Geology of the QR gold deposit, Quesnel River area, British Columbia

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ABSTRACT

The QR gold deposit lies in the Cariboo plateau region of central British Columbia. The deposit was discovered in 1977 and since then a mineable reserve of 1.3 million tonnes grading 4.7 g/t Au has been outlined in three separate zones. Soil sampling of glacial tills followed by diamond drilling of favourable host rocks proved to be key exploration techniques.

The deposit is situated in the southern Quesnel terrane along the eastern fringe of the Intermontane Belt which here comprises a sequence of basic and intermediate volcanics and a series of stocks of alkaline affinity; generally diorite, monzonite and syenite. Hornfels and epidote-rich ferromagnesian exoskarn and sulphide-rich mantos have developed in a metamorphic aureole formed around a central diorite stock. Gold-rich zones lie along the outer periphery of the aureole where bodies of gold-bearing epidote-rich skarn and auriferous mantos rich in epidote and pyrite have formed in beds of calcareous tuffite lying at the top of a thick basaltic sequence. The deposit is regarded as a subclass of gold skarn deposits. Diagnostic features are its association with alkalic intrusive rocks in a subvolcanic setting and the presence of oxidized, epidote-rich mineral assemblages.

Introduction

The QR gold deposit lies within the Cariboo plateau region of central British Columbia, 58 km southeast of Quesnel. The deposit, owned by Kinross Gold, was discovered during a regional reconnaissance program by Dome Exploration (Canada) Limited and Newconex Canadian Exploration in 1977. Considerable exploration and development has been done since that time. Mineable reserves of 1.3 million tonnes grading 4.7 g/t Au have been outlined to date in three zones.

Previous research has described the gold-bearing rocks at QR in terms of classic porphyry copper alteration patterns. This paper is the first to apply a skarn terminology to the description of the intensely propylitized host rock of the QR deposit. The definition of skarn used in this paper is after Burt (1977), Einaudi and Burt (1982) and Ray and Webster (1991) wherein the term describes "coarse grained calcium or magnesian silicate alteration, commonly rich in Fe, Al and possibly Mn, formed at relatively high temperatures by the replacement of original, often carbonate-rich rocks". Burt (1977) noted that close to the earth's surface and in the presence of CO_2-poor fluids, skarn silicates can form at quite low temperatures. Nomenclature used for the descriptions of volcanic rocks conforms to recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks (Le Maitre, 1989).

The location of the QR property is given in Figure 1. Approximate coordinates are latitude 52°41′N and longitude 121°47′W on NTS map 93A/12. The property is situated in the Cariboo region of central British Columbia, 58 km southeast of Quesnel and 10 km west of Quesnel Forks. Access to the site is by a series of gravel-surfaced public roads from Quesnel to Sardine Flats and by the Nyland Lake access road to the property, an overall distance of 73 km.

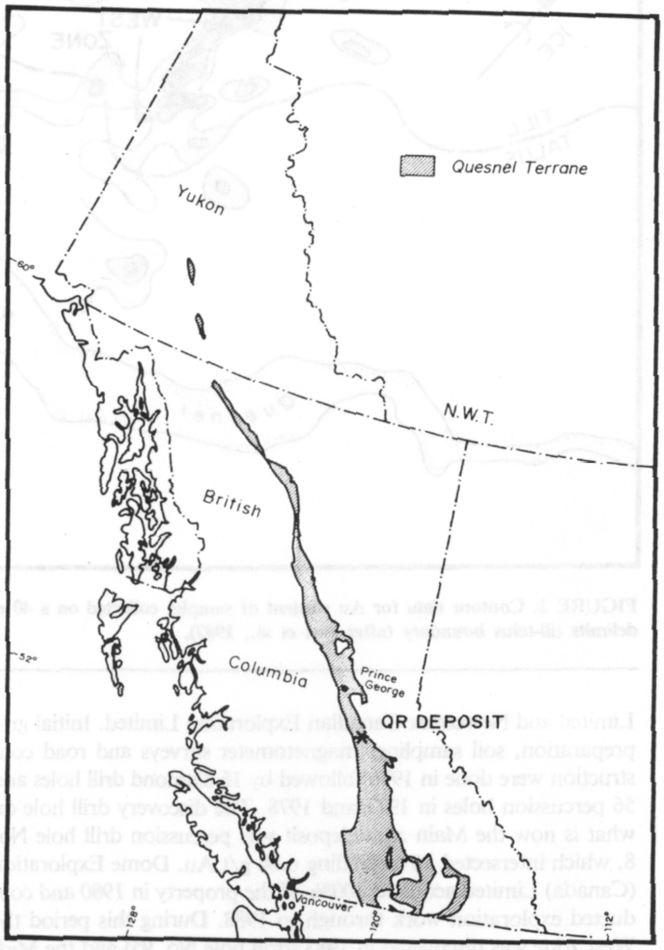

FIGURE 1. Location map of the QR Gold Deposit. Shaded area marks the location of Quesnellia or the Quesnel terrane (after Gabrielse et al., 1991).

Local terrain consists of rolling hill country typical of the Cariboo plateau region of central British Columbia. The deeply-incised valleys of Quesnel River and Maud Creek lie near the south and east boundaries of the property, respectively. The deposit, at an elevation of 1000 m, is situated in a low depression between the bluffs above the Quesnel River to the south and a swampy, muskeg-filled valley in which a small brook drains northerly to Maud Creek. Relief from the lowlands of the Quesnel River valley to timbered summits northwest of the deposit is 500 m. Bedrock material, including the gold-bearing zones, is generally covered by a mantle of glacial till or talus several metres thick.

History

The QR deposit was staked in 1975 during a regional reconnaissance program conducted by Fox Geological Consultants Ltd. (the Cariboo project) on behalf of Dome Exploration (Canada)

