

# ALTERATION OF FRAGMENTAL BASALTIC ROCKS: THE QUESNEL RIVER GOLD DEPOSIT, CENTRAL BRITISH COLUMBIA (93A/12W)

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## INTRODUCTION

The Quesnel River (QR, MI 93A-151) gold deposit is located in the interior plateau region of central British Columbia, about 58 kilometres southeast of Quesnel (52°40'N; 121°47'W) (Figure 2-7-1). The deposit was discovered during a regional reconnaissance program in 1977 by Fox Geological Consultants Limited for Dome Exploration (Canada) Limited. Exploration work since then has been successful in outlining reserves of 990 000 tonnes grading 7.29 grams per tonne gold in two separate zones (P.E. Fox, personal communication, 1987).

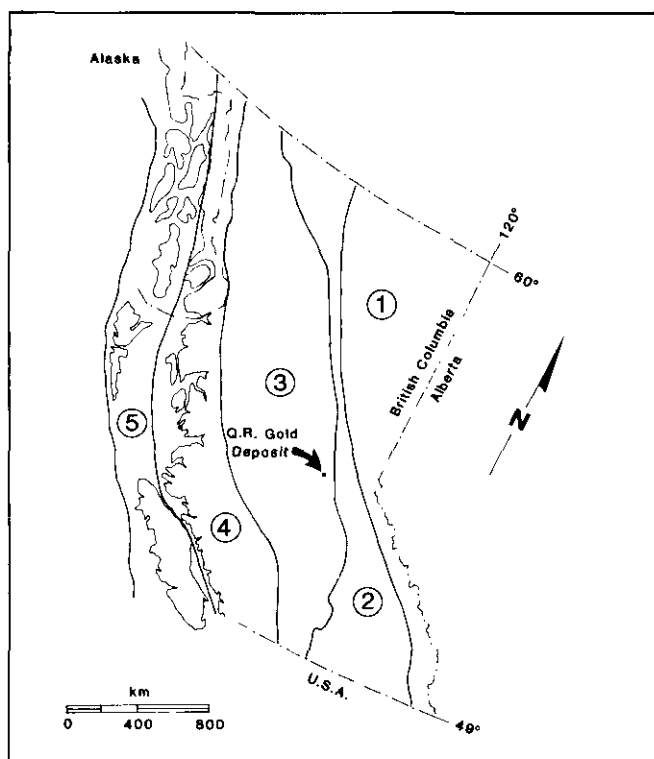


Figure 2-7-1. Location of the Quesnel River (QR) gold deposit with respect to the major tectonic subdivisions of the Canadian Cordillera: (1) Eastern Marginal Belt, (2) Omineca Belt, (3) Intermontane Belt, (4) Coast Belt, (5) Insular Belt (modified after McMillan and Panteleyev, 1980).

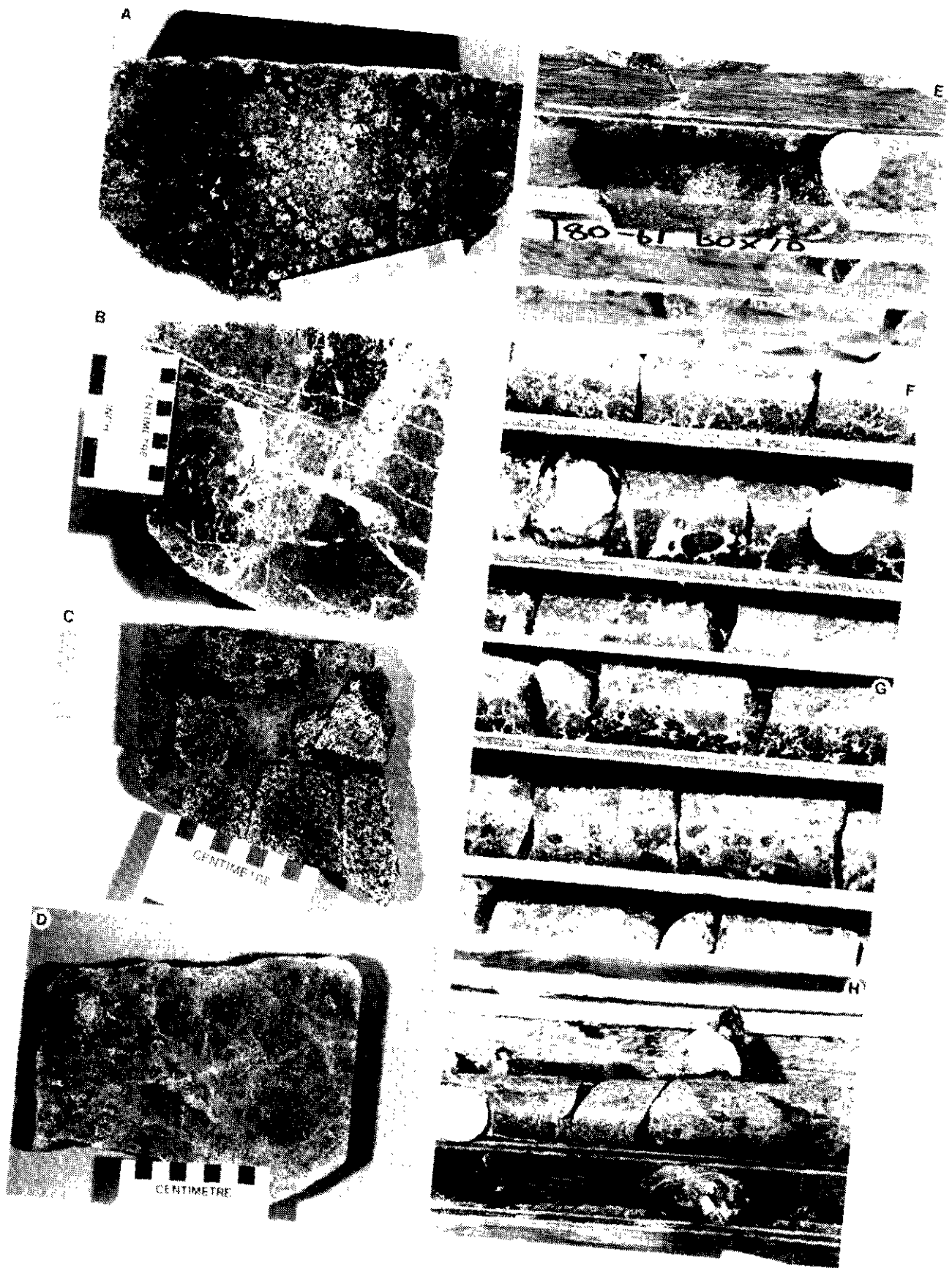
Recent geological work in the area to the east of the QR deposit includes tectonostratigraphic studies by Rees (1981, 1987), Rees and Ferri (1983), Struik (1986) and Bloodgood (1987). Bailey (1978) studied the stratigraphy and petrology of volcanic rocks to the south and Morton (1976) worked on both the volcanic and intrusive rocks and associated copper mineralization to the southeast. University theses on the QR deposit include completed studies by Melling (1982) and Zwicker (1987). Current work by the British Columbia Ministry of Energy, Mines and Petroleum Resources is focusing on the geological setting and economic potential of gold and copper-gold mineralization in the Quesnel belt (Panteleyev, 1987).

