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# A REVIEW OF ASPECTS
# OF THE
# GOLDEN BEAR PROPERTY
# NORTHERN BRITISH COLUMBIA

**Prepared For**

**NORTH AMERICAN METALS CORP.**

**By**

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## General Statement

The Golden Bear mine area (Muddy Lake region) of northern British Columbia is an area in which gold mineralization was discovered relatively recently, initially during regional exploration by Chevron Minerals Ltd. Following the acquisition of the area by North American Metals Corp. ("NAM", several zones of gold mineralization have been defined and mining operations established on some of these deposits. In February, 1997, Mr. Dunham Craig of NAM requested Bailey Geological Consultants (Canada) Ltd. to provide a general appraisal of the geological setting, exploration results and gold potential of the area for the purpose of establishing the nature of the known gold deposits and whether continued exploration is justified at detailed and reconnaissance levels.

The writer has no recent experience in the area under discussion although he has visited the Golden Bear area during exploration activities by Chevron Minerals Ltd. Information for this summary is mostly derived from a report provided by NAM.

In the opinion of the writer, exploration work by NAM personnel has been exemplary and could be held as a model by which other exploration companies should conduct their exploration programmes, using a staged approach but always based on sound geological and geochemical work, forming a foundation for more advanced and detailed exploration. The report supplied was clear, concise and technically well-founded. A single, deficiency, however, of all work to date is that there seems to have been little attempt to integrate the geological knowledge collected to form a model which may be used to guide further exploration. This is discussed below.

## Structural Development

Cooley (1996) has provided excellent documentation of the structural development of the Golden Bear region although his interpretation differs somewhat from those of earlier workers. In general, however, the structural development of the region can be divided into three periods; i) thrusting and early Mesozoic folding (probably Lower to Middle Triassic - the so called "Tahltanian" Orogeny - not Upper Permian as considered by Oliver (1996)- referenced in Cooley (1996)), and accompanying penetrative deformation; ii) Middle Jurassic folding and thrusting (e.g. the Bajocian King Salmon and Nahlin thrusts) as Stikinia docked with terranes to the east; iii) brittle deformation, normal and strike-slip faulting. From the point of view of gold deposition, it is this latter period which is important although the Lower Jurassic was an important metallogenic period in terms of the development of copper-gold porphyry and related deposits. During this period and extending into the Middle Jurassic, the gold - base metal deposits of the Iskut region also formed, deposits which occur at high crustal levels and as exhalites.

The age of the initiation of strike slip faulting is difficult to establish in much of Stikinia. In central British Columbia to the northwest of the Nation Lakes, a fault between Permian limestone and Takla volcanic strata, temporally and compositionally equivalent to the Stuhini volcanics, is at least as old as Lower to Middle Cretaceous as the strike slip fault is cut by a Cretaceous pluton. Similarly, strike slip movement along a fault separating Cache Creek from Quesnellia in the Quesnel Lake region also occurred during the Cretaceous in that a Cretaceous pluton here is cut by the fault and Cretaceous sediments are preserved within fault angle depressions. Such sediments are also preserved within the Pinchi - Thibert - Teslin fault system further to the north. However, these observations do not date the time of initiation of faulting. Cooley (1996) suggests that the Ophir Break developed during the Lower to Middle Jurassic while some major faults to the east along the eastern margin of Stikinia and along the eastern margin of the Cache Creek Group (e.g. the Pinchi Fault) have been considered to have formed during the Upper Triassic or Lower Jurassic. Faulting of Upper Triassic plutonic rocks to the north of the Golden Bear area provides some constraint on the time of development of the Ophir Break.

## Time of Gold Deposition

Relationships between gold mineralization and zones of brecciation and fracturing related to the Ophir Break and other faults of the region clearly indicate that dilatancy caused by faulting was the main structural control of gold mineralization. Gold mineralization, therefore, postdates the formation of northerly- and northwesterly-striking faults but fault movement appears to have continued after hydrothermal activity and gold deposition ceased.

Two observations can be made with respect to time of gold mineralization. Firstly, an altered and gold-mineralized dyke of intermediate composition has been recognised at the Kodiak B deposit. Secondly, oxidation zones of the Kodiak group of deposits are still preserved despite the current rate of uplift of the Coast Range. The second observation would suggest that, as oxidation probably formed in the near surface environment as a result of the influence of oxidised groundwaters on the sulphide deposits, an estimate of rate of uplift would give some indication of the age of the deposit. This follows from studies of Carlin-type gold deposits which suggest that these deposits formed at pressures of around 400 bars (e.g. 370 - 430 bars at Getchell, Nevada (Bagby and Cline, 1990)), or a depth of less than one kilometre if hydrostatic pressure exceeded lithostatic pressure, generally thought to be the case. While depth of formation theorectically could be greater, most workers are of the opinion that such depths are realistic (see review by Bagby and Berger, 1985). A model which is possibly applicable to the Golden Bear deposits is discussed below.

