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Geoscience BC

Mineralogy of supergene carbonate-hosted nonsulphide Zn-Pb mineralization in southern and central British Columbia

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1. Introduction

Carbonate-hosted nonsulphide base metal (CHNSBM) deposits are formed when primary sulphide ore is oxidized and base metals pass into solution, either precipitating as nonsulphide minerals directly above the sulphide protore as “direct replacement” style mineralization, or travelling away from the sulphides with percolating waters and precipitating as “wallrock replacement” style mineralization up to hundreds of metres away from the sulphide protore (Figure 1) (Simandl and Paradis, 2009). Direct replacement deposits are commonly referred to as “red ores”, as they contain gossanous mineralogy and high concentrations of iron oxides with typically >20% Zn (Reichert and Borg, 2008). Wallrock replacement deposits are often referred to as “white ores” due to the lack of gossans (i.e., low concentration of iron oxides) and higher concentrations of Zn (up to 40%), and are preferable from an economic and metallurgical standpoint.

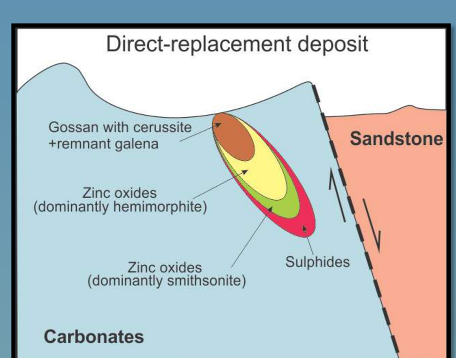

Figure 1a. Direct replacement deposits occur immediately above sulphide ore, where nonsulphide minerals are precipitated as Fe- and Zn-rich gossans due to oxidizing chemical reactions (Simandl and Paradis, 2009).

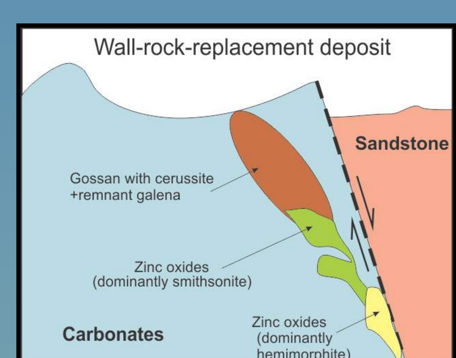

Figure 1b. Wallrock replacement deposits are formed when Zn liberated from the sulphide ore travels with percolating fluid away from the protore and migrates out into the carbonate host rock, where it precipitates nonsulphide Zn minerals (Simandl and Paradis, 2009.)

Both styles of mineralization are known to exist in B.C., but the non-sulphide mineralogy has not been characterized in detail. Due to the high concentration of Zn and Pb, combined with the ease of extracting non-sulphide Zn and Pb ore with modern hydrometallurgical techniques, CHNSBM deposits are clearly valid exploration targets. Samples from the Red Bird, Oxide and Lomond deposits of the Salmo district and from the Cariboo Zinc property of the Quesnel Lake district are analyzed petro-graphically and geochemically to characterize the nonsulphide minera-logy. Characterization of these deposits will ultimately assist in creating deposit models for nonsulphide Zn-Pb deposits in B.C.

2. Geologic Setting

CHNSBM mineralization occurs in the Salmo district of the Kootenay terrane and in the Quesnel Lake district of the Cariboo terrane of southern and central BC (Figure 2). Both regions comprise thick sequences of thrust-imbricated, polydeformed, and metamorphosed Proterozoic to Early Mesozoic carbonates, siliciclastic rocks, basinal shales, and subordinate volcanic rocks (Paradis, 2007).

