Earth Sciences
2018; 7(1): 17-22
http://www.sciencepublishinggroup.com/j/earth
doi: 10.11648/j.earth.20180701.14
ISSN: 2328-5974 (Print); ISSN: 2328-5982 (Online)

Metallogenic Series of Gold Deposits in the Cariboo Gold Mining District, British Columbia, Canada

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To cite this article:
Jian Zhao Yin. Metallogenic Series of Gold Deposits in the Cariboo Gold Mining District, British Columbia, Canada. *Earth Sciences*. Vol. 7, No. 1, 2018, pp. 17-22. doi: 10.11648/j.earth.20180701.14

Received: November 24, 2017; **Accepted**: December 4, 2017; **Published**: January 11, 2018

Abstract: The Cariboo gold mining district is located in central British Columbia, Canada. Recorded gold production from the area totals more than 3.87 million ounces, including an estimated 2.64 million ounces from placer mining from 101 creeks and 1.23 million ounces from lode mining. The district consists of two dominant metallogenic series of gold deposits: quartz vein and pyrite replacement styles. The quartz vein series includes strike vein, diagonal vein, orthogonal vein, and quartz veinlets, while the pyrite replacement includes replacement in limestone and that in calcareous clastic rock.

Keywords: Cariboo Gold Mining District, Metallogenic Series, Pyrite Replacement, Quartz Vein, Barkerville Terrane, Omineca Belt, Canadian Cordillera, Quesnel Highland

1. Introduction

The Cariboo mining district on NTS map sheet 093H/3, 4, surrounds the community of Wells, central British Columbia, approximately 80 km east of Quesnel, 120 km southeast of Prince George and 500 km north of Vancouver, situated within the Quesnel Highlands on the eastern edge of the Interior Plateau. The highlands have an average width and length of approximately 50 km and 160 km, respectively, extending from Bowron Lake south to Mahood Lake (Figure 1).

The Quesnel Highlands are the remnants of rolling plateau formed initially from bedrocks lain down as the ancient North American Plate moved westwards colliding with offshore seabed and island groups. The bedrocks were then overlain by lava flows emanating from Chilcotin volcanoes that filled the lowlands between the Coast and Cariboo Mountains. These remnants rise gradually from roughly 1,500 m above sea level in the west to more than 1,900 m above sea level in the east, and become progressively more dissected with elevation.

The topography is moderate, rising from about 1,200 metres at Wells to just over 1,600 metres on Barkerville Mountain. Summits are generally rounded, having been glaciated by continental ice sheets during the Pleistocene Epoch [1]. Ice direction is generally to the northwest near Wells and glacial till is the most widespread surficial deposit in the area.

The landscape in the area has been altered locally by mining activities that began in the early 1860s. Hydraulic mining has resulted in over-steepened, erosion-prone stream banks in some areas, while placer and underground mining have modified the landscape through the creation of tailings mounds, waste rock piles, and the establishment of roads and trails across forested mountain slopes.

The area is located between the Coast and northern Rocky Mountains. The Cariboo mining district is within the Southern Cordillera region, as defined by the Geological Survey of Canada for the purpose of describing seismic risk [2].

The district encompasses (from northwest to southeast) the former producing Hardscrabble Tungsten-Gold Mine, Mosquito Creek Gold Mine, Aurum Gold Mine, Island Mountain Gold Mine, Cariboo Gold Quartz Mine, Bonanza Ledge Gold Mine, the Cariboo Thompson Gold & Silver Mine, and the Cariboo Hudson Gold Mine.

