

THE LISTWANITE – LODE GOLD ASSOCIATION IN BRITISH COLUMBIA

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KEYWORDS: Economic geology, listwanite, lode gold, mariposite, oceanic terrane, ophiolite, ultramafic, deposit model.

INTRODUCTION

Listwanite is a term long used by Soviet geologists working in the Ural goldfields of Russia (Goncharenko, 1970; Kuleshevich, 1984) that is now used in Europe and North America. It describes a mineralogical assemblage that results from the carbonatization of serpentinized ultramafic rocks and represents a distinctive alteration suite that is commonly

associated with quartz-carbonate lode gold deposits. In British Columbia, as in the California Mother Lode deposits, listwanites are most commonly recognized within and near major fault zones cutting Paleozoic and Mesozoic oceanic and island arc accretionary terranes that have been affected by tectonism, metamorphism and plutonism.

The Listwanite Project was started in 1989 to investigate, document and develop a deposit model for the listwanite-lode gold association in the Canadian Cordillera. Aspects relevant to the development of such a model being addressed during this study include:

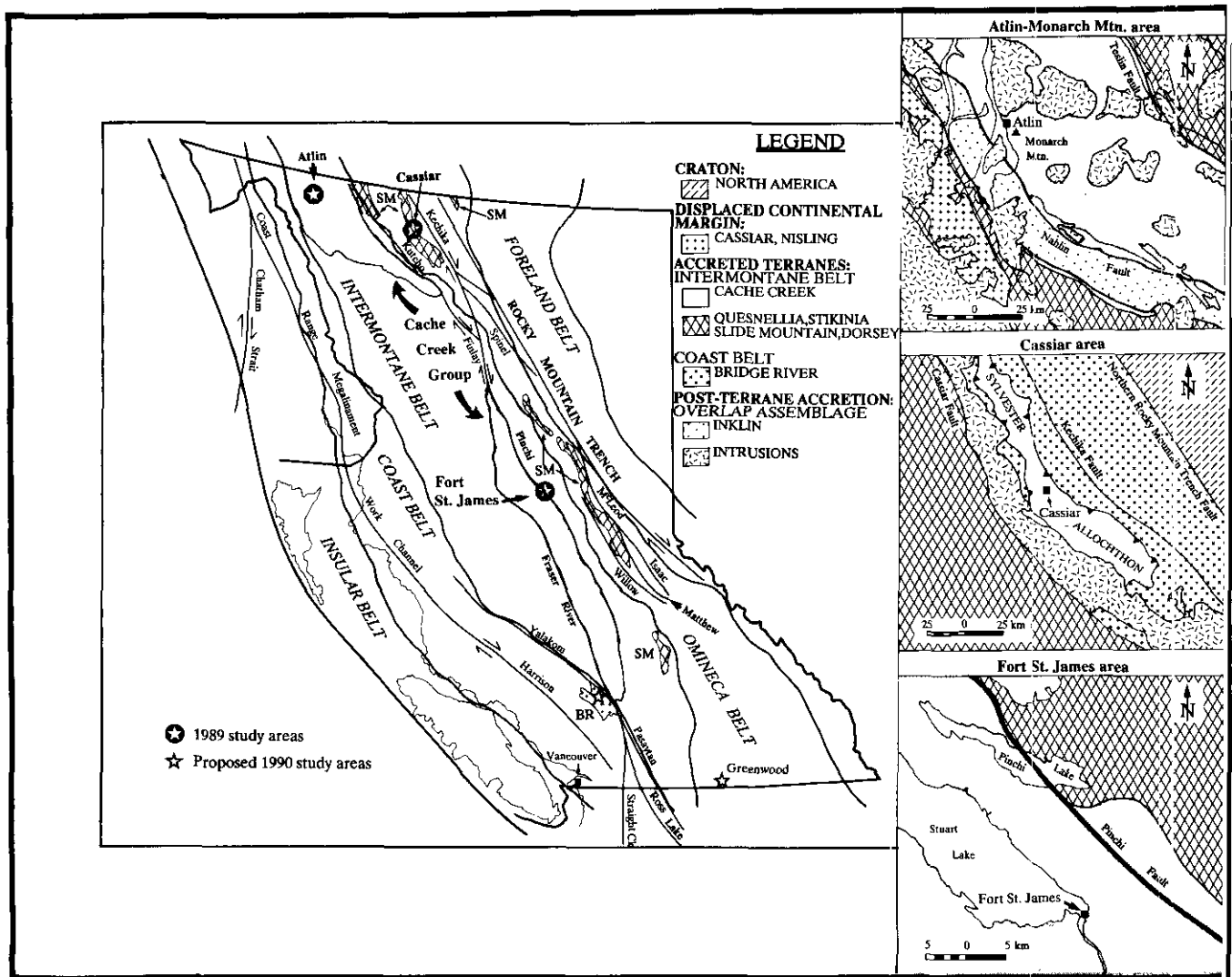


Figure 3-2-1. Location map showing simplified terrane boundaries, major transcurrent faults, the Cache Creek (CC), Slide Mountain (SM) and Bridge River (BR) terranes and the 1989 and proposed 1990 study areas.

- The setting of these deposits within the framework of tectonically dismembered ophiolitic assemblages, by combining detailed mapping, petrographic analysis, microprobe and geochemical studies.
- The age of alteration and associated mineralization using K-Ar dating of mariposite.
- Relationships between listwanitic lode gold and spatially associated alkaline intrusions will be investigated geochemically using both trace element and lead isotopic signatures.
- The potential of listwanitic alteration zones as sites of hydrothermal platinum group element (PGE) mineralization will also be investigated geochemically. As most, if not all, known hydrothermal PGE + gold occurrences are associated with sulphides, sampling focused on sulphide-bearing quartz veins or gossanous zones, generally in gabbroic and, more commonly, basaltic rocks.