The purpose of this report is to: briefly describe the geological setting of the QR gold deposit, document the distribution and types of alteration associated with gold in the deposit, and describe the mineralogy and textures of the *principal alteration types with emphasis on those features which may be used to constrain an applicable genetic model.*

## REGIONAL GEOLOGICAL SETTING

The QR deposit is situated within the allochthonous Quesnel terrane of the Intermontane Belt near its boundary with the Omineca Belt in the Canadian Cordillera. East of the boundary, the Omineca Belt consists of Upper Proterozoic and Paleozoic psammitic and pelitic sedimentary rocks of the Snowshoe Group and deformed Paleozoic granitic intrusive rocks (Quesnel Lake gneiss) (Rees, 1981). West of the boundary the Intermontane Belt consists of Upper Paleozoic basaltic and ultramafic rocks of the Antler Formation, overlain by Lower Mesozoic phyllitic pelites (Black Phyllite) followed by basaltic volcanic, volcanoclastic and sedimentary rocks and cogenetic intrusions collectively called the Takla Group (Rees, 1987).

In the Quesnel Lake area the boundary between the two belts is marked by the west-dipping Quesnel Lake shear zone (Brown and Rees, 1981; Brown *et al.*, 1985), a thrust fault across which marked contrasts in strain and metamorphic gradients occur (Rees, 1987). This structural boundary has also been called the Eureka thrust to the north (Struik, 1986) and to the south (Bloodgood, 1987). The rocks of the Omineca Belt are highly strained by several phases of deformation and metamorphic grade increases from greenschist facies near the boundary, through garnet, staurolite-kyanite and sillimanite facies to the east (Rees, 1987). The rocks of the Intermontane Belt are at low to very low meta-



morphic grades which decrease from greenschist near the boundary (Rees, 1987) to prehnite-pumpellyite facies in the vicinity of the QR deposit to the west (Bailey, 1978). Rocks of the Antler Formation and Black Phyllite unit are strongly foliated, particularly near the Quesnel Lake shear zone. The Takla Group rocks lack evidence of penetrative deformation (Rees, 1981).

Of particular relevance to this study are a group of alkalic intrusions which form northwesterly trending linear belts, several hundred kilometres or more in length, that are largely restricted to the Intermontane Belt. The intrusions (175 to 201 Ma), typically small plugs and stocks up to a few kilometres in diameter, range in composition from syenogabbro to alkali syenite (Barr *et al.*, 1976). Based on geochemistry and age determinations, the intrusive rocks are interpreted to be essentially cogenetic with the volcanic rocks which they intrude (Barr *et al.*, 1976; Hodgson *et al.*, 1976; Panteleyev, 1987). The economic potential for porphyry copper and copper-gold deposits associated with this group of alkalic intrusions has been recognized for many years (Campbell and Tipper, 1970; Barr *et al.*, 1976); only recently are they being re-evaluated solely for gold potential with comparisons being drawn with the QR deposit. Chloritized biotite from diorite of the QR stock has been dated recently by potassium-argon at  $201 \pm 7$  million years (Panteleyev, 1987).

## LOCAL GEOLOGY

The QR gold deposit is located about 1 kilometre north of the Quesnel River on the crest of the north wall of a deeply incised river valley. The property (Figure 2-7-2) was originally mapped by P.E. Fox in 1976. Outcrop is sparse and consequently much of the geological information presented in Figure 2-7-2 is based on diamond-drilling data. The property is underlain by fragmental basaltic rocks and fine-grained sedimentary rocks, both of the Takla Group. The rock units strike east and dip moderately to the south. These rocks are cut by intrusive rocks of the alkalic QR stock.

The basaltic rocks occur as layers up to 30 metres thick which are composed of subangular to rounded, lapilli and ash-sized fragments in a fine-grained matrix (Plates 2-7-1A and 2-7-1E). Locally, block-sized fragments are also present. In general, these fragmental rocks are poorly sorted and both matrix and framework-supported types exist. Rarely, both normal and reverse size-grading of the fragments occurs. Individual beds are most commonly monolithologic and the fragments are porphyritic, consisting of phenocrysts of augite, hornblende and plagioclase in an aphanitic,

hyalopilitic groundmass. Augite (10 to 20 per cent) is subhedral to euhedral, optically zoned and up to 4 millimetres in size. Hornblende (2 to 20 per cent) is euhedral, prismatic, up to 4 millimetres in length and locally glomeroporphyritic. Plagioclase (1 to 25 per cent) is euhedral, lath shaped up to 2 millimetres in length, and locally aligned within individual fragments (Plate 2-7-1C). Amygdules, where present, comprise less than 3 per cent of the mode. The matrix consists of broken phenocrysts and very fine-grained, ash-sized particles and feldspar microlites.

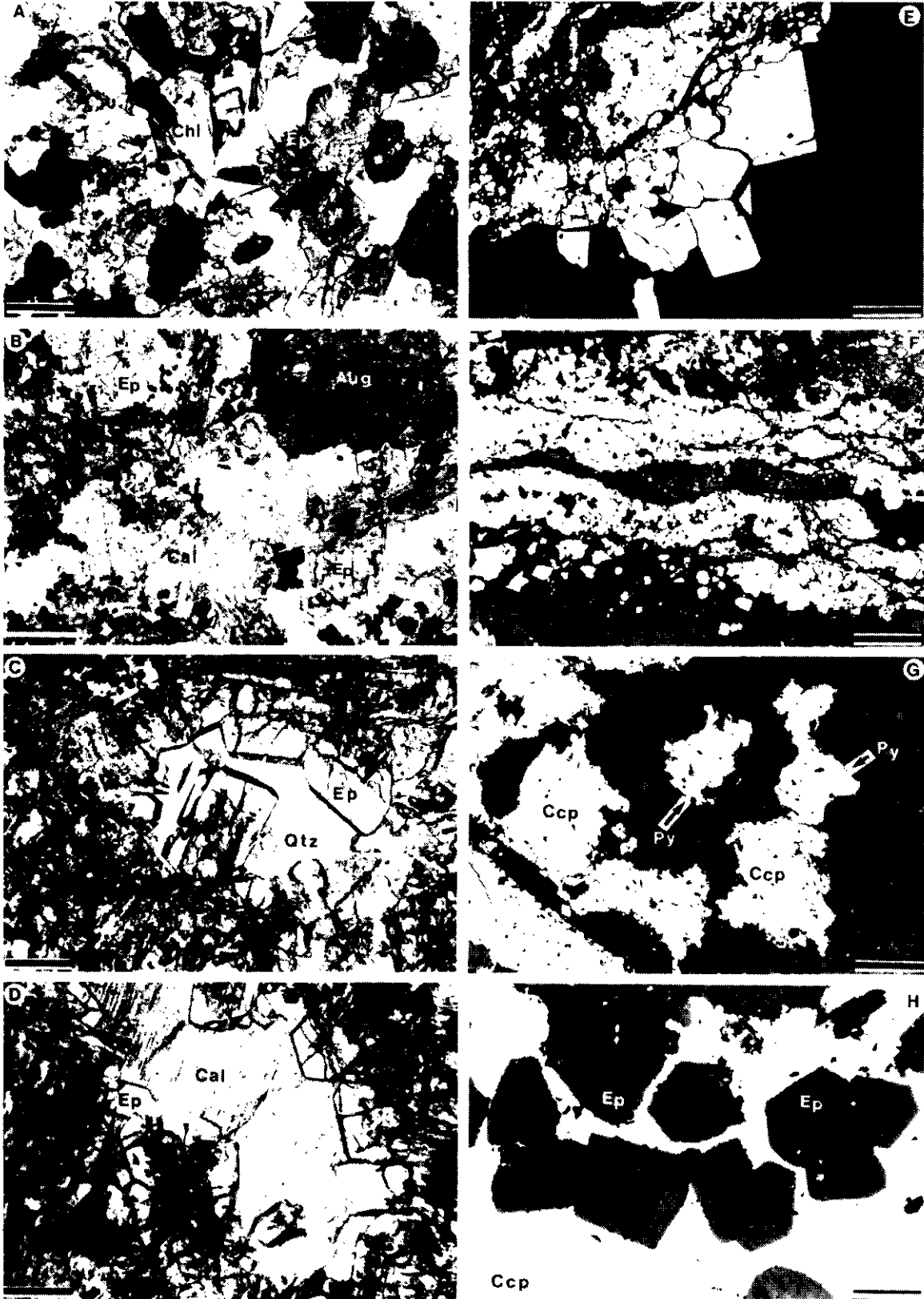
Overlying the fragmental basalts, and partially interbedded with them, is a succession of sedimentary rocks. These rocks consist of thinly bedded black argillite and siltstone. The rocks are fine grained, locally calcareous and contain up to 7 per cent fine-grained disseminated pyrite.

