PETROLOGY AND GEOCHEMISTRY OF TIN AND TUNGSTEN MINERALIZED PLUTONS, MCQUESTEN RIVER REGION, CENTRAL YUKON

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ABSTRACT

Mid-Cretaceous plutons in the McQuesten River region intrude Upper Proterozoic to Mississippian miogeoclinal metasedimentary rocks of Selwyn Basin. They form a belt trending east from the Tintina Trench which can be roughly subdivided into two parallel belts. Plutonic rocks fall into three main groups: (1) biotite-muscovite (two-mica) granite in the southernmost belt which follows the trend of the McQuesten Anticline; (2) biotite-hornblende quartz monzonite, granite and granodiorite in the northern belt which follows the thrust faulted contact of the Hyland Group (Grit Unit) with the Road River Formation; and (3) hornblende-biotite syenite and associated quartz syenite, quartz monzonite, granite and tourmaline-orbicular granite along the north edge of the northern belt.

Tin-silver breccias veins and skarns are spatially associated with the two-mica granites, while tungsten-gold skarns and sheeted veins are associated with biotite-hornblende granite, quartz monzonite and granodiorite. The concentrically zoned syenite intrusion in the northern belt (ZETA) includes all the plutonic phases (two-mica granite, biotite-hornblende granitoids, and hornblende-biotite syenitoids), and links them cogenetically through the fractional crystallization process. The ZETA tin-silver veins (MINFILE 115P 047) are associated with the tourmaline orbicular granite, which is the most evolved phase of the concentrically zoned ZETA syenite intrusion.

Petrologic and geochemical variation between the three main rock groups is consistent with plutonic rocks of the belt being cogenetic, the two-mica granite being the most evolved phase. Trace and rare earth element variations further suggest that the entire McQuesten plutonic suite formed from melted sedimentary rocks, and that fractionation accounts for the evolution of the individual rock types and their associated mineral deposits.

Plutons in the McQuesten region resemble those of the Selwyn and Tombstone Plutonic Suites. They are post- to syntectonic, roughly circular in shape, and intrude miogeoclinal metasedimentary rocks of ancient North America. They show a concentric zonation and are surrounded by contact aureoles. The intrusive suite is bimodal, with a southern belt consisting of evolved two-mica granites and a northern belt consisting of less evolved biotite-hornblende granites. Lavas associated with the plutons are believed to be coeval.

The two main igneous types in each belt have been compared in detail. Both types are petrographically similar in that they contain quartz, plagioclase, K feldspar, microperthitic orthoclase and a range of accessory minerals including apatite, zircon, allanite, titanite and tourmaline.

Distinguishing features typical of the two-mica granites include their more quartz-rich nature, a more restricted potassium feldspar to plagioclase ratio, and a more common myrmekitic texture. Minerals in the two-mica granite generally have a more subhedral form and the biotite shows reddish brown pleochroism. The biotite-hornblende granitoids are distinguished by accessory dark green to brown pleochroic hornblende and dark brown pleochroic clinopyroxene. The biotite has chocolate brown pleochroism and an unusually large number of inclusions. The accessory minerals titanite, allanite and magnetite appear to be more abundant in the biotite-hornblende rocks. Red-brown biotite, pale green hornblende and beige clinopyroxene occur in the less abundant syenites, along with minor nepheline and enhanced amounts of magnetite and titanite.

Chemically, the rocks are subalkaline (two-mica and biotite-hornblende rocks) to alkaline (syenite).

The two-mica granites are characterized by normative corundum, higher alkalies and lower amounts of iron, calcium and magnesium than the biotite-hornblende rocks. The biotite-hornblende granites are distinguished by higher amounts of normative clinopyroxene, and the syenites by normative nepheline. Na_2O/K_2O, $Na_2O/K_2O/CaO$ *and Rb/Ba/Sr ratios are similar to other S-type granites.*

McQuesten region biotite-hornblende granodiorites are chemically distinguished from those of the Selwyn and Tombstone Suites by their peraluminous composition, lower modal quartz content, and higher iron to alkalies and magnesium ratios. Equivalent rocks of the Tombstone Plutonic Suite contain aegirine-augite indicating an A-type origin. In the McQuesten region, tungsten is associated with the biotite-hornblende rocks, whereas in the Selwyn area it is associated with two-mica granites.

RÉSUMÉ

Des plutons du Crétacé moyen pénètrent, dans la région de la rivière McQuesten, les roches sédimentaires métamorphisées miogéoclinales du bassin de Selwyn datant du Protérozoïque supérieur au Mississippien. Ils forment une zone s'allongeant vers l'est depuis le sillon de Tintina et qui peut grossièrement être subdivisée en deux zones parallèles. Il existe trois grands groupes de roches : 1) granite à biotite et muscovite (deux micas) dans la zone la plus méridionale qui suit l'orientation de l'anticlinal de McQuesten, 2) monzonite quartzique à biotite et hornblende, granite et granodiorite dans la zone septentrionale qui longe le contact par faille chevauchante entre le groupe de Hyland (unité de grit) et la formation de Road River et 3) syénite à hornblende et biotite et syénite quartzique associée, monzonite quartzique, granite et granite orbiculaire à tourmaline le long de la bordure de la zone septentrionale.

Les veines de brèche et les skarns stannifères et argentifères sont spatialement associés aux granites à deux micas alors que les skarns et les groupes de filons séparés de stériles renfermant du tungstène et de l'or sont associés au granite à biotite et hornblende, à la monzonite quartzique et à la granodiorite. L'intrusion de syénite à zonation concentrique de la zone septentrionale (ZETA) englobe toutes les phases plutoniques (granite à deux micas, granitoïdes à biotite et hornblende et syénitoïdes à hornblende et biotite) et les associe cogénétiquement les unes aux autres par le processus de la cristallisation fractionée. Les veines stannifères et argentifères ZETA sont associées au granite oprbiculaire à tourmaline qui constitue la phase la plus évoluée de l'intrusion de syénite à zonation concentrique ZETA.

Les variations pétrologiques et géochimiques entre les trois groupes confirment le caractère cogénétique des roches plutoniques de la zone, le granite à deux micas constituant la phase la plus évoluée. Les variations de la composition en éléments à l'état de traces et en terres rares suggèrent de plus que tout l'ensemble de la zone plutonique de McQuesten s'est formé à partir de roches sédimentaires fondues et que le fractionnement explique l'évolution des types individuels de roches ainsi que les dépôts de minéraux qui leurs sont associés.

Les plutons de la région de McQuesten sont quelque peu similaires aux suites plutoniques de Selwyn et de Tombstone. Ils sont contemporains du tectonisme, ou postérieurs à ce dernier, de forme approximativement circulaire et pénètrent les roches sédimentaires métamorphisées miogéoclinales de l'ancienne Amérique du Nord. Il présentent une zonation concentrique et sont entourés d'auréoles de contact. La suite intrusive est bimodale, comportant une zone méridionale qui consiste en granites à deux micas évolués et une zone septentrionale qui consiste en granites à biotite et hornblende moins évolués. Les laves associées aux plutons seraient contemporaines.

Les deux principaux types de roches ignées de chaque zone ont été comparés de manière détaillée. Les deux types sont pétrographiquement similaires du fait qu'ils renferment du quartz, du plagioclase, du feldspath potassique, de l'orthoclase microperthitique et une gamme de minéraux accessoires incluant l'apatite, le zircon, l'allanite, la titanite et la tourmaline.

Parmi les caractéristiques distinctives typiques des granites à deux micas mentionnons leur teneur plus élevée en quartz, un rapport feldspath potassique sur plagioclase moindre et une structure plus couramment myrmékitique. Les minéraux dans le granite à deux micas présentent généralement une forme davantage hypidiomorphe et la biotite présente un pléochroïsme brun rougeâtre. Les granitoïdes à biotite et hornblende se distinguent par la présence de hornblende pléochroïque vert foncé à brune et de clinopyroxène pléochroïque brun. La biotite présente un pléochroïsme brun chocolat et un nombre inhabituellement élevé d'inclusions. Les minéraux accessoires que sont la titanite, l'allanite et la magnétite semblent plus abondants dans les roches à biotite et hornblende. Les syénites, qui constituent les membres les moins abondants de ces suites, renferment de la biotite rouge-brun, de la hornblende vert pâle et du clinopyroxène beige. Parmi les minéraux accessoires mentionnons la néphéline, et des quantités accrues *de magnétite et de titanite.*

Chimiquement, les roches sont de subalcalines (roches à deux micas et à biotite et hornblende) à alcalines (syénite). Les granites à deux micas sont caractérisés par la présence de corindon normatif, par des alcalinités plus élevées et par des quantités moindres de fer, de calcium et de magnésium que celles présentes dans les roches à biotite et hornblende. Les granites à biotite et hornblende se distinguent par des quantités plus grandes de clinopyroxène normatif et les syénites par la présence de néphéline normative. Les rapports Na_2O/K_2O, $Na_2O/K_2O/CaO$ et Rb/Ba/Sr sont similaires à ceux des autres granites de type S.

Les granodiorites à biotite et hornblende de la région de McQuesten se distinguent chimiquement de celles des suites de Selwyn et de Tombstone par leur composition hyperalumineuse, leur teneur moindre en quartz modal et leurs rapports fer sur métaux alcalins et magnésium plus élevés. Les roches équivalentes de la suite plutonique de Tombstone renferment de l'augite aegyrinique, ce qui indique une origine de type A. Dans la région de McQuesten, le tungstène est associé aux roches à hornblende et biotite alors que dans la région de Selwyn il est associé aux granites à deux micas.

INTRODUCTION

Felsic plutons form a 30 x 150 km belt that trends east from Tintina Trench to Mayo Lake (30 km east of Keno Hill) in central Yukon (Fig. 1). They are mid-Cretaceous and intrude Upper Proterozoic to Mississippian metasedimentary rocks of the North American miogeocline. These plutons include over 20 stocks and plugs, and abundant dykes, many with associated metallic mineral occurrences and deposits. Keno and Galena Hill silver-lead-zinc veins have produced over 6 400 tonnes (206 million ounces) of silver since 1913 (Watson 1986), and are genetically related to the Mayo Lake Batholith (distal; Lynch 1988). Pluton-proximal mineralization includes the Ray Gulch skarn (MINFILE 106D 027) which has probable and possible reserves of 5.4 million tonnes grading 0.82% WO_3 (Lennan 1986). In the McQuesten River region, eleven plutons are directly associated with tin-tungsten-silver-gold veins, breccias and/or skarns (Fig. 2; Emond and Lynch 1992; Emond 1986, 1985, 1983).

Mid-Cretaceous, felsic plutons in the northern Canadian Cordillera post-tectonically intrude folded miogeoclinal sedimentary rocks of the Foreland Fold and Thrust Belt (the Omineca Crystalline Belt) and adjoining ductilely deformed metasedimentary rocks of Yukon Tanana Terrane which overlie the continental crust of ancestral North America. Local studies by Anderson and others have resulted in the naming of several plutonic suites based partly on geographic location, and partly on intrusion characteristics (Fig. 1; Woodsworth et al. 1989).

The McQuesten plutonic belt is part of the Selwyn Plutonic Suite of eastern Yukon. In the southeast part of the Selwyn Plutonic Suite (in the Selwyn Mountains), tungsten-copper (zinc) skarn deposits are associated with peraluminous, two-mica plutons (Anderson 1988). These deposits include MacTung (MINFILE 105O 002), with defined geologic reserves of 32 million tonnes grading 0.92% WO_3 (Atkinson and Baker 1986); and the Cantung (NWT) deposit, which produced nearly 39 000 tonnes WO_3 to the end of 1982 (Sinclair 1986).

The Tombstone Plutonic Suite intrudes folded and thrusted passive continental margin carbonate and clastic rocks (Anderson 1988) in the Tombstone Mountains (Fig. 1). It shows similarities to the Selwyn Plutonic Suite. However, several Late Proterozoic periods of extension in this area probably thinned the crust substantially (Thompson and Eisbacher 1984), resulting in more alkalic compositions and minor mafic phases. Vein, breccia, skarn, and disseminated U-Th-Sb-W-Mo-Sn-Ag-Au and base metal occurrences are associated with these plutons. Plutons in the northwestern part of the McQuesten River region were previously included in the Tombstone Plutonic Suite.

Little information is available on the granites in the Mayo-McQuesten area (Abercrombie 1990, Sinclair 1986, Kuran 1982). This report provides descriptions of the petrology and geochemistry of the McQuesten plutons, and comparisons with the well-documented Selwyn and Tombstone Suites. Additional information about mid-Cretaceous plutonism in the northern Cordillera will assist in interpretation of related mineral deposits.

GEOLOGIC SETTING

The McQuesten River region lies in Selwyn Basin, within the Omineca Crystalline Belt of the Canadian Cordillera. North American miogeoclinal rocks of the Late Proterozoic-Early Cambrian Hyland Group (formerly known as the Grit Unit) were thrust northward onto Ordovician to Silurian Road River Formation and Mississippian Keno Hill Quartzite (Wheeler and McFeely 1987, Eisbacher 1981, Bostock 1946 and 1964) during Late Triassic to Early Jurassic arc-continent collision. Thrusting formed a prominent east-northeast-striking cataclastic foliation, as well as the McQuesten Anticline, the limbs of which dip north and south at a shallow angle (Boyle 1965; Fig. 2).

Felsic intrusions were emplaced in the metasedimentary rocks of the ancient continental margin in the mid-Cretaceous (83 to 108 Ma; biotite, K/Ar, Stevens et al. 1982) and coeval lavas were extruded (85 Ma; whole rock, K/Ar, Hunt and Roddick 1987; Fig. 2). Igneous rocks from the McQuesten River region have high initial Sr isotope ratios (generally over 0.71; Abercrombie 1990; Sinclair 1986) indicating addition of radiogenic Sr from sialic Precambrian crust.

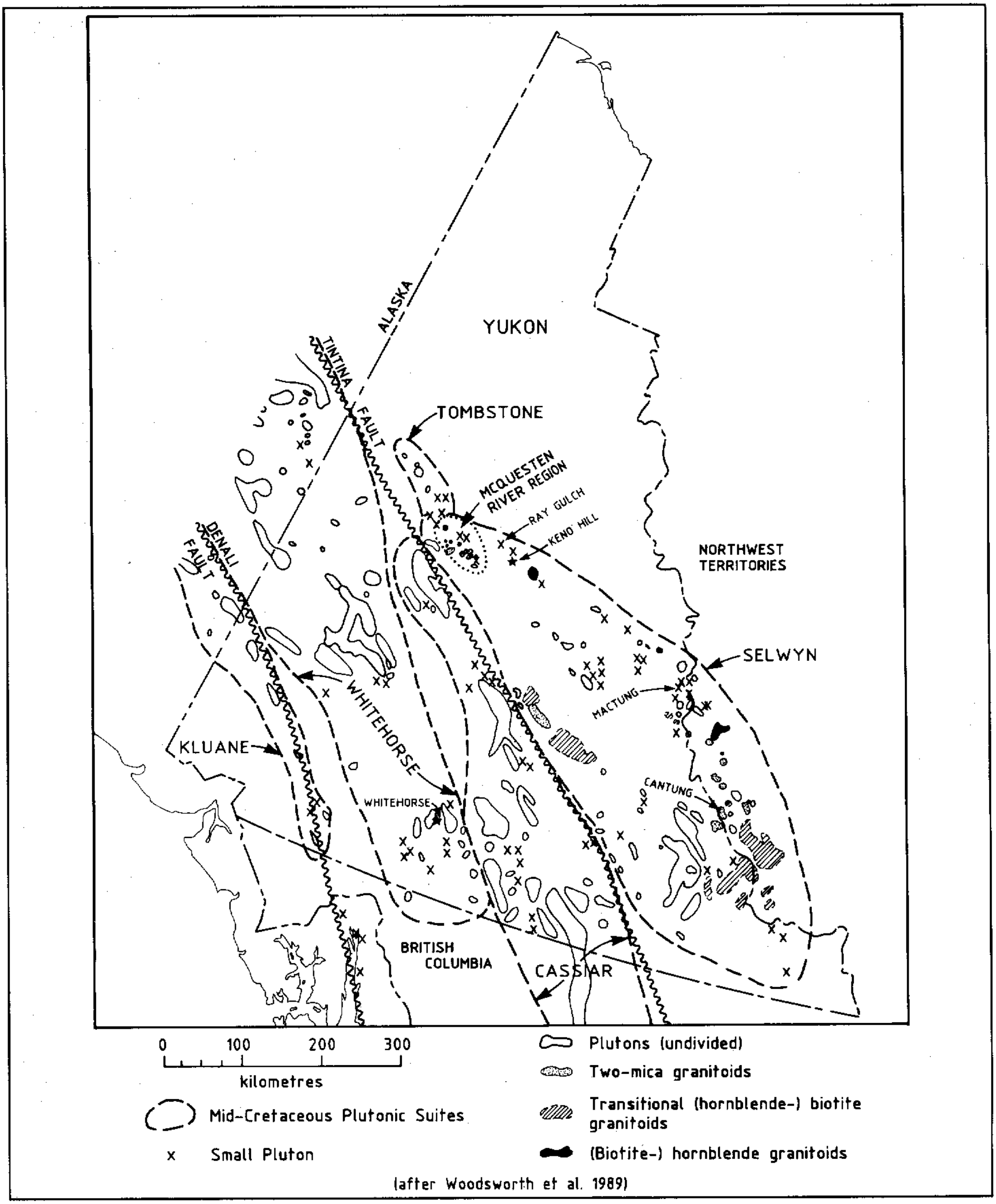

Figure 1. Location of the McQuesten River region and of mid-Cretaceous plutonic suites in Yukon (after Woodsworth et al. 1989).

