

BLUE RIVER CARBONATITES, BRITISH COLUMBIA - PRIMARY EXPLORATION TARGETS FOR TANTALUM

By George J. Simandl^{1,2}, Peter C. Jones³ and Melissa Rotella²

KEYWORDS: Carbonatite, columbite, pyrochlore, tantalum, niobium, Fir, Verity, Blue River.

INTRODUCTION

Prices for tantalum raw materials skyrocketed in 2000 to US\$350.00/lb, and as a result, unconventional tantalum resources such as carbonatites came into the spotlight (Simandl, 2002). British Columbia hosts several carbonatite and alkaline complex-type occurrences, specialty granites and pegmatites (Pell, 1994; Pell and Hora 1990). The carbonatites are well known for associated niobium, rare earth elements (REE), phosphate, vermiculite, fluorite, zirconium, uranium, thorium, titanium, copper and iron mineralization (Richardson and Birkett, 1996; Birkett and Simandl, 1999).

The tantalum content of the minerals pyrochlore and columbite in carbonatites is generally low. Exceptional Ta concentrations in pyrochlore hosted by carbonatites are typically associated with high UO_2 or Th_2O_5 contents. Uranium-bearing pyrochlores from Siberia are reported to contain up to 26.9% Ta_2O_5 (Pozharitskaya and Samoylov, 1972; Hogarth, 1989). For this reason, some of the tantalum-rich uranopyrochlore deposits were previously investigated as sources of tantalum in the former USSR (Kapustin, 1974). Pyrochlore group minerals, hosted by carbonatites, with high tantalum content were also reported at Sokli in Finland (Lindqvist and Rehtijarvi, 1979), at Crevier in Quebec (Laplante, 1980) and elsewhere.

This paper outlines some observations and results of a two-day field visit of the Verity, Fir and Serpentine carbonatite deposits in the Blue River area. Nine representative surface samples, collected by the senior author, were studied using polarizing and reflecting microscopes.

The composition of ore minerals was determined using electron microprobe. The methodology and whole rock analytical methods are described in Annex I.

Pyrochlore and columbite are the main Ta-bearing minerals and the tantalum and niobium content of the whole rock samples are within the range of previously reported analyses.

BLUE RIVER CARBONATITE DEPOSITS

LOCATION AND PREVIOUS WORK

At least 12 carbonatite and syenite occurrences are known to occur in the Blue River area of central British Columbia (Figure 1). The Verity, Fir and Serpentine carbonatites are part of this cluster located to the east of both the North Thompson River and the Canadian National Railway, approximately 35 km north from the community of Blue River. The Verity and Fir carbonatites outcrop on logging roads, while the Serpentine carbonatite is within 500 metres of an active logging road. Shallow overburden

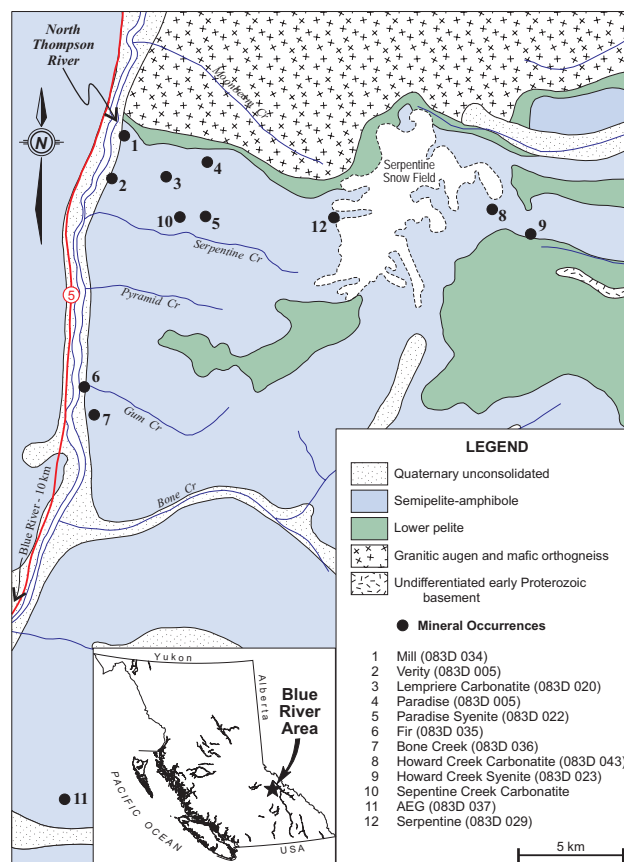


Figure 1. Location and geological setting of the Blue River carbonatite and syenite occurrences. The Verity, Fir and Serpentine carbonatites are discussed in this paper. BC MINFILE numbers are listed in parentheses. Modified from Mountjoy (1992).

¹ BC Ministry of Energy and Mines
George.Simandl@gems2.gov.bc.ca

² University of Victoria

³ Carleton University

and dense underbush cover most of the area surrounding the Fir, Verity and Serpentine occurrences and consequently the carbonatites are exposed only as isolated outcrops.

The area containing the carbonatites was originally staked in 1950 for vermiculite and was subsequently explored for uranium. Follow-up exploration resulted in the discovery of pyrochlore. The property has been intermittently prospected since the fifties. Details of the exploration history of the area are provided by Dahrouge (2002). The Verity and Fir carbonatites are currently being re-evaluated as a potential source of Ta and Nb (Dahrouge, 2002; Simandl, 2002).

GEOLOGICAL SETTING

The Blue River occurrences are part of a broad zone of carbonatites that follow the Rocky Mountain Trench. They are located within the Omineca Belt and more precisely within the northeastern margin of the Shuswap Metamorphic Complex mapped by Campbell (1968). These carbonatites are hosted by the semipelite-amphibolite unit (Figure 1) of the Hydrynian Horseshief Creek Group (Mountjoy, 1992). The complexly deformed rocks have reached amphibolite facies metamorphism and both sillimanite and kyanite are reported in this area (Campbell, 1967; Diegel, 1989). Some of the carbonatites, including the three carbonatites that we examined, appear to predate deformation and peak metamorphic conditions.

VERITY DEPOSIT

The Verity carbonatite was traced over 800 metres by a combination of extensive trenching and drilling (Smith, 1952 and Rowe, 1958), but most of the trenches have since collapsed. Carbonatite outcrops as a beige, fractured and rubble-like rock (Photo 1a). This appearance is due to severe chemical and physical weathering. Surface samples from the Verity deposit were classified petrographically as beforosite (a dolomite-carbonatite). Beforosite in outcrops consists mainly of dolomite (>65%, 1-4mm), apatite (3-20%, 2-3 mm), calcite (<10%), and light green to blue-green alkali amphibole (<10%, 1-3 mm). Pyrochlore and columbite (ferrocolumbite) are present as minor constituents.

Vermiculite was reported at Verity by McCammon (1953). The beforosite-semipelite contacts are marked by fenite (Rowe, 1958); however, they are not exposed in the areas visited. In 1981 and 1982 an exploration program by Anschutz (Canada) Mining Ltd. resulted in resource estimates of 2 million tonnes of 0.118% Nb₂O₅ and 0.020% Ta₂O₅ (Aquist, 1982). During the early part of 2001, the inferred resource of the Verity-Paradise project was estimated at 3.06 million tonnes grading 196 ppm Ta₂O₅, 646 ppm Nb₂O₅ and 3.20% P₂O₅ (Dahrouge, 2002, this volume). Additional drilling and bulk sampling was completed late in 2001 by Commerce Resources Corp.