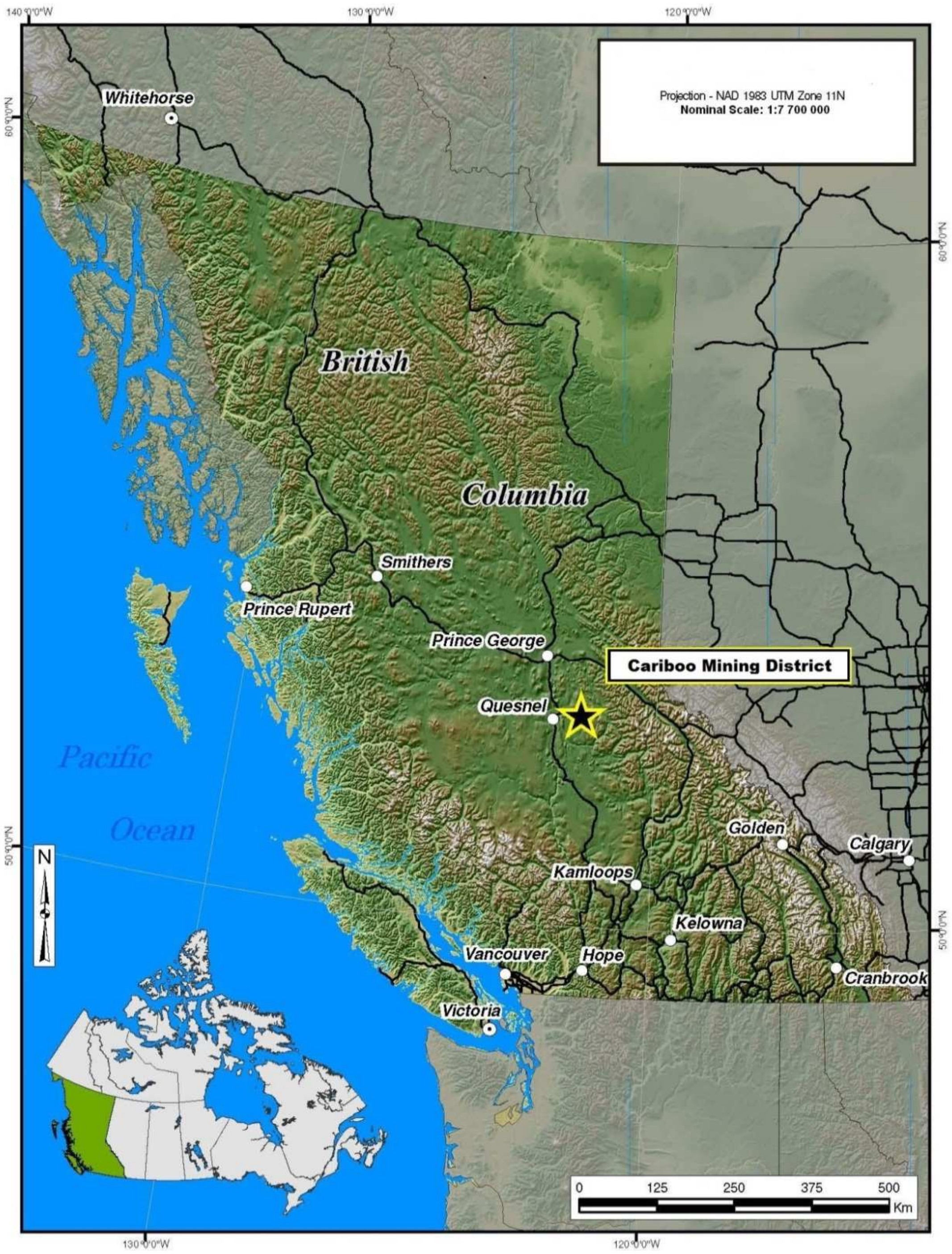

Figure 1. *Property location.*

2. History

Cariboo mining district is situated within the Cariboo Gold Belt (Figure 2), a world-class producer of gold that has had a history of mining dating from the Cariboo Gold Rush in the 1860's. Recorded gold production from the area totals more than 3.87 million ounces, including an estimated 2.64 million ounces from placer mining from 101 creeks and 1.23 million ounces from lode mining.

