Rare Metal-bearing Deposits in British Columbia with Selected Examples

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Geofile 2012-02

Suggested Reference:
Simandl, G.J., Prussin, E.A., Hancock, K. and Meredith-Jones, S. (2012): Rare metal-bearing deposits in British Columbia with Selected Examples, *BC Ministry of Energy Mines*, BC Geological Survey, Geofile 2012-02.

British Columbia Ministry of Energy and Mines · University of Victoria · Natural Resources Canada / Ressources naturelles Canada · TGI 4 Ore Systems · Geological Survey of Canada / Commission géologique du Canada 1842

Background Information

The term "rare metal" (RM) refers to uncommon, nonferrous metals derived from geographically restricted areas. The expression "Specialty metal" is used interchangeably with "rare metal". Examples of RMs include: tantalum (Ta), niobium (Nb), zirconium (Zr), hafnium (Hf), lithium (Li), beryllium (Be), gallium (Ga), germanium (Ge), and rare earth elements (REE). According to IUPAC (IR-3.6.2, March 2004), REEs includes yttrium (Y), scandium (Sc) and the lanthanide series elements: La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu. REE are further subdivided into the light rare (LREE) and the heavy rare (HREE) categories. LREEs include Y, Sc, La, Ce, Pr, Nd, Sm, Eu and Gd and HREE include Tb, Dy, Ho, Er, Tm, Yb and Lu. Promethium (Pm) does not occur in nature and therefore is not covered by our study. Germanium (Ge), gallium (Ga) and vanadium (V) have also been classified as RMs, but they are excluded from this study because they are not covered under the mandate of the Specialty Metals component of the TGI-4 program.

RM mining is of minor importance relative to Cu, Ni, or Fe mining in terms of value and tonnage. However, high technology industries cannot operate effectively without RMs. Although other materials can be substituted for several RMs, they are either more expensive or less effective. RMs are critical for development of "green" technologies and for the reduction of greenhouse gas emissions (eg. high power magnets for hybrid car drives, Li for energy storage). Table 1 describes the prices, uses and market information for selected RMs.

Table 1: The size of the market, uses and prices of selected rare metals (USGS, 2010, Industrial Minerals - September 2010; Industry contacts).

Rare Metal	Annual Production Estimate	Representative Price (US$ unless noted otherwise)	Main Producing Countries	Main Uses
Nb	62 000 tonnes of Nb content	Ferroniobium (65% Nb): $37-39/kg	Brazil (9%) Canada (7%)	Steel industry (76%, ferroniobium); Aerospatial/military applications (24% Super alloys)
Ta	670 tonnes of Ta content	Tantalite concentrate: $110/lb Ta_2O_5: $220 - 230/kg	Historically Australia and Canada, recently Brazil, Rwanda, and DR Congo	Ta capacitors (60% of total use) are essential for automotive electronics, pagers, personal computers, and portable telephones etc.
Zr	Zircon or baddeleite (industrial mineral): 1.1 - 1.3 million tonnes	Zircon conc: FOB Australia $830-980/tonne; Fused ZrO_2 monoclinic, CIF European port: $4400–5200/tonne Zr metal $50-100/kg	Australia, South Africa, China, Ukraine, Indonesia and Brazil	Zircon: ceramics, foundry, opacifier, and refractory products. Zr metal: noncorrosive applications in nuclear industry, oxygen sensors, combustion control, flue gas monitoring, condenser ceramics; cubic zirconia
Be	200 tonnes of Be content	Beryllium-copper master alloy: $120/ lb	Contained Be: USA (176 tonnes), China (20 tonnes), Mozambique (1 tonne). Also: Kazakhstan and Russia (tonnages not available)	Computer and telecommunications (> 50%), also: aerospace / defence, appliances, automotive electronics, medical and industrial x-ray equipment
REE	139 000 tonnes of REO content (including Y)	Bastnaesite concentrate: 70% leached, CIF Europe $2.25/lb. REOs (FOB China; bulk, 99%): Ce_2O_3: $22-38/kg; Eu_2O_3: $575-585/kg; La_2O_3: $20-23/kg; Nd_2O_3: $48-49/kg; Pr_2O_3: $48-49/kg	China (95% of total production)	Catalytic converters, permanent magnets, rechargeable batteries for electric and hybrid vehicles, glass additives, glass-polishing compounds; catalysts in oil refining, armaments, base-metal alloys, lighter flints, pyrophoric alloys, electronic thermometers, fibre optics, lasers, oxygen sensors, superconductors, x-ray-intensifying screens
Li	25 300 tonnes of Li content	Li carbonate (USA), large contracts $2.3-2.4/lb. Spodumene concentrate.: > 7.25% LiO_2 (FOB West Virginia): $700-770/tonne	Australia and Canada (pegmatites) Chile, Argentina, Australia, China, Portugal and Zimbabwe (lithium brines)	Ceramics and glass (31%); batteries (23%); lubricants (10%); continuous casting, 4%; aluminum production (3%)
Cs	Not available	$642/50 grams of 99.8% Cs	Canada Pollucite produced at Bernic Lake is transformed into Cs formate and rented to oil and gas drilling companies	Formate brines (high-density, low-viscosity drilling fluids), Atomic resonance frequency standard in atomic clocks, GPS satellites, internet, cell phone transmissions, aircraft guidance systems and medical applications

For example, exploration companies currently maintain over 400 active REE projects worldwide. Of these, 237 are grassroots (no drilling), 135 have limited drilling, 42 are in the advanced exploration stage, 12 are in the pre-feasibility stage, 9 are at the feasibility stage and 2 operations are under construction (Intierra, 2011). High potential exists for recovery of REE as a by-product of uranium and/or phosphate fertilizer production. REE resources on the seafloor have been reviewed (Kato *et al.*, 2011). Brazil is the main source of Nb and Chile, Australia, China, Zimbabwe and Brazil are the main sources of Li and Li-compounds. Significant proportions of Ta-bearing concentrates originating from unstable regions of Africa are considered 'conflict minerals' and this contributed to the reopening of Ta mines in Western countries.

British Columbia's (BC) deposits

The accompanying map shows the location and geological setting of known RM occurrences in BC. The RM-bearing deposits in BC can be loosely grouped into seven geological categories listed and described below.

1) Carbonatite/Syenite
2) Peralkaline Intrusion-Related
3) Skarn
4) Pegmatite/Granite
5) Placer/Paleoplacer
6) Sedimentary Phosphate
7) Other

Carbonatite/Syenite

Carbonatites are carbonate-rich, intrusive or extrusive igneous rocks consisting of more than 50 percent carbonate minerals (Wolley and Kempe, 1989). However, some of these rocks may be carbothermal in origin. They form plugs, dikes, sills and breccia zones and are associated with fenitization (Na, K, Fe alteration) and syenites. Carbonatites contain economic concentrations of Nb (± Ta) and LREEs. They may contain Fe, Sr, Mo, Cu, U, Th, Ca- and Mg-carbonates, fluorite, barite, vermiculite, apatite (phosphate) and others (Mariano, 1989a,b; Richardson and Birkett, 1996a,b; Birkett and Simandl, 1999).

Peralkaline Intrusion-Related

Alkaline intrusions are characterized by their content of feldspathoids, alkali amphiboles and pyroxenes (Sørensen, 1986). Peralkaline intrusions are described as agpaitic if their agpaitic index ((Na + K) / Al) is greater than unity (Salvi and Williams-Jones, 2004). They are characterized by the presence of aegirine, arfvedsonite, enigmatite, etc. Like carbonatites, peralkaline intrusions, especially those of agpaitic type, are known to contain large quantities of RMs, though the ore mineralogy and chemistry differ significantly from carbonatites. Peralkaline intrusion-associated deposits chiefly contain Zr, Nb, Ta, Y, HREE, Th, and Be (Richardson and Birkett, 1996c). These elements are contained in Zr-Ti minerals such as eudialyte. These deposits represent potential sources of HREE and Y. Currently, HREE are primarily sourced in China, where they are derived from ion adsorption clay deposits.

Pegmatite/Granite

Granitic pegmatites are major sources of Ta, Li, Rb, Cs, Be, Sn and industrial minerals (Sinclair, 1996). These pegmatites are derived from a granitic source to which they are related. Chemical evolution through a Li-rich pegmatite group is reflected by enrichment in volatiles, increased fractionation and increased complexity in the zoning of individual pegmatites. The complexity of pegmatite zoning increases with distance from the granitic source (Trueman and Cerny, 1982; London, 2008). The idealized sequence reflecting the chemical evolution of a granite through primitive pegmatite into an evolved pegmatite is as follows:

granite > barren (ceramic) pegmatite > Be pegmatite > Be, Nb, Ta pegmatite Li, Be, Ta, Nb pegmatite > Li, Cs, Be, Ta, Nb pegmatite.

World-class pegmatites containing economic concentrations of Ta and/or Li are rather uncommon, due in part to their large size. Information regarding pegmatite-/granite-related or other known Be occurrences in BC is compiled by Legun (2004, 2005). Most of the BC Be occurrences correspond to small aquamarine showings; however, Hellroaring Creek prospect was explored with Be production in mind.

Skarn

Skarns are contact metamorphic or metasomatic zones formed by mass and chemical transfer between igneous rocks and adjacent lithologies. They consist of pyroxene, garnet, idocrase, wollastonite, actinolite, magnetite, hematite and epidote. They are important sources of Au, base metals, Fe, W and a variety of industrial minerals. Several of the skarn deposits contain notable concentrations of REE or Be. Be-bearing skarns typically have a W- or Sn-affinity although some of them are classified as Zn-Pb or Mo skarns by Ray and Webster (1997).

Placer/Paleoplacer

Placers and paleoplacers are significant sources of precious metals (Au, Pt and Pd), zircon, Ti oxides, Ta, monazite (REE) and gemstones. 440 known placer/paleoplacers are known in BC. They are classified either as 'marine' or 'surficial' placers. Marine placer deposits are located along the west coast of BC and are reported to contain a variety of minerals including Au, ilmenite, rutile, cassiterite, PGEs, zircon, magnetite, gemstones, garnet, monazite and various industrial minerals (Levson, 1995a).

RM-bearing surficial placers are found in SE BC, near areas of alkaline igneous activity and are characterized by a Nb, U, Th, ± REE, ± Ta, ± Zr assemblage. Most heavy minerals associated with Au are discarded and are not routinely analysed for REE, Nb or Ta, and some of them may contain RM-bearing minerals.

Sedimentary Phosphate

Recovery of REE from phosphate rocks took place during the 1960's and 70's (ex. Finland by Kemira Oy). Methods for REE recovery during phosphate fertilizer manufacturing are described by Hibashi (1985), and commercial REE production from phosphate rock (Hibashi, *ibid.*). The Fernie Formation in southern BC and the Whistler Member of the Sulphur Mountain Formation in northeastern BC are two of the more promising geological units in terms of REE concentrations in BC. A summary of information concerning sedimentary phosphate deposits in BC and their REE content is given by Butrenchuk (1996) as well as by Simandl *et al.* (2011a, b, c).

Other Deposits

Several deposits, for example Rexspar, (investigated as a source of fluorospar and U, associated with metavolcanic rocks) do not fit in any of the above deposit types (Preto, 1978). Other occurrences were assigned to more than one deposit type. An example is the Heff occurrence which has been described both as an Iron Oxide Copper Gold (IOCG) deposit (Ray and Webster, 2000) and as a skarn (Ray and Webster, 1997). To reduce the risk of misclassifying the above deposits, we grouped them into an "other" category.

Metallurgical Considerations

Metallurgy is often more important than geological and geotechnical constraints during the early assessment of RM deposits.

All the universal principles of applied mineralogy are valid when assessing REE deposits. Generally, REE-bearing carbonates and fluoro-carbonates are easy to deal with using conventional extraction methods. Examples of operations that rely on fluoro-carbonates (mainly bastnaesite [$(Ce, La)(CO_3)F$]) are the Mountain Pass (USA) and Byan Obo (China) mines.

Deposits containing REE phosphates (mainly monazite [$(La,Ce,Nd)PO_4$]) typically have higher Th content (environmental constraints in developed countries). Good examples are the Steenkamskraal monazite-apatite-quartz vein (South Africa) and monazite placer deposits in Brazil and Australia (Castor, 1994).

REE-bearing silicates (example: allanite [$(Ca;Ce)_2(Al;Fe^{2+};Fe^{3+})_3(SiO_4)(Si_2O_7)O(OH)$]) and a number of exotic minerals associated with peralkaline intrusion-hosted deposits such as eudialyte [$Na_4(Ca;Ce)_2(Fe^{2+};Mn^{2+})ZrSi_8O_{22}(OH; Cl)_2$] represent the highest degree of metallurgical difficulty. There is currently no commercial production of REE from silicates; however, recent industry press releases suggest that over the last few years significant progress has been achieved. Recovery of REE as a by-product of phosphate fertilizer does add complexity to fertilizer plant circuits but should not interfere with production. Similarly, HREE recovery from uranium ores is a relatively well established procedure previously used in Canada.

Principal Nb ore minerals are pyrochlore ($(Ca,Na)_2(Nb,Ta,Ti)_2O_6(OH,F)$), ferrocolumbite ($Fe^{2+}Nb_2O_6$) and fersmite ($(Ca,Ce,Na)(Nb,Ta,Ti)_2(O,OH,F)_6$). In Russia, Nb is also recovered from loparite ($(Ce,Na,Ca)_2(Ti,Nb)_2O_6$).

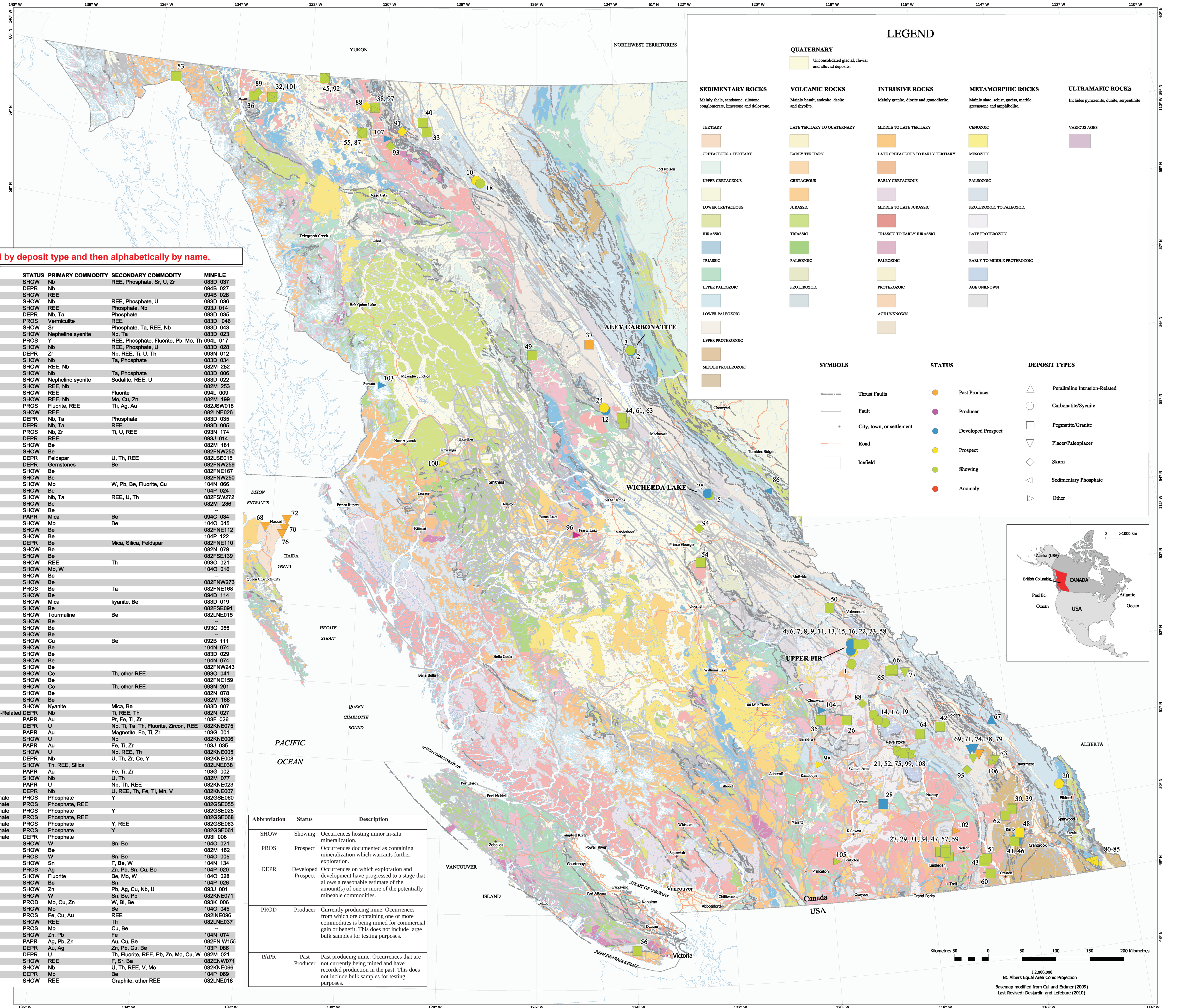


Table 2: Map deposits, organized by deposit type and then alphabetically by name.

LABEL	NAME	DEPOSIT TYPE	STATUS	PRIMARY COMMODITY	SECONDARY COMMODITY	MINFILE
1	Aeg (Mud Lake)	Carbonatite/Syenite	SHOW	Nb	REE, Phosphate, Sr, U, Zr	083D 037
2	Aley	Carbonatite/Syenite	DEPR	Nb		094B 027
3	Aley Dykes	Carbonatite/Syenite	SHOW	REE		094B 028
4	Bone Creek	Carbonatite/Syenite	SHOW	Nb	REE, Phosphate, U	083D 036
5	Carbo	Carbonatite/Syenite	SHOW	REE	Phosphate, Nb	093J 014
6	Fir	Carbonatite/Syenite	DEPR	Nb, Ta	Phosphate	083D 035
7	Hodgie	Carbonatite/Syenite	PROS	Vermiculite	REE	083D 046
8	Howard Creek Carbonatite	Carbonatite/Syenite	SHOW	Sr	Phosphate, Ta, REE, Nb	083D 043
9	Howard Creek Syenite	Carbonatite/Syenite	SHOW	Nepheline syenite	Nb, Ta	083D 023
10	Kechika Yttrium	Carbonatite/Syenite	PROS	Y	REE, Phosphate, Fluorite, Pb, Mo, Th	094L 017
11	Lempriere Carbonatite	Carbonatite/Syenite	SHOW	Nb	REE, Phosphate, U	083D 028
12	Lonnie	Carbonatite/Syenite	DEPR	Zr	Nb, REE, Ti, U, Th	093N 012
13	Mill	Carbonatite/Syenite	SHOW	Nb	Ta, Phosphate	083D 034
14	Mt. Grace Carbonatite	Carbonatite/Syenite	SHOW	REE, Nb		082M 252
15	Paradise	Carbonatite/Syenite	SHOW	Nb	Ta, Phosphate	083D 006
16	Paradise Syenite	Carbonatite/Syenite	SHOW	Nepheline syenite	Sodalite, REE, U	083D 022
17	Perry River Carbonatite	Carbonatite/Syenite	SHOW	REE, Nb		082M 253
18	Rar 4	Carbonatite/Syenite	SHOW	REE	Fluorite	094L 009
19	Ren	Carbonatite/Syenite	SHOW	REE, Nb	Mo, Cu, Zn	082M 199
20	Rock Canyon Creek	Carbonatite/Syenite	PROS	Fluorite, REE	Th, Ag, Au	082JSW018
21	Three Valley Gap	Carbonatite/Syenite	SHOW	REE		082LNE026
22	Upper Fir	Carbonatite/Syenite	DEPR	Nb, Ta	Phosphate	083D 035
23	Verity	Carbonatite/Syenite	DEPR	Nb, Ta	REE	083D 005
24	Virgil	Carbonatite/Syenite	PROS	Nb, Zr	Ti, U, REE	093N 174
25	Wicheeda Lake	Carbonatite/Syenite	DEPR	REE		093J 014
26	Adam'S Lake	Pegmatite/Granite	SHOW	Be		082M 181
27	Airey Creek	Pegmatite/Granite	SHOW	Be		082FNW250
28	Bearcub	Pegmatite/Granite	DEPR	Feldspar	U, Th, REE	082LSE015
29	Blu Starr	Pegmatite/Granite	DEPR	Gemstones	Be	082FNW259
30	Blue Hammer	Pegmatite/Granite	SHOW	Be		082FNE167
31	BQ Claims	Pegmatite/Granite	SHOW	Be		082FNW250
32	Candy	Pegmatite/Granite	SHOW	Mo	W, Pb, Be, Fluorite, Cu	104N 066
33	Cassiar Beryl	Pegmatite/Granite	SHOW	Be		104P 024
34	Crescent	Pegmatite/Granite	SHOW	Nb, Ta	REE, U, Th	082FSW272
35	Dunn Peak	Pegmatite/Granite	SHOW	Be		082M 286
36	East Of Atlin	Pegmatite/Granite	SHOW	Be		--
37	Family Farm	Pegmatite/Granite	PAPR	Mica	Be	094C 034
38	Gazoo Nw	Pegmatite/Granite	SHOW	Mo	Be	104O 045
39	Greenland Creek Beryl	Pegmatite/Granite	SHOW	Be		082FNE112
40	Harvey Lake	Pegmatite/Granite	SHOW	Be		104P 122
41	Hellroaring Creek	Pegmatite/Granite	DEPR	Be	Mica, Silica, Feldspar	082FNE110
42	Incomappleux River	Pegmatite/Granite	SHOW	