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THE GEOLOGICAL SETTING OF INDUSTRIAL MINERALS, PRECIOUS STONES AND AU-AG VEINS IN TERTIARY OUTLIERS OF THE OKANAGAN - BOUNDARY DISTRICT (82E, 82L)

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KEYWORDS: Tertiary outliers, quarry granite, dimension stone, Au/Ag veins, zeolites, agates, diatomite.

INTRODUCTION

The Tertiary rocks of the interior of British Columbia comprise a number of poorly explored outliers peripheral to the mining camps and basement terranes. The object of the present study is to review the young lithologies with a view to delineating areas of high mineral potential in the light of new discoveries and evolving market needs.

The interior plateau area of British Columbia is blanketed by deeply dissected early Tertiary lavas, associated pyroclastic rocks and intercalated sedimentary units. These rocks occur within a northwesterly-trending belt about 150 kilometres wide, extending 800 kilometres from the Republic Mining District in Washington State to the Babine Lake area of central British Columbia. The thickness of these rocks ranges from less than 100 metres to more than 1200 metres. The base of the succession where best developed is composed of fluvial sandstone and conglomerate (Gaylord et al., 1994). The upper boundary of these rocks is generally coincident with a gently rolling 'upland surface' locally unconformably covered by a veneer of Miocene and younger 'plateau' basalt.

During the summer of 1995 the author visited mineral occurrences associated with the Tertiary assemblages in the Okanagan-Boundary district. Figure 1 shows the location of these occurrences (open circles) and the principal geological tracts (Church, 1995) underlying the area that define the mining camps, major plutons, metamorphic complexes, accreted Mesozoic and Paleozoic terranes, and the Tertiary outliers (stippled areas on Figure 1).

The new MINFILE locations identified by this work include rhodonite, perlite, tufa, zeolites, dimension stones, feldspar and quartz crystals ('Herkimer diamonds'), silver/gold veins, ornamental stone and diatomite occurrences.

GEOLOGICAL SETTING

This study encompasses the Penticton (82E), and Vernon (82L, south half) quadrangles - a total area of about 20000 square kilometres (Figure 1). The boundaries of the geological tracts is based on Cairnes (1940), Little (1957) and Tempelman Kluit (1989), for the Kettle River and Penticton areas, Okulitch (1978, 1991) for the Vernon area, and the tectonic assemblage map of the Canadian Cordillera by Wheeler and McFeely (1991).

The Okanagan-Boundary district consists principally of accreted Mesozoic oceanic terranes (Pacific plate) in the western part and Proterozoic-Paleozoic pericratonic (North American plate) rocks in the east (the Shuswap-Monashee complex). The Okanagan fault system is the boundary between these regimes. The rocks are overprinted by several episodes of metamorphism related to the intrusion of numerous Triassic to Tertiary plutons. Tertiary graben and half-graben structures (late orogenic) infilled with rocks of the Penticton and Kamloops groups are genetically related to the Okanagan fault system and similar rifts in the Kettle River area (Fig.2).

The early Tertiary continental sedimentary and volcanic rocks and associated intrusions fill the Toroda Creek graben that bisects the Okanagan Highlands in the Midway area (Fig.1, insets). The Springbrook Formation, at the base of the succession, is a polymictic conglomerate containing clasts derived from a geologically diverse pre-Tertiary metamorphic terrane. This is followed by the Eocene Kettle River Formation consisting of rhyolite tuffs, sandstones, shales and minor conglomerates that are, in turn, overlain conformably by the Marron Formation consisting of phonolite, trachyte and andesite lava flows and breccias. This stratigraphy / lithology is remarkably similar to the Penticton Group of the central Okanagan Valley, 60 kilometres to the northwest (Monger, 1968; Church, 1973). In the north Okanagan area, the Penticton Group is overlain unconformably by Miocene plateau basalt (Fig.1, Inset A); near Vernon the felsic Penticton volcanics are replaced by Eocene andesites and basalts typical of the Kamloops Group (Church and Evans, 1983).

