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Precious Metal Vein Mineralization in the Doctors Point, Harrison Lake Area, Southwestern British Columbia, and its Relationship to a Regional Belt of Tertiary Plutonism

by

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ABSTRACT

A belt of Tertiary plutonism that extends southwards from British Columbia into Washington State is associated with 13 widely separated areas of vein-hosted gold mineralization. The most northerly mineralized area lies adjacent to the Harrison Lake fault at Doctors Point, where a Cretaceous, arc-related supracrustal sequence is intruded by several small plutons of diorite to quartz diorite composition and calcalkaline affinities. The pluton margins are spatially associated with numerous shallow-dipping, gold-bearing, sulfide-rich quartz veins that are enveloped by zones of sericite-quartz-chlorite alteration. K/Ar dating indicates that the plutons were emplaced between 23 and 25 Ma ago and that the late hydrothermal vein mineralization occurred c. 22.7 Ma. The veins were controlled by sets of cone sheet fractures developed during the forcible intrusion of the mid-Tertiary plutons. The micron-sized gold is mainly enclosed within the pyrite and arsenopyrite; trace amounts of chalcopyrite, molybdenum, galena, tetrahedrite, sphalerite, argentite, native bismuth and lead-bismuth sulphosalts are also generally present. Mineralization is associated with geochemical enrichments in gold, silver, arsenic, antimony, zinc, mercury, copper, bismuth, iron and potassium; destruction of the host rock feldspars and ferromagnesian minerals during mineralization

has resulted in a geochemical depletion in magnesium, calcium, sodium and strontium.

Other mineralized areas related to the Tertiary plutonic belt includes the RN mine mineralization situated 45 kilometers south of Doctors Point, where small diorite intrusions host quartz-vein stockworks containing visible gold. K/Ar dating indicates the intrusions and related gold mineralization were essentially synchronous with that at Doctors Point. Further south, satellite stocks to the Tertiary Mount Barr and Chilliwack batholiths are spatially related to 11 areas of vein-hosted gold mineralization, two of which were producing mines.

Overall, this Tertiary vein mineralization is associated with relatively small stocks of dioritic composition. The gold varies from coarse, free and quartz-hosted to micron-sized inclusions within the sulfides. Regionally, the morphology, sulfide content and geochemistry of the veins are highly variable but in most veins the gold is characteristically associated with bismuth tellurides in trace quantities.

Introduction

The northwest-trending Harrison Lake fault system, situated approximately 100 kilometers east-northeast of Vancouver, B.C. (Figure 1) is associated with regional hot spring activity and sporadic precious metal mineralizaton (Ray et al, 1984; 1985); this includes fracture-controlled mineralization at the Providence and RN mines (Figure 1) where very small production has been reported. In the late 1970s, gold-silver-rich vein mineralization was discovered at Doctors Point, on the southwest shore of Harrison Lake, approximately 45 kilometers north-northeast of Harrison Hot Spring. In 1981-1983 Rhyolite Resources Inc. initiated a drilling and exploration program in the area. This paper describes the geology of the Doctors Point area and presents analytical and radiometric data which provide an insight into the age, controls and geochemistry of the auriferous mineralization. It also outlines the relationship between the Doctors Point mineralization and a belt of Tertiary plutonism and associated gold-bearing veins elsewhere in the region.

Regional Geology

The Harrison Lake fault system is a major dislocation exceeding 100 kilometers in length which passes through Harrison Lake (Figure 1). It separates contrasting geological regimes (Roddick, 1965; Monger, 1970). To the northeast are highly deformed, largely supracrustal rocks that were originally called the Slollicum Series (Crickmay, 1925, 1930) but which have recently been termed the Slollicum package (Monger, 1986). These schistose rocks are penetratively deformed and regionally metamorphosed in the greenschist to lower amphibolite facies; they may be metamorphosed equivalents of the Upper Triassic Cadwallader Group (Monger, 1986).

With the exception of the Chilliwack-Cultus package which outcrops south of the lake (Figure 1), most of the rocks on the southwest side of the fault are younger, less deformed and of lower metamorphic grade. They include a variety of volcanic, volcaniclastic and sedimentary rocks of largely Jura-Cretaceous age, as well as some intrusive plutons and migmatites. To the southwest, the Lower to Middle Jurassic Harrison Lake Formation (Crickmay, 1925; Arthur, 1986) comprises a sequence of intermediate to acid volcanic flows and pyroclastics that hosts the Seneca massive sulfide deposit (Watanabe, 1974; Urabe et al, 1983). These rocks are overlain by Middle to Upper Jurassic sediments and tuffs of the Mysterious Creek and Billhook Creek Formations which in turn are unconformably overlain by a sequence of Lower Cretaceous rocks. A thin, lowermost portion of this Cretaceous sequence is occupied by sediments of the Peninsula Formation; these pass conformably upwards into tuffs, sediments and volcanics of the Brokenback Hill Formation which probably ranges from Upper Valanginian to Middle Albian in age (Ray et al, 1985; Arthur, 1986). The upper portion of this formation underlies the Doctors Point area where it is intruded by several diorite to quartz diorite plutons (Figure 2) which are spatially and temporally related to the auriferous vein mineralization which is the subject of this paper.

The old Providence mine is situated approximately 5 kilometers south of Doctors Point (Figures 1 and 3). It includes both gold-bearing quartz veins and gold-poor, silver-rich quartz-carbonate veins which outcrop close to the Harrison Lake shoreline. Minor gold production was reported from the quartz veins at the turn of the century (B.C. Ministry of Mines Annual Reports; 1897, 1901) but no details on their mineralogy, geology or precise location are available. The silver-rich veins are described by Ray et al (1985); they are hosted in basaltic flows and tuffs of the Brokenback Hill Formation and form steeply dipping structures up to 0.7 meters thick that comprise a carbonate-sulfide matrix containing brecciated quartz vein fragments. The predominant sulfides are sphalerite and silver-rich galena, with minor pyrite, chalcopyrite and bornite. Analyses indicate the mineralization is rich in silver, antimony, arsenic and mercury, but no gold is reported (Ray et al, 1985).

The Harrison Lake fault is associated with a deformation zone 1 to 2 kilometers wide, marked by an intense slaty cleavage and linear stretch fabrics (Arthur, 1986). The fault has undergone a long history of recurrent thrust, strike-slip and normal fault movements which ended prior to the development of the Fraser fault system in the Eocene (Monger, 1986).

Geology of the Doctors Point area

The geology of the Doctors Point area is shown in Figures 2 and 3 together with the location of various geochemical and radiometric samples. The Brokenback Hill Formation between Doctors Point and the Providence mine comprises a northeasterly dipping, variable package of volcaniclastic, volcanic and sedimentary rocks. Bedding-cleavage intersections indicate that the entire section occupies the northeastern limb of a major northerly-trending anticline; there is no evidence of structural repetition and graded bedding shows the sequence is not tectonically inverted. Consequently the rocks between the Providence mine and Doctors Point areas are considered to form part of a continuous, north to northeasterly younging sequence. Volcanic flows and tuffs are more abundant in the lower, more southerly part of the section while north of Doctors Bay in the upper part of the succession, flows are rarer and sedimentary and volcaniclastic rocks predominate. The sediments include massive to slaty black argillites, as well as volcanic sandstones and thinly bedded siltstones that locally display well defined grading. Thin beds of conglomerate are also present; southwest of Doctors Bay a coarse polymictic conglomerate contains angular to subrounded clasts of assorted volcanic, limestone and bedded sedimentary rocks, up to 0.6 meters in diameter. Some sedimentary rocks contain argillite rip-up clasts and display evidence of soft-sediment deformation, load casting and chaotic slumping. These variable sedimentary features suggest that the Brokenback Hill Formation was deposited during alternating episodes of low and high energy sedimentation and periodic explosive volcanic activity.

The volcaniclastic rocks vary from massive to thinly bedded crystal-lithic tuffs and lapilli tuffs through to chaotic, coarse volcanic breccias containing abundant angular to subangular clasts up to 15 centimeters in diameter; most of the clasts are of volcanic origin and of basalt and andesite composition, although rare fragments of dacitic material are present in the upper parts of the volcaniclastic succession. The mafic aquagene breccias are characterized by rounded clots of carbonate rimmed with epidote, and most of the tuffs and flows are highly chloritised.

The highly altered volcanic rocks are generally massive, and pillowed flows have only been identified close to the Providence mine, where the individual,vesicular pillows reach 25 centimeters in diameter. In thin section the more mafic flows are seen to contain highly altered remnant crystals of augite up to 4 millimeters in length which subophitically enclose interlocking lathes of andesine-labradorite plagioclase. Alteration products include chlorite, epidote, tremolite-actinolite and hornblende. Some basaltic rocks with abundant coarse plagioclase phenocrysts up to 0.5 centimeters in diameter probably represent subvolcanic intrusions.

A south to north change in both the appearance and chemical composition of the volcanic and tuffaceous rocks is noted in the area. In the southern, more basal section the volcanic rocks are very dark coloured and geochemical analyses (Table 1) indicate they mostly represent subalkaline basalts that possess tholeiitic to transitional calcakaline affinities (Figures 4A, 4B and 5).. In the higher part of the sequence however, towards Doctors Bay (Figure 2), the volcanic and volcaniclastic rocks are very light grey in color and generally silicious; these pale colored rocks were originally mapped as dacites by Ray et al (1985) but geochemical analyses indicate they are subalkaline andesites (Figures 4A and 5). The south to north variation in composition probably marks an original progressive temporal change from basaltic to andesitic volcanism due to differentiation, rather than being the result of later alteration developed during the emplacement of the diorite plutons at Doctors Point. A discrimination plot (Figure 6) shows the basaltic rocks largely represent low potassium island-arc tholeiites.

The supracrustal rocks in the Doctors Point area are intruded by at least five plutons that range from diorite to quartz diorite in composition; geochemical analyses (Table 2), indicate they are subalkalic, calcalkaline intrusions (Figures 7A; 7B).The plutons range in size from the 30-meter-wide Island pluton which outcrops on the small island in Doctors Bay through to the large, incompletely mapped Doctors Point pluton further north (Figure 2); the latter body is notable for its higher quartz content and for the presence of rounded mafic xenoliths which are rarely present in the other four smaller bodies. The three remaining bodies, the Nagy, Doctors Bay and Peninsula plutons (Figure 2) form sub-circular masses between 50 and 500 meters in diameter with highly irregular margins.

The fresh diorite is generally grey colored and massive textured, but the western margin of the Peninsula pluton (Figure 2) exhibits a vertically inclined, rhythmic compositional layering consisting of subtle, diffuse concentrations of light and dark minerals. There are no sharp boundaries between the individual layers which are mostly regular and vary from 1 to 2 centimeters in thickness.

Biotite is the most widespread mafic mineral in the plutons but hornblende may exceed 20 per cent by volume in the more mafic diorites. In thin section the rocks are seen to contain fresh, euhedral, twinned andesine plagioclase crystals up to 3 millimeters in length, with minor amounts of zoned potassium feldspar crystals. The hornblende crystals mostly pseudomorph original pyroxene, and rare remnants of augite are intermittently preserved within the amphibole. Locally the diorites contain clots and disseminations of pyrite, but this sulfide contains no gold.