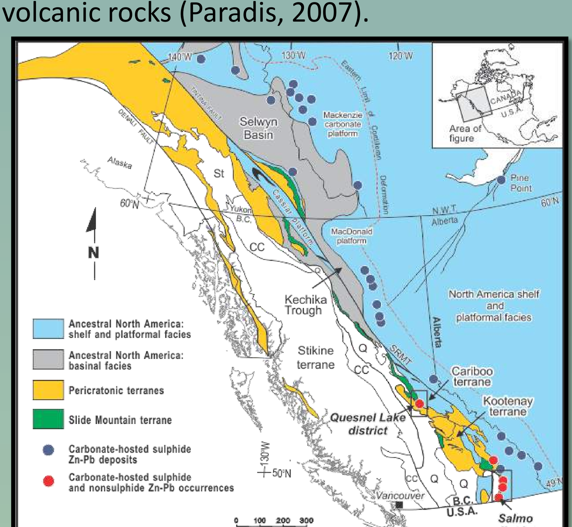

Figure 2. Simplified geologic map of the Canadian Cordillera, with the location of the Kootenay and Cariboo terranes. The project areas lie within the Salmo and Quesnel Lake districts of southern and central B.C. (modified from Paradis et al., 2009). CC = Cache Creek terrane, St = Stikine terrane, Q = Quesnel terrane, and SRMT = southern Rocky Mountain Trench.

In the Salmo district, sulphide and nonsulphide mineralization of the Red Bird, Reeves MacDonald, Oxide, HB, and Jersey deposits occur in Lower Cambrian carbonates of the Reeves member of the Laib Formation. Mid Cambrian carbonates of the Nelway Formation host the Lomond showing (Gorzynski, 2001). The carbonate rocks are bounded on both sides by thick successions of siliciclastic rocks. General geology of the Salmo district is shown in Figure 3.

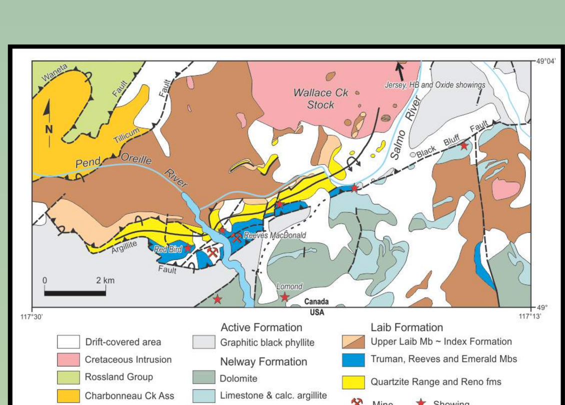

Figure 3. Geological map of the Salmo district in southern B.C., showing locations of known Zn-Pb sulphide and nonsulphide deposits. Deposits analyzed in this study are labelled (Reeves MacDonald, Lomond and Red Bird), while the HB, Jersey and Oxide showings outcrop off the north edge of the map within the same Reeves Member dolostone of the Laib Formation.

In the Quesnel Lake district, sulphide and nonsulphide deposits of the Cariboo Zinc property are hosted by the Late Proterozoic dolostone-dolomitic limestone of the Cunningham Formation of the Cariboo Group (Figure 4) (Paradis et al. 2009).

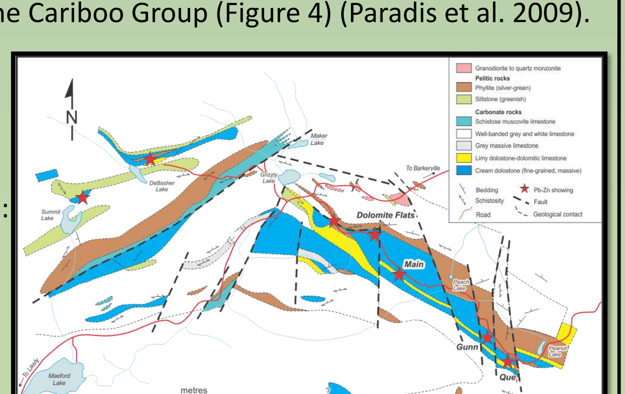

Figure 4. General geology of the Cariboo Zinc property with location of the studied showings: Dolomite Flats, Main, Gunn, and Que (modified from Paradis et al., 2009).