Structural control of the Tertiary outliers is related to a herringbone pattern of conjugate shears trending northeast and northwest. These are important elements in a north-south stress scheme responsible for the many northerly-trending grabens found scattered throughout the southern interior of British Columbia from the Fraser River to the Rocky Mountains. The period 45 to 53 Ma witnessed intense volcanic and tectonic activity across the Cordillera. This interval corresponds with a period of northerly movement of the Pacific plate suggesting that the same stress engine acting on the Pacific plate may have been active throughout the Cordillera during the Eocene. This may explain a complex inter-relationship of shears, tension faults and folds and the simultaneous development of grabens, folding and thrusting in the southern interior and eastern British Columbia.

RESOURCES

The first comprehensive evaluations of the mineral deposits of the region were by Cairnes (1937) and Jones (1959). From these studies it is clear that some geological units are mineralized and others are relatively barren. It is also apparent that many types of deposits occur in the region and that these tend to cluster forming distinctive mineralized tracts (Kilby, 1995; Hoy et al, 1994).

The traditional prospecting philosophy proposed by Cairnes (1937) holds that intrusive rocks are the prime source of mineralization in the region. This philosophy seems to be valid for precious and base metal deposits in the mining camps; however, the relationship is not established for some epithermal vein systems related to the volcanic process and many non-metallic deposits.

The deposits visited during the 1995 field season by the author are Au-Ag veins and non-metallic deposits related to the Tertiary basins and young volcanic processes. These include: the Angel Hot Spring tufa deposit near Kelowna (Church, in press); the Clearcut Rhodonite occurrence in the Greenwood area (Simandl and Church, 1996); the Terrace Mountain Perlite deposit in the Vernon area (Simandl, Church and Hodgson, 1996); the Mount Swite agate locality west of Kelowna, epithermal vein occurrences such as Picture Rock near Midway and the City of Paris Au-Ag quartz vein system on the Lexington property at the north end of the Republic graben (Seraphim et al., 1995) and zeolite occurrences associated with the sedimentary rocks in the lower part of the Tertiary sequence (Hora and Church, 1986).

Penticton Group Resources

The Penticton Group provides a brief but continuous record of Eocene deposition and graben development in the Okanagan-Boundary district. The group consists of six well defined formations having an aggregated thickness of 2500 metres in the type area. At the base are polymictic fluvial conglomerates, arkosic sandstones and coeval rhyolite volcaniclastics. Above this are thick andesite, trachyte and phonolite lava flows that are succeeded upward by dacitic domes. These units are followed by more volcanic breccias, fluvial/lacustrine beds and, uppermost, a thrust/landslide complex and fanglomerates (Church, 1982b).

The mixed volcanic suite includes a widely distributed alkaline unit similar to the rhomb porphyries of the Kenya rift, east Africa, and the Oslo region of Norway. The enriched LREE patterns of these rocks is typical of highly evolved rift magma sequences (Fig. 3).

Zeolite Occurrences (Nos. 1 to 4, Midway area)

Zeolites are most abundant in the lower part of the Penticton Group, apparently as the result of 'load' metamorphism, although the composition of the host rocks is a controlling factor. For example, there is a close association of natrolite and secondary analcite with calcite in amygdale-fillings in the sodic rhomb-porphyry lavas of the Yellow Lake member. It may be that these minerals formed, excluding quartz, at the time of first cooling of the undersaturated lavas. However, the association of clinoptilolite with tuffaceous sedimentary rocks high in the section suggests the possibility of authigenic origin of some zeolites. Elsewhere, the occurrence of laumontite and heulandite in fissures throughout wide sections of the Penticton Group is evidence of an episode of low grade regional metamorphism (Hora and Church, 1986).

During the 1995 field season, a broad program was undertaken to sample the Kettle River Formation for zeolites. This unit, consisting of arkosic sandstone, granite boulder conglomerate and rhyolite tuffaceous beds at the base of the Penticton Group, was deemed to offer opportunity for new zeolite discoveries employing the 'load' metamorphism model. Approximately 60 samples were collected from the Kettle River Formation in the Toroda Creek graben near Rock Creek and Midway. X-ray diffraction and thin section analyses of these samples showed a preponderance of feldspar and quartz with variable amounts of clay. Four samples contained accessory zeolites - all in the Rock Creek area. These consisted of stilbite in one sample (**No.1**, Fig.1) from granite boulder conglomerate, northwest of Conkle Lake, and three samples (**Nos.2-4**, Fig.1) with harmotome from rhyolite tuff northeast of Conkle Lake and two similar samples near the U.S. border.