The plutons are enveloped by hornfelsic aureoles, 100 to 250 meters wide, marked by intense recrystallization of the country rock. Close to the pluton margins the hornfels contains fine-grained red biotite and is characterized by silicification with some disseminated fine-grained pyrite, pyrrhotite and magnetite. The sulfides may exceed 15 per cent by volume immediately adjacent to the plutons but they do not carry gold. In rare cases, the hornfelsic rocks close to the plutons also contain cordierite, andalusite, garnet and coarse poikiloblastic biotite.

K/Ar radiometric analyses of biotite and hornblende samples collected from the Doctors Point and Doctors Bay plutons (Figure 3; Table 3) give ages ranging between 19.3 and 24.7 Ma; this suggests the plutonism at Doctors Point is mid-Tertiary in age and occurred after the final pre-Early Tertiary movements along the Harrison Lake fault. Field evidence suggests that the emplacement of the elongate Doctors Point pluton, which extends across to the northern shore of Harrison Lake was partly controlled by northerly to northwesterly striking fractures that crosscut and postdate the Harrison Lake fault (J.W.H. Monger, personal communication, 1988).

Mineralization

The gold-silver mineralization at Doctors Point is hosted in long, narrow, gently dipping (10 to 35 degrees) vuggy quartz-sulfide veins. These veins show an overall spatial relationship to the margins of the diorite bodies; most are associated with the subcircular Doctors Bay pluton and generally dip towards its core (Figure 2). The veins are believed to have been controlled by a set of low-angle structures which probably represent cone sheet fractures formed during the forcible intrusion of the diorite plutons (Figures 8 and 9). Most of the cone sheet fractures are unmineralized; they form narrow (less than 3 centimeter-wide), subparallel gently inclined structures spaced from 5 to 20 meters apart, that often trend parallel to the jointing (Figure 9). Minor reverse fault movements, marked by slickensiding, occurred along the fractures prior to the mineralizing event. Locally these movements caused some diorites to override the adjacent hornfelsic rocks (Figure 9) although the offset across most fractures is generally less than 10 meters.

On surface the mineralized veins vary from a few centimeters to 1 meter in width but drilling has intersected individual veins up to 3 meters wide (Figures 10A and 10B). Locally, the mineralization forms numerous very thin veins spaced 2 to 8 centimeters apart, and some veins bifurcate and rejoin one another in a complex manner (Figure 9). They include both clear and white vuggy quartz as well as some minor feldspar and variable amounts of sericite; the vugs are lined with small euhedral quartz crystals. Pyrite and arsenopyrite are the commonest sulfides; in places the veins comprise coarse, massive sulfide material in which quartz may be subordinate or absent. Surface leaching has caused abundant boxwork textures in the sulfide-rich veins and many mineralized outcrops are coated with green scorodite ($FeAsO_4.H_2O$), an alteration product of the arsenopyrite. Locally the veins also contain minor amounts of chalcopyrite and rarely, molybdenite and galena. Analyses of mineralized outcrops (Table 4) and drill core (Figure 10B) show that the vein mineralization is sporadically enriched in gold, silver, arsenic, copper, antimony, bismuth, mercury and zinc.

Veins are traceable at surface for over 35 meters, but drilling indicates some exceed 200 meters in strike length. One outcropping mineralized zone at the northern end of the Nagy pluton (Vein No. 5, Figure 2) is traceable from the diorite into the adjacent sulfide-rich hornfels with no apparent dislocation or change in either mineralogy, grade or vein dimension. Veins have been found in at least 12 locations (Figure 2), 11 of which are underlain by either diorite or hornfelsic rocks and are generally situated close to a pluton margin. However, the southernmost vein (Vein No. 1, Figure 2) lies 400 meters south of the Doctors Bay pluton, well outside the hornfelsic aureole. Analyses on sulfide-rich samples collected from veins at 10 of the 12 known mineralized localities are shown in Table 4. The mineralized veins close to the pluton margins generally show high values of arsenic, gold and silver with silver:gold ratios ranging from 1:1 to 10:1; lead and zinc are present only in trace amounts. By contrast, the southernmost, more distal mineralized vein, which lies outside the hornfelsic aureole, has much higher silver:gold ratios and is highly enriched in silver, lead, zinc and antimony (Table 4) as well as gold and arsenic. This vein is distinct from the other veins in containing abundant galena and tetrahedrite with the arsenopyrite. The southerly enrichment in lead, zinc, silver and antimony, and increase in the silver:gold ratios may indicate a temperature controlled mineral and element zoning in the veins away from the pluton margins.

The veins are usually enveloped by bleached alteration zones in which the primary features of the original host rock type is largely unrecognizable (Figure 10A). These zones consist mainly of a fine-grained assemblage of quartz and randomly orientated sericite with lesser amounts of chlorite, kaolinite, potassium feldspar, clinozoisite, carbonate and disseminated pyrite which is rimmed by chloritised biotite. In places the alteration envelopes carry trace amounts of gold and they vary from a few centimeters to over 3 meters in thickness. The larger zones are usually associated with the thicker veins, and the hangingwalls commonly contain wider envelopes than the footwalls. The intensely bleached zones pass gradually outwards into a broader envelope of weak kaolin alteration (Figure 10A and 10B) in which the original textures of the host rocks are recognizable. This zone may exceed 8 meters in thickness and locally contains disseminated pyrite but no gold.

Figures 10A and 10B shows a vertical drill hole through a 2.5-meter thick sulfide-rich quartz vein and its associated footwall and hangingwall alteration envelopes hosted within coarse-grained diorite; the hole was collared in the Doctors Bay pluton close to its western margin, in the vicinity of the No. 3 vein (Figure 2). The trace element enrichment of various metallic elements, including gold, associated with the vein is shown in Figure 10B, and Figure 10A demonstrates that vein mineralization is accompanied by increases in iron and potassium (represented largely by sulfides and sericite respectively) and by depletions in magnesium, calcium, sodium and strontium. The removal of the latter four elements is largely due to the breakdown of original ferromagnesian minerals and plagioclase in the diorite during the mineralizing process.

A petrographic and scanning electron microscope (SEM) study of the Doctors Point mineralization (Littlejohn, 1983) showed that the native gold is associated mainly with the pyrite and to a lesser extent with arsenopyrite. Gold forms small rounded inclusions, mostly less than 0.01 millimeter in diameter, and tends to be concentrated close to the edges of the sulfide crystals. The sulfides are cut by numerous microfractures filled with calcite, pyrite, clay minerals, native bismuth and lead-bismuth sulphosalts. The bismuth minerals are associated with argentite, and some native bismuth contains minute inclusions of chalcopyrite. Littlejohn (1983) concluded that development of the veins involved two episodes of precious metal mineralization. The first included the introduction of the sulfides, gold and quartz followed by a period of microbrecciation. The second episode resulted in the introduction of the silver-lead bismuth minerals into the microfractures.

Sericite from the intensely bleached alteration envelope adjacent to the mineralized vein in drill hole 82R-11 (Figure 10A) yielded a K/Ar radiometric age of 22.7 Ma (Table 3) which is accepted as the age of the mineralization. This date is very similar, but slightly younger than the K/Ar ages of 23.3 and 24.7 Ma obtained for the hosting Doctors Bay pluton (Table 3); it strongly suggests that the vein mineralization at Doctors Point is temporally related to the diorite plutons and represents a late hydrothermal phase of this magmatic event.

Following the deposition and deformation of the Brokenback Hill Formation which terminated with the pre-Eocene movements along the Harrison Lake fault, the sequence of events related to the mineralization at Doctors Point was (1) mid-Tertiary forcible intrusion of the diorite plutons accompanied by minor barren sulfide mineralization; (2) development of low-angle cone sheet fractures; (3) minor reverse-fault movements; (4) gold-arsenopyrite-quartz vein mineralization along some fractures; (5) microbrecciation followed by the introduction of minor silver-bismuth mineralization; (6) late subvertical faulting.

Regional Considerations

The Doctors Point mineralization is the most northerly recognised example of at least 13 vein-hosted gold occurrences that are associated with a belt of Tertiary dioritic plutonism that extends southwards for over 100 kilometers into Washington State (Figure 11). At the south end of Harrison Lake the RN mine property is underlain by deformed and hornfelsed metapelites of the Chilliwack-Cultus package (Monger, 1986) which are intruded by at least nine stocks (Bruland, 1988) that are generally between 50 and 1000 meters in diameter and of quartz diorite composition. Gold is hosted in white quartz veins and stringers that reach a maximum thickness of 0.3 meter and which are mainly developed in the intrusions. The veins form several variably orientated sets as well as closely spaced stockworks developed in crackle breccias. These stockworks generally comprise gently incline veins between 1 and 10 millimeters in thickness that steepen with depth. The veins contain pyrrhotite and pyrite, lesser amounts of chalcopyrite, molybdenite, carbonate, and sericite and traces of scheelite and bismuth tellurides in a gangue of white quartz. Crustiform banding of the sulfide is common in the wider veins, and gold is found either with the pyrrhotite, as visible grains up to 5 millimeters long in the quartz, or more rarely as a gold-silver-bismuth telluride (Bruland, 1988). Bruland also reports that three generations of mineralization have been identified. Initial pyrite-arsenopyrite mineralization was succeeded by pyrrhotite-chalcopyrite and finally by the introduction of marcasite, native gold and gold-silver-bismuth tellurides.

The mineralized veins at RN mine property are associated with a weak, sporadic geochemical enrichment in arsenic but there is no major enhancement in mercury. However, like the veins at Doctors Point, they contain variable amounts of sericite which is usually concentrated toward the vein margins. K/Ar analysis on hornblende suggests that the diorites at the RN mine were emplaced 25.7 Ma ago, while analysis of sericite taken from a gold-bearing quartz vein indicates that mineralization occurred 24.5 Ma ago (Table 3). This is essentially synchronous with the plutonism and auriferous vein mineralization at Doctors Point.

A similar gold occurrence is reported at the Laidlaw property (McClaren,1971), east of the RN mine about 14 kilometers southwest of Hope (Figure 11). Deformed metasedimentary rocks are intruded by several elongate diorite to quartz diorite bodies that reach 75 meters in width. These bodies are probably related to the Mount Barr batholith which lies 6 kilometers further to the south (Figure 11); this batholith has yielded K/Ar biotite ages between 16 and 24 Ma (Richards and White, 1970; Richards and McTaggart, 1976). Native gold at the Laidlaw property is hosted in two quartz vein sets that cut the diorite. These veins carry pyrrhotite, arsenopyrite, pyrite, chalcopyrite, secondary marcasite, trace bismuth tellurides and native gold (McClaren,1971).