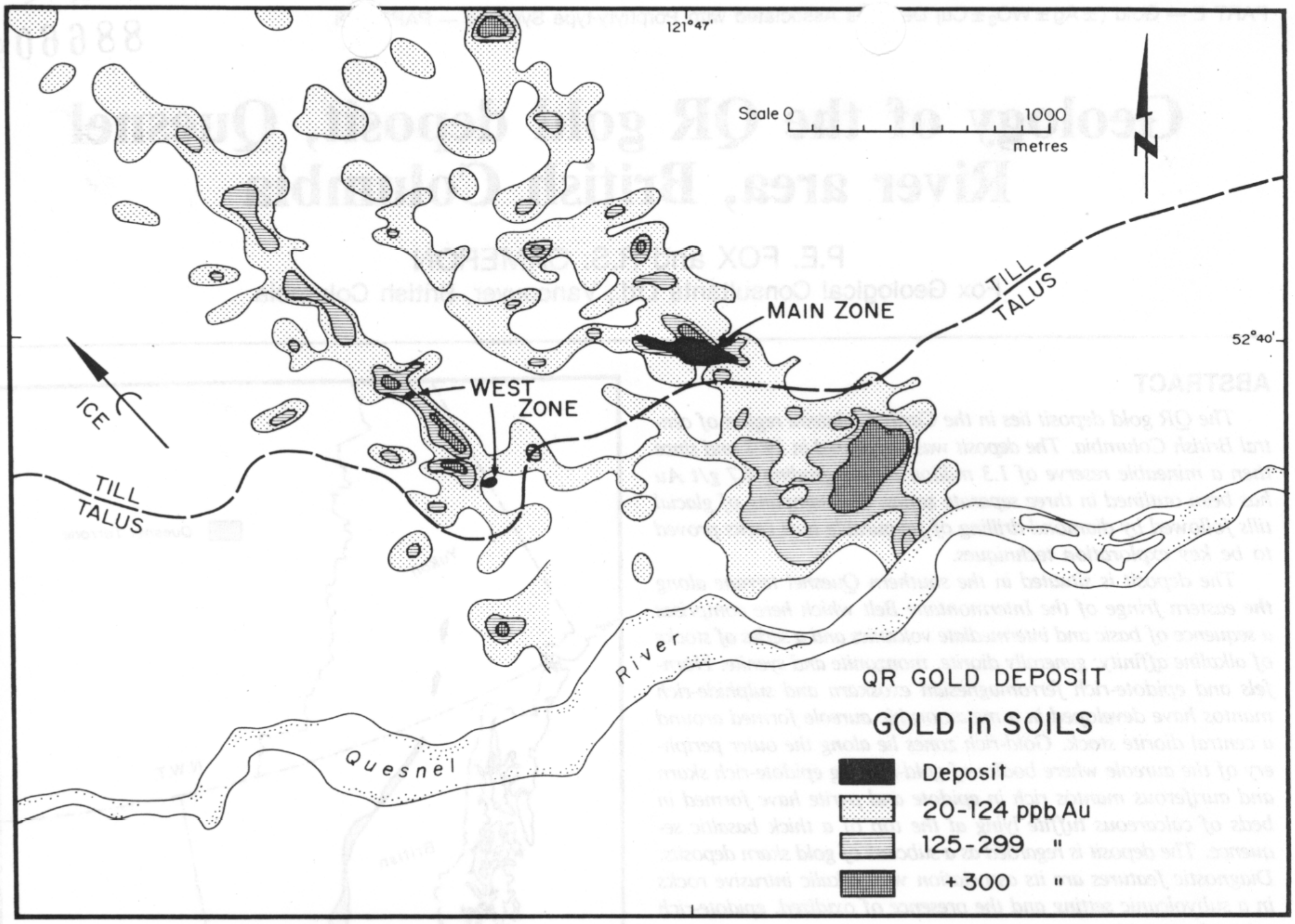

FIGURE 2. Contour data for Au content of samples collected on a 40 m by 100 m grid. Subcrop position of mineralized zones in black. Dashed line delimits till-talus boundary (after Fox et al., 1987).

Limited and Newconex Canadian Exploration Limited. Initial grid preparation, soil sampling, magnetometer surveys and road construction were done in 1976 followed by 16 diamond drill holes and 56 percussion holes in 1977 and 1978. The discovery drill hole on what is now the Main zone deposit was percussion drill hole No. 8, which intersected 36 m grading 6.64 g/t Au. Dome Exploration (Canada) Limited acquired 100% of the property in 1980 and conducted exploration work through to 1988. During this period the West zone was discovered in 1983 (drill hole No. 95) and the Midwest zone in 1986 (drill hole No. 187). QPX Minerals Ltd. acquired the property in 1988 and completed detailed drilling (127 holes) of all zones together with stepout exploration holes. QPX completed a feasibility study encompassing a combined open pit-underground operation to mill some 750 tonnes per day. Preliminary reserves reported by QPX in 1989 are as follows: Main zone — 1 122 000 tonnes grading 3.50 g/t Au; Midwest zone — 333 000 tonnes grading 5.87 g/t Au; West zone — 156 040 tonnes grading 9.72 g/t Au. An Approval in Principle for development of the project was issued by the British Columbia Mine Development Committee in July, 1990.

Rea Gold Corporation acquired the property in 1990. Detailed drilling to confirm ore reserve estimates was completed on the Main zone, as were mine planning details. CMP Resources Ltd. acquired the property in October, 1992 and completed a feasibility study update in which mineable reserves in the three zones total 1 333 000 tonnes grading 4.7 g/t Au to be processed at approximately 750 tonnes per day. To date, 433 diamond drill holes have been completed comprising 64 700 m and an additional 4300 m in 56 percussion holes. Kinross Gold acquired the property in 1993 following the amalgamation of CMP Resources, Plexus Resources and an Ontario company. Construction of an 800 tonnes per day mine and mill commenced in 1994 and startup is planned for the spring of 1995.

Applied Exploration Techniques

Sampling of glacial till to delineate gold and arsenic dispersion, followed by diamond drilling along the favourable contact zone, proved to be the key exploration methods in outlining the three mineralized zones discovered to date. Till sampling methods and a discussion of results is provided by Fox et al. (1987). Figure 2 shows the distribution of gold in tills in the vicinity of the QR deposit (after Fox et al., 1987). The highest concentration for the Main zone dispersion train lies directly over the deposit, but at the West zone mineralized subcrop lies 200 m up-ice from peak gold concentrations in till. The down-ice dispersion trains for both zones are some 1500 m long and peak gold concentrations reach 1000 ppb Au.

Exploration drilling along the favourable contact led to the discovery of the Midwest zone in 1986; a deposit lying 65 m below surface and having no surface expression. Further drilling along faulted extensions of the Main zone led to the discovery of gold-bearing skarn at depth to the north and east.