Dimension Stone (No. 5, Beaverdell area)

Granite as a dimension stone resource was described by Carr (1955). Since this study, the demographics of the province have changed, leading to increasing demands for building stone and decorative granite products. Consequently the relatively fresh and undeformed granitic rocks of the readily accessible Okanagan - Boundary district are a target for exploration and quarry development.

Granite porphyry stocks near Penticton and Beaverdell are believed to be subvolcanic intrusions and feeders to the Kettle River rhyolite. These bodies cut Jurassic and Cretaceous granites and in turn are cut by middle Eocene rhomb-porphyry dikes and syenite and monzonite phases of the Coryell batholith (Inset B, Fig.1).

The Shingle Creek porphyry is located immediately west of Penticton on the Penticton Indian Reserve (Bostock, 1966). The porphyry consists of an irregularly-shaped lenticular stock (2 x 7 km) concave to the south with several large offshoot dikes at the western boundary. It is characterized by large twinned K-spars (1-10 cm), smaller plagioclase phenocrysts (to 1.5 cm), quartz bipyramid euhedra/ subhedra (to 1 cm) and minor mafic minerals (magnetite/ biotite) in a medium to fine grained matrix of similar composition. The stock intrudes diorite and granodiorite phases of the Okanagan batholith and part of its own volcanic pile that consists of rhyolite tuff and breccia containing large broken sanidine phenocrysts. The age of the porphyry, based on K/Ar analysis of fine grained biotite inclusions within sanidine phenocrysts, is 52.4 ± 1.8Ma (Church, 1982a). The bipyramidal quartz crystals ('Herkimer diamonds') and large, commonly twinned, sanidine and orthoclase phenocrysts that weather free of the host rock are of interest to mineralogists and rock hounds.

The Beaverdell porphyry is a granitic stock centred 14 kilometres south of Beaverdell (**No.5**, Fig.1) and is similar in appearance and setting to the Shingle Creek porphyry. It has been the focus of intermittant quarry development (the Beaverdell Granite Quarry) by Continental Granite and Marble Ltd. since the early 1960's. In 1990 the ground was restaked and became part of the Cascade Coral property owned by 1885 Holdings Ltd. The property is presently owned and operated by Margranite Industries Ltd.

The Beaverdell porphyry is a subcircular stock (5 km diam.) exposed mostly northeast of the Kettle River in the drainage basin of Dominion Creek, in the area west of Boyer Creek and south of the mouth of Tuzo Creek. The stock (dated 49.4 ± 0.7 Ma, this study)and satellitic dikes intrude granodiorite phases of the Okanagan batholith (Jur.-Cret.) on Tuzo and Boyer Creeks and basal Tertiary rhyolite and conglomerate that contain clasts of the Okanagan batholith, in the headwater area of Dominion Creek. The stock is cut by numerous basaltic dikes (Miocene-Pliocene) and a few Coryell-related pulaskite and rhomb-porphyry dikes (Eocene) as seen along Highway 33.

