



**THE MOSQUITO CREEK MINE, CARIBOO GOLD BELT
(93H/4)**

By D. J. Alldrick

INTRODUCTION

The underground mine of Mosquito Creek Gold Mining Company Limited is located in east-central British Columbia 2 kilometres west of the historic mining town of Wells at latitude 56 degrees 6 minutes north and longitude 121 degrees 36 minutes west. The Ministry initiated this field project in May, 1982 in response to the general revival of interest in precious metals in British Columbia and the renewed mining and exploration activity in the Wells area.

The specific objectives of the project are:

- (1) To document structural and stratigraphic controls of the mineralized zones and to identify potential marker horizons that could be useful in exploration programs.
- (2) To sample one representative ore zone and its host rocks for study of their petrographical and geochemical characteristics.
- (3) To collect samples for fossil and radiometric studies to determine the age of host rocks, metamorphism, and mineralization.

HISTORY AND PREVIOUS WORK

Prospectors discovered the first placer gold deposits in the region during the winter of 1860. Since then production has been virtually continuous. Several major placer operations were active during the 1982 season; many are reworking old placer leases with mechanized mining equipment which enables them to reach deeper Tertiary gravel beds that were inaccessible to early miners.

Hardrock mining started at the Cariboo Gold Quartz mine in 1933 and at Island Mountain mine in 1934. Apart from a four-year shutdown during the war, Cariboo Gold Quartz mine operated until 1959 and Island Mountain mine until 1967. The latest underground operation began in 1980 with the opening of the Mosquito Creek mine.

Sutherland Brown (1957, p. 10) reviewed the extensive early geological work in the region. Since that bulletin, major studies undertaken in the area include two unpublished summary reports by Campbell (1966, 1969), radiometric studies of precious metal deposits in the cordillera by Andrew (1982) and Andrew, Godwin, and Sinclair (this volume), and a continuing program of regional mapping by Struik of the Geological Survey of Canada (1980, 1981a, 1981b, 1982a, 1982b). Carlyle (in press)