The district includes the former Cariboo Gold Quartz Mine (CGQ), situated on southeast of Jack of Clubs Lake (Figure 1, 2 & 3), which produced 1.68 million tons grading 0.37 oz/ton Au from 1933 to 1959, primarily from quartz veins. Three other past producing gold mines, the Island Mountain (IGM), Aurum and Mosquito Creek Gold Mines (MGM), are located on the northwest of the Jack of Clubs Lake. The IGM (1934-1967) and MGM (1980-1983) produced 603,800 ounces of gold from approximately 1.35 million tons of ore from quartz-type ore with an average grade of 0.35 ounces per ton (12.0 g/T) gold and replacement ore with an average grade of 0.67 ounces per ton (23.0 g/T) gold [3] [4].

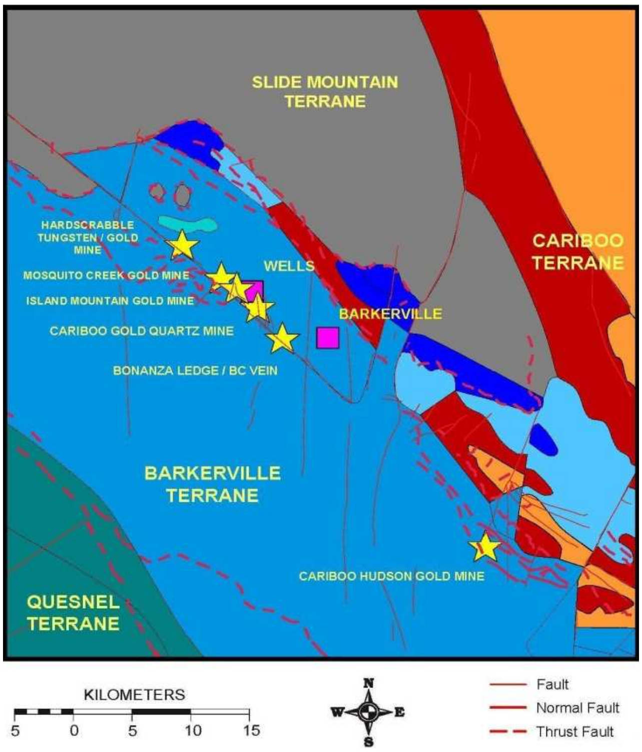

Figure 2. *Regional geology.*

Production from the CGQ on Cow Mountain was obtained from several zones including the Tailings, No.1, Rainbow, Sanders, and Pinkerton Zones.

Under the direction of Mr. Fred Wells, lode gold in the form of auriferous quartz veins was prospected southeast of the Jack of Clubs Lake in the late 1920s. The Cariboo Gold Quartz Mining Company Ltd. was formed to develop the resource, and underground mining was carried out, producing approximately 660,000 ounces of gold from 1,682,000 tons milled. This production came from the "No 1 Mine" which extended over a strike length of approximately 1,500 m (5,000 feet).

Wharf Resources Ltd. purchased the property not long after the mine closure. In a 1973 report to that company, consultant E. E. Mason, P. Eng., stated that "The No.1 Mine reserves of 117,010 tons constitute 51 ore remnants scattered through 13 levels of workings and across a distance of 5,000 feet" [5].

Wharf Resources drilled 105 percussion holes totaling 3,931 m (12,898 feet) in the Sanders Zone in 1980-81, to an approximate depth of 30.5 m (100 feet). Based on this information, V. F. Hollister, P. Eng., concluded, in November, 1981, that drilling had provided "a minimum of 360,000 tons of drill-indicated [open pit] reserves that contain an average of 0.119 oz. Au per ton", and that a larger potential was implied. A cut-off grade of 0.03 oz/t was used. A June, 1984, report by David Bolin, consultant to Golder Associates, developed an open pit design with approximately 361,000 tons of ore at an average grade of 0.177 oz/t Au, using a cut-off grade of 0.03 oz/t Au [6] [7].