The QR stock intrudes both the fragmental basaltic rocks and sedimentary rocks. It is medium grained, equigranular and consists of plagioclase (50 per cent), biotite (20 per cent), augite (15 per cent), up to 10 per cent pink feldspar and variable amounts of magnetite. The stock is about 1.5 by 1 kilometre and displays a crude concentric zonation. The diorite margin of the stock is about 100 metres thick and envelops a core of monzodiorite and rare syenite (Fox *et al.*, 1987). All rocks are cut by mafic porphyritic dykes (locally termed hornblende porphyry) which are probably related to the stock. The dykes are fine grained and contain phenocrysts of hornblende (15 per cent) and plagioclase  $An_{31}$  (15 per cent) which define a trachytic texture. Country rocks near the intrusive contact are hornfelsed. The sediments are recrystallized and andradite garnet is common in the basaltic rocks.

The volcanic rocks and sediments on the property lack evidence of any penetrative tectonic fabric and structural elements are restricted to two types of faults which crosscut stratigraphy at high angles (Figures 2-7-2 and 2-7-3). The first type is characterized by several subparallel, north to northwest-striking, west-dipping normal faults which progressively lower the hangingwall to the west. The second type comprises the youngest structural features on the property. Wally's fault strikes north-northwest and dips 20 degrees to the southeast. It is a reverse fault which truncates the Main zone and displaces the hangingwall about 240 metres to the southwest. The West zone fault is a thrust which strikes northwest and dips 35 degrees to the southwest. Displacement of the hangingwall is estimated to be at least 500 metres to the northeast (Fox *et al.*, 1987). Both faults are characterized by anastomosing, foliated, chlorite-rich gouge and fracture zones.

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Plate 2-7-1. Photographs of polished slabs and diamond-drill core from the Main zone: (A) Typical, least-altered, matrix-supported, fragmental basalt. Note the porphyritic texture. (B) Strongly carbonatized, fragmental porphyritic basalt. Note the carbonate matrix which surrounds the fragments and carbonate-filled drusy cavity. (C) Weakly propylitized fragmental basalt in which the fine-grained matrix has been completely altered to the propylitic mineral assemblage. Note the large relict fragments of porphyritic basalt which contain aligned hornblende phenocrysts. (D) Strongly propylitized fragmental basalt. Note the complete absence of relict unaltered clasts and the presence of disseminated pyrite. (E) Typical, least-altered, matrix-supported, fragmental basalt. (F) Strongly carbonatized, fragmental basalt. Note the carbonate matrix which surrounds the fragments. (G) Strongly carbonatized fragmental rocks. Note the presence of both carbonate cement and carbonatization of the fine-grained basaltic matrix which surrounds the fragments. (H) Strongly carbonatized fragmental basalt containing broken fragments of colloform-textured pyrite. Carbonatization is manifested by the partial replacement of both fragments and matrix.



## ALTERATION TYPES AND GOLD DISTRIBUTION WITHIN THE FRAGMENTAL BASALTIC ROCKS

Gold concentrations occur in an alteration halo of variable intensity which extends up to 300 metres into the fragmental basaltic rocks north of the QR stock. The deposit consists of two discrete zones about 800 metres apart (Figure 2-7-2). The West zone is a tabular conformable sulphide body which occurs in propylitically altered fragmental basaltic rocks. It is underlain by variably altered propylitic rocks and overlain by bedded siltstone, argillite and, locally, weakly carbonatized

fragmental basaltic rocks. In the Main zone (Figure 2-7-3), highest gold grades occur adjacent to an abrupt, discordant alteration front between the auriferous, propylitically altered fragmental basaltic rocks and barren, strongly carbonatized fragmental basaltic rocks. The deposit is overlain by bedded siltstone and argillite and bounded to the east and at depth by the west-dipping, reverse Wally's fault (Figure 2-7-4).

Four distinct types of alteration are recognized in the rocks adjacent to, and comprising, the QR deposit. These are: weakly carbonatized, strongly carbonatized, weakly propylitized and strongly propylitized. The following discussion of the distribution of alteration types and the mineralogy and