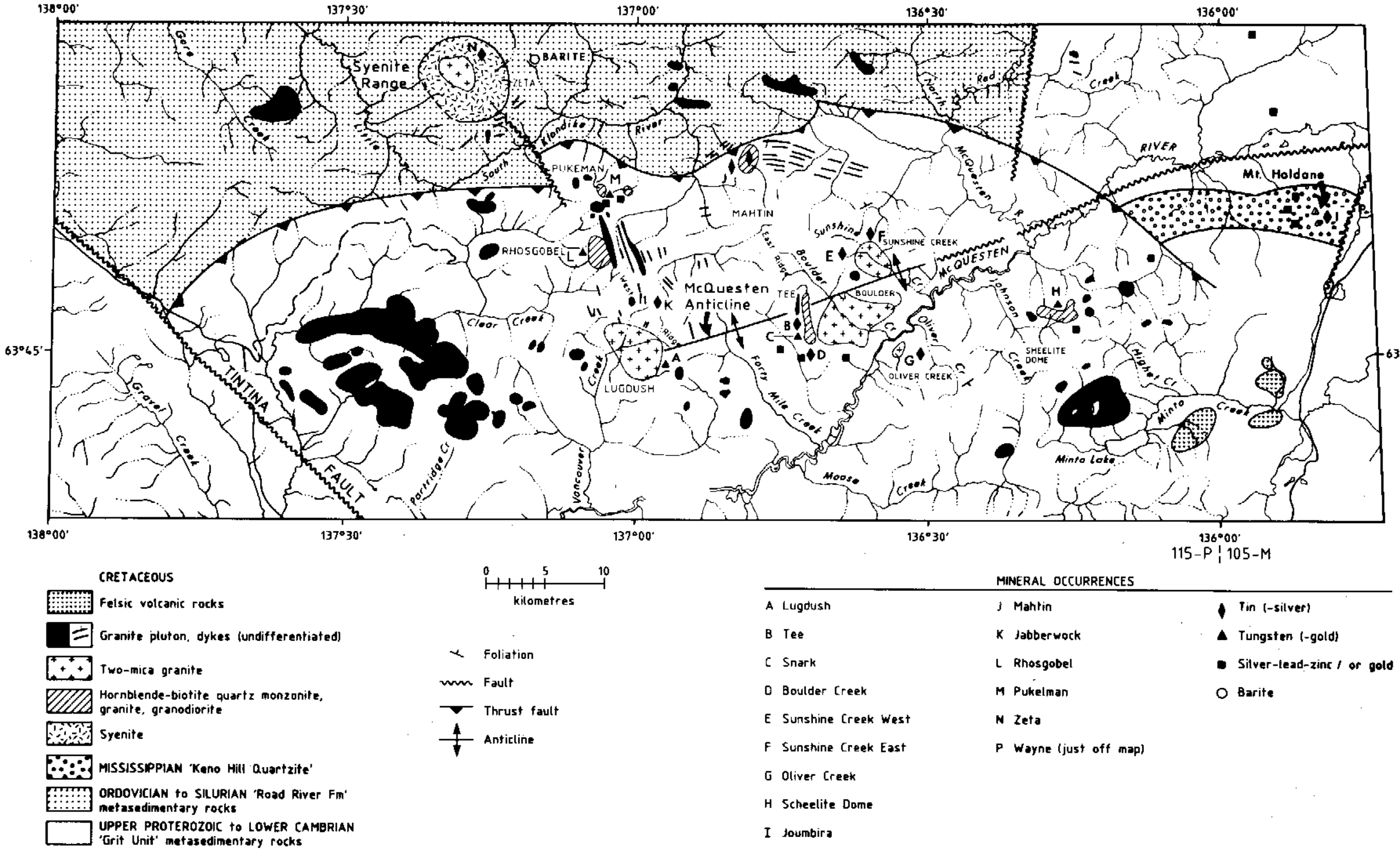

Figure 2. Geology and mineral occurrence map, McQuesten River region. Also shows distribution of two-mica granites, biotite-hornblende granitoids, hornblende-biotite syenites).

Field relations and regional geology show that the plutons were emplaced at a high level in Precambrian to Paleozoic sialic crust after a period of major deformation related to arc-continent collision. However, the coincidence of the suite along the McQuesten Anticline may indicate that some crustal warping was due to plutonism, and large batholiths may underlie the area.

CHARACTERISTICS OF INTRUSIONS

Stocks and plugs in the McQuesten River region outline two east-trending belts, a southern belt which follows the trend of the McQuesten Anticline, and a northern belt which follows the thrust faulted contact of the Hyland Group with the Road River Formation (Fig. 2).

Many of the intrusions are circular to subcircular in plan, and contacts with the surrounding metasedimentary rocks are discordant. Mineral foliation in the intrusions is restricted to and concordant with pluton margins. Xenoliths are uncommon except for large roof pendants in an intrusion near Minto Lake (Fig. 2) and fine grained diorite inclusions in some dykes. Contacts are sharp and in most cases plutons remain coarse grained to their margins, except the LUGDUSH (MINFILE 115P 009)[1] stock which has a fine-grained rim. Around the intrusions are contact aureoles of andalusite and/or biotite hornfels, calc-silicate hornfels, quartzite and minor tourmalinite.

Dykes are scattered through the metasedimentary rocks, and sheeted dyke systems also follow regional fault trends. One system in the MAHTIN (MINFILE 115P 007) area trends east-southeast, and another between JABBERWOCK (MINFILE 115P 051) and PUKELMAN (MINFILE 115P 013) trends north to north-northwest. Dykes also occur in the contact zones, both inside and outside the plutons. These dykes include tourmaline and muscovite-bearing aplites found in the endocontact zone at OLIVER CREEK (MINFILE 115P 030).

Intrusions are heterogeneous and commonly zoned from a more mafic rim to a more felsic core. This zoning is observed at ZETA (MINFILE 115P 047)(granite rimmed by syenite), SUNSHINE CREEK (MINFILE 115P 031)(granite rimmed by granodiorite), LUGDUSH (MINFILE 115P 009)(granite rimmed by dacite), BOULDER CREEK (MINFILE 115P 048) and TEE (MINFILE 115P 008a)(the BOULDER CREEK granite may be rimmed by the TEE granodiorite). Contacts between the zones vary from sharp to gradational. Rocks are medium to coarse-grained, and textures range from porphyritic to glomeroporphyritic, megacrystic and seriate.

There are three main groups of rocks. Biotite-muscovite ("two-mica") granite occurs in the southern belt (SUNSHINE CREEK (MINFILE 115P 031), BOULDER CREEK (MINFILE 115P 048), LUGDUSH (MINFILE 115P 009), OLIVER CREEK (MINFILE 115P 030) and JOUMBIRA (MINFILE 105M 031)). Biotite-hornblende quartz-monzonite, granite, and granodiorite are found mainly in the northern belt (at PUKELMAN (MINFILE 115P 013), RHOSGOBEL (MINFILE 115P 012), MAHTIN (MINFILE 115P 007), TEE (MINFILE 115P 008a) and SCHEELITE DOME (MINFILE 115P 004)). Hornblende-biotite syenite, quartz syenite, quartz monzonite, granite and tourmaline orbicular granite (ZETA (MINFILE 115P 047) zoned stock), and syenite dykes (MAHTIN (MINFILE 115P 007)), are confined to the northern belt. Intermediate and mafic rocks are rare.

PETROGRAPHY

Mineralogy and chemical composition separate the McQuesten plutonic belt into the three groupings described above. The following summary is based on petrographic descriptions of 50 samples of igneous rocks. Table 1 lists petrographic characteristics. Table 2 lists estimates of the mineral modes. Rocks were named according to Streckeisen (1973, Fig. 3).

(1) Two-mica Granite

Biotite-muscovite granite varies from allotriomorphic to hypidiomorphic granular and from equigranular to seriate or porphyritic. It contains mainly quartz and plagioclase, and locally K feldspar phenocrysts. Quartz and plagioclase are commonly glomerophyric, and K feldspar and quartz are megacrystic at LUGDUSH (MINFILE 115P 009). Myrmekite is common, especially in dyke rocks. Alteration includes sericitization of plagioclase, chloritization of biotite, and some microclinization and minor epidotization of the groundmass. Plagioclase varies from oligoclase to andesine and commonly shows concentric zoning. Inclusions of apatite, biotite and plagioclase occur in some plagioclase cores. Alkali feldspar phenocrysts consist of microperthitic orthoclase. Microcline is abundant in the groundmass of the JOUMBIRA (MINFILE 105M 031) plug, and is probably secondary. Quartz is strained, embayed, and has formed around phenocrysts. Interstitial biotite and muscovite consist of ragged, bent flakes. They occur both as separate grains and intergrown with each other. Pleochroic red-brown to light yellow biotite predominates. The biotite contains zircon inclusions with radiation haloes and minor apatite. Some muscovite is a fine grained alteration product, but other separate, medium sized grains appear primary (interstitial). It is pleochroic in shades of pink, clear and pale blue. Accessory minerals generally comprise less than 1% of the rock and include apatite, zircon, tourmaline, fluorite, monazite, opaques and titanite. Euhedral to subhedral apatite is particulary abundant in the SUNSHINE CREEK (MINFILE 115P 031) stock where it reaches up to several per cent. Primary, concentrically-zoned tourmaline is abundant in the OLIVER CREEK (MINFILE 115P 030) plug, with orange-brown cores and blue rims (Emond 1985). Titanite occurs only in the SNARK (MINFILE 115P 008b) dyke. Associated fine to medium-grained porphryitic to equigranular dykes include aplite, rhyodacite and quartz latite. Quartz, plagioclase and K feldspar occur as phenocrysts, and minor biotite and muscovite occur in the groundmass. Quartz amygdules are found at SUNSHINE CREEK EAST

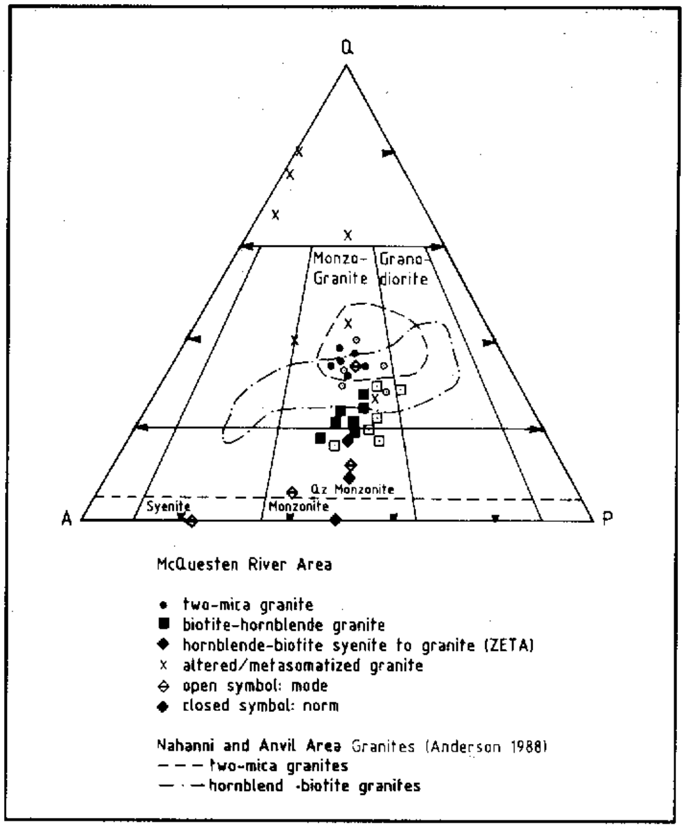

Figure 3. Quartz-orthoclase-plagioclase triangular diagram for felsic plutonic rocks of the McQuesten River region. Modes and normative composition are shown with the outline of the Streckeisen (1973) classification. Also shown is the outline of granitoids from the Selwyn Plutonic Suite (after Anderson 1988).

(MINFILE 115P 031b). Dykes are albitized, sericitized and tourmalinized at JOUMBIRA (MINFILE 105M 031) and OLIVER CREEK (MINFILE 115P 030), and sericitized and silicified at SUNSHINE CREEK (MINFILE 115P 031).

(2) Hornblende-Biotite Granite, Quartz Monzonite and Granodiorite

These rocks generally contain up to 20 % less modal quartz than the two-mica granites (Fig. 3). The hornblende-biotite granitoids are mainly hypidiomorphic and idiomorphic granular (locally allotriomorphic granular) and porphyritic. As well as normal phenocrysts of quartz, plagioclase and alkali feldspar, they contain perthitic K feldspar megacrysts, and quartz "clots" and glomerophyrs. Quartz phenocrysts commonly have square cross sections. Groundmass consists of perthite, plagioclase, hornblende, biotite and quartz in varying proportions. Myrmekite was not observed in these rocks. Alteration includes sericitization and microclinization of plagioclase, chloritization of biotite and hornblende, biotitization and epidotization of hornblende, uralitization of clinopyroxene, and minor secondary carbonate.

Plagioclase consists of slightly more calcic andesine, with more oscillatory zoning than in the two-mica granite. Alkali feldspar is mostly perthitic orthoclase, with minor replacement microcline. Quartz is strained.

Biotite and hornblende are interstitial and commonly intergrown. Biotite is more abundant than hornblende, and has higher absorption and cleaner edges than biotite in the two-mica granite. Pleochroism varies from chocolate brown to light yellowish brown at PUKELMAN (MINFILE 115P 013) and RHOSGOBEL (MINFILE 115P 012), to reddish brown at TEE (MINFILE 115P 008a) and SCHEELITE DOME (MINFILE 115P 004). Hornblende is mostly light brownish green to pale yellow, and also pinkish green and light bluish green, except at PUKELMAN and RHOSGOBEL, where it is grass green to pale yellow. Some hornblende is poikilitic, and some zoned. Up to 2% beige to clear pleochroic augite occurs with the hornblende and biotite.

Euhedral to subhedral accessory minerals include allanite, titanite, apatite, zircon, magnetite and other opaques. Locally, several percent titanite is associated with mafic minerals. Allanite is commonly twinned and has chlorite overgrowths.

Dykes are fine to coarse grained and porphyritic, with phenocrysts of plagioclase, perthite, quartz, hornblende and biotite. Composition varies mostly from quartz latite to latite. Alteration includes mainly chloritization of hornblende and some sericitization of plagioclase, but albite, carbonate, muscovite, epidote and tourmaline also occur as alteration minerals in places. Rare biotite-phyric lamprophyre occurs near SCHEELITE DOME (MINFILE 115P 004).

(3) Hornblende (-Biotite) Syenite, Quartz Syenite, Quartz Monzonite and Granite

These rocks form a zoned intrusion (ZETA; MINFILE 115P 047), in the Syenite Range. According to Abercrombie (1990), the modal composition of these rocks varies from syenite at the rim through quartz syenite and granite to tourmaline orbicular granite in the core. The present study showed variation from syenite to low-quartz quartz monzonite to quartz monzonite to tourmaline orbicular granite. Textures range from equigranular to porphyritic, with euhedral alkali feldspar phenocrysts.

In the syenite, plagioclase and hornblende are intersitial or occur along fractures. Nepheline occurs in the syenite as a late magmatic mineral along grain boundaries, and is commonly scarred by inclusion tracks. Late magmatic overgrowths of hornblende occur on clinopyroxene. A myrmekitic texture occurs along the margins of perthite phenocrysts. Alteration consists of K feldspathization of plagioclase, biotitization of hornblende, and late calcite.

The central part of the intrusion is perthite and plagioclase-phyric quartz monzonite to equigranular granite with a core of tourmaline orbicular granite. "Epitactic" texture, an intergrowth of K feldspar, tourmaline, interstitial quartz and sericitic plagioclase, is common in the orbicules

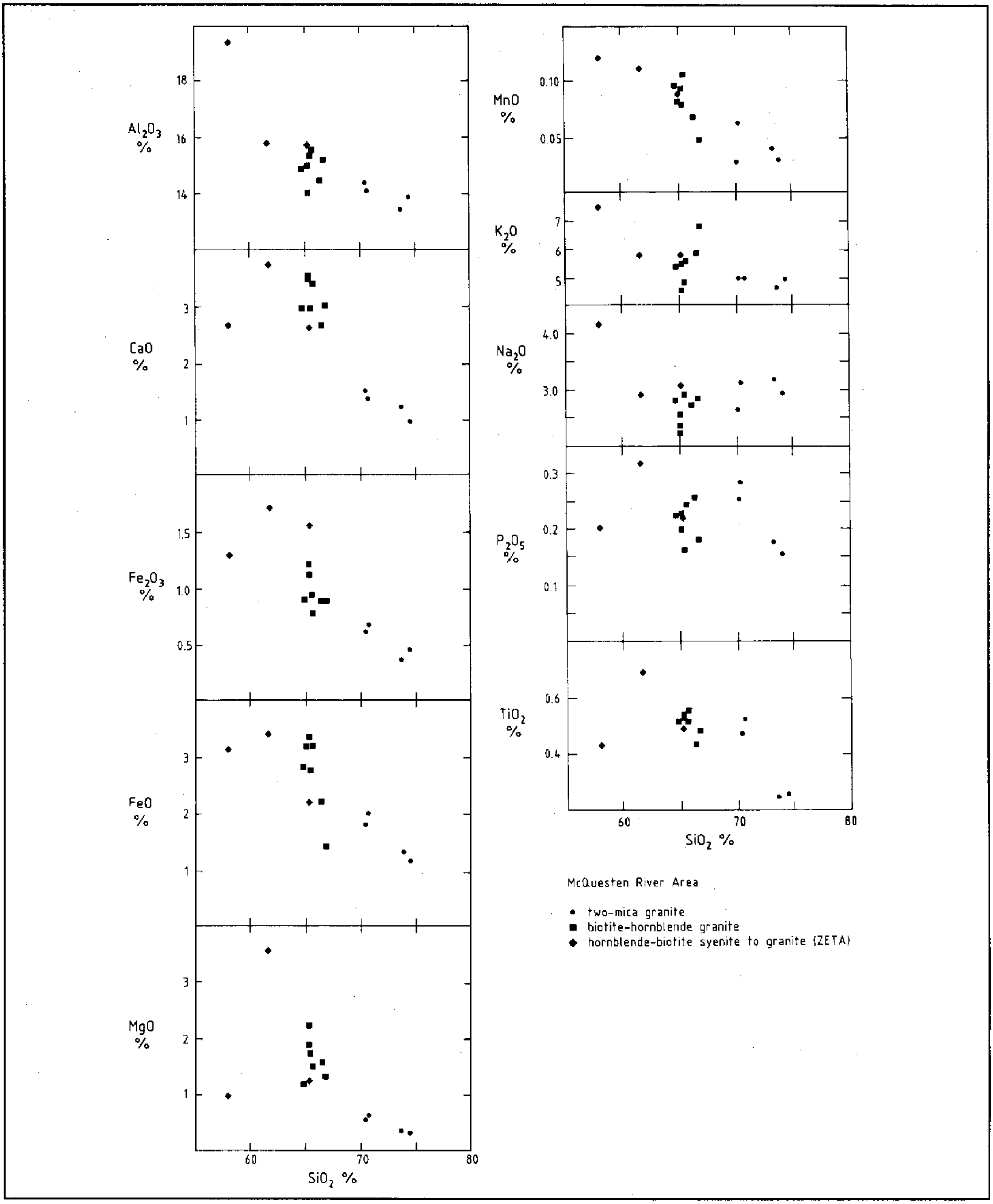

Figure 4a. Harker diagrams for felsic plutonic rocks of the McQuesten River region. (a) Major elements vs SiO_2.

