

# Nickeliferous Minerals in the Cassiar Asbestos Deposit, Northern British Columbia (NTS 104P/05) - Relevance for Nickel Exploration

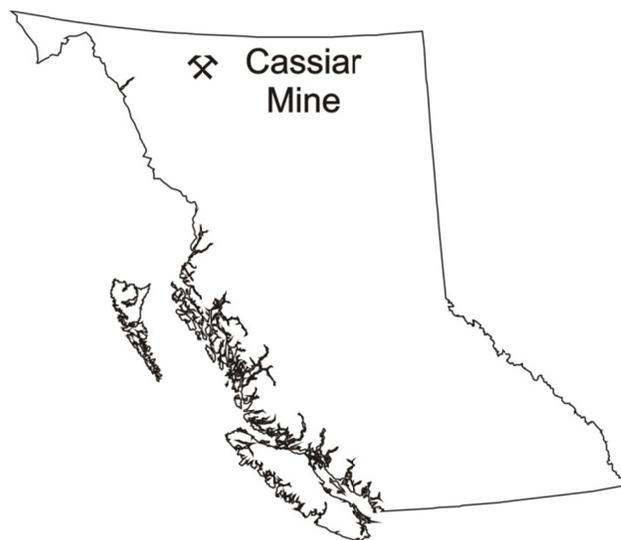
by Z.D. Hora<sup>1</sup>, A. Langrová<sup>2</sup> and E. Pivec<sup>3</sup>

**KEYWORDS:** Cassiar deposit, MINFILE 104P 005, chrysotile asbestos, Cr-magnetite, magnetite, nickel, Ni, heazlewoodite, serpentinization products and nickel minerals, awaruite

## INTRODUCTION

The discovery of nickel and cobalt bearing minerals in a rhodonite sample from the Bridge River Complex in 2006 (Hora *et al.*, 2007) raised our interest in nickel occurrences associated with the serpentinization of ultramafic rocks in British Columbia. A number of reports from sites in Quebec and Northwest Territories described occurrences of nickel sulphides and nickel-iron alloys as a co-product of serpentinization (Nickel, 1959; Chamberlain *et al.*, 1965; Chamberlain, 1966; Eckstrand, 1975). In British Columbia, there are a number of reports of possible similar nickel minerals. For example, previous workers identified “some nickeliferous sand” in alluvial gold from the Fraser River (Sutton, 1888), awaruite on Wheaton Creek in Cassiar District in the late 1800s (Holland, 1940; Ramdohr, 1950), Letain Creek (Krishnarao, 1964) and nickel-iron (possible awaruite Ni<sub>3</sub>Fe) in the Blue River area north of Cassiar (Gabrielse, 1963; Wolfe, 1964). In the Cassiar asbestos deposit (MINFILE 104P 005), O’Hanley *et al.* (1992) identified pentlandite and heazlewoodite. However, the distribution of nickel at Cassiar did not receive any closer attention.

With all this in mind, the Cassiar mine tailings pile was sampled during the summer of 2008 and several fresh samples collected from the minesite ore zone in 1990 were selected for a preliminary study with specific attention given to minerals with nickel content (Figure 1).



**Figure 1.** Location of study area, Cassiar, northern British Columbia.

## Cassiar Mineralogy

Two samples of Cassiar mine tailings were collected directly from the tailings impoundment. The first sample (#001) represented a visually typical bulk tailings material. The second sample had the magnetic component separated in the field using a permanent magnet (#002). Previous work by Cassiar Asbestos Ltd. carried during 1986 over the period of several months identified that material dumped into Cassiar tailings contain in average by weight of approximately 9% of magnetite (Hancock, 1988). Laboratory results of 3131 ppm nickel in the magnetic sample (#002) and 2230.9 ppm nickel in the bulk sample (#001) shown in Table 1 encouraged the more detailed study. That involved XRD mineral identification in individual samples and analytical microprobe examination.