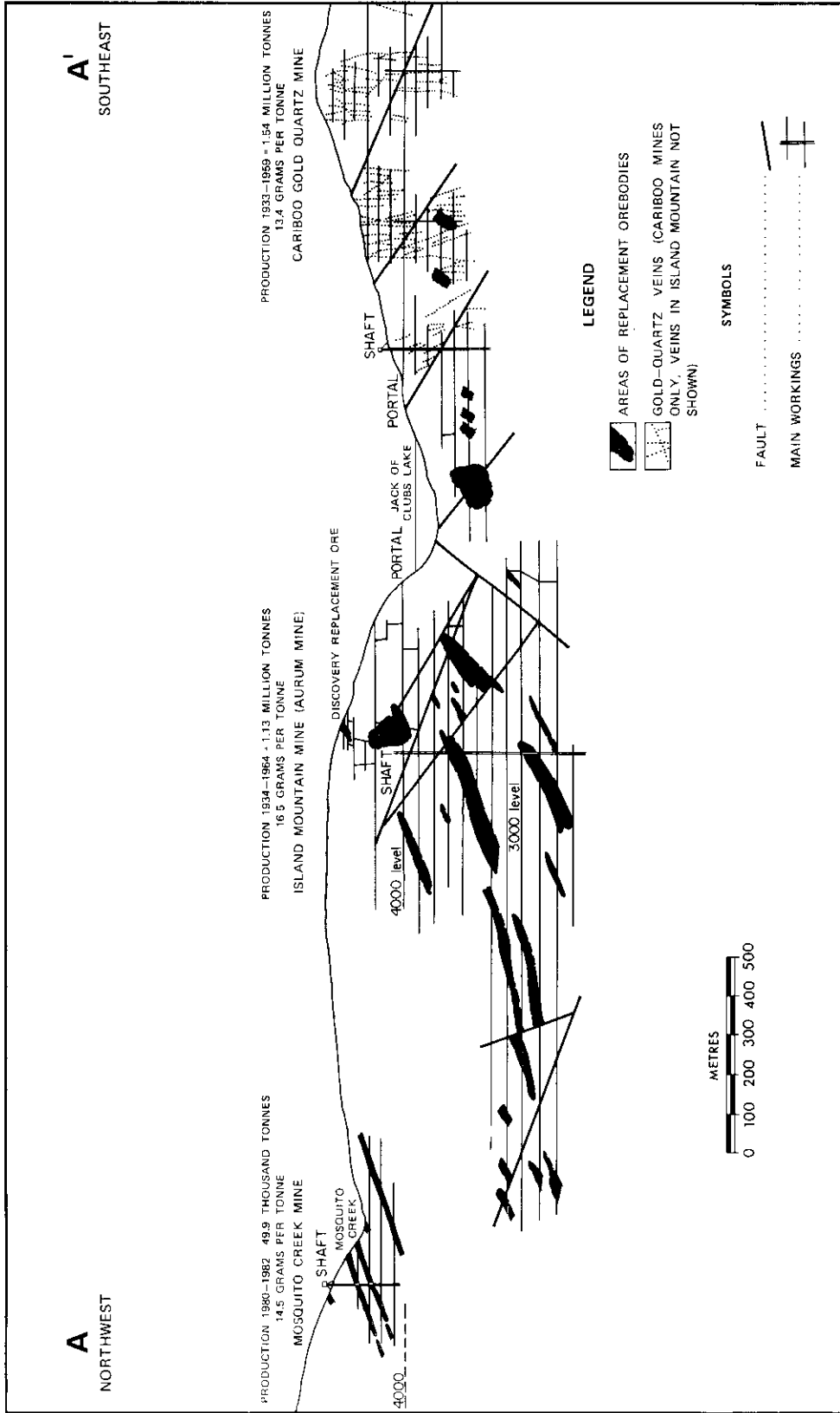


Figure 29. Longitudinal section. Projections of Mosquito Creek, Island Mountain, and Cariboo Gold Quartz mines (modified after Campbell, 1969).

produced a geological review of the Mosquito Creek mine for a field trip to the mine in May, 1983 before the annual GAC/MAC/CGU meeting in Victoria.

Sutherland Brown (1957) provides the most comprehensive description of mineral deposits in the region. For detailed information about the Mosquito Creek, Island Mountain, and Cariboo Gold Quartz mines, the reader is referred to Carlyle (in press), Benedict (1945), and Skerl (1948) respectively.

REGIONAL GEOLOGY

A simplified geological map of the Wells area is presented on Figure 28. The region is dominated by a thick, highly deformed sedimentary sequence of distinctive quartzites, conglomerates, grits, siltites, slates, phyllites, marbles, limestones, dolomites, amphibolites, and meta-tuff (?). From fossil studies Struik (1982b) ascribes an Upper Paleozoic age to the overall sequence. He assigned a Mississippian age to rocks of the Baker member in the Mosquito Creek mine based on an uncertain correlation of mine strata with a crinoidal limestone in the northwest corner of his map-area. Earlier, Struik (1981b) reported conodonts of Pennsylvanian to Lower Permian age from a bioclastic limestone bed in the Rainbow member.

The sedimentary sequence has been folded and regionally metamorphosed to greenschist facies. Small amounts of fine euhedral pyrite are disseminated through most of the rocks. Struik (1981a) inferred that the main folding event took place between Early Jurassic and Late Cretaceous time from stratigraphic and structural relationships throughout the region. Andrew (1982) obtained a Lower Jurassic (179 ± 8 Ma) whole rock K/Ar date for a sample of phyllite from the Cariboo Gold Quartz mine. It is interpreted to be a metamorphic date.

Regional folds trend northwesterly and are overturned toward the southwest, with dips ranging between 40 and 55 degrees northeast. An important feature of this folding is the rhythmic development of minor folds down the limbs of the main folds. In the mine area these drag folds plunge 21 degrees at north 40 degrees west to north 50 degrees west; they host the majority of the ore zones.

LOCAL GEOLOGY

Figures 29 through 32 illustrate geological relationships in the Mosquito Creek mine. In the mine workings only the upper part of the pale-coloured Mississippian (?) Baker member and the lower part of the dark-coloured Pennsylvanian to Lower Permian Rainbow member are exposed.