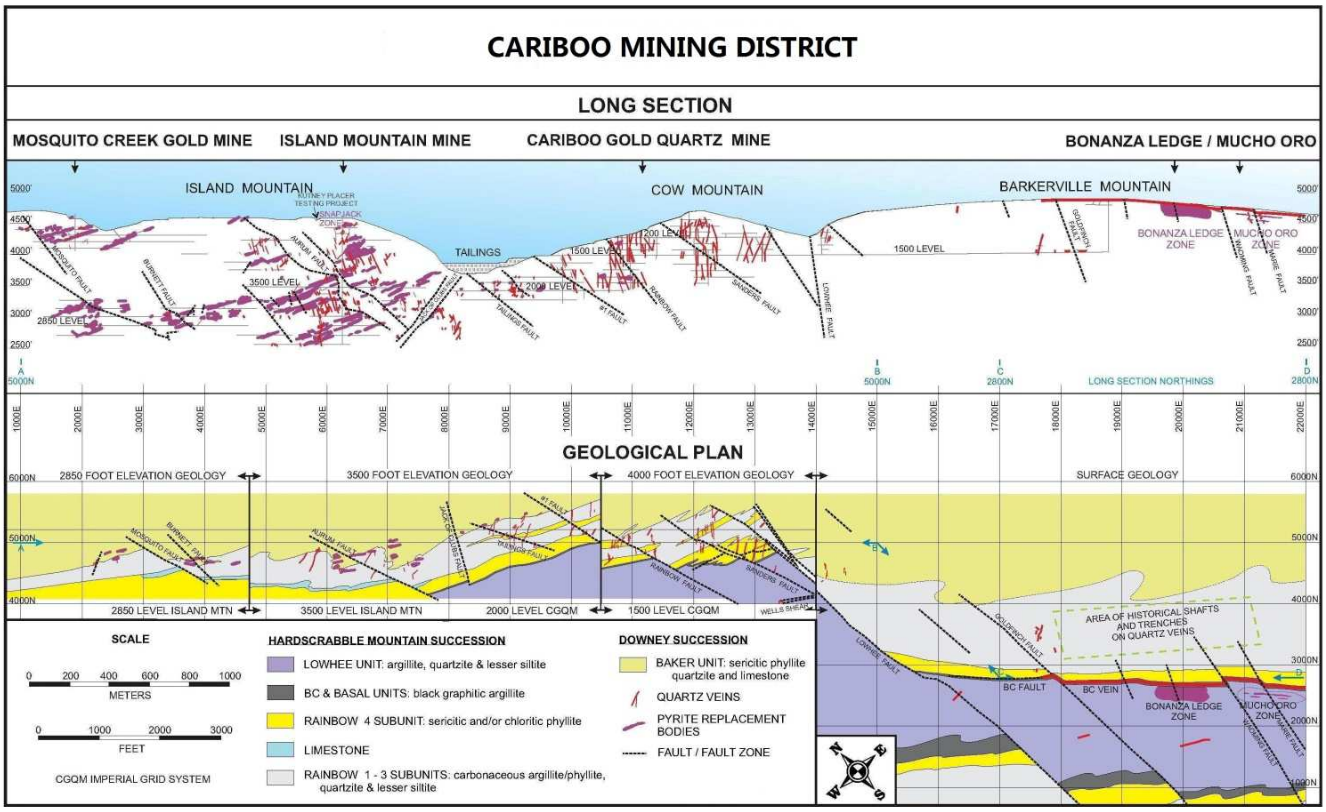

Figure 3. *Geology and long section of Cariboo mining district.*

In May, 2000, Consulting Geologist Ronald Simpson reworked basically the same data but using a more conservative tonnage factor (11.5 cubic feet per ton versus 11 cubic feet per ton) and a more conservative search ellipse for calculating block grades in his model. A mixture of metric and imperial units was used for reporting, but "cutoffs" were reported in grams per tonne (g/T) gold. For comparison purposes with Dykes figures, Simpson included a resource calculation for a grade cutoff of 0.686 g/T (i.e. 0.02 oz/ton). This calculation came to approximately 8,720,000 tons at 0.059 ounces per ton, containing 515,000 ounces of gold; all of this in the Inferred Resource category [8].