Since the Coast Range has been considered to have uplift rates of about 1km to 4km in the last 10MY (Matthews, 1992) the preservation of oxidized sulphide ore at the surface suggests that the deposits could not have been formed during the Jurassic as indicated by radiometric dates obtained by Schroeter (1987). On the other hand, younger radiometric ages range from Middle Cretaceous to Miocene and illustrate the problems associated with trying to radiometrically date such deposits. A major problem in potassium/argon dating of micas, especially sericite, from ore deposits, is that often the mica records a history of several hydrothermal overprints and, in addition, may reflect later heating unrelated to ore deposition. In the case of the Golden Bear deposits, it is quite reasonable to assume that a later heating event of Miocene age (the Relay Mountain event) has affected the K/Ar isotopic systematics established during ore deposition.

The age of the mineralized intermediate dyke in the Kodiak B deposit can be no older than Lower Jurassic and no younger than the Relay Mountain volcanics. If faulting began during Lower Jurassic times, it is likely that the dyke is of younger age. 14Ma mafic dykes are of Relay Mountain volcanic age and postdate gold mineralization. Although it is possible that the dyke is of Lower to Middle Jurassic age (Laberge Group), from a consideration of the possible age of faulting and of uplift

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rates, it is considered more likely that a probable time of gold mineralization of the Golden Bear region is that of the age of the Sloko Group, i.e. Eocene, and is possibly related to the same magmatic event during which the Samotua Caldera, about ten kilometres to the west of Golden Bear, was formed. The Eocene was a significant period in terms of gold mineralization throughout the Intermontane Belt of British Columbia and includes such deposits as Mount Skukum and Skukum Creek in southwestern Yukon, the deposits of the Toogogone region and those of the Chilcotin. All are related to late Cretaceous - Eocene crustal extension and all formed at a high crustal level.

## Controls of Gold Mineralization

Clearly the major control of gold mineralization is major north- and northwest-trending faults, especially where changes in fault attitude and zones of brecciation occur, forming dilatant zones. Gold was probably deposited in these zones by a combination of cooling of hydrothermal solutions by volume expansion and also by the reaction between sulphur-rich acid solutions with carbonate strata. Although Stuhini volcanic rocks are also occassionally mineralized, the bulk of the mineralization occurs within silicified carbonate. However, there does not appear to be any single carbonate unit which is preferentially more mineralized than any other.

The suggestion that gold deposits preferentially formed in the axial zones of $D_2$ folds where these zones are cut by faults of the Ophir Break may have some value in that axial planar fracturing may have contributed to the porosity of the rocks in these structural sites. Nevertheless, apart from the Kodiak deposits, gold mineralization does not seem to have any particular relationship to $D_2$ folds in general.

It is difficult to establish why $D_2/D_3$ interference folds should be valid structural targets for testing. Brittle tectonic fracturing combined with possible hydraulic fracturing, leading to an increase in porosity and dilatancy and gold deposition due to adiabatic expansion or chemical reaction with carbonate appear to be the main controls of mineralization. Initial subvertical brittle fracturing caused by faulting is almost certainly the primary control. The apparent regular spacing of the Kodiak deposits, about 250m apart, is difficult to rationalise in terms of fold interference patterns because folding occurred much earlier than faulting and ore deposition. The preservation of such patterns in a fault zone of the magnitude of the Ophir Break, especially when fault movements occurred both pre-mineralization and post-mineralization, is probably unlikely.

A more relevant approach is to ask the question why known gold mineralization occurs only within a four kilometre long section of the Ophir Break athough the Ophir Break and associated faults can be traced for over 25 kilometres from Tatsamenie Lake in the north to the Moosehorn Batholith in the south. If permeability and fracture porosity were the only factors, the entire region between the Moosehorn Batholith and Tatsamenie Lake should be prospective. If gold is preferentially concentrated in carbonate rocks the area of prospectivity is about eight kilometres long, bounded by the Ophir Break to the east and the Limestone Creek fault to the west. A further five or six kilometres of limestone occur to the northwest, at the southwest end of Tatsamenie Lake.

