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EVIDENCE FOR EARLY TRIASSIC FELSIC MAGMATISM IN THE ASHCROFT (92I) MAP AREA, BRITISH COLUMBIA

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INTRODUCTION

This report presents U-Pb geochronology, and major, trace and rare earth element data for a package of felsic to intermediate composition volcanic and intrusive rocks. These rocks, previously correlated with the Nicola Group, occur within the western portion of the Ashcroft (92I) map area in southwestern British Columbia (Figure 1).

Rocks examined in the current study include silicic ash and crystal tuffs, and an intrusion of dioritic to tonalitic composition. These units are lithologically similar to volcanic rocks of the Kutcho Assemblage and contemporaneous plutonic bodies which intrude the Kutcho Assemblage, 950 km to the north (Marr, pers. comm., 1995; Childe and Thompson, 1995b). The objectives of this study were to obtain precise age and geochemical data for these rocks, to determine if they could represent an offset portion of the Kutcho Assemblage.

NICOLA GROUP

The Nicola Group is a Late Triassic to Early Jurassic island arc assemblage within the Quesnel terrane. It is comprised of submarine to subaerial, predominantly mafic volcanic and volcaniclastic rocks, their intrusive equivalents and associated clastic and chemical sedimentary rocks (Preto, 1977; Monger *et al.*, 1991). The Nicola Group has been broadly divided into western, central and eastern belts on the basis of lithology and lithogeochemistry (Mortimer, 1986; Monger *et al.*, 1991). Variation from calc-alkaline to shoshinitic compositions from west to east has been interpreted to reflect eastward dipping subduction in the Nicola arc (Mortimer, 1986).

Mafic and lesser felsic volcanic and intrusive rocks previously assigned to the western belt of the Nicola Group have been mapped in the Ashcroft (92I) and Hope (92H) map areas by Preto (1977), Grette (1978), Travers (1978), Shannon (1982), and Monger and McMillan (1984).

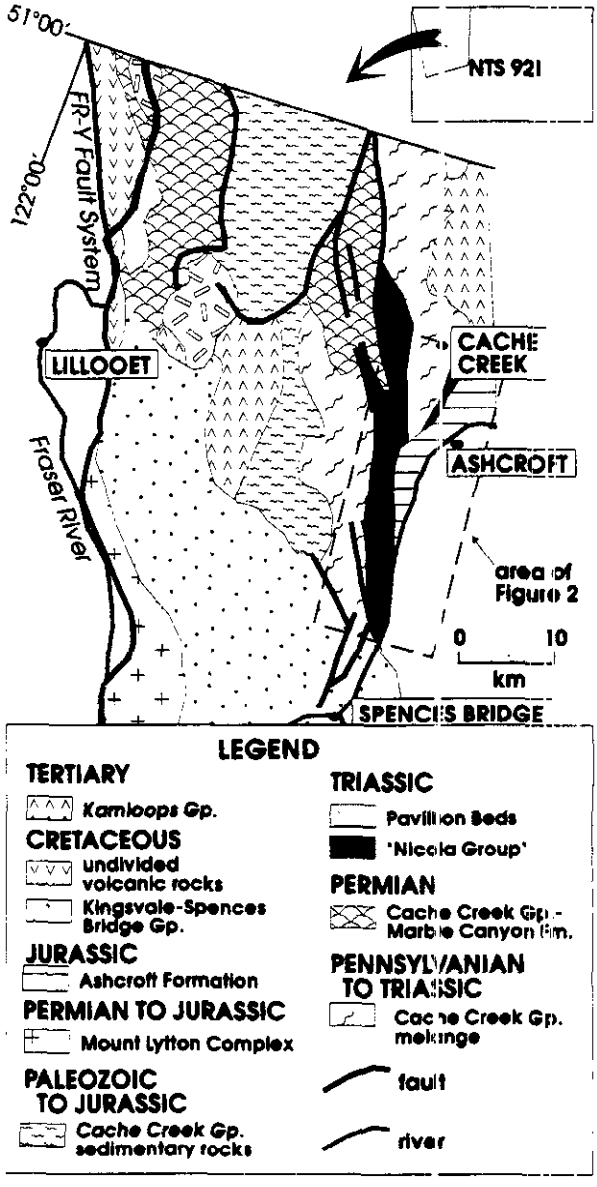

Figure 1. Generalized geology between Lillooet and Ashcroft, the outlined area is detailed in Figure 2 (FR-Y = Fraser River - Yalakom); (modified from Monger et al., 199).