Abstract

Carbonate-hosted nonsulphide base metal (CHNSBM) deposits form in supergene environments when base metal sulphides are oxidized and chemical weathering causes the metals to be leached out and deposited as metal-bearing gossans. The nonsulphide minerals can be deposited by “direct replacement” immediately above the sulphide protore, or can travel away from the sulphide protore with percolating water and be deposited as “wallrock replacement” deposits. Both forms of mineralization have been recognized as valid exploration targets in B.C., but detailed mineralogy and chemistry of representative deposits is needed to better establish exploration models. Petrography, XRD and SEM/EDS analyses were completed on selected nonsulphide deposits, i.e., Redbird, Lomond, and Oxide in the Salmo district of the Kootenay terrane, and Cariboo Zinc property in the Quesnel Lake district of the Cariboo terrane. All of the nonsulphide deposits studied fit the direct replacement style of nonsulphide mineralization with the exception of the Oxide property, which shows traits of wallrock replacement style mineralization.

3. Nonsulphide Mineralogy

Petrographic analyses, X-ray diffraction techniques, and scanning electron microscopy/energy-dispersive X-ray spectrometry revealed subtle differences in mineralogy across the various nonsulphide deposits of Salmo and Quesnel Lake districts. Deposits of the Salmo district, specifically Red Bird and Lomond, are generally more gossanous compared to those of the Cariboo Zinc property, which are more siliceous. Specific nonsulphide mineralogy for each deposit is listed in Table 1. Included is the mineralogy of the sulphide protore from the Reeves MacDonald, Jersey, and HB deposits.

Table 1: Mineralogy of samples from selected deposits of the Salmo and Quesnel Lake districts
* = trace (<2%) ** = minor (2 – 10%) *** = major (>10%)

		Silica	Carbonates				Hydrated zinc carbonates	Zinc Silicates	Hydrated Zinc Silicates	Oxides		Phosphates	Lead Sulphates	Sulphides			Amount of Oxidation (Qualitative)
	Name	Quartz	Calcite	Dolomite	Smithsonite	Cerussite	Hydrozincite	Willemite	Hemimorphite	Goethite	Hematite	Hopeite	Anglesite	Galena	Sphalerite	Pyrite	
	Formula	SiO_2	$CaCO_3$	$CaMg(CO_3)_2$	$ZnCO_3$	$PbCO_3$	$Zn_5(CO_3)_2(OH)_6$	Zn_2SiO_4	$Zn_4Si_2O_7(OH)_2 \cdot H_2O$	FeO(OH)	Fe_2O_3	$Zn_3(PO_4)_2.4H2O$	$PbSO_4$	PbS	ZnS	FeS_2	
Salmo district	**Redbird Property**																
	C-473745A	*	**	***					**						*		***
	C-473745C		**	**					***								***
	09-SP-174	**	***						*	***							***
	09-SP-191						*		***								***
	09-SP-192	*		***					**								**
	09-SP-193	**		***					**	**							**
	09-SP-201	**	***	***					*						*		**
	09-SP-203	**	**	***					*						**		*
	09-SP-207		*	*					***	***							***
	09-SP-204	**	**	***					**						*		**
	09-SP-196			***				*	**						*	*	**
	Reeves MacDonald																
	2007-SP-022-11	***	***	***										*	**	**	
	Lomond																
	2008-GS-22C					**				***	***						***
	Jersey																
	08-SP-75-2			***					*						***	**	*
	HB																
	2007-SP-033-2	*	***	***											***	*	*
	Oxide																
	2008-SP-85			**					***			***					**
	2008-SP-88								***								***
Quesnel Lake district	**Cariboo Zinc**																
	09-SP-221B	*		***	***										**	*	***
	09-SP-222B	***		***					*							*	
	09-SP-224B			***	***				***					*	*	*	***
	09-SP-225B	***		*	***	**			**				**	***	***	*	***
	09-SP-228	***		**										*	**	**	*
	09-SP-230			***	***				***					***			**
	09-SP-231D	***		***					**					**			*
	09-SP-231E	***		***		*			*					**			*
	09-SP-237A	**		**			**		***								***
	09-SP-242			**	***	**	**		***					***			**
	09-SP-225D	**		***	***	**								***			**
	#495	***		***	***				***								**