Regional Geology

The QR gold deposit is situated near the eastern edge of the Intermontane Belt in a north-northwest trending assemblage of Upper Triassic-Lower Jurassic volcanic rocks often referred to as Quesnellia or the Quesnel terrane (Fig. 1). The Quesnel terrane forms

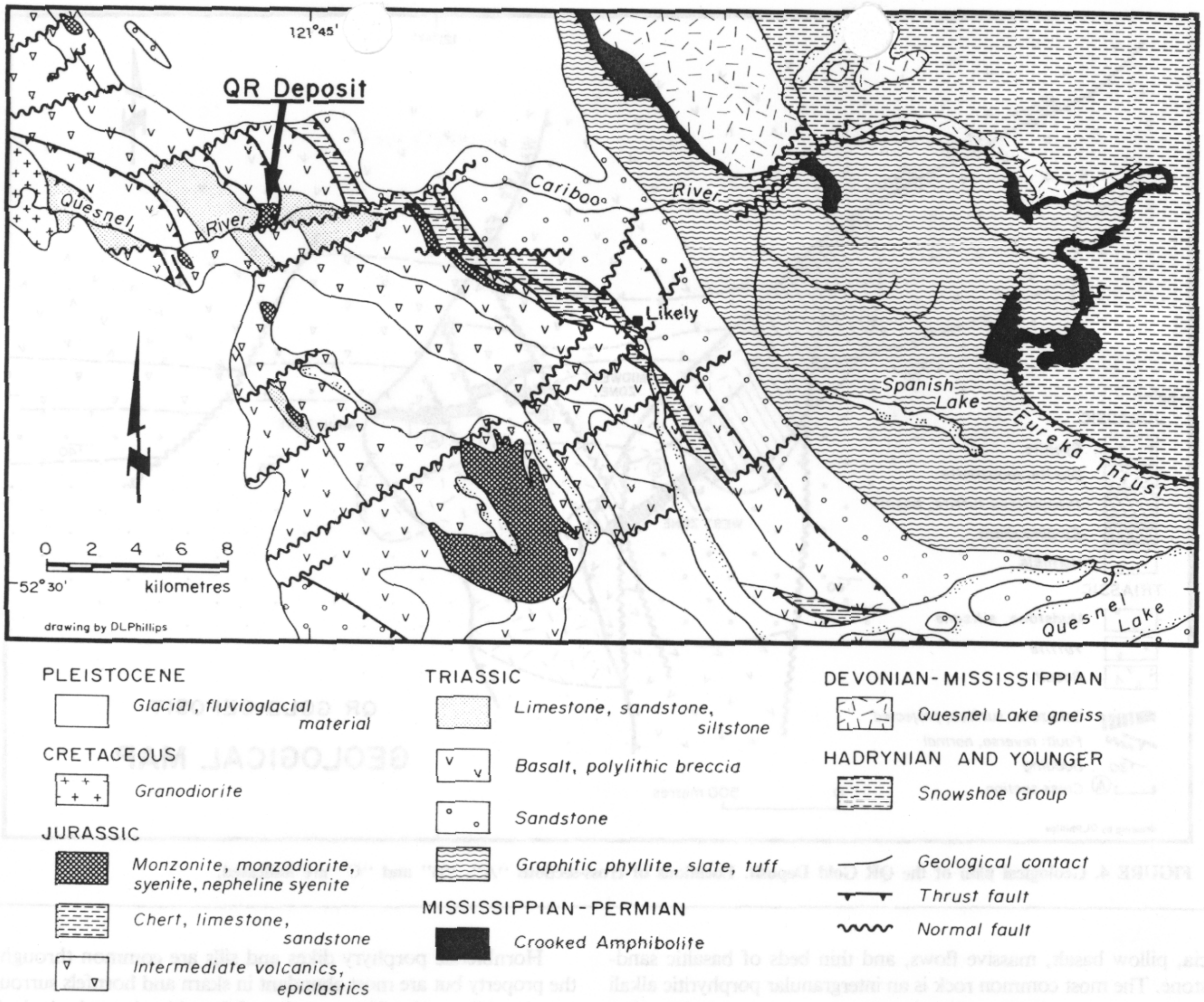

FIGURE 3. Regional geology of the area of the QR Gold Deposit (modified from Melling et al., 1990 and Bailey, 1990).

a volcanic belt that stretches from the 49th parallel to 62°N and in part comprises rocks of the Nicola and Takla Groups. Detailed petrologic and stratigraphic studies were undertaken by Lefebure (1976) and Preto (1979) in the Nicola Group and by Morton (1976), Bailey (1990), Panteleyev (1987) and Panteleyev and Hancock (1988) in the Horsefly, Morehead Lake and Swift River areas.

In the vicinity of the QR gold deposit, the Quesnel terrane forms a narrow belt of basic and intermediate volcanic and plutonic alkalic rocks and a variety of sedimentary rocks (Fig. 3). The belt is crudely symmetrical about a central axis of Jurassic basic to intermediate volcanic rocks flanked to the east and west by Triassic basic volcanics and successively by flyschoid sediments. The western margin is in fault contact with the Cache Creek Group, possibly along extensions of the Pinchi Fault.

The oldest rocks are basaltic sandstone and conglomerate, minor volcanic breccia, limestone and mudstone. These rocks make up much of the eastern flank of the Quesnel terrane. Overlying these sedimentary rocks and comprising much of the volcanic belt are some 5000 m of Triassic age alkalic basic volcanic rocks which include green and maroon autobreccias, pillow breccias, pillow lavas and massive flows of alkali basalt to trachybasalt composition. A thin succession, up to 300 m thick, of limestone, calcareous mudstone, siltstone and calcareous basaltic tuffite overlies the basalt sequence and marks the end of Triassic volcanism. A Jurassic sequence of intermediate rocks, up to 2500 m thick, unconformably overlies the Triassic rocks. Compact monolithologic pyroclastic breccias and lapilli tuff predominate and merge outward from eruptive centres into heterolithic epiclastic breccias and sediments.

A linear belt of alkalic stocks composed of diorite, monzonite and syenite lies within the volcanic strata and marks the eruptive centres of the Jurassic age intermediate flows and breccias. The stocks are hosts for numerous alkalic suite porphyry copper deposits and prospects including the Mount Polley deposit located 10 km south of the QR property.

Lithochemical analysis of volcanic and intrusive rocks of the Quesnel terrane show the rocks as being alkalic; total alkalies >5%, $TiO_2 < 1.0\%$, and moderately undersaturated with respect to silica. Most rocks have up to 5% normative nepheline.

Local Geology

Strata within the vicinity of the QR deposit consists of three main units: alkali basalt, calcareous tuffite and calcareous mudstone. These rocks strike east and dip moderately south and are intruded by dikes of hornblende porphyry and a diorite stock. The latter is exposed along steep bluffs overlooking the Quesnel River valley. A geological plan is given in Figure 4 and typical cross-sections in Figures 5, 6 and 7. Textural details of the main lithological units are described by Melling (1982, 1987), Zwicker (1987), Melling and Watkinson (1987), Fox et al. (1987) and Melling et al. (1990).