This report provides a brief overview of the tectonic setting and development of the listwanite–lode gold deposit type. British Columbia examples are compared to deposits described in the literature. The Atlin, Cassiar (Erickson) and Fort St. James areas in northern British Columbia were investigated during the 1989 field season (Figure 3-2-1). Investigation of listwanite-associated lode gold deposits in southern British Columbia is planned for the 1990 season. Results of detailed mapping in the Atlin area are reported elsewhere (Ash and Arksey, 1990a, this volume, 1990b).

LISTWANITES

TECTONIC SETTING

Listwanite-associated lode gold deposits with serpentinized and carbonatized ultramafic rocks are characteristic of tectonically disrupted ophiolite sequences in accreted oceanic terranes. This tectonic setting produces thrusting and stacking of units, favorable hostrocks (serpentinite), and regional-scale reverse and normal faults to channel fluid flow.

Accreted oceanic terranes of Paleozoic to Mesozoic age, containing dismembered ophiolite packages occur along the length of the Canadian Cordillera and include the Cache Creek (CC), Slide Mountain (SM) and Bridge River (BR) terranes (Figure 3-2-1). These terranes contain oceanic uppermost mantle, crustal and sedimentary rocks, most commonly with tectonic contact relationships (Monger *et al.*, 1982). Ultramafic rocks, serpentinized to varying degrees, are represented mainly by residual mantle harzburgite (defined in Ash and Arksey, 1990a, this volume). Oceanic crustal rocks are dominated by metabasalts and are commonly referred to as greenstones. Oceanic crustal plutonic rocks, including ultramafic cumulates, gabbro, diorite and trondhjemite, may be present but are generally minor constituents. Sedimentary units include deep-water cherts and argillites as well as shallow-water limestones.

Some Cordilleran oceanic terranes are well known as gold producers, others are under-explored. Listwanitic alteration characterizes both the Bridge River (BR) camp in the south, the largest gold camp in the province, and the active Cassiar (SM) and Atlin (CC) camps in the north. The recently

defined Snowbird (CC) gold prospect (X-Cal Resources Limited) located near Fort St. James in central British Columbia is also a typical listwanite–lode gold occurrence.