**Gold Mineralization Model**

The nature of gold mineralization at Golden Bear in terms of element association, its gross confinement to carbonate units and its association with major structural breaks, strongly suggests that a Carlin-type model can be applied to the region. In this model strongly acid auriferous solutions passing up major structures cause the replacement of limestone or dolomite with silica accompanied by the deposition of gold and sulphides, mainly pyrite, but commonly accompanied by arsenical and antimonial species. The main reason for Carlin deposits to be economic is a later oxidation event during which sulphides were destroyed, freeing gold from sulphide lattices and allowing heap leaching to be an efficient means of gold extraction. Nevertheless, it has been estimated (A. S. Radtke, *pers. comm.,* 1996) that for every ounce of gold extracted by heap leaching Carlin ore, there are ten ounces associated with sulphides which have yet to be extracted. Some of these sulphide-rich ore deposits have only recently been discovered by deep drilling programmes and it is the identification of these deep zones which is now the focus of exploration in those camps such as Carlin and Getchell where near-surface exploration is virtually complete. If Newmont manages to perfect its bioleach process of sulphide ores, enormous potential opens up for the mining of these deposits.

Gold deposits of Carlin-type are formed from acid, nonoxidised (although highly oxidising) hydrothermal solutions whose chemistry suggests a calcalkalic plutonic source. Deposits formed from such solutions tend to be potassic, deficient in iron oxides and poor in base metals. Gold is probably transported as chloro species given the instability of thio complexes in acid solutions at reasonably high temperatures and, thus, with appropriate bulk compositions, wallrock alteration is dominated by potassic phyllosilicates (sericite, illite and other potassic hydromicas) and in central zones directly associated with gold mineralization, strong silicification. Deposits of this nature tend to be intermediate in terms of level of deposition between the high sulphidation epithermal deposits and the true mesothermal porphyry-type deposits and, in the case of the Carlin deposits themselves, appear to have formed at depths of between about one and two kilometres (350kb - 700kb).

The mineralogical characteristics of the Golden Bear deposits are similar to those of Carlin and while the form of the deposits may be different, this is probably a function of host rock characteristics. The most productive carbonate units of Carlin and related deposits in Nevada are those units in which there is a considerable clastic component, i.e. silty carbonates. When acid solutions dissolve carbonate there is a meshwork of clastic grains remaining and which impart a considerable permeability and porosity to the rock, allowing large quantities of auriferous solutions to pass through and deposit gold and silica. In those units where the carbonates are relatively pure, fracture porosity is the controlling factor in gold deposition and the deposits are usually small unless there is considerable refracturing caused by solution overpressure and tectonism. However, these deposits are usually near-surface and tend to form strictly within the epithermal regime where hydrostatic pressures can reach values much greater than lithostatic pressure and where episodic boiling, self-sealing and refracturing is a common feature. In most cases these latter deposits tend to be of vein aspect rather than containing disseminated gold and being pervasively mineralized.

The Golden Bear deposits occur in a terrane in which the carbonates are relatively pure and, although gold deposits occur in most parts of the carbonate stratigraphy, all are characterised by an initial fracture porosity which is probably mainly of tectonic origin (although this statement should be tempered by the fact that the writer has not viewed drill logs or core of most of these deposits).

The reason that most known gold deposits of the Golden Bear region are confined to the Ophir Break is that this fault zone is probably a fundamental and profound crustal break, accessing a heat and hydrothermal solution source which may be manifested as an Eocene pluton at depth. Such a magma source is consistent with a Carlin model and, although manifestations of such a source are rare within Carlin deposits themselves, there are a number of lines of evidence to suggest that these deposits are of magmatic-hydrothermal character. The main evidence is from the composition of the hydrothermal solutions themselves as determined from the study of fluid inclusions. Secondly, the high heat flow necessary for the development of large gold - sulphide deposits is best explained as being derived from a rising magmatic source and, hence, the necessity for prospective fracture zones to be deep crustal structures to tap such a source. Thirdly, the metal budget of such deposits and their rock/water ratios demand that gold is derived from a concentrating medium and cannot be explained solely by leaching from wallrock. Another line of evidence is the abundance of silica in such deposits and which is best explained as being derived from an exsolving felsic magma. A number of other arguments can be forwarded to support the view of these deposits being of magmatic hydrothermal origin and a review of the relevant literature can be supplied if required.