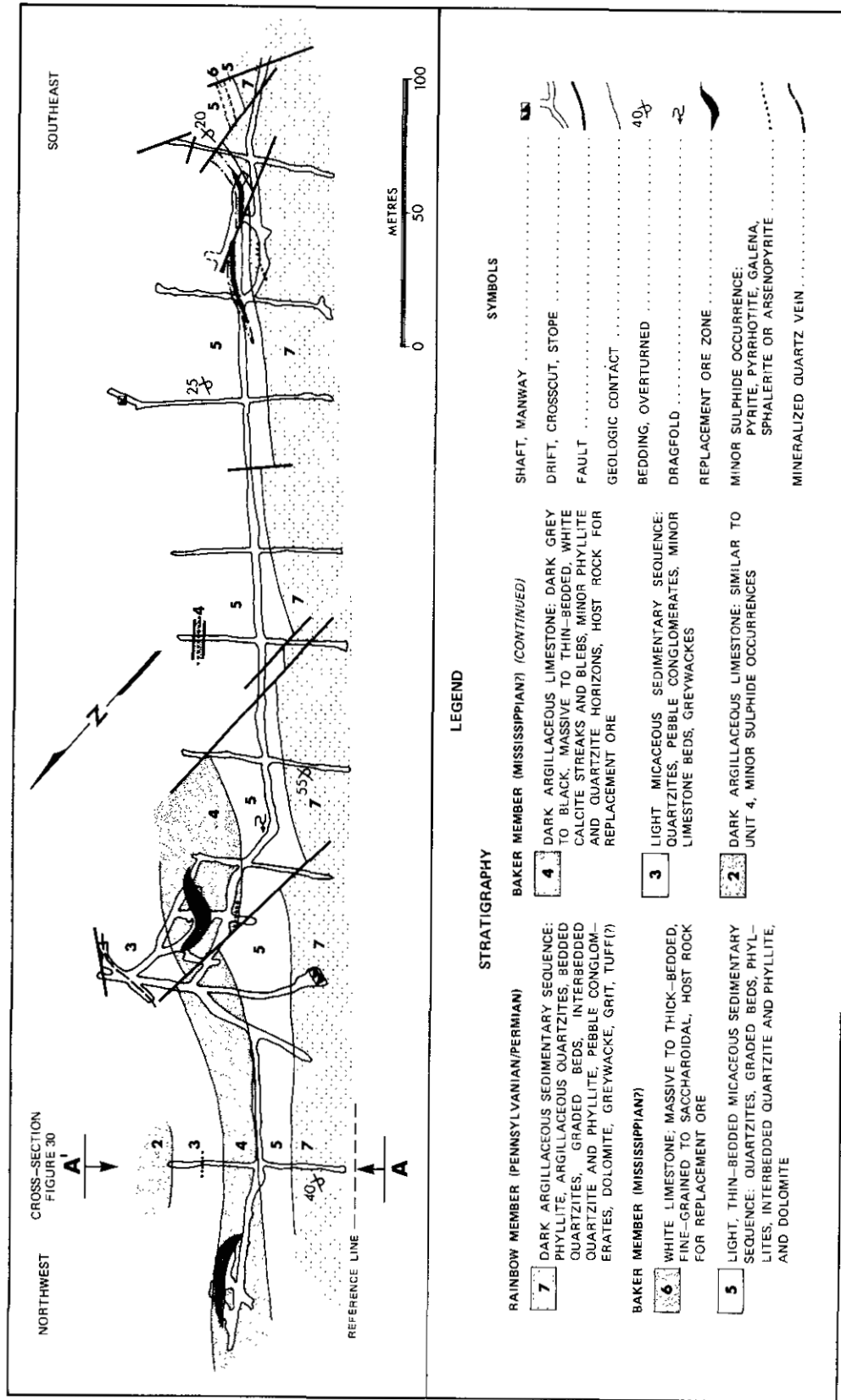


Figure 30. Geology of the No. 2 Level, Mosquito Creek Gold mine.

