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CORDILLERAN SECTION

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STRUCTURAL ENVIRONMENT AND GOLD IN THE CANADIAN CORDILLERA

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STRUCTURE AND MINERALIZATION AT THE MOSQUITO CREEK GOLD MINE CARIBOO DISTRICT, B. C.

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INTRODUCTION

The Mosquito Creek (MC), Island Mountain (IM) and Cariboo Gold Quartz (CGQ) mines exploit a large gold deposit in the Wells-Barkerville area, east-central British Columbia (Fig. 1). The area occurs within the Barkerville Terrane, composed dominantly of clastic sedimentary rocks (Struik, 1988). These three mines have produced ~40 tonnes of Au (1.3 million ounces) from quartz-pyrite veins and from pyritic lenses in limestone (so-called "replacement orebodies"). Typical grade of quartz-pyrite vein orebodies is on the order of 12 g/t, and that of pyritic orebodies on the order of 20 g/t; pyritic orebodies are currently the main exploration target at MC.

Gold deposits along the Cariboo Gold Belt possess some geological attributes typical of "mesothermal" gold deposits, such as Au:Ag ratio of 8.5:1, host rocks metamorphosed to greenschist grade, and the presence of diagnostic hydrothermal minerals such as scheelite. However, they differ from typical mesothermal deposits by their occurrence in a dominantly sedimentary environment and by the lack of spatial association with major faults or recognized shear zones (Fig. 1).

As will be documented below, both stratigraphy and structure are important controls of gold mineralization along the Cariboo Gold Belt, and a knowledge of the local and regional structure is essential to understand and predict the distribution of favourable lithologies. This document presents results of a preliminary structural analysis at MC, combining structural information on IM and CGQ available in the literature.

GEOLOGY

The geology, stratigraphy and structure of the Wells-Barkerville area are complex. This is reflected by the diversity of stratigraphic and structural interpretations proposed by the different geologists who have worked in the area (See for example Hanson, 1935; Sutherland Brown, 1957; and Struik, 1988). The rocks of the area are dominated by micaceous quartzites and phyllites, with minor proportions of limestone and mafic volcanic rocks. The rock units are parallel to the regional NW-SE structural trend, and are metamorphosed to greenschist facies.

At the scale of the MC, IM and CGQ deposits, gold mineralization is distributed along the stratigraphic contact between the pale quartzite, phyllite, minor limestone and mafic volcanics of the "Baker Member" to the NE, and the dark quartzite and phyllite of the "Rainbow Member" to the SE (Fig. 2). This stratigraphic nomenclature, proposed

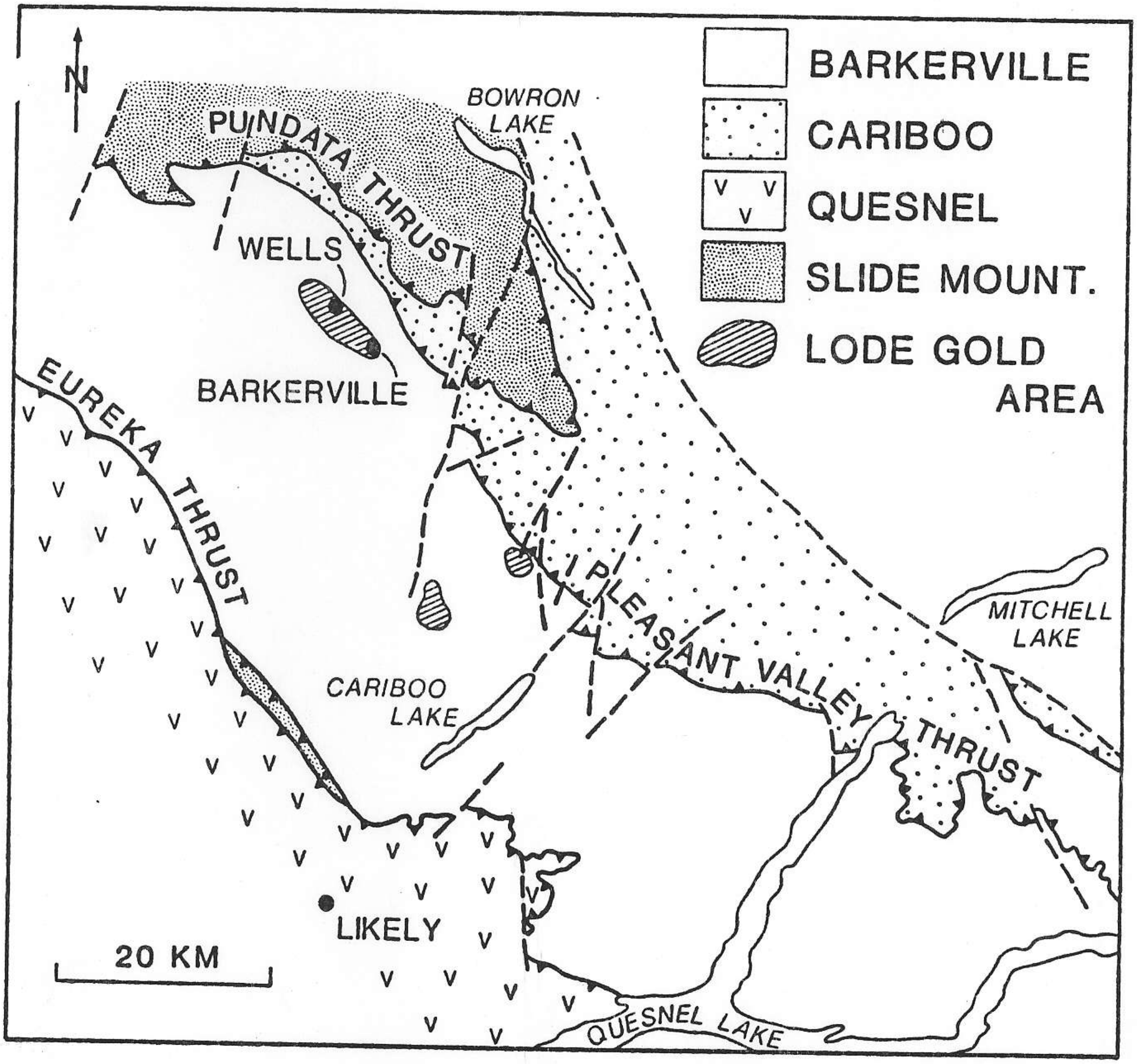


Figure 1 : General location map of the Wells area, showing the Barkerville and surrounding terranes, as well as major faults; modified from Struik (1988).