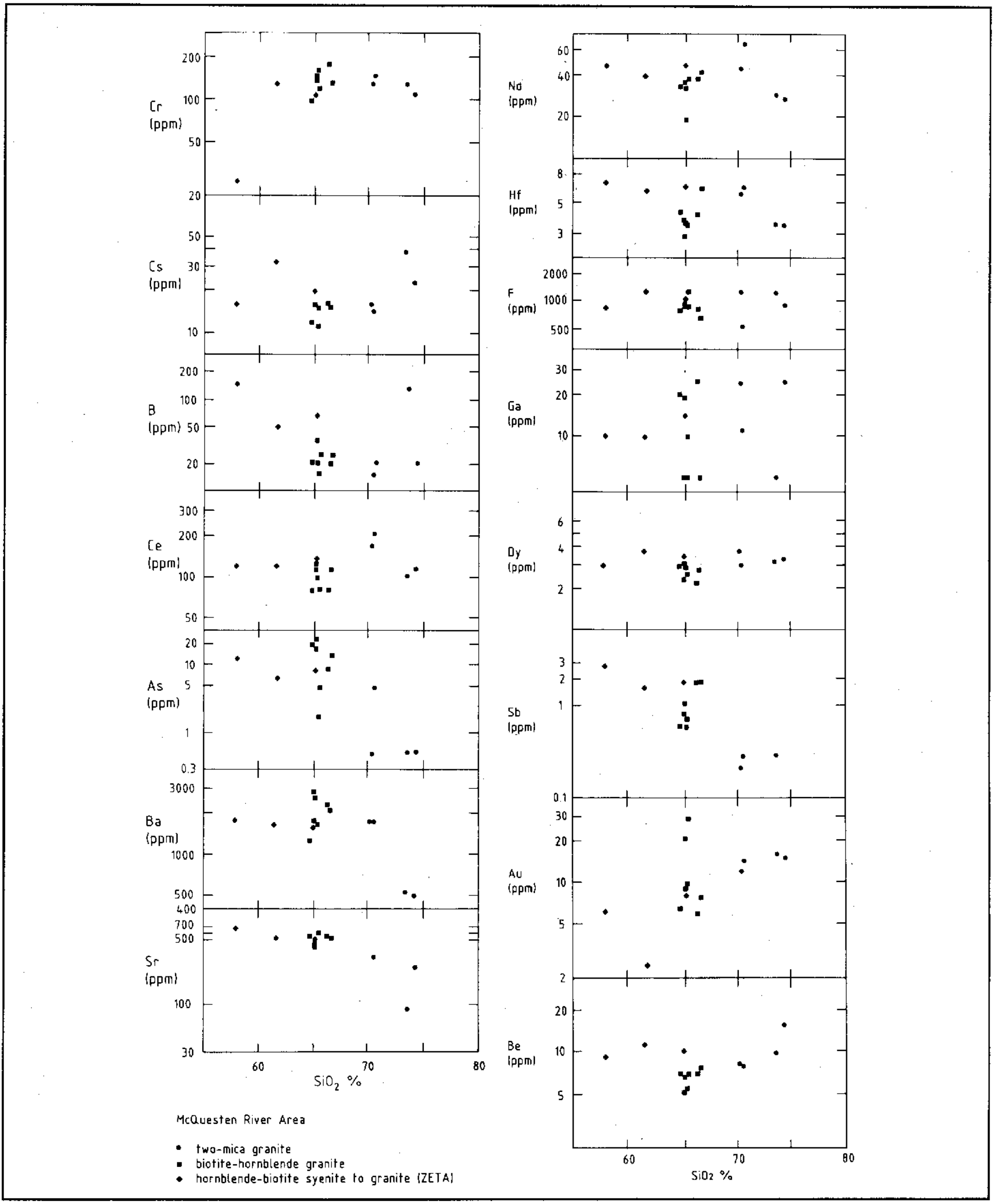

Figure 4b. Harker diagrams for felsic plutonic rocks of the McQuesten River region. (b). Minor and trace elements vs SiO_2.

which range up to 10 cm or more in diameter. Up to 1% tourmaline also occurs disseminated in the granite. The tourmaline includes both brown to black and blue to clear pleochroic varieties. Up to 2% muscovite occurs as free grains and as sericitic alteration of feldspar. Cassiterite is intergrown with the tourmaline.

Both the quartz monzonite and the quartz syenite (Abercrombie 1990) contain approximately 5% modal quartz and lie compositionally and spatially between the syenite and the quartz monzonite to granite core.

Petrographically, the hornblende-biotite syenite and quartz monzonite resemble the biotite-hornblende granitoids, and the granite resembles the two-mica granites (see sections 1 and 2). Points of similarity include mineral morphology and pleochroism. Alkali feldspar is perthite, and plagioclase is oligoclase or andesine. Hornblende predominates over biotite, and has strong absorption with dark green-brown to red-brown to yellow-green pleochroism, with a bright green variety in the granite. Biotite also shows strong absorption, with dark red-brown to light yellow-brown pleochroism in the syenite, and chocolate brown to light yellow-brown pleochroism in the granite. Up to 5% of the rock consists of medium to light brown pleochroic clinopyroxene, probably augite. Inclusion-rich augite cores are commonly overgrown by hornblende with a similar orientation. Euhedral to subhedral accessory minerals include tourmaline, muscovite, allanite, titanite, cassiterite, apatite, zircon and rutile. After tourmaline in the tourmaline-rich granite, allanite (up to 1%) is the most abundant accessory mineral. Tourmaline, muscovite and cassiterite occur mainly in the orbicular granite. According to Abercrombie (1990), the syenite and quartz syenite contain magmatic epidote, indicating lithostatic pressure of crystallization greater than 8 kbar (Zen and Hammerstrom, 1984).

Quartz-plagioclase porphyry dykes occur just inside the contact of the syenite intrusion at ZETA (MINFILE 115P 047). The dykes contain round quartz phenocrysts, and both biotite and muscovite are present. Greisenization, including abundant sericitization and tourmalinization, is common, especially near the tourmaline-rich tin-silver veins. Radiating aggregates of tourmaline needles, which locally make up more than 10% of the rock, are associated with cassiterite.

Sheeted porphyry dykes, including hornblende syenite, latite and quartz latite, occur near a hornblende-biotite intrusion at MAHTIN (115P 007). Phenocrysts consist mostly of alkali feldspar, plagioclase and hornblende, with minor quartz and biotite. Accessory minerals include augite and titanite, and minor zircon, apatite, epidote and calcite.

GEOCHEMISTRY

Twenty-five samples of plutons and dykes associated with tin and tungsten mineralization, some from each of the three groups of rocks outlined above, were analysed for major, minor, trace and some rare earth elements (Table 2).

Generally CIPW normative mineralogy is similar to modal estimates (Fig. 3). The two-mica granite, biotite-hornblende granite, and hornblende-biotite syenite are geochemically distinct. The more evolved phases from the core of the ZETA (MINFILE 115P 047) syenitic intrusion are similar to the hornblende-biotite granitoids and two-mica granites from the rest of the region. The phases grade from hornblende-biotite syenite to quartz monzonite to biotite-hornblende granite to two-mica granite. Harker diagram variation trends are irregular, although some useful patterns were recognized (Fig. 4). Some exceptions to trends noted below may be significant to individual plutons, but are not discussed here. All rocks are peraluminous (Shand index A/CNK = molar $Al_2O_3/(CaO + Na_2O + K_2O)$ greater than 1.0), but the two-mica granites have a slightly higher ratios (greater than 1.1; Fig. 5) than the hornblende-biotite granitoids.

In the following paragraphs, the term 'average' as applied to granite, granodiorite, syenite, etc. is based on analytical data published by Cox et al. (1979).

(1) Two-mica Granites

The two-mica granites are peraluminous, with higher SiO_2, K_2O and P_2O_5, and lower Fe_2O_3, MnO, MgO, CaO and Na_2O than 'average' granite. Analyses indicate 1.86 to 2.59% normative corundum and 2.34 to 4.09% hypersthene (Fig. 6). The sum of normative albite, orthoclase and quartz ("Differentiation Index" (D.I.) of Thornton and Tuttle, 1960) makes up 82 to 89% of the calculated norm, and normative anorthite ranges from 4.32 to 10.07%. Normative quartz, plagioclase and orthoclase are subequal, with slightly higher quartz. Average compositions are shown in Table 3. Harker diagram patterns are regular: SiO_2 and Na_2O (and trace elements Rb, Be, Sb, B, Cs, Au and Y) increase; and Al_2O_3, CaO, Fe_2O_3, FeO, MgO and TiO_2 (as well as Ba, Hf and Sr) decrease (Fig. 4a and 4b). This indicates that fractional crystallization probably controlled the formation of these granites. Analyses resemble those of low calcium, low magnesium, high potassium calc-alkaline granitoids (White and Chappell 1983). They also are similar in SiO_2, Al_2O_3, TiO_2, MnO and P_2O_5 content to the "tin granites" of the Seward Penninsula (Hudson and Arth 1983), but higher in K_2O, lower in Fe_2O_3 and Na_2O, and slightly lower in MgO and FeO.

(2) Hornblende-biotite Granitoids

Hornblende-biotite granite, quartz monzonite and granodiorite have levels of SiO_2, TiO_2, CaO, MgO, MnO and P_2O_5 similar to 'average' granodiorite, but much higher amounts of K_2O (Sb and Sr), and lower Na_2O, Al_2O_3, Fe_2O_3, Be, Au and Y (Fig. 4a and 4b). They are less evolved than the two-mica granites, with lower SiO_2, Na_2O+K_2O versus Fe-oxides, MgO, CaO, Rb, Y and Nb (Figs. 5, 7, 8 and Table 3), and higher levels of Ca, Fe and Mg oxides, TiO_2, MnO, Al_2O_3, Sr, Ba, Sb, As and Ba/Rb (Fig. 9, Table 3). Other distinguishing features include a lower D.I. (70 to 81%), higher normative pyroxene (3.42 to 9.43% hypersthene, up to 4.03% diopside), and zero normative corundum except at TEE (MINFILE 115P 008a) and SCHEELITE DOME

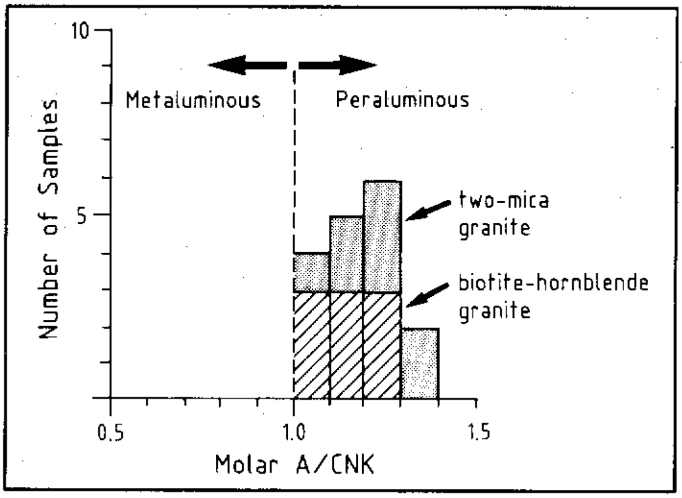

Figure 5. Shand Index diagram (histogram of molar $Al_2O_3/(CaO+Na_2O+K_2O)$).

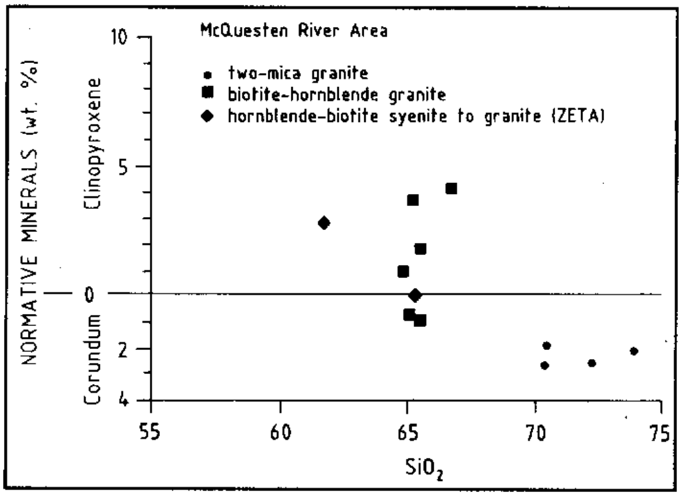

Figure 6. Normative clinopyroxene and corundum vs SiO_2.

(MINFILE 115P 004)(up to 0.89%). Internal variations are shown by Harker diagrams (Figs. 4a and 4b). SiO_2, K_2O and Na_2O increase, and CaO, FeO, MnO and TiO_2 decrease. Trace elements are less variable than in the two-mica granites.

(3) ZETA Zoned Intrusion (Syenite-Quartz Monzonite-Granite)

The D.I. for these rocks varies from 67 to 77%. A/CNK values are all surprisingly high, ranging from 1.09 to 1.15. Hornblende (-biotite) syenite is characterized by normative and modal nepheline, olivine, very minor corundum, and no pyroxene (Table 3). Modal SiO_2 and Na_2O resemble 'average' syenite, but Al_2O_3, CaO, K_2O and P_2O_5 are more similar to 'average' phonolite, except for FeO which is at least 1% higher, and TiO_2 which is slightly lower.

The quartz monzonite is characterized by 12.85% normative hypersthene and 2.9% diopside, and also has the highest normative magnetite and ilmenite of all rocks analysed. Its composition is mostly intermediate between the syenite and granite, although it has the lowest D.I. of the three. Chemically it is also similar to the hornblende-biotite granitoids.

The tourmaline orbicular granite in the core of the ZETA intrusion is not strictly comparable with the other granitoids, due to the high silica (78.5%) and boron (2850 ppm) content associated with the large orbicules (analysis not shown in Table 2). However, the interstitial granitic material resembles the two-mica granite in modal and trace element composition (Fig. 3). It appears to be slightly more evolved than the two-mica granite. The tourmaline orbicular granite shows several notable features when compared to other granitoids: (1) severe depletion of Ba, (2) depletion of Ce, Dy, F, Ga, Au, Hf, Nd, Sr and Y, and (3) enrichment in Sb.

Variation from syenite to quartz monzonite to granite corresponds to Harker trends, with increasing SiO_2 and decreasing MnO, but little variation in trace elements. Variation from syenite to quartz monzonite is marked by an increase in SiO_2, CaO, Fe_2O_3, FeO, MgO, P_2O_5 and TiO_2 and the trace elements Cs, Cr and F, and a sharp decrease in Na_2O, K_2O, Sb, As, B and Au. Variation from quartz monzonite to granite is marked by a decrease in SiO_2, CaO, Fe_2O_3, FeO, MgO, P_2O_5 and TiO_2, and an increase in Na_2O, B, Ga and Au. The variation in Ca, Fe, Mg, P and Ti is probably due to pyroxene, apatite and sphene fractionation.

Compared to both the two-mica and hornblende-biotite granitoids, the zoned syenite to quartz monzonite to granite intrusion contains similar amounts of As, Ba, F, Ga, Sr and Y, slightly higher amounts of Be, Sb, B, Ce, Cs, Dy, Hf and Nd; and slightly lower values of Cr and Au (Fig. 4b and Table 3). The quantities of Be, B, Ce, Cs and Dy in the ZETA intrusion rocks are similar to those in the highly evolved phases of the two-mica granites.

Rb-Ba-Sr Relationships

The two-mica granite is significantly enriched in Rb with respect to Ba and Sr compared to the hornblende-biotite granite, with the core of the SUNSHINE CREEK (MINFILE 115P 031) intrusion being the most enriched (Fig. 9). The Ba/Sr and Ba/Rb ratio increases in the hornblende-biotite granites and syenites from the less evolved PUKELMAN, RHOSGOBEL (MINFILE 115P 012) and ZETA (MINFILE 115P 047) intrusions, through the MAHTIN (MINFILE 115P 007) intrusions, to the more evolved TEE (MINFILE 115P 008a) and SCHEELITE DOME (MINFILE 115P 004) intrusions. The latter intrusions have similar Ba/Sr and Ba/Rb ratios to the least evolved of the two-mica granites.

RARE EARTH ELEMENTS

The following rare earth elements (REE's) were analysed: La, Ce, Nd, Sm, Eu, Gd, Tb, Dy, Yb and Lu (Table 2).

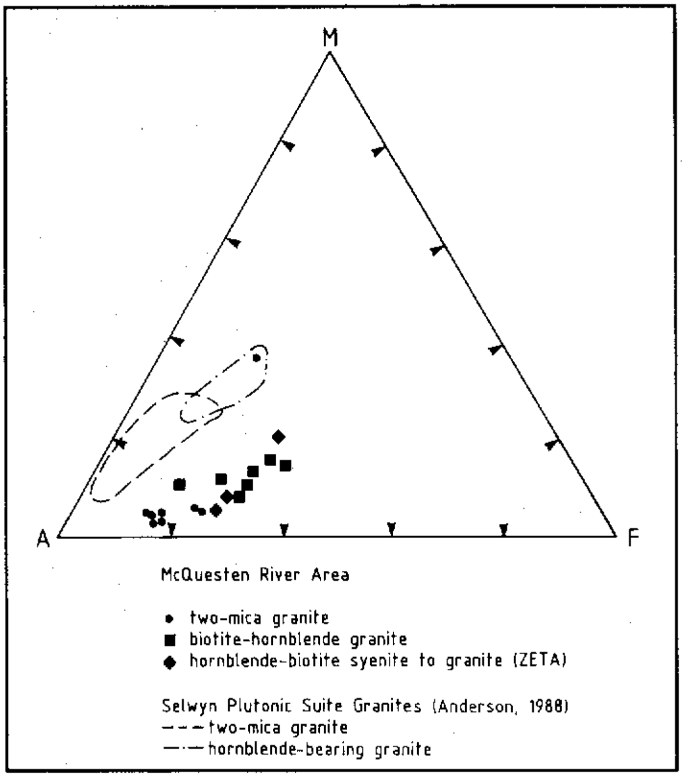

Figure 7. AFM diagram (triangular, Na_2O+K_2O vs Fe_2O_3+FeO vs MgO).

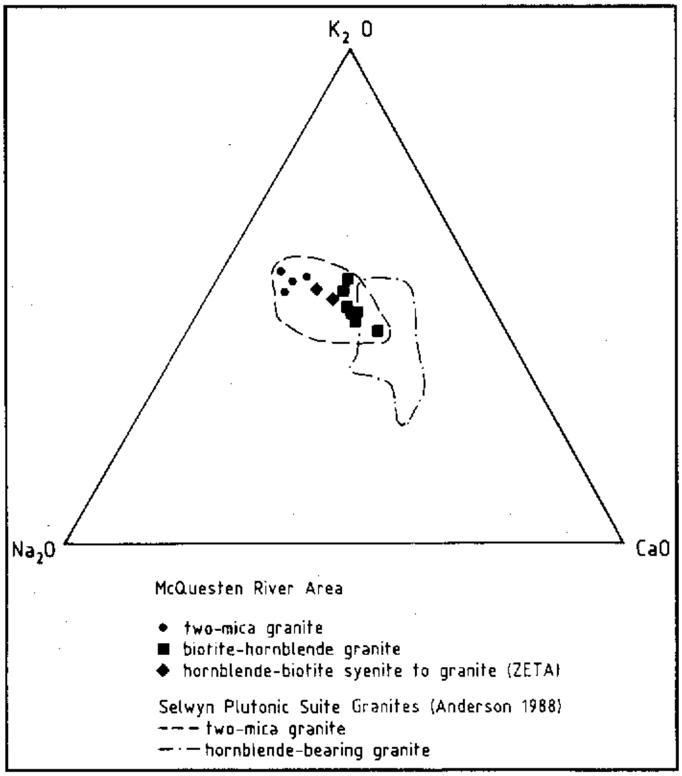

Figure 8. Na_2O-K_2O-CaO triangular diagram.