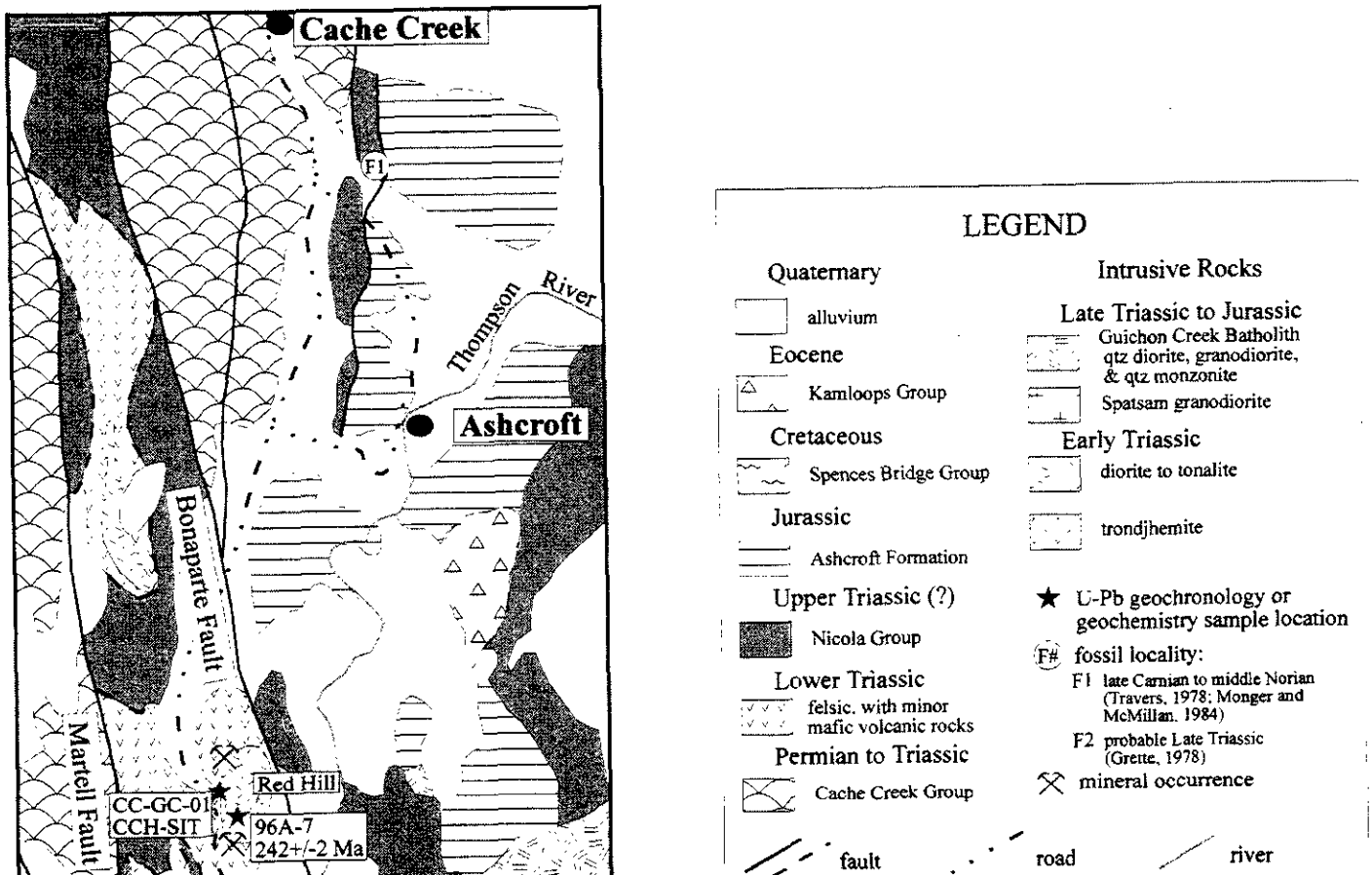

Figure 2. Geology of the Spences Bridge - Cache Creek area (modified from Ladd, 1981; Monger and McMillan, 1984).