The Bonanza Ledge gold deposit was discovered in March of 2000 on the south-western flank of Barkerville Mountain. The Bonanza Ledge Zone contains significant gold grades associated with pyrite mineralization developed in a strongly sericite-silica-dolomite/carbonate-pyrite altered turbidite sequence in the footwall of the BC Vein, a strike quartz vein from which several auriferous pyritic ore shoots were historically mined from the Cariboo Gold Quartz workings (15 Level). A decline was driven into the Bonanza Ledge gold deposit, to obtain a bulk sample and to conduct underground diamond drilling to further define the deposit [9].

During the last several years after Bonanza Ledge Zone was discovered, work in the district has included geologic mapping, trenching, grid establishment, surface geophysics including magnetic, SP, VLF, IP and gravity surveys, soil geochemistry, surface and underground drilling.

3. Geological Setting

The area lies within the Barkerville Terrane, part of the Omineca Belt of the Canadian Cordillera [10] [11] [12]. The Barkerville Terrane consists of a late Proterozoic and/or Paleozoic sequence of continental shelf and slope deposits developed adjacent to the craton of Ancestral North America, and includes clastic sedimentary rocks along with lesser amounts of volcanic rocks and carbonates. It is structurally the lowest exposed stratigraphic sequence in area and is more deformed & metamorphosed than adjacent terranes (Figure 2).

Rocks of the Snowshoe Group in the district have been metamorphosed to lower greenschist facies, generally of lower metamorphic grade than other sequences in the Barkerville Terrane.

Rocks of the Barkerville Terrane were subjected to an early period of ductile deformation that resulted in westward directed, asymmetrical folds plunging shallowly to the northwest. Post metamorphic open folds with upright cleavage are superimposed on earlier structures. During late Cretaceous to early Tertiary time, the terrane was disrupted by northwest trending dextral strike-slip faults such as the Willow Fault, a major strike-slip fault of unknown displacement that has been mapped through Mount Tom, Island Mountain, Cow Mountain and Richfield Mountain in the Wells area. Northwest and north-trending faults, with an important normal component and generally apparent right lateral displacements, record extension, probably associated with transcurrent movement. The north striking cross faults are an important control for the gold vein mineralization [13].

Stratigraphic position, host rock lithologies, and proximity to north-striking fault zones are important guides to the different styles of gold mineralization recognized in the district. The mineralization is probably stratabound, in that each style is confined for the most part to a particular section of the local stratigraphy. Historical production has been from mesothermal pyrite-bearing quartz vein systems that cut turbiditic rocks, and from semi-massive to massive pyrite replacement type bodies that occur in carbonate-rich rocks structurally higher but stratigraphically lower in the sequence.

The area is underlain by a northwest striking, moderately northeast dipping sequence of rocks on the steep, overturned limb of a southwest-verging antiform (Figure 2 & 3), which, in turn, is on the northeast flank of the Island Mountain anticlinorium.

Stratigraphitic nomenclature for the sequence of rocks at the district has been modified several times. Hanson included the sequence in two members, a structurally upper carbonate-dominated sequence of lighter coloured rocks comprising the "Baker Member" and a lower sequence of darker coloured siliceous metaturbidite rocks he called the "Rainbow Member" or Rainbow quartzite. Sutherland Brown included the Baker Member and structurally upper portion of the Rainbow Member in the Snowshoe Formation, which, in turn, was subsequently included in the Downey Succession of Struik (1988). Structurally lower portions of the Rainbow Member were included in the Midas Formation of Sutherland Brown and subsequently in the Hardscrabble Mountain Succession of Struik [14] [15].

The area is underlain by the Baker, Rainbow, BC, Lowhee and Basal Units. The Baker and upper Rainbow Units are part of Struik's Downey Succession and the lower Rainbow, BC, Lowhee and Basal Units, comprise part of the Hardscrabble Mountain Succession. It should be noted that the Rainbow Member of Hanson includes the Rainbow and BC Units of Rhys, and the BC Unit does not correspond to the BC or Basal Argillite Member of Hanson [14].