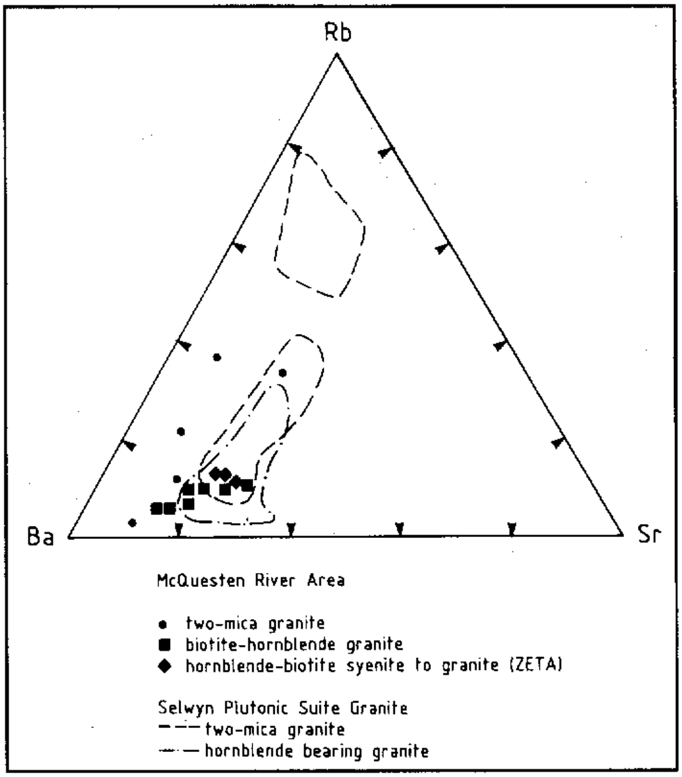

Figure 9. Rb-Ba-Sr triangular diagram (ratios of ppm quantities).

Chondrite normalized graphs were used as an aid to interpretation (Fig. 10). However, due to the detection limits of Eu and Gd (2 ppm and 200 ppm, respectively), the graphs are abnormal, with a positive Gd anomaly but no negative Eu anomaly.

All patterns have negative slopes showing light rare earth (LREE) enrichment, and lower abundances of heavy rare earths (HREE). The following rock types are listed in decreasing order of LREE enrichment: (1) two-mica granite from LUGDUSH (MINFILE 115P 009); (2) two-mica granite from the rim of SUNSHINE CREEK (MINFILE 115P 031), syenite and quartz monzonite from ZETA (MINFILE 115P 047), hornblende-biotite granodiorite from TEE (MINFILE 115P 008a), hornblende-biotite granite from RHOSGOBEL (MINFILE 115P 012) and PUKELMAN (MINFILE 115P 013), and two-mica granite from the core of SUNSHINE CREEK (MINFILE 115P 031); (3) two-mica rhyodacite dyke from JOUMBIRA (105M 031), sericitized dacite rim of LUGDUSH (MINFILE 115P 009)(hornblende-biotite), and rhyodacite dykes from SNARK (MINFILE 115P 008b), ZETA (MINFILE 115P 047), SUNSHINE CREEK WEST (MINFILE 115P 031) and WAYNE (MINFILE 105M 029). The third group shows less LREE enrichment and slightly more HREE depletion. The rim of the SUNSHINE CREEK pluton is enriched in LREE relative to the core. This is explained by fractionation of apatite, which forms more than

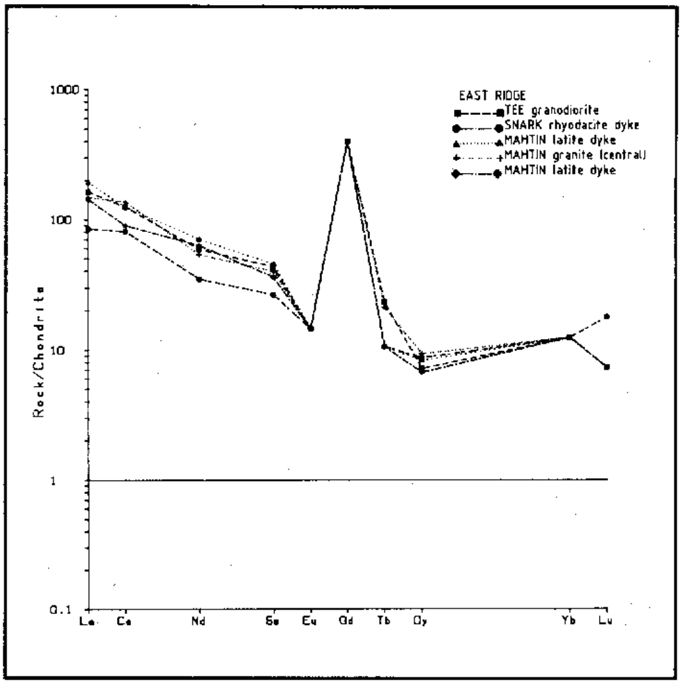

Fig. 10a Chondrite-normalized rare earth element diagram: East Ridge.

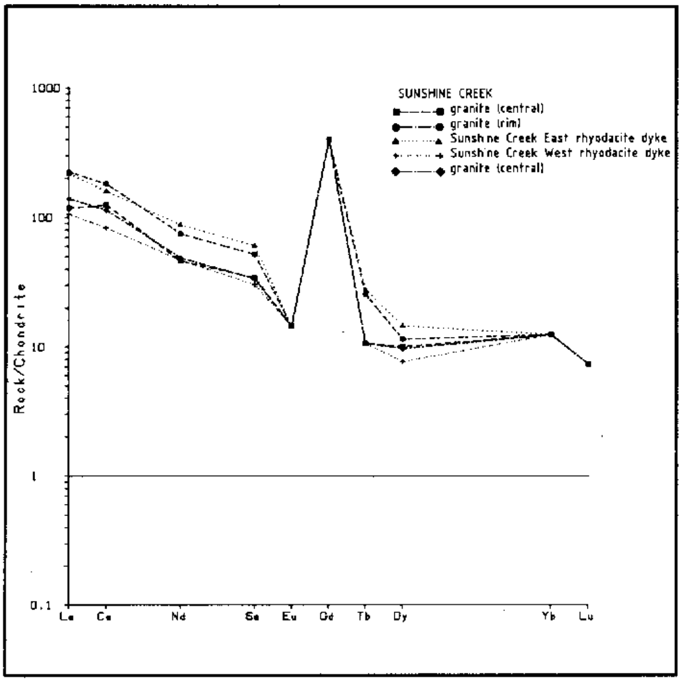

Fig. 10b Chondrite-normalized rare earth element diagram: Sunshine Creek.

2% of the rim. Most phases of the zoned syenite to granite intrusion at ZETA are similar, but the orbicular granite is relatively depleted in HREE, an indication of its highly evolved nature.

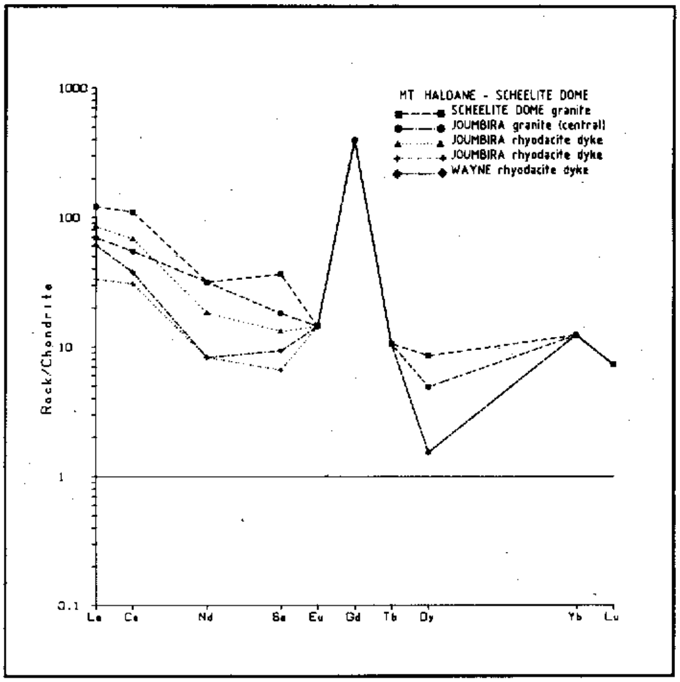

Fig. 10c Chondrite-normalized rare earth element diagram: Mt. Haldane & Scheelite Dome.

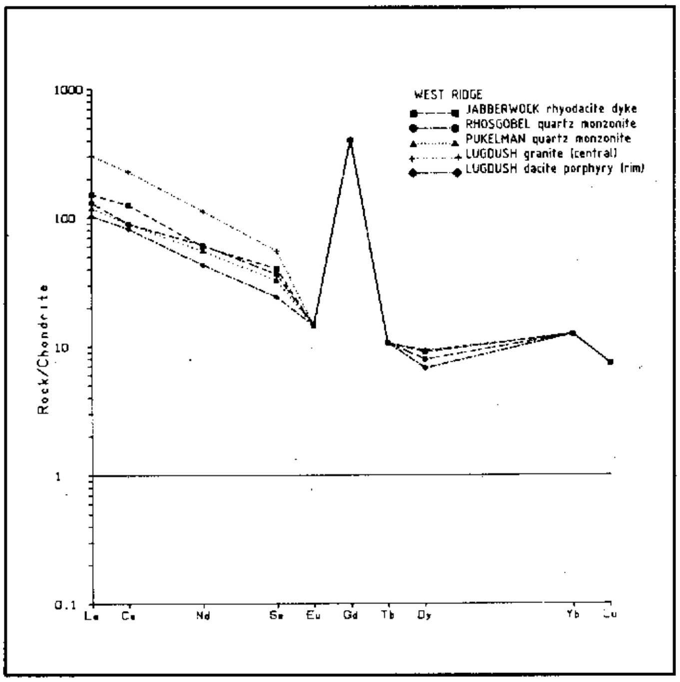

Fig. 10d Chondrite-normalized rare earth element diagram: West Ridge.

INCOMPATIBLE AND RARE EARTH VARIATION AS AN AID TO TECTONIC INTERPRETATION

Pearce et al. (1984) used trace element variations to distinguish between granites from different tectonic settings. They defined a granite as any plutonic rock containing more

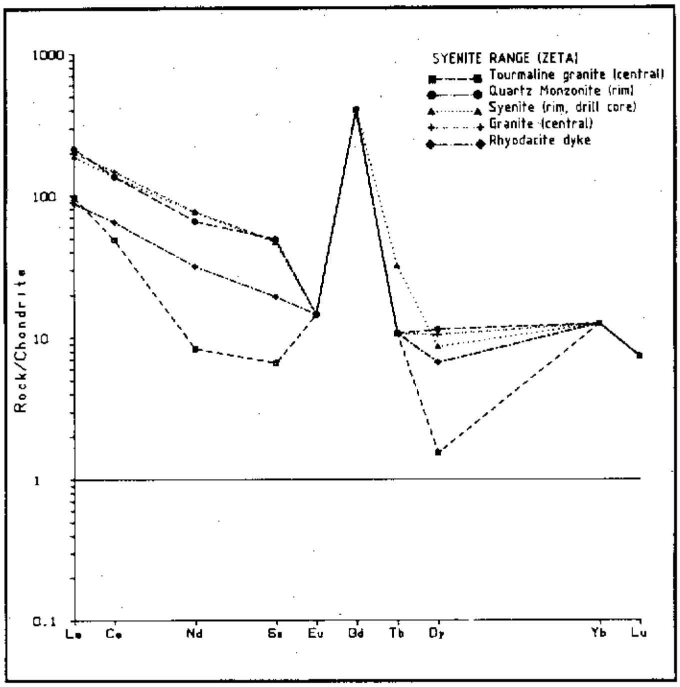

Fig. 10e. Chondrite-normalized rare earth element diagrams from Syenite Range (Zeta).

than 5% modal quartz. The following four groups of granites were established: (1) ocean ridge (ORG), (2) volcanic arc (VAG), (3) within plate (WPG), and (4) collision (COLG) granites. These groups were further subdivided according to their precise setting: for instance the latter group was divided into syn- and post-COLG's. "Using ORG-normalized geochemical patterns and element-SiO_2 plots ... most granite groups exhibit distinctive trace element characteristics ... Post-collision granites present the main problem of tectonic classification, since their characteristics depend on the thickness and composition of the lithosphere involved in the collision event and on the precise timing and location of magmatism. Provided they are coupled with a consideration of geological constraints, however, studies of trace element compositions can clearly help in the elucidation of post-Archean tectonic settings." (Pearce et al. 1984, p. 956).

Elements included in the diagrams are restricted to those thought to behave incompatibly during fractionation of MORB to felsic composition. The rare earth elements are represented by Ce, Sm and Yb. In the diagrams, the elements are plotted in order of increasing incompatibility during MORB genesis (from Yb to Rb). Flat patterns (near unity) reflect granite with a simple genetic history: derived from convecting upper mantle, derived from a basalt parent by fractional crystallization, or unaffected by crustal melting, assimilation or volatile-dominated processes. Deviations from these flat patterns indicate a more complex genetic history for the granite.

ORG-normalized diagrams for the McQuesten plutonic rocks are shown in Figures 11a-e. Some examples of collision and volcanic arc granites from Pearce et al. (1984) are shown in Figures 11f-h. The McQuesten rocks show patterns similar to "collision" and Chilean "volcanic arc" granites. All of the samples have very high values which are 30 to 90 times the norm, (a feature typical of evolved granites), high Rb and Th compared to Ta and Nb, with Th to Ta ratios ranging from 5:1 to 50:1 (typical of "crust-dominated" plutons), and a general increase in the trace elements from Yb to Rb. Several patterns also show negative Ba anomalies, and/or positive Ce and Sm anomalies with respect to adjacent elements, another "crust-dominated" feature.

Negative Ba anomalies are characteristic of two-mica granites at SUNSHINE CREEK (MINFILE 115P 031) and LUGDUSH (MINFILE 115P 009). The rim of the SUNSHINE CREEK (MINFILE 115P 031) pluton is similarly depleted in barium with respect to the core. This is consistent with Ba depletion in the magma at a late stage in the differentiation process. The syenite from ZETA (MINFILE 115P 047) shows a pattern similar to the other granites, but without the Ba anomaly. The hornblende-biotite granites show a consistent decrease from Rb to Ba to Th, or a slight positive Ba anomaly.

Positive Ce and Sm anomalies occur in the two-mica granite at LUGDUSH (MINFILE 115P 009), but are absent in the centre of the SUNSHINE CREEK (MINFILE 115P 031) stock. The latter is probably due to apatite crystallization in the rim causing depletion of LREE in the residual magma. Positive Ce and Sm are also associated with in hornblende-biotite granite at SCHEELITE DOME (MINFILE 115P 004), TEE (MINFILE 115P 008a) and MAHTIN (MINFILE 115P 007).

Some positive Zr anomalies are present in hornblende-biotite granites at RHOSGOBEL (MINFILE 115P 012), PUKELMAN (MINFILE 115P 013) and SCHEELITE DOME (MINFILE 115P 004), and in tourmaline orbicular granite and dyke rock from ZETA (MINFILE 115P 047). This can be explained by accumulation of zircon crystals at more mafic compositions (Pearce et al. 1984).

Hornblende-biotite syenite and granite from ZETA (MINFILE 115P 047), MAHTIN (MINFILE 115P 007), PUKELMAN (MINFILE 115P 013) and RHOSGOBEL (MINFILE 115P 012)(the northern belt), have a lesser Th:Ta ratio, and are richer in Nb than other granites (both hornblende-biotite and two-mica granites), indicating a less crust-dominated origin.

A rhyodacite dyke and the central two-mica granite plug at JOUMBIRA (MINFILE 105M 031), and the dacite rim of LUGDUSH (MINFILE 115P 009) each show a positive Ba anomaly, very low Y and a slight Zr anomaly. The positive Ba and low Y could be due to alteration, since the feldspar is commonly sericitized.

The general similarities in these trace element patterns and abundances suggest that melted sedimentary rocks formed the entire McQuesten plutonic belt. Even rocks which show evidence of alteration or metasomatism in thin section show strikingly similar trace element patterns.

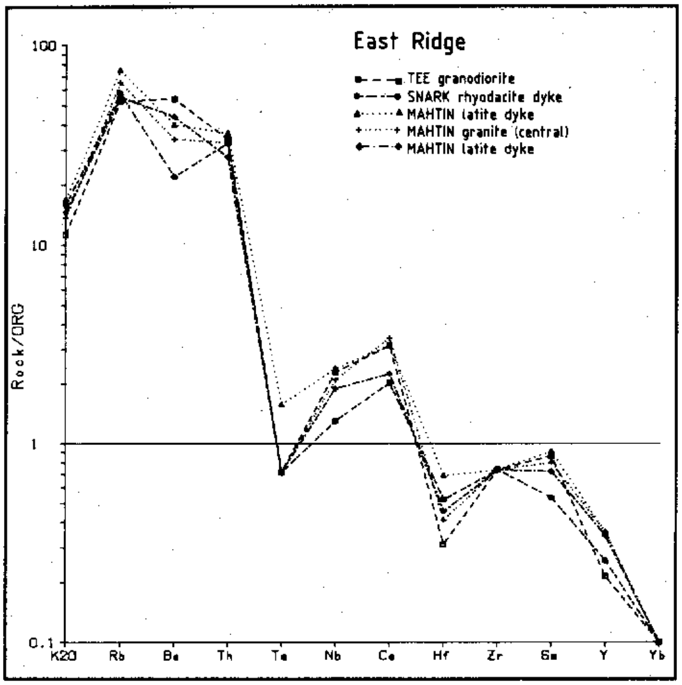

Fig. 11a.

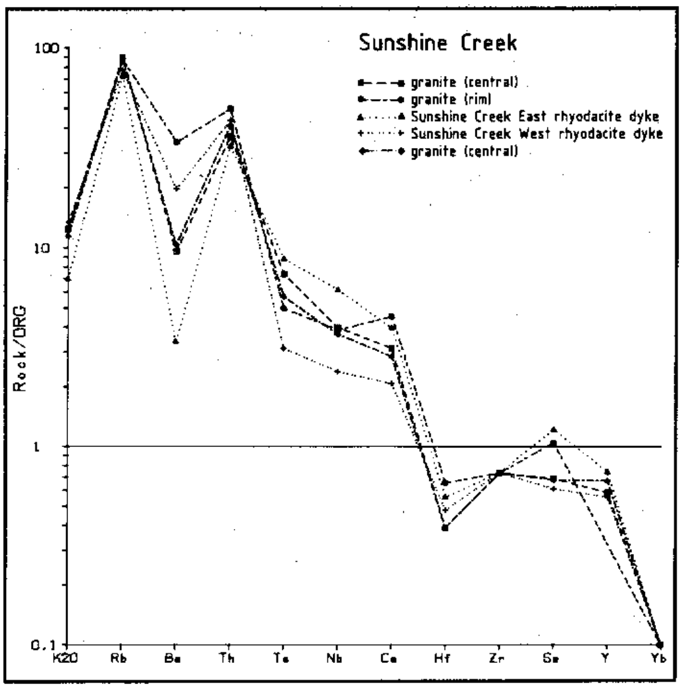

Fig. 11b.