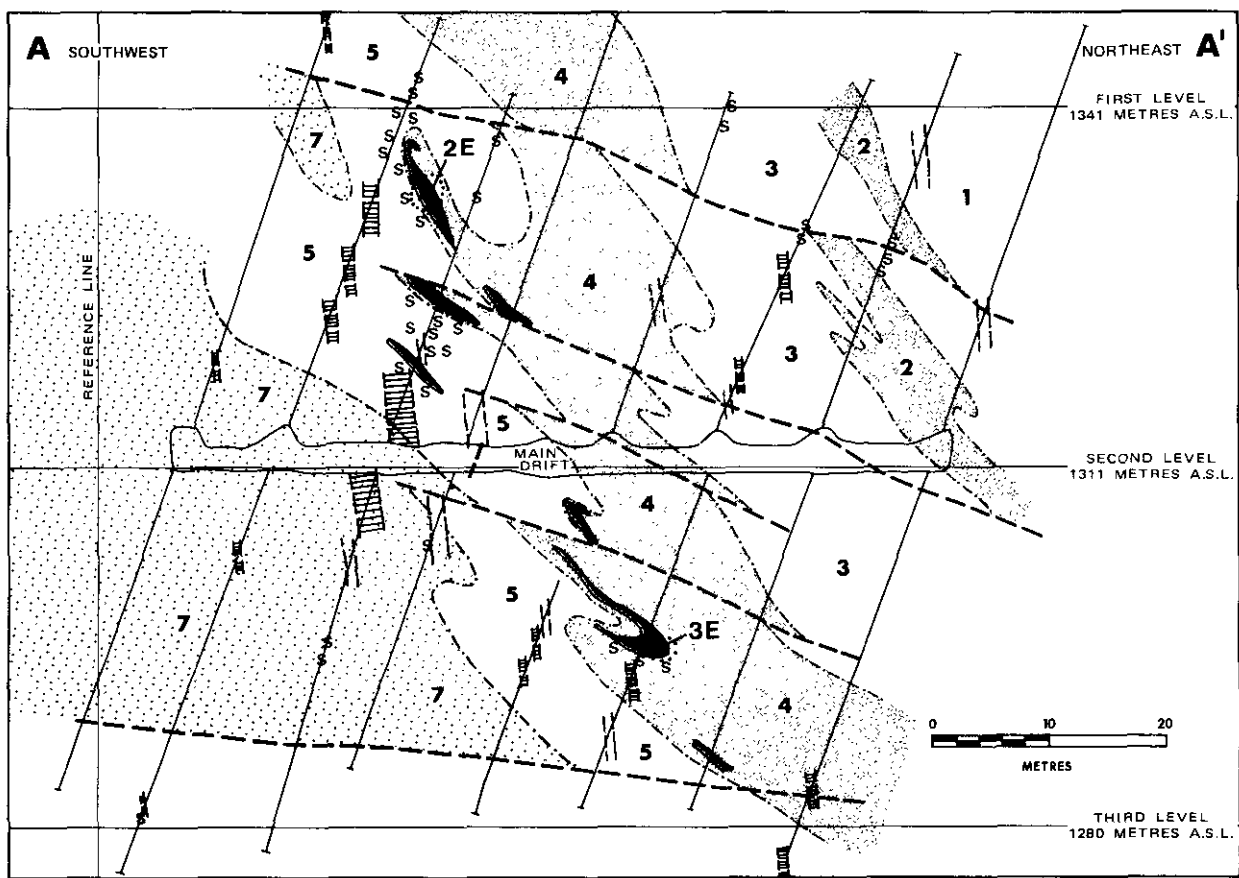
The identification of many exposures of graded bedding in both Baker and Rainbow rocks was a key factor in establishing stratigraphic 'tops.' Most graded layers are less than 10 centimetres thick but individual beds are up to 2 metres thick. The graded beds generally consist of basal fine-grained white to buff quartzite that grades upward to black phyllite. Minor fine carbonate grains occur in both zones and the phyllite displays coarse rhombic dolomite crystals. The orientation of these beds indicates that the mine strata are overturned.

Workings on Level 3 of the mine expose a distinctive bed that is well up in the Rainbow member (unit 7, Fig. 30). The bed lies about 60 metres stratigraphically above the Rainbow-Baker contact and consists of dark greyish green, fine-grained, massive to faintly laminated rock with abundant fine pyrrhotite lamellae and rare scattered coarse pyrite crystals. While the euhedral pyrite is interpreted to be metamorphic, the distinctive pyrrhotite texture is thought to be primary. The rock is tentatively identified as metamorphosed tuff.

Lensing out of sedimentary strata made identification of key marker beds in the mine workings difficult. Virtually all lithologies are correlatable over short distances but few are continuous over the entire 500-metre length of the mine workings. Potentially useful units are: ore-hosting limestones, thin-bedded white quartzites, and orange to buff-weathering dolomite layers. All three lithologies are readily identifiable, even in intensely cleaved exposures. On Level 2 (Fig. 30) drag folding and intense faulting obscure the probable continuity of these beds near the southeastern limit of the mine workings. Any of these markers can be used as a prospecting guide in exploration programs in the area, and other units may prove useful locally.