Structure in the district is briefly discussed as follows:

Deformation and folding: at least three phases of folding and fabric development occur in the region and are responsible for the major regional map patterns. The early deformation event records significant, ductile penetrative shortening. Deformation 2 is associated with a spaced to penetrative northeast-dipping foliation. The youngest deformation results in spaced, northwest trending, and steeply dipping crenulation cleavage in the area.

Faults: faults and shear zones developed in the area are of several generations and orientations. These include:

North trending faults: moderate to steep east-dipping faults; for example, No. 1, Rainbow, Sanders, Lowhee, Goldfinch, Waoming and Marie Faults (Figure 3).

Strike faults: northwest-trending, and moderate to steep northeast-dipping (45° - 80°) set of faults; probably the oldest set of faults in the area; one of the most important strike faults in the study area is the BC Fault Zone, localized mainly in the BC Argillite Unit and occupied by the BC quartz vein (Figure 3).

4. Deposit Types and Mineralization

4.1. Deposit Types

There are two principal types of gold deposits in the district; namely, quartz vein and pyrite replacement styles of gold.

4.1.1. Quartz Veins

Based on orientation, four types of quartz veins have been recognized in the district [12]:

Transverse (orthogonal) veins: describing the orientation of vein set with respect to compositional layering of strata. They typically strike northeast at 30° - 40° with sub-vertical to steep southeast dips. The most abundant type regionally, these are generally small quartz extension veins with strike lengths of 2 - 15 feet. Larger transverse veins are present in ore zones at the former CGQ, and other locations in the district. At the CGQ these veins made up 60% - 70% of the quartz ore.

Diagonal (oblique) veins: these veins typically strikes north 70° - 90° east, vertical or north dipping in orientation at the CGQ, and steep south dipping at the IGM. Veins of this type are sinistral shear veins that generally have longer strike lengths than transverse veins. These veins are few in number but larger than the transverse veins. At the IGM only diagonal veins were mineable.

Strike veins: the earliest of the veins, strike parallel to northwest trending bedding and parallel/subparallel to S2 foliation, and dip 45 - 70 to the northeast, generally more steeply than bedding. Although not abundant, these are the most prominent and longest veins in the district, forming resistant outcrops which were the focus of early lode gold prospecting and mining in the area. Veins of this type, which include the BC, Canusa and Black Bull veins (Figure 2 & 3), are generally erratically gold bearing and only limited production has been obtained from them.

Northerly veins: veins of this type were described in Frederick William Nielson's report in 2000. Northerly veins strike NNE and occur within faults. They commonly exhibit crushed zones and are difficult to mine.

Transverse and diagonal veins together were called "B veins", while strike veins called "A veins", by Hanson and Uglow. "A veins" were thought to form early as tension crack infillings [14].

In the IGM, the diagonal veins are regularly spaced at intervals of approximately 30 m. The diagonal and orthogonal veins are the most important types for vein-hosted gold mineralizatio. Both orthogonal and diagonal veins were mined in the CGQ but diagonal veins only were mined at Island Mountain. Hall (1999a) notes that the northerly and diagonal veins are a conjugate set possibly occupying brittle shear zones. Robert and Taylor suggest that the northerly, diagonal and orthogonal veins are "broadly contemporaneous and formed progressively during continued deformation (mostly along L2) related to the F2 folding."[14]

Individual veins are arranged en echelon due to minor displacements across cleavages and flat faults in less competent beds and showed better continuity down dip than along strike. Stopes developed on the quartz veins averaged 0.9 - 1.8 m (3.0 - 6.0 feet) in width, 30 – 38 m (100 - 125 feet) in length and about 30 m (100 feet) on the dip of the veins (Hall, 1999a &1999b).

The gold-bearing pyrite-quartz veins typically occur in siliceous turbiditic rocks of the Rainbow Unit generally within 100 m of its contact with the structurally overlying but stratigraphically lower Baker Unit. Many transverse veins and some stringers off the ends of diagonal veins extend short distances into Baker Unit. The more common type of transverse veins either cut straight through the diagonal veins or extends straight out from either wall. All the transverse veins are essentially straight, and either branch off diagonal veins or go straight through them [7].