Identification of mineral phases was made by x-ray powder diffraction, using a Phillips X’Pert APD that employs CoK $\alpha$  radiation and secondary monochromator. Scanning speed was set to 1<sup>o</sup>/min, generator voltage to 40 kV and current to 30 mA. Analytical microprobe examination used a CAMECA SX-100 electron microprobe using the wavelength dispersive technique. The beam diameter was 2 $\mu$ m with an accelerating potential of 15 kV. A beam current of 10 nA was

<sup>1</sup> British Columbia Geological Survey, Victoria, BC (retired)

<sup>2</sup> Institute of Geology, Academy of Sciences of the Czech Republic, Prague, Czech Republic

<sup>3</sup> Institute of Geology, Academy of Sciences of the Czech Republic, Prague, Czech Republic (retired)

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the BC Ministry of Forests, Mines and Lands website at <http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/Fieldwork>.

**Table 1.** Analytical results, Cassiar mine tailings samples, British Columbia.

Sample	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppm	Ni ppm	Co ppm	Mn ppm	Fe %	As ppm	U ppm	Au ppb
CAS 001	0.3	2.6	19	17	<0.1	3131	207	921	18.24	13	<0.1	
CAS 002	0.2	0.9	1	14	<0.1	2230.9	84.3	562	5.21	<0.5	<0.1	<0.5

Th ppm	Sr ppm	Cd ppm	Sb ppm	Bi ppm	V ppm	Ca %	P ppm	La ppm	Cr ppm	Mg %	Ba ppm	Ti %
<0.1	1	<0.1	<0.1	0.5	38	0.11	<0.001	<1	1594	14.45	3	0.004
<0.1	2	<0.1	<0.1	<0.1	30	0.08	<0.001	<1	1372	2148	4	0.004

B ppm	Al %	Na %	K %	W ppm	Hg ppm	Sc ppm	Tl ppm	S %	Ga ppm	Se ppm
<20	0.29	<0.001	<0.01	<0.1	0.02	7.7	<0.1	<0.05	<1	<0.5
32	0.38	<0.001	<0.01	<0.1	<0.01	13.3	<0.1	<0.05	<1	<0.5

ACME Analytical Laboratories Ltd.  
Method 1DX

measured on a Faraday cup. The standards employed were synthetic and natural minerals. The data were reduced using the Merlot correction ( $\phi$ ).

### Silicate minerals

Serpentinite mineral aggregates at Cassiar consist mainly of the mixture of chrysotile and antigorite (O'Hanley *et al.*, 1992). The XRD results of tailings samples confirmed the presence of these minerals, the chrysotile being both ortho and clinochrysotile. This study identified the presence of baumite  $(Mg,Fe,Mn,Zn)_3Si_2O_5(OH)_4$ , caryopilite  $(Mg,Mn)_3Si_2O_5(OH)_4$  and jamborite  $(Ni^{+2},Ni^{+3},Fe)(OH)_2(OH,S,H_2O)$ . All these silicate minerals together with magnesite and stichtite  $(Mg_6Cr_6(CO_3)(OH)_{16} \cdot 4H_2O)$  were reported previously (O'Hanley *et al.*, 1992) and are serpentinization products. Other studies of the serpentinization on ore zone samples showed it was so pervasive, that no primary constituents like olivine or pyroxene have been preserved (Gabrielse, 1960, O'Hanley *et al.*, 1992).

### Opaque minerals

Sample #002 was processed on magnetic separator for a further study. The resulting magnetic concentrate contained the Cr-magnetite  $Fe(Fe,Cr)_2O_4$  and magnetite ( $Fe_3O_4$ ) only. Because of increased Ni content in the analysis of the magnetic concentrate it was expected to find a presence of trevorite ( $NiFe_2O_4$ ) component in magnetite or Ni-Fe alloys awaruite ( $Ni_3Fe$ ) or taenite (NiFe). However, petrographic and x-ray analysis did not identify the presence of nickel minerals. A possible explanation for absence of awaruite may be its usual association with antigorite (Eckstrand, 1975). Antigorite is a higher alteration temperature mineral product than chrysotile.

### MICROPROBE WORK

Microanalytical study was made on polished rock samples collected in 1990 from the ore zone as well as polished grains of magnetic concentrate. Nickel in these samples was found to be primarily in three main minerals—Cr-magnetite, magnetite and heazlewoodite. The chemical compositions are presented in Table 2.