The lowermost stratigraphic unit, which forms ridges and low summits north of the Quesnel River, consists of at least 850 m of alkali basalt comprising monolithologic autobreccia, pillow brec-

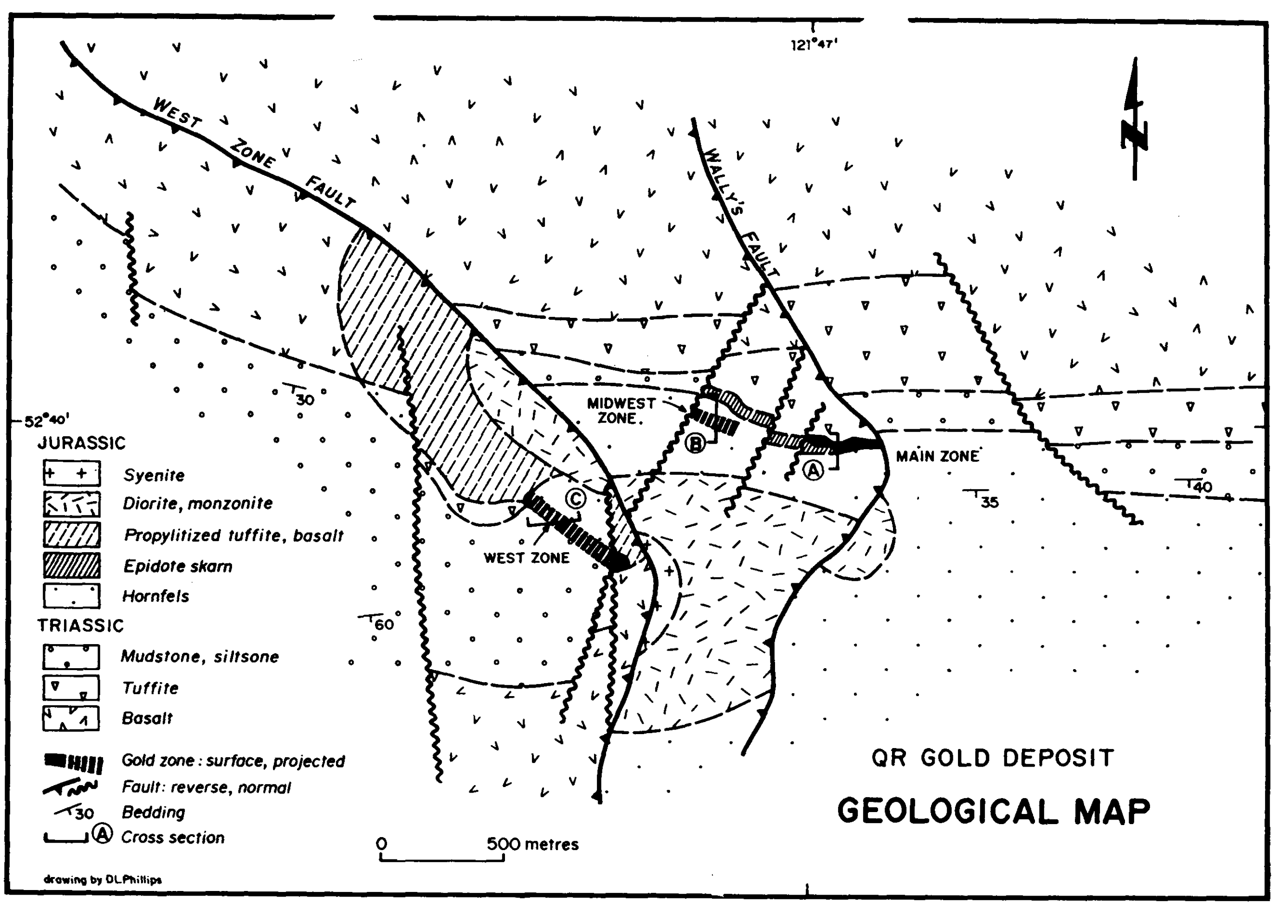

FIGURE 4. Geological plan of the QR Gold Deposit. Locations of cross-sections "A", "B" and "C" are indicated.

cia, pillow basalt, massive flows, and thin beds of basaltic sandstone. The most common rock is an intergranular porphyritic alkali basalt consisting of 20% euhedral augite phenocrysts and 10% tabular plagioclase phenocrysts within a fine grained groundmass. Olivine and analcime phenocrysts are present in thick flows immediately to the northwest.

The top of the basalt unit grades into poorly sorted blocky basaltic tuffite. Textures are dominantly epiclastic comprising framework-supported clasts of basalt set in a matrix of finer grained lithic fragments and glass shards. The matrix is rich in grey, micritic calcite and locally contains up to 10% fine-grained framboidal and colloform pyrite. This tuffite unit varies from less than 5 m thick to more than 80 m thick and locally grades laterally from calcite-cemented tuffaceous basaltic breccia into lapillistone. Volcanic textures within the fragments are commonly obscured by intense carbonate alteration (Melling, 1982; Melling et al., 1990). Pyrite content in the tuffite varies from 5% to over 20% with framboidal, colloform and banded textures most common.

A thin bedded, fissile black mudstone and siltstone unit, 200 m thick, overlies the tuffite unit. Where converted to hornfels near the QR stock, it forms conspicuous, cliff-forming gossans along the Quesnel River valley. The mudstone unit is calcareous, in part carbonaceous, and contains up to 10% fine-grained disseminated pyrite.

The QR stock and related hornblende porphyry dikes and sills intrude and alter the above rocks. The QR stock is a medium-grained, equigranular body measuring 1000 m by 1500 m. The stock consists of a diorite margin, 100 m thick, enclosing a core of monzonite and rare syenite. The diorite typically consists of 15% augite, 20% biotite, 50% tabular subhedral plagioclase, 10% or less K-feldspar and variable amounts of magnetite. A K-Ar date obtained from chloritized biotite within the diorite margin of the QR stock returned an age of 201 ± 7 Ma (Panteleyev, 1986).

Hornblende porphyry dikes and sills are common throughout the property but are most abundant in skarn and hornfels surrounding the QR stock. They consist of hornblende and plagioclase phenocrysts set in a fine-grained groundmass of plagioclase microlites. Locally the dikes are intensely altered to endoskarn consisting of calcite, epidote, clinozoisite, and tremolite (Melling et al., 1990, Fig. 6a).

Surrounding the stock is a halo of propylitized tuffite, skarn and hornfels that extends up to 300 m into the surrounding beds of tuffite and mudstone. Basaltic tuffite is variably propylitized and skarn-altered and the mudstone unit is altered to a bleached, massive, fine grained hornfels. Gold occurs in bodies of epidote-rich skarn and sulphide-rich mantos within skarn-altered and propylitized equivalents of calcareous tuffite.