LITHOGEOCHEMISTRY

Major and trace element content of the nine samples are summarized in Table 1.

The Verity carbonatite plots in the magnesio-carbonatite field on the CaO - MgO - (FeO+Fe₂O₃+MnO) ternary diagram (Figure 2) developed by Woolley and Kempe (1989). This confirms our terminology based on petrographic observations.

Verity samples Ver-1, 2 and 3 contain 192.8, 158.5 and 287.7 ppm of Ta respectively. The Nb content of these samples is 585.6, 1996.2 and 2421.6 ppm respectively and their P₂O₅ content is 2.89, 2.62 and 1.07 %. W, Mo, Sb and Sn are at or below instrument detection limits and are therefore not shown in Table 1.

NIOBIUM AND TANTALUM MINERALS

The main ore minerals of the Verity deposit, pyrochlore and columbite, were previously identified by Rowe (1958), Hogarth (1961), Heinrich (1962) and Jones (1957). Both of these minerals were determined to contain some UO₂ (Rowe, 1958 and Heinrich, 1980). It was suggested that the radioactivity in the Verity columbite is caused by submicroscopic inclusions of metamict pyrochlore (Heinrich, 1962). Van der Veen (1963) also identified fersmite and columbite replacing pyrochlore; however, the mineral paragenesis remains controversial (Mariano, 1989).

The most striking ore mineral appears to be a coarse, dark, reddish black euhedral to subhedral pyrochlore (Photo 1b). Similar pyrochlore samples, with abundant mineral inclusions, have been described in the literature (Hogarth, 1961). However, most pyrochlores and columbites from the Verity carbonatite observed in thin section are finer-grained and are not euhedral (Photos 1c and 1d). Results of microprobe analysis of the pyrochlore

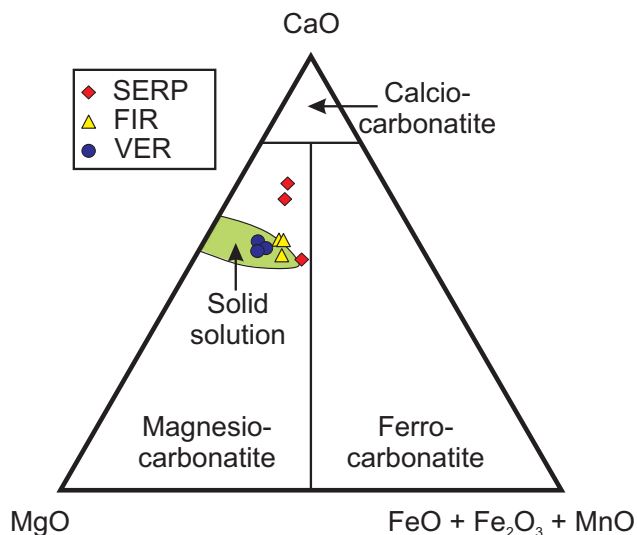


Figure 2. Chemical composition of the Verity, Fir and Serpentine carbonatites; classification as proposed by Woolley and Kempe (1989). Shaded area represents dolomite-ankerite solid solution field.



Photo 1a.

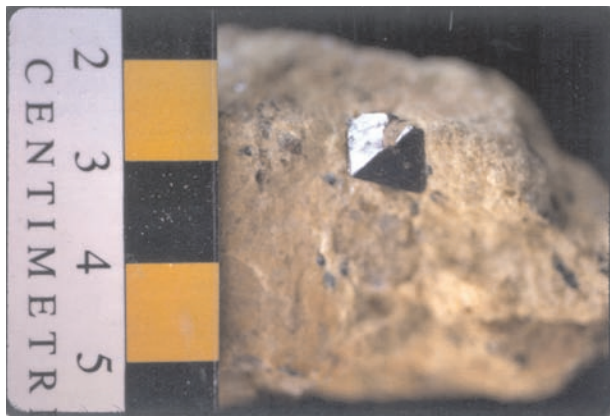


Photo 1b

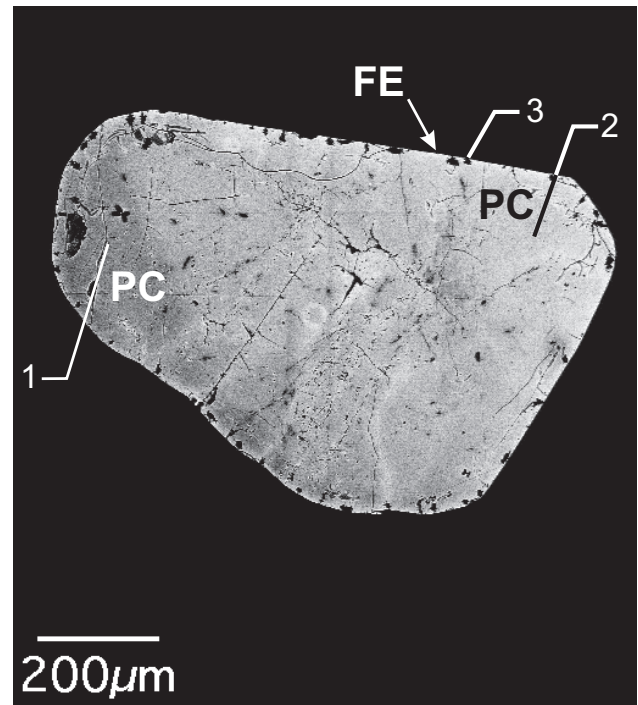


Photo 1c

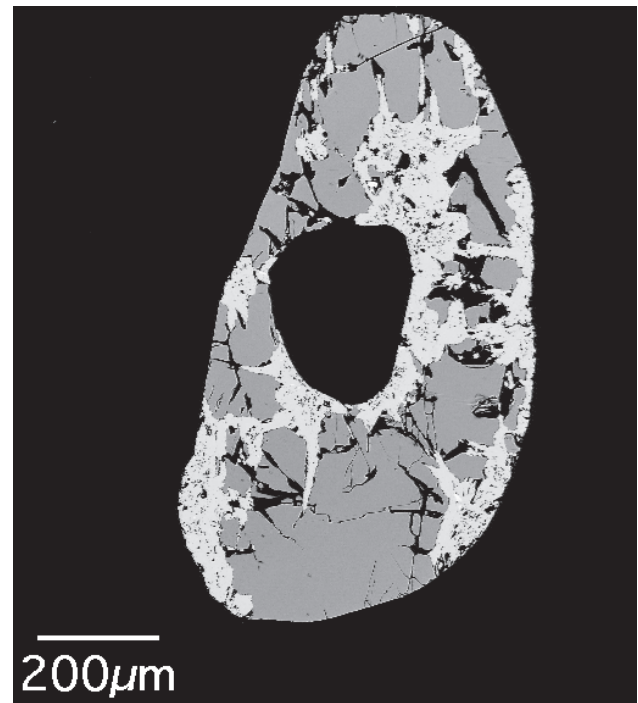


Photo 1d

Photo 1. The Verity deposit, a) Specimen pit (photo by Mike Cathro); b) Euhedral pyrochlore in beforosite, Specimen pit; c) Tantalum/uranium-bearing pyrochlore (PC), backscatter electron photomicrograph (microprobe analyses 1 and 2 correspond to Ver1-2A#1, #2 in Table 2; microprobe analysis 3 corresponds to an iron oxide rim; silicates and carbonates are black; d) Pyrochlore (dark gray) is being replaced by columbite (light gray), carbonates in black; backscatter electron photomicrograph.

crystals are given in Table 2. The elements MgO, MnO, K₂O, WO₃ and ZrO were at, or below the detection limit of the instrument and are not provided in this Table. Pyrochlore crystals are commonly zoned (Photo 1c), and chemical variations within the same grain may be seen in Table 2. These variations suggest that the highest Ta concentrations in pyrochlore are associated with the highest UO₂ content. There are two clusters on Figure 3. Cluster A is formed by analyses from both Verity and Fir deposits, cluster B represents exclusively Ta- and U-rich pyrochlore from the Verity deposit. Based on the above microprobe data, pyrochlore group minerals belong to the pyrochlore subgroup as defined by Hogarth (1989) and plot within the pyrochlore field on the Ti-Nb-Ta diagram (Figure 3).