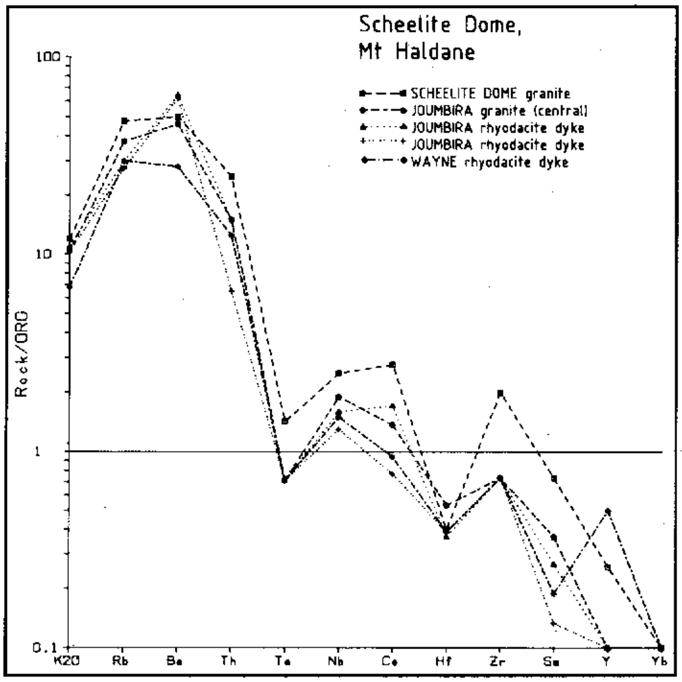

Fig. 11c.

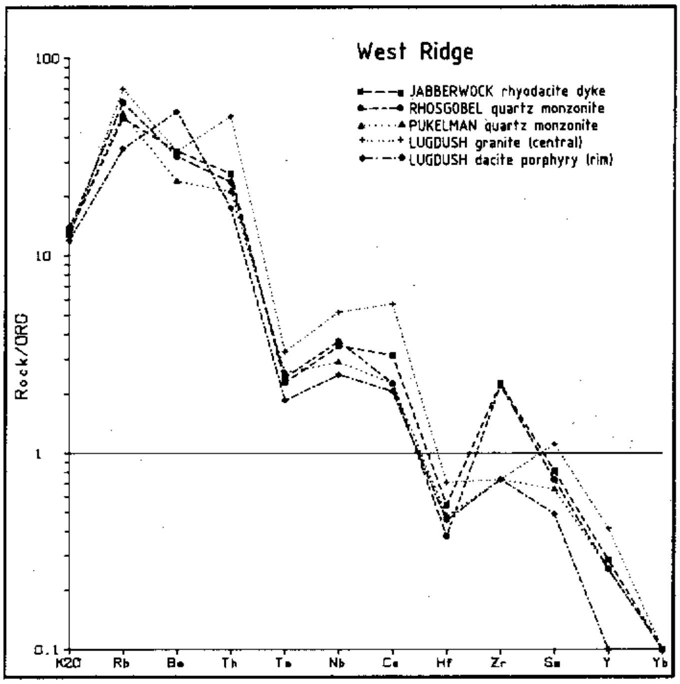

Fig. 11c.

Figure 11. Ocean Ridge-normalized diagrams for trace elements (normalized according to values given by Pearce et al. (1984)) for felsic plutonic rocks from the McQuesten River region. (a) East Ridge, (b) Sunshine Creek, (c) Mt Haldane and Scheelite Dome; (d) West Ridge.

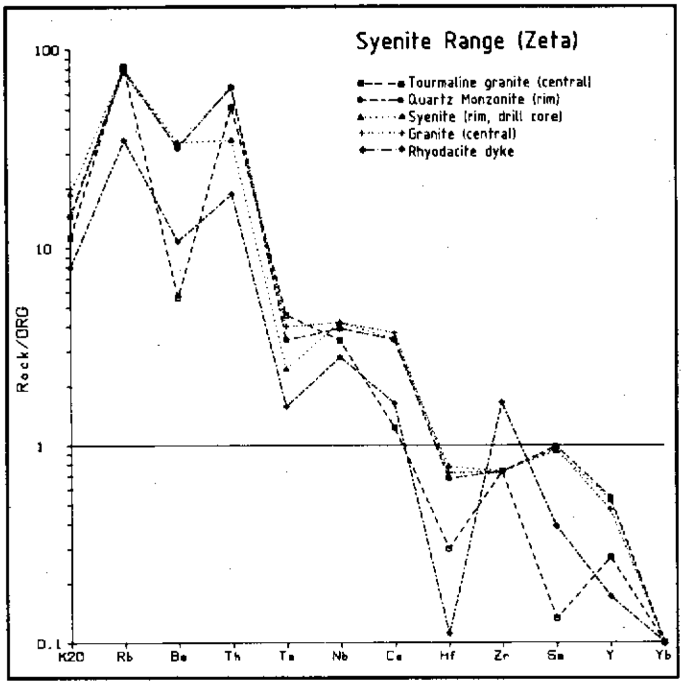

Fig. 11e.

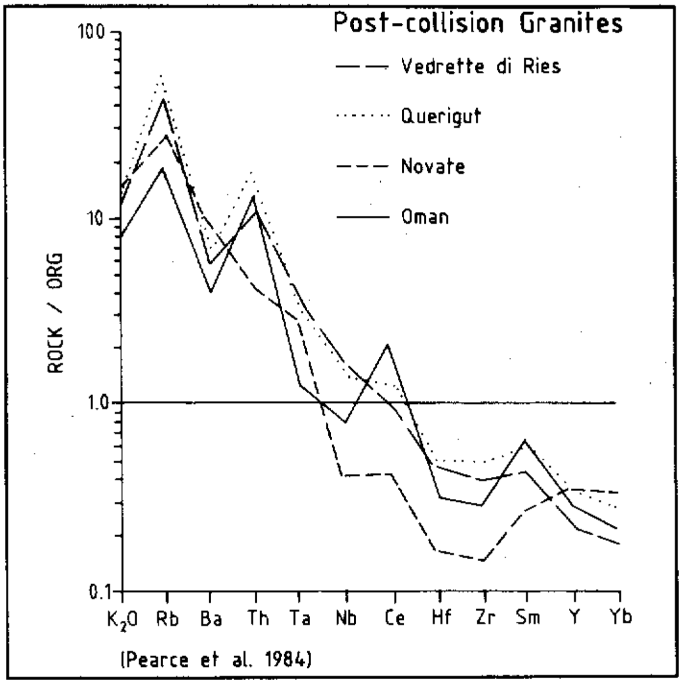

Fig. 11f.

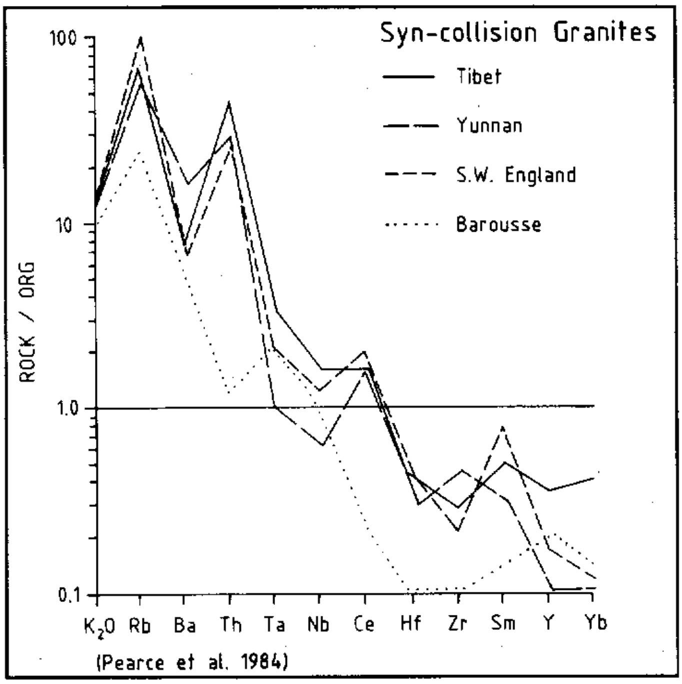

Fig. 11g.

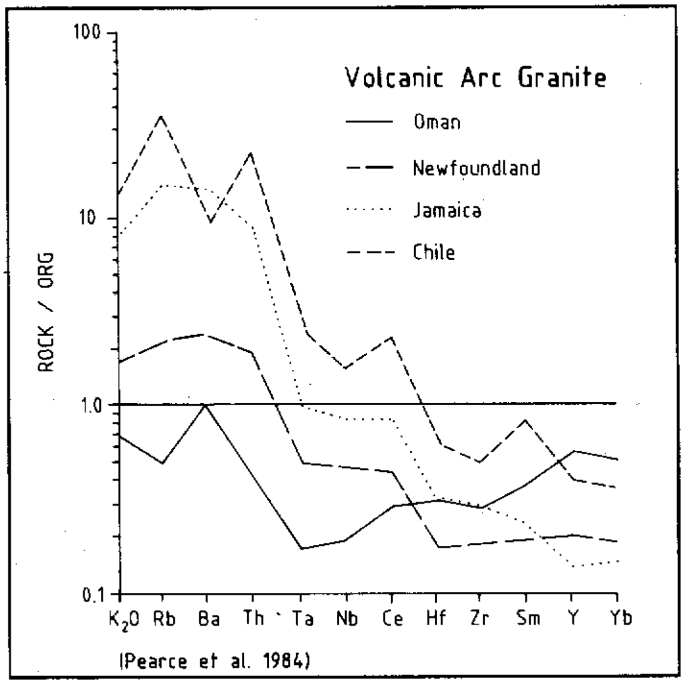

Fig. 11h.

Figure 11. Ocean Ridge-normalized diagrams for trace elements (normalized according to values given by Pearce et al. (1984)) for felsic plutonic rocks from the McQuesten River region. (e) Syenite Range (Zeta); and examples from Pearce et al. (1984): (f) Post-collision granites, (g) Syn-collision granites, and (h) Volcanic arc granites.

Trace Element Variation Diagrams used in Tectonic Interpretation

Pearce et al. (1984) were able to discriminate further between ocean ridge (ORG), volcanic arc (VAG), within plate (WPG) and collision (COLG) granites by graphing Y, Yb, Rb, Ta and Nb versus SiO_2, and also Nb vs Y, Ta vs Yb, Rb vs Y+Nb, and Rb vs Yb+Ta. McQuesten area samples plot mostly in the field of collision granites, but some show compositional similarity to within-plate granites. Calculated ratios of Y, Yb, Rb and Ta versus SiO_2, as well as the ratios Ta vs Yb and Rb vs Yb+Ta plot mostly within the COLG and VAG fields as expected (Fig. 12)[2]. However, Y vs SiO_2, and Nb vs Y diagrams show that samples from SUNSHINE CREEK (MINFILE 115P 031), ZETA (MINFILE 115P 047) and LUGDUSH (MINFILE 115P 009) have WPG affinities. Niobium is somewhat high compared to COLG, and samples plotted on an Nb vs SiO_2 graph almost all lie in the WPG and ORG fields (Fig. 12b). Most samples on the Rb vs Y+Nb diagram plot in the syn-COLG and VAG fields, but several fall near or within the WPG field (Fig. 12c).

Whalen et al. (1987) used Ga/Al ratios, various major element ratios and Y, Ce, Nb and Zr as discriminants in distinguishing A-type granites from M-, I- and S-type granites. Similar plots were made using analyses of McQuesten area plutonic rocks (Fig. 13). Two-mica granites mostly show Ga/Al ratios typical of I- and S-type granites, but a few plutons such as SUNSHINE CREEK (MINFILE 115P 031) have higher ratios more typical of fractionated felsic granites (Whalen et al., 1987). The biotite-hornblende granites gave lower $(K_2O + Na_2O)/CaO$ and FeO/MgO ratios (Fig. 13a, b). Also $K_2O + Na_2O$, Zr, Ce and Zn values in some samples are higher than for most regular I- and S-type granites, again explainable by fractionation. Nb values are all higher than I- and S-types (Fig. 13c). Diagrams using the sum of Zr, Nb, Ce and Y on the abscissa were used similarly to Ga/Al plots. Due to high Nb and Y content, the samples plotted out of the field of OGT (unfractionated M-, I- and S-type granites), slightly toward the A type average (Fig. 13d). Most major element ratios, including FeO/MgO, $(K_2O + Na_2O)/CaO$, and Rb/Ba, plotted outside the OGT field. These granites are not believed to have an A-type origin, but it appears that fractionation has played an important role in their formation.

COMPARISON WITH SELWYN AND TOMBSTONE PLUTONIC SUITES

Intrusive phases similar to those in the McQuesten region occur in the Selwyn and Tombstone Plutonic Suites (Anderson 1987, 1988; Pigage and Anderson 1985). Composite and zoned syenites in the Selwyn Mountains are documented by Smit et al. (1985) and similar rocks in the Tombstone Mountains are documented by Anderson (1987).

Overall similarities

Points of overall geological similarity are listed in Table 4, and are summarized below: (1) The intrusions are post- to syn-tectonic. (2) They intrude upper Proterozoic to Jurassic, miogeoclinal metasedimentary host rocks. (3) They have a subcircular form indicative of forceful emplacement. (4) They have formed contact aureoles with andalusite and biotite (typical of shallow emplacement). (5) Some intrusions, especially syenitic plutons at Emerald Lake and in the Tombstone Range, show concentric zoning indicative of fractional crystallization in situ. (6) Each suite has bimodal characteristics, with the southernmost intrusions consisting oftwo-mica granite, and the northernmost intrusions consisting of less evolved biotite-hornblende granite. Bimodal characteristics of the Selwyn Plutonic Suite were documented by Anderson (1983). (7) Coeval volcanic rocks and dykes accompany the intrusions, for example the South Fork Volcanics in the Tay River area.

Petrographic similarities

Petrographic analysis shows the following similarities between the three different plutonic suites. (1) Modal compositions show that the two-mica granites are more quartz-rich, and more restricted in K feldspar:plagioclase ratio than the hornblende-biotite granites. McQuesten area granites are similar to the Nahanni and Anvil area granites as shown in Fig. 3, although batholiths in the Nahanni-Flat River area show less variation between phases, and include a "transitional phase" of two-mica granite with minor hornblende (Anderson 1988). (2) Igneous texture varies from hypidiomorphic to allotriomorphic granular in the two-mica granite, to hypidiomorphic and idiomorphic granular in biotite-hornblende granite. (3) Feldspar and quartz phenocrysts show similar morphology. Microperthitic orthoclase megacrysts are characteristic. (4) Biotite is ubiquitous as an accessory mineral. Other distinctive accessory minerals include muscovite in the two-mica granites, hornblende and minor clinopyroxene in the biotite-hornblende granites, and nepheline in the syenites. (5) Biotite has chocolate brown pleochroism in biotite-hornblende granites compared to reddish brown in the two-mica granites. Hornblende is a darker green to brown compared to pale green in the two-mica granites, and clinopyroxene is dark brown, compared to beige in the two-mica granites. (6) Other accessory minerals include apatite, zircon, allanite, titanite, and tourmaline. Monazite occurs mainly in the two-mica granites. Titanite, allanite and magnetite are mostly associated with the hornblende-biotite granites. Magnetite and titanite are confined to the syenite. (7) Inclusions of zircon and allanite in biotite are more abundant in the hornblende-biotite granite. (8) Myrmekitic (or granophyric) texture is particularly common in the two-mica granites.

Anderson (1988) described two-mica granites with minor hornblende, confined mainly to large batholiths in the southeastern part of the Selwyn Plutonic Suite, as "transitional". Their chemistry is intermediate between the hornblende-biotite and two-mica granites. Uncommon but

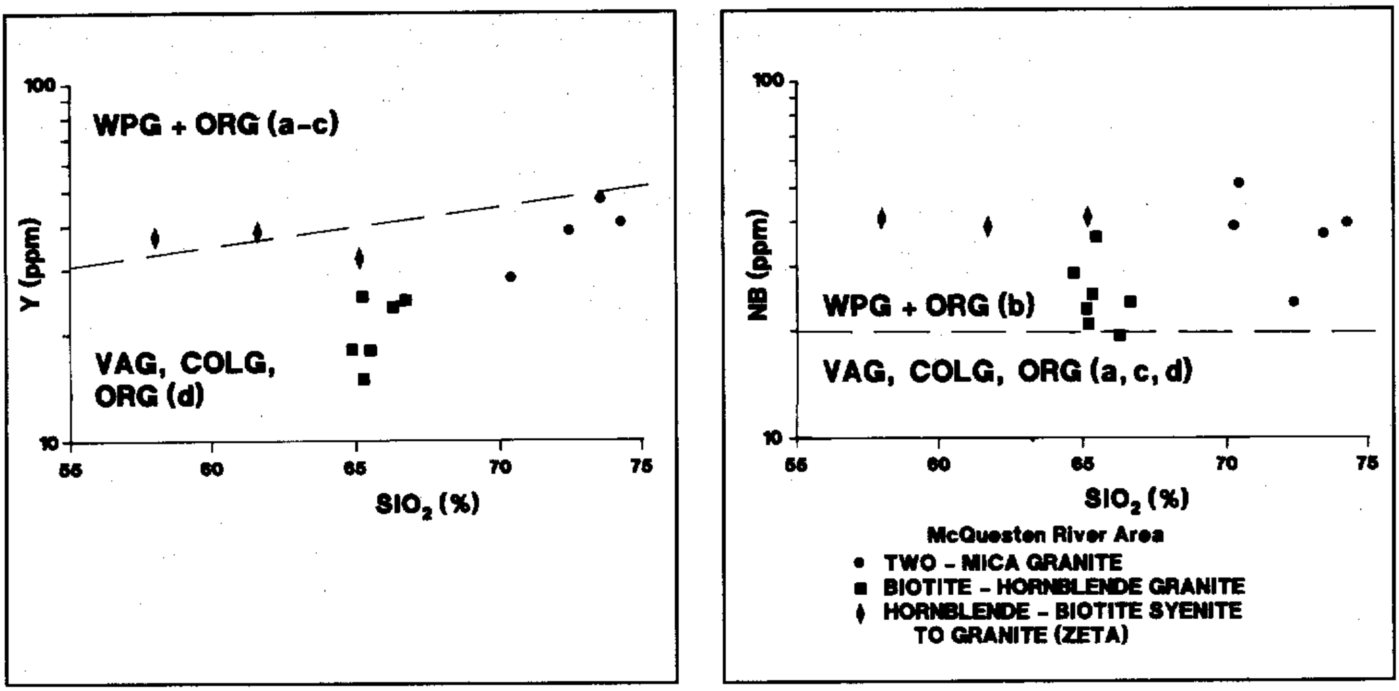

Fig. 12a.

Fig. 12b.