The Margranite quarry is located near the south margin of the stock (Lat. 49°20.4', Long. 119°03.25') on Highway 33 (**No.5**, Fig. 1). The quarry trends northeast from the highway following a 40 metre-wide band of massive, lightly jointed granite porphyry 'quarry rock' for a distance of approximately 130 metres (Photo 1). This band of quarry rock is flanked on the northwest by alternate bands of highly fractured and weakly fractured porphyry of the same composition (Figure 4). A study of the fracture pattern shows three main joint sets - subhorizontal sheeting (differential expansion/contraction due to cooling and/or off-loading), a principal joint set averaging 035°/60°NW and a secondary set at 090°/55°N (Figure 5). The typical rock at the quarry face contains rectangular phenocrysts of pink K-spar (to 6 cm.) set in a granular matrix of 55% orthoclase, 15% quartz, 20% plagioclase, and 10% combined biotite, hornblende, and magnetite (Kidlark, 1990). The chemical composition of the porphyry is 72.35% SiO_2, 0.29% TiO_2, 14.89% Al_2O_3, 1.40% Fe_2O_3, 0.03% MnO, 0.46% MgO, 1.39% CaO, 4.44% Na_2O, and 4.74% K_2O (major oxides recast to 100% and total iron given as Fe_2O_3). This closely resembles the composition of the Shingle Creek porphyry which is 72.18% SiO_2, 0.39% TiO_2, 15.16% Al_2O_3, 1.69% Fe_2O_3, 0.05% MnO, 0.57% MgO, 2.53% CaO, 2.63% Na_2O, and 4.80% K_2O. Physical testing of the quarry rock by the B.C. Ministry of Transport and Highways in 1986 yielded the following results (Kidlark, 1990):

Specific gravity	2.61	
Density	162.63 lb/ft^3,	(2605 kg/m^3)
Absorption	0.50 wt%	
Strength (comp.)	8110-9543 psi	(55.92-65.80 MPa)
Strength (trans.)	1151-1460 psi	(7.94 -10.07 MPa)

Since 1993 the quarry has produced blocks for tiles and polished slabs and crushed and sized fragments for terrazzo and precast concrete slab products. Total production is estimated to be several hundred tonnes.

Perlite, Agate and Epithermal Veins

The Tertiary outliers in the Kelowna and Vernon area were first mapped by Jones (1959) and Cairnes (1940); however, there was no attempt at the time to describe the structure of these rocks nor to distinguish the Eocene and Miocene assemblages. More recent investigations have led to a better understanding of the detailed geology and the subsequent discovery of important veins and perlite, agate and opal occurrences.

Perlite and Agate (Nos. 6 and 7, Kelowna area)

During the course of detailed mapping, perlite (**No.6**, Fig.1) was found by the author on Terrace Mountain 30 kilometres southwest of Vernon and agates (**No.7**, Fig.1) were collected near the summit of Mount Swite 12 kilometres northwest of Kelowna (Church, 1980a,b). Also, in 1991 the Klinker opal deposit was located by prospectors north of McGregor Creek 23 kilometres northwest of Vernon.

The Terrace Mountain perlite occurs in a porphyrytic obsidian unit exposed in cuts on the road leading to the forest look-out tower on Terrace Mountain (Lat. 50°06', Long. 119°38). The perlitic rocks are mottled light grey and brown and consist of 15% plagioclase phenocrysts (2 to 7 mm) and accessory biotite in a glassy matrix with characteristic concentric 'perlitic' cracks (Simandl et al 1996). The expansion of the rock when heated is negatively affected by low water content and porphyritic characteristics according to preliminary tests by the Ministry of Highways laboratory in Victoria.

The Terrace Mountain area is underlain by relatively fresh volcanic rocks, equivalent in part to the Penticton Group (Inset A, Fig.1), in a northerly elongated, westerly dipping half graben structure. This structure developed on a basement complex consisting of highly folded and faulted Paleozoic and Mesozoic oceanic cherts, turbidites, greenstones and younger granitic rocks (Church, 1980a, 1982b). The volcanic succession on Terrace Mountain is about 900 metres thick and consists, from top to bottom, of fine grained dacite, forming a ~30 metre thick tilted cap on the summit, underlain by a ~120 metre thick layer of porphyritic obsidian, underlain in turn by a series of feldspar porphyry trachyandesite lava flows ~180 metres thick, and a series of andesitic lava flows and breccias ~550 metres thick at the base. The summit dacite is tentatively correlated with similar rocks near Naswhito Creek, 20 kilometres to the north; the porphyrytic obsidian may be equivalent to the Bouleau Lake ash flow deposit that occurs below the Naswhito Creek unit north of Bouleau Lake and in the drainage basin of Ewers Creek (Read, 1996). The feldspar porphyry trachyandesites and andesitic units exposed on the lower slopes of Terrace Mountain are correlated with the Kitley Lake and Attenborough Creek members (Church, 1982).