Structure

Volcanic and sedimentary rocks in the vicinity of the QR deposit are in most areas undeformed. Penetrative fabrics are absent and fold structures are rare. The main structural element within the area of the deposit is a series of subparallel northerly-trending, west-dipping normal faults. These faults displace the main basalt-siltstone contact progressively to the west.

The youngest structural features are two low angle reverse faults: Wally's Fault and the West Zone Fault (Fig. 4). Wally's Fault strikes northwest, dips 20° southwest, and truncates the Main zone. Hangingwall rocks have been displaced about 240 m to the southeast. The West Zone Fault is located 1100 m west of Wally's Fault and also strikes northwest but dips 35° to the southwest. Absolute displacement has not been determined; however, movement of the hangingwall is estimated to be at least 500 m to the northeast, making it dominantly a thrust fault. Both the West Zone Fault and Wally's Fault are anastamosing, foliated, chlorite-rich gouge zones

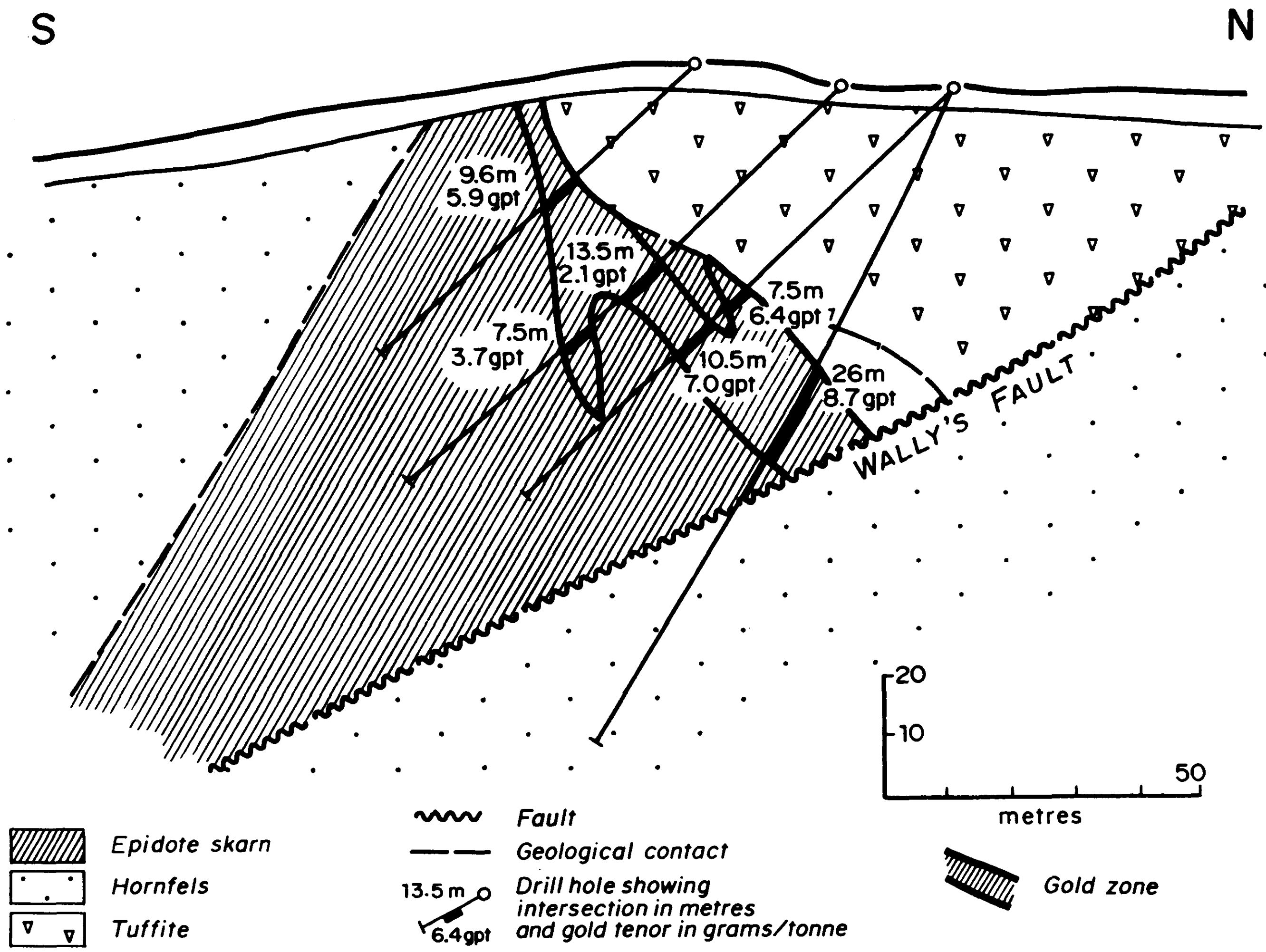

FIGURE 5. Cross-section "A" looking west through the Main zone deposit. Location of cross-section is shown in Figure 4.

and fracture zones up to a combined thickness of 30 m. At surface they are the loci of narrow swamps, bogs and shallow depressions.

Alteration and Mineralization

The QR gold deposit comprises three separate zones; the Main zone, which was the initial discovery in 1977; the West zone deposit discovered in 1983 and the Midwest zone discovered in 1986. All zones are hosted by propylitically altered and skarn-altered equivalents of pyritic, carbonate-rich fragmental basaltic tuffite lying beneath the hornfelsed mudstone unit.

Main Zone

The Main zone (Figs. 4 and 5) consists of south-dipping strata of hornfels, epidote skarn and propylitized tuffite in which gold is concentrated for some 300 m along a north-dipping contact (the skarn front) that separates barren and unaltered tuffite to the north from skarn and propylitized tuffite to the south. Propylitized tuffite is a mottled green, epidote-rich augite porphyry that comprises much of the western part of the mineralized zone. It consists of variable amounts of pyrite, chalcopyrite, chlorite, calcite, tremolite, plagioclase, augite, and fine-grained disseminated epidote. Pyrite-carbonate veinlets, epidote-rich fracture coatings and pyrite-epidote veinlets, seams and coarse aggregates are common throughout. Pyrite up to 5% forms disseminated grains, coarse aggregates and stringers up to 3 mm thick.

Epidote skarn (Melling et al., 1990, Fig. 6d), which comprises the bulk of the Main zone, consists of equigranular aggregates of epidote, pyrite, carbonate, and lesser amounts of chlorite, quartz and andradite. Pyrite content varies from 2% to massive sulphide lenses and pods containing up to 80% pyrite. Unreplaced rock fragments of propylitized tuffite are common throughout the skarn bodies. Chalcopyrite is present in amounts up to 5% but generally occurs as irregularly-shaped aggregates comprising less than 1% of the rock. The overall copper tenor is 0.1%.