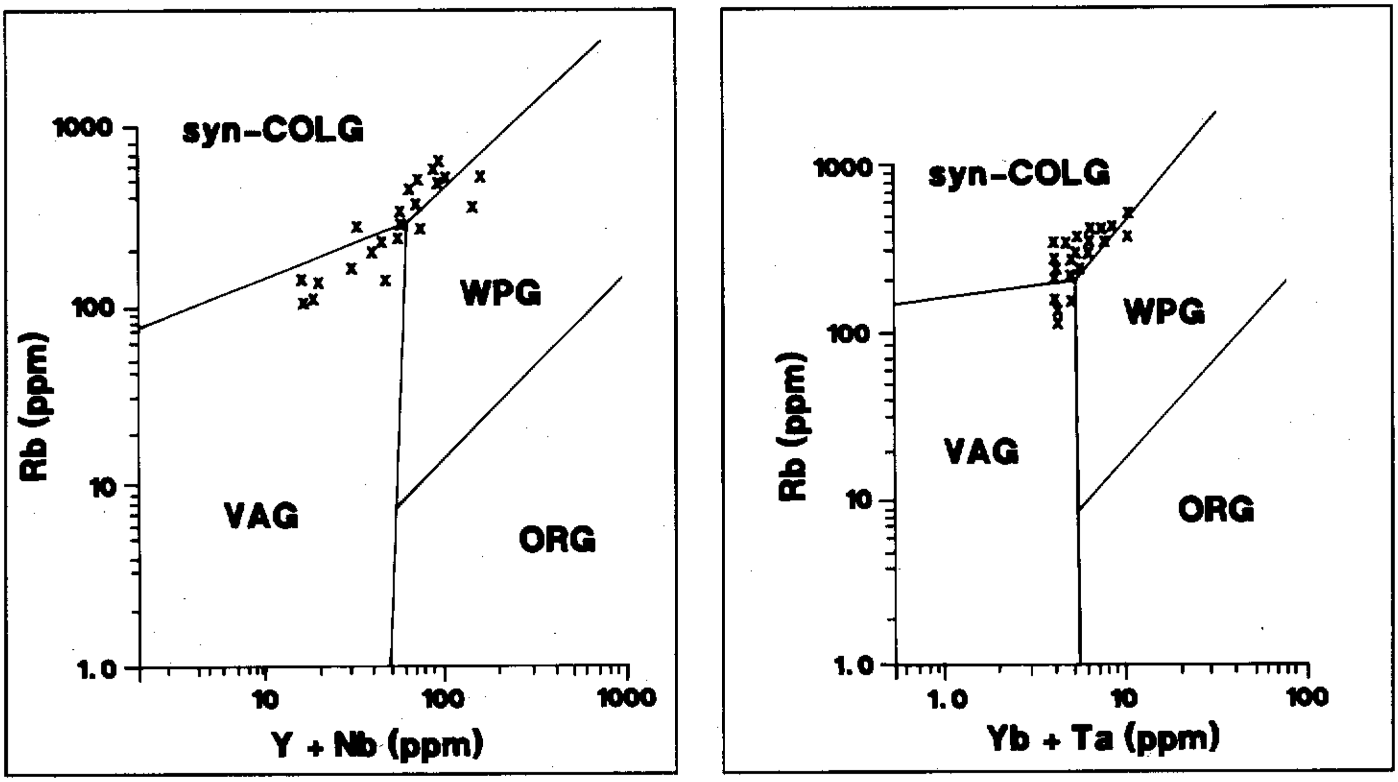

Fig. 12c.

Fig. 12d.

Figure 12. Trace element diagrams for indicating tectonic origin of granites (fields as defined by Pearce et al. (1984)): (a) Y vs SiO_2, (b) Nb vs SiO_2, (c) Rb vs Y+Nb, (d) Rb vs Yb + Ta; Terms: WPG= within plate granites; ORG = ocean ridge granites; VAG = volcanic arc granites; COLG = collision granites.

Trace Element Variation Diagrams used in Tectonic Interpretation

Pearce et al. (1984) were able to discriminate further between ocean ridge (ORG), volcanic arc (VAG), within plate (WPG) and collision (COLG) granites by graphing Y, Yb, Rb, Ta and Nb versus SiO_2, and also Nb vs Y, Ta vs Yb, Rb vs Y+Nb, and Rb vs Yb+Ta. McQuesten area samples plot mostly in the field of collision granites, but some show compositional similarity to within-plate granites. Calculated ratios of Y, Yb, Rb and Ta versus SiO_2, as well as the ratios Ta vs Yb and Rb vs Yb+Ta plot mostly within the COLG and VAG fields as expected (Fig. 12)[2]. However, Y vs SiO_2, and Nb vs Y diagrams show that samples from SUNSHINE CREEK (MINFILE 115P 031), ZETA (MINFILE 115P 047) and LUGDUSH (MINFILE 115P 009) have WPG affinities. Niobium is somewhat high compared to COLG, and samples plotted on an Nb vs SiO_2 graph almost all lie in the WPG and ORG fields (Fig. 12b). Most samples on the Rb vs Y+Nb diagram plot in the syn-COLG and VAG fields, but several fall near or within the WPG field (Fig. 12c).

Whalen et al. (1987) used Ga/Al ratios, various major element ratios and Y, Ce, Nb and Zr as discriminants in distinguishing A-type granites from M-, I- and S-type granites. Similar plots were made using analyses of McQuesten area plutonic rocks (Fig. 13). Two-mica granites mostly show Ga/Al ratios typical of I- and S-type granites, but a few plutons such as SUNSHINE CREEK (MINFILE 115P 031) have higher ratios more typical of fractionated felsic granites (Whalen et al., 1987). The biotite-hornblende granites gave lower (K_2O + Na_2O)/CaO and FeO/MgO ratios (Fig. 13a, b). Also K_2O + Na_2O, Zr, Ce and Zn values in some samples are higher than for most regular I- and S-type granites, again explainable by fractionation. Nb values are all higher than I- and S-types (Fig. 13c). Diagrams using the sum of Zr, Nb, Ce and Y on the abscissa were used similarly to Ga/Al plots. Due to high Nb and Y content, the samples plotted out of the field of OGT (unfractionated M-, I- and S-type granites), slightly toward the A type average (Fig. 13d). Most major element ratios, including FeO/MgO, (K_2O + Na_2O)/CaO, and Rb/Ba, plotted outside the OGT field. These granites are not believed to have an A-type origin, but it appears that fractionation has played an important role in their formation.

COMPARISON WITH SELWYN AND TOMBSTONE PLUTONIC SUITES

Intrusive phases similar to those in the McQuesten region occur in the Selwyn and Tombstone Plutonic Suites (Anderson 1987, 1988; Pigage and Anderson 1985). Composite and zoned syenites in the Selwyn Mountains are documented by Smit et al. (1985) and similar rocks in the Tombstone Mountains are documented by Anderson (1987).

Overall similarities

Points of overall geological similarity are listed in Table 4, and are summarized below: (1) The intrusions are post- to syn-tectonic. (2) They intrude upper Proterozoic to Jurassic, miogeoclinal metasedimentary host rocks. (3) They have a subcircular form indicative of forceful emplacement. (4) They have formed contact aureoles with andalusite and biotite (typical of shallow emplacement). (5) Some intrusions, especially syenitic plutons at Emerald Lake and in the Tombstone Range, show concentric zoning indicative of fractional crystallization in situ. (6) Each suite has bimodal characteristics, with the southernmost intrusions consisting oftwo-mica granite, and the northernmost intrusions consisting of less evolved biotite-hornblende granite. Bimodal characteristics of the Selwyn Plutonic Suite were documented by Anderson (1983). (7) Coeval volcanic rocks and dykes accompany the intrusions, for example the South Fork Volcanics in the Tay River area.

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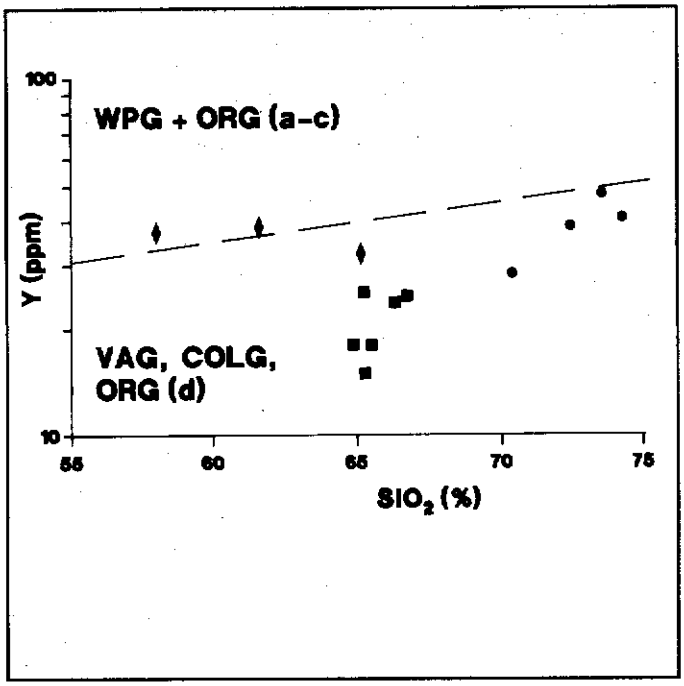

Fig. 12a.

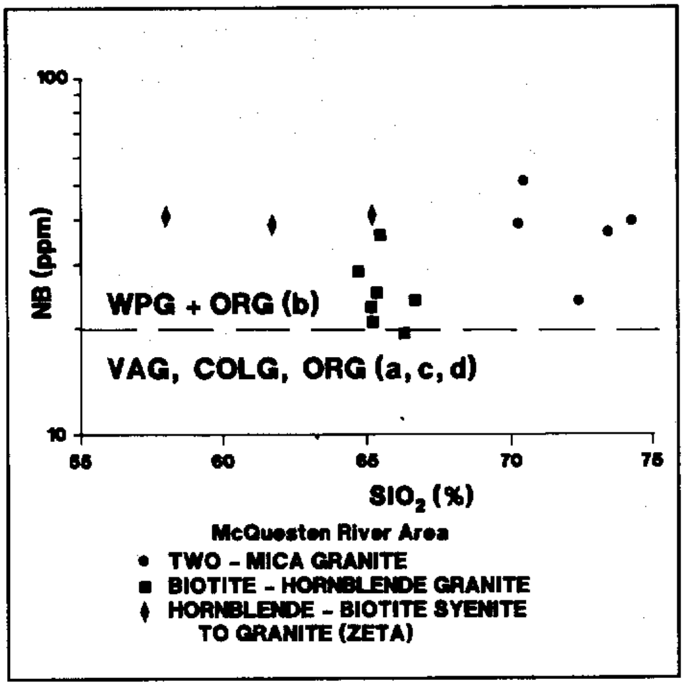

Fig. 12b.

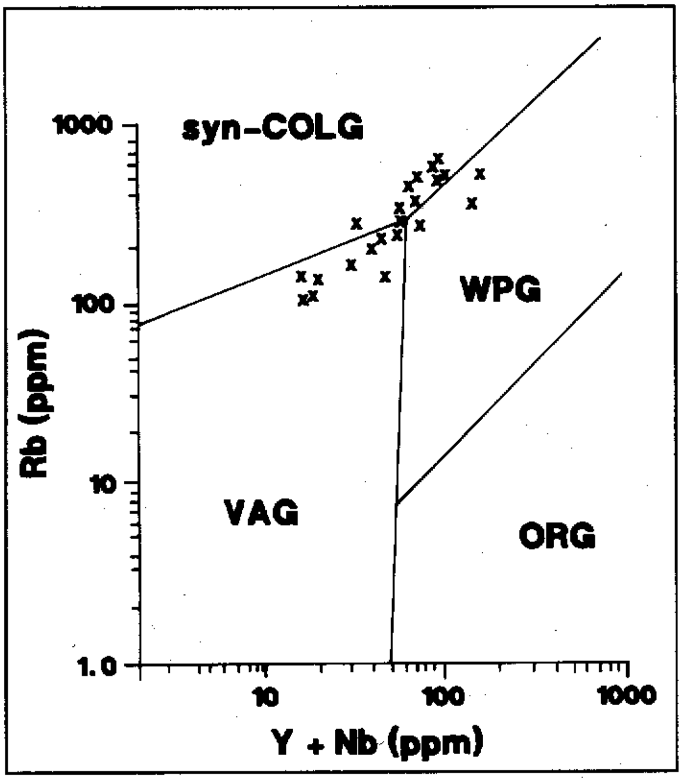

Fig. 12c.

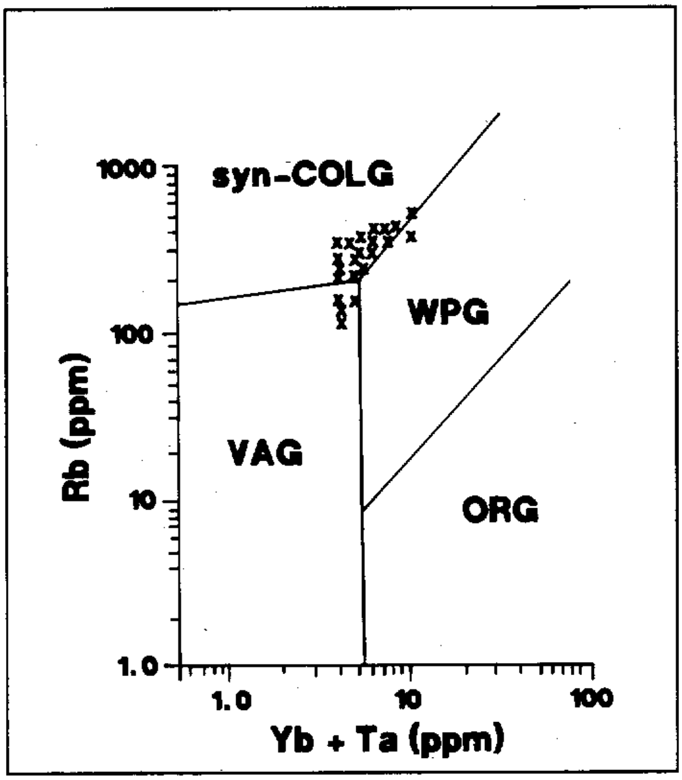

Fig. 12d.

Figure 12. Trace element diagrams for indicating tectonic origin of granites (fields as defined by Pearce et al. (1984)): (a) Y vs SiO$_2$, (b) Nb vs SiO$_2$, (c) Rb vs Y+Nb, (d) Rb vs Yb + Ta; Terms: WPG= within plate granites; ORG = ocean ridge granites; VAG = volcanic arc granites; COLG = collision granites.

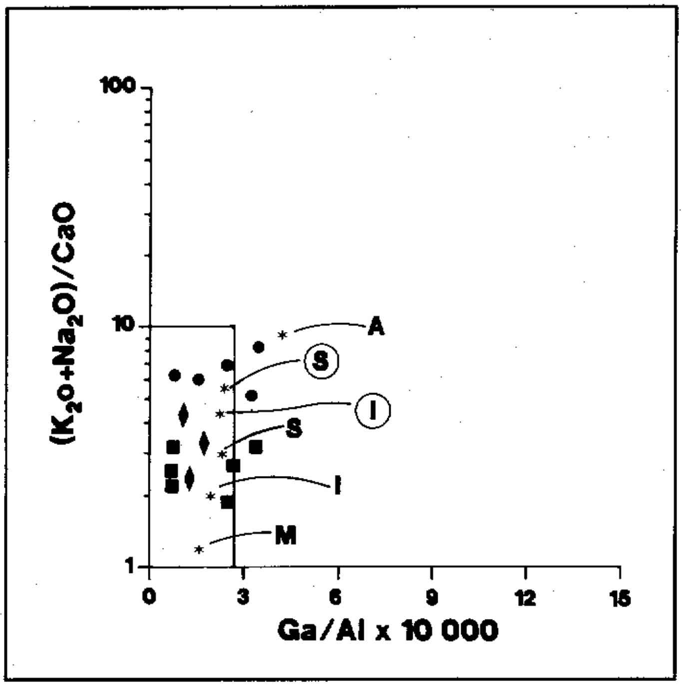

Fig. 13a. $(K_2O+Na_2O)/CaO$ vs Ga/Al*10000

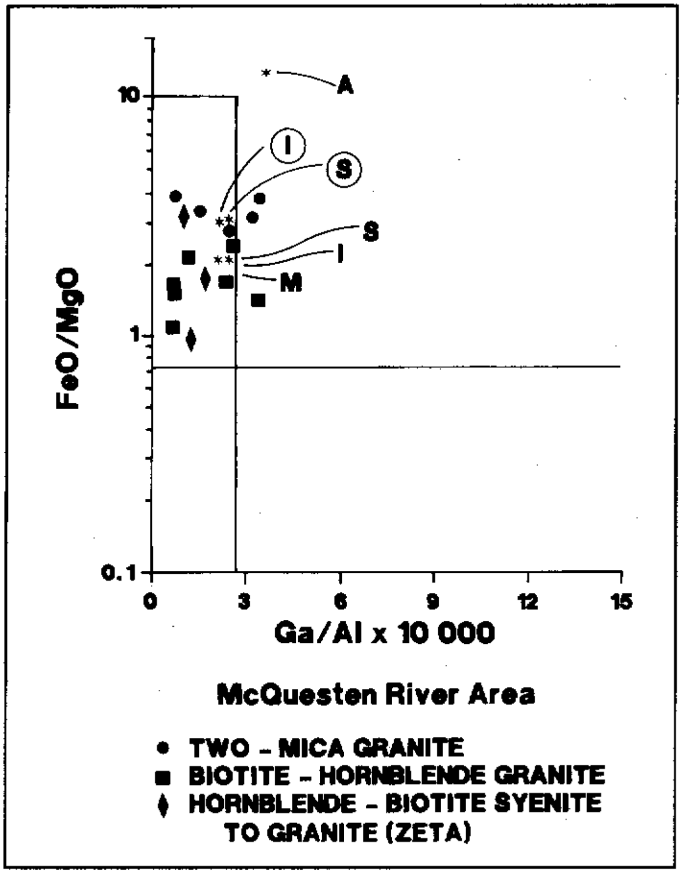

Fig. 13b. FeO/MgO vs Ga/Al*10000

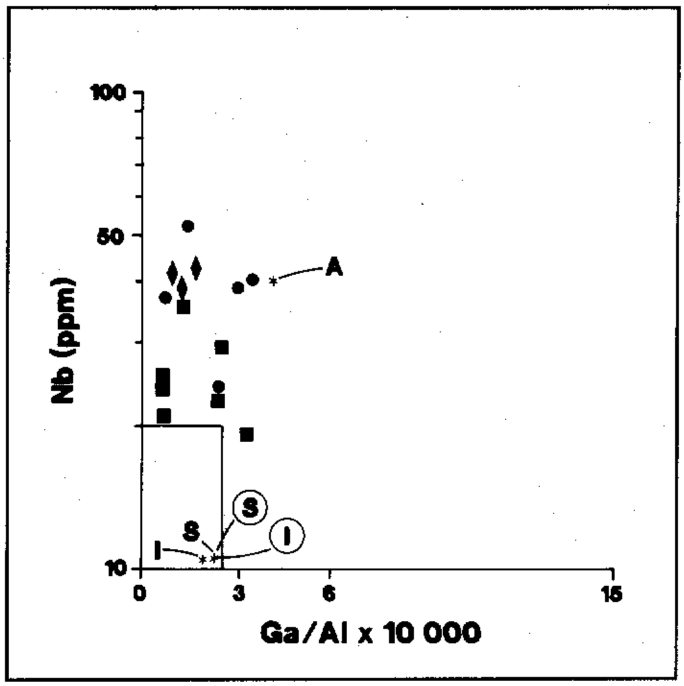

Fig. 13c. Nb vs Ga/Al*10000;

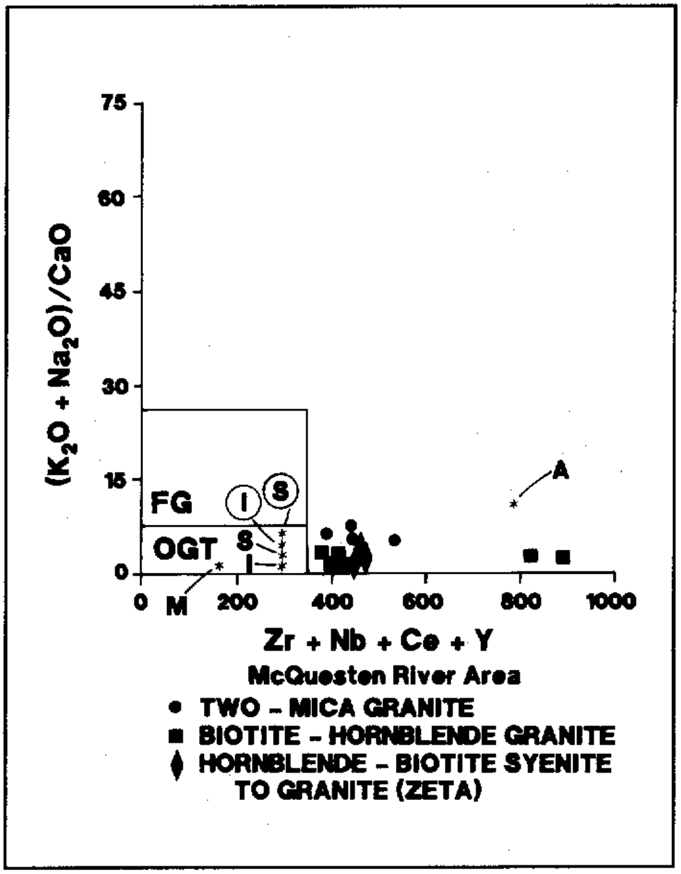

Fig. 13d. $(K_2O+Na_2O)/CaO$ vs Zr+Nb+Ce+Y.