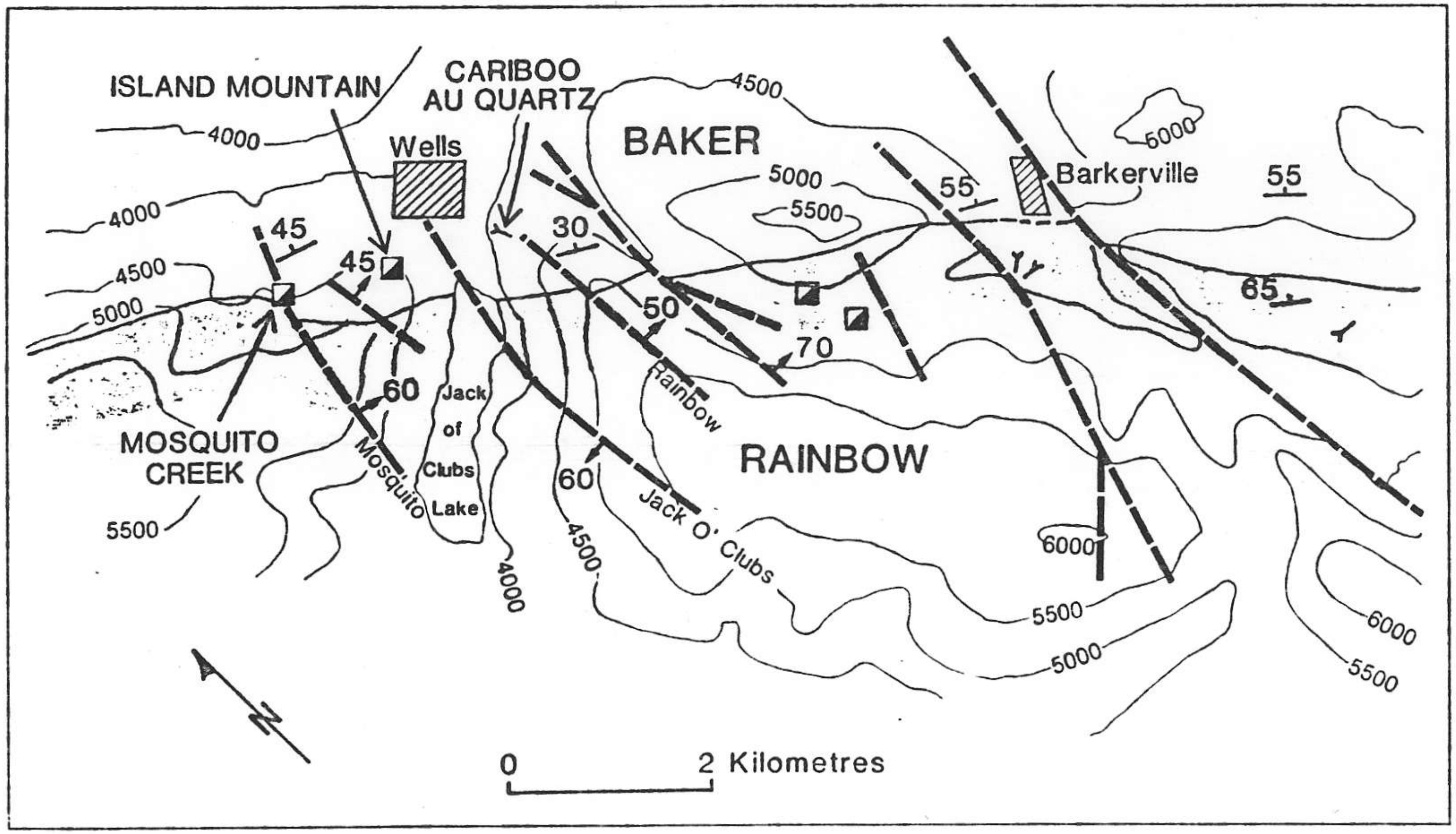


Figure 2: Simplified geological map of the Wells-Barkerville area, showing the location of the Mosquito Creek, Island Mountain and Cariboo Gold Quartz mines along the contact between the Baker and Rainbow "members", defining the northern segment of the Cariboo Gold Belt; modified from Campbell. (1966).

by Hanson (1935) and followed in the mines, is simple and practical; it will be adopted in this document. The Baker member and the NE portion of the Rainbow member correspond to the Snowshoe Fm of Sutherland Brown (1957; also Downey succession of Struik, 1988); the SW portion of the Rainbow member corresponds to the Midas Fm (also the Hardsrabble Mountain succession of Struik, 1988).

In the mines, the Baker-Rainbow contact is characterized by the proximity of a discontinuous marker limestone bed, the Aurum limestone (also designated the 339 limestone or the Baker limestone; Figs. 3, 4, 5). Other marker limestone beds are also present; of particular importance is the Main Band limestone, NE of the Baker-Rainbow contact which, at MC, is mineralized and converges at a small angle toward the Baker-Rainbow contact (Figs. 3 and 5).

The rocks of the Baker and Rainbow members strike NW-SE, and generally dip 30-60° to the NE; local graded beds in the quartzite suggest that the sequence is overturned (Figs. 5 and 7a). The rocks are folded by asymmetric, Z-shaped folds with shallow NE-dipping axial planes and with hinges plunging 20° to the NW. On the basis of these asymmetric folds, the rocks of the Baker and Rainbow members at MC, IM and CGQ have generally been regarded as lying on the SW limb of an overturned anticline (Fig. 8; Benedict, 1945; Sutherland Brown, 1957).

A number of faults striking N-S and dipping 40-70 to the E dextrally offset the Baker-Rainbow contact (Fig. 2). These faults postdate the folding of the rocks and have an important component of normal displacement (Benedict, 1945).

A stratigraphio control of the mineralization is reflected in the distribution of the two types of ore at MC, IM and CGQ mines: quartz-pyrite veins are almost exclusively restricted to the Rainbow rocks, within -100 m from the Rainbow-Baker contact, and the pyritic orebodies occur in limestone bands in the Baker rocks (Figs. 3 and 4). At IM and CGQ mines, pyritic mineralization is restricted to the Aurum limestone band along the Baker-Rainbow contact. At MC, most of the pyritic mineralization occurs along the Main Band limestone (Figs. 5 and 6).

STRUCTURAL ANALYSIS AT MC

The structural history at MC is complex, and its understanding is essential to the search of favourable "horizons" and of orebodies within them, and to the formulation of adequate genetic models. Generally, most of the rocks at MC display low to moderate strain and primary features such as bedding are easily recognized. One important exception is the Main Band limestone and the immediately adjacent rocks (Fig. 5), in which high strains are indicated by a discontinuous layering and by folded and boudinaged veinlets (Fig. 7b).

Three foliations/cleavages have been distinguished on the basis of their nature and their cross-cutting relationships. The earliest recognized foliation, S_1, corresponds to the (tectonic ?) layering in the Main Band limestone and adjacent rocks, about which calcite veinlets