One of the largest Tertiary plutons in the belt is the composite Chilliwack batholith which exceeds 950 square kilometers in area and straddles the International boundary (Figure 11). It yields K/Ar ages between 16 and 35 Ma (Richards and White, 1970; Richards and McTaggart, 1976; Vance, 1985) and it or its satellite stocks are spatially associated with at least 10 separate gold-bearing vein properties (Figure 11), including two former producing gold mines, the Boundary Red Mountain and Lone Jack mines. At the former mine the vitrous, milky white fissure-filled quartz veins reach 3 meters in width and are controlled by the sheared contact between an intrusive diorite body and older metasedimentary rocks. The veins contain visible gold, minor pyrrhotite, pyrite and chalcopyrite and traces of bismuth tellurides (Moen, 1969). Vein development involved two stages of mineralization. The initial introduction of the quartz and sulfides was followed by recurrent movements and microbrecciation after which the gold and bismuth telluride mineralization occurred. At the Lone Jack mine, three quartz veins up to 2 meters thick occupy fissures within phyllitic schists. No diorite is seen at the mine but the main Chilliwack batholith outcrops lie only 1.5 kilometers east of the property. The Lone Jack veins, like those at the Boundary Red Mountain mine, contain early quartz-sulfide and later gold-bismuth telluride phases of mineralization that were separated from each other by an episode of microbrecciation (Moen, 1969). The paragenesis, as determined by Lindstrom (1941), was pyrite followed in turn by pyrrhotite, chalcopyrite, bismuth tellurides and finally gold.

The remaining eight gold prospects situated close to the western margin of the Chilliwack batholith are all quartz vein occurrences; the veins at the Pierce Mountain, Slesse Creek, Quartz Mountain and Saginaw occurrences (Figure 11) are spatially associated with small dioritic bodies intruding metasedimentary rocks and the poorly exposed area surrounding the Gold Basin occurrence is underlain by quartz diorite and argillaceous sediments (Moen, 1969). The Saginaw quartz veins contain gold with disseminated chalcopyrite, pyrite and silver-rich galena, while both the Terra Alta and Lone Star gold-bearing quartz veins (Figure 11) carry bismuth tellurides.

South of the Chilliwack batholith, the belt of Tertiary plutons continues to the 47th parallel where it is represented by the Cloudy Pass pluton, the Cascade Pass stock and the Snoqualmie batholith (Grant, 1969; Figure 11); these bodies have yielded a range of K/Ar and zircon ages between 17 and 30 Ma (Curtis et al, 1961; Baadsgaard et al, 1961; Misch, 1966; Crowder et al, 1966; Tabor and Crowder, 1969, Cater, 1982). Although gold mineralization is not reported, this southern belt of Tertiary plutons are spatially associated with numerous copper occurrences (Grant, 1969; Figure 11). This, together with the Tertiary gold mineralization further to the north suggests that the southern segment of the plutonic belt has exploration potential for gold.

Conclusions

At Doctors Point on the western shore of Harrison Lake, a Cretaceous, arc-related assemblage of sediments and basaltic to andesitic volcanics and tuffs is intruded by several plutons of diorite to quartz diorite composition and calcalkaline affinities. The pluton margins and their hornfels aureoles are spatially associated with numerous shallow-dipping, gold-bearing, sulfide-rich quartz veins which are usually enveloped by narrow, bleached zones of sericite-quartz-chlorite alteration. Sericite from the alteration yields a K/Ar age of 22.7 Ma which is accepted as the age of mineralization; this is similar but slightly younger than K/Ar ages of 23.2 and 24.7 Ma obtained from the hosting plutons. Thus, the mineralization represents a late hydrothermal event related to period of mid-Tertiary magmatism, and the orientation of the veins suggests they were developed and controlled along sets of cone sheet fractures formed during the forcible intrusion of the subcircular plutons. The micron-sized gold is associated mainly with pyrite and to a lesser extent arsenopyrite; the silver-gold ratios in the veins generally range from 1:1 to 10:1. Mineralization is associated with enrichments in gold, silver, arsenic, antimony, zinc, mercury, bismuth, iron, copper and potassium, and depletion of magnesium, calcium, sodium and strontium. Variable trace amounts of chalcopyrite, molybdenite, galena, tetrahedrite, sphalerite, argentite, native bismuth, and lead-bismuth sulphosalts occur sporadically. However, one auriferous arsenopyrite-rich vein is unusual in containing abundant galena and tetrahedrite. It outcrops further from an intrusive body than any other mineralization, and is hosted by rocks well outside the hornfelsic aureole. This raises the possibility that a temperature controlled mineral and element zoning exists in the veins outwards from the intrusive contacts.

The Doctors Point mineralization is believed to form one of at least 13 gold occurrences associated with a southerly trending belt of Tertiary plutonism. However, the emplacement of some gold-bearing intrusions such as the Doctors Point pluton may have also been partly controlled by northwesterly trending cross faults. The plutonic belt can be traced for over 100 kilometers from Canada southwards into Washington State; it contains the Mount Barr and

Chilliwack batholiths whose satellite intrusions are closely associated with 11 gold-bearing vein properties, including two former producing mines. In addition, at the southern end of Harrison Lake, K/Ar analyses indicate that the RN gold mineralization occurred 24.5 Ma ago and the hosting diorite bodies were intruded 25.7 Ma ago; this is essentially synchronous with the intrusions and mineralization at Doctors Point.

Overall, the regional mid-Tertiary gold mineralization is associated with relatively small intrusions of diorite and quartz diorite composition, some of which form satellite stocks to larger batholiths. The gold is invariably hosted in massive to vuggy white quartz veins that fill tension fractures developed either within the plutons or close to the intrusive contacts where competency differences resulted in brittle, open-space fracturing. The gold varies from coarse and visible, to micron-sized gold associated with variable quantities of sulfides which include pyrite and arsenopyrite. In many areas the gold is intimately associated with bismuth tellurides and at some localities several generations of mineralization occurred during minor recurrent movements that produced microbrecciation in the veins. However, the degree of arsenic, mercury, bismuth and antimony geochemical enrichment associated with the Tertiary gold mineralization throughout the region is highly variable. Also the morphology of the individual veins is

ACKNOWLEDGEMENTS

This study formed part of a project conducted by the Mineral Deposits Section, at the Ministry of Energy, Mines and Petroleum Resources, Victoria. I wish to thank the following: S. Coombes, D.R. MacQuarrie, G. Nagy, P. Desjardin, A.J. Arthur, W.J. McMillan, T. Hoy, B.N. Church, M.A. Fournier, the management and staff of Rhyolite Resources Inc., Hanson Lake Gold Mines Ltd., and Kerr Addison Mines Ltd including J. Stewart, R.A. Dujardin, and T. Bruland. Thanks are also expressed to J.W.H. Monger and H. Tipper of the Geological Survey of Canada, to J. Harakal of the University of British Columbia Geochronology Laboratory, the staff of the British Columbia Ministry of Energy, Mines and Petroleum Resources Laboratory, J. Armitage for drafting the figures, and to B. Mordant for typing the manuscript.

varied and includes shallow-dipping structures controlled by cone sheet fracturing, stockwork and crackle breccia veinlets, and discrete, steeply dipping quartz veins injected along sheared pluton margins. Re-evaluation of the precious metal mineralization in the Tertiary plutonic belt and further exploration along its projected northern and southern extensions is recommended.

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Table 1. Analytical results of volcanic and volcaniclastic samples, Doctors Point, British Columbia

Sample No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	LOI	TOTAL	Y	Zr
RR 104	47.75	1.04	19.33	9.75	0.35	4.28	7.82	2.48	1.73	4.6	99.13	20	51
RR 105	45.69	0.93	14.95	9.99	1.01	2.39	7.41	0.80	6.65	8.7	98.52	20	45
RR 106	53.44	0.71	17.91	9.05	0.19	3.68	6.49	2.55	0.58	5.1	99.70	18	72
RR 108	46.96	1.07	18.29	10.72	0.26	5.47	11.12	2.02	0.14	3.8	99.85	20	66
RR 109	56.15	0.90	19.34	7.37	0.13	1.85	7.76	3.67	1.53	1.5	100.20	24	84
RR 115	53.40	1.42	16.06	13.19	0.34	4.13	7.35	3.19	0.54	0.9	100.52	24	66
RR 170	53.36	0.95	17.12	7.35	0.12	4.70	6.72	4.01	1.15	5.1	100.58	18	120
RR 172	56.07	0.75	17.13	7.65	0.14	3.84	7.98	2.77	0.68	2.6	99.61	16	63
RR 174	48.58	1.03	19.31	9.95	0.50	5.25	6.12	2.87	0.43	5.7	99.74	18	45
RR 175	50.69	0.81	18.47	10.12	0.17	4.73	6.84	3.38	0.58	4.1	99.89	16	39
RR 176	50.66	0.81	18.57	8.98	0.25	3.00	10.36	2.39	0.62	4.9	100.54	16	42
RR 177	52.38	1.19	19.08	9.12	0.18	3.29	7.11	4.36	0.28	3.6	100.59	20	60
RR 178	48.29	0.94	18.15	11.32	0.20	5.06	9.91	1.18	0.54	5.2	100.79	16	36
RR 175D	51.08	0.80	18.42	10.07	0.18	4.79	6.88	3.39	0.56	4.3	100.47	18	39
RR 107	59.07	0.78	16.82	6.47	0.17	3.47	5.24	2.89	0.94	4.6	100.45	26	90
RR 110	53.11	0.96	18.76	9.15	0.12	4.18	5.52	3.41	0.62	4.4	100.23	22	72
RR 111	61.82	0.79	18.06	7.32	0.13	2.09	4.07	2.79	1.14	2.5	100.71	26	100
RR 114	62.02	0.81	17.61	7.30	0.13	2.08	4.13	2.72	1.13	2.5	100.43	26	90
RR 163	62.12	1.21	17.69	8.70	0.16	1.70	2.01	2.62	1.83	2.3	100.34	42	160
RR 169	61.87	0.80	16.52	6.64	0.04	2.74	0.83	0.08	4.93	3.9	98.35	28	140
RR 171	61.01	0.86	17.16	7.27	0.06	3.67	1.49	1.00	3.25	4.1	99.87	28	130

Y and Zr in PPM; all other values in per cent.

SAMPLE DESCRIPTIONS (for locations see Figure 3)

Dark colored volcanic and tuff samples, generally of basaltic composition.

RR 104 - Mafic, vesicular, pillowed volcanic.
RR 105 - Mafic, chloritized aquagene breccia.
RR 106 - Chloritized volcanic. Ophitic textured plagioclase crystals up to 3 millimeters long; original pyroxenes replaced by chlorite.
RR 108 - Mafic volcanic. Ophitic textured plagioclase (An 62) with chloritized amphibole; minor epidote and carbonate.
RR 109 - Coarse feldspar porphyry flow or sub-volcanic intrusion. Plagioclase phenocrysts up to 5 millimeters long with minor hornblende.
RR 115 - Mafic, massive volcanic. Ophitic textures; altered amphibole.
RR 170 - Mafic, chloritized volcanic. Minor epidote.
RR 172 - Mafic crystal-lapilli tuff.
RR 174 - Crystal tuff. Abundant plagioclase crystals with minor amphibole.
RR 175 - Fresh crystal tuff. Abundant plagioclase with some augite crystals up to 5 millimeters long.
RR 176 - Chloritized crystal tuff. Abundant altered plagioclase with some augite and remnant amphibole crystals.
RR 177 - Chloritized crystal tuff. Minor epidote and carbonate.
RR 178 - Chloritized crystal tuff. Minor epidote.
RR 175D - Altered crystal tuff containing some augite crystals.

Pale colored volcanic and tuff samples, generally of andesitic compositon.