Red Bird:

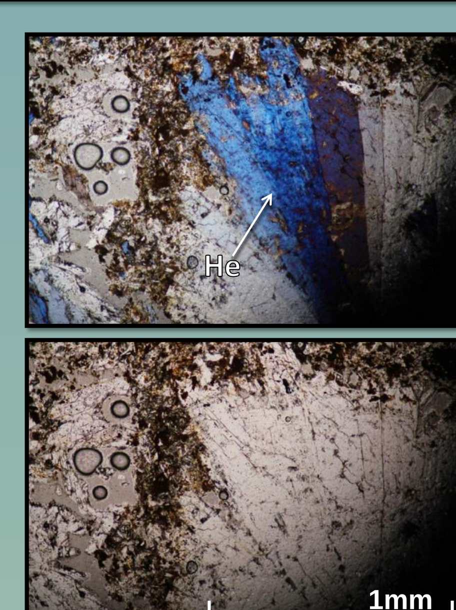

Figure 5. XPL (top) and PPL (bottom) micrographs of a large hemimorphite grain surrounded by iron oxides. 10x/0.30 Pol magnification. Sample number C-473745C, Red Bird. He = hemimorphite.

Oxide:

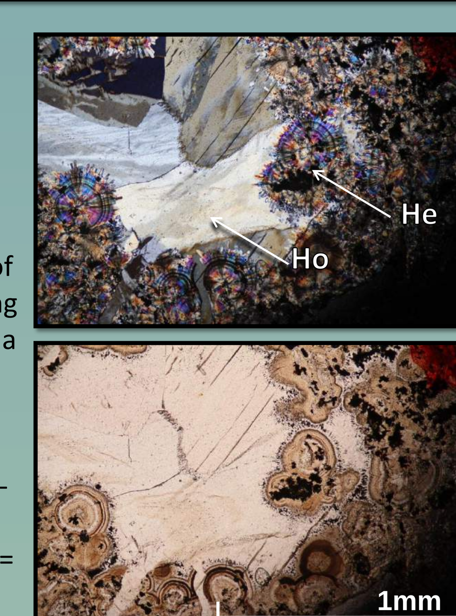

Figure 6. XPL (top) and PPL (bottom) micrographs of radiating rosettes of hemimorphite being infilled by hopeite, a zinc phosphate. 10x/0.30 Pol magnification. Sample number 08-SP-85, Oxide. He = hemimorphite, Ho = hopeite.

Cariboo Zinc:

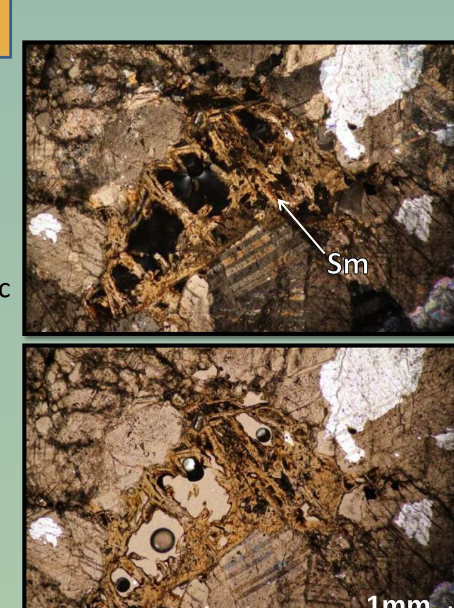

Figure 7. XPL (top) and PPL (bottom) micrographs of smithsonite infilling a vug within a weathered dolomitic groundmass. 10x/0.30 Pol magnification. Sample 09-SP-221B, Cariboo Zinc. Sm = smithsonite.