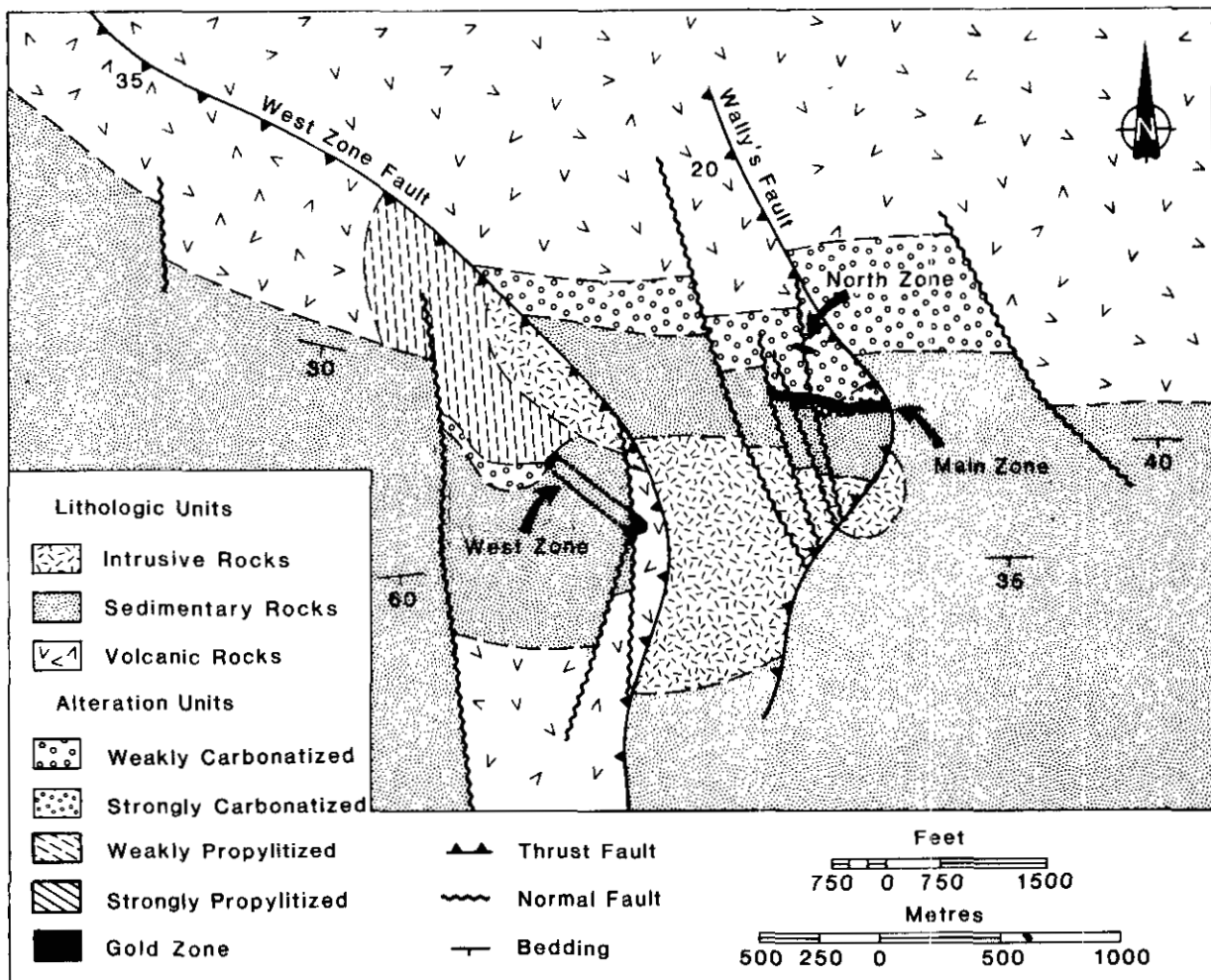


Figure 2-7-2. Geology of the Quesnel River property showing the distribution of lithologic and alteration units, structural features and the location of gold zones (modified after Fox *et al.*, 1987).

Plate 2-7-2. Photomicrographs of the mineralogy and textures in altered fragmental rocks from the Main zone. Mineral abbreviations after Kretz (1983). (A) Bowtie-textured chlorite with epidote, quartz and calcite. Sample 180-21-38.4, strongly propylitized. Transmitted light, crossed nicols. Scale bar = 0.4 mm. (B) Sparry interstitial calcite, euhedral epidote and relict augite phenocryst. Sample QR-8-108.2, strongly propylitized. Transmitted light, crossed nicols. Scale bar = 0.4 mm. (C) Euhedral epidote surrounding and projecting into interstitial quartz. Sample QR-8-37.3 strongly propylitized. Transmitted light, crossed nicols. Scale bar = 0.4 mm. (D) Euhedral epidote surrounding and projecting into sparry interstitial calcite. Sample QR-8-37.3, strongly propylitized. Transmitted light, crossed nicols. Scale bar = 0.4 mm. (E) Adjacent euhedral and anhedral-textured pyrite. Sample QR-8-24.3, strongly propylitized. Reflected light. Scale bar = 0.4 mm. (F) Banded anhedral pyrite. Sample QR-8-24.3, strongly propylitized. Reflected light. Scale bar = 0.4 mm. (G) Anhedral chalcopyrite aggregates rimmed by small euhedral pyrite grains. Sample 180-21-38.4, strongly propylitized. Reflected light. Scale bar = 0.2 mm. (H) Epidote euhedra engulfed by irregular anhedral chalcopyrite aggregate. Sample 180-21-36.1, strongly propylitized. Reflected light. Scale bar = 0.4 mm.

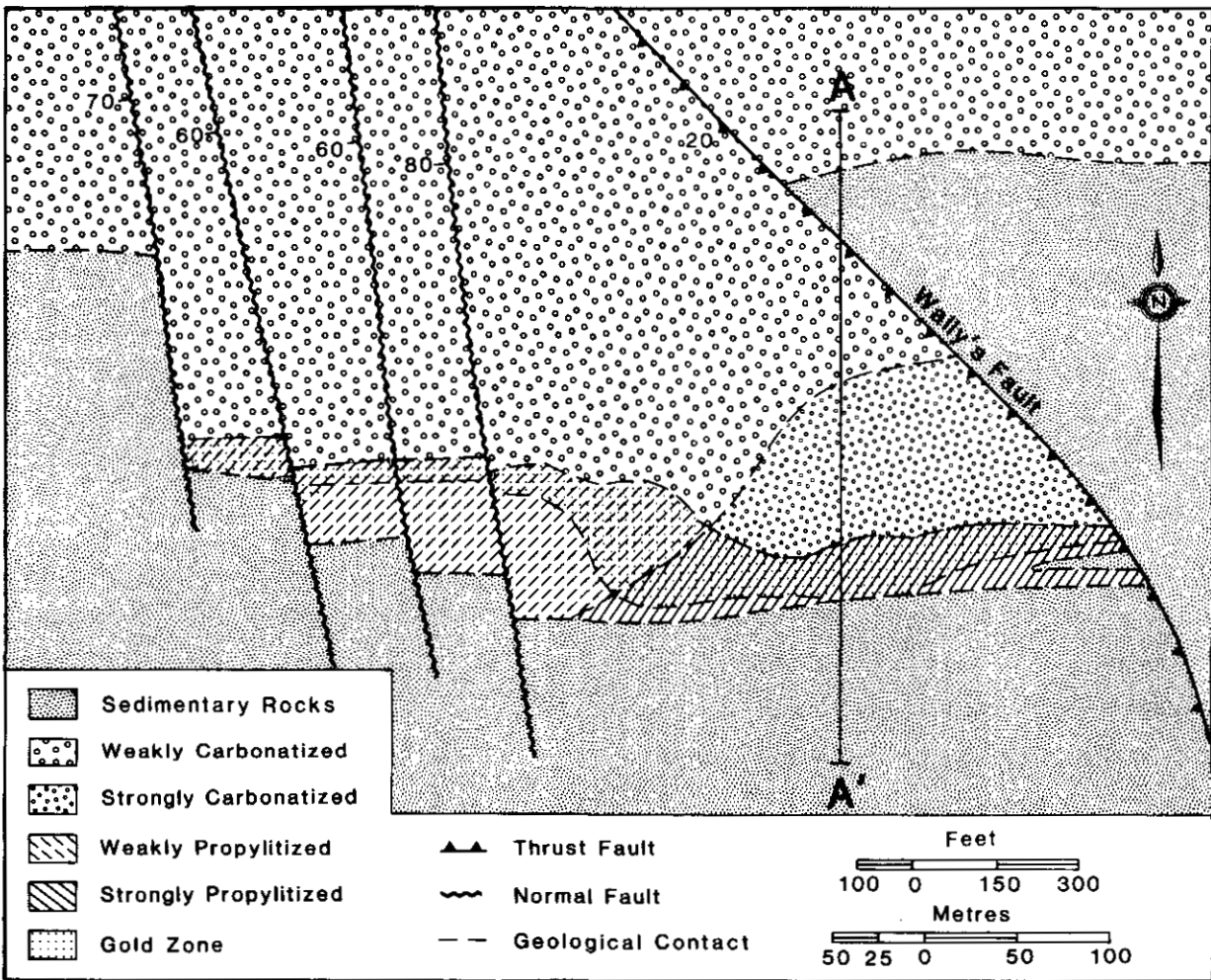


Figure 2-7-3. Geology of the Main zone of the Quesnel River (QR) gold deposit; cross-section A-A' is shown in Figure 2-7-4 (modified after Fox *et al.*, 1987).

textures which characterize them is restricted to the Main zone of the QR deposit. The mineralogy was determined optically and checked using a combination of staining techniques, X-ray diffraction and microprobe analysis.