Other examples of listwanite-related gold deposits within accreted oceanic terranes of North America are, most notably, the many deposits throughout the California Mother Lode district (for further discussion see: Knopf, 1929; Böhlke and Kistler, 1986; Böhlke, 1989; Weir and Kerrick, 1987). The Mount Vernon deposit in northern Washington State (Gresens *et al.*, 1982) and ophiolite belts in the Duna zone of the Appalachian orogen in Newfoundland (Tuach *et al.*, 1988) also display characteristic listwanite–lode gold associations. Listwanite-related gold deposits are also present within accreted oceanic terranes in Saudi Arabia, Mali (West Africa), the Maritime Alps in northwest Italy, and Morocco (Buisson and Leblanc, 1985a, b).

Somewhat similar and possibly related gold deposits in the Juneau belt of southeast Alaska are also structurally controlled lodes within accreted oceanic assemblages. Goldfarb *et al.* (1988) found that the mineralizing fluids of the Juneau belt are chemically similar to ore-forming fluids in the Mother Lode deposits.

GENESIS

The dynamics of collisional orogenic belts like the Cordillera appear to play a fundamental role in the development of listwanite-associated lode gold deposits. Consuming plate margin tectonic processes instigate subduction, crustal thickening and partial melting which result in metamorphism and plutonism. The combined effects of these processes provide a number of mechanisms which may facilitate the generation of mineralizing fluids. Among these are deep seated magmatic activity, metamorphic dehydration reactions and deep circulation of meteoric waters (Böhlke and Kistler, 1986). Most importantly, brittle to ductile deformation generates fault zones which act as pathways for the altering and mineralizing fluids. Geochemical data suggest that the principal ore-forming fluids are derived primarily by metamorphic dehydration under amphibolite-grade metamorphic conditions, with possible contributions from meteoric or magmatic sources (*see review in Kerrick, 1989*). However, the source of both the fluids and the gold is a topic of current debate. Nesbitt *et al.* (1986) have suggested that mesothermal gold deposits throughout the Canadian Cordillera result from deep circulation and evolution of meteoric water in structures associated with major transcurrent fault zones.

Listwanite forms when fluids rich in carbon dioxide permeate and alter previously altered ultramafic rocks, usually serpentinite. Distinctive iron-magnesium carbonates and chromium mica (mariposite in North American terminology or fuchsite in Europe and Russia) are formed.

The importance of the serpentinized ultramafic rock is that it acts as a preferential sink for carbon dioxide from the migrating hydrothermal fluid. Carbonatization is represented by both the pervasive alteration and replacement of the ultramafic rocks and by dolomite veining. Carbonate minerals which replace the ultramafic rocks form by hydrolysis of iron, magnesium, calcium and manganese silicates to carbonates in which wallrocks donate the bivalent metal cations (Kerrick, 1983). Sericitization as a result of

potassium metasomatism is commonly reflected by the formation of mariposite in which the chrome is inherited from the ultramafic hostrock as it cannot be taken up by the carbonate (Boyle, 1979)

Although the genetic significance of the ultramafic rocks remains a subject of debate, the spatial relationship between carbonatized ultramafic rocks and gold deposition appears to be consistent. Böhlke and Kistler (1986), Böhlke (1989) and Wittkopp, (1983) noted that mineralized quartz veins in the California Mother Lode deposits show a spatial association with serpentinite bodies and that the largest concentrations of free gold occur at or near the intersection of veins with the carbonatized ultramafic rocks. Pike (1976) has pointed out the association of carbonatized ultramafic volcanic rocks with the Archean quartz-carbonate lode gold deposits of Northern Ontario. Lode gold showings throughout the Atlin region (Bloodgood *et al.*, 1989; Rees, 1989) and deposits in the Erickson gold camp (Boronowski, 1988) display similar spatial relationships. Some authors argue that the ultramafic rocks are the source of the gold (Buisson and Leblanc, 1985a, b, 1987; Wittkopp, 1983) but this is far from being unanimously accepted.

MINERALIZATION

The generally accepted current hypothesis for gold deposition in and near listwanites invokes low-salinity hydrothermal fluids rich in carbon dioxide which carry gold as a bisulphide complex, $\text{Au}(\text{HS})_2$ (Böhlke, 1989; Kerrich, 1989).