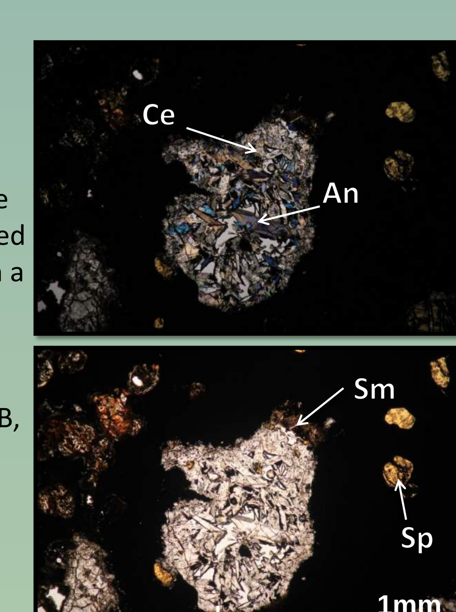

Figure 8. XPL (top) and PPL (bottom) micrographs of cerussite, anglesite laths and weathered smithsonite within a dolomitic matrix. 10x/0.30 Pol magnification. Sample 09-SP-225B, Cariboo Zinc. Sp = sphalerite, Ce = cerussite, An = anglesite, Sm = smithsonite.

4. Sulphide Protore

Massive sulphide deposits of the Salmo district (e.g., Reeves MacDonald, Jersey and HB) consist of stratabound and stratiform lens-shaped concentrations of sulphides (pyrite, sphalerite, galena, local pyrrhotite and rare arsenopyrite) in isoclinally folded dolomitized carbonate layers. An example of typical sulphide ore in the Salmo district can be seen in Figure 9, and a typical field outcrop can be seen in Figure 10.

Deposits of the Cariboo Zinc property consist of pervasive fine-grained sulphide and nonsulphide disseminations and aggregates forming pods, masses, veins, and breccias in a dolostone-dolomitic limestone unit. Sulphides are galena, sphalerite, and trace amounts of pyrite. A typical outcrop at the Cariboo Zinc Property, which is much less deformed than the rocks of the Salmo district, can be seen in Figure 11.

Jersey Ore

Figure 9. Reflected light PPL micrograph of disseminated pyrite overprinting sphalerite in a dolomite groundmass. 10x/0.30 Pol magnification. Sample 08-SP-75-2, Jersey mine, Salmo district.

Salmo district

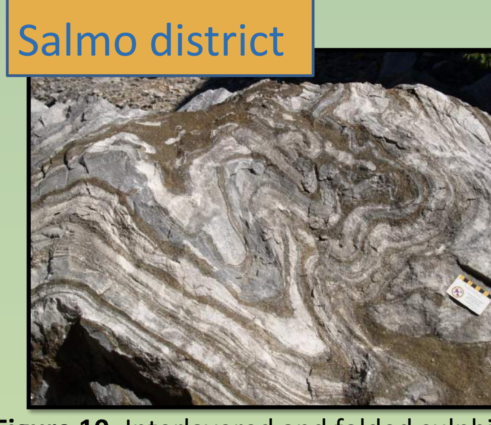

Figure 10. Interlayered and folded sulphides (mostly pyrite with minor sphalerite and galena) and dolomitic limestone of the Reeves member of the Laib Formation, Salmo district.

Cariboo Zinc

Figure 11. Quartz-sphalerite-galena-nonsulphide (after sphalerite) vein at the Main showing of the Cariboo Zinc property.