### PROPYLITICALLY ALTERED FRAGMENTAL ROCKS

The weakly and strongly propylitized alteration types are gradational and reflect the intensity of textural and mineralogic changes of the host rocks. Their hydrothermal mineral assemblages are similar, but their modal proportions vary. Gold is associated with both types of alteration. Figure 2-7-4 illustrates the distribution of primary lithologies, alteration types, structural features and gold.

The weakly and strongly propylitized rocks form thick, interlayered, laterally extensive units which have the same attitude as the overlying and interbedded sedimentary rocks. Due to the intensity of propylitic alteration, subdivision into primary lithologic units was not possible; however, since the degree of hydrothermal alteration is always in part a function of permeability, the distribution of the propylitic alteration types is interpreted to reflect the original stratigraphy. The

strongly propylitized fragmental rocks had a greater permeability due to variations in matrix to fragment ratio, fragment size, phenocryst abundance and degree of induration.

Plate 2-7-1C is a typical specimen of weakly propylitized fragmental basalt. The matrix has been completely altered to the propylitic assemblage and reaction rims are developed around the fragments. Relatively unaltered phenocrysts of augite and hornblende persist within the fragment interiors. Plate 2-7-1D illustrates strongly propylitized fragmental basalt in which vestiges of primary fragments are obscure. The rock has a granular texture and disseminated sulphides are more abundant in this specimen.

The alteration minerals which characterize the propylitic assemblage include: epidote (50 per cent), chlorite (20 per cent), calcite (15 per cent), quartz (10 per cent), tremolite (5 per cent) and traces of clinozoisite. Epidote euhedra (about 1 millimetre in size) are optically zoned and microprobe data indicate that iron content increases systematically within individual grains from core to rim. The abundance of epidote and its uniform grain size give these rocks their green colour and granular texture at the hand-specimen scale. Epidote is an alteration product of augite, hornblende and plagioclase.



Chlorite occurs as irregular fan-shaped aggregates which display sweeping extinction (Plate 2-7-2A) and two different anomalous interference colours. Berlin blue colours are characteristic of chlorite disseminated in the silicate-rich groundmass. Iron content in this type of chlorite is high and FeO/FeO + MgO ratios average 0.65. Locally chlorite aggregates which display greenish grey birefringence are completely engulfed by sulphides. These are interpreted to have much lower FeO/FeO + MgO ratios. Chlorite replaces both augite and hornblende.

Both quartz (Plate 2-7-2C) and calcite (Plates 2-7-2B and D) form large (>2-millimetres) interstitial patches within the altered groundmass. These segregations consist of medium to coarse-grained interlocking crystals. Commonly, epidote euhedra project into or occur isolated within the interstices. Little or no iron is present in calcite. Calcite replaces augite, hornblende and plagioclase phenocrysts and microlites. Quartz is an alteration product of augite and hornblende. Tremolite occurs as curved, parallel fibrous aggregates and is probably an alteration product of hornblende.

### CARBONATIZED FRAGMENTAL BASALTIC ROCKS

The weak and strong carbonatization is also gradational and reflects variations in the modal abundance of calcite. Megascopically, the rocks locally consist of lapilli and ash-sized fragments in a coarse-grained calcite cement (Plates 2-7-1F and G). Irregular seams of calcite-cemented fragments and calcite-filled drusy cavities rimmed by fine-

grained sulphides also occur (Plate 2-7-1B). In many cases calcite occurs as a pervasive replacement of phenocrysts, groundmass and matrix where veinlets of calcite are common. In Melling's (1982) detailed petrographic study of the strongly carbonatized rocks intersected by diamond-drill hole QR-7, he subdivided them into individual stratigraphic units characterized by their phenocryst assemblages, fragment sizes and shapes, grading and fragment/matrix ratios.

In thin section the carbonatized rocks are seen to consist of vitrophyric fragments cemented by coarse interlocking calcite. Grain boundaries are distinct and crystal dimensions are a function of the sizes of the interstices. The calcite cement may comprise up to 15 per cent of the volume of the rocks. In diamond-drill hole QR-7, the carbonate-cemented fragmental rocks are restricted to the upper half of the strongly carbonatized unit (Figure 2-7-4).

Calcite also occurs in variable quantities as a replacement product of phenocrysts, groundmass and matrix to the fragments. Phenocrysts of augite, hornblende and plagioclase are altered along cleavage traces and grain boundaries. In the groundmass and the matrix, calcite occurs in fine-grained patches which display diffuse grain boundaries. Bifurcating calcite veinlets are particularly abundant in rocks lacking calcite cement. These are locally cut by veinlets containing prehnite, stilbite and calcite.

### SULPHIDE MINERALOGY

Sulphide minerals occur in all four types of alteration recognized in the Main zone, but are most common and