The magmatic hydrothermal nature of the Carlin deposits is also supported by recent high resolution aeromagnetic surveying of the district in which a distinct deep, circular, magnetic anomaly can best be explained as a pluton of felsic or intermediate composition at a depth of perhaps several kilometres beneath the essentially magnetically isotropic overlying carbonate and siliciclastic strata. This magnetic anomaly occurs only in the area of the Carlin deposits; although the Carlin trend continues to the northwest and southeast, the major deposits all lie within the area of influence of this anomaly. Although gravity data of the region is of much coarser resolution than the magnetic data, negative free air and Bouguer anomalies in the Carlin area add weight to the magnetic interpretation of the presence of an underlying pluton.

**Discussion**

Although work in the Golden Bear region has been undertaken in an extremely professional manner, in general this work has been carried out in a entirely empirical fashion except for the structural study made in attempt to determine the controls of mineralization and to predict additional areas which may contain gold deposits. In the report to hand it appears that there has been no attempt to intergrete the exploration data into a working model which may be applied to the region as a whole. Thus, it appears that although the observation that all known deposits occur along major faults has been well tested, there has been no extension of this thinking in terms of why this may be the case, or why the carbonates are mineralized and not the Stuhini volcanics which elsewhere in the region host good mineralization.

In terms of an ore deposit model, it is the absence of anomalous copper (and, to some extent, other base metals) which, above all else, suggests that the gold mineralization of the Golden Bear region is not Lower Jurassic in age but more likely related to Eocene magmatism. In addition, the "toxic" element signatures not only suggest a Carlin model but also suggest that the Eocene was more likely the period of mineralization than the Lower Jurassic.

Geological and geochemical coverage of the Golden Bear region is reasonably complete and it is unlikely that any significant features which may indicate the presence of a surface or near surface gold deposits have not been investigated. However, while ground geophysical coverage has been reasonably extensive, to the writer's knowledge there has been no regional high resolution aeromagnetic survey carried out. In addition, while geochemistry has successfully outlined zones of gold mineralization proven by subsequent trenching and sampling, zones of anomalous "indicator" elements without gold do not appear to have been tested. The siliceous alteration zone of the Totem area must have been sampled and, although results have not been supplied. Was this zone anomalous in arsenic, antimony, possibly mercury, or manganese, elements which may indicate an underlying gold deposit?

A final point in terms of exploration philosophy is that of the internal structure of the Paleozoic carbonate block bounded to the east by the Ophir Break and to the west by the Limestone Creek Fault. Structural mapping has not discerned any major faults in this block but, as the writer is well aware, the carbonate stratigraphy of the Upper Paleozoic within the Stikine Terrane is very difficult to subdivide without good marker horizons and in upland regions with a veneer of till, moraine and glacial ice. Nevertheless, the important faults are those which are clearly fundamental structures and although minor faults may have significant localising effects on ore deposition, they are not the structures which control primary hydrothermal fluid focusing from deep seated sources.

## Recommendations for Further Work

Within the Golden Bear project area there is not much more that may be done in terms of ground exploration. However, without benefit of discussions with NAM geologists, the following is recommended.

1. A high resolution aeromagnetic survey be undertaken of the Golden Bear region to test the possibility of a deep seated pluton (perhaps lying to the east of the Samotua Caldera) and over which the Ophir Break and Limestone Creek structures may be superimposed.

2. A more detailed stratigraphic study be instigated to ascertain whether "dirty" limestones lie within the Upper Paleozoic stratigraphic sequence and where, i.e. are there facies changes along strike or down dip (or down the paleoslope) and where are these facies in relation to the Ophir Break and the Limestone Creek Fault.

3. Other carbonate sequences in the region be examined, initially by geological mapping and by geochemical methods, especially if adjacent to regional throughgoing fault systems.

4. Alteration assemblages be mapped from surface exposures and in drillcore in the vicinity of known deposits to establish whether faulting has displaced gold mineralization or whether additional gold mineralization may be expected down plunge, down dip or along strike. This, of course, is easier said than done in carbonate-hosted ore but there are, nevertheless, intensities of alteration, especially in terms of silification and mica development (illite and sericite and the ordering of the mica structures) which can be useful in providing ore vectors. This is especially significant in terms of a Carlin model

in which the larger deposits all have significant sulphide gold resources and some, e.g. Post-Betze (Purple Vein), have multi-ounce ore at depth underneath an oxide cap.

5. Since the postmineral climate was conducive to the establishment of oxide ore reserves, a prospecting programme, if not already carried out, should be instigated to look for occurrences of jasperoid which on the surface can be quite insignificant but could overlie relatively large zones of mineralization.

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