RR 107 - Altered crystal tuff with minor veinlets of tremolite-actinolite.
RR 110 - Unaltered crystal-lapilli tuff. Fresh volcanic fragments up to 8 millimeters in diameter.
RR 111 - Silicious lapilli tuff. Chloritized volcanic fragments up to 5 millimeters in diameter.
RR 114 - Weakly hornfelsed lapilli tuff with abundant andesitic volcanic clasts and rare dacitic fragments.
RR 163 - Silicious, hornfelsed crystal tuff.
RR 169 - Silicious bedded crystal tuff. Minor pyrite.
RR 171 - Silicious crystal-lapilli tuff. Abundant fresh andesite volcanic fragments.

Table 2. Analytical results of diorite and quartz diorite pluton samples, Doctors Point, British Columbia

Field No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	LOI	TOTAL
RR 118	54.21	0.76	18.74	8.12	0.12	4.93	8.29	2.69	1.27	1.8	100.93
RR 119	54.26	0.72	17.39	8.12	0.15	5.32	8.92	2.56	1.01	2.6	101.05
RR 120	58.32	0.64	18.25	7.56	0.14	4.83	8.76	2.96	1.08	1.0	103.54
RR 121	55.58	0.69	16.99	7.92	0.15	5.73	8.82	2.79	1.00	0.4	100.07
RR 122	56.40	0.65	17.67	7.21	0.14	4.45	8.08	2.89	1.08	1.2	99.77
RR 123	58.06	0.66	16.63	7.46	0.13	4.51	7.61	2.85	1.16	1.0	100.07
RR 125	54.55	0.85	18.22	8.68	0.16	4.62	8.50	3.20	0.77	0.6	100.15
RR 127	54.94	0.87	18.13	8.58	0.16	4.47	8.39	3.22	0.81	0.6	100.17
RR 157	53.36	0.77	18.59	8.22	0.12	5.14	8.76	2.61	1.29	1.6	100.46
RR 161	62.89	0.61	16.27	5.44	0.10	2.72	5.27	3.50	1.91	0.7	99.41
RR 167	55.68	0.86	18.35	8.05	0.12	3.52	7.31	3.37	1.06	1.1	99.42
RR 168	56.87	0.86	17.92	8.11	0.18	3.65	7.49	3.27	1.10	0.7	100.15

SAMPLE DESCRIPTIONS (for locations see Figure 3)

RR 118 - Doctors Bay pluton. Hornblende-biotite diorite. 15% mafics; 2-4% quartz.
RR 119 - Nagy pluton. Hornblende-biotite-quartz diorite. 15-20% mafics; 5-6% quartz.
RR 120 - Nagy pluton. Hornblende-biotite-quartz diorite. 10% mafics; 6-8% quartz.
RR 121 - Nagy pluton. Pyroxene-hornblende diorite. 15% mafics; 1-3% quartz.
RR 122 - Nagy pluton. Pyroxene-hornblende-biotite diorite. 15% mafics. 2-4% quartz.
RR 123 - Doctors Point pluton. Biotite-hornblende-quartz diorite. 8-10% mafics; 5-8% quartz.
RR 125 - Doctors Point pluton. Hornblende-biotite-pyroxene diorite. 20% mafics (mostly amphibole with minor pyroxene); 2-4% quartz.
RR 127 - Doctors Point pluton. Hornblende-biotite-pyroxene-quartz diorite. 10% mafics; trace pyroxene; 3-6% quartz.
RR 157 - Doctors Bay pluton. Hornblende-biotite diorite. 20% mafics; 1-2% quartz.
RR 161 - Doctors Point pluton. Hornblende-biotite-quartz diorite. 5% mafics; 5-10% quartz.
RR 167 - Peninsula pluton. Hornblende-biotite diorite. 10% mafics; 2-4% quartz.
RR 168 - Peninsula pluton. Hornblende-biotite diorite. 8% mafics; 2-5% quartz.

Table 3. K/Ar ages from Doctors Point and RN mine areas, Harrison Lake

SAMPLE NO.	UTM CO-COORDINATES	MINERAL	%K	Ar^{40*1}
RR 56	573100E; 5500100N	Biotite	6.91±0.02	6.268
RR 56	573100E; 5500100N	Hornblende	1.112±0.01	1.083
RR 64A	573250E; 5499950N	Sericite	8.65±0.03	7.695
RR 127	572300E; 5501600N	Biotite	7.40±0.02	5.907
RR 127	572300E; 5501600N	Hornblende	0.391±0.002	0.295
RR 54	591200E; 5465100N	Hornblende	0.19±0.002	0.1915
RR 55	591200E 5465100N	Sericite	8.38±0.13	8.021

SAMPLE NO.	COMMENTS	AGE (Ma)
RR 56	Drill core from the Doctors Bay pluton (diorite)	23.2±0.8
RR 56	Drill core from the Doctors Bay pluton (diorite)	24.7±1.0
RR 64A	Kaolin-sericite alteration halo adjacent to a gold-bearing quartz sulfide vein that cuts the Doctors Bay pluton	22.7±0.8
RR 127	Doctors Point pluton (quartz diorite)	20.4±0.8
RR 127	Doctors Point pluton (quartz diorite)	19.3±0.8
RR 54	Diorite pluton at the RN mine exploratory adit, Harrison Lake	25.7±1.0

RR 55	Gold-bearing quartz-sericite-pyrrhotite vein, RN mine exploratory adit, Harrison Lake	24.5±1.0

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[1] $x10^{-6}$cc/gm

All samples collected by G.E. Ray.

Potassium analyses completed at the British Columbia Ministry of Energy, Mines and Petroleum Resources Laboratory. Victoria, B.C. .

Argon analyses completed by J. Harakal, Geochronology Laboratory, The University of British Columbia. Vancouver. .

Table 4. Trace element analytical results of grab samples from ten mineralized veins at Doctors Point, Harrison Lake. (For vein locations see Figure 2)

Vein No.	1	1	2	3	4	4	5	6	7	8	9	10
Sample No.	28924	27851	28925	28927	28928	27855	28929	28931	28932	28933	28934	28935
Au	29	3.3	8.9	7.2	34.6	8	9.6	<0.3	12.7	26	<0.3	70
Ag	953	247	10	16	37	12	90	35	3	140	1	110
Cu	0.28%	0.21	400	200	100	0.36%	1.24%	720	40	600	100	0.17%
Pb	2.95%	5.5%	140	400	100	48	400	330	30	700	10	400
Zn	374	712	25	33	30	44	211	74	18	71	42	115
Co	<2	<2	13	7	<2	5	182	8	5	13	29	6
Mo	<6	8	8	<6	<6	7	<6	<6	<6	<6	<6	<6
Ni	<2	6	9	<2	<2	16	29	13	<2	15	18	0.11%
Sb	0.99%	3.3%	186	300	112	580	58	36	325	72	<3	0.11%
Bi	7	5	50	120	62	55	42	6	80	32	20	58
As	19.1%	8.0%	26.4%	29.6%	16.8%	5.7%	0.34%	3.16%	25.4%	0.41	70	14.0%
Hg	1308ppb	534ppb	44ppb	54ppb	321ppb	710ppb	44ppb	35ppb	120ppb	40ppb	70ppb	1240ppb

All values in ppm except where stated as per cent or ppb

Analytical methods used for data in Tables 1, 2 and 4 and Figures 10A and 10B

Major elements by Flame AAS with a precision of 0.75% relative standard deviation.

~~CO_2 by Leco Induction furnace, volumetric~~.

Ag, Co, Cu, Mo, Pb, Zn, As, Sb, Bi, Ni and Sr by Flame AAS.

Hg by cold vapour/AAS. ✓

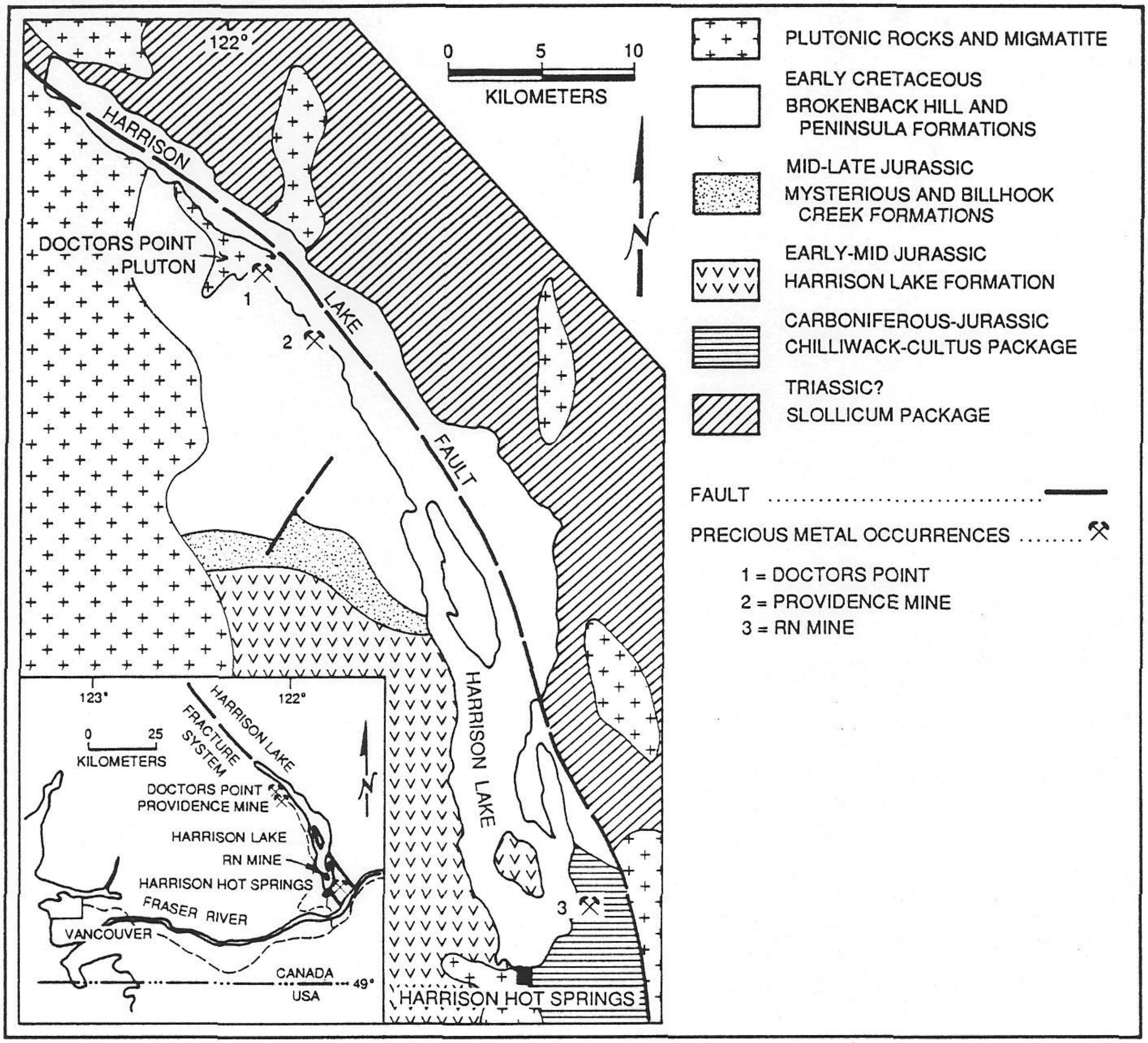
Au. ppm = Fire assay and gravimetric finish; ppb = Fire assay and AA finish.

LOI calculated by heating predried samples to 1050°C for 2 hours.