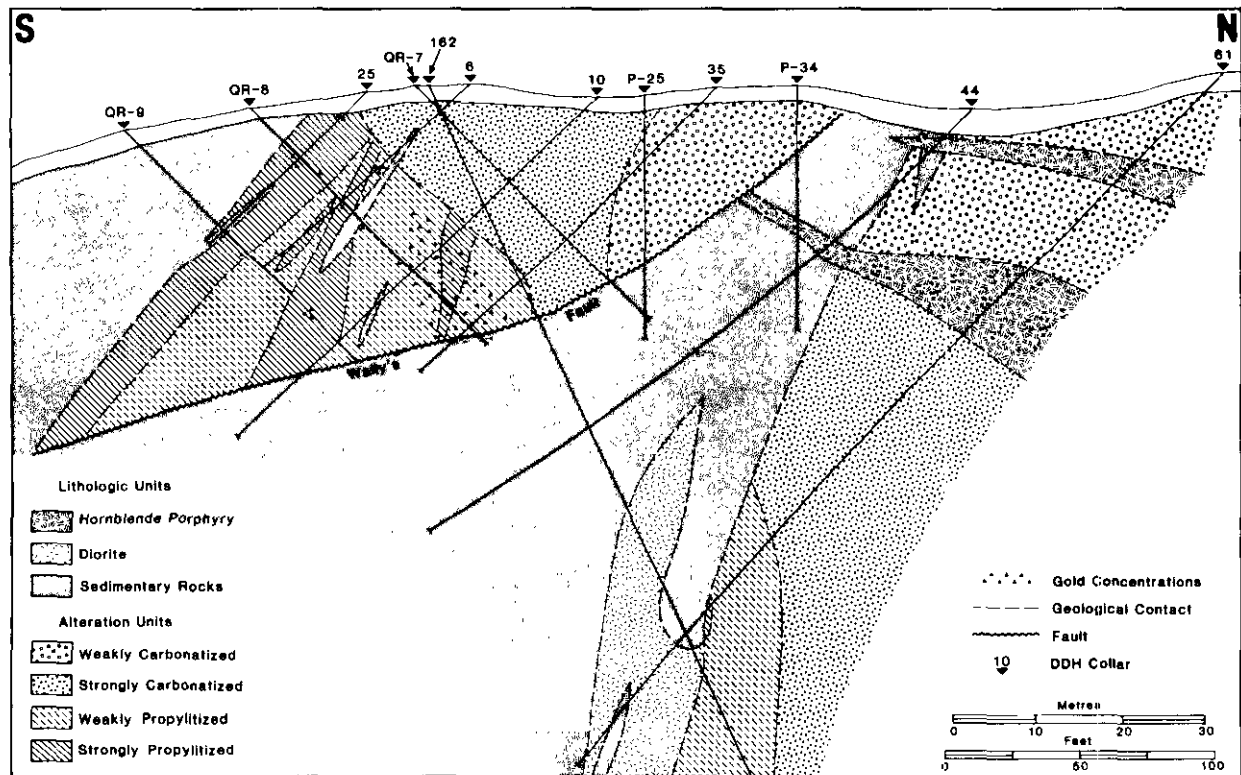
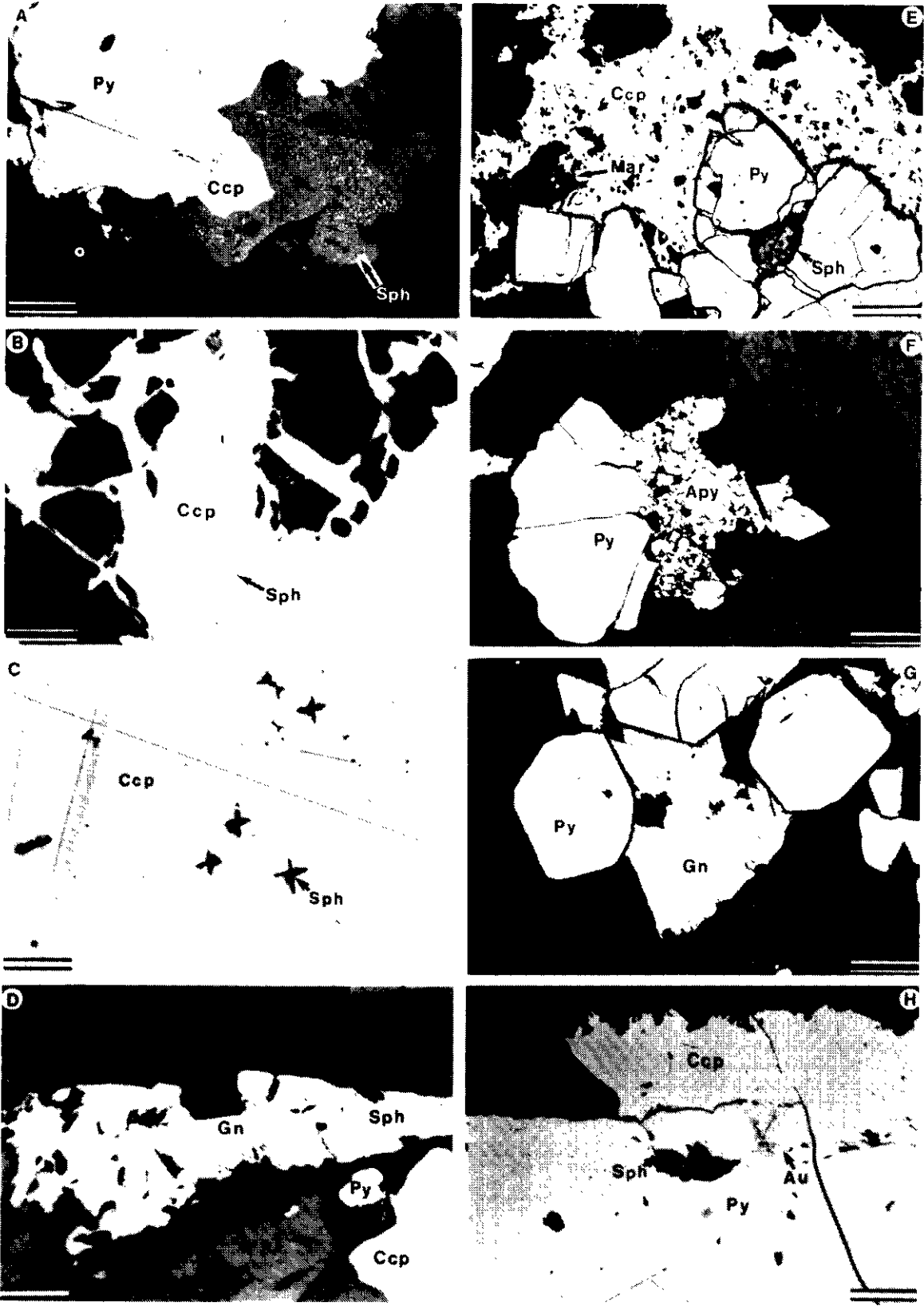


Figure 2-7-4. Cross-section A-A' looking west through the Main zone of the Quesnel River (QR) gold deposit. Location of cross-section is shown in Figure 2-7-3 (modified after Fox *et al.*, 1987).





abundant in the strongly propylitized fragmental rocks. The more significant sulphide textural relationships, which may be used to constrain the genesis of the deposit, are summarized here for both the carbonatized and propylitized fragmental rocks.

The only sulphide present in the barren carbonatized rocks is pyrite which averages 1 or 2 per cent and rarely comprises up to 7 per cent of the mode. It is common as small subhedra and euhedra homogeneously disseminated within the ash and lapilli-sized fragments. It also occurs at the grain boundaries of altered phenocrysts and rims fragments. Small bifurcating veinlets are also present.

Of particular significance are the framboidal and colloform-textured pyrite in the carbonatized rocks. The framboidal pyrite occurs as equant isolated grains, in clusters (Plate 2-7-4E) and elongate aggregates (Plate 2-7-4F). The colloform-textured pyrite grains are broken and occur at both the microscopic (Plates 2-7-4G and H) and megascopic scales (Plate 2-7-1H). These textural relationships indicate that in the carbonatized rocks, pyrite nucleation and growth occurred in extremely porous host rocks which were susceptible to additional reworking.

The propylitically altered fragmental rocks from the Main zone contain variable amounts of sulphide minerals and gold. Sulphides may comprise up to 40 per cent of the mode and include abundant pyrite and chalcopyrite, lesser sphalerite, rare arsenopyrite, marcasite, galena, pyrrhotite and gold. In the specimens studied, the sulphides typically occur in fine to coarse, irregularly shaped, ragged disseminations and clots up to 1 centimetre in size.

Pyrite comprises about 60 per cent of the total sulphides present, but locally up to 97 per cent of the mode. The smallest grains are euhedral and disseminated, while the larger grains are subhedral to euhedral, moderately fractured and tend to occur in aggregates (Plate 2-7-2E). Rarely, small veinlets of fine-grained pyrite are also present (Plate 2-7-2F). The pyrite locally contains small inclusions of gangue, chalcopyrite, sphalerite and pyrrhotite. These inclusions are generally elliptical to circular. Rare composite inclusions of *chalcopyrite/sphalerite* and *chalcopyrite/pyrrhotite* are also present. As there is no evidence to support replacement of other sulphides by pyrite, these textures are interpreted to indicate contemporaneous growth of pyrite and the included sulphides.

Smooth grain boundaries are common where epidote euhedra project into pyrite. Additional smooth and irregular mutual grain boundary relationships occur with chalcopyrite, sphalerite, galena and arsenopyrite (Plates 2-7-3A, E, F and

G). In no instance was framboidal or colloform-textured pyrite observed in the propylitically altered rocks.

Chalcopyrite locally comprises up to 40 per cent of the sulphide mode. It generally occurs in ragged, irregular grains of variable size (Plate 2-7-3E) and rarely infills fractures in pyrite. Inclusions of sphalerite are common and locally display delicate stellar and dendritic shapes (Plate 2-7-3C). Small pyrite euhedra occur disseminated within the chalcopyrite and along the perimeter of some of the larger grains (Plate 2-7-2G). Epidote euhedra commonly project into and are locally completely engulfed by chalcopyrite (Plate 2-7-2H). Sphalerite occurs as elongate inclusions within chalcopyrite adjacent and parallel to epidote grain boundaries.