Mine scale structural features are illustrated on Figures 29 through 32. Several minor folds were noted with an average plunge of 21 degrees toward north 45 degrees west. Orientation of strata on Figure 31 was determined from many well-exposed lithological contacts that strike north 50 degrees west with dips averaging 50 degrees northeast. Cleavage varies considerably in both orientation and intensity. Its development ranges from negligible to locally so intense that cleavage obscures rock textures and causes poor drill core recovery. Cleavage orientation roughly parallels the strike of rock strata but dips are shallower, ranging from 0 to 50 degrees and averaging 30 degrees northeast. The orientation of cleavage closer to horizontal than the dip of the rock strata supports the conclusion of overturned folds in the mine area. Prominent lineations throughout the mine parallel minor fold axes.

Faults abound in the mine. Most fall into two categories: north-south-striking, steeply east-dipping dextral faults (Fig. 30), and shallow, normal faults parallel to the cleavage (Fig. 31). The latter are abundant but often subtle, with little or no gouge. Benedict (1945) discusses them in some detail; they produce a limited but repetitive displacement which produces an overall apparent dip of 70 degrees northeast in the mine strata (Figs. 31 and 32).



LEGEND

STRATIGRAPHY

RAINBOW MEMBER

7 BLACK AND GREY CLASTIC SEDIMENTS

BAKER MEMBER

5 PALE, THIN-BEDDED CLASTIC SEDIMENTS

4 GREY LIMESTONE

3 PALE MIXED CLASTIC SEDIMENTS

2 GREY LIMESTONE

1 CONGLOMERATE

SYMBOLS

SULPHIDE MINERALIZATION AND SERICITE ALTERATION

REPLACEMENT MINERALIZATION

QUARTZ VEIN: BARREN, MINERALIZED . . .

SERICITE SCHIST ZONE **S**

GEOLOGICAL CONTACT

FAULT

STOPE

DIAMOND DRILL HOLE

Figure 31. Geological cross-section of the No. 2 Crosscut West, No. 2 Level, Mosquito Creek Gold mine.

MINERALIZATION

Gold ore occurs in a large number of discrete, relatively small deposits along a total strike length of 45 kilometres that includes the Mosquito Creek, Island Mountain, and Cariboo Gold Quartz mines (Fig. 29) (Sutherland Brown, 1957). These occurrences consist of either auriferous pyrite in quartz veins in the Rainbow member (Fig. 33) or stratabound, massive auriferous pyrite lenses, termed 'replacement ore,' within and at the contacts of limestone beds of the Baker member (Fig. 31).

Quartz Vein Ore

The mine rocks are cut by numerous generations of intersecting quartz veins; the majority are barren. A minority of these veins carry coarse pyrite which is invariably auriferous. Ore-bearing quartz veins carry up to 25 per cent pyrite and grade up to 70 grams gold per tonne, although average production grades are considerably lower. Ore veins in Mosquito Creek mine reach 5 metres in width; the ultimate length and height of the near-vertical veins is still to be determined.

Mineralized quartz veins occurred in all three of the major mines at Wells. At Cariboo Gold Quartz, where total production was 1.54 million tonnes grading 13.4 grams gold per tonne from 1933 to 1959 (Carlyle, in press), the quartz veins were the main source of ore. At Mosquito Creek mine, during high metal price cycles, production has come from three quartz veins with grades ranging from 4.5 to 7.9 grams gold per tonne. These mineralized quartz veins at Mosquito Creek mine occur within Baker member rocks and accessory minerals in the veins are ankerite, galena, sphalerite, and sericite. However, Skerl (1948) also reports free gold, cosalite, argentite, and chalcopyrite from quartz veins at Cariboo Gold Quartz mine. Figure 33 is a sketch of a major quartz vein at Cariboo Gold Quartz mine. It shows that the vein is most extensively developed in Rainbow rocks but where the vein system continues into Baker member rocks it intersects and terminates in a 'replacement ore' lens.

Sericite from mineralized quartz veins at Cariboo Gold Quartz and Mosquito Creek mine has yielded Late Jurassic/Early Cretaceous K/Ar dates of 141 ± 5 (Andrew, 1982) and 139 ± 5 (G. Klein, personal communication) respectively, from sites roughly 4 kilometres apart.

Replacement Ore

The historic term 'replacement ore' is used for the stratabound massive pyrite ore lenses despite its genetic implications. While quartz vein ore is most abundant in Rainbow rocks and only rarely occurs in Baker rocks, replacement ore occurs only within Baker rocks. Typically, replacement ore lenses occur within or at the contacts of the limestone lenses (Figs. 30 and 31). The ore lenses generally occur within 25 metres of the contact between dark Rainbow member beds and pale Baker beds.