5. XRD Patterns

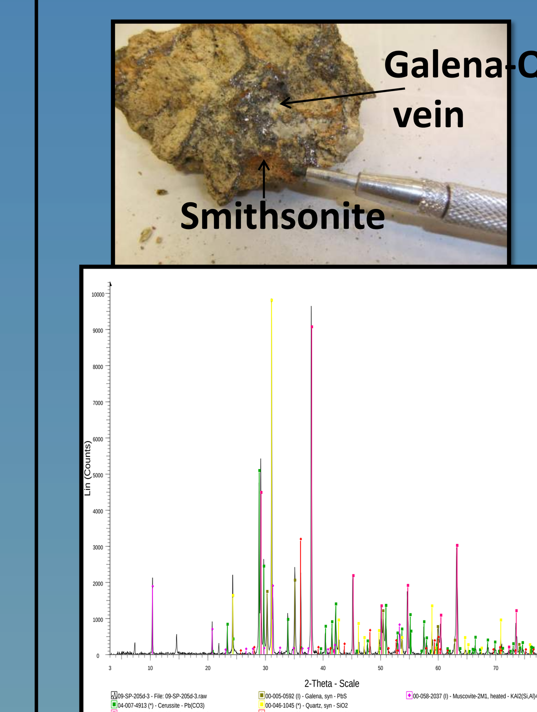

Figure 12. XRD pattern results from a typical nonsulphide-rich Quesnel district sample. Sample 09-SP-225D, Cariboo Zinc property.

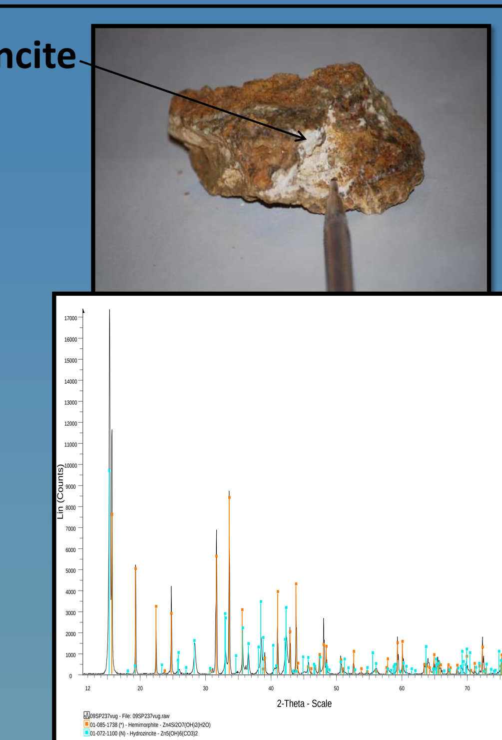

Figure 13. XRD pattern from white, friable hydrozincite within an oxidized hemimorphite -dolomite groundmass. Sample 09-SP-237A, Cariboo Zinc property.

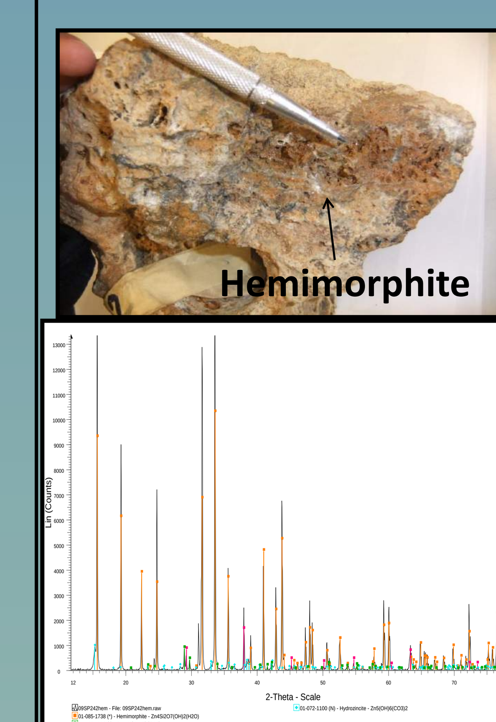

Figure 14. XRD pattern from radiating, fracture-controlled hemimorphite intergrown with oxidized smithsonite (rusty brown), white powdery hydrozincite, and background cerussite (not visible). Sample 09-SP-242, Cariboo Zinc property.