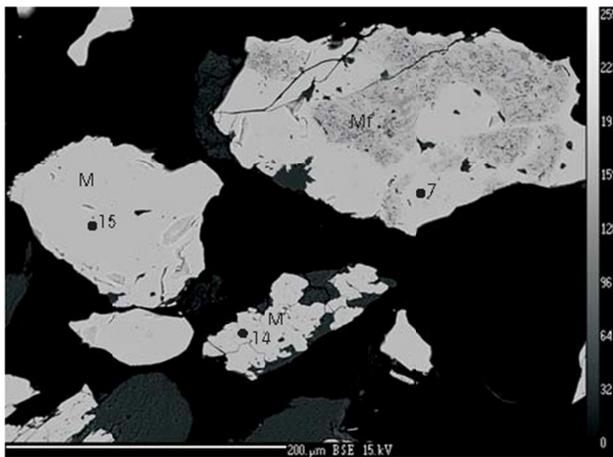
Cr-magnetite and magnetite, both magnetic minerals, are the most common minerals in the samples with significant nickel contents. In magnetite, 9 out of 16 measurements show Ni contents between 0.03% and 0.6%, the remaining 7 between 0.87% and 1.57%. Similar values are reported for magnetite from a Western Australia serpentinized dunite (Donaldson, 1981). Nickel content in Cr-magnetite is of similar values. Out of ten measurements six average 0.24% and the remaining four average 1.07% nickel. As expected, Cr-magnetite contains Al, Mg and Mn, while these elements are low or practically absent in the magnetite.

The third nickeliferous mineral from Cassiar - heazlewoodite ( $Ni_3S_2$ ) is considerably less common in studied rock samples and is present in grains of very small size around 25 to 100  $\mu m$ . The chemical compositions of the opaque minerals are shown in Table 2.

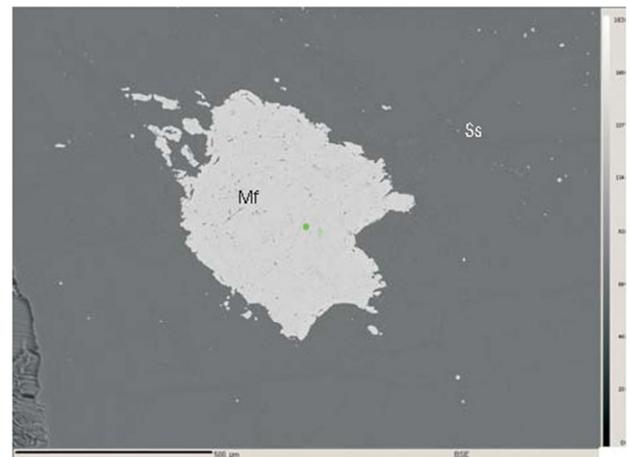
As shown on the microphotographs (Figures 2a, b, e), Cr-magnetite predates the magnetite. Donaldson (1981) describes similar age relationship between magnetite and chromite from Archean dunitites in Western Australia. Cr-magnetite is less resistant to alteration (Figures 2c, d), which can be particularly noticed where in contact with magnetite (Figures 2a, b, e).

**Table 2.** Representative opaque minerals, Cassiar mine.

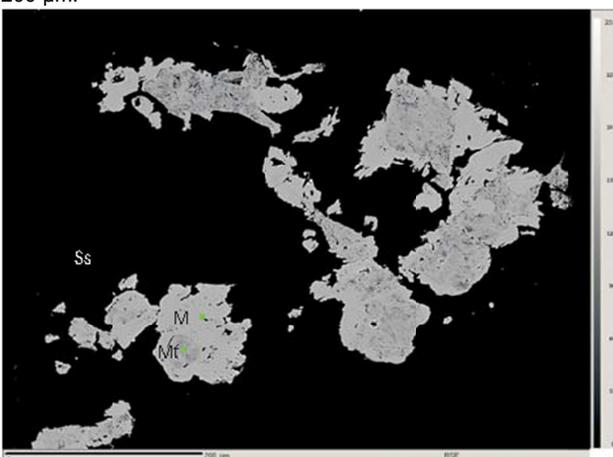
Sample No.	magnetite						Cr - magnetite			heazlewoodite			
	3	6	7	13	14	15	4	8	10	1	5	9	12
%													
Fe	69.19	69.77	69.72	70.79	62.80	72.46	35.32	35.49	45.10	0.00	0.51	0.08	53.44
Ni	0.63	0.75	0.97	0.52	1.57	0.17	0.42	0.76	0.64	71.65	71.17	71.92	1.17
Al	0.00	0.00	0.02	0.1	0.00		1.28	1.54	0.75				0.02
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.40	27.35	27.88	0.00
Cr	1.79	1.21	1.02	1.02	5.55		18.08	17.83	16.83				13.09
Mn	0.36	0.20	0.23	0.00	0.65	0.00	3.59	3.79	3.09	0.00	0.00	0.02	2.67
Co	0.08	0.00	0.00	0.00	0.13	0.00	0.22	0.23	0.26	0.03	0.04	0.00	0.21
As	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.02	
O	21.28	21.08	21.12	20.41	21.40	20.80	23.69	23.89	23.65				22.87
Mg	0.52	0.44	0.52	0.31	0.31		4.37	4.18	1.77				0.56
Total %	93.85	93.39	92.45	93.15	92.39	93.43	86.96	87.7	92.06	99.16	99.07	99.92	94.03