In addition to this lithologic association, most of the replacement lenses are structurally controlled. The massive pyrite lenses are commonly localized in the crests or noses of the minor folds and less frequently in fold troughs. However, significant tonnages of ore also occur in steeply dipping limbs of the main fold structure and in flat-lying tabular lenses where the limestones have 'rolled out' or flattened.

At Island Mountain mine ore lenses ranged from 500 to 35 000 tonnes, and averaged 2 000 to 7 000 tonnes. Typical dimensions are 2 to 3 metres thick, 6 metres wide, and from 30 to many hundreds of metres long down plunge. Replacement ore zones have average cross-section areas of 10 square metres, necessitating tight exploration drill spacing and careful study of peripheral alteration features in order to recognize 'near misses' in drilling.

The pyrite lenses are fine-grained and usually massive. Locally they display faint banding parallel to the host strata. The finest grained pyrite contains the highest gold values. Overall grades from 30 years of production at Island Mountain mine averaged 16.5 grams gold per tonne and 2.4 grams silver per tonne (Carlyle, in press). However, grades from replacement ore alone, which supplied roughly 60 per cent of the production, averaged 23.0 grams gold per tonne and 3.4 grams silver per tonne. Overall grades at Mosquito Creek to December, 1982 mine averaged 14.5 grams gold per tonne from 49 940 tonnes of quartz vein and replacement ore combined.

Ore lenses have sharp hangingwall and footwall contacts; laterally they grade progressively into coarser barren pyrite with coarse arsenopyrite, minor amounts of disseminated galena, sphalerite and rare pyrrhotite, then into silicified limestone, sericitized limestone or sericite schist. The host rock is always limestone; dolomitized, silicified, or sericitized limestone; or sericite schist. In the schist, pervasive sericitization has obliterated the original lithology. One small replacement ore occurrence in sericite schist host rock is illustrated on Figure 31. Comparison with ore lenses in sericitized limestone suggests that the schists are derived from limestone as well. Carlyle (in press) noted that sericitization is most intense in the structural footwall of the pyrite lenses.

Short (2 to 4-metre), narrow (less than 5-centimetre) veins of massive galena and sphalerite mineralization occur in the hangingwall oriented at right angles to the ore lenses; similar veins occur, but are rare, in the footwall. Minor amounts of turquoise-green chromium-bearing mariposite characterize the hangingwall alteration zones. Recognition of these alteration features and peripheral accessory minerals at the mine enlarges 'targets' for exploration diamond drilling.

Some quartz veinlets show crosscutting relationships that clearly postdate the ore, but at least one major vein may be contemporaneous with a massive pyrite lens. In an excellent exposure in the 2E stope at