Columbite, or more precisely its iron-rich variety called ferrocolumbite, is also present within the Verity de-

posit. Until recently columbite from the Blue River area was not believed to contain detectable tantalum concentrations (Mariano 1989). Microprobe analysis of columbite (Table 3) indicates that its Ta₂O₅ content ranges from 1.51 to 3.33 wt%. The elements F, K₂O, SrO and ZrO are at or below the detection limit of the instrument and are not shown in this Table. The UO₂ and Th₂O₅ contents of colum-

TABLE 1
MAJOR AND TRACE ELEMENT ANALYSES OF THE VERITY, FIR AND SERPENTINE CARBONATITES
(FOR THE DESCRIPTION OF ANALYTICAL METHODS, SEE THE TEXT)

Element	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	MnO	Cr ₂ O ₃	Ba	Ni	Sc	LOI	TOT/C	TOT/S	SUM
Units	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	%	%	%	%
Method	ICPES	ICPES	ICPES	ICPES	ICPES	ICPES	ICPES	ICPES	ICPES	ICPES	ICPES	ICPES	ICPES	ICPES	FUS	LECO	LECO	SUM
Field No.																		
SERP-1	7.04	0.18	6.04	11.94	36.73	0.15	0.29	1.68	0.03	0.10	0.005	283	< 20	19	35.5	9.99	0.07	99.72
SERP-3	43.10	3.06	8.93	10.66	22.32	0.50	0.43	0.21	1.11	0.14	< 0.001	27	< 20	14	9.3	2.19	0.05	99.77
SERP-4	5.38	0.38	5.16	10.25	37.35	0.11	0.04	1.46	0.06	0.10	0.003	253	21	19	39.5	10.77	0.03	99.83
FIR-1	2.55	0.05	7.14	14.51	30.34	0.37	0.05	0.01	3.23	0.60	0.008	71	< 20	5	39.5	10.96	0.06	98.37
FIR-2	2.64	0.07	8.60	15.58	29.19	0.38	0.04	0.02	1.12	0.63	0.005	49	< 20	5	40.7	11.83	0.12	98.98
FIR-3D	2.77	0.04	7.63	14.03	30.16	0.48	0.06	0.03	3.27	0.57	0.013	34	< 20	6	38.3	10.77	0.04	97.36
VER-1	1.82	< 0.03	5.56	17.10	30.59	0.16	0.13	0.03	2.89	0.20	0.025	103	87	14	40.7	11.83	0.01	99.24
VER-2	2.85	< 0.03	6.69	16.35	29.19	0.22	0.20	0.07	2.62	0.22	0.007	119	< 20	26	39.9	11.25	0.03	98.35
VER-3	1.49	< 0.03	5.96	17.49	28.97	0.19	0.09	0.03	1.07	0.23	0.015	136	32	16	42.7	12.42	0.01	98.27

Element	Co	Cs	Ga	Hf	Nb	Rb	Sr	Ta	Th	Ti	U	V	Zr	Y	La	Ce	Pr	
Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
Method	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	
Field No.																		
SERP-1	35.1	0.2	2	4.6	87.9	12	1509.1	15.2	1.4	0.2	0.2	57	151.0	31.1	102.2	208.7	25.17	
SERP-3	24.6	0.9	9.4	1.2	29.9	7.6	621.8	9.1	3.6	0.2	5.3	111	44.7	20.6	85.6	170.1	18.78	
SERP-4	28.8	0.2	3	4.6	90.9	2.5	1599.0	16.3	1.0	0.1	0.1	58	165.7	31.6	108.3	219.7	26.08	
FIR-1	11.4	< 0.1	0.9	< 0.5	1450.2	< 0.5	4783.7	188.9	18.9	0.2	9.2	< 5	7.3	32.4	150.1	333.7	39.83	
FIR-2	15.9	< 0.1	0.8	< 0.5	1294.3	0.6	4310.5	107.7	2.1	0.1	1.3	5	7.1	16.2	75.4	160.4	18.44	
FIR-3D	11.2	0.1	< 0.5	< 0.5	4009.5	< 0.5	4626.1	251.2	38.0	0.1	7.9	< 5	7.6	33.2	164.6	367.0	42.95	
VER-1	22.9	0.1	4.9	< 0.5	585.6	2.8	3660.6	192.8	2.0	0.1	158.1	12	4.8	19.6	158.1	334.7	38.84	
VER-2	22.1	0.2	3.5	0.8	1996.2	6.5	4271.7	158.5	11.1	0.1	52.2	48	17.0	20.0	167.2	355.1	40.7	
VER-3	27.8	0.1	1.1	0.9	2421.6	1.8	4408.1	287.7	10.3	0.1	197.2	21	19.0	13.0	117.2	245.4	27.05	

Element	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Cu	Pb	Zn	Ni	As	Cd	
Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
Method	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	LMBMS	ARIC	ARIC	ARIC	ARIC	ARIC	ARIC	
Field No.																	
SERP-1	18.2	5.39	12.37	1.51	7.39	1.34	2.91	0.36	1.96	0.23	118	< 3	18	22	2	< 0.2	
SERP-3	10.0	2.82	6.82	0.85	4.69	0.84	2.28	0.29	1.94	0.28	2	4	12	6	< 2	< 0.2	
SERP-4	16.5	5.46	13.20	1.60	7.85	1.29	2.94	0.34	1.80	0.25	135	< 3	14	18	3	0.3	
FIR-1	25.6	7.81	17.29	1.97	9.16	1.51	3.26	0.38	2.00	0.26	< 1	< 3	32	< 1	< 2	1.0	
FIR-2	10.9	3.54	7.67	0.91	4.16	0.73	1.75	0.21	1.15	0.14	< 1	< 3	31	< 1	< 2	0.9	
FIR-3D	26.3	8.10	17.82	2.08	9.66	1.54	3.38	0.35	2.11	0.23	< 1	< 3	29	< 1	< 2	0.9	
VER-1	23.5	6.61	13.82	1.45	6.30	0.96	1.86	0.17	1.00	0.10	3	< 3	19	1	< 2	0.5	
VER-2	23.2	6.82	14.90	1.53	6.67	0.96	1.95	0.16	0.92	0.10	1	< 3	23	< 1	< 2	0.7	
VER-3	14.2	4.17	8.53	0.97	4.31	0.61	1.27	0.12	0.76	0.09	1	< 3	19	< 1	< 2	0.7	