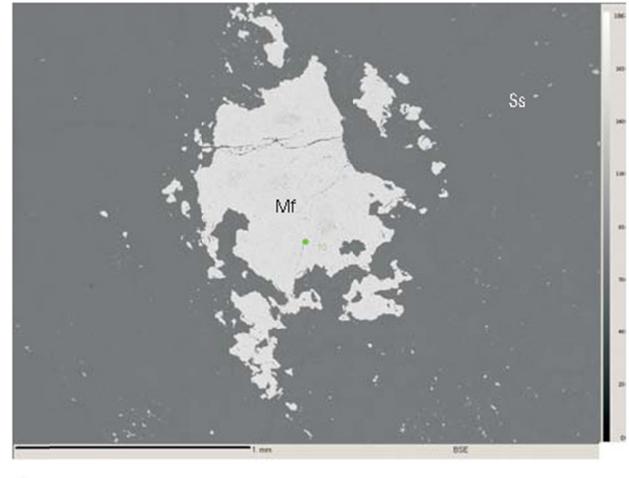
**Figure 2a.** Scanning electron microprobe (SEM) photomicrograph showing separated magnetite grains. White fields correspond to magnetite (M), dark and altered fields to Cr-magnetite (Mf); both with variable contents of Ni (analytical points 7, 14, 15); scale bar 200 µm.



**Figure 2c.** Scanning electron microprobe (SEM) photomicrograph showing rock polished section, single grain of Cr-magnetite (Mf) in serpentinite (Ss); (analytical point 8); scale bar 100 µm.



**Figure 2b.** Scanning electron microprobe (SEM) photomicrograph showing rock polished section of serpentinite (Ss) with grains of Cr-magnetite (Mf) altered to magnetite (M), (analytical points 4, 5); scale bar 200 µm.



**Figure 2d.** Scanning electron microprobe (SEM) photomicrograph showing rock polished section, grains of Cr-magnetite (Mf) partly crushed and weakly altered (analytical point 10); scale bar 1 mm.

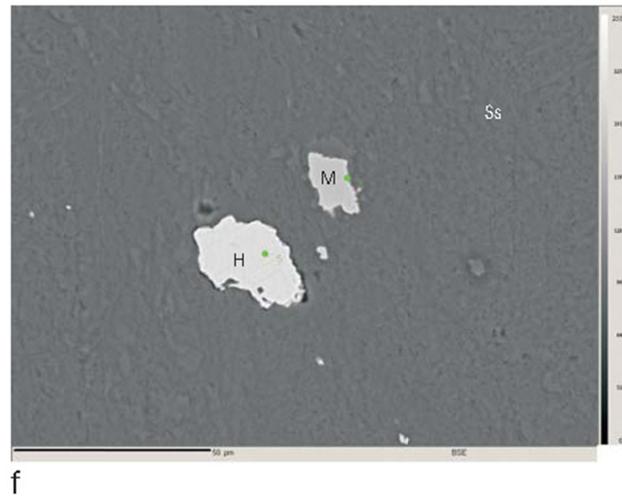


**Figure 2e.** Scanning electron microprobe (SEM) photomicrograph showing rock polished section, Cr-magnetite grains (Mf) completely surrounded by magnetite (analytical points 12, 13); scale bar 50 µm.