Y and Zr by XRF.

Y and Zr analyses completed by X-Ray Laboratories Ltd, Don Mills, Ontario.

All other analyses completed at the B.C. Ministry of Energy, Mines and Petroleum Resources Laboratory, Victoria.



1

Figure 1: Regional geology of the Harrison Lake area showing the locations of the Doctors Point and RN mine gold mineralization (adapted after Roddick 1965, Monger 1970, 1986, and Arthur 1986).

X Yes

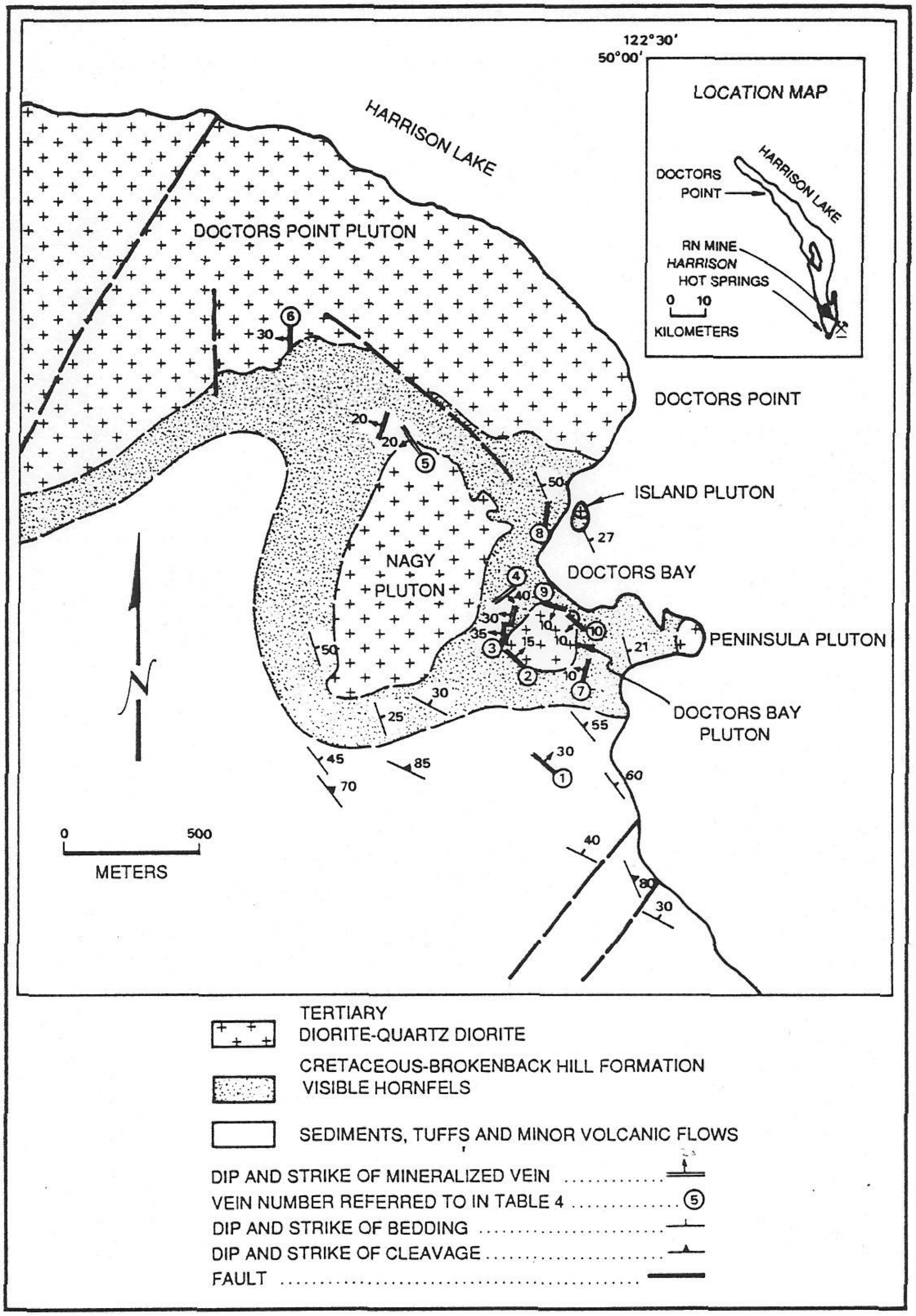


Figure 2: Geology of the Doctors Point area showing locations of the auriferous veins in relation to the intrusive plutons (After Ray et al 1984)

2

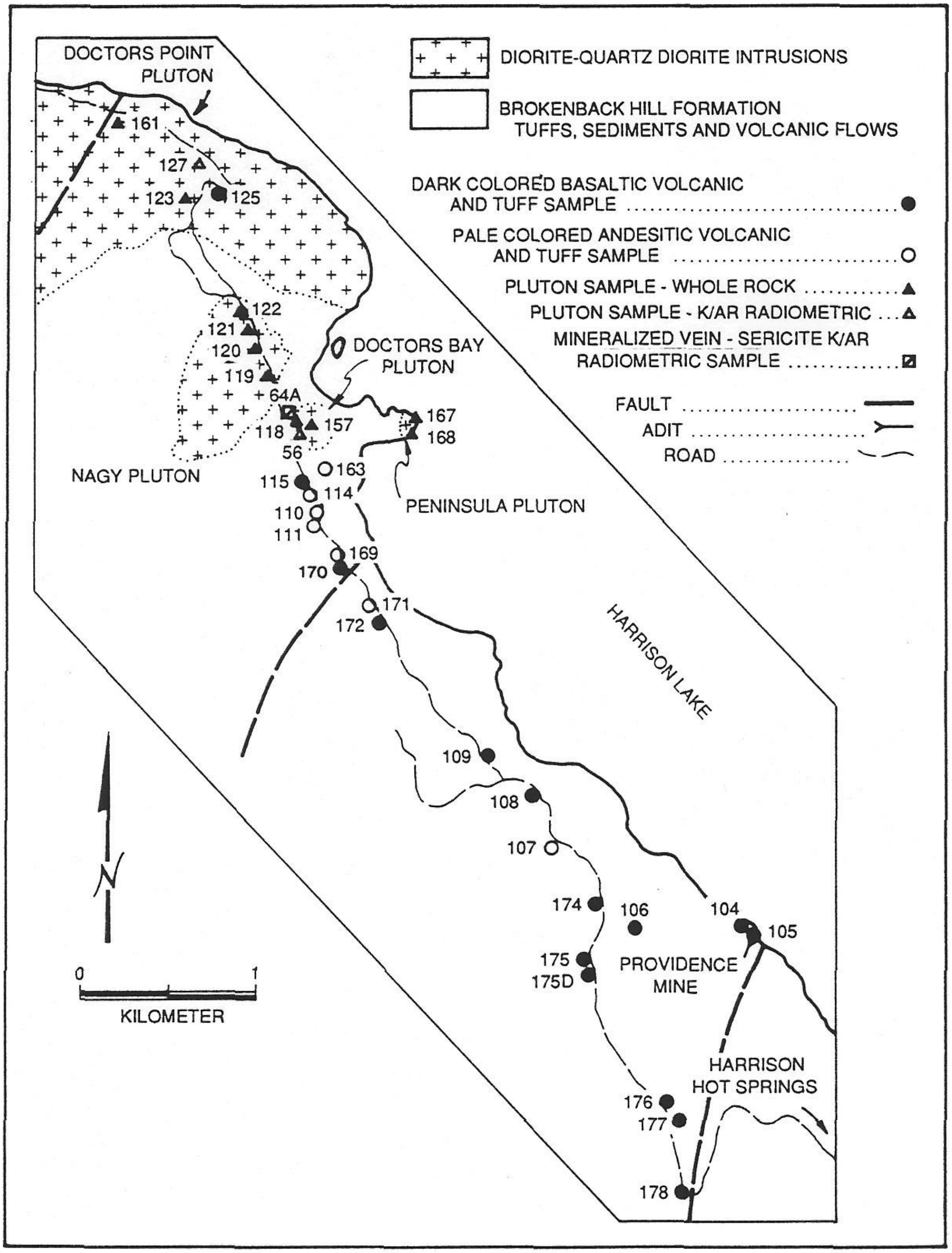
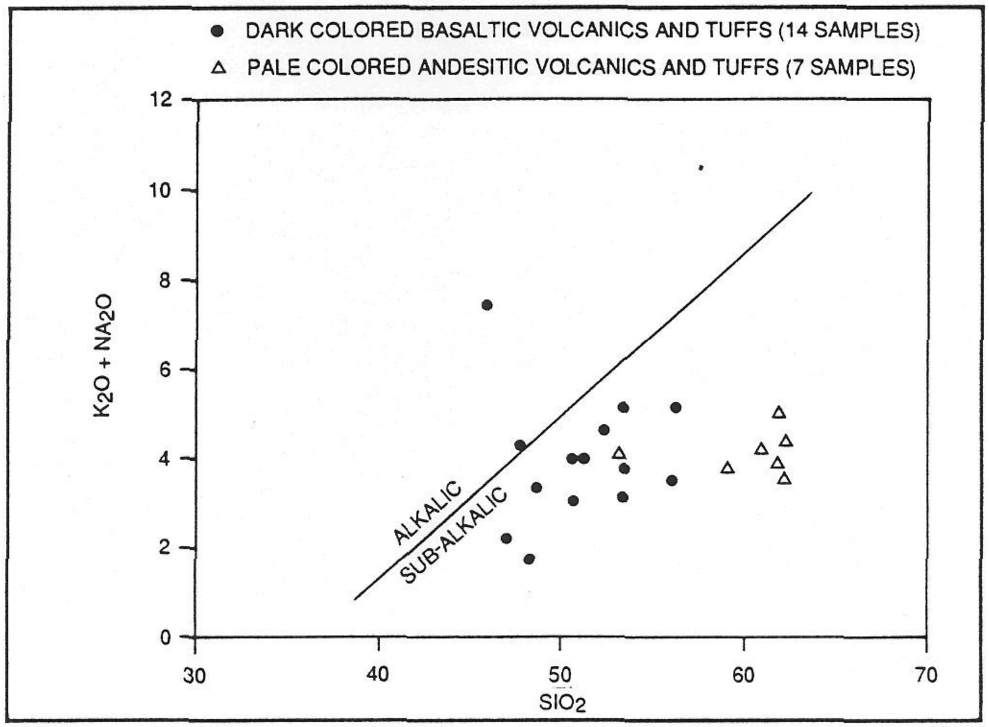
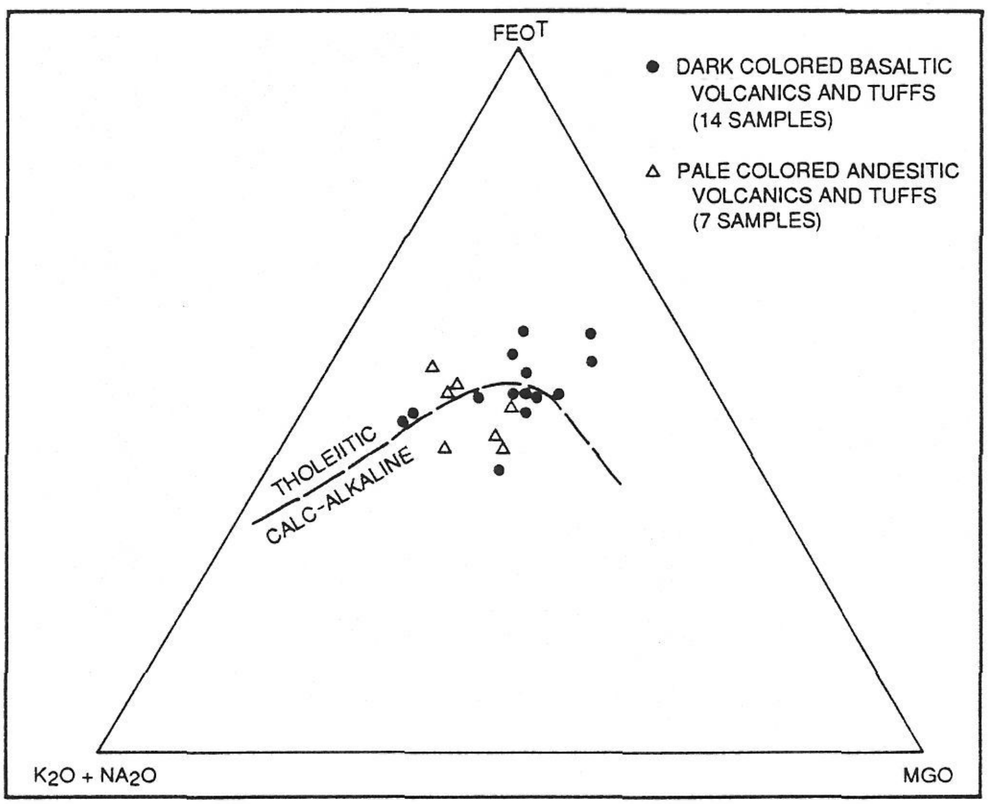