KUTCHO ASSEMBLAGE

The Kutcho Assemblage, in north-central British Columbia, forms the lowermost unit in the fault-bounded King Salmon Allochthon. It is composed of tholeiitic bimodal volcanic rocks and sedimentary rocks and is intruded by contemporaneous, probably comagmatic plutonic rocks (Gabrielse, 1979; Thorstad and Gabrielse, 1986; Childe and Thompson, 1995a and b, submitted). Magmatism occurred in the Latest Permian to Early Triassic (Childe and Thompson, 1995a and b). The Kutcho Assemblage is host to the Kutcho Creek volcanogenic massive sulphide deposit, with reserves of 17 Mt, grading 1.6% Cu, 2.3% Zn, 29 g/t Ag and 0.3 g/t Au (Bridge *et al.*, 1986).

GEOLOGY

The current study examines felsic volcanic and intrusive rocks formerly assigned to the Nicola Group between the Martell and Bonaparte Faults, in the Venables Valley and Red Hill areas (Figure 2). Within the Venables Valley area, Grette (1978) divided rocks into three main units. From inferred oldest to youngest these units are: (1) mafic to felsic volcanic rocks, related

intrusive rocks, and volcanic derived sedimentary rocks; (2) thick, massive to bedded limestone; and (3) argillite and thin bedded limestone, with minor volcanic rocks.

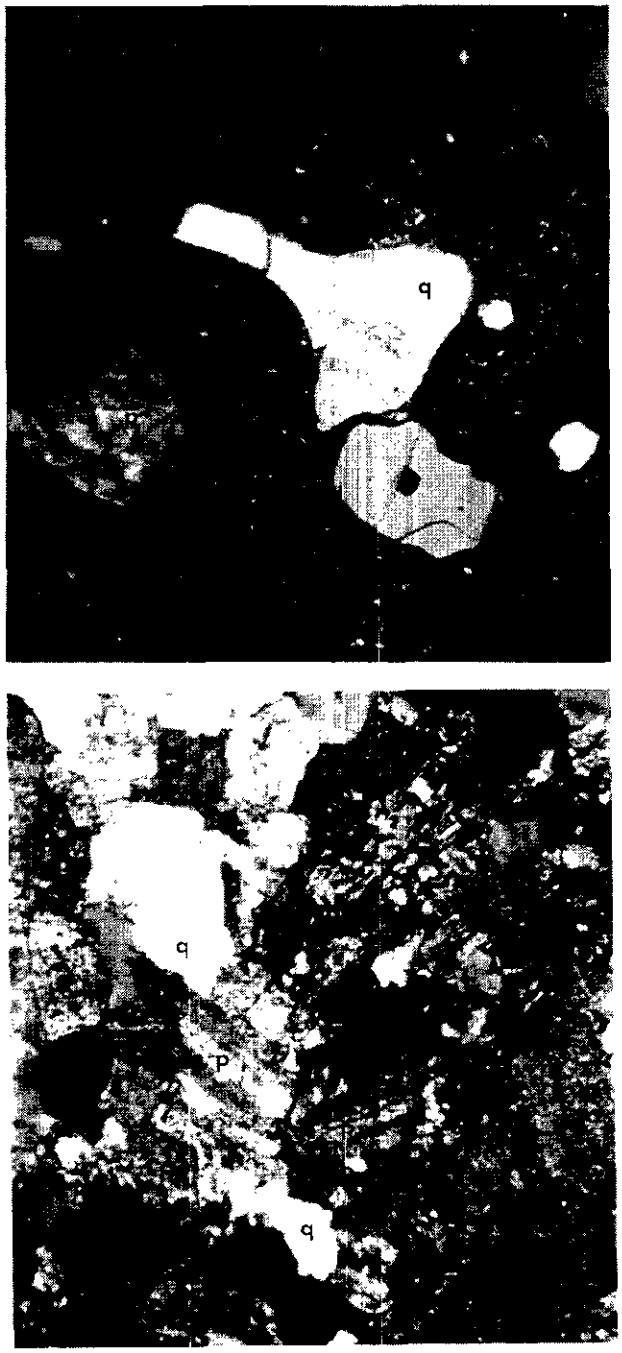

Figure 3. a) photomicrograph of rhyolite crystal tuff (96A-2) showing a broken quartz grain (photograph width 5 mm), b) photomicrograph of tonalite (96A-7) showing equigranular texture (photograph width 5 mm), p = plagioclase, q = quartz.