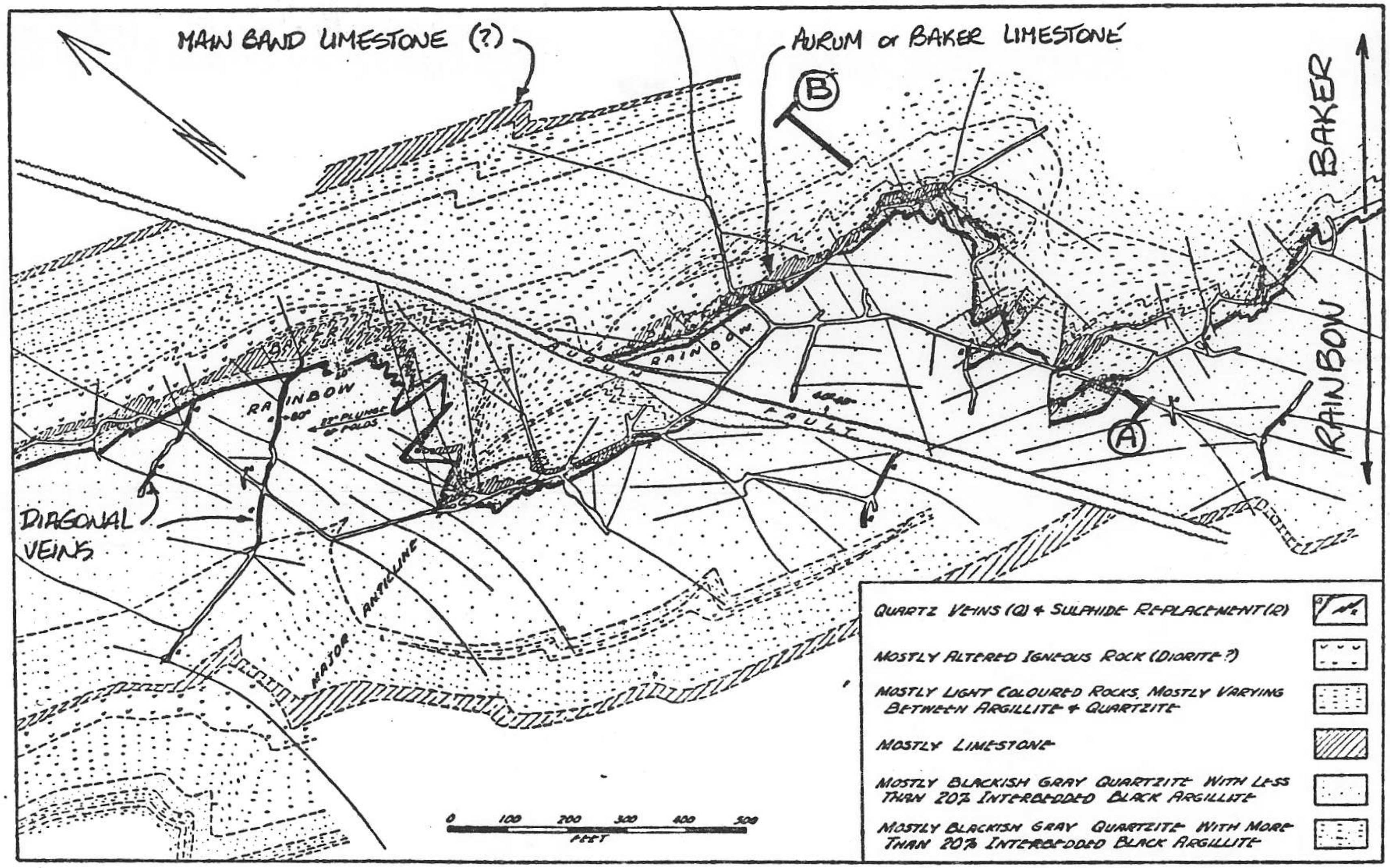


Figure 3: Generalized geological plan of 3500-foot level of the Island Mountain mine; the approximate position of X-section on Figure 4 is indicated; from Benedict (1945).

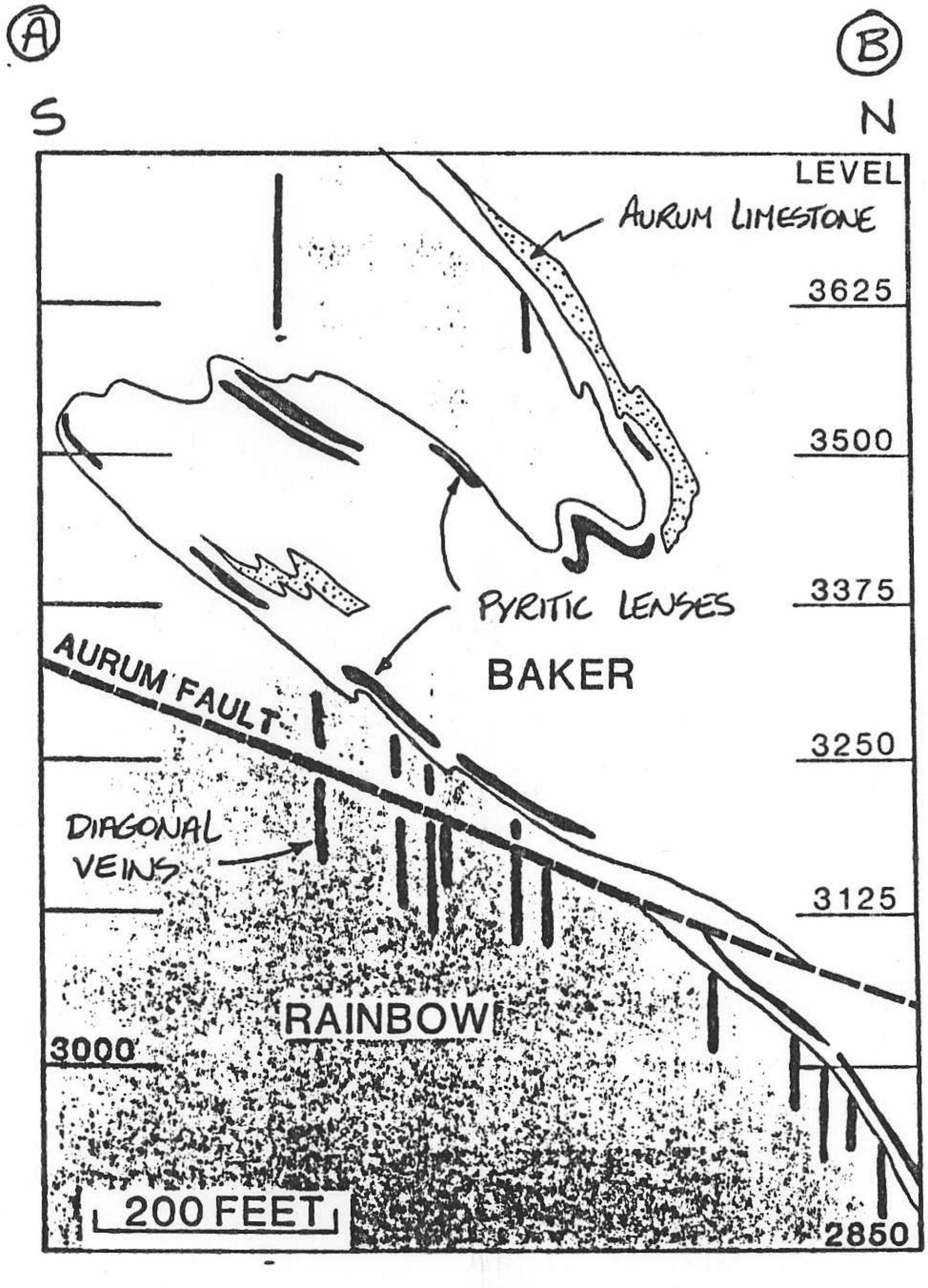


Figure 4: Generalized cross-section through Island Mountain mine, showing the relative distribution of pyritic lenses and diagonal quartz-pyrite veins; modified from Campbell (1966).

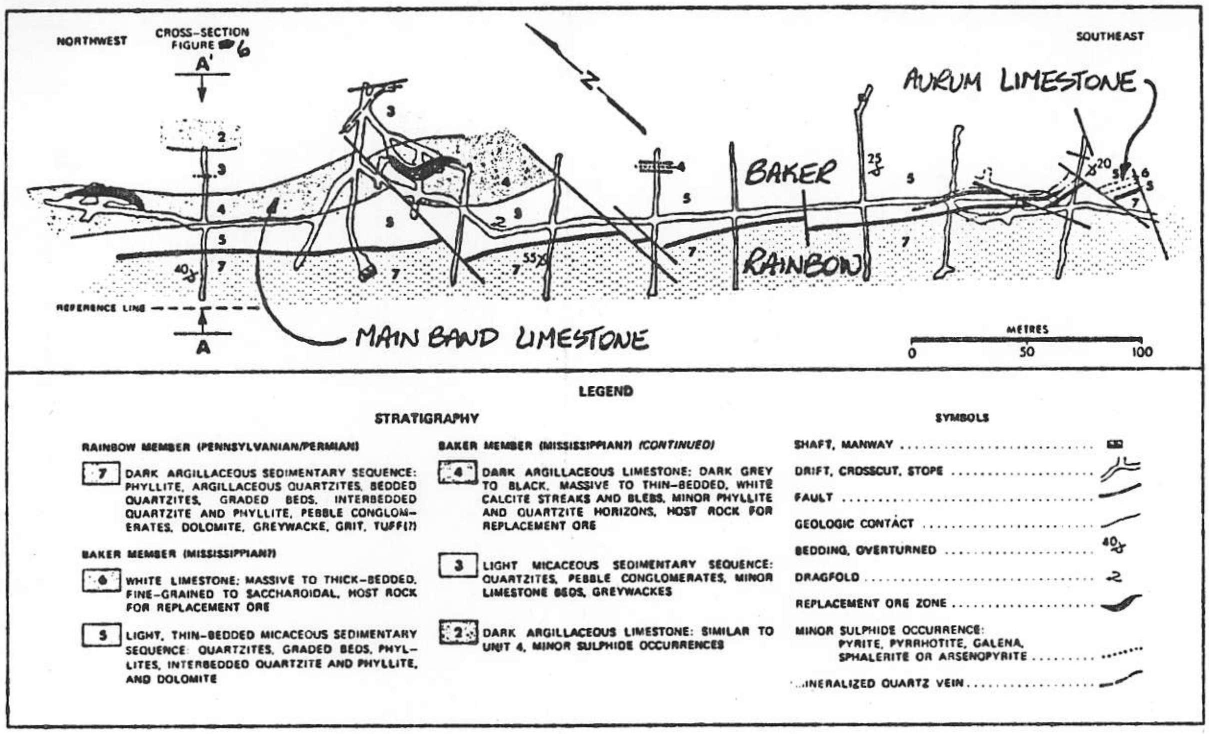


Figure 5: Simplified geology of level 2, Mosquito Creek gold mine; from Alldrick (1983)