Figure 3: Locations of the geochemical and K/Ar radiometric samples, Doctors Point area. (Numbers refer to sample numbers in Tables 1, 2 and 3).

Figure 4A : Alkali vs. silica plots (after MacDonald 1968 ; Irvine and Baragar 1971) illustrating the sub-alkalic nature of the volcanic and tuffaceous rocks in the Doctors Point area.

Figure 4B : AFM plot of volcanic and tuffaceous rocks in the Doctors Point area.





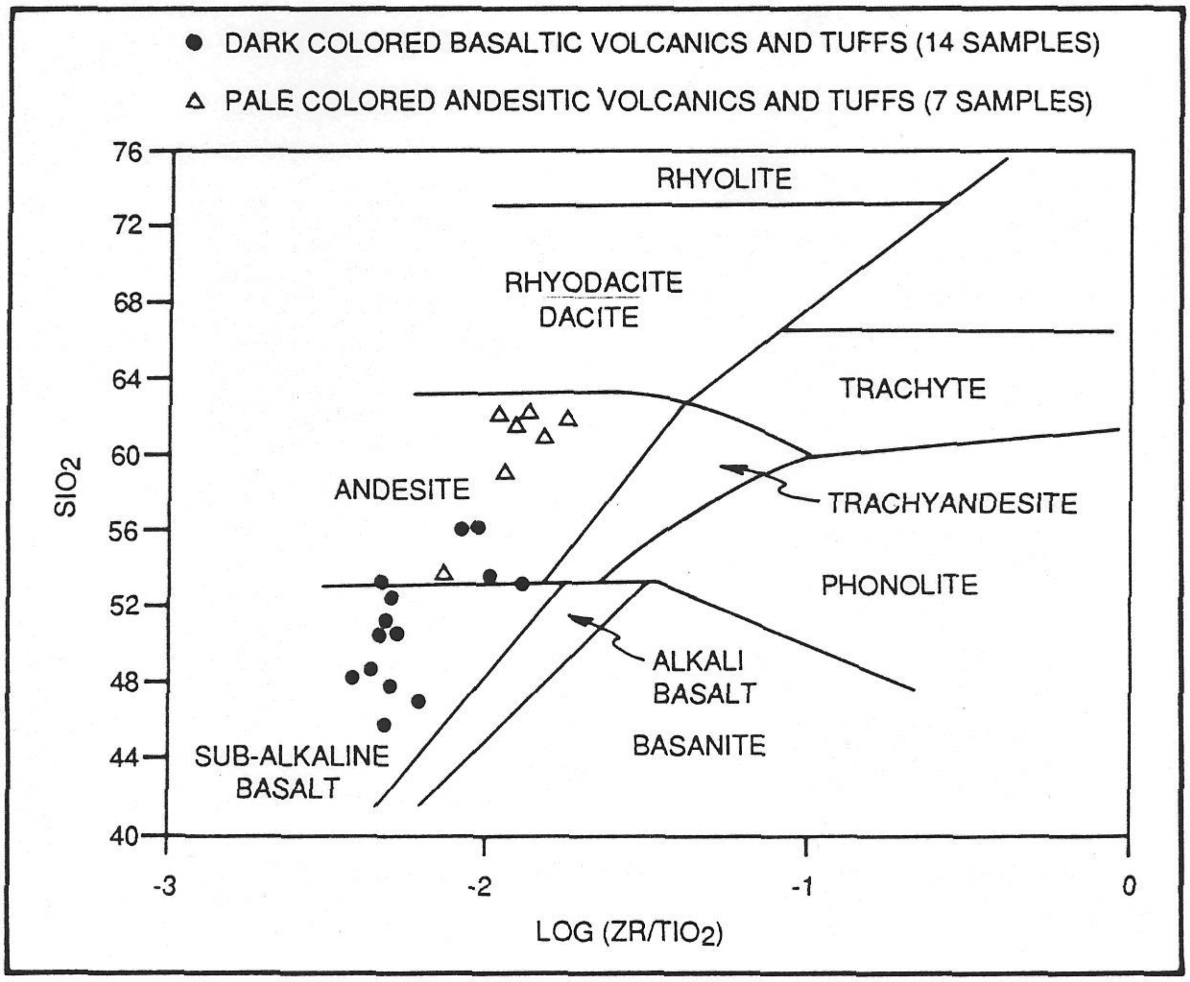


Figure 5: Plot of SiO_2 vs. log (Zr/TiO_2) (after Floyd and Winchester 1978) illustrating the basaltic and andesitic compositions of the volcanic and tuffaceous rocks, Doctors Point.

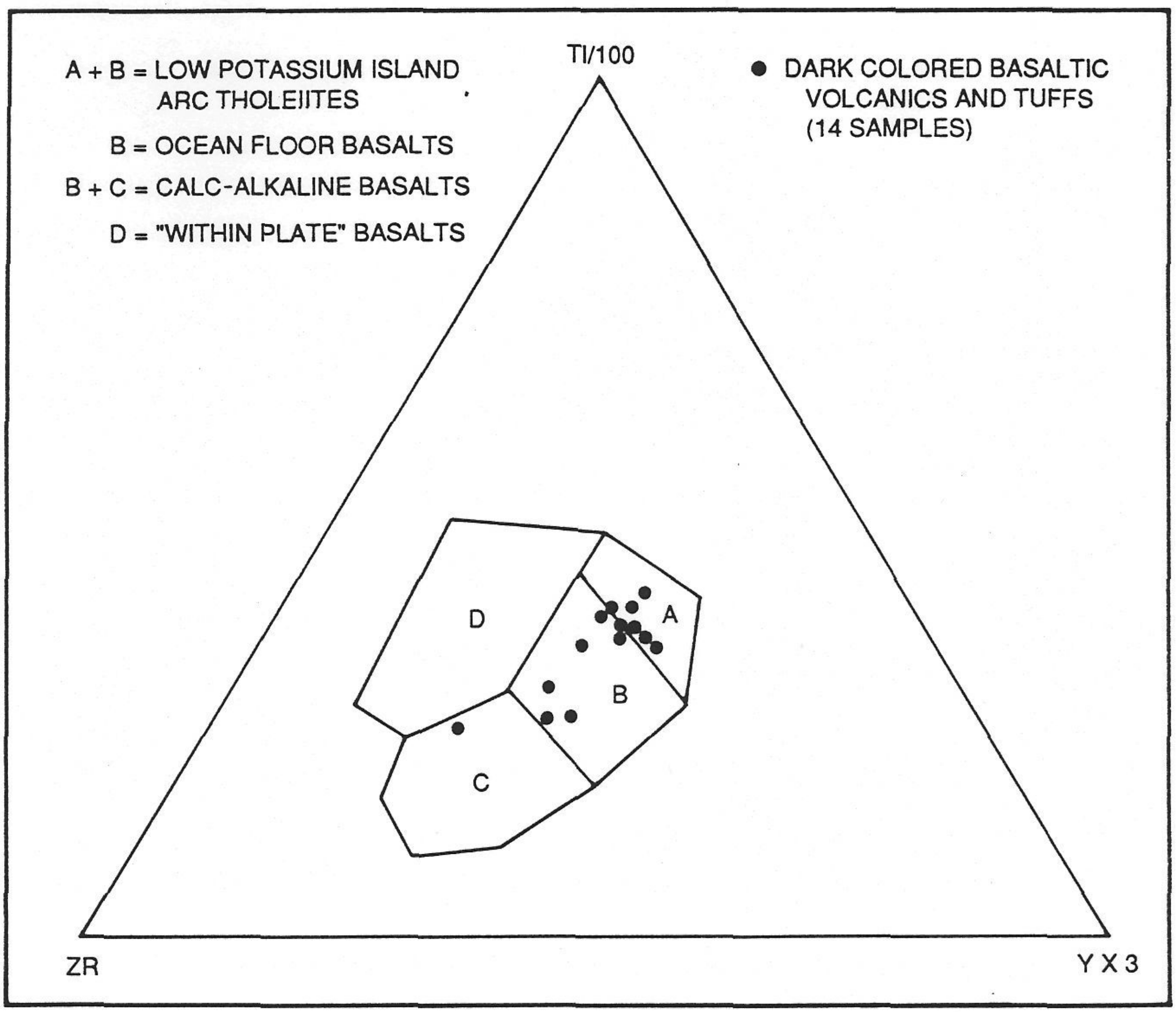
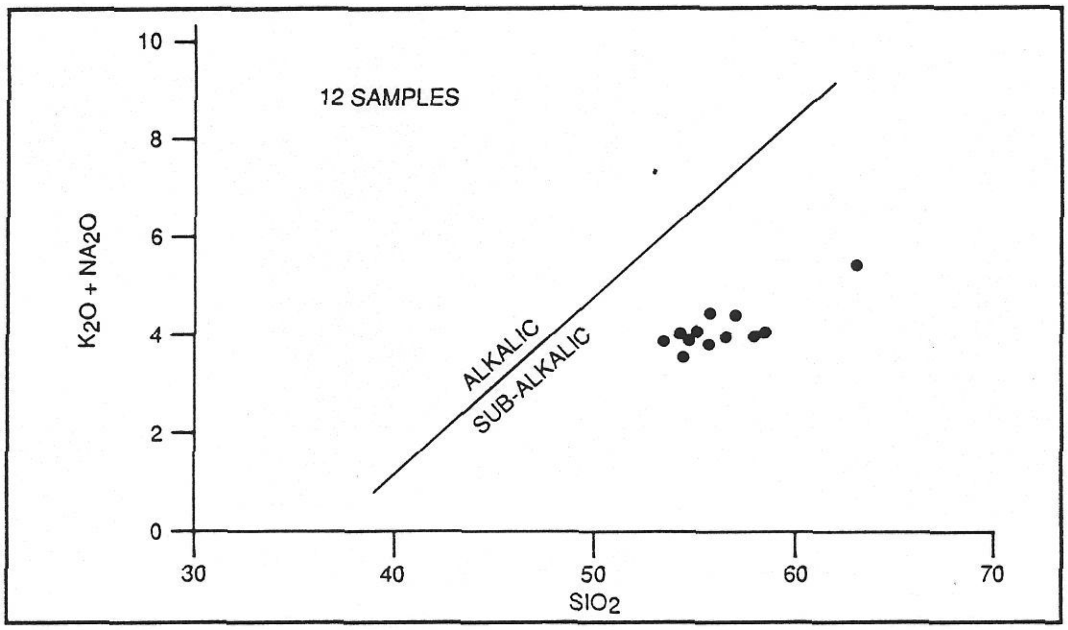
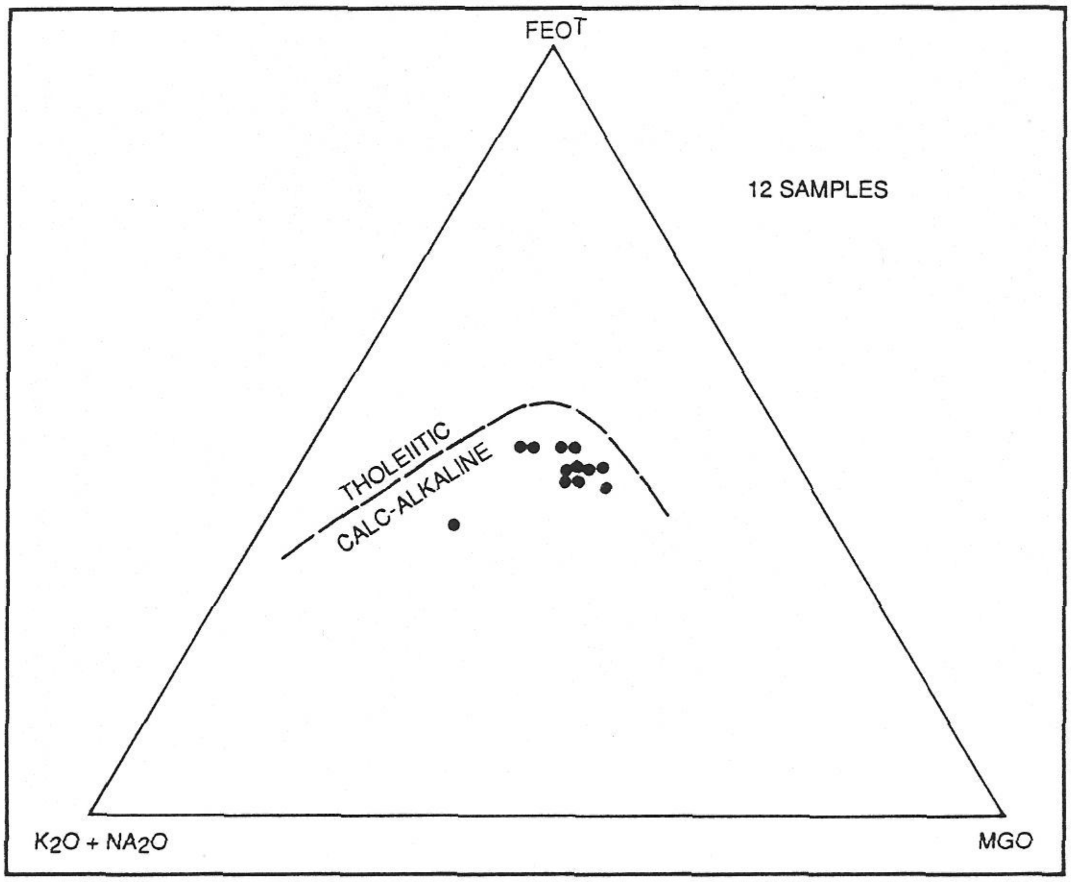