To the north, in the Red Hill area, Ladd (1981) proposed four subdivisions for volcanic rocks, thought to be interbedded, and hence of contemporaneous age, which were assigned to the Nicola Group. These are (1) felsic crystal tuffs characterized by large quartz grains; (2) chlorite-rich mafic schist, with relict phenocrysts; (3) silicified greenstone; and (4) altered massive chloritic basalt. On Red Hill, Ladd (1981) mapped felsic tuffs cross cut by a series of fine- to coarse-grained granodioritic to tonalitic plutons. Three kilometers southwest of Red Hill, Ladd (1981) observed trondhjemite grading into rhyolite tuffs, and suggested that the intrusion was hypabissal, with the volcanic and intrusive units being emplaced in the same magmatic event.

Felsic volcanic rocks from the Venables Valley and Red Hill consist of massive to bedded crystal to ash tuffs. Crystal tuffs are characterized by 2 to 5 mm diameter glassy quartz and/or plagioclase phenocrysts within a fine-grained quartzo-feldspathic matrix. Quartz and plagioclase commonly occur as broken grains, reflecting the pyroclastic nature of these rocks (Figure 3a). The crystal tuffs contain scattered flow-banded, aphanitic clasts and sporadic layers of wispy chlorite, which may be remnants of flattened pumice fragments. Ash tuffs are characterized by a fine-grained quartzo-feldspathic matrix with rare 1 to 2 mm diameter quartz and plagioclase crystals.

The diorite to tonalite body that intrudes the volcanic rocks on Red Hill has a medium-grained granitic texture, and contains varying proportions of plagioclase, hornblende and quartz, with minor secondary calcite and epidote (Figure 3b).

Biochronological constraints from south, east and north of the study area consist of probable Late Triassic conodonts from limestone (Grette, 1978), Late Triassic ammonites and pelecypods from argillite (Monger and McMillan, 1984), and middle Norian ammonites from sediments overlain by mafic volcanic rocks of the Nicola Group (Travers, 1978) (Figure 2). However, these age determinations do not assist in constraining the age of felsic magmatism, as the dated sedimentary rocks are not found in conformable contact with the felsic rocks.

Grette (1978) obtained an Early Jurassic Rb-Sr whole rock isochron age of 196 +/-15 Ma, with a Sr_i of 0.7043 (±0.0002) from felsic volcanic and intrusive rocks within the study area; Grette attributed the elevated Sr_i to contamination by seawater Sr. The isochron is highly dependent on a sample of altered dacite. Hydrothermal alteration has the potential to perturb Rb-Sr systematics (Shirey, 1991). Regardless of the mechanism of isotopic disturbance, the validity of this age determination is suspect.

U-PB GEOCHRONOLOGY

One sample of tonalite (96A-7) and three samples of crystal tuff (96A-1, 96-A3, and CC-GC-01) were collected and processed for U-Pb zircon analysis, as described below. Of the four samples, only the tonalite contained sufficient zircon for U-Pb analysis. The low Zr concentrations in the crystal tuffs (65-91 ppm), along with the relatively fine grain size may be responsible for the scarcity of recoverable zircon in the tuffs.