Graphitic gouge typically occurs along contacts of the large veins with the host rocks. One good example is BC Vein within BC Fault Zone. Proximity to north striking fault zones, density of quartz veining and pyrite content prove to be important guides to ore within the Rainbow Unit [14].

The Rainbow and Sanders Zones provided the bulk of pre-war production; largely from complex and relatively wide quartz structures in the Rainbow Unit, tending to occur within and adjacent to the fault zones on Cow Mountain.

4.1.2. Pyrite Replacement Ore Bodies

There exist two different types of pyrite replacement ore bodies in the district. One occurs mainly in limestones of Baker and Rainbow Units, and the other in clastic rocks of mainly Lowhee 1 Sub-unit (Figure 2 & 3)

Pyrite replacement in limestone: ore of this type was historically mined by Aurum, Island Mountain and Mosquito Creek Gold Mines and occurs within limestones of the Baker and Rainbow Units. The ore bodies occur in the form of pipes or pencil-like ore shoots which have the attitude of the regional structure, plunging about N45W at an angle of 22 degrees. Ore consists of fine-grained massive pyrite. Most of the ore has been mined from the footwall part of the Baker Unit within 15 m (50 feet) horizontally of its contact with the Rainbow Unit. A good deal of this ore has been found only a few feet from the contact. Small amounts of ore have also been mined from the Johns Limestone and the 309 Limestone of the Rainbow Unit at Island Mountain.

Pyrite replacement in clastic rocks: prospecting for auriferous pyrite replacement ore had been focused on the metamorphosed limestones of the Baker and Rainbow Units until the Bonanza Ledge gold deposit was discovered in clastic rocks of Lowhee 1 Sub-unit, approximately 300 m stratigraphically above (structurally below) the Baker/Rainbow contact on the Barkerville Mountain in March of 2000. This discovery provides explorationists with a challenge to find additional, potentially economic, pyrite replacement mineralization in a new stratigraphic horizon. Bonanza Ledge style gold mineralization was mainly confined to the Lowhee 1 Sub-unit in the footwall of the BC Vein/BC Fault Zone. Mineralization within the Bonanza Ledge Zone, comprising high grade auriferous pyrite, occurs in a semi-concordant zone of northwest-trending, northeast dipping sericite-carbonate and pyrite alteration that is up to 76 m (250 feet) thick [14].

Both of the two types of replacement mineralization have very simple and similar sulphide assemblages; that is, dominant pyrite with minor pyrrhotite, chalcopyrite, galena and/or very slight traces of sphalerite. Interestingly, the size of the Bonanza Ledge replacement-style ore body in clastic rocks, is much larger than those of the Island Mountain or Mosquito Creek style in limestones.

4.2. Mineralization

There are two major kinds of mineralization in the area; that is, pyrite replacement and quartz vein styles of gold mineralization.

Struik concluded that lode gold concentrations as auriferous replacement pyrite in limestone are located in the hinge zones, and less commonly along the limbs of regional and minor folds. Gold-bearing quartz veins cross-cut, and therefore are assumed to be younger than the regional folds. Examples are common of vein and replacement gold mineralization of the same age and of replacements located in the paths of quartz veins. The auriferous replacement pyrite is therefore considered to have formed after the regional folds which control the distribution of replacement ore [7].

5. Conclusion

Based on the deposit types and mineralization styles discussed above, the metallogenic series in the district are summarized in Table 1 as follows:

Table 1. *Metallogenic series of gold deposits in the district.*

Metallogenic Series	Sub Metallogenic Series	Example Gold Mines
Pyrite replacement series	Limestone series	Island and Cow Mountains
	Clastic rock series	Bonanza Ledge on Barkerville Mountain
Quartz vein/venlet series	Strike vein	BC Vein on Barkerville Mountain
	Diagonal vein	Cow and Barkerville Mountains
	Orthogonal vein	Island, Cow and Barkerville Mountains
	Quart veinlet	Island, Cow and Barkerville Mountains

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