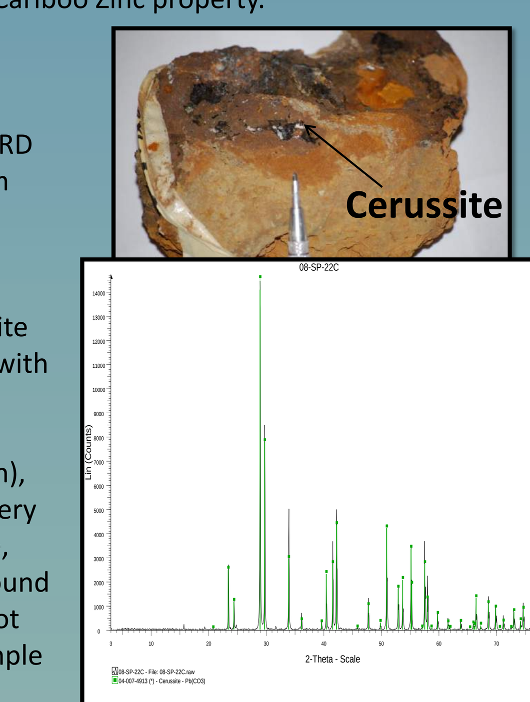

Figure 15. XRD pattern of small, prismatic cerussite crystals in a goethite-hematite-rich vug. Sample 08-GS-22C, Lomond deposit, Salmo district.

6. Scanning Electron Microscopy

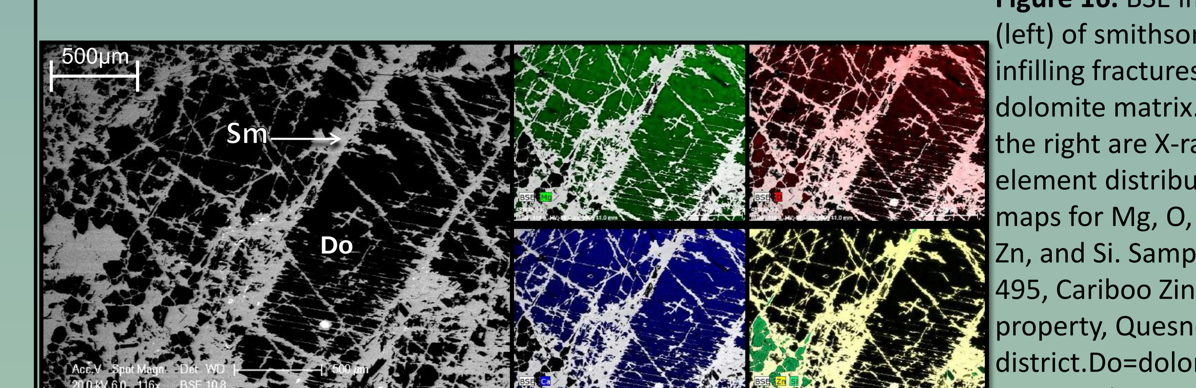

Figure 16. BSE image (left) of smithsonite infilling fractures in dolomite matrix. To the right are X-ray element distribution maps for Mg, O, Ca, Zn, and Si. Sample 495, Cariboo Zinc property, Quesnel district.Do=dolomite, Sm= smithsonite.