analytical techniques

Sample preparation and U-Pb analyses were carried out at the Geochronology Laboratory of the University of British Columbia. The samples were processed and zircon was separated using conventional crushing, grinding, Wilfley table and heavy liquid techniques. All fractions were air abraded prior to analysis, to reduce the effects of surface-correlated lead loss (Krogh, 1982). Zircon grains were selected based on criteria such as magnetic susceptibility, clarity, morphology and size. Procedures for dissolution of zircon and extraction and purification of uranium and lead follow those of Parrish *et al.* (1987). Uranium and lead were loaded onto single, degassed refined rhenium filaments using the silica gel and phosphoric acid emitter technique. Procedural blanks were 9 and 6 picograms for lead and uranium, respectively. Errors assigned to individual analyses were calculated using the numerical error propagation method of Roddick (1987) and all errors are quoted at the 2σ level. Ages were calculated using the decay constants recommended by Steiger and Jäger (1977). Age designations were based on the time scale of Harland *et al.* (1990) and the revised age of the Permo-Triassic boundary by Renne *et al.* (1995). Common lead corrections were made using the two-stage growth model of Stacey and Kramers (1975). Discordia lines were regressed using a modified York-II model (York, 1969; Parrish *et al.*, 1987). Uranium-lead analytical results are presented in Table 1.

analytical results

The tonalite (96A-7) contained abundant coarse-grained tabular to prismatic zircon with few colourless baguette-shaped inclusions and good clarity. Analysis of four fractions of zircon yielded $^{207}Pb/^{206}Pb$ ages of 238 to 244 Ma. The error ellipse of fraction C slightly overlaps the concordia curve, with a $^{206}Pb/^{238}U$ age of 236 Ma, which provides a minimum age for this rock. However, an Early Triassic age of 242 +/-2 Ma, based on the weighted mean $^{207}Pb/^{206}Pb$ age of all four fractions, is considered the best estimate of the age of this rock.

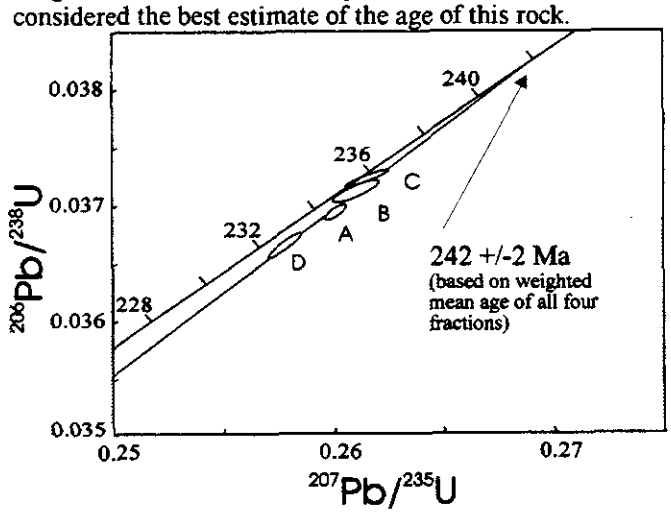

Figure 4. U-Pb concordia diagram for tonalite sample 96A-7.

Table 1. U-Pb zircon analytical data

Fraction[1]	Wt.	U	Pb[2]	^{206}Pb[3]	Pb[4]	^{208}Pb[5]	Isotopic ratios(±1σ,%)[6]			Isotopic dates(Ma,±2σ)[6]		
	mg	ppm	ppm	^{204}Pb	pg	%	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
tonalite 96A-7												
A,c,N1,t	0.455	183	7	7528	26	8.3	0.03694±0.09	0.2601±0.09	0.05107±0.06	233.8±0.4	234.8±0.4	244.0±2.7
B,c,N1,t	0.204	139	5	8223	8	7.3	0.03712±0.13	0.2610±0.20	0.05100±0.11	235.0±0.6	235.5±0.8	240.9±5.2
C,c,N1,t	0.226	135	5	7877	9	7.6	0.03723±0.10	0.2615±0.19	0.05095±0.10	235.7±0.5	235.9±0.8	238.4±4.8
D,m,N1,t	0.265	169	6	8496	12	7.8	0.03666±0.14	0.2578±0.15	0.05101±0.05	232.1±0.7	232.9±0.6	241.2±2.5

[1]All fractions are air abraded; Grain size, smallest dimension: c= +134μm, m=-134μm+74μm
Magnetic codes: Franz magnetic separator sideslope at which grains are nonmagnetic; e.g., N1=nonmagnetic at 1°;
Field strength for all fractions =1.8A; Front slope for all fractions=20°; Grain character codes: t=tabular