Figure 6: Zr – Ti – Y plot (After Pearce 1975) of the volcanic and tuffaceous rocks, Doctors Point

Figure 7A: Alkali vs. silica plot (After MacDonald 1968; Irvine and Baragar 1971) illustrating the sub-alkalic nature of the intrusive plutons, Doctors Point.

Figure 7B: AFM plot illustrating the calc-alkaline nature of the intrusive plutons, Doctors Point.





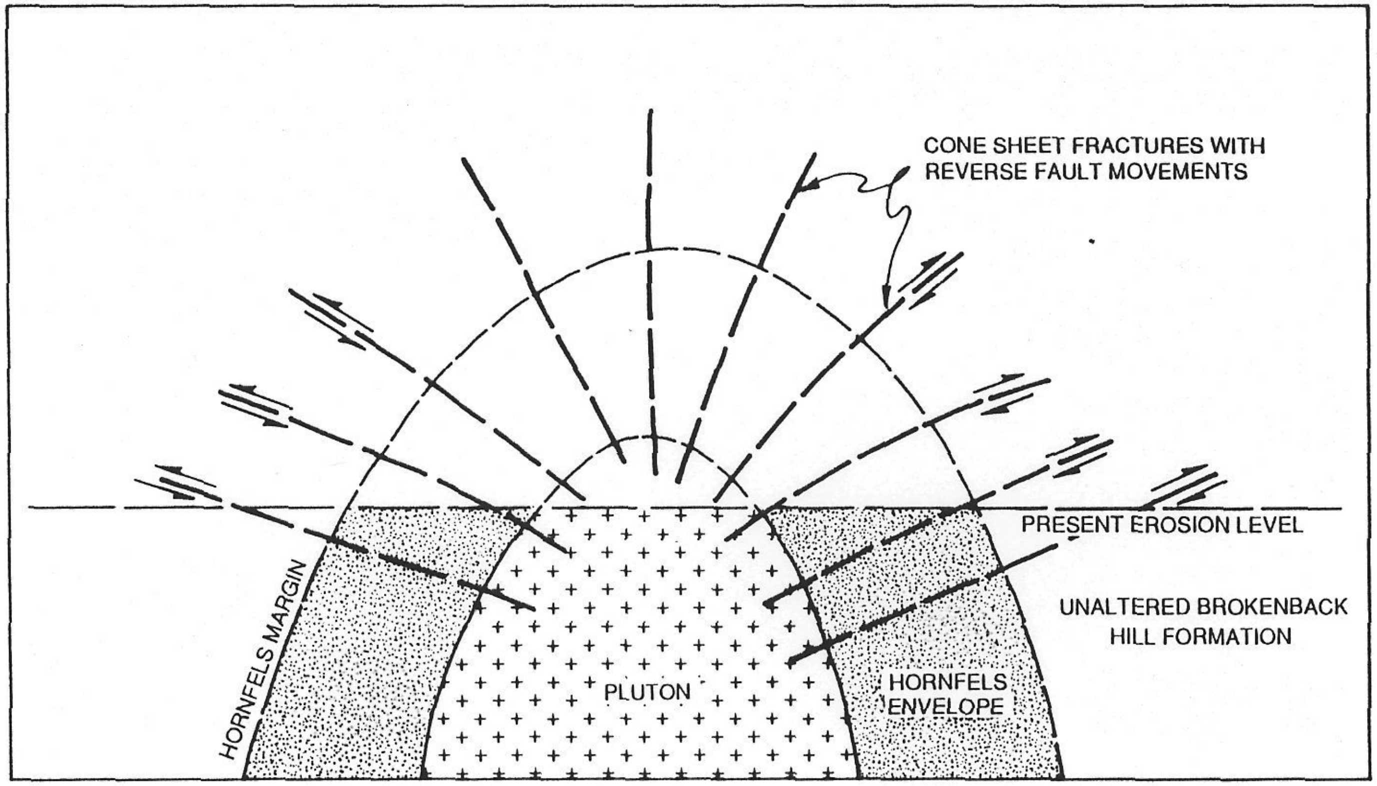


Figure 8: Model for cone-sheet fracture control of the mineralized veins, Doctors Point, Harrison Lake.

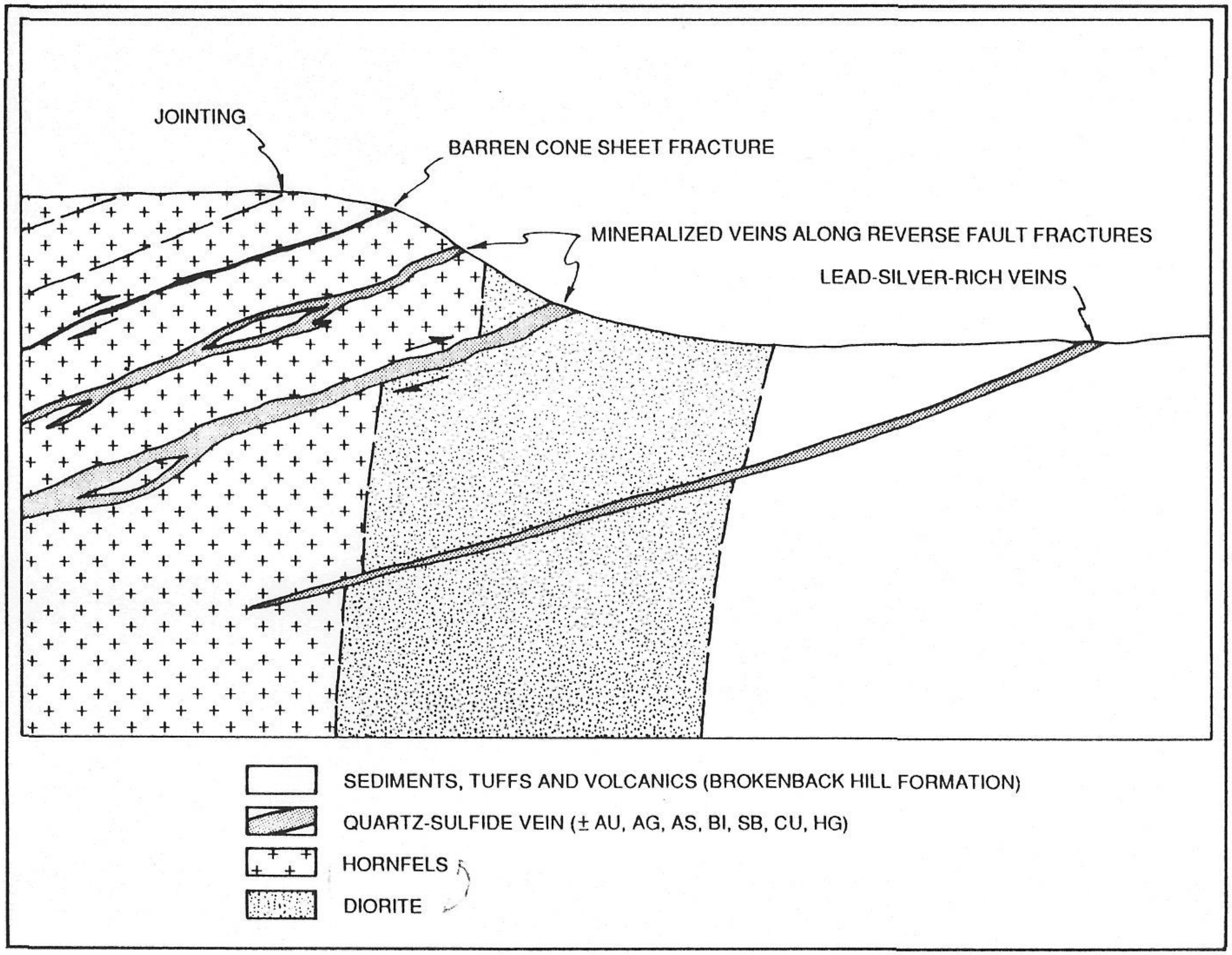


Figure 9: Schematic section showing relationship between mineralized veins and the cone-sheet fractures developed adjacent to the pluton margins, Doctors Point

Figure 10A: Geology, major element and Sr geochemistry of drillhole 82R-11, Doctors Point, Hanson Lake.