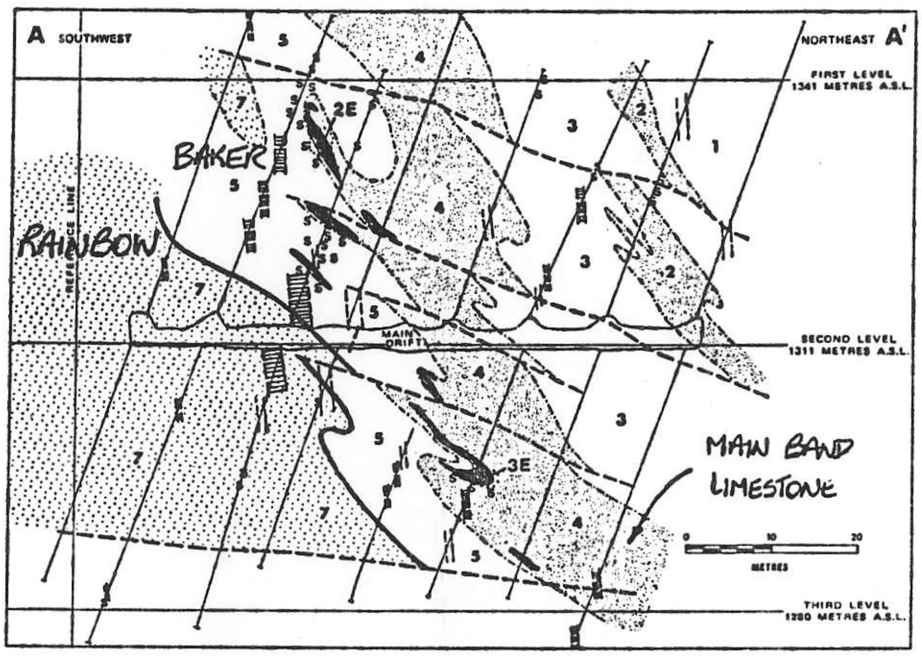


Figure 6: Simplified cross-section between levels 1 and 3, Mosquito Creek gold mine; from Alldrick (1983).

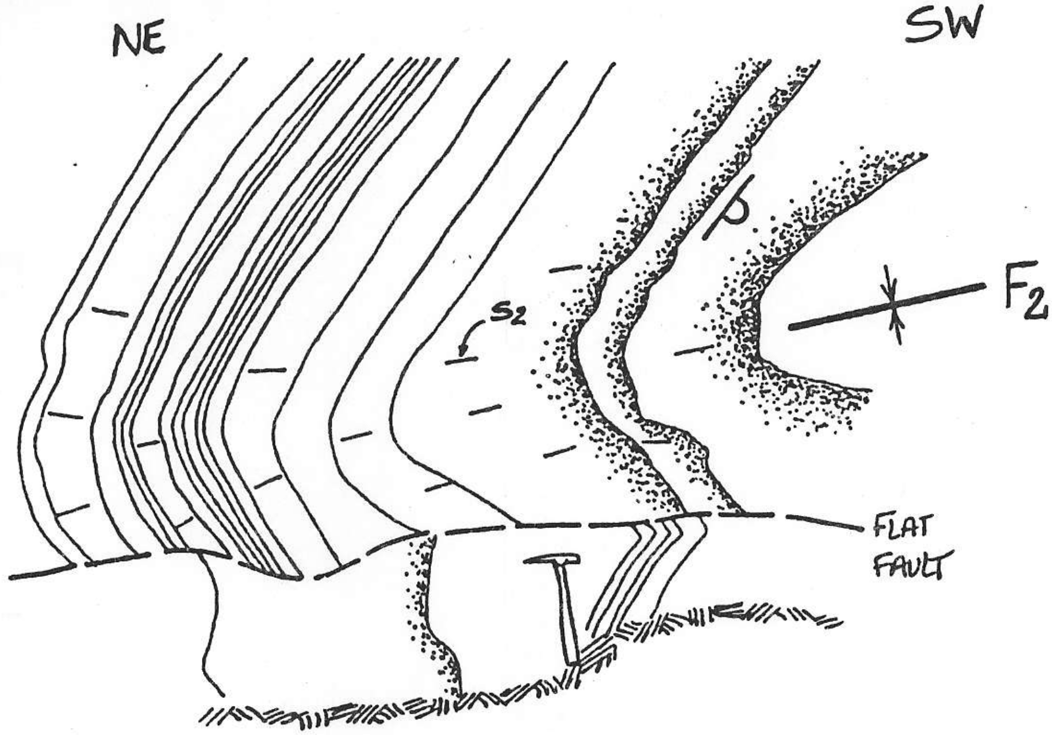


Figure 7a: Cross-section of folded quartzite beds of Baker member at MC; the short limb of the asymmetric fold has been faulted off; note the overturned beds on the NE-dipping long limb of the fold. Sketched from a slide.

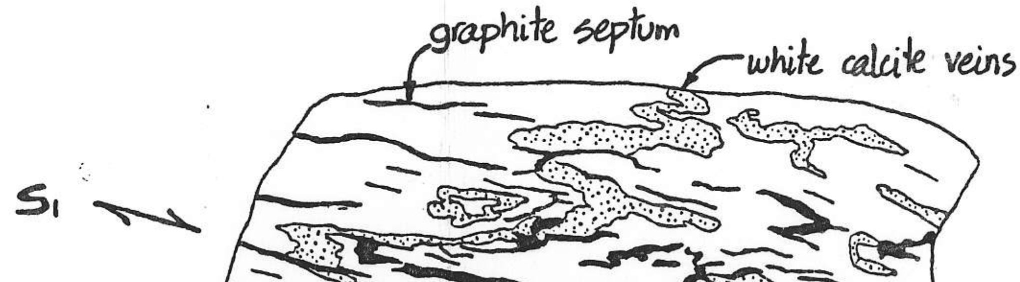


Figure 7b: Typical sample of deformed Main Band limestone at MC; S1 is defined by the graphitic septa; note the folded and boudinaged calcite veins. Sample cut perpendicular to L2

are disrupted and folded (Fig. 7b). S_1 is approximately parallel to the limestone unit; it strikes NW-SE and dips moderately to the NE (Fig. 9a). The presence of high internal strain, and the folding and boudinage of veinlets associated with S_1 suggest that the Main Band limestone could have acted as a slip surface. Such slip could be related to either folding or faulting.

Another early foliation is commonly present in low strain rocks at MC. It is parallel to bedding and corresponds to a parting in the coarser grained quartzites and to alignment of phyllosilicates in the phyllites. This early foliation is designated S_1(?) because it is not known at present if it is related to S_1 in the Main Band limestone. Bedding/cleavage relationships and possible opposing facing directions suggest the presence of previously unrecognized F_1(?) folds (Fig. 10).