[2]Radiogenic Pb

[3]Measured ratio corrected for spike and Pb fractionation of 0.0043/amu ±20% (Daly collector)

[4]Total common Pb in analysis based on blank isotopic composition

[5]Radiogenic Pb

[6]Corrected for blank Pb, U and common Pb (Stacey-Kramers (1975) model Pb composition at the $^{207}Pb/^{206}Pb$ age of fraction, or age of sample)

Table 2. Major and trace element data

sample number	lithology	SiO2 %	TiO2 %	Al2O3 %	Fe2O3 %	MnO %	MgO %	CaO %	Na2O %	K2O %	P2O5 %	LOI	Total	BaO ppm
96A-1	qtz+plag crystal tuff	69.76	0.30	12.12	2.77	0.15	1.54	3.79	3.18	1.70	0.06	4.21	99.63	309
96A-2	qtz+plag crystal tuff	79.63	0.22	11.88	0.78	0.02	0.41	0.27	6.26	0.07	0.05	0.53	100.13	28
96A-3	qtz+plag crystal tuff	77.90	0.19	10.00	1.72	0.10	0.70	2.40	4.45	0.22	0.04	2.45	100.19	95
96A-4	plag crystal tuff	60.80	0.60	15.24	8.61	0.16	3.64	1.53	6.00	0.05	0.11	3.43	100.21	64
96A-5	siliceous ash tuff	76.77	0.26	9.78	2.79	0.10	1.22	2.00	4.95	0.20	0.07	2.36	100.52	37
96A-6	qtz+plag crystal tuff	75.58	0.26	12.18	1.96	0.08	0.63	1.27	6.15	0.20	0.06	1.66	100.04	46
96A-7	tonalite	62.54	0.62	15.59	7.11	0.13	2.78	4.83	3.27	1.61	0.09	1.97	100.61	433
CC-GC-01	qtz crystal tuff	76.79	0.24	13.70	0.57	0.01	1.12	0.23	4.46	1.45	0.04	1.30	99.95	251
CCH-SIT	qtz+plag crystal tuff	76.51	0.27	13.65	1.23	0.00	0.20	0.27	5.90	0.92	0.03	1.03	100.03	137
Detection Limits (ppm):		60	35	120	30	30	95	15	75	25	35			17

sample number	Co ppm	Cr2O3 ppm	Cu ppm	Ni ppm	V ppm	Zn ppm	Ga ppm	Nb ppm	Pb ppm	Rb ppm	Sr ppm	Th ppm	U ppm	Y ppm	Zr ppm
96A-1	23	17	11	7	26	103	13	3.4	1.1	20.7	170.1	<d/l	4.5	35.6	84.0
96A-2	44	<d/l	<d/l	<d/l	<d/l	51	10	3.7	<d/l	<d/l	111.1	<d/l	3.6	34.2	108.1
96A-3	44	27	6	11	<d/l	72	10	3.0	<d/l	2.8	163.5	<d/l	3.8	33.7	91.4
96A-4	36	<d/l	6	4	197	104	16	4.3	2.7	<d/l	91.9	<d/l	5.2	25.6	27.8
96A-5	28	16	7	<d/l	49	67	8	3.8	<d/l	<d/l	82.8	<d/l	4.1	27.4	60.7
96A-6	36	20	<d/l	7	23	61	10	4.7	<d/l	1.6	69.2	<d/l	3.9	21.5	79.1
96A-7	31	47	68	9	150	97	14	3.1	2.5	36.4	155.6	3.3	5.5	36.8	112.2
CC-GC-01	30	<d/l	4	<d/l	23	45	15	7.6	<d/l	14.5	61.6	<d/l	<d/l	11.9	65.0
CCH-SIT	44	<d/l	12	<d/l	17	40	13	5.5	<d/l	7.9	75.4	<d/l	<d/l	32.2	88.8
Detection Limits (ppm)	10	15	2	3	10	2	1	1	1	1	1	1	1	1	1