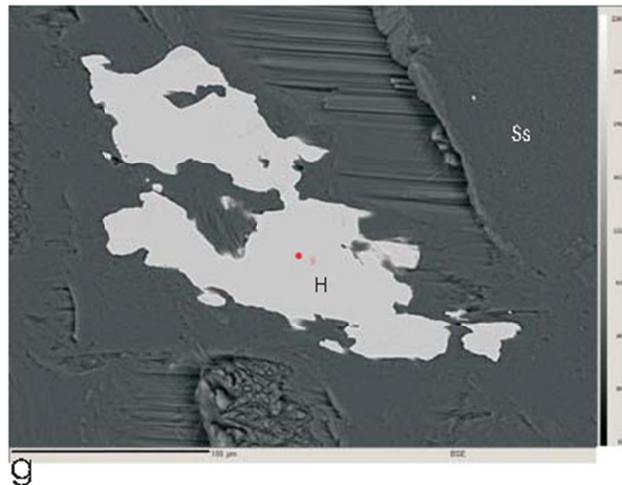
Heazlewoodite is the only mineral with Ni as a main component identified in Cassiar samples. It is described as a typical component of serpentinites from many localities (Eckstrand, 1975; Frost, 1985; Ramdohr 1967) and it is particularly common in association with chrysotile asbestos. As shown on Figures 2f and 2g, in the Cassiar samples of this study it occurs in isolated, very small grains of irregular shape between 25 and 100 µm in diameter.

## DISCUSSION

Opaque nickel minerals formed as a co-product of serpentinization of ultramafic rocks are a relatively common occurrence in Canada and worldwide. Ramdohr in 1950 was one of the early authors who realized the significance of this phenomenon, pointing out that the size of the grains is usually so minute that they often escape notice. Serpentinization is a highly reducing process and while only a small portion of the silicate FeO enters into the serpentine formula. The bulk of the iron forms magnetite and together with other minor metallic elements (namely S, As and Sb) forms alloys or occurs as native metals. If no free oxygen is available during the serpentinization process, it then gives the possibility for the occurrence of many, mostly extremely fine-grained minerals, like native metals and alloys of iron, nickel, cobalt and copper, sulphides with low sulphur, and similar arsenides and antimonides (Ramdohr, 1967). Such elements have under most conditions a very limited mobility and usually remain as interstitial grains at the place of their origin. Similar in situ nickel mineralization is described by Eckstrand (1975) from northern Quebec and by Chamberlain (1966) and Nickel (1959) from asbestos deposits in Quebec. Under some circumstances, such fine-grained mineralization may be mobilized to form coarser grained disseminations and higher grade accumulations (Frost, 1985), but the formation process is



**Figure 2f.** Scanning electron microprobe (SEM) photomicrograph showing rock polished section, grains of magnetite (M) (analytical point 6) and heazlewoodite (H) (analytical point 5); scale bar 50 µm.



**Figure 2g.** Scanning electron microprobe (SEM) photomicrograph showing rock polished section, large grain of heazlewoodite (H) (analytical point 9); scale bar 150 µm.

not yet fully understood. It has been suggested, that some originally low grade sulphide copper-nickel deposits were also enriched by a serpentinization process at a later stage (Donaldson, 1981). In his paper about nickel sulphide mineralization in Western Australia, Donaldson (1981) describes studies, where larger scale movement of nickel is considered possible in the presence of sulphur with chloride in solutions.

In British Columbia, recent discoveries of several coarser awaruite zones over large tracts of ultramafic rocks in the area between Fort St. James and Ogden Mountain suggest an economic potential of ultramafic belts for a possibility of bulk mineable nickel deposits (First Point Minerals, 2009). Awaruite is also reported from the Shulaps Range and Dease Lake area in northern British Columbia (Bradshaw, 2008).

## CONCLUSIONS

- More attention should be paid to the potential for non-sulphide nickel minerals.
- Serpentinization has been documented to produce secondary sulphide and non-sulphide nickel minerals.
- British Columbia has considerable distribution of serpentinized ultramafics with a number of proven and suspected awaruite showings.
- Cassiar mine tailings have low grade nickel present in Cr-magnetite and magnetite.
- Cassiar tailings are a potential low cost source for heavy media suspension material that could be used for coal deposits, like the Groundhog.