TABLE 2
MICROPROBE ANALYSES OF PYROCHLORE FROM THE VERITY (VER) AND FIR (FIR) DEPOSITS

ANALYSIS	Nb ₂ O ₅	Ta ₂ O ₅	TiO ₂	FeO	ThO ₂	UO ₂	La ₂ O ₃	Ce ₂ O ₃	Y ₂ O ₃	CaO	SrO	PbO	Na ₂ O	F	Total
FIR3A-A2#1	60.04	3.68	1.51	0.00	0.54	0.03	0.15	0.24	0.15	13.95	0.73	0.00	7.71	5.29	94.05
FIR3A-A2#2	70.18	1.36	1.58	0.06	0.47	0.02	0.18	0.24	0.22	15.31	0.77	0.01	7.42	5.72	103.54
FIR3A-A2#3	66.38	5.24	1.60	0.02	0.52	0.01	0.18	0.29	0.15	14.92	0.67	0.00	7.24	5.48	102.70
FIR3A-A3#1	64.35	3.39	1.60	0.00	0.63	0.00	0.00	0.33	0.17	14.96	0.78	0.05	7.77	5.03	99.14
FIR3A-A3#2	66.01	5.80	1.53	0.00	0.65	0.03	0.14	0.41	0.08	14.72	1.00	0.05	7.72	4.99	103.13
FIR3A-A3#3	65.60	4.66	1.55	0.03	0.44	0.07	0.21	0.38	0.15	14.98	1.00	0.00	7.75	5.33	102.15
FIR3D-A1#1	67.68	3.81	1.74	0.00	0.40	0.00	0.00	0.25	0.20	15.24	0.73	0.00	7.69	4.94	102.68
FIR3D-A1#2	66.81	5.58	1.62	0.00	0.39	0.06	0.14	0.32	0.17	14.89	0.85	0.00	7.74	4.91	103.49
FIR3D-A1#3	65.42	6.27	1.67	0.01	0.45	0.17	0.05	0.22	0.17	15.25	0.69	0.00	7.53	4.95	102.90
FIR3D-A1#4	68.14	3.80	1.78	0.02	0.48	0.07	0.10	0.29	0.17	15.33	0.78	0.04	7.62	4.90	103.55
FIR3D-A1#5	68.11	3.71	1.72	0.04	0.54	0.03	0.12	0.29	0.18	15.09	0.75	0.00	7.72	5.12	103.53
FIR3D-A1#6	63.23	4.83	1.51	0.03	0.38	0.00	0.01	0.31	0.16	13.79	0.83	0.00	7.71	5.46	98.26
FIR3D-A2#1	69.45	1.66	1.77	0.01	0.65	0.00	0.16	0.12	0.00	15.38	0.88	0.00	7.80	5.32	103.20
FIR3D-A2#2	65.73	6.00	1.65	0.06	0.52	0.12	0.22	0.21	0.04	14.64	1.03	0.00	7.50	5.20	102.92
FIR3E-A1#1	65.70	6.40	1.59	0.03	1.12	0.00	0.02	0.17	0.07	14.41	0.85	0.00	7.66	4.92	102.95
FIR3E-A1#2	66.42	4.21	1.67	0.00	1.41	0.00	0.00	0.16	0.18	14.94	0.71	0.00	7.78	5.19	102.69
FIR3E-A1#3	66.10	5.01	1.69	0.01	1.47	0.01	0.07	0.14	0.11	15.00	0.74	0.08	7.66	5.05	103.15
FIR3E-A1#4	65.63	5.75	1.63	0.03	1.26	0.00	0.07	0.17	0.14	14.77	0.94	0.00	7.61	4.86	102.87
FIR3E-A3#6	67.70	2.84	1.50	0.06	1.16	0.00	0.08	0.25	0.15	14.91	0.84	0.00	8.02	5.22	102.78
FIR3E-A3#7	65.46	5.70	1.45	0.01	1.06	0.00	0.10	0.19	0.21	14.96	0.71	0.01	7.97	5.07	102.99
MEAN	66.21	4.49	1.62	0.02	0.73	0.03	0.10	0.25	0.14	14.87	0.81	0.01	7.68	5.15	102.13
VER1-A1#1	55.95	11.86	2.86	0.03	0.21	7.22	0.00	0.29	0.00	11.89	0.00	0.00	7.23	3.01	100.59
VER1-A1#2	54.91	12.04	2.86	0.00	0.16	7.70	0.08	0.03	0.13	11.92	0.00	0.19	6.78	2.88	99.72
VER1-A1#3	54.17	11.99	2.92	0.37	0.02	7.67	0.16	0.19	0.00	11.68	0.58	0.00	6.76	2.95	99.52
VER1-A2#1	53.53	12.05	2.98	0.16	0.02	9.83	0.08	0.16	0.13	11.77	0.36	0.13	6.95	3.00	101.26
VER1-A2#2	52.18	12.05	3.00	0.13	0.00	9.72	0.02	0.13	0.14	11.67	0.37	0.13	6.96	2.90	99.46
VER2-A1#1	68.10	2.09	2.28	0.05	0.31	0.20	0.00	0.28	0.15	15.91	0.66	0.10	7.44	5.47	103.13
VER2-A1#2	67.69	2.06	2.30	0.04	0.18	0.13	0.30	0.45	0.14	15.51	0.79	0.04	7.43	5.32	102.45
VER2-A2#1	66.42	1.58	2.56	0.05	0.35	0.12	0.21	0.39	0.19	15.86	0.54	0.00	7.50	5.22	101.07
VER2-A3#1	65.34	1.61	2.58	0.08	0.35	0.09	0.21	0.41	0.22	15.63	0.67	0.01	7.42	5.47	100.16
VER2-A3#2	64.97	1.56	2.50	0.05	0.18	0.09	0.08	0.36	0.19	15.46	0.66	0.03	7.40	5.52	99.13
MEAN	60.33	6.89	2.68	0.10	0.18	4.28	0.11	0.27	0.13	13.73	0.46	0.06	7.19	4.17	100.65

(The analytical total as shown here was not adjusted for the oxygen equivalent of fluorine, such an adjustment can be made by multiplying the F value by 0.42 (at wt O/ 2x at wt F) and subtracting this number from the "Total")