The second foliation, S_2, is variably developed and range from a spaced cleavage to a continuous, penetrative cleavage, locally associated with intense transposition of bedding and S_1 layering (see below). S_2 strikes E-W and dips ~22° to the N (Fig. 8b); it is axial planar to asymmetric, consistently Z-shaped F_2 folds (Fig. 7a). F_2 folds plunge at ~20° to the NW and range from open to tight. S_2 contains a strong elongation lineation, L_2, which plunges at ~20° to the NW (Fig. 9b), and which is parallel to F_2 fold axes and to $L_{0/2}$ and $L_{1/2}$ intersection lineations. As shown in Figure 9a, the poles of bedding and of S_1 (in Main Band limestone) fall along a great circle whose pole coincides with L_2 and the plunge of fold axes.

A third, generally weakly developed foliation, S_3, strikes NW-SE and is subvertical (Fig. 10). It is related to a broad open anticlinorium to the west (see Struik, 1988) and has no effect on the distribution of lithologies at the mine scale.

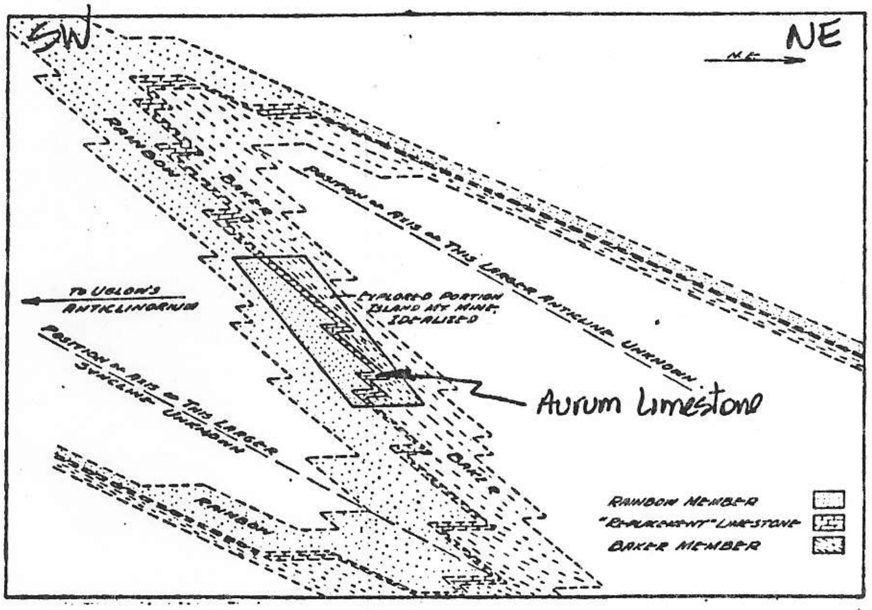
In addition to the northerly striking faults described in the previous section, there are abundant late NE-SW striking faults with shallow dips to the NW. These faults have a normal component of displacement, with offsets on the order of several metres.

MINERALIZATION

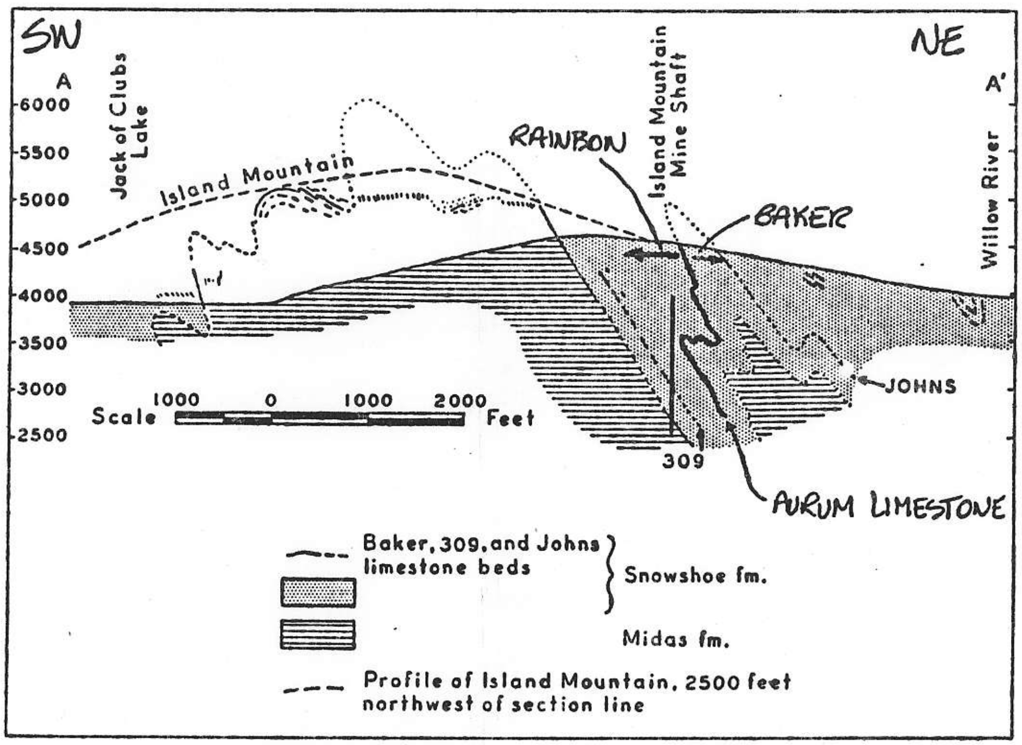
As indicated above, the two sources of ore at MC, IM and CGQ were quartz-pyrite veins and pyritic lenses in limestone. These have been previously described in detail (see Johnston and Uglow, 1926; Hanson, 1935; Benedict, 1945; Skerl, 1948; Richards, 1948; Sutherland Brown, 1957), and only the most significant points and some new observations are reported here.

Quartz-pyrite veins

Four main types of mineralized quartz-pyrite veins are present at CGQ, IM and MC: strike, northerly, diagonal and orthogonal veins. If all these types of veins have been exploited, only the diagonal and orthogonal veins contributed significant tonnage of ore. The distribution of the northerly, diagonal and orthogonal veins is stratigraphically controlled: they all occur in the rocks of the Rainbow

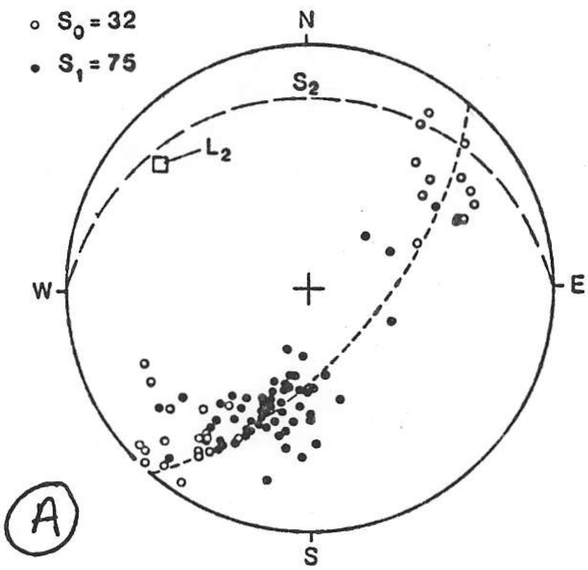


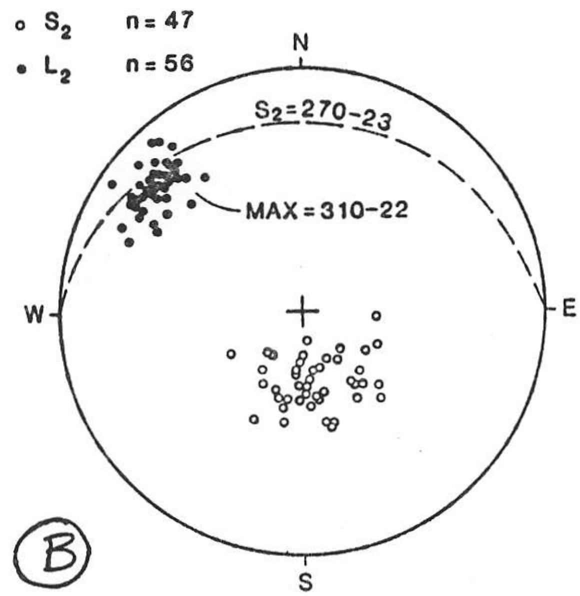
from Benedict (1945)



from Sutherland Brown (1957)