Gold occurs as finely disseminated micron-sized particles along pyrite and chalcopyrite grain boundaries. The highest and most consistent gold assays are obtained within 50 m of the skarn front. Although auriferous rocks are present farther away from the skarn front toward the diorite stock and in the overlying hornfelsed sediments, such zones are discontinuous and gold tenor is erratic.

West Zone

The West zone, a tabular body some 400 m long, lies 800 m west of the Main zone deposit (Figs. 4 and 7). The zone subcrops below till at its northern and southern ends but elsewhere lies about 90 m below surface.

Like the Midwest zone farther east, the West zone is a thin manto lying at the contact between well-bedded hornfels and variably propylitized and skarn-altered tuffite (Fig. 7). The deposit is composed of propylitized tuffite, interbedded lenses of pyritic hornfels and discontinuous lenses of massive sulphide all lying within a tabular body of propylitized rock and epidote skarn near a faulted remnant of the QR stock (Fig. 4). Sulphides are mostly pyrite with lesser amounts of pyrrhotite, chalcopyrite, arsenopyrite and galena. Like the Main zone, the best gold tenor is located close to the outer edge of the propylitized zone where coarse gold is often seen.

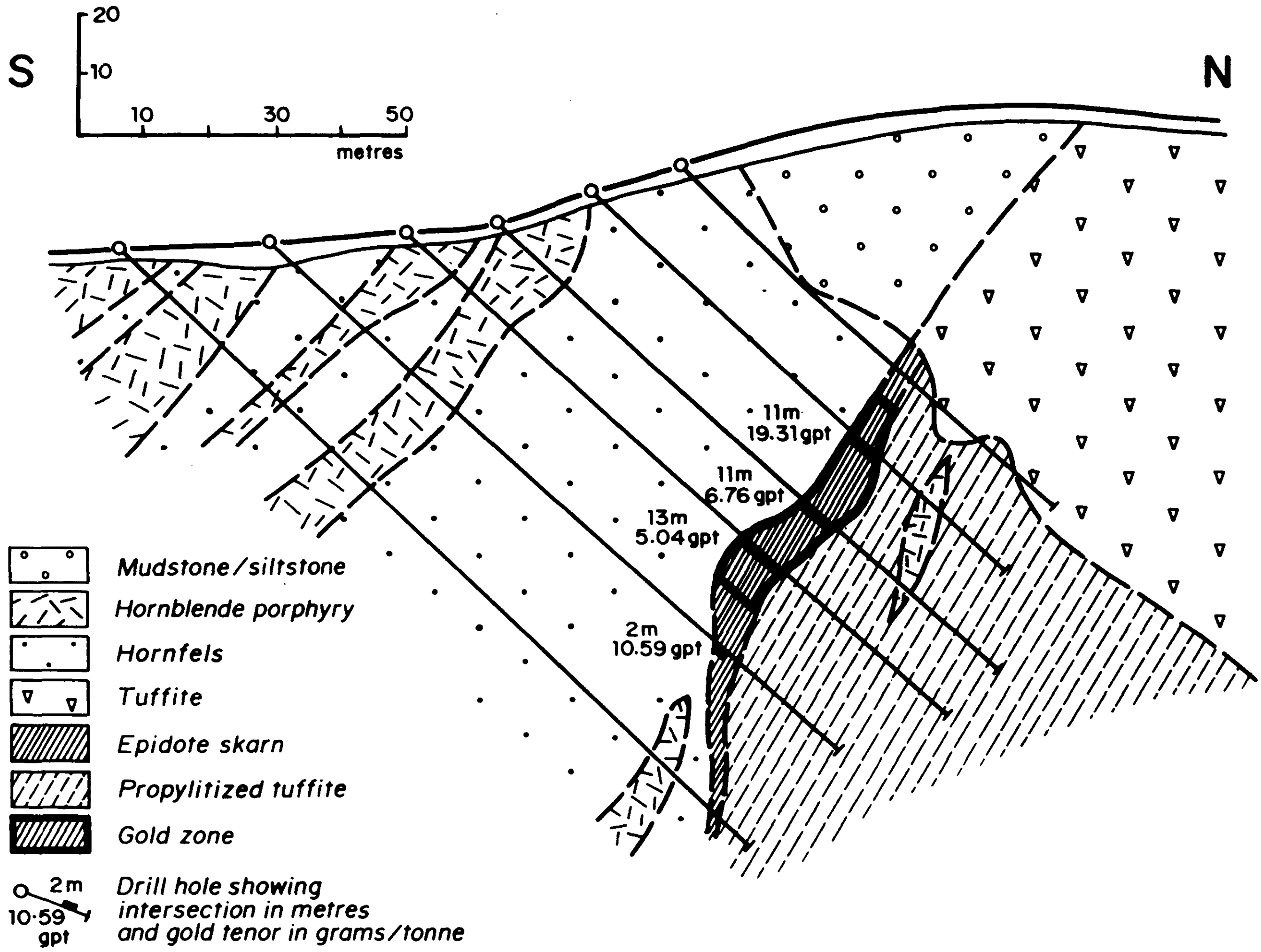

FIGURE 6. Cross-section "B" looking west through the Midwest zone deposit. Location of cross-section is shown in Figure 4.

Midwest Zone

The Midwest zone is located 300 m west of the Main zone. The Midwest deposit is a thick tabular body, 120 m long, 15 m thick and 80 m wide, dipping 55° south (Figs. 4 and 6). The mineralized zone lies 65 m below surface and, as with the Main and West zones, occurs within propylitized rocks at the hornfels contact. The Midwest zone is composed of propylitized tuffite with local seams of massive pyrite, pyrrhotite and trace amounts of chalcopyrite. Bands of magnetite are a minor component of sulphide-rich intervals. The Midwest deposit is separated from the Main zone by a series of northeast-striking normal faults. The intervening propylitized tuffite and garnet skarn is erratically mineralized and of low gold tenor.

Genesis

Genesis of the deposit, as discussed by Fox et al. (1987), is related to the evolution of volcanism in the Quesnel Trough, the principal features of which are summarized below.

1. deposition of basic alkaline submarine volcanic rocks from fissure-style eruptions;
2. deposition of calcareous mudstone and epiclastic sedimentary rocks during a volcanic hiatus;
3. pyrite-carbonate alteration of porous basaltic tuffite by a mixture of magmatic and sulphate-rich meteoric water;
4. intrusion of hornblende porphyry dikes (precursors of the QR stock);
5. intrusion of the QR stock during a period of intermediate volcanism;
6. formation of a contact metamorphic aureole around the QR stock and development of gold-bearing skarn and sulphide mantos within beds of calcareous tuffite along the outer edge of the contact aureole; and
7. normal and reverse faulting.