TABLE 3
MICROPROBE ANALYSES OF COLUMBITE FROM THE VERITY (VER) AND FIR (FIR) DEPOSITS

ANALYSIS	Nb ₂ O ₅	Ta ₂ O ₅	TiO ₂	SiO ₂	FeO	ZrO ₂	ThO ₂	UO ₂	La ₂ O ₃	Ce ₂ O ₃	Y ₂ O ₃	MgO	CaO	MnO	PbO	Na ₂ O	WO ₃	TOTAL
FIR3A-A2#4	79.34	1.12	1.25	0.00	15.70	0.00	0.00	0.06	0.00	0.00	0.38	3.24	0.04	1.32	0.00	0.00	0.04	102.49
FIR3A-A2#5	77.67	1.46	1.40	0.00	15.60	0.00	0.08	0.04	0.00	0.00	0.38	3.31	0.05	1.29	0.00	0.02	0.00	101.30
FIR3A-A3#4	78.50	1.25	1.17	0.00	15.99	0.01	0.03	0.00	0.12	0.01	0.31	2.11	0.04	1.40	0.00	0.02	0.07	101.03
FIR3D-A2#1	78.12	1.07	1.73	0.00	15.97	0.00	0.04	0.00	0.00	0.01	0.25	2.39	0.05	1.25	0.00	0.00	0.00	100.89
FIR3D-A2#2	78.43	0.67	1.62	0.00	16.20	0.00	0.00	0.00	0.00	0.06	0.31	2.45	0.05	1.32	0.00	0.00	0.00	101.12
FIR3E-A1#5	77.23	1.59	1.39	0.00	16.41	0.00	0.00	0.02	0.00	0.00	0.35	1.75	0.04	1.28	0.00	0.00	0.00	100.06
FIR3E-A1#6	76.99	1.73	0.98	0.00	17.18	0.00	0.00	0.00	0.05	0.00	0.28	1.09	0.24	1.58	0.06	0.02	0.04	100.25
FIR3E-A2#1	78.04	0.31	1.84	0.00	16.12	0.07	0.00	0.02	0.00	0.00	0.22	1.75	0.05	1.20	0.00	0.00	0.07	99.70
FIR3E-A2#2	76.91	2.29	1.57	0.00	15.79	0.00	0.05	0.00	0.00	0.00	0.27	1.77	0.03	1.23	0.03	0.00	0.00	99.94
FIR3E-A2#3	77.42	1.91	1.39	0.00	16.03	0.00	0.00	0.07	0.00	0.00	0.26	1.64	0.04	1.25	0.00	0.02	0.00	100.03
FIR3E-A2#4	77.50	2.14	1.47	0.00	15.47	0.00	0.08	0.00	0.01	0.00	0.23	1.75	0.05	1.29	0.09	0.00	0.04	100.14
FIR3E-A3#1	76.48	1.82	1.52	0.00	15.99	0.00	0.12	0.00	0.00	0.02	0.28	2.93	0.05	1.30	0.07	0.00	0.00	100.58
FIR3E-A3#2	78.44	1.23	1.32	0.00	15.89	0.00	0.00	0.00	0.05	0.00	0.31	2.83	0.05	1.24	0.05	0.02	0.00	101.43
FIR3E-A3#3	77.18	2.87	1.42	0.00	15.91	0.00	0.03	0.06	0.10	0.00	0.33	2.83	0.04	1.22	0.00	0.00	0.00	102.01
FIR3E-A3#4	77.32	1.29	1.24	0.00	16.01	0.00	0.01	0.08	0.01	0.00	0.30	2.91	0.10	1.30	0.02	0.00	0.00	100.60
FIR3E-A3#5	77.72	0.98	1.35	0.00	16.20	0.01	0.06	0.00	0.00	0.01	0.33	2.87	0.05	1.30	0.00	0.00	0.00	100.90
FIR3E-A4#1	78.46	0.84	1.62	0.00	16.19	0.04	0.00	0.00	0.01	0.00	0.29	2.48	0.03	1.29	0.01	0.01	0.12	101.39
FIR3E-A4#2	77.91	1.76	1.66	0.00	15.97	0.00	0.04	0.00	0.00	0.00	0.33	2.32	0.05	1.32	0.01	0.02	0.03	101.42
FIR3E-A4#3	78.03	1.74	1.36	0.00	15.97	0.00	0.00	0.01	0.03	0.00	0.29	2.24	0.06	1.35	0.05	0.01	0.00	101.14
MEAN	77.76	1.46	1.44	0.00	16.03	0.01	0.03	0.02	0.02	0.01	0.30	2.36	0.06	1.30	0.02	0.01	0.02	100.85
VER1-A2#3 *	0.03	0.01	0.00	1.87	73.67	0.03	0.03	0.02	0.01	0.02	0.01	0.40	0.80	0.00	0.00	0.74	0.04	77.77
VER1-A2#4 *	3.36	0.08	0.07	5.38	69.49	0.00	0.02	0.00	0.05	0.04	0.00	1.30	1.39	0.13	0.01	0.07	0.00	81.40
VER2-A1#3	74.12	1.92	2.65	0.00	20.18	0.00	0.15	0.14	0.08	0.01	0.35	0.30	0.10	0.18	0.00	0.05	0.00	100.23
VER2-A1#4	73.95	3.33	1.94	0.00	19.44	0.00	0.33	0.06	0.01	0.00	0.29	0.25	0.25	0.18	0.00	0.00	0.00	100.05
VER2-A1#5	75.92	1.51	1.70	0.00	19.73	0.00	0.23	0.11	0.00	0.00	0.30	0.17	0.23	0.24	0.11	0.01	0.04	100.30
VER2-A2#2	71.96	1.67	2.86	0.08	20.28	0.00	0.24	0.03	0.03	0.05	0.28	0.28	0.12	0.11	0.01	0.02	0.40	98.42
VER2-A2#3	72.96	1.79	2.94	0.00	20.13	0.00	0.21	0.18	0.05	0.06	0.30	0.31	0.22	0.28	0.00	0.00	0.12	99.56
VER2-A2#4	72.54	2.43	2.55	0.00	20.41	0.00	0.09	0.03	0.00	0.04	0.34	0.16	0.12	0.15	0.00	0.02	0.12	99.01
VER2-A3#3	70.54	1.55	2.65	0.00	20.60	0.00	0.29	0.00	0.10	0.00	0.35	0.16	0.11	0.11	0.00	0.02	0.00	96.50
VER2-A3#4	70.19	1.88	2.79	0.00	20.62	0.00	0.33	0.04	0.13	0.14	0.33	0.13	0.17	0.21	0.09	0.00	0.00	97.06
MEAN	72.77	2.01	2.51	0.01	20.17	0.00	0.23	0.07	0.05	0.04	0.32	0.22	0.17	0.18	0.03	0.02	0.09	98.89

* Iron oxide rims were not used to calculate the mean

bite from the Verity deposit, as indicated by our microprobe analyses, do not exceed 0.18 and 0.33% respectively. The tapiolite and columbite-tantalite compositional fields and the gap that separates these fields are shown on Figure 4. These compositional fields represent a compilation of pegmatite-hosted columbite-tantalite data by Černý *et al.* (1992). This figure permits us to illustrate the restricted Ta/Nb and Mn/Fe ratios of columbites from the Blue River area relative to columbite-tantalite that occurs in pegmatites. All the samples from the Verity carbonatite plot near the ferrocolumbite end-member. Furthermore, columbite from the Verity carbonatite appears to have lower Nb and higher TiO₂, ThO₂ and FeO content than that from the Fir carbonatite (Table 3).

The zoning of the pyrochlore and columbite crystals and their heterogeneity is readily observed on backscatter electron photomicrographs, see Photo 1c as an example. In some cases, columbites have rims consisting of iron oxide with a very low Ta and Nb (Table 3).

The REE contents of both pyrochlore and columbite are relatively low, therefore it is likely that a substantial proportion of the total REE indicated in whole rock analyses is accounted for by other minerals. One such mineral was tentatively identified as a fluorocarbonate based on semiquantitative microprobe analysis (36.36% Ce₂O₃, 18.94% La₂O₅, 9.63% F, 4.49% ThO₂, 3.54% Nb₂O₅, 2.94% CaO, 1.27% FeO, 0.5% SrO₂ and 0.19% TiO₂).

Detailed studies could determine if the paragenetic relationship between columbite and pyrochlore that we observed are consistent on the deposit scale. However, this aspect lies outside the scope of this study.