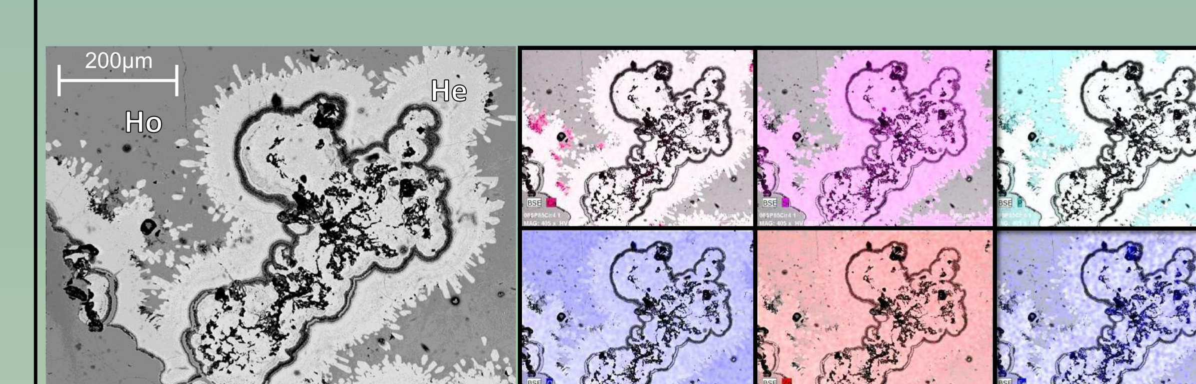

Figure 17. BSE image (left) of hopeite and hemimorphite with minor background calcite. To the right are X-ray element distribution maps for Ca, Si, P, O, Zn, Fe. Sample 08-SP-85, Oxide deposit, Salmo District, British Columbia. Ho = hopeite, He = hemimorphite.

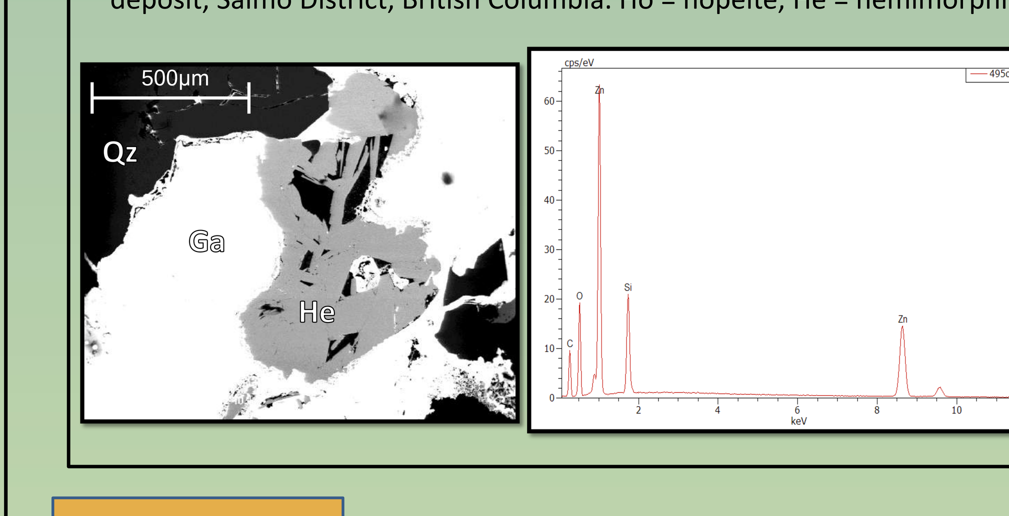

Figure 18. BSE image (left) of hemimorphite within a galena-quartz vein. EDS of He (right). Sample 495, Cariboo Zinc Property. He = hemimorphite, Ga = galena, Qz = quartz.

7. Summary

The nonsulphide mineralogy of the Red Bird deposit of the Salmo district is primarily composed of hemimorphite, with one sample showing remnants of hydrozincite on the outer crust. The oxidized rocks of this area are extremely gossanous “red ores”, likely due to the original presence of significant pyrite in the protore. The Oxide showing of the Salmo district contains zinc phosphates as well as hemimorphite, and no remnant sulphides were found. The nonsulphide mineralogy of the Cariboo Zinc property is more variable than the Salmo district, consisting of hemimorphite, smithsonite, cerussite, hydrozincite, and anglesite. Remnants of galena is common and absence of pyrite is notable.

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