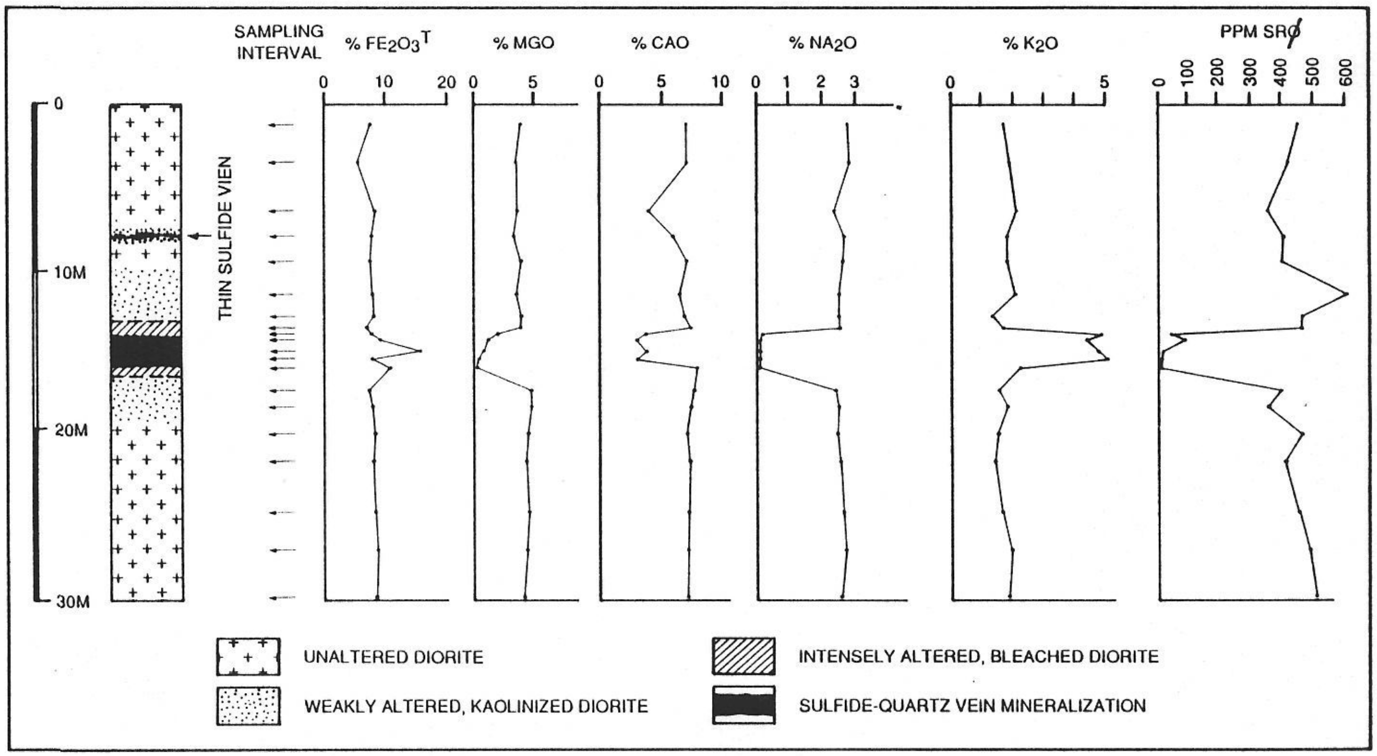
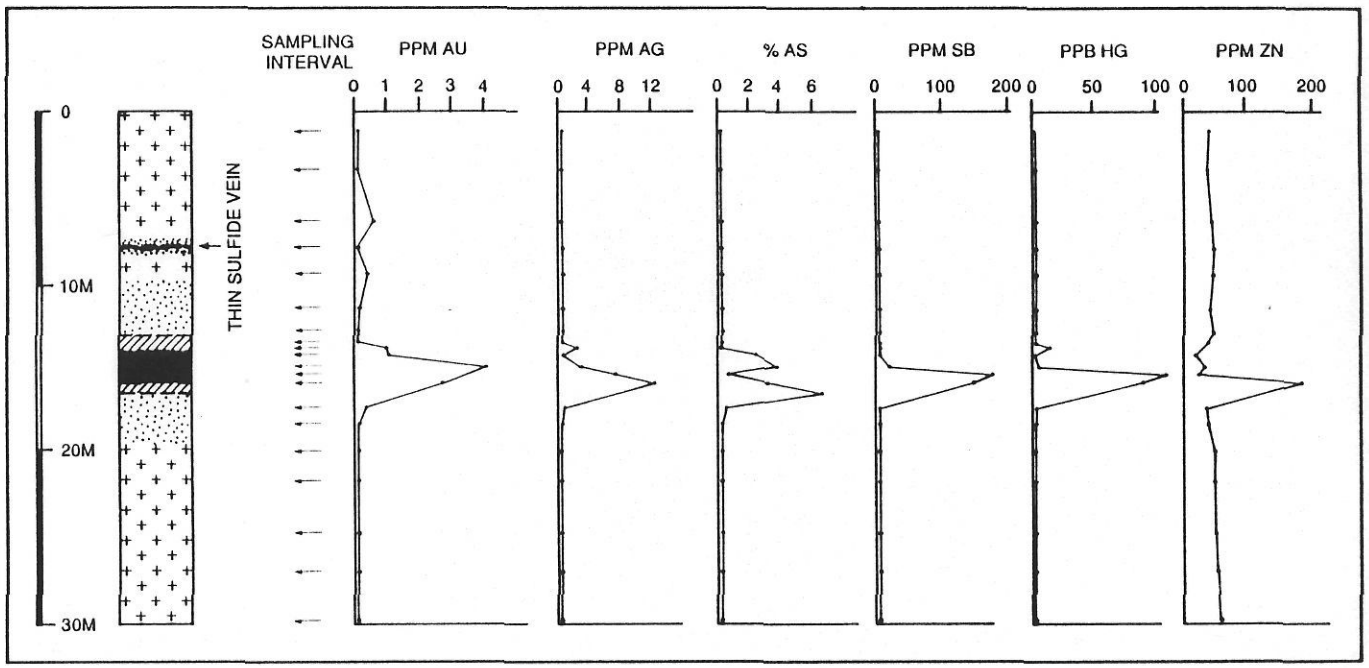


Figure 10B : Geology and trace element geochemistry of drillhole 82R-11, Doctors Point, Hanson Lake.



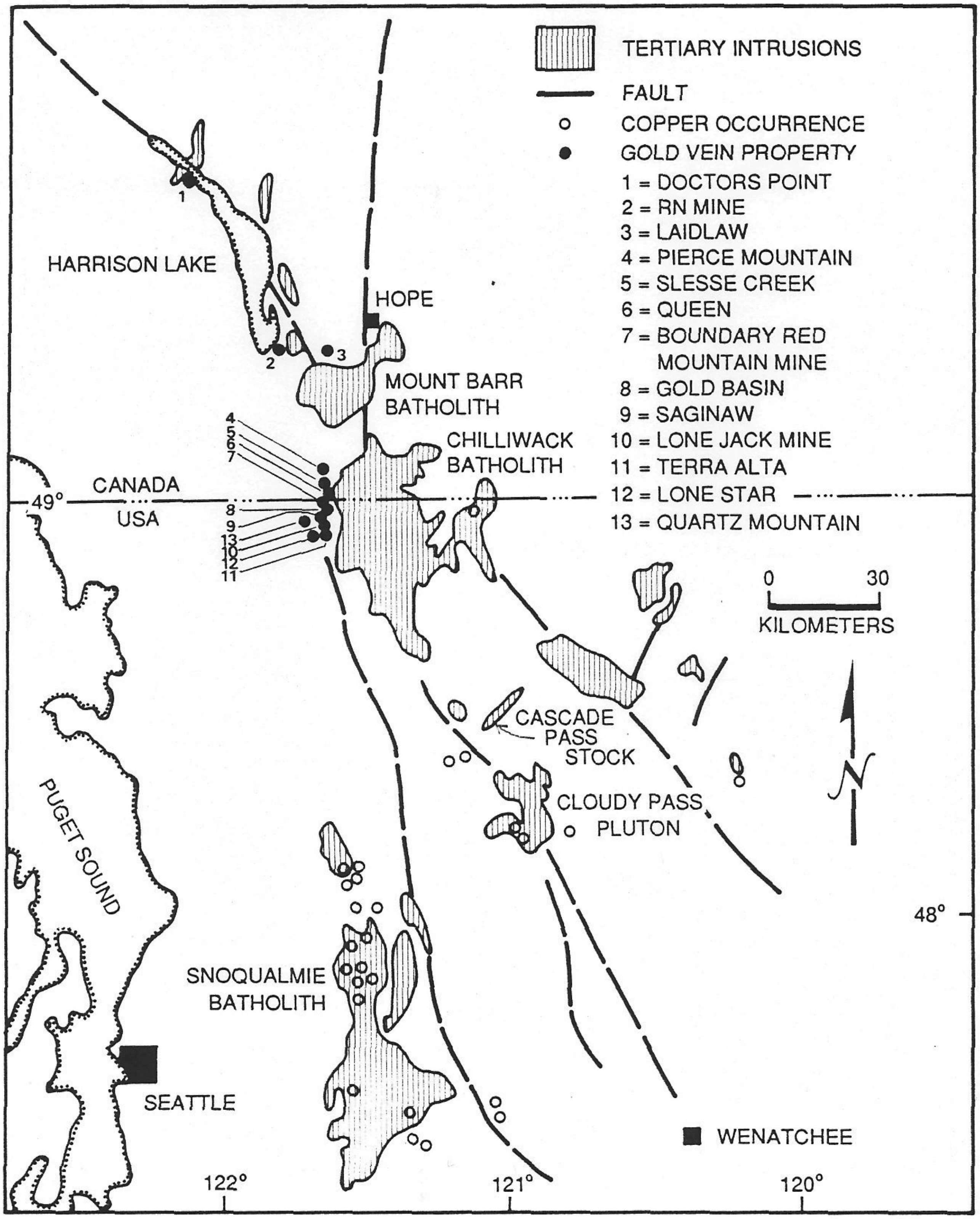


Figure 11: Tertiary plutonic belt south of Harrison Lake showing locations of gold vein mineralization and copper occurrences (copper occurrences and geology in Washington State after Grant 1969).