Sphalerite may comprise up to 5 per cent of the sulphide mode. Small blebs and rods of chalcopyrite are very common within most sphalerite grains and rarely display crude crystallographic alignment (Plates 2-7-3A, D and H). Sphalerite is most closely spatially related to chalcopyrite, but isolated grains also occur within the silicate/carbonate gangue. Sphalerite grains which are free of chalcopyrite blebs are rare. In one case intergrowths of chalcopyrite-free sphalerite and sphalerite containing chalcopyrite blebs are present (Plate 2-7-3A). In addition, chalcopyrite-free sphalerite appears to be replacing chalcopyrite along fractures and grain boundaries (Plate 2-7-3B). These textural relationships suggest two stages of sphalerite precipitation.

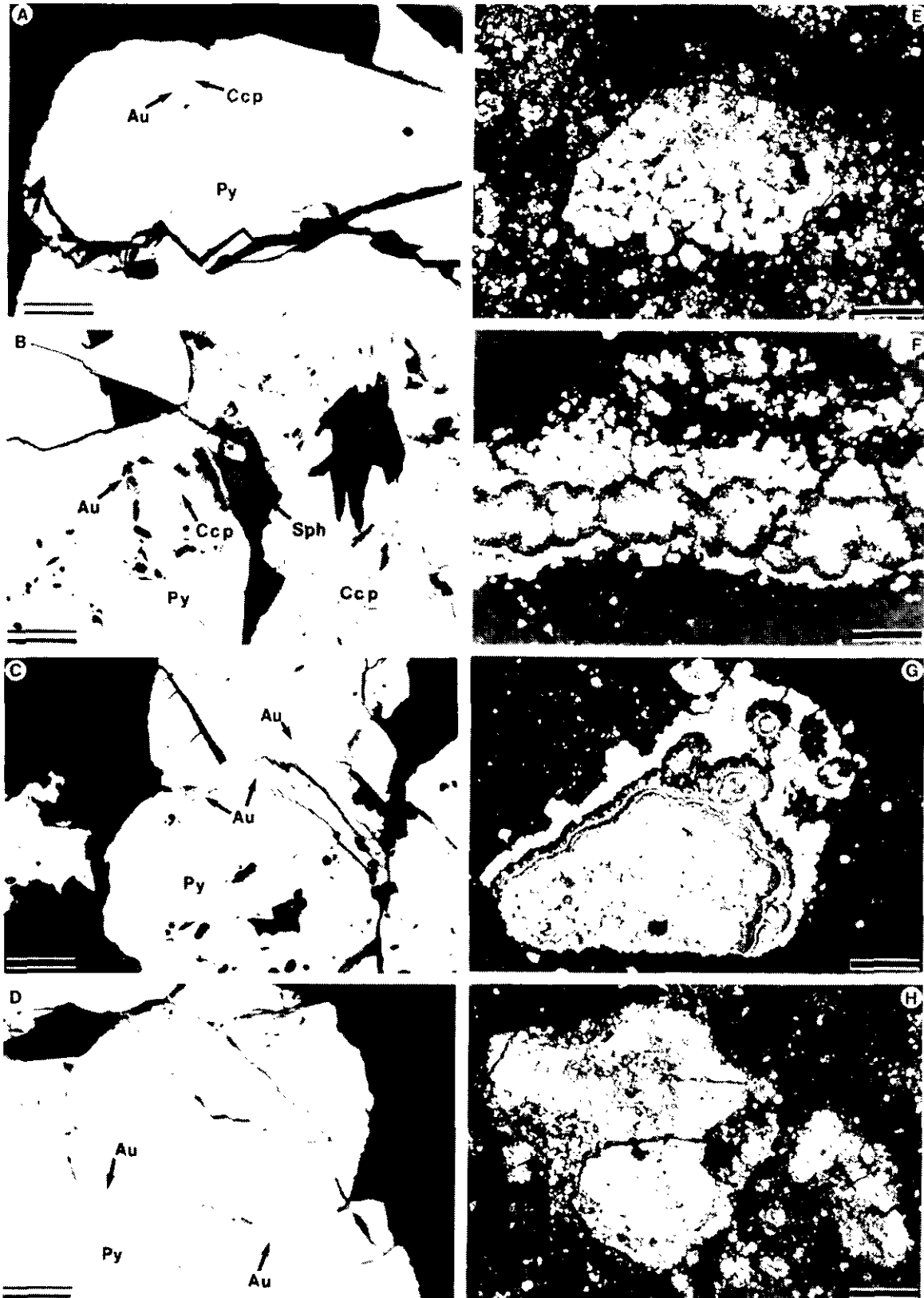
Arsenopyrite is locally present in trace quantities (<1 per cent). It occurs as inclusion-free, fractured euhedra (Plate 2-7-3F). It is most commonly associated with pyrite and either attached to it or forming adjacent isolated grains. No petrographic relationships were noted between arsenopyrite and gold although the specimens containing arsenopyrite were obtained from drill-core assay intervals grading in excess of 20 grams per tonne gold.

Marcasite occurs in trace amounts as ragged clusters adjacent to pyrite and chalcopyrite (Plate 2-7-3E). Rare, inclusion-free galena is anhedral to euhedral and most commonly associated with pyrite and sphalerite (Plates 2-7-3D and G).

Gold in sulphide-rich specimens from the Main zone has several modes of occurrence including:

- Infilling fractures in pyrite (Plates 2-7-4C and D).
- Equant inclusions in pyrite.
- Attached to pyrite grain boundaries.
- At pyrite/chalcopyrite grain boundaries (Plates 2-7-3H, 2-7-4A and B).
- Attached to chalcopyrite grains.

Plate 2-7-3. Photomicrographs of sulphides and gold in samples from the Main zone in reflected light. Mineral abbreviations after Kretz (1983). (A) Sphalerite and chalcopyrite attached to anhedral pyrite. Note the two types of sphalerite, one containing unoriented blebs of chalcopyrite and one containing no chalcopyrite inclusions. Sample 180-21-38.4, strongly propylitized. Scale bar = 0.05 mm. (B) Sphalerite replacing chalcopyrite along grain boundaries and fractures. Sample 180-21-47.4, strongly propylitized. Scale bar = 0.1 mm. (C) Stellar sphalerite inclusions in chalcopyrite. Sample 180-21-23.2, strongly propylitized. Scale bar = 0.05 mm. (D) Sphalerite, chalcopyrite, pyrite and galena. Note the unoriented chalcopyrite blebs in sphalerite. Sample 180-21-36.1, strongly propylitized. Scale bar = 0.01 mm. (E) Subhedral pyrite, chalcopyrite, sphalerite and marcasite. Marcasite is dark mottled grain on left. Sample 180-21-23.2, strongly propylitized. Scale bar = 0.04 mm. (F) Fractured arsenopyrite and pyrite. Sample 180-21-34.1, strongly propylitized. Scale bar = 0.04 mm. (G) Euhedral pyrite and galena. Sample 180-21-36.1, strongly propylitized. (H) Pyrite, chalcopyrite, sphalerite and gold. Note the unoriented chalcopyrite blebs in sphalerite and the occurrence of gold at the grain boundary between pyrite and chalcopyrite, but within the latter. Sample 180-21-38.4, strongly propylitized. Scale bar = 0.05 mm.