Table 3. Rare earth element data

sample number	Au ppb	Ag ppm	As ppm	Br ppm	Cs ppm	Hf ppm	Hg ppm	Ir ppb	Sb ppm	Sc ppm	Se ppm	Ta ppm	W ppm	La ppm	Ce ppm	Nd ppm	Sm ppm	Eu ppm	Tb ppm	Yb ppm	Lu ppm
96A-3	<d/l	<d/l	<d/l	<d/l	<d/l	3.3	<d/l	<d/l	0.4	10.8	<d/l	0.9	212	5.5	14	9	2.64	0.80	0.7	3.17	0.44
96A-6	<d/l	<d/l	1	<d/l	<d/l	2.3	<d/l	<d/l	0.5	7.9	<d/l	1.0	150	4.4	11	7	1.66	0.51	0.4	1.79	0.25
96A-7	<d/l	<d/l	2	<d/l	1.1	4.5	<d/l	<d/l	0.6	23.1	<d/l	<d/l	108	6.5	19	11	3.18	0.86	0.8	3.48	0.48
Detection Limits	2 ppb	2 ppm	1 ppm	0.5 ppm	0.2 ppm	0.2 ppm	1 ppm	1 ppm	0.1 ppm	0.1 ppm	0.5 ppm	0.3 ppm	1 ppm	0.1 ppm	1 ppm	1 ppm	0.01 ppm	0.05 ppm	0.1 ppm	0.05 ppm	0.01 ppm

GEOCHEMISTRY

major and trace elements

A suite of one intrusive and eight volcanic rock samples were analyzed for major and trace element abundances, using x-ray fluorescence at McGill University in Montreal, Quebec. Volcanic rocks range in composition from dacite to rhyolite (61-80% SiO_2, 0.19-0.30% TiO_2), whereas the intrusive rock has a tonalitic composition (63% SiO_2, 0.62% TiO_2) (Figure 5a and Table 2). All samples have relatively low K_2O (0.05-1.70%) and high Na_2O (3.18-6.26%) concentrations.

Volcanic and intrusive rocks analyzed in this study have Zr/Y ratios of 1.1 to 5.5 (Table 2). Using the limits defined by Barrett and MacLean (1994), these rocks have a predominantly tholeiitic magmatic affinity (Figure 5b).

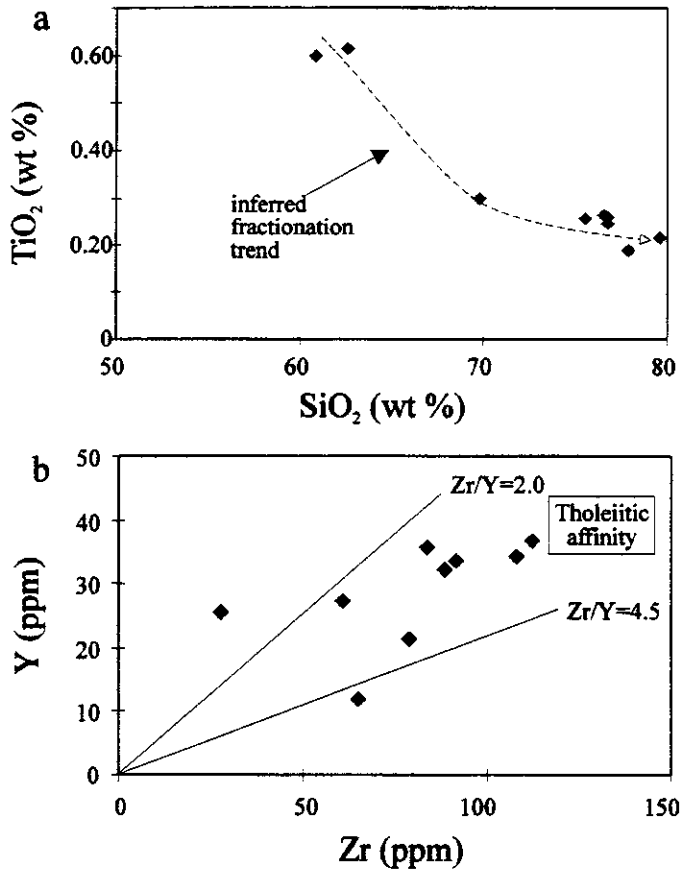

Figure 5. a) TiO_2 versus Al_2O_3 diagram b) Zr versus Y diagram (Barrett and MacLean, 1994) for samples of volcanic and intrusive rocks.

rare earth elements

Rare earth element (REE) concentrations were determined for samples of two rhyolite crystal tuffs and the tonalite by neutron activation analysis at Actlabs in Ancaster, Ontario. All samples are characterized by near-flat patterns (Figure 6 and Table 4). These patterns, combined with low REE concentrations indicate derivation of the rhyolite tuffs and tonalite from primitive magmatic sources.