Figure 8: Two proposed cross-sections through Island Mountain mine, showing the position of the mine workings on the SW limb of an overturned anticline





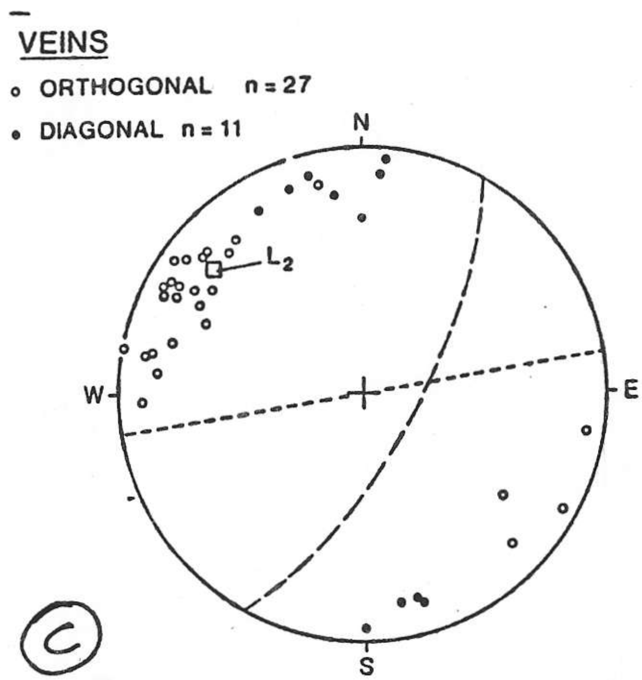


Figure 9 : Structural data at from Mosquito Creek

A- Poles of S_0 and S_1 (in Main Band limestone)

B- Poles of S_2 and L_2 (includes fold hinges, elongation and intersection lineations)

C- Poles of orthogonal and diagonal veins.

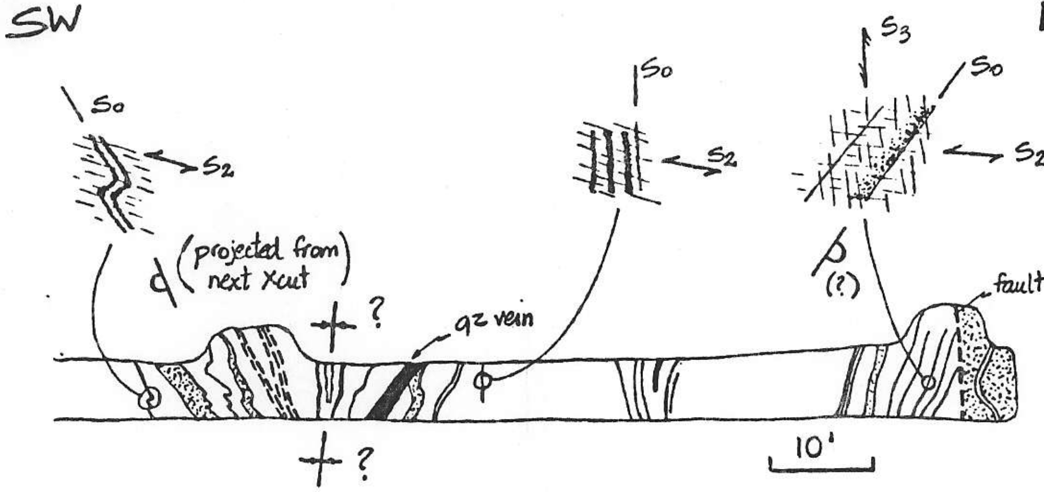


Figure 10: Bedding / cleavage relationships in a cross-cut in Baker member, level 3, Mosquito Creek. Opposite facing directions in graded beds suggest the presence of early (F1) folds.

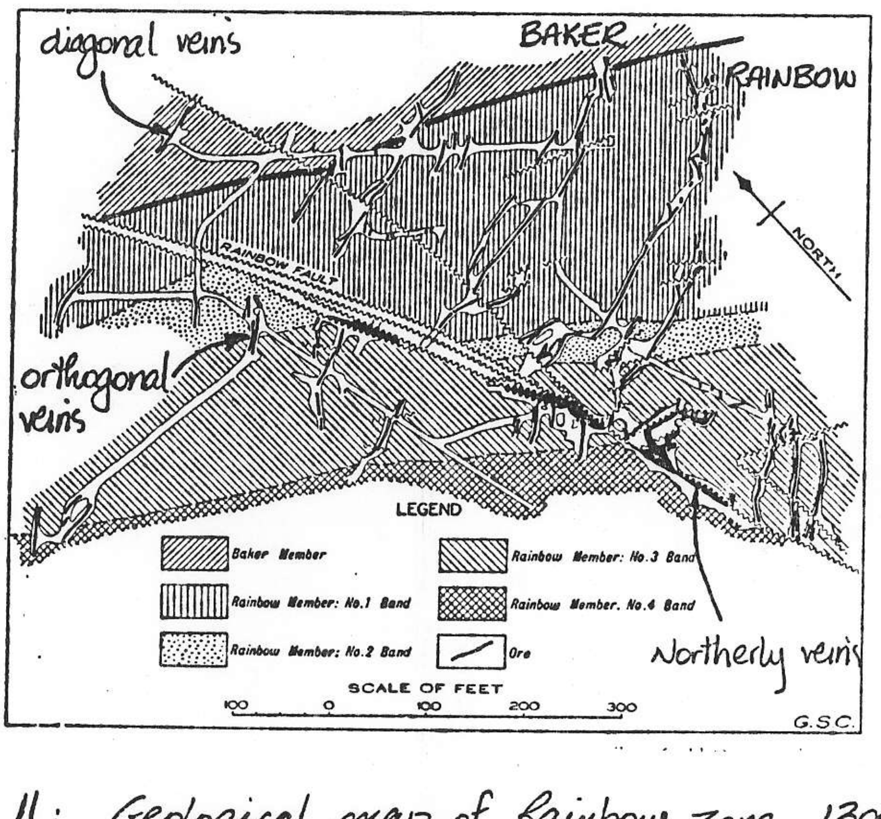


Figure 11: Geological map of Rainbow zone, 1300-foot level, Cariboo gold quartz mine, showing the different types of veins and their relations to major faults; from Richards (1948).

member, within ~100 m of the Rainbow-Baker contact (Figs. 3 and 4). Along this narrow stratigraphic interval, the diagonal and orthogonal veins are not evenly distributed: according to Richards (1948), they tend to be more abundant in the vicinity of the N-S faults (Fig. 11).

Strike veins are the earliest and the least common veins; they strike NW-SE, parallel to bedding, and dip more steeply than bedding, at 45-70° to the NE (Richards, 1948). These veins predate the northerly faults.

Northerly veins were only exploited at CGQ, where they occupy northerly faults, reaching a few tens of metres in length (Fig. 10a; Richards, 1948). These veins were clearly deposited in existing faults, but were locally crushed and brecciated by subsequent movements along the faults. Given that the northerly faults offset already folded (F_2) rocks, these northerly veins therefore postdate development of these folds.