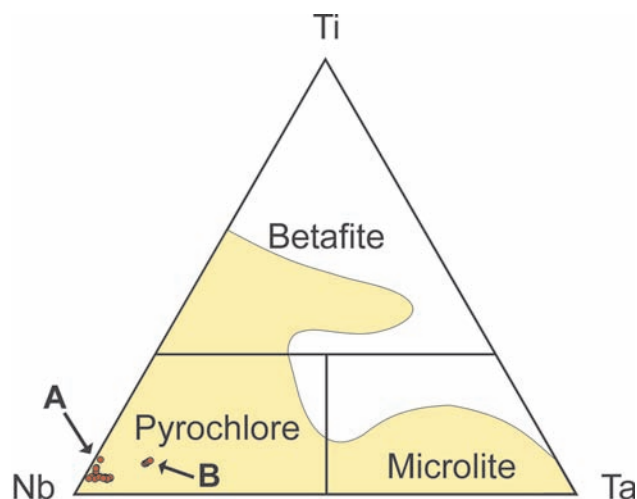


Figure 3. Composition of pyrochlores from the Verity and Fir deposits. Fields of pyrochlore subgroup, microlite and betafite are from Černý and Ercit (1986). Shaded area represents a known compositional range of pyrochlore group minerals.

FIR DEPOSIT

Outcrops of the Fir deposit result from breaks in the topography on the steep, west-facing slope of Mount Chedale. The best surface exposure measures 4.5 by 2.5 metres and appears to have been moved by gravity or frost heaving. However, diamond drilling has proved the presence of mineralized carbonatite at depth. Dahrouge (2002)

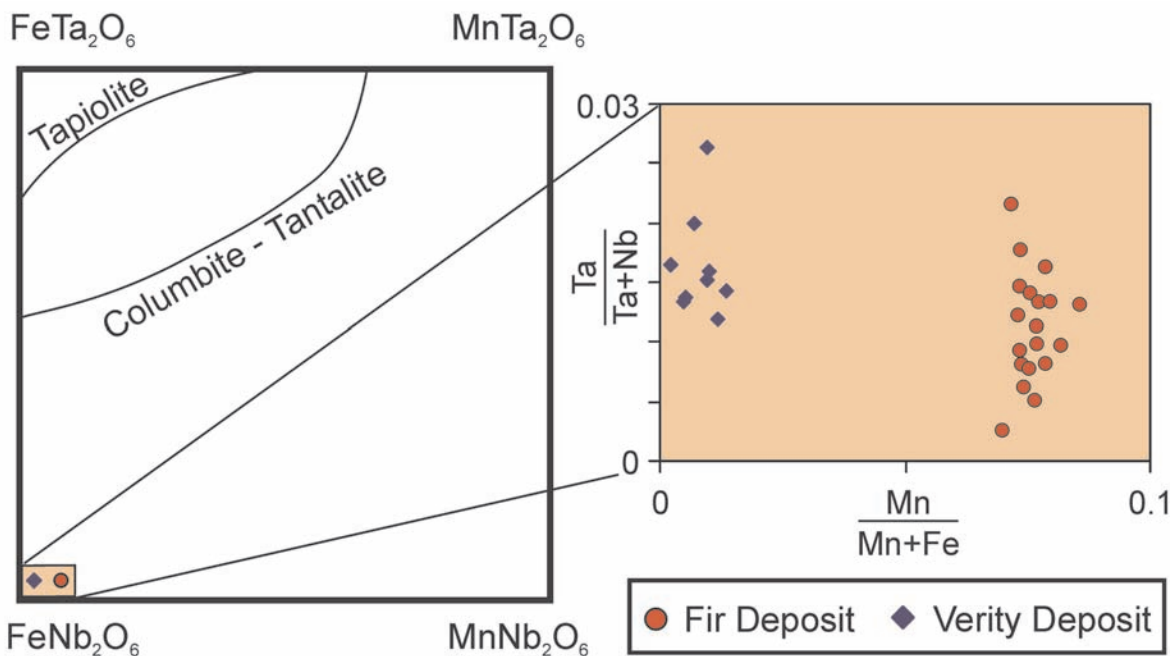


Figure 4. Columbites from the Verity and Fir deposits appear to form two distinct populations. Fir deposit contains columbite with higher Ta content, but all samples correspond to the ferrocolumbite end member. The grid is based on the composition of natural minerals (Černý *et al.*, 1992).

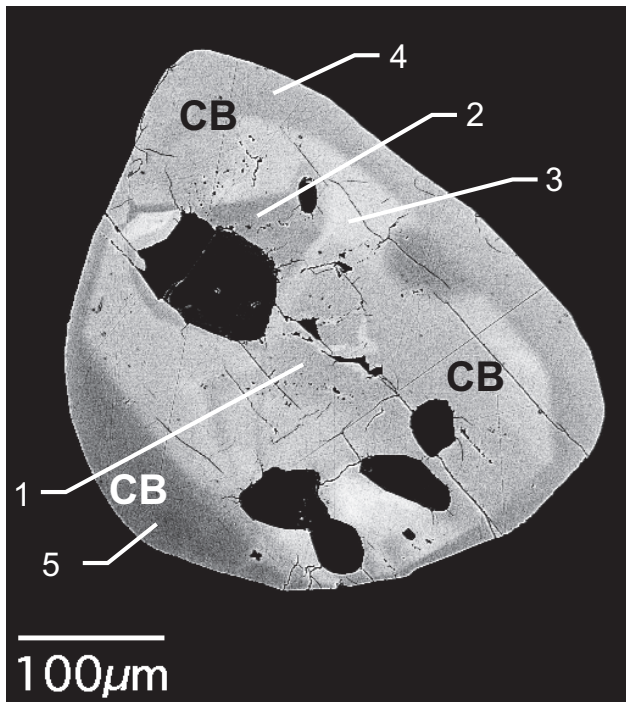


Photo 2a

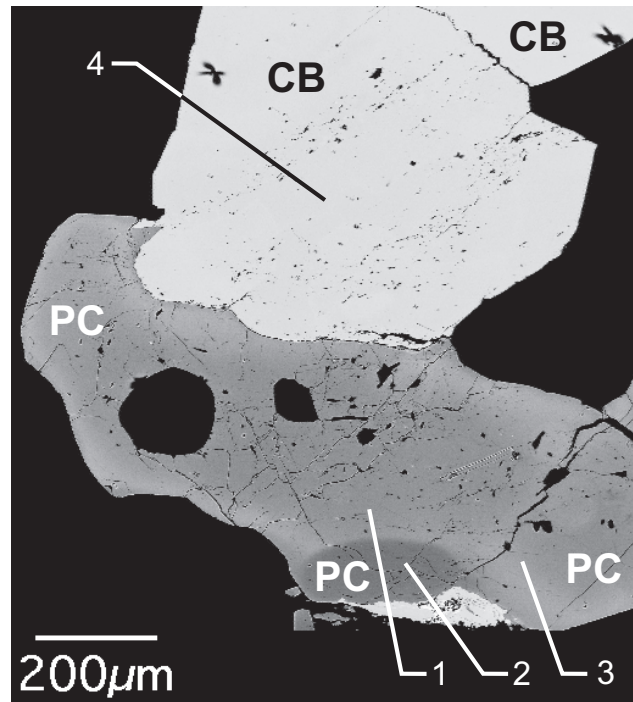


Photo 2b

Photo 2. Backscatter electron photomicrographs from the Fir carbonatite; a) Columbite set in dolomitic carbonatite, dolomite in black. Note the strong zoning. Locations 1, 2, 3, 4 and 5 correspond to microprobe analyses FIR3E-A3#1, #2, #3, #4 and #5 in Table 3 b) Pyrochlore (PC) and columbite (CB) in dolomite; Locations of microprobe analyses 1, 2, 3 and 4 correspond to microprobe analyses Fir #A-A2#1, #2, #3 in Table 2 and Fir 3A-A2#4 in Table 3.

indicates that the Fir deposit consists of two subparallel, sill-like bodies within a nearly flat-lying metasedimentary sequence. The Fir deposit has been intersected by ten drill holes over an area of 350 by 450 metres. According to Dahrouge (2002), drilling results indicate values of 200 to 250 ppm Ta_2O_5 , 500 to 1000 ppm Nb_2O_5 and 3 to 4 % P_2O_5 . In outcrop, this carbonatite is less weathered than the Verity carbonatite and displays moderate to well-developed centimeter-scale layering. This may be due to original magmatic texture, but is more likely metamorphic in origin. This carbonatite (beforsite) consists mainly of dolomite (>80%, 1-3 mm), calcite occurring mainly as fracture fillings or coatings (<5%), amphibole (<7%, < 4mm, prismatic) and colorless to very pale green apatite (<20%).