Various mechanisms recently reviewed by Kerrich (1989) have been proposed for the precipitation of gold. These include:

- fluctuations in fluid pressure in the seismic-aseismic transition zone promote carbon dioxide and hydrogen sulphide immiscibility with attendant gold deposition,
- reduction of the mineralizing fluid by graphitic rocks, or
- sulphide precipitation promoted by iron-rich lithologies.

The second mechanism was suggested by Dussel (1986) to account for gold precipitation at the Erickson mine near Cassiar, British Columbia. Buisson and Leblanc (1985b, 1987) suggest that acid gold-bearing solutions precipitate silica, pyrite, arsenides and gold when entering the reducing and alkaline environment of the carbonatized rocks.

In addition to gold, other metallic mineralization associated with the gold showings investigated includes various types of sulphides (Fe, As, Pb, Cu, Zn, Ni, Co, Sb) commonly with associated arsenides and tellurides. Metal types and abundances vary on both the deposit and regional scale. Some deposits display a diversity of metals while others are selectively enriched in a specific metal or group of metals. The Atlin gold camp illustrates this local variability. The Pictou prospect located 2 kilometres east of Atlin contains a wide range of base metal sulphides, including galena, chalcopyrite, sphalerite, arsenopyrite, pyrrargyrite (Ag_3SbS_3) and gersdorffite ($\text{Fe,Ni}(\text{As,S})$, (Ballantyne, personal communication) but sulphide mineralogy at the

Yellowjacket prospect, 5 kilometres to the northeast, is dominated by pyrite, arsenopyrite and gersdorffite (Bozek, 1989). In contrast the Surprise showing, 7 kilometres to the east, has galena as the only sulphide identified in hand sample.

Silver generally displays a correlation with anomalous gold values, and was an important byproduct at the Erickson and Taurus gold mines near Cassiar (Schroeter and Pan-teleyev, 1985). At the Snowbird gold prospect, antimony is present in significant amounts as massive 1 to 4-centimetre grey stibnite lenses in white quartz-carbonate veins.

Although cobalt and nickel mineralization has not been identified in British Columbia listwanites, the Bon Azzer ophiolite in Morocco contains listwanite formed along faults marginal to a large serpentinite unit with quartz-carbonate lenses hosting cobalt-nickel arsenide mineralization. It represents a type of listwanitic cobalt-nickel deposit with accessory gold (Leblanc, 1986).

A number of factors combine to suggest that listwanitic alteration zones may be a potential host for hydrothermal platinum group element (PGE) mineralization. PGEs are found primarily in mafic and ultramafic rocks. Analysis for this group of elements has historically been difficult and frequently inaccurate, especially at the low concentrations in rock samples. Present day analytical techniques have overcome this problem (Theyer, 1988).

PGE concentrations occurring in hydrothermal copper and nickel sulphide ores have been reported from a number of localities including: Northwestern Ontario (Rowell and Edgar, 1986), Wyoming (McCallum *et al.*, 1976) and South Africa (Mihalik *et al.*, 1974). Theyer (1988) has recently reported anomalous platinum and palladium values in quartz veins containing 1 to 2 per cent pyrite from northern Manitoba. Further, Mountain and Wood (1988) made thermodynamic calculations on the solubility of platinum and palladium at temperatures up to 300°C. They found that bisulphide and/or hydroxide complexing are potential mechanisms for transport of these metals. Thus listwanite-generating fluids may be capable of transporting these elements.

DESCRIPTION AND IDENTIFICATION

A clearly identifiable mineralogical alteration assemblage after serpentinite consists of green chromium-bearing mica with quartz and carbonate veins in a recessive orange-brown limonitic groundmass formed by the weathering of iron-rich magnesite.

Listwanite zones form along major faults cutting or marginal to serpentinitized ophiolite peridotites (Figure 3-2-2). Alteration is characteristically most intense within and above the mineralizing structure where iron magnesite/mariposite rocks are generally sheared and cut by networks of quartz-carbonate veins. The intensity of carbonatization of the serpentinitized ultramafic rocks is zoned outward from the faults, producing a distinctive alteration halo (Table 3-2-1).