The age of the Terrace Mountain perlite, determined from potassium-argon analysis of the biotite phenocrysts, is 52.3 ± 1.8 Ma (Church, 1980a). This is similar to the age of the Marron Formation, Penticton Group (Church, 1973; 1982b). In the Kelowna area the Kitley Lake and Attenborough Creek members on Mount Swite and Carrot Mountain occur in a northerly-trending graben that is unconformably overlain by Chilcotin basalt (11.8 ± 0.4 Ma).

The Mount Swite agate locality (Lat. 49°57.8', Long. 119°37.5') is accessed from the Bear Creek (Lambly Creek) road via the Hidden Creek logging road that passes ~2 kilometres east of the summit (Figure 6). The agates consist of quartz and chalcedony filling amygdules and fissures in the Attenborough Creek member (Photo 2). The amygdules are commonly elongated almond-shaped structures (0.5 to 5 cm), filled with fine grained blue-grey quartz, chalcedony and white plume opal aligned parallel to flow direction of the lava. Thunder eggs are larger agates (> 6 cm.) with radiating quartz crystals lining vugs and/or chalcedony in variegated horizontal or concentric bands on cavity floors or walls. Agates are believed to form within gas cavities of volcanic host rocks when microcrystalline chalcedony fibres nucleate on vug walls and grow inward. Oscillatory zoning and iris banding is the result of variations in silica concentrations in solutions at the tips of the growing chalcedonic fibers forming smooth and regular or botryoidal surfaces parallel to the banding (Heaney and Davis, 1995). The most probable source of the silica-rich solutions is the host Attenborough Creek andesite. Analyses of the andesite from different locations shows uniform composition and excess silica based on norm calculations. For example, the andesite from Mount Swite contains 57.04% SiO_2, 1.08% TiO_2, 16.79% Al_2O_3, 5.03% Fe_2O_3, 2.38% FeO, 0.10% MnO, 4.05% MgO, 6.70% CaO, 3.36% Na_2O and 3.47% K_2O (major oxides recast to 100) that yields 6.57% free silica/quartz (CIPW norm). By comparison Attenborough Creek andesite from Terrace Mountain shows 57.29% SiO_2, 1.18% TiO_2, 16.02% Al_2O_3, 4.55% Fe_2O_3, 2.32% FeO, 0.11% MnO, 4.00% MgO, 7.46% CaO, 2.96% Na_2O, 4.11% K_2O that yields 6.43% normative quartz. It is concluded that part of the excess silica, accompanied by fluids and gases, moved from the andesite lava to gas cavities and fracture openings during the original lava cooling process.

The Klinker deposit includes several occurrences of agate and opal in basal units of the Kamloops Group in the McGregor Creek area (Lat. 50°21.6', Long. 119°33.8'). The agate and opal occurs in fractures as full or partial fillings in basaltic andesite breccia and lahar deposits of the Dewdrop Flats formation (Read, 1996). The agate is commonly layered with grey, white and clear bands. The opal is commonly white and orange or red; precious opal is clear and full of colour including fire-orange and fire-green. The host rocks may be the same as the Kamloops Group in the Salmon River area (Church and Evans, 1983) and similar in composition to the Attenborough Creek member of the Penticton Group. Analysis of Kamloops basaltic andesite shows 56.64% SiO_2, 1.00% TiO2, 15.12% Al_2O_3, 2.44% Fe_2O_3, 5.48% FeO, 0.12% MnO, 5.97% MgO, 6.71% CaO, 2.49% Na_2O, 4.03% K_2O that yields only 3.7% normative quartz (see Church and Evans, 1983 - Table 2, no.2). This normative quartz may be the source of silica in geodes; however, because the banding in the agate and opal is generally not parallel to bedding in the host rocks, silicification is believed to be subsequent to deposition of the host rocks and major tectonic events.