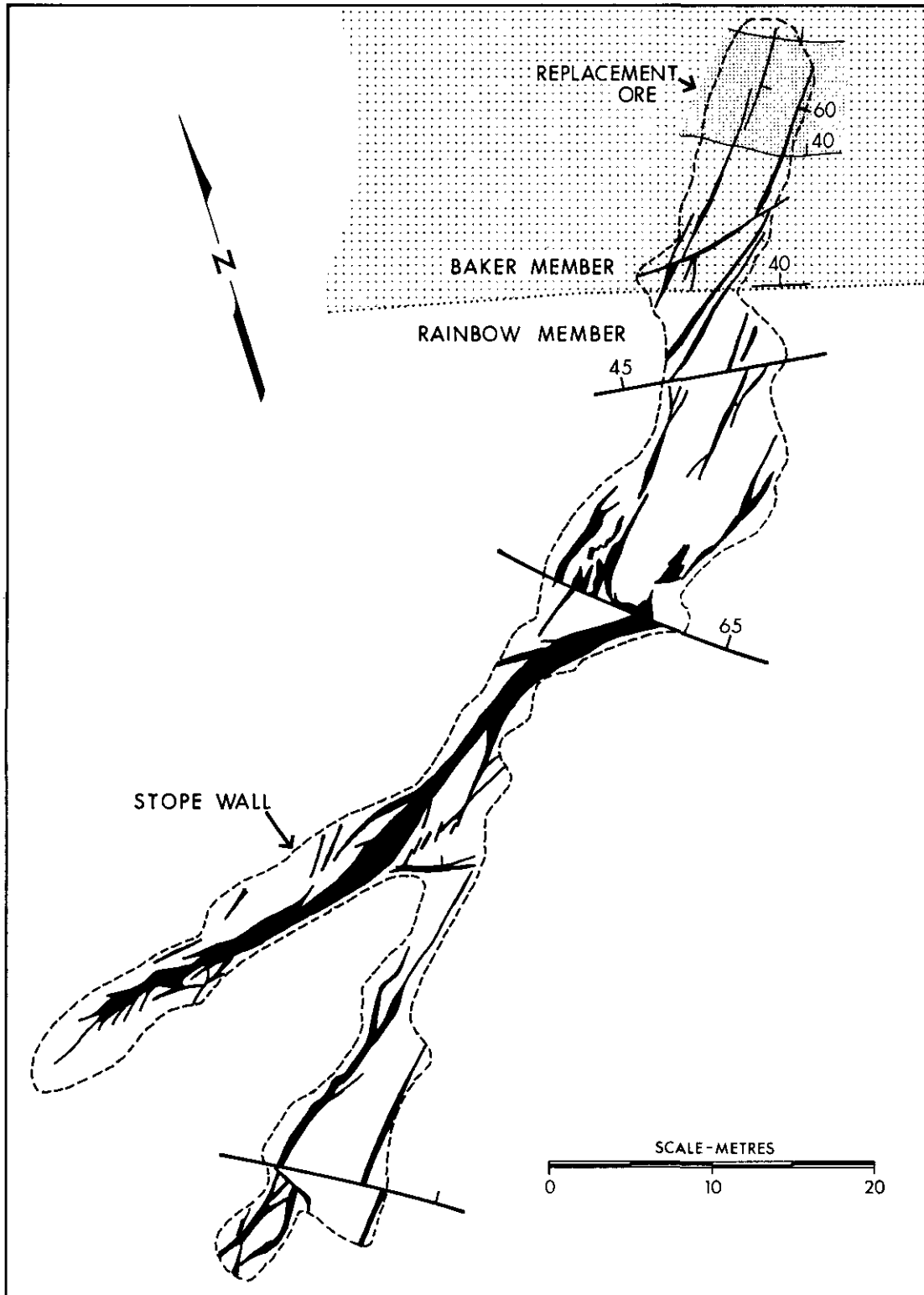


Figure 33. Plan of the 19-2 stope vein system, Cariboo Gold Quartz mine (after Skerl, 1948).

Mosquito Creek mine, a vertical 2-metre-wide barren quartz vein penetrates the massive pyrite lens and terminates abruptly at the hangingwall contact with sericite schists. The lateral margins of this massive white quartz vein are interlayered with stratiform silicified galena-sphalerite-pyrite mineralization which grades laterally into fine-grained massive pyrite of typical replacement ore.

GENESIS

Carlyle (in press) describes the three main genetic theories of mineralization developed since mining operations began in 1933:

- (1) Metals were remobilized from the country rock during regional metamorphism and were reconcentrated in dilation zones, such as fold axes.
- (2) Hydrothermal fluids rose from a deeply buried source along a complex fracture network of quartz veins and preferentially replaced the limestone beds.
- (3) Hydrothermal fluids rose from a deeply buried source up the major north-striking faults and preferentially replaced limestone beds. Quartz vein ore then developed outward from the replacement ore lenses.

Recently developed metallogenic concepts of volcanic exhalative and/or sedimentary exhalative deposits were considered for this area but neither of the models fits well with observed data such as: quartz vein mineralization in the stratigraphic hangingwall; atypically high gold/base metal ratios; trace metal associations of arsenic, bismuth, tungsten; and Late Jurassic/Early Cretaceous radiometric dates for the quartz vein ore which contrast with Carboniferous fossil dates of the host rock.

Lead isotope analyses reported by Andrew, *et al.* (this volume) provide a Pb/Pb model age of 185 ± 50 Ma for the lead mineralization which covers a broad enough range to be contemporaneous with regional metamorphism (K/Ar age of 179 ± 8 Ma) or with post-tectonic magmatism (K/Ar age of 143 ± 14 Ma) (Pigage, 1977). Andrew, *et al.* have concluded that the lead, and by inference the gold, in these deposits was derived from crustal rocks either by lateral secretion during Middle Mesozoic regional metamorphism or by hydrothermal leaching related to Late Jurassic/Early Cretaceous post-tectonic magmatism.