Diagonal veins are relatively common; they are subvertical and strike 070-090° (Fig. 9c). Typical dimensions are on the order of 30-50 m horizontally and vertically, and up to a few metres thick. These veins postdate development of most of the S_2-L_2 fabric, as they locally include fragments of already foliated and lineated wallrocks. However, these veins have been subsequently slightly deformed: they are commonly buckled and slightly folded. The nature of the host fracture is not determined with confidence at this stage, but the lack of significant offset of markers by the veins, and the lack of foliation parallel to the vein walls suggest that the diagonal veins occupy essentially extensional veins.

Orthogonal veins are the most abundant type of vein; they are nearly perpendicular to L_2, strike 030-040° and dip 70° to the SE (Fig. 9c). At MC, they are typically several metres long and a few tens of centimetres thick, but reach length of ~30 m and thicknesses of 1 m. These veins clearly occupy extensional fractures, and have not been subsequently significantly deformed. They postdate development of S_2 and F_2 folds and represent an increment of extension in the direction of L_2. Orthogonal veins have locally been observed to crosscut diagonal veins at MC.

At IM and CGQ, Benedict (1945) and Skerl (1948) describe orthogonal veins that form splays off diagonal veins, and vice-versa, producing arrays of veins that were bulk mined. Such relationships indicate that the two types of veins in such cases are coeval. If the development of orthogonal and diagonal veins overlapped in time, local cross-cutting relationships and the minor deformation of diagonal veins indicate that the orthogonal veins are on average younger that the diagonal veins. The age of northerly veins relative to the orthogonal and diagonal veins is not as clear. However, the overall spatial association of the ddagonal veins with the the major northerly faults noted by Richards (1948) would suggest that all three types of veins are broadly contemporaneous and formed progressively during continued deformation (mostly extension along L_2) related to the F_2 folding.

Pyritic lenses

Pyritic lenses are the major source of ore at MC and IM. At IM and CGQ, pyritic lenses occur within or adjacent to the Aurum limestone, whereas at MC most of them occur close to the footwall and hangingwall of the Main Band limestone (Figs. 5 and 6). The pyrite orebodies tend to be commonly but not exclusively spatially associated with F_2 fold hinges. They range in shape from shallowly NW-plunging pipes parallel to L_2 where located in fold hinges, to tabular bodies where located on the long limbs of the folds (Fig. 4). Typical stope dimensions for orebodies in fold hinges are a few metres by a few metres in cross section, and up to a few hundred metres in the down plunge direction (Campbell, 1966).

The pyrite orebodies consist of individual or stacked lenses (layers) of massive to semi-massive pyrite, up to 50 cm thick (Fig. 12). The pyrite is generally fine grained, except on the fringes of the orebodies where it occurs as coarse porphyroblasts. The fine grained pyrite carries gold grades commonly in excess of 50 g/t, whereas the coarse, probably recrystallized, pyrite only carries a few g/t or less.

At MC, several complete or partial cross-sections through pyrite orebodies have been examined. In some cases, the pyrite layers or lenses are parallel to the strongly developed foliation (S_2) in the host limestone (Fig. 12a). The same foliation is also developed within the pyrite layers, suggesting that these layers predate foliation development. In other cases, such as shown in Figure 12b, pyrite layers are clearly parallel to the bedding, and both are transposed by S_2 and folded. In extreme cases of transposition of the sulphides by S_2, the layering becomes completely obliterated.

Pyrite lenses have generally been considered as the result of post-folding replacement of the limestone bands along F_2 fold hinges, where intersected by diagonal veins (Skerl, 1948; Alldrick, 1983). However, the above structural relations clearly indicate that the pyrite layers are at least locally parallel to bedding and have been folded and transposed by S_2. Furthermore, the model of replacement of the limestone where intersected by diagonal veins is not supported by the fact that most diagonal veins are restricted to the Rainbow member and that the mineralized limestone bands occur within the Baker member, with minimal spatial overlap between the two.

DISCUSSION

Several of the above preliminary observations at MC reported above may have significant implications for understanding the distribution of favourable limestone bands and for the genesis of the deposit, and hence for exploration.

For example, the fact that the pyrite lenses predate development of S_2 and associated F_2 folds raises the possibility that the pyrite layers, and probably some of the gold, are syn-sedimentary in origin, as initially suggested by Don Sutherland (Pers. Comm., 1987). Such an