Figure 13. Trace element diagrams for indication of petrogenesis (fields of OGT=unfractionated M, I and S granites; and FG=fractionated granites as defined by Whalen et al. (1987)). Average M, I, S and A types are shown by their respective letters; while fractionated I and S types are circled.

Apparently similar rocks occur in the McQuesten region, for instance on the margin of the LUGDUSH (MINFILE 115P 009) stock. This is a medium grained biotite-quartz-feldspar porphyry which contains sericite and chlorite pseudomorphs after hornblende, and has a composition intermediate between the two major granite types.

Petrographic characteristics of the McQuesten area rocks which are not recognized in the Selwyn Plutonic Suite include glomerophyric quartz and plagioclase, most notably in the two-mica granite, tourmaline orbicules (such as at ZETA (MINFILE 115P 047)), and microclinization and albitization of feldspar. These characteristics may indicate that the McQuesten granites are slightly more evolved.

Geochemical similarities

McQuesten area rocks show geochemical similarities to the Selwyn and Anvil suites (Gordey and Anderson, in press; Anderson 1988). (1) The two-mica granites contain normative corundum, while the hornblende-biotite granites contain normative clinopyroxene and little or no normative corundum. The syenites contain normative nepheline. (2) The two-mica and hornblende-biotite granites form two subalkaline groups, the former containing more than 70% silica and the latter, less than 67% silica (Fig. 14). The syenite and quartz monzonite are alkaline, similar to the Tombstone syenite. (3) The rocks are mainly subalkaline to calc-alkaline, and from hornblende-biotite to two-mica granite the composition shifts toward higher alkalis and lower Fe and Mg (Fig. 7). (4) The rocks have similar Na_2O to K_2O ratios which plot in the field of S-type granites. (5) They have similar Na_2O to K_2O to CaO ratios. Alkalis increase and calcium decreases from the hornblende-biotite to the two-mica granites (Fig. 8). (6) They have similar Rb-Ba-Sr relationships, except that some of the Selwyn two-mica granites have higher Rb values.

Differences:

There are some notable differences between the McQuesten granites and rocks of the Selwyn and Tombstone Suites. (1) Biotite-hornblende granites of the McQuesten region have a lower ratio of modal quartz to alkali feldspar and plagioclase than those in the Selwyn and Anvil regions (Fig. 3). (2) The McQuesten rocks are all peraluminous, whereas in the Selwyn and Anvil plutonic suites only the hornblende-biotite granite is metaluminous, and only the two-mica granite is peraluminous. (3) The McQuesten granites contain more iron compared to alkalis and magnesium (Fig. 7). (4) Unlike rocks of the Tombstone Suite which contain aegirine-augite, the McQuesten syenite and quartz monzonite intrusions entirely lack A-type characteristics.

DISCUSSION

Plutonic rocks in the McQuesten River region are generally bimodal, with two-mica granites in the south and hornblende-biotite granitoids and syenitoids in the north. There is a broad transition from hornblende-bearing nepheline syenite, to poorly evolved hornblende-bearing, clinopyroxene-normative biotite quartz monzonite, to granite, to more evolved, peraluminous, corundum-normative muscovite-bearing biotite granite (Fig. 3). The coexistance of all three of the above phases in the ZETA (MINFILE 115P 047) zoned intrusion suggests they form a comagmatic suite. This is supported by Rb-Ba-Sr trends. A primary trend of Ba enrichment is observed in the less evolved biotite-hornblende granites, and a secondary trend of Rb enrichment is seen in the more evolved two-mica granites. This is consistent with differentiation trends for felsic magmatic suites (Bouseily and Sokkary 1975). All phases of the McQuesten Plutonic Suite show similar patterns of trace elements (normalized to ocean ridge granite), providing further evidence of a comagmatic origin. These trace element patterns are doubly useful in that they have not been affected by alteration processes. The patterns recognized include high Ba and Th with respect to Ta and Nb, high Ce and Sm values with respect to adjacent elements, and an increase in abundance of trace elements from Yb to Rb. These trace element patterns are typical of collision and volcanic arc granites with a "crust-dominated" source. Other trace elements are consistent with this interpretation, except for slightly elevated Nb and Y values which are more typical of granite originating within a plate. The original magmas were probably melts of, or melts contaminated by, sialic lower crustal material. Rb/Sr ratios greater than 0.71 reported by Abercrombie (1990), and Kuran (1982) support this conclusion.

Crustal trace element patterns such as a lower Th:Ta ratio and higher Nb values are more characteristic of the two-mica granites and the hornblende-biotite granitoids of the southern belt than of hornblende-biotite granitoids of the northern McQuesten belt. The hornblende-biotite granitoids in the south even have positive Ce and Sm anomalies, whereas those in the north do not.

High Rb and negative Ba anomalies indicate the highly evolved nature of the two-mica granites in the southern belt. Lower Rb and less negative Ba anomalies are apparent in the less evolved biotite-hornblende phase, especially in the north.

Two-mica granites from the McQuesten region have typical S-type characteristics. For instance, they are peraluminous, have K_2O greater than Na_2O (Fig. 15), relatively low TiO_2, and FeO greater than Fe_2O_3 (Fig. 16). However, the biotite-hornblende granitoids contain less SiO_2 and show petrographic features (e.g., darker, chocolate brown biotite) more similar to 'I-type' granites of the Selwyn Plutonic Suite (Gordey and Anderson, in press). Any A-type characteristics, i.e. a few high Ga/Al ratios and high Zr+Nb+Ce+Y values (due to high Nb and Y), are likely due to fractionation of S-, or I-type magmas.

Major metals are also partitioned between the two main igneous phases in the McQuesten River region. Tin-(silver) mineralization is associated with the two-mica granite at OLIVER CREEK (MINFILE 115P 030), SUNSHINE CREEK (MINFILE 115P 031), BOULDER CREEK (MINFILE 115P 048) and JOUMBIRA (MINFILE 105M 031) in the southern belt, and ZETA (MINFILE 115P 047) in the northern belt, while tungsten (-gold) mineralization is associated with

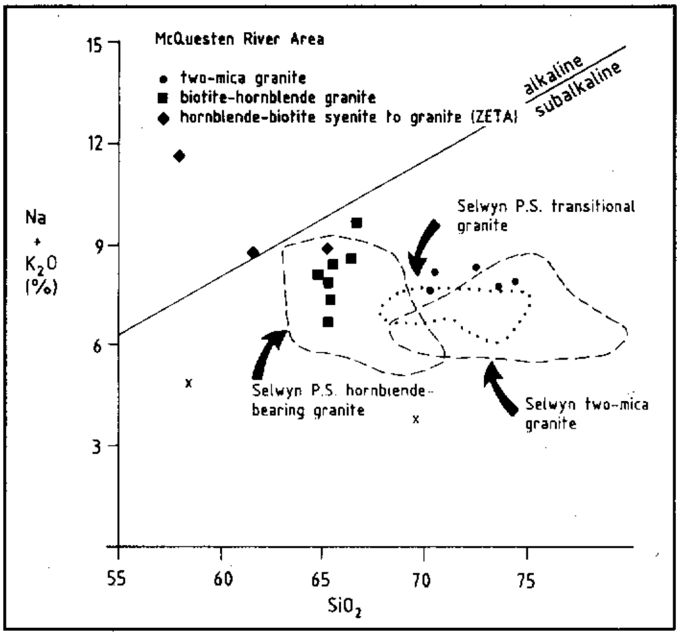

Figure 14. Na_2O+K_2O vs SiO_2 of McQuesten River plutonic rocks. Outline of composition of granites from the Selwyn Plutonic Suite (after Anderson 1988) is also shown.

biotite-hornblende granite at PUKELMAN (MINFILE 115P 013) and RHOSGOBEL (MINFILE 115P 012) in the northern belt and at SCHEELITE DOME (MINFILE 115P 004) and LUGDUSH (MINFILE 115P 009) in the southern belt (Emond, 1992). The LUGDUSH (MINFILE 115P 009) pluton is mainly a two-mica granite, but it is rimmed with sericitized hornblende-biotite dacite which formed the associated W skarn. At SCHEELITE DOME (MINFILE 115P 004), TEE (MINFILE 115P 008a) and SNARK (MINFILE 115P 008b) the tungsten skarns associated with biotite-hornblende granite also contain sulphide minerals and tin.

Metallic minerals help to characterize the McQuesten plutonic suite as a unique entity, distinct from the Selwyn and Tombstone plutonic suites. Numerous tin showings occur in the McQuesten belt, and its tungsten deposits are associated with biotite-hornblende rocks, whereas the southeast part of the Selwyn Plutonic Suite contains larger and more numerous tungsten deposits which are associated with two-mica granites (Anderson, 1988).

The Selwyn Plutonic Suite postdated the arc-continent collision (Tempelman-Kluit 1981, 1979). The magmas which formed these rocks are commonly believed to have formed by relaxation of isotherms associated with post-collision crustal thickening causing melting of the lower crust. However, it is also possible that these magmas were formed by low angle east-dipping subduction originating west of the 'Stikine arc' (Tempelman-Kluit 1979) causing melting of the lower crust or the 'downgoing slab'. Formation by subduction could possibly explain the bimodal distribution of the Selwyn intrusions and also some of their 'I' type characteristics.

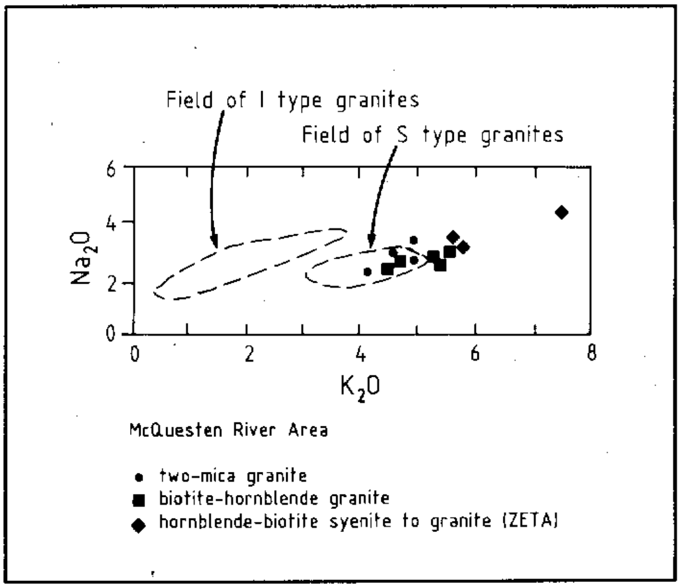

Figure 15. Plot of Na_2O vs K_2O for I and S type granites.

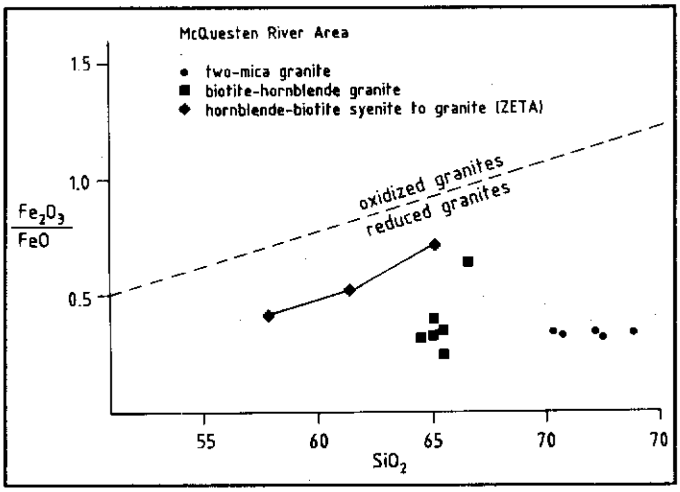

Figure 16. Fe_2O_3/FeO vs SiO_2 of McQuesten River plutonic rocks showing oxidized and reduced granitoid classification.

The presence of syenite along the north edge of the McQuesten region links rocks of the McQuesten region to the syenites and 'A' type granites in the Tombstone Mountains to the northwest. There, a different intrusive suite was emplaced as a result of extensive Proterozoic crustal thinning and a difference in the composition of the lower crust (Anderson 1987). Since the granitoid rocks in the northern McQuesten region lack 'A' type characteristics, they have been included in the Selwyn Plutonic Suite, and may mark the southern margin of thinned crust. Syenites in the McQuesten region show a close relationship to the granites, particularly at the ZETA property (MINFILE 115P 047) where the syenites and granites appear to be differentiation products of a single magma.

SUMMARY

Plutonic rocks of the McQuesten River region are comagmatic and consist mainly of hornblende syenite, biotite-hornblende granite and two-mica granite. Small plutons were forcefully emplaced at a high level in the crust and fractionally crystallized in place. The plutonic rocks form two east-trending belts: a northern belt with more mafic biotite-hornblende granitic and syenitic rocks, and a southern belt with more felsic biotite-muscovite (two-mica) granites. The two-mica granite, which crystallized from the most evolved and therefore volatile-rich (i.e., boron-rich) melt, is associated with tin-silver veins and skarns. The less evolved biotite-hornblende granite is associated with tungsten-gold skarns and veins.

The McQuesten Plutonic Belt is broadly similar to the Selwyn Plutonic Suite in its geometry and bimodal character. Differences in chemistry and metallization, however, indicate that the McQuesten intrusions are more highly evolved.

ACKNOWLEDGMENTS

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Appendix 1. Abbreviations (used in tables).

ALL,AL	allanite	NOS	nosean
AP	apatite	OP	opaque minerals
AN	anatase	OR	orthoclase
BI	biotite	PL	plagioclase
COR	corundum	PX	pyroxene
CAN	cancrinite	QZ	quartz
CPX	clinopyroxene	RU	rutile
DI	diopside	SPH	sphene
FL	fluorite	TO	tourmaline
GT	garnet	ZR	zircon
HB	hornblende	DAC	dacite
KSP	K feldspar	GRAN	granite
MEL	melanite	GRANODI	granodiorite
MON	monazite	QZMZ	quartz monzonite
MT	magnetite	RHYODAC	rhyodacite
MU	muscovite	SY	syenite
NE	nepheline		

1. In this report, the mineral property name is also used when referring to the associated pluton.

2. Due to space constraints, some of these diagrams have been omitted.

Table 1. Petrology of Plutonic Rocks of the McQuesten River Area[1]

	TWO-MICA GRANITE	HORNBLENDE-BIOTITE GRANITE	HORNBLENDE-(BIOTITE) SYENITE
MAIN MINERALS	QZ, PL(Ol-An), KSP	QZ, PL(An), KSP	KSP, PL(Ol-An), HB
ESSENTIAL MINERALS	BI>MU	BI>HB	HB>>BI
BIOTITE	reddish- to orange-brown to lt yellow brown	chocolate brown to lt yellow-brown -minor rusty brown	chocolate brown to dk red brown to lt yellow
HORNBLENDE	none	lt brownish green to yellow-clear to grass green - also pinkish clear, lt bluish green)	dk green-brown to red-brown to yellow-green
ACCESSORY MINERALS	AP, ZR, MON, TO (OP, SPH)	ALL, AP, ZR, SPH (OP-MT)	ALL, RU, AP, ZR, SPH, NE
TEXTURES	allotrio- to hypidiomorphic granular, myrmekite, ragged edges (mica), strained embayed quartz, quartz glomophyrs, megacrystic KSP, equigranular to seriate to porphyritic	hypidio- to idiomorphic granular, smooth edges (mica), strained quartz, quartz glomophyrs, KSP megacrysts and clots poikilolitic & zoned HB, porphyritic	idio- to hypidiomorphic granular myrmekite, porphyritic to equigranular
ALTERATION	ser. of PL chl. of BI perth. of KSP microcl. of KSP epidote	ser. of PL chl. of BI & HB microcl. of PL biot. of HB epidot. of HB carbonate albitization ural. of PX	biot. of HB ural. of PX perth. of HB carbonate

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[1] Abbreviations: see Appendix 1.