- Inclusions in chalcopyrite.
- Isolated grains in the silicate/carbonate gangue.

Gold grains associated with pyrite always tend to occur close to grain boundaries. These textures suggest that gold deposition occurred late in the paragenetic sequence. The gold is an unusually bright whitish yellow under reflected light. Microprobe data indicate that these grains contain about 60 weight per cent silver and are thus electrum.

## RELATIONSHIPS BETWEEN THE ALTERED FRAGMENTAL ROCKS AND THE OCCURRENCE OF GOLD

The contact between the propylitically altered and carbonatized rocks is very sharp and may be seen to occur over intervals less than 1 metre and even at the thin-section scale. This alteration front is perpendicular to bedding in the sedimentary and fragmental basaltic rocks (Figure 2-7-4). The propylitic alteration decreases in intensity to the south, away from the front; to the north carbonatization decreases toward the least altered fragmental basaltic rocks. The altered rocks are locally overlain conformably by epidote and calcite-bearing sedimentary rocks and truncated at depth by the west-dipping Wally's fault. Sulphides are more abundant in the propylitically altered rocks and pyrite is the only sulphide present in the carbonatized rocks. Gold is restricted to the propylitically altered rocks. The highest gold concentrations tend to occur adjacent to the alteration front.

## DISCUSSION

The preceding discussion of the Main zone of the QR deposit has focused on descriptive documentation of the geological setting, local stratigraphy, alteration types and their distribution, mineralogy and textural relationships. Based on the work completed and in light of published data and models for Canadian mineral deposits, particularly in the Cordillera, constraints may be placed on the origin of the QR deposit.

Carbonatization of the fragmental basaltic rocks appears to have occurred very early, prior to complete induration. The calcite cement and broken colloform-textured pyrite indicate that fluids rich in CO<sub>2</sub>, and perhaps sulphur, percolated through the volcanic pile, at depth through fracture networks and at surface through unconsolidated lapilli and ash-sized basaltic fragments. Pyrite and calcite were deposited as colloform-textured aggregates and cement in open spaces in the basaltic gravel. Carbonatization is common in many Archean gold deposits, however, it commonly displays a zonation of carbonate minerals and ankerite predominates

(Fyon *et al.*, 1983; Melling *et al.*, 1986). In addition, carbonatization in these deposits appears to have occurred at moderate crustal levels, in or near major zones of deformation (Colvine *et al.*, 1984; Roberts, 1987). Carbonatization associated with Cordilleran mesothermal lode gold deposits is also common, but is generally dominated by ankeritic or dolomitic carbonate assemblages which display a closer spatial relationship to gold (Nesbitt *et al.*, 1986). Cordilleran epithermal gold deposits do occur in the near-surface environment, however, carbonatization is not widespread and is restricted to being only one component of the outer propylitic alteration envelope.

The QR deposit is enriched not only in gold, silver and copper, but also contains significant concentrations of arsenic, zinc, molybdenum, antimony, vanadium, iron and magnesium, as shown by geochemical analyses of till samples (Fox *et al.*, 1987). These elemental associations are common in Archean and epithermal gold deposits and porphyry copper-gold deposits. In the QR deposit, copper content averages about 0.03 per cent (Fox, personal communication, 1987) and arsenic and zinc have been shown to occur in arsenopyrite and sphalerite respectively. Copper contents in porphyry deposits are commonly higher (0.4 to 1.0 per cent) and occur in much greater tonnages (20 million tonnes) (McMillan and Panteleyev, 1980). The volcanic class of porphyry copper-gold deposits has associated gold and silver (Sinclair *et al.*, 1982); however, grades of both are less than a tenth that of the QR deposit.

Gold:silver ratios in the Main zone of the QR deposit are about 1. This is lower than many Archean gold deposits (Kerrick, 1983) and much higher than in many epithermal gold and porphyry copper-gold deposits (Nesbitt *et al.*, 1986; Panteleyev, 1986).

In the QR deposit gold is most closely associated with sulphides in the propylitically altered rocks. Propylitic alteration assemblages are common in both epithermal gold and porphyry copper-gold deposits of the Cordillera; however, they generally form distal envelopes and are not spatially associated with the highest metallic mineral concentrations. Epidote-rich rocks are not commonly associated with Archean or Cordilleran mesothermal gold deposits.

Veining is extremely common within the zones of alteration in Archean mesothermal and epithermal gold deposits. Porphyry copper-gold deposits commonly have extensive fracture and crackle zones in which mineralization is surrounded by narrow alteration envelopes. In the Main zone of the QR deposit alteration is extremely pervasive and veining is minimal to absent.

The propylitic assemblage is at least spatially associated with the QR stock; however, the source of the gold-bearing

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Plate 2-7-4. Photomicrographs of sulphides and gold in samples from the Main zone in reflected light. Mineral abbreviations after Kretz (1983). (A) Gold at grain boundary between pyrite and chalcopyrite but within the latter. Sample 180-21-38.4, strongly propylitized. Scale bar = 0.05 mm. (B) Composite inclusion of gold and chalcopyrite in pyrite. Sphalerite is also present. Sample 180-21-38.4, strongly propylitized. Scale bar = 0.05 mm. (C) Gold infilling fractures in pyrite. Sample 180-21-38.4, strongly propylitized. Scale bar = 0.05 mm. (D) Gold infilling a fracture in chalcopyrite. Sample 180-21-38.4. Scale bar = 0.05 mm. (E) Equant cluster of framboidal pyrite. Sample 180-30-24.7, strongly carbonatized. Scale bar = 0.2 mm. (F) Elongate aggregate of framboidal pyrite. Sample 180-30-24.7, strongly carbonatized. Scale bar = 0.4 mm. (G) Fragment of colloform-textured pyrite. Sample 180-30-24.7, strongly carbonatized. Scale bar = 0.4 mm. (H) Colloform-textured pyrite. Sample 180-30-24.7, strongly carbonatized. Scale bar = 0.4 mm.

fluids and the timing relationships with respect to carbonatization remain equivocal. Bailey and Hodgson (1979) have demonstrated that the propylitic alteration at the Cariboo-Bell porphyry copper-gold deposit occurred in part prior to cessation of phreatic volcanism. The fragmental host rocks of the QR deposit are hydroclastic breccias formed by thermal quenching or steam explosions (Melling, 1982) and carbonatization has been shown to have occurred before induration and final reworking of the host rocks. Evidence of phreatomagmatic eruptions, which would be expected if the QR stock had intruded into such a fluid-saturated volcanic pile, are lacking.

Fox *et al.* (1987) are correct in suggesting that the alteration front developed between the propylitized and carbonatized rocks would have constituted a pronounced pH-Eh barrier at the time of gold precipitation; however, the timing relationships between these two types of alteration remain unclear. The replacement of the carbonatized rocks by the propylitic assemblage would have required the removal of massive quantities of CO<sub>2</sub>, the possibility of which remains to be demonstrated.

Future work will focus on isotopic study of the propylitically altered and carbonatized rocks from the Main zone. Calcite and pyrite samples from both types of alteration have been submitted for sulphur, carbon and oxygen isotopic analyses. These data will be used to constrain the possible sources of various components in the alteration system and the respective roles of meteoric, magmatic and seawater in the genesis of the deposit. These data may also be useful in documenting the timing relationships between the two types of alteration. The temporal relationships of the alteration types and the subjacent alkalic QR stock remain equivocal and will be the subject of further investigation. Study of the West zone deposit will also be initiated.

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