LITHOGEOCHEMISTRY

Whole rock and trace element analyses of the samples collected during our study are given in Table 1 and as expected, the samples plot within magnesiocarbonatite field (Figure 2). The Fir carbonatite was reported to have higher Ta content than the Verity deposit, including 8.2 metres assaying 319 ppm Ta_2O_5 , 1400 ppm Nb_2O_5 and 3.15 % P_2O_5 (Dahrouge, 2002). The data confirm the Fir deposit's unusual tantalum concentrations and results are in line with previously reported chemical analyses (Table 1).

NIOBIUM AND TANTALUM MINERALS

Similar to the Verity deposit, the main Ta-Nb ore minerals which were identified in polished thin sections of the Fir deposit are columbite (Photo 2a) and pyrochlore (Photo 2b). According to Dahrouge (2002), the high Ta/Nb ratio and high Ta content of the Fir deposit is explained by a high columbite to pyrochlore ratio, estimated at 20:1. Microprobe analyses presented in this study suggest that there is compositional difference between the columbite from the Verity and Fir deposits. Columbite from the Fir deposit has lower TiO_2 , FeO, ThO_2 , UO_2 , CaO and higher MnO and MgO content than the Verity columbite. Columbite from Fir analyzed during this study contains less than 0.08 and 0.12 % of UO_2 and Th_2O_5 respectively. The composition of pyrochlore from the Fir deposit is shown on Figure 4 and in Table 2. Fir pyrochlores show less variation in Ta_2O_5 , and appear to have lower TiO_2 , UO_2 and higher SrO, CaO and ThO_2 content than pyrochlores from Verity.

"SERPENTINE" CARBONATITE

A carbonatite showing was found 1 km from the intersection of Serpentine Creek Forest Service Road and Road 752 on the side of the decommissioned road. It may correspond to the "Serpentine" occurrence, first reported by Digel *et al.* (1989). The exposed carbonatite is strongly fractured and may be referred to as rubble or scree rather than an outcrop, in which the largest fragments are less than

10 centimetres in longest dimension. Most of the scree consists of particles 1 centimetre or less in size. Fresh surfaces appear pale gray and weathered surfaces appear beige or rusty brown. The carbonatite consists mainly of calcite (> 85%, <6mm), olivine (<5%, <2cm), bronze-colored biotite, possibly vermiculite (<5%), apatite (<2%), ilmenite / magnetite (<4%), amphibole (<2%) and dolomite (<2%). Pyrite and chalcopyrite (< 0.5% combined) are minor constituents. The contacts between the carbonatite and the host rock are not exposed, however, green amphibole-rich blocks and rubble within the overburden. These blocks consist mainly of mafic minerals (mainly amphibole and clinopyroxene, <75%) and carbonates (<25%), typical skarn mineralogy. Chemical analyses of calcitic carbonatite and fenite rubble are given in Table 1. The Serpentine carbonatite has a much lower Nb and Ta content than the two previously described occurrences and it contains bronze-colored mica (possibly vermiculite). Visual estimates from this single outcrop, suggest that mica content is too low to be of economic interest.

The samples from the Serpentine carbonatite were described as sövite (coarse calcite-carbonatite) in the field, microscope examination confirmed that they consist mainly of calcite, but contain also small proportion of dolomite. Although they plot as magnesiocarbonatites (Figure 2), they should be called sövites based on their mineralogy. The third sample (SERP-3), from the Serpentine carbonatite plots also in the magnesiocarbonatite field, but based on large proportion of silicate minerals, it should be referred to as skarn rather than carbonatite. The term skarn is preferred to fenite, based on mineralogy and on low NaO and K₂O content of amphiboles forming this rock.

DISCUSSION

This study confirms that Ta and Nb concentrations in representative samples from the Verity and Fir carbonatites are similar to concentrations reported in literature (Dahrouge 2002). When compared to typical carbonatites, Fir and Verity have relatively high Ta/Nb ratios.

Most of the Ta and Nb at the Verity and Fir deposits is contained in columbite and pyrochlore. There is a variation in the composition of pyrochlore and columbite within both the Verity and Fir deposits, as some pyrochlores are strongly zoned and some of the Verity pyrochlores have a relatively high UO₂ and Ta₂O₅ content (Table 2). The highest U and Th concentrations in columbite obtained during this study correspond to 0.18 and 0.33 % UO₂ and ThO₂ respectively (Table 3), however, the mean UO₂ and ThO₂ contents of columbite are much lower. Our analyses suggest that columbites from the Fir and Verity deposits are chemically distant (Table 3, Figure 4).

Although the Verity deposit is renowned for large museum quality, pyrochlore crystals (Photo 2b), a large proportion of the pyrochlores observed under binocular microscope and in thin section appear to be in the 0.2 to 1.5 mm size range. Overall, columbite, which in some cases appears to replace pyrochlore, is probably finer-grained than pyrochlore, but it can be still considered as "coarse" com-

pared to some other unconventional tantalum resources discussed by Simandl (2002).

Further research would be required to confirm our observations, describe and understand the zoning of ore minerals and their chemistry and paragenesis. Variations in Ta, Nb, U and Th composition of pyrochlore and columbite on deposit and regional scales also remain to a large extent unexplained.

The uranium and thorium content of columbite and pyrochlore is not being overlooked by the Commerce Resources Corp., since the company is considering the potential of uranium recovery as a tantalum and niobium byproduct (Commerce Resources Corp., News Release, February 18, 2002). They plan to complete bench scale metallurgical testing that may provide an important contribution to understanding the metallurgy and ore mineralogy of the Fir and Verity deposits.

SUMMARY

The Verity and Fir deposits represent significant Ta resources. The economic viability of these resources will depend on environmental and metallurgical constraints (including U and Th content of the concentrate), acceptability of the Ta/Nb concentrate by processors and refiners, Ta and Nb market conditions and defining ore reserves with further exploration and engineering studies, (Simandl, 2002). It is possible that other carbonatites with high tantalum values will be discovered in British Columbia.

ACKNOWLEDGMENTS

Angela Rossley and Claire Skillen drafted the figures. Ryan Grywal of Commerce Resources Corp. showed us two of the three showings which we had the opportunity to examine. Microprobe work was done at Carleton University.

Suggestions by David Lefebure and Brian Grant from the British Columbia Ministry of Energy and Mines. Jody Dahrouge from Commerce Resources Corp. and Consolidated Excelsior Resources Inc. improved an earlier version of this manuscript.

REFERENCES

- Aquist, B. (1982): Blue River Carbonatites, British Columbia; *B.C. Ministry of Energy Mines and Petroleum Resources*, Assessment Report 11 130, 15 pages.
- Birkett, T. and Simandl, G.J. (1999): Carbonatite-associated deposits (Magmatic, Replacement and Residual); *in: Selected British Columbia Mineral Deposit Profiles, Volume 3., Industrial Minerals*, G.J. Simandl, Z.D. Hora and D.V. Lefebure, Editors; *British Columbia Ministry of Energy and Mines*, pages 73-76.
- Campbell, R.B. (1967): Canoe River, British Columbia, *Geological Survey of Canada*, Map 15-1967.
- Černý, P and Ercit, T.S. (1986): Mineralogy of Niobium and Tantalum; Crystal Chemical Relationships, Paragenetic Aspects and their Economic Implications; *in: Lanthanides, Tantalum and Niobium*; Peter Moeller, Peter Ercit and Francis Saupe (editor): Special Publication of the Society for Geology Ap-

- plied to Mineral Deposits, #7, *Springer-Verlag*, pages 27-79.
- Černý, P., Ercit, T.S. and Wise M.A. (1992): The Tantalite-Tapiolite Gap: Natural assemblages versus Experimental Data; *Canadian Mineralogist*, Vol. 30, pages 587-596.
- Dahrouge, J. (2002): The Fir Carbonatite, a Potential Tantalum-Niobium Resource; in Exploration and Mining in BC; *British Columbia Ministry of Energy and Mines*, (this volume).
- Digel, S.G., Ghent, E.D. and Simony, P.S. (1989): Metamorphism and Structure of the Mount Cheadle area, Monashee Mountains, British Columbia; in Current Research, Part E, *Geological Survey of Canada*, Paper 89-1E, p.95-100.
- Heinrich, E. Wm. (1962): Radioactive Columbite; *American Mineralogist*, Vol. 47, p.1363-1379.
- Hogarth, D.D. (1961): Study of pyrochlore and Betafite; *Canadian Mineralogist*, Vol.6, p.610-633.
- Hogarth, D.D. (1989): Pyrochlore, Apatite and Amphibole: Distinctive Minerals in Carbonatites; in Keith Bell (ed.). Carbonatites, Genesis and Evolution; *Unwin Hyman*, London; pages 105-148.
- Jones, R.J. (1957): Columbium (Niobium) and Tantalum; *Canada Department of Mines and Technical Surveys, Mines Branch*, Memorandum Series No.135, 56 pages.
- Kapustin, Yu., L. (1974): Carbonatites as a Major Rare Metal Source in Geologya Syr'evye Resursy Redkikh Elementov v SSSR; Tezisy Dokladowma Vsesoyusmom Soveshchani; 2nd edition, G.I. Gorbunov (ed.), 44-46. *Akademiya Nauk* (in Russian).
- Laplante, R. (1980): Etude de la mineralization en Nb-Ta-U du Complex Igné Alcalin de Crevier, Compté de Roberval, Lac St.Jean, P.Q. M.Sc. Thesis, *Ecole Polytechnique de Montréal*.
- Lindqvist, K. and Rehtijärvi, P. (1979): Pyrochlore from the Sokli Carbonatite Complex, Northern Finland; *Bulletin of the Geological Society of Finland*; vol.50, pages 81-93.
- Mariano, A.N. (1989): Nature of Economic Mineralization in Carbonatites and Related Rocks; in Carbonatites Keith Bell editor, *Unwin Yman*, London pages 149-176.
- McCammon, J.W. (1953): Lempriere; Minister of Mines Annual Report for the Year Ended 31st December 1952; *British Columbia Department of Mines*, pages 115-119.
- Mountjoy, K.J.(1992): Minfile NTS 083D-Canoe River Area and Part of 083C -Brazeau; British Columbia; *British Columbia Ministry of Energy and Mines*, MINFILE, 133 pages.
- Pell, J. (1994): Carbonatites, Nepheline Syenites, Kimberlites and Related Rocks in British Columbia; *British Columbia Ministry of Energy and Mines*, Bulletin 88, 133 pages.
- Pell, J. and Hora, Z.D (1990): High-tech Metals in British Columbia; British Columbia; *British Columbia Ministry of Energy and Mines*, Information Circular 1990-19, 28 pages.
- Pozharitskaya, L. K and Samoylov, V.S. (1972): Petrologiya, Mineralogiya I Geokhimiya Karbonatitov Vostochnoi Sibiri; L.M. Salikov (ed.) Moskow; *Nauka* (in Russian).
- Richardson, D.G. and Birkett, T.C. (1996): Carbonatite associated Deposits; in Geology of Canadian Mineral Deposit Types, O.R. Ecstrand, W.D. Sinclair and R.I. Thorpe, Editors, *Geological Survey of Canada*, Geology of Canada Number 8, pages 541-558.
- Rowe, R.P. (1958): Niobium (Columbium) deposits of Canada; *Geological Survey of Canada*, Economic Geology Series, vol.18, 108 pages.
- Simandl, G.J. (2002): Tantalum Market and Resources: An Overview; in Geological Fieldwork 2001, Paper 2002-1; *British Columbia Ministry of Energy and Mines*, pages 315-320.
- Smith, A. (1952): Report on Verity Columbium-Uranium Prospect, North Thompson River, British Columbia (unpublished report).
- van der Veen, A.H., (1963): A Study of Pyrochlore. Verhandelingen van het Koninklijk Nederlands Geologisch. Mijnbouwkunding Genootschap, Geologische Serie; Koninklijk Nederlands Mijnbouwkunding Geologisch Genootschap, Delf, Netherlands, 188 pages.
- Woolley, A.R. and Kempe, D.R.C. (1989): Carbonatites: nomenclature, average chemical compositions, and element distribution; in Keith Bell (ed.). Carbonatites, Genesis and Evolution; *Unwin Hyman*, London; pages 1-37.

ANNEX I

CHEMICAL ANALYSES

All samples were ground using a steel mill. Major element chemistry was determined using lithium metaborate fusion followed by Inductively Coupled Plasma Emission Spectrometry (ICPES). Lost on ignition (LOI) was determined during the sample fusion (at 1000°C). Total carbon and sulphur were determined using the Leco combustion method. Most of trace elements were analysed by lithium metaborate fusion followed by Inductively Coupled Plasma Mass Spectrometry (ICPMS). The comparison with the known standard suggests that REE and possibly Nb extraction was incomplete, but that the level of Ta extraction was more than acceptable for the intended purposes. Concentrations of W, Mo, Cu, Pb, Sn, Zn, Ni, As, Cd, Sb, Bi and Ag were determined using Aqua regia digestions followed by ICPES.

W, Mo, Sb, Sn are at or below instrument detection limits and are therefore not shown in Table 1.

MICROPROBE

Quantitative analyses were made on fully automated Camebax MBX electron probe by wavelength dispersive x-ray analyses (WDX). Operating conditions were 20kv accelerating potential and a beam current of 35 nano-amperes (nA) for pyrochlore and columbite. Peak counting times were 30-60 seconds or 40,000 counts, depending upon which came first. X-ray ray lines were chosen to minimize or eliminate possible elemental interferences. Corrections were made for any instances of overlap. Raw x-ray data were converted to elemental weight % by the Cameca PAP matrix correction program. A suite of well characterized natural and synthetic minerals and compounds were used as calibration standards. Analyses are accurate to 1-2 % relative for major elements, 3-5 % relative for minor elements (< 1 wt %). Elements at or near minimum detection limit MDL (0.02-0.06 wt %) have relative errors approaching 100%.