Listwanite alteration assemblages are highly variable in appearance depending on the relative abundance of the alteration minerals and the distribution of different fabrics produced by inhomogeneous strain. Hydrothermally altered serpentinites with minor quartz stringers and disseminated

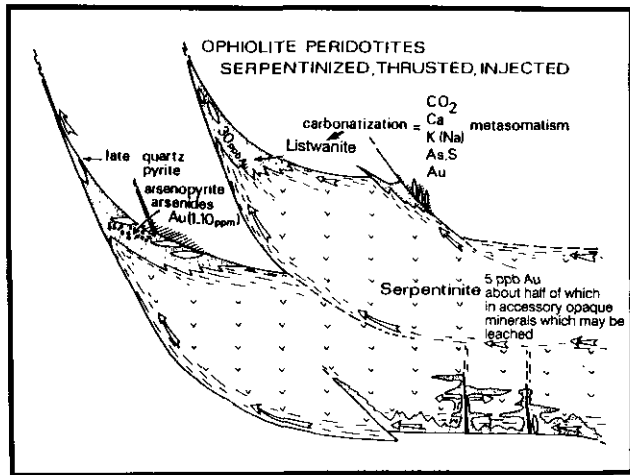


Figure 3-2-2. Generalized listwanitic alteration model which invokes carbonatization of serpentinitized ultramafic rocks and the development of gold-bearing veins in and above thrust, normal and/or reverse faults (modified from Buisson and LeBlanc, 1985).

mariposite commonly range from massive to moderately deformed. Those containing high proportions of mariposite commonly form a quartz-carbonate-mariposite schist. However, rocks may vary from massive to schistose to brecciated within the complete range of alteration assemblages present.

Commonly zones marginal to or containing small slivers of carbonatized ultramafic rocks are lithologically heterogeneous and represent tectonic mélanges containing all or some portions of the oceanic assemblages described previously. Within these zones both alteration and deformation are inhomogeneously developed. Carbonatization is generally most intense in the more mafic lithologies. More massive rocks, for example volcanics, cherts and limestones, are often brecciated; fine-grained clastic sediments appear to take up a large part of the strain and are generally intensely sheared and may contain variably sized knockers of the more massive lithologies. Many of these knockers are themselves brecciated and recemented by hydrothermal carbonate, providing evidence for multiple episodes of brecciation and carbonatization. The Yellowjacket (Lefebvre and Gunning, 1988), Beavis (Bloodgood *et al.*, 1989) and McKee Creek showings in the Atlin area are representative examples of listwanitic alteration associated with tectonic mélange assemblages. Fault zones at both the Erickson gold-silver mine in Cassiar and the Snowbird gold prospect near Fort St. James are defined by structural contact relationships between metabasalts and argillaceous sediments. Slivers of ultramafic rock several metres to tens of metres in width are discontinuously distributed along low-angle fault contacts and are highly sheared and schistose.

EXPLORATION GUIDELINES

The fundamental depositional control for this deposit type is the localization of hydrothermal alteration sites along major fault zones within, marginal to, or containing ultramafic rocks. As a first approach to exploration, prominent

TABLE 3-2-1
CHARACTERISTIC ALTERATION ASSEMBLAGE OF LISTWANITE

HOST	Increase in Intensity of Alteration →			FAULT
Serpentinite	Talc Carbonate	Quartz (veinlets) Talc Carbonate	Quartz Carbonate Mariposite Au, Ag Sulphides	

linears outlined on topographic maps or aerial photographs within or adjacent to exposures of ultramafic rocks are sites worth prospecting. The fact that the majority of ultramafic rocks contained in oceanic terranes are mantle derived implies that their contacts must be faulted. Therefore, margins of serpentinitized ultramafic bodies are also potential sites of alteration and mineralization.