Epithermal Veins, (Nos. 8 and 9, Midway Area)

The Toroda Creek graben is one of a number of Tertiary grabens in southern British Coulmbia and northern Washington State which have localized epithermal precious metal mineralization. A significant gold-silver deposit associated with these structures is the Cannon mine at Republic, Washington. Similar occurrences in British Columbia include the Brett, and Dusty Mac mines in the Okanagan area (Meyers, 1988; Church, 1973), the Picture Rock occurrence near Midway (**No.8**, Fig.1) and the City of Paris mine on the Lexington property near Greenwood (**No.9**, Fig.1).

The Picture Rock and City of Paris veins are associated with a belt of serpentinite that traverses the Lexington-Lone Star area on the Canada-U.S. border, and thence through the Midway mine area north of the town of Midway then southwesterly arching back into Washington State (Little, 1983). The serpentinite is believed to be part of a disrupted Paleozoic ophiolite that includes a number of peridotite, talc and listwanite bodies (Fyles, 1990). Because of the ductile nature of these rocks, the belt has become a tectonically active zone and the locus of much shearing, thrusting, igneous intrusion and vein mineralization. The common Mg-Fe carbonate (listwanite) alteration and serpentinization are believed to be related to major thrusting of the ophiolitic rocks during the Jurassic. In the late Cretaceous and early Tertiary these thrusts were re-activated by a tectonic squeeze directed subparallel to the developing N-S elongated graben structures. Accompanying igneous activity is believed to be related to numerous vein deposits.

The Picture Rock quarry is 4.5 kilometres northwest of Midway between Bauer and Ingram Creeks directly under a major hydroelectric power line (Lat. 49°02.3', Long. 118°47.8'). Access is by a dirt road to the power line from the former railway crossing on Highway 3, west of Midway. The quarry is 500 metres south of the Midway mine from which about 19 tonnes of Ag-Au ore with lead and zinc credits were shipped in the late 1960's and early 1970's. The Rainbow claims covering the area was explored for large tonnage precious metal potential by Dentonia Resources and Kettle River resources in 1983, Kerr Addison Mines Ltd. in 1984, BP Resources Canada Ltd. from 1987 to 1989 and Minnova Inc. in 1989 and 1990 (Lee, 1990). Through this period to present, ornamental quartz has been obtained from the Picture Rock locality for lapidary purposes.

At the Picture Rock quarry epithermal quartz veins cut altered serpentinite (listwanite) and feldspar porphyry dikes. The quarry actually comprises a group of small detached and interconnected pits deveolped over a radius of several tens of metres on the crest of a low ridge. The veins are generally narrow (up to 50 cm wide) and mostly shallow dipping to the east and northeast. Typically the veins are delicately banded in white, grey, light blue and blue-green layers that are developed parallel to the vein walls or around listwanitic breccia clasts (Photo 3). Except for the largest veins, seen by the floor of the main pit, which has a hanging wall composed mostly of dickite several centimetres thick, the walls are little altered by the veining. The veins have epithermal Au, Ag, As, Sb signatures, with anomalous but subeconomic precious metal values (Lee, 1990).

The Picture Rock quartz has proven attractive for the manufacture of clock faces and ornaments by local artisans. The bluish-green colour of some of the chalcedony was thought to be due to the presence of nickle, as chrysophrase derived from the ultramafic and listwanitic host rocks. However, analysis of a sample of the bluish vein material yielded only 15 ppm Ni. Other elements, possibly contributing to the the colour, include 71 ppm Co, 94 ppm Mn, 0.46% Fe, 538 ppm Sr, 96 ppm Cr, 100 ppm Na and 641ppm W.

Chrysoprase

Exploration on the Lexington property (**No.9**, Fig.1) in the Greenwood area has focussed on the gold and silver-bearing quartz veins and stockworks associated with the Lexington quartz porphyry and serpentinite hostrocks. Workers at the City of Paris mine explored and developed a system of discontinuous quartz veins extending for about 300 metres along the upper contact of the Lexington quartz porphyry and in the overlying serpentinite. The accessory minerals in these veins include pyrite, chalcopyrite, galena, sphalerite and less commonly, tetrahedrite. In 1900 the City of Paris mine yielded 1900 tonnes of ore grading 13.7 g/t gold, 71 g/t silver and 3.12 % copper (Seraphim et al., 1995).