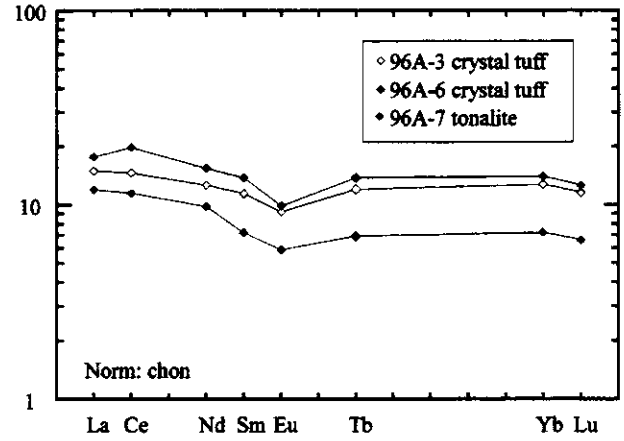

Figure 6. Rare earth element diagram for one tonalite and two rhyolite crystal tuffs.

DISCUSSION AND TECTONIC IMPLICATIONS

An Early Triassic age of 242 +/-2 Ma for the tonalite dated in this study is older than rocks of the Nicola Group and contemporaneous plutonism, but is indistinguishable from rocks of the Kutcho Assemblage (McMillan et al., 1982; Monger and McMillan, 1984; Childe and Thompson, 1995a and b).

The strong similarity between the REE patterns of the rhyolites and tonalite suggests that the volcanic and intrusive rocks were derived from the same magmatic source, and are probably of similar age. The low-K tholeiitic chemistry of these rocks is comparable to those of the Kutcho Assemblage, and dissimilar from the calc-alkaline to shoshinitic chemistry characteristic of the Nicola Group (Mortimer, 1986; Thompson *et al.*, 1995; Barrett et al., in press).

Based on the data presented in this paper, felsic volcanic and intrusive rocks which occur between the Martell and Bonaparte Faults, near Ashcroft, are tentatively correlated with the Permo-Triassic Kutcho Assemblage, rather than the Late Triassic to Early Jurassic Nicola Group. Mafic volcanic rocks assigned to the Nicola Group occur both to the east and west of the Bonaparte Fault (Figure 2). The presence of Late Triassic fossils imply that this correlation is valid for basaltic rocks which occur east of the Bonaparte Fault. However, the age of basaltic rocks that occur west of the Bonaparte Fault, in proximity to, and possibly interbedded with rhyolite tuffs, is not constrained. These basaltic rocks may be contemporaneous with the Early Triassic felsic rocks, rather than the younger Nicola Group lavas. Detailed mapping and geochemistry, accompanied by additional U-Pb geochronology are necessary in order to determine the extent of Early Triassic age rocks with primitive arc affinity in this region.

VMS POTENTIAL

The presence of rocks of Kutcho Assemblage age and affinity within the Ashcroft map area raises the potential for Kutcho Creek-equivalent Cu-Zn volcanogenic massive sulphide mineralization.

A number of copper occurrences are known within the Venables Valley - Red Hill area. The Red Hill showing (B.C. MINFILE 092INW042) contains chalcopyrite, chalcocite, and secondary Cu minerals that occur within chlorite and sericite altered pyritic greenstone, in proximity to Early Triassic rhyolite tuffs and tonalite. Also on Red Hill are unnamed gossans containing malachite and azurite (Ladd, 1981). Rhyolite tuff-hosted mineralization includes two unnamed copper occurrences, which occur approximately 1 km east of the trondhjemite body, southwest of Red Hill (Ladd, 1981). Based on the correlation of these rocks with the Kutcho Assemblage proposed in this paper, mineralized occurrences within this area should be explored for Cu-Zn VMS potential.

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