## ACKNOWLEDGMENTS

Several persons helped with preparing this report. Mitch Mihalyuk and Garry Payie provided moral support, numerous discussions, and Garry Payie collected the samples from Cassiar tailings. In course of laboratory work, V. Sedláček helped with magnetic separation and J. Dobrovolný with x-ray records. For the technical assistance with data collection and report preparation we thank J. Pávková and V. Šrein. Dave Lefebure provided constructive comments in improving the original manuscript.

## REFERENCES

- Anonymous (2009): Nickel-Iron Alloy Properties North America; First Point Minerals Corp., PowerPoint presentation, 26 pages.
- Bradshaw, P.M.D. (2008): First Point Acquires Two More Large Nickel Properties in British Columbia; First Point Minerals press release, January 10, 2008, 2 pages.
- Chamberlain, J.A. (1966): Heazlewoodite and Awaruite in Serpentinites of the Eastern Townships, Quebec; Canadian Mineralogist, Volume 8, pages 519-522.
- Chamberlain, J.A., McLeod, C.R., Traill, R.J. and Lachance, G.E. (1965): Native Metals in the Muskox Intrusion; Canadian Journal of Earth Sciences, Volume 2, pages 188-215.
- Donaldson, M.J. (1981): Redistribution of Ore Elements during Serpentinization and Talc-Carbonate Alteration of Some Archean Dunites, Western Australia; Economic Geology, Volume 76, pages 1698-1713.
- Eckstrand, O.R. (1975): The Dumont Serpentinite: A Model for Control of Nickeliferous Opaque Mineral Assemblages by Alteration Reactions in Ultramafic Rocks; Economic Geology, Vol.70, pages 183-201.
- Frost, B.R. (1985): On the Stability of Sulfides, Oxides, and Native Metals in Serpentinite; Journal of Petrology, Volume 26, pages 31-63.
- Gabrielse, H. (1960): The Genesis of Chrysotile Asbestos in the Cassiar Asbestos Deposit, Northern British Columbia; Economic Geology, Volume 55, pages 327-337.
- Gabrielse, H. (1963): McDame Map Area, Cassiar District, British Columbia; Geological Survey of Canada, Memoir 319, 138 pages.
- Hancock, K.D. (1988): Magnetite Occurrences in British Columbia; B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1988-28, 153 pages.
- Holland, S.S. (1940): Placer Gold Deposits, Wheaton (Boulder) Creek, Cassiar District, Northern British Columbia; British Columbia Department of Mines, Bulletin 2, 43 pages.
- Hora, Z.D., Langrová, A. and Pivec, E. (2007): Rhodonite from the Bridge River Assemblage, Downton Creek (NTS 092J/09), Southwestern British Columbia; B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 2007-1, pages 39-43.
- Krishnarao, J.S.R. (1964): Native Nickel – Iron Alloy, its Mode of Occurrence, Distribution and Origin; Economic Geology, Volume 59, pages 443-448.
- O'Hanley, D.S., Schandl, E.S. and Wicks, F.J. (1992): The Origin of Rodingites from Cassiar, British Columbia, and their use to Estimate T and P (H<sub>2</sub>O) During Serpentinization; Geochimica and Cosmochimica Acta, Volume 56, pages 97-108.
- Nickel, E.H. (1959): The Occurrence of Native Nickel-iron in the Serpentine Rock of the Eastern Townships of Quebec Province; Canadian Mineralogist, Volume 6, pages 307-319.
- Ramdohr, P. (1950): Über Josephinit, Awaruit, Souesit, ihre Eigenschaften, Entstehung und Paragenesis; Mineralogical Magazine, Volume XXIX, Number 2112, pages 374-394.
- Ramdohr, P. (1967): A Widespread Mineral Association, Connected with Serpentinization; Neues Jahrbuch für Mineralogie, Abhandlungen, Band 107, pages 241-265.
- Sutton, W.J. (1888): Cobalt and Nickel; in Report by W.J. Sutton, Government Assayer, Annual Report of the Minister of Mines for the Year Ending 31<sup>st</sup> December 1888, Province of British Columbia, page 325.
- Wolfe, W.J. (1964): The Blue River Ultramafic Intrusion, Cassiar District, British Columbia; Geological Survey of Canada, Paper 64-48, 15 pages.