Theories regarding the genesis of the mineralization generally involve the Lexington quartz porphyry. The data on the age of the Lexington quartz porphyry indicate that it was emplaced in the early Jurassic, near the time of accretion of Quesnellia to the North American plate and that the parental magma was contaminated by, or rooted in, early Proterozoic rocks. The serpentinite in the Lexington area was emplaced first, probably as a ductile body into a major northeast dipping fault zone. Later, the Lexington magma, in one or several pulses, intruded the same fault zone dividing the serpentine into upper and lower limbs. This was followed by a pulse of copper-gold porphyry type mineralization. Continued movement on the fault zone resulted in penetrative deformation of the serpentinite and the Lexington quartz porphyry that made the contacts between these units locally indistinct. Later movement fractured the margins of the intrusion allowing emplacement of the City of Paris vein system which was then sheared by still younger movement. Relatively fresh and undeformed dikes, thought to be related to the tensional fissures of the Republic graben, clearly cross-cut the porphyry mineralization.

The age of the vein system is related to reactivation of thrusting at the contact between the Lexington quartz porphyry and hangingwall serpentinite during the development of the Republic graben. Although the veins clearly existed prior to emplacement of many of the Tertiary dikes, as evidenced by the ponding of these dikes adjacent to the veins, the veins are clearly younger than the penetrative deformation that is commonly seen in the surrounding country rocks.

Chilcotin Group Resources

The Chilcotin basalts are a contiguous suite of lavas which occur in the central and southern interior region of British Columbia. The ages of the lavas, which spread thinly over an area 25 000 km^2, range from 24 Ma to Recent. The basalts, which show only a small variation in composition, are predominantly transitional in character (quartz tholeiites and mildly silica undersaturated alkali basalts). Most of the basalts, many of which contain spinel peridotite xenoliths, resemble oceanic island basalts and were derived from a garnet peridotite source, probably the asthenospheric mantle. The subordinate quartz-normative tholeiites are characterized by a distinct LILE enrichment relative to high-field strength elements (Fig. 7). The source of these rocks, which compositionally resemble continental flood basalts, was probably subcontinental lithospheric mantle enriched by earlier subduction processes. Upwelling of asthenospheric mantle, a source of the majority of the basalts, probably triggered melting in the subcontinental lithosphere (Dostal et al., 1996).

The spectrum of resources associated with these basalts includes peridot from dunite and/or lherzolite inclusions (Brearley and Scarfe, 1984; Hamilton and Edwards, 1996), diatomite from sedimentary rocks interbedded with the lava flows (Hora and Hancock, 1995), basalt for castings (Woller et al., 1992) and uranium from fluvial channels.

Basal uranium deposits are a major mineral resource and occur at Hydraulic Lake, east of Kelowna, and on the Blizzard property northeast of Beaverdell - the latter being the more important occurrence. At Blizzard the uranium is found in basal conglomerate, sandstone and shale below Chilcotin basalt lava flows (Photo 4). The mineralization consists of uranyl phosphate coatings of mainly autunite and ningyoite on clastics and void fillings. Basement rocks include Nelson and Valhalla granitic rocks and some Eocene Tertiary volcanics assigned to the Penticton Group. The ore reserves are estimated to be 2.2 million tonnes grading 0.214% U_3O_8 (Sawyer, 1979).

Diatomaceous earth associated with the Blizzard uranium deposit has been reported by Read (1996). The diatoms are hosted by carbonaceous shales, intercalated with the Chilcotin basalt lava flows filling paleo-stream channels. Similar diatomaceous earth was recently discovered in logging road cuts in the headwater area of Ewer Creek (Lat. 52°25', Long. 119°37'), several kilometres northwest of the Klinker opal deposit in the Vernon area. These rocks are absorbant, light in colour and weight, and contain a mixture of tuffaceous debris and diatom filaments. The age of these rocks appears to be Miocene based on preliminary evaluations of well preserved fossil leaves and pollen grains (personal communication in 1996 with L. Donaldson, Okanagan College.)