Table 2. Major-element, normative mineral and modal composition of samples from the McQuesten Granite Belt

Associated Mineral	LUGDUSH	LUGDUSH	TEE	SUNSHINE CREEK	SUNSHINE CREEK	SUNSHINE CREEK	SCHEELITE DOME	JOUMBIRA	JOUMBIRA	MAHTIN	MAHTIN	RHOSGL	PUKELMAN	ZETA	ZETA	ZETA
Occurrence	Core	Rim	Stock	Central	Stock	Dyke		Plug	Dyke	Plug	Dyke			Margin	Margin	Core
Sample No.	242	237	203	281,2	279	275	208	219	244	227	221	235	236	264	256	258
(New)	(12)	(11)	(1)	(23,24)	(22)	(20)	(3)	(5)	(13)	(7)	(6)	(9)	(10)	(19)	(16)	(17)
Rock Type	GRAN	DAC	GRDI	GRAN	GRDI	RYOD	GRAN	GRAN	RYOD	GRAN	GRAN	QZMZ	QZMZ	SY	QZMZ	GRAN
Accessory Minerals	BI	BI-MU (HB?)	BI-HB	BI-MU	BI-MU	BI(HB?)	BI-HB	BI-MU	BI-HB	HB-BI	HB-BI	HB-BI	HB-BI	HB (BI)	HB-BI	HB-BI
Major Oxides(wt %)																
SiO_2	70.61	68.46	65.25	73.99	70.39	72.54	65.40	72.23	70.61	65.26	66.72	65.56	64.82	58.04	61.67	65.27
Al_2O_3	14.20	15.46	14.98	13.70	14.42	14.26	15.38	13.60	15.35	14.05	15.24	15.54	14.89	19.37	15.82	15.72
Fe_2O_3	0.67	0.98	1.20	0.42	0.63	0.35	0.94	0.53	0.65	1.12	0.89	0.78	0.90	1.30	1.72	1.57
FeO	2.00	2.25	3.20	1.22	1.80	1.10	2.75	1.55	0.75	3.35	1.40	3.20	2.80	3.15	3.40	2.20
MgO	0.60	0.99	1.87	0.32	0.57	0.40	1.71	0.71	0.37	2.21	1.31	1.47	1.16	0.98	3.55	1.25
CaO	1.36	2.54	3.49	0.94	1.49	1.21	2.97	1.76	2.15	3.53	3.02	3.40	2.97	2.67	3.74	2.63
Na_2O	3.12	3.08	2.22	3.04	2.65	2.86	2.60	2.20	2.84	2.36	2.83	2.89	2.80	4.14	2.92	3.08
K_2O	4.99	4.79	4.51	4.76	4.98	5.37	4.80	4.18	4.41	5.46	6.78	5.55	5.35	7.52	5.81	5.77
TiO_2	0.52	0.45	0.53	0.24	0.47	0.32	0.51	0.32	0.19	0.54	0.48	0.55	0.51	0.43	0.69	0.50
P_2O_5	0.28	0.16	0.23	0.16	0.25	0.21	0.16	0.14	0.09	0.20	0.18	0.24	0.23	0.20	0.32	0.23
MnO	0.06	0.06	0.08	0.04	0.03	0.03	0.08	0.03	0.01	0.09	0.05	0.10	0.09	0.12	0.11	0.09
LOI	0.80	1.40	0.80	0.70	1.10	1.00	0.70	0.90	1.10	0.80	1.10	0.90	1.20	0.90	0.80	0.90
Total	99.21	100.61	98.36	99.68	98.77	99.66	98.01	98.16	98.53	98.96	99.99	100.19	97.71	98.82	100.55	99.21
molar A/CNK	1.20	1.23	1.28	1.23	1.31		1.27	1.40	1.35	1.08	1.03	1.12	1.13	1.11	1.09	1.15
DIFF INDEX																
CIPW NORMS																
Q	29.16	24.20	23.28	34.97	31.52	32.14	21.65	38.03	31.66	19.11	16.49	17.24	19.01		8.34	16.60
C	1.86	0.97	0.65	1.96	2.56	2.04	0.89	2.59	2.21					0.04		0.17
OR	29.48	28.30	26.65	28.10	29.42	31.73	28.36	24.70	26.05	32.26	40.06	32.79	31.61	44.43	34.33	34.09
AB	26.40	26.06	18.78	25.72	22.42	24.20	22.00	18.61	24.03	19.96	23.94	24.45	23.69	30.97	24.70	26.06
AN	4.91	11.55	15.81	4.32	5.75	4.63	13.68	7.81	10.07	11.61	8.85	13.03	12.25	11.93	12.90	11.54
NE														2.19		
DI										3.77	4.03	1.87	0.81		2.90	
HY	4.09	5.85	9.43	2.52	3.74	2.34	8.18	3.90	2.94	8.51	3.42	7.01	6.44		12.85	7.09
MT	0.83	1.00	1.37	0.51	0.76	0.45	1.15	0.65	0.42	1.40	0.70	1.25	1.16	1.39	1.59	1.16
IL	0.98	0.85	1.00	0.46	0.89	0.60	0.96	0.60	0.36	1.02	0.91	1.04	0.96	0.81	1.31	0.94
FA	0.22	0.12	0.18	0.12	0.19	0.16	0.12	0.11	0.07	0.15	0.14	0.18	0.18	0.15	0.25	0.18
EN	1.49	2.46	4.65	0.80	1.41	0.99	4.25	1.76	0.92	4.51	2.06	3.23	2.71		7.96	3.11
FS	2.59	3.39	4.77	1.72	2.32	1.34	3.92	2.13	1.42	4.00	1.35	3.78	3.73		4.88	3.98
WOLL										1.91	2.06	0.94	0.40		1.48	
EN(DP)										0.98	1.19	0.43	0.17		0.87	
FS(DP)										0.87	0.77	0.50	0.23		0.53	
OL														5.62		
OL (FOR)														1.70		
OL (FAY)														3.91		

Table 2. (continued)

Associated Mineral	LUGDUSH	LUGDUSH	TEE	SUNSHINE CREEK	SUNSHINE CREEK	SUNSHINE CREEK	SCHEELITE DOME	JOUMBIRA	JOUMBIRA	MAHTIN	MAHTIN	RHOSGL	PUKEL	ZETA	ZETA	ZETA
Occurrence	Core	Rim	Stock	Central	Stock	Dyke		Plug	Dyke	Plug	Dyke			Margin	Margin	Core
Sample No.	242	237	203	281,2	279	275	208	219	244	227	221	235	236	264	256	258
(New)	(12)	(11)	(1)	(23,24)	(22)	(20)	(3)	(5)	(13)	(7)	(6)	(9)	(10)	(19)	(16)	(17)
Rock Type	GRAN	DAC	GRDI	GRAN	GRDI	RYOD	GRAN	GRAN	RYOD	GRAN	GRAN	QZMZ	QZMZ	SY	QZMZ	GRAN
Accessory Minerals	BI	BI-MU (HB?)	BI-HB	BI-MU	BI-MU	BI(HB?)	BI-HB	BI-MU	BI-HB	HB-BI	HB-BI	HB-BI	HB-BI	HB (BI)	HB-BI	HB-BI
Minor Elements (ppm)																
Large Cations																
Ba	1700	2700	2700	500	1700	990	2500	2300	3200	1700	2000	1600	1200	1700	1600	1600
Cs	14	11	16	30	16	10	11	14	4	16	15	15	12	16	32	20
Rb	280	140	210	360	350	310	190	150	120	260	300	240	210	320	320	310
Sr	315	510	455	162.5		145	475	305	380	420	515	555	520	655	525	495
Rb/Sr	0.90	0.27	0.46	2.21		2.14	0.4	0.49	0.32	0.62	0.58	0.43	0.40	0.49	0.61	0.63
Rare Earth Elements																
La	100	34	54	42	74	35	40	23	28	49	64	43	39	62	71	66
Ce	200	72	110	105	160	73	97.0	48.0	60	120	110	79	79	120	120	130
Nd	67	26	35	28	45	28	19	19.0	11	32	42	37	33	45	39	46
Sm	10.0	4.4	7.8	6.2	9.4	5.5	6.6	3.3	2.4	7.2	8.2	6.6	5.9	8.4	8.9	8.6
Tb	<1	<1	1	<1	1	<1	<1	<1	<1	1	<1	<1	<1	2	<1	<1
Dy	3	2	2	3	4	3	3	2	<1	3	3	3	3	3	4	3
High Valence Cations																
Th	41.0	14.0	27.0	31.0	40.0	35.0	20.0	12.0	12.0	26.0	29.0	19.0	17.0	28.0	51.8	51.3
U	4.8	4.7	9.2	14.8	12.0	8.8	9.1	5.4	4.1	7.2	5.0	7.3	8.2	5.6	13.0	10.0
Hf	6	4	3	4	6	4	4	5	3	4	6	3	4	7	6	7
Ta	2	1	<1	4	4	2	1	<1	<1	<1	1	2	2	2	2	3
Nb	52	25	23	38	39	24	25	19	16	21	24	37	29	42	39	42
Y	29	7	15	44		39	18	<5	<5	25	25	18	18	37	38	33
Ga	11	20	19	15*	24	18	<1	20	59	<10	<10	10	20	10	10	14
B	20	20	35	75	15	45	15	25	15	20	25	25	20	145	50	65
Zr	<500	<500	<500	<500	<500	<500	680	<500	<500	<500	<500	750	<500	<500	<500	<500
W	<2	<2	<2	6	<2	<2	11	<2	<2	<2	<2	<2	23	<2	13	<2
Mo	<2	<2	<2	2*	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Th/U	8.5	3.0	2.93	2.1	3.3	4.0	2.20	2.22	2.92	3.61	5.8	2.60	2.07	5	3.98	5.13
Other Metals																
Au (ppb)	14	10	20	16	12	18	9	<5	7	9	8	28	6	6	<5	8
Ag	<5	<5	<5	<5	<5	7	7	<5	<5	7	<5	<5	<5	<5	<5	<5
Sb	0.3	0.6	0.8	0.2*	0.2	2.1	0.6	0.9	0.5	1.0	1.8	0.7	0.6	2.7	1.6	1.8
As	5	11	16	<1	<1	131	<3	0.9	0.5	22	13	4	19	12	6	8
Cr	150	120	140	120	130	86	160	101	15	150	130	120	98	<50	130	110
Zn	<200	<200	<200	<200	<200	210	<200	810	230	<200	<200	<200	<200	<200	<200	<200
Sc	5.2	5.5	11.0	4.9	7.0	3.4	11.0	3.9	1.4	13.0	8.3	9.5	7.1	3.8	11.0	6.9
Be	7.6	4.8	5.0	12.2	7.7	6.7	5.1	3.9	2.9	6.5	7.4	6.7	6.7	9.2	11.0	9.9
F	550	450	900	1120	1300	420	900	620	280	1000	660	1300	850	840	1250	1050

Analyses were performed by Bondar-Clegg & Company Ltd., North Vancouver using mainly the following methods: 1) major and minor elements - D.C. Plasma (also Titrimetric for FeO; and Gravimetric for Loss on Ignition); 2) trace elements - Neutron Activation (and also X-ray fluorescence for Sr, Y, Ga and In; D.C. Plasma for Ge; Turbidimetric for Cl; and Atomic Absorption for Be).

Abbreviations: see Appendix 1

Table 3. Average composition of Granitoid Rocks in the McQuesten River Area

	Two-Mica Granite **n=4[1]**	**Hornblende-Biotite Quartz Monzonite, Granite** **n=6**	**Hornblende-Biotite Syenite** **n=1**
MAJOR OXIDE ANALYSES (WT %)			
SiO_2	71.80 (70.39-73.99)	65.50 (64.82-66.72)	58.04
Al_2O_3	13.98 (13.60-14.42)	15.01 (14.05-15.54)	19.37
Fe_2O_3	0.56 (0.42-0.67)	0.97 (0.78-1.20)	1.30
FeO	1.64 (1.22-2.00)	2.78 (1.40-3.20)	3.15
MgO	0.55 (0.32-0.71)	1.62 (1.16-2.21)	0.98
CaO	1.38 (0.94-1.49)	3.23 (2.97-3.53)	2.67
Na_2O	2.75 (2.20-3.12)	2.61 (2.22-2.89)	4.14
K_2O	4.73 (4.18-4.99)	5.41 (4.51-6.78)	7.52
TiO_2	0.38 (0.24-0.52)	0.52 (0.48-0.55)	0.43
P_2O_5	0.25 (0.14-0.28)	0.21 (0.18-0.24)	0.20
MnO	0.04 (0.03-0.06)	0.08 (0.05-0.10)	0.12
molar A/CNK	1.28 (1.20-1.40)	1.15 (1.03-1.28)	1.11
DIFF INDEX			
CIPW NORMS			
Q	33.42 (29.16-38.03)	19.46 (16.49-23.28)	
C	2.24 (1.86-2.59)	0.26 (0-0.89)	0.04
OR	27.92 (24.70-29.48)	31.96 (26.65-40.06)	44.43
AB	23.29 (18.61-26.40)	22.14 (18.78-24.45)	30.97
AN	5.70 (4.32-7.81)	12.54 (8.85-15.81)	11.93
NE			2.19
DI		1.75 (0-4.03)	
HY	3.56 (2.52-4.09)	6.66 (3.42-9.3)	
MT	0.69 (0.51-0.83)	1.17 (0.70-1.40)	1.39
IL	0.73 (0.46-0.98)	0.98 (0.91-1.04)	0.81
FA	0.16 (0.11-0.22)	0.16 (0.12-0.18)	0.15
EN	1.37 (0.80-1.76)	3.57 (2.06-4.65)	
FS	2.19 (1.72-2.59)	3.59 (1.35-4.77)	
WOLL		0.88 (0-2.06)	
EN(DP)		0.46 (0-1.19)	
FS(DP)		0.40 (0-0.87)	
OL			5.62
OL(FOR)			1.70
OL(FAY)			3.91
MINOR ELEMENTS (PPM):			
Large Cations			
Ba	1550 (500-2300)	1950 (1200-2700)	1700
Cs	18 (14-30)	14 (11-16)	16
Rb	280 (150-360)	235 (190-300)	320
Sr	261 (162.5-315)	490 (420-555)	655
Rb/Sr	1.2 (0.49-2.21)	.48 (0.40-0.62)	0.49
Rare Earth Elements			
La	49 (23-100)	48 (39-64)	62
Ce	128 (48-200)	99 (79-120)	120
Nd	39 (19-67)	33 (19-42)	45
Sm	7.2 (3.3-10.0)	7.0 (5.9-8.2)	8.4
Tb	<1 (<1-1)	<1 (<1-1)	2
Dy	3 (2-4)	3 (2-3)	3
High Valence Cations			
Th	31.0 (12-41)	23.0 (17-29)	28.0
U	9.2 (4.8-14.8)	7.7 (5.0-9.2)	5.6
Hf	5 (4-6)	4 (3-6)	7
Ta	3 (<1-4)	1 (<1-2)	2
Nb	37 (19-52)	26 (21-37)	42
Y	25 (<5-44)	20 (15-25)	37
Ga	17 (11-24)	<10 (<10-20)	10
B	34 (15-75)	23 (15-35)	145
Zr	<500	<500 (<500-750)	<500
W	2 (<2-6)	6 (<2-23)	<2
Mo	<2 (<2-2)	<2	<2
Th/U	4.03 (2.1-8.5)	3.20 (2.07-5.80)	5
Other Metals			
Au (ppb)	11 (<5-16)	13 (6-28)	6
Ag	<5	<5 (<5-7)	<5
Sb	0.4 (0.2-0.9)	0.9 (0.6-1.8)	2.7
As	27 (<1-101)	12 (<3-22)	12
Cr	140 (120-170)	133 (98-160)	<50
Zn	280 (<2-810)	<200	<200
Sc	5.2 (3.9-7.0)	10.0 (7.1-13.0)	3.8
Be	7.8 (3.9-12.2)	6.2 (5.0-7.4)	9.2
F	900 (550-1300)	940 (660-1300)	840

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[1] When n>1, the first value is the mean; this is followed by the range, in parentheses.

Table 4. Comparison of plutonic rocks of the McQuesten area with the Selwyn and Tombstone Plutonic Suites

	MCQUESTEN	SELWYN	TOMBSTONE
GEOLOGICAL SETTING	Late Proterozoic to Miss. metased. rx	Late Proterozoic to Miss. metased. & metavol. rocks	M. Proterozoic to Jurassic metased. rx. Zone of suspect Late Proterozoic extension.
INTRUSION CHARACTERISTICS	Zoned, nearby coeval volcs, contact aureoles, roof pendants, subcircular, heterogeneous, stocks, plugs, dykes	Zoned, composite, overlain by coeval volcs, subcircular, heterogeneous, batholiths, plugs, stocks, dykes	subcircular to circular, post-tectonic, cogenetic dykes & volcanics
PHASES	1) QZ-rich felsic (bi-mu granite)	1) QZ-rich felsic (hb-free bi-mu granite to granodi.	1) no two-mica granite
		1a) Transitional variety between 1) and 2: a two-mica granite with minor hb.	
	2) felsic (hb-bi quartz monz, granodi, granite)	2) felsic (hb-bi granite, granodi, quartz syenite)	2) siliceous felsic (hb-bi monzogranite)
	3) QZ-poor felsic (hb-bi (hb-bi syenite, quartz monzonite to granite)	3) QZ-poor felsic (hb-bi (hb-bi alkali feldspar syenite to syenite to qtz syenite to qtz monzonite to granite)	3) QZ-poor felsic (hb ± bi alkali to feldspar syenite)
			4) Mafic to Intermed. (Subordinate)(hb-clinopyroxenite, hb-diorite, tinguaite, bi-monzonite)
ACCESSORY MINERALOGY	1) MU, BI, AP, ZR, TO, MON	1) MU, BI, GT, TO, AP, AL, ZR, AN, MON, HB, CPX	
	2) BI, HB, AL, SPH, AP, ZR, CPX, MT	2) BI, HB, MT, SPH, AP, AL,TO,ZR,CPX	2) HB, BI
	3) HB, BI, AL, SPH AP, ZR, RU, NE, CT, TO	3) HB, BI, SPH, MT, AP, ZR, AL	3) HB, BI, SPH, FL, AEGIRINE-AUGITE, MT, MEL, AP, CAN, NOS, NE
TEXTURES	allotriom. to hypid. gran. seriate, porph., megacrystic, glomerophyric, myrmekite, microperthite	hypid. gran., equigran, seriate, megacrystic, myrmekite microperthite	equigranular, megacrystic, porph., granophyric, graphic granite, myrmekite, microperthite
ALTERATION MINERALS	chlor., ser., microcliniz.,ep., calc., albit., uralit.	chlor., ser., ep., calc., sphene, saussur.	
ASSOCIATED MINERAL DEPOSITS	Sn-Ag veins, skarns assoc. with two-mica granite W-Au skarn & veins assoc. with hb-bi granite; Ag-Pb-Zn veins distal to plutons	large W-Cu skarns assoc. with two-mica granite Cu-Mo-Fe-As-Zn (Au-W) skarn & vein showings assoc. with hb-bi granite	F, U, Th, Sb, W, Sn, Mo, Ag, Au, base metal; sulphides dissem. & veins,
GEOCHEMISTRY	1) Corundum norm > 70% SiO_2 (70-75) $K_2O > Na_2O$	1) Corundum norm silicic, high K, low Ca & Mg,	
	2) CPX norm. < 70% SiO_2 (64-66)	2) CPX norm, lower norm. corundum & silica, higher cafemic, TiO_2,MnO,Sr,Ba,La,Y,K/Rb, Ba/Rb,lower salic oxides, D.I.,Rb,Rb/Sr,K/Ba	
	3) NE to COR norm. (from syenite to granite)< 60 % SiO_2 (58)		3) QZ or NE norm.
	Peraluminous (hb-bearing - lower Shand Ind.	Per- to metalum. (hb-bearing - lower Shand Index)	
	Subalkaline (minor alkaline)	Subalkaline (minor alkaline)	Alkaline to subalkaline
	Calc-alkaline (2-mica granite-higher alkalis, lower Fe, Mg)	Calc-alkaline (2-mica granite-higher alkalis, lower Fe, Mg)	

Abbreviations: see Appendix 1