewhere, such as the EoCambrian to Cambrian Midas and Mural Formations, and the Early Devonian carbonate clastic succession or black pelite unit above the Late Silurian to Early Devonian unconformity.

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