Linears defined by aeromagnetic lows in serpentinite may delineate zones of carbonatization. Magnetite formed during the serpentinitization of ultramafic rocks produces a strong magnetic signature. Carbonatization results in the destruction of magnetite, creating zones of reduced magnetic susceptibility. The application of aeromagnetic lows as an exploration tool in delineating zones of carbonatization in ultramafics has been discussed by Gresens *et al.* (1982). This approach has been applied by Homestake Mineral Development Company in the Atlin camp and has proven successful (D. Marud, personal communication, 1989).

Once a fossil hydrothermal system has been identified the explorationist must assess whether or not the system contains gold. Various reported geochemical pathfinders associated with listwanitic alteration systems and related to gold mineralization can aid this assessment and are summarized in Table 3-2-2. All authors indicate that arsenic displays a consistent correlation with gold, as is typical of gold deposits in general. Bozek (1989) found that arsenic and antimony showed the strongest correlation and widest dispersion halo in carbonatized serpentinite at both the Pictou and Yellowjacket prospects near Atlin.

Alkalis also show a strong association with mineralization, potassium in particular often corresponds with abundance of mariposite. Gresens *et al.* (1982) found that lithium showed the widest and most regular dispersion halo within listwanitic rocks at the Mount Vernon deposit in Washington and suggest a tentative correlation of highest lithium with highest gold values. Both potassium and sodium also show enrichment haloes but are erratic in their lateral distribution, which is attributed to localization in unevenly distributed vein minerals. At the Erickson gold mine near Cassiar, Sketchley (1986) found that both barium and potassium display a positive correlation with gold in carbonatized metabasaltic rocks.

Base metals, most commonly copper, lead and zinc, are also associated with listwanitic lode gold deposits, but tend to have a somewhat more erratic distribution. Such an association may reflect the nature of the environment in which these deposits form. Primary concentration of base metals (massive sulphides) is inherent in the process of oceanic crustal formation. Later, epigenetic mineralizing fluids channeled along major shear zones within the oceanic rocks may

encounter primary base metal concentrations and become selectively enriched.

TABLE 3-2-2
POTENTIAL PATHFINDER ELEMENTS FOR GOLD IN LISTWANITE

Location	Strong positive correlation with Au	Positive and sporadic correlation with Au	Source
Atlin, B.C.			
Yellowjacket	As, Sb	Ag, X	Bozek (1989)
Pictou	As, Sb	Ag, Cd, Cu, Pb, Zn	
Cassiar, B.C.			
Erickson	As, Ba, K, B	Ag, Cu, Pb, Zn, Sb	Sketchley (1986)
Washington State			
Mount Vernon	Li	K, Na, Zn, Pb	Gresens et al. (1982)
European ophiolites	As, K	Sb, Ba, B, Bi, Ag, Cu	Buisson and Leblanc (1985b)

CONCLUSION

Listwanite (carbonatized ultramafic rock) is a distinctive alteration assemblage commonly associated with quartz-carbonate lodes that have the potential for high-grade gold mineralization. Known listwanitic lode gold deposits are:

- Structurally controlled epigenetic deposits.
- Characteristically found within accreted oceanic terranes and associated with ophiolitic ultramafic rocks that have been tectonically dismembered.
- Generally high-grade, low-tonnage deposits with erratic distribution of gold.

A model relating listwanite alteration and gold mineralization to the deformation history of their ophiolitic hostrocks throughout the Canadian Cordillera, will provide a useful guide to future exploration for mesothermal gold deposits, historically the most significant gold producers in the province (Barr, 1980).

ACKNOWLEDGMENTS

The authors would like to extend their gratitude to Darcy Marud and Joanne Bozek of Homestake Mineral Development Company and Linda Dandy of Mark Management in the Atlin area, to Matt Ball and the staff of Total Energold Corporation at the Erickson Mine and to Brian Game of X-Cal Resources Ltd. at the Snowbird prospect, for their insightful discussions, providing field visits and making maps and data readily available to us. This report has benefited from reviews by Bill McMillan, Andre Panteleyev, Ron Smyth, Mitch Mihalynuk, JoAnne Nelson and MaryAnne Bloodgood.

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