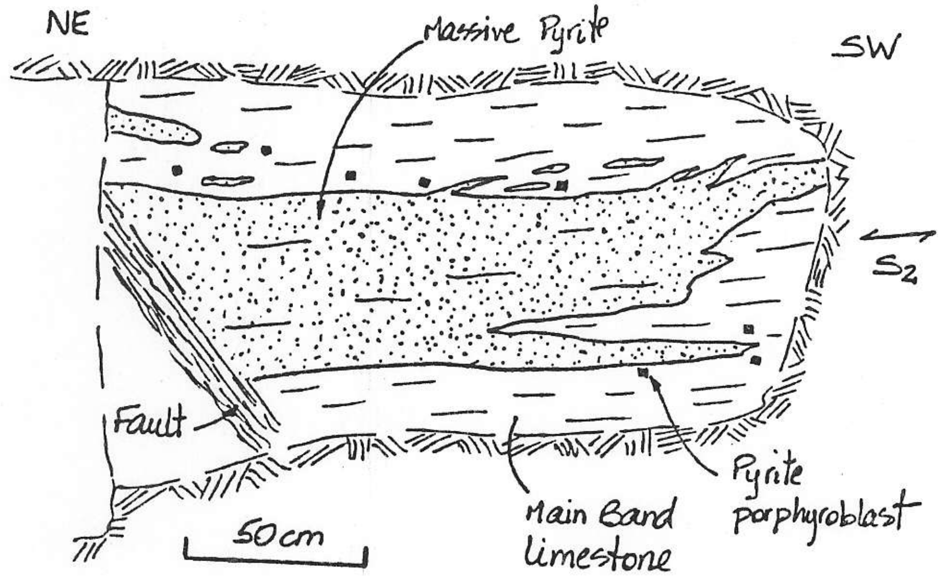


Figure 12a: Cross-section of typical pyrite layer in main Band limestone

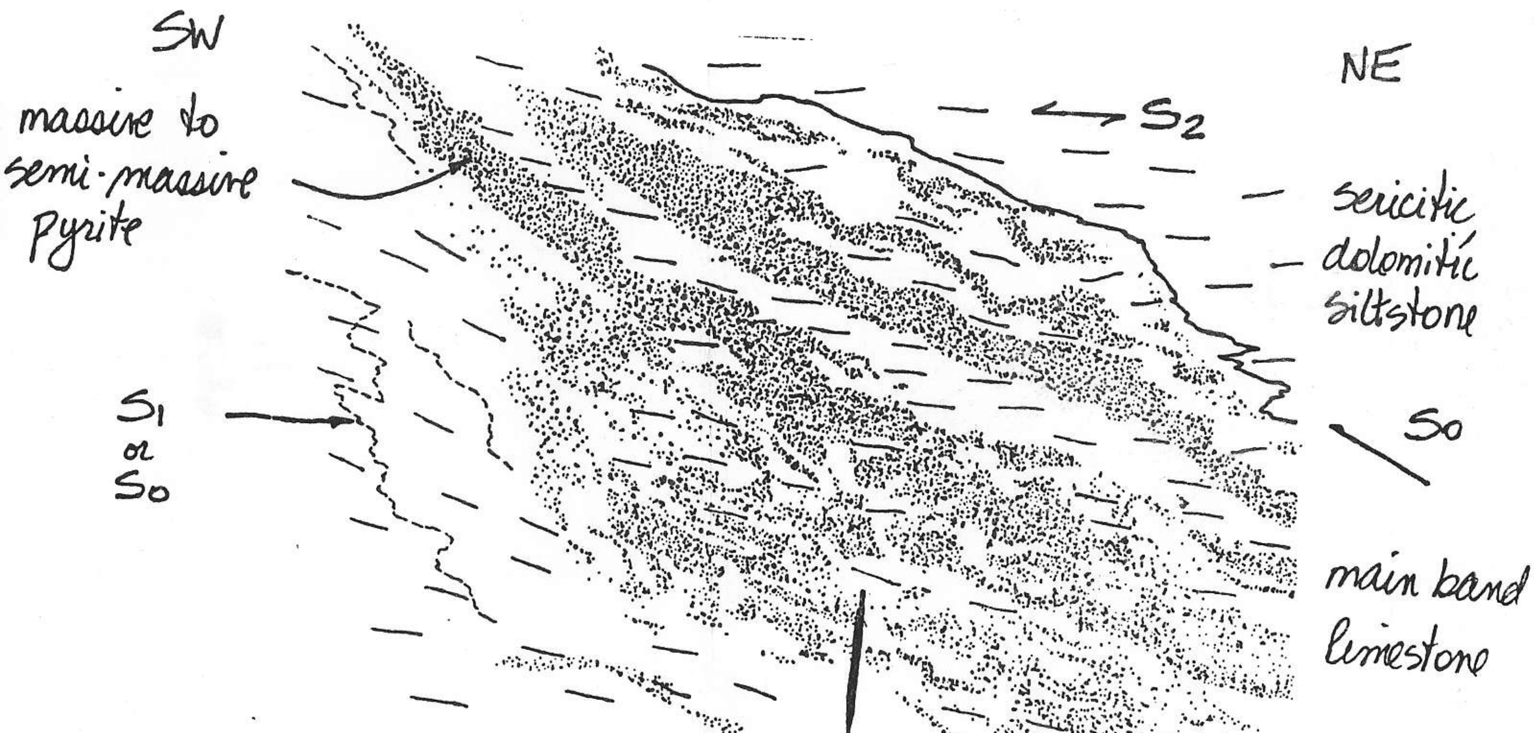


Figure 12b: Cross-section of pyrite layers, parallel to hangingwall contact of Main Band limestone, superimposed by S2.

interpretation would also be supported by the fact that the pyrite orebodies are not exclusively associated with fold hinges and can occur anywhere along the folds (see Fig. 4), and by the fact that when recrystallizing into coarse porphyroblasts, the pyrite is depleted of much of its gold.

Of great importance is the possibility that the Main Band limestone acted as a slip surface, either as a result of folding or of faulting. The low angle convergence of the Main Band limestone with the Aurum limestone at MC could indeed result from isoclinal folding. Given that both limestone bands are affected by F_2 of the same asymmetry, such fold would have to be an F_1 fold. This hypothesis would be supported by the possible presence of F_1 folds documented here (Fig. 10). Alternatively, the Main Band limestone may be the locus of a fault cutting the stratigraphy at low angle; such interpretation would be compatible with the high strain being restricted to the Main Band limestone and the immediately adjacent rocks. If this is the case, offset and repetition of favourable limestone bands will occur and documentation of the nature of such fault becomes of prime importance. Both scenarios open up the possibility that favourable limestone bands, Aurum or Main Band, can be repeated at the scale of the deposit, and that exploration should not be restricted to any one limestone band, as it was in the past.

It should be clear that the above hypotheses, if they are compatible with currently available data, remain to be tested by further detailed structural analysis in the mines and surrounding areas.

ACKNOWLEDGEMENTS

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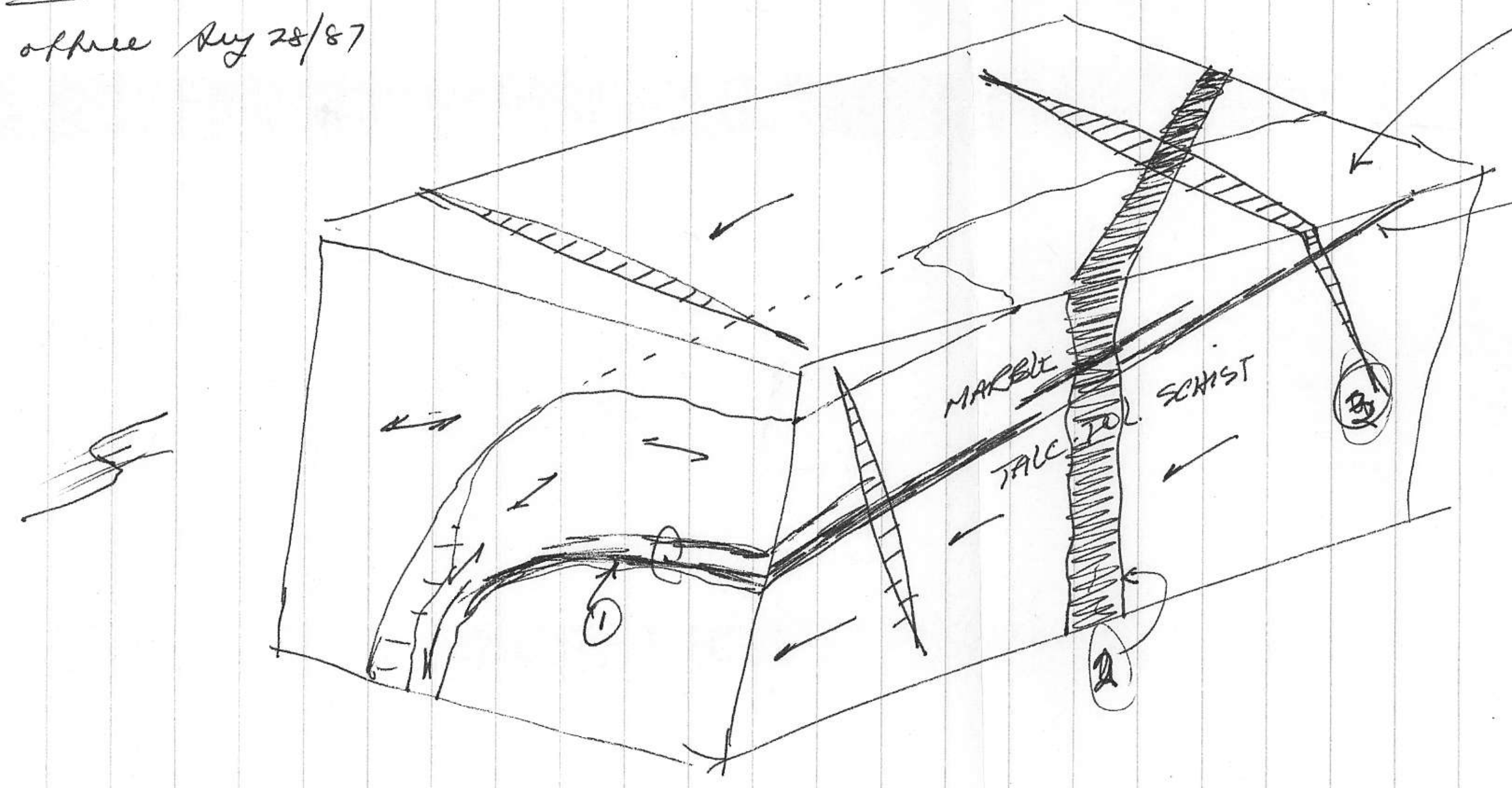
Francois Robert's
sketch of Mosquito Ck Au mine.

went to office Aug 28/87

marble host for replacement mineralization



main replacement lenses, cylindrical, at contact with talc-dolomite rock (?) metavolc. Syntectonic.
Cut by (2) stage 2 inclined veins + (3) tensional + veins — with basemetals + Au. No PbZn or repl. mineralogy.

Godwin dating Pb as mid Jur.
Sericite with veins is ~140 Ma (?) late Jurassic. – eK

Host is Mesozoic(?) or Late Paleozoic. Accretion of Quesnellia in early Jurassic

See also D Alldrick
Fieldwork 1982