Lherzolite xenoliths (inclusions) are found in Chilcotin basaltic rocks at several localities in the Okanagan Highlands (Hamilton and Edwards, 1996). These rocks are sought by gemnologists and rock hounds for peridote and a source material for crafting cabochons. The most notable occurrences are associated with volcanic vents near Ideal Lake (Lat. 50°01', Long. 119°06'), Hydraulic Lake (Lat. 49°46', Long. 119°11') and Lightning Peak (49°52.7', Long. 118°31.7'). The host basalt at Lightning Peak has been dated at 2.5 ± 0.1 Ma by the K/Ar analysis. The xenoliths are subrounded and range in size from less than 1 cm to more than 15 cm. They are composed mainly of a granular (or porphyrytic) mixture of green olivine (70-85 %), dark brown orthopyroxene (5-10 %) accompanied by accessory bright green clinopyroxene (chrome diopside), black spinel/magnetite and (rarely) amphibole (Brearly and Scarfe, 1984). Average grain size of these rocks ranges from <1 mm (magnetite) to 4 mm (olivine and clinopyroxene). Porphyrytic varieties contain orthopyroxene (poikilitic) and/or olivine (clear peridote) up to 1 cm, as seen at the Lightning Peak locality.

MINERAL POTENTIAL

The Okanagan-Boundary district is part of a broad, well mineralized area in south-central British Columbia. The district is actually a quilt of mining camps and less favourably endowed mineralized tracts. Examples of Tertiary areas with good mineral potential include the Brett gold-silver deposit near Vernon and the Terrace Mountain perlite. Areas with some good potential are underlain by some of the large batholiths such as the Okanagan intrusions and the Coryell bodies that locally feature quarries and metal deposits (i.e. The Lynx-Late copper mineralization hosted by the Allendale Lake stock). Zeolite deposits in the Penticton and Toroda Creek grabens also have important potential for future exploitation. The production of industrial minerals and building stone from the district is commonly from areas not otherwise mineralized and having low potential for metal deposits - for example granite quarries are mostly free of quartz veins, alteration and sulphide mineralization.

This report is a preliminary study of the mineral potential of the district based on current exploration trends. A more complete evaluation of resources requires additional ground-truthing and research drawing upon government and industry expertise in mineral commodities and local geology.

The following is a list of new MINFILE numbers for the description of previously unidentified mineral deposits examined by the author in 1995.

Terrace Mountain Perlite*	MINFILE 082LSW160
Ewer Creek Diatomite	MINFILE 082LSW159
Mount Swite Agate	MINFILE 082ENW106
Angel Hot Spring Tufa*	MINFILE 082ENW107
Picture Rock (ornamental stone)	MINFILE 082ESE242
Clearcut Rhodonite*	MINFILE 082ESE241
Shingle Creek (feldspar, quartz)	MINFILE 082ESW166
Lightning Peak (lherzolite)	MINFILE 082ENE018

(*separate reports in preparation or recently published elsewhere - see reference list below)

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Photo 1. Scenes from the Marganite quarry (Beaverdell porphyry), 15 kilometres south of Beaverdell.
Photo 2. Agates from Mount Swite (black markers are 1 cm).
Photo 3. Breccia in epithermal quartz vein, Picture Rock quarry, Midway area.
Photo 4. Mineralized conglomerate at the base of Chilcotin basalt, Hydraulic Lake area.

Figure 1. Map of the Okanagan Highlands (Okanagan-Boundary district) showing geological tracts and Tertiary mineral occurrences (Tertiary outliers are stippled); apparent discontinuities along the Canada/USA boundary is due to thrust faulting.
Figure 2. Proposed cross-section of early Tertiary horst and graben structure model, projected to the Kettle River/Republic area (Church, 1988).
Figure 3. Spidergram plot for volcanic rocks of the Penticton Group showing typical alkalic LREE enrichment.
Figure 4. Geological setting of the Margranite (Beaverdell) quarry (after Kidlark, 1990).
Figure 5. Fracture frequency plot for the Beaverdell porphyry.
Figure 6. Geological setting of the Mount Swite agate localities.
Figure 7. Scatter plot showing Zr/Nb vs. FeO/MgO variations for the Chilcotin basalt - quartz tholeiites (vertical dispersion of points), alkali olivine basalt (horizontal dispersion).