Given the distribution of all the known gold deposits over a 45-kilometre strike length along a single fold limb, a regional tectonic control for the mineralizing event seems necessary. The writer envisages the gold-bearing fluids were derived from the crustal rocks during regional metamorphism and emplaced late in the tectonic cycle during a period of fault readjustment (~ 140 Ma). The fluids penetrated the folded, overturned

strata, precipitating mineralized quartz veins and reacting with carbonate beds when encountered. Fluids flowed along dilatant fold noses and troughs within the limestones, precipitating in massive sulphide lenses.

EXPLORATION

Successful exploration in the region has been based either on direct prospecting or on drilling near the critical Rainbow-Baker contact. Trenching has always been an essential part of the exploration programs because slopes throughout the area are steep and glacial overburden is deep.

The usefulness of geophysical methods such as IP, EM/VLF-EM, and SP is limited because trace disseminated pyrite is ubiquitous, carbon content is high in some strata, major fault zones are frequent, and typical orebodies are very small. A test induced polarization survey at Mosquito Creek mine delineated the contact between the Baker member and the highly carbonaceous Rainbow member. Resolution was sufficient to show displacement of the contact along by a major north-south fault. More useful results were obtained in a recent VLF-EM survey on the Mosquito Creek mines property where the Rainbow-Baker contact is delineated by bands of adjacent high and low anomalous values that follow the contact and show the same north-south fault displacement. The advantages of the VLF system over the IP technique lie in speed, simplicity, and lower cost. Correlation of filtered VLF results with property geology suggests that the anomalous VLF-EM lows or troughs may coincide with subcropping non-conductive limestone units.

Geochemical soil surveys in the region have produced gold anomalies and arsenic, lead, bismuth, silver, and copper are being used as pathfinder elements to avoid the problem of redistributed placer gold in the glacial till. Unfortunately, chemical metal dispersion, thick glacial overburden, soil creep, and small targets make spotting follow-up diamond-drill holes difficult. Follow-up of anomalies by trenching would probably be as cost-effective as drilling.

On a mine scale, systematic exploration for replacement ore at the Mosquito Creek mine involves establishing a regular spacing of exploration crosscuts off the main southeast-northwest drift (Fig. 30) and a regular pattern of inclined drill holes from each crosscut (Fig. 31). This tight drill pattern is essential because ore zones and their alteration halos are small. Once ore is intersected, it is developed by mining along the plunge of the hosting minor folds (Fig. 29).

The exploration potential for more of these relatively small, but high grade gold deposits is excellent. Surface and underground exploration programs at Mosquito Creek mine have discovered additional reserves of replacement ore. Substantial reserves had been established at depth in the Island Mountain mine when it closed in 1967. Production from the

Cariboo Gold Quartz mine was predominantly from quartz vein ore in the Rainbow member (Figs. 29 and 33) while the existence and potential of the replacement ore within the Baker member was unrecognized. The mineral potential of minor limestone horizons within the Rainbow member rocks has yet to be evaluated.

CONCLUSIONS

The Cariboo Gold Belt is one of the major gold producing regions of the Canadian Cordillera. The Mosquito Creek mine produces ore from a number of deposits that are distributed along the strike extension of ore-bearing strata that yielded 37 697 kilograms of gold and 4 354 kilograms of silver since underground mining commenced in the area in 1933.

The many ore deposits of the belt occur in a structurally overturned metasedimentary rock sequence of the Carboniferous Cariboo Group. Lower Jurassic regional metamorphism produced greenschist facies mineralogy. Deformation produced regional, northwest-trending overturned folds with associated rhythmically spaced minor folds. Early Cretaceous lower grade quartz vein ore deposits are hosted predominantly in the dark carbonaceous rocks of the Pennsylvanian/Permian Rainbow member. Higher grade replacement ore deposits are hosted within and at the contacts of altered limestone horizons in the light-coloured Mississippian Baker member. The replacement ore deposits are localized by parasitic, minor folds and the crests and troughs of these folds may be continuously or discontinuously mineralized for many hundreds of metres down plunge.

The ore deposits are clearly epigenetic although the exact mechanism of their emplacement has still to be determined. The gold was likely derived from deeper crustal rocks.

The Cariboo Gold Belt offers excellent exploration potential within, between, and beyond the existing mine workings. An effective exploration program in this environment should combine detailed prospecting and geological mapping with soil geochemistry and VLF-EM geophysics. Initial work should be followed by an aggressive trenching program. The grade of replacement ore lenses and their orientation is so uniform and predictable that mining can be initiated directly from a subcrop exposure or a single drill hole intersection.

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