Discussion

The QR gold deposit is a precious metal enriched (PME) skarn associated with dioritic rocks of alkaline affinity. An alkalis-silica plot (after Ettlinger and Ray, 1989) is given in Figure 8 in which the composition of the intrusive rocks at QR and the average composition of the Hedley intrusions at the Nickel Plate gold skarn deposit (Table I) are compared to intrusions associated with a variety of PME skarns in the Western Cordillera. The QR rocks plot in the alkalic field whereas virtually all of the other skarn-related intrusions are subalkalic. The QR skarn also differs in its mineralogical make-up. QR skarn is pyrite- and epidote-rich and is unlike the pyroxene-garnet-pyrrhotite assemblages typical of PME skarn associated with subalkalic intrusions. Arsenic and bismuth minerals, typical accessory minerals in gold skarns, are rare or absent. Plots for SiO_2, Fe_2O_3, alkalis and CaO are given in Figure 9 (modified after Ray and Webster, 1991). Silica and total Fe contents (Fig. 9a) are similar to typical skarn-related intrusions at Hedley. In terms of alkali ratios versus CaO content (Fig. 9b), the QR diorite has a higher alkali ratio (K_2O/Na_2O) and lower CaO content than the Hedley intrusions. The QR rocks also have higher Fe_2O_3/FeO ratios (average 1.02) than the Hedley intrusions (average 0.24, Table 1).

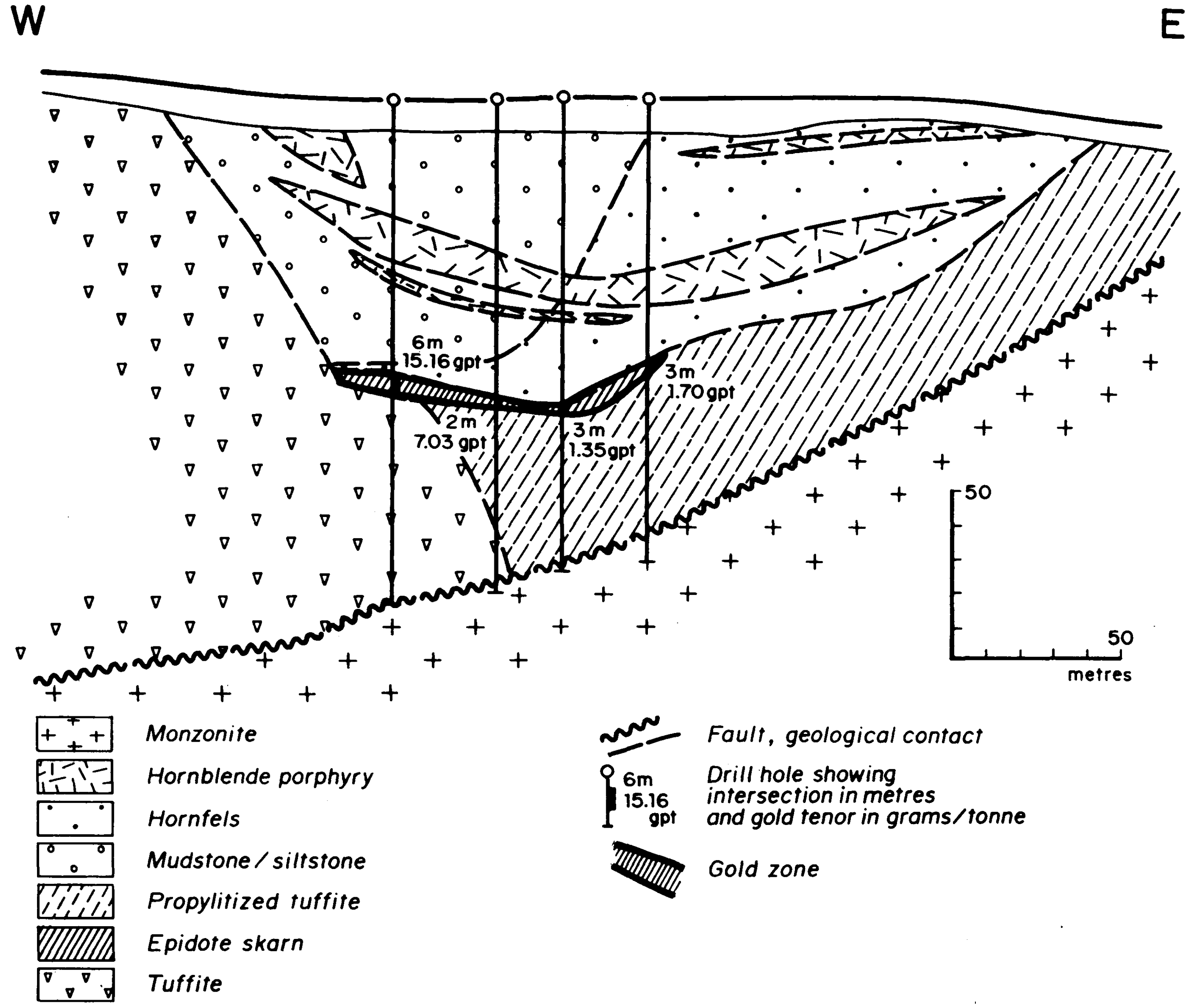

FIGURE 7. Cross-section "C" looking north through the West zone deposit. Location of cross-section is shown in Figure 4.

Carbon, oxygen and sulphur isotopes reported by Melling et al. (1990) reflect the complex history and genesis of the QR deposit as set out above. The $d^{18}O$ and $d^{13}C$ values for calcite from the host calcareous breccias and tuffs and nearby epidote skarn are similar, suggesting that source reservoirs for C and O were similar. In addition, the $d^{18}O$ values for calcite are similar to those determined for a variety of porphyry copper deposits (Taylor, 1978) and appear to be consistent with a magmatic origin. However, the $d^{13}C$ values are depleted relative to calcite associated with porphyry copper deposits. Sulphur isotopes as determined by Melling et al. (1990) differ for the skarn units and host calcareous strata. The $d^{34}S$ values obtained from pyrite from the various QR skarn units compare to average values for a large number of porphyry deposits (−5.5 to +6.5 per mil), while $d^{34}S$ values obtained from unaltered calcareous QR host rocks are typical of seawater sulphate (−6.7 to +0.2 per mil). These observations are consistent with the proposed evolution detailed above.

The QR deposit is similar in many respects to other gold-enriched skarns but differs from typical gold skarn deposits by the presence of relatively oxidized assemblages, pyrite vs pyrrhotite and epidote vs pyroxene, high Fe_2O/FeO and K_2O/Na_2O ratios, lack of arsenic and bismuth minerals, and association with alkalic intrusive rocks. Mineral assemblages at QR are typical of low temperature ferromagnesian exoskarns developed from mafic protoliths. Like many gold skarn deposits, the best gold tenors at QR occur at the skarn front or outer limit of the contact aureole where the skarn front intersects calcareous tuffite. Isotope chemistry is consistent with a magmatic source for gold and hydrothermal fluids.

TABLE 1. Major oxide analyses for samples of the QR diorite stock, QR hornblende porphyry dikes and average of Hedley intrusions. Data for Hedley intrusions from Ray and Webster (1991). Total iron (T*) reported as Fe_2O_3

	QR diorite	QR dike	Hedley intrusions
SiO	51.35	52.64	54.60
Al_2O_3	17.76	15.02	18.50
Fe_2O_3	9.38	8.98	7.90
MgO	3.68	5.31	4.00
CaO	8.20	6.96	8.60
Na_2O	3.59	4.37	3.20
K_2O	2.20	2.48	1.40
TiO_2	1.03	0.72	0.70
P_2O_5	0.40	0.38	0.18
MnO	0.18	0.16	0.14
$Na_2O + K_2O$	5.79	6.85	4.60

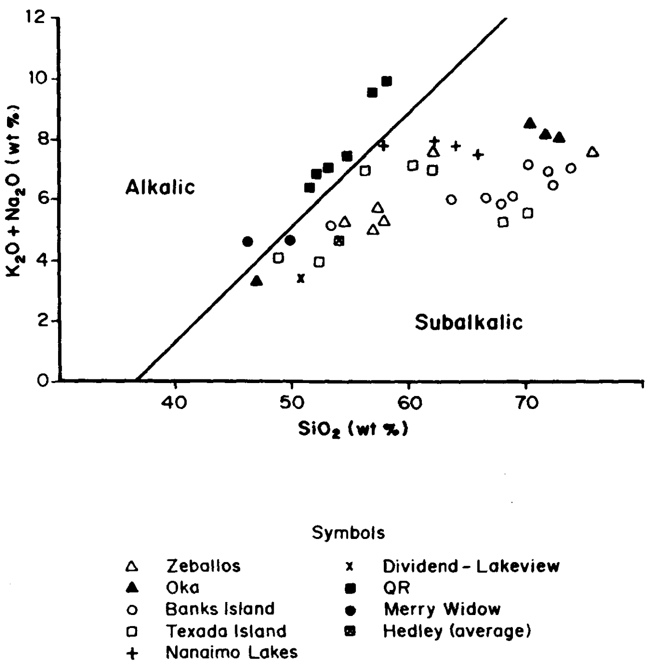

FIGURE 8. Total alkalis versus silica plot of precious metal enriched unaltered skarn-related intrusions in British Columbia including the QR diorite and hornblende porphyry dikes (after Ettlinger and Ray, 1989).

Conclusions

The QR skarn deposit is regarded as a subtype of a group of gold skarn deposits. Diagnostic features of the QR subtype are the association with alkalic intrusive rocks, relatively oxidized mineral assemblages (pyrite, magnetite, epidote), epidote-rich skarn, and formation at shallow depths in a subvolcanic environment.

Acknowledgments

The authors wish to acknowledge the management of CMP Resources Ltd. for permission to publish this paper. The authors thank Dr. D.G. Bailey, Dr. B. Smee, G. Kulla, and E.L. Faulkner for critically reviewing this paper. The authors are also indebted to Dr. G. Ray for many constructive comments and suggestions regarding Au skarn deposits. The authors thank D. Phillips for drafting the figures herein on short notice.

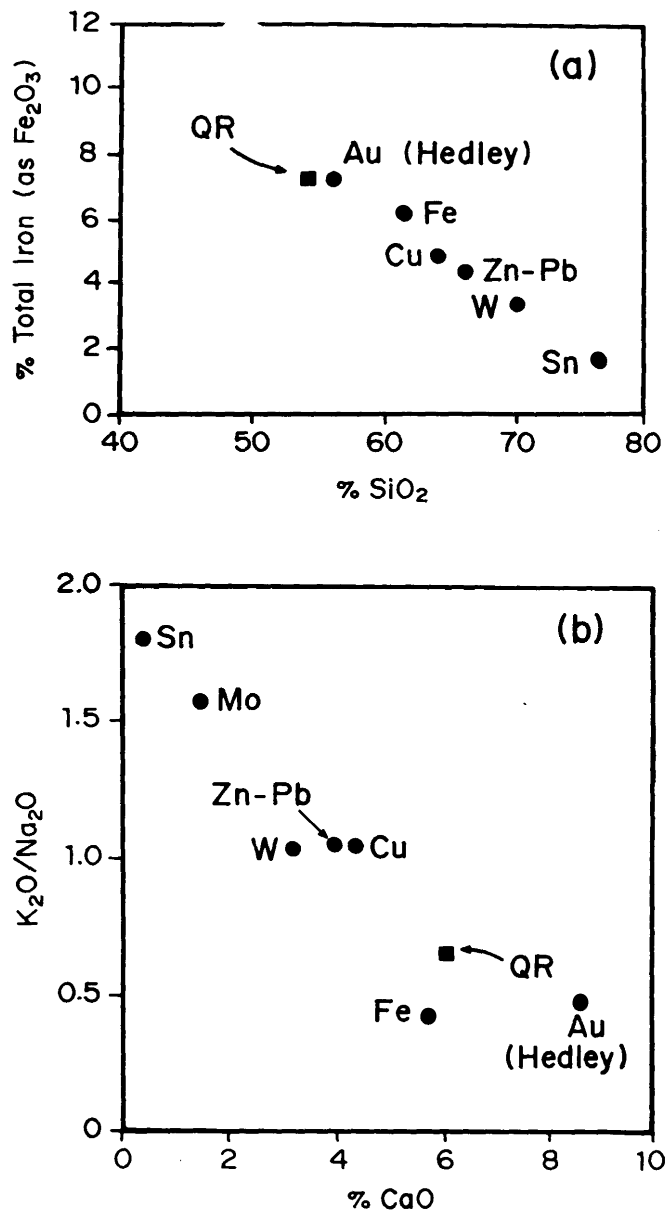

FIGURE 9. Plots using mean geochemical values of unaltered intrusions associated with various skarn deposit subclasses and including values for the QR Gold deposit (after Ray and Webster, 1991); (a) Total iron (expressed at Fe_2O_3) versus silica plot; (b) K_2O/Na_2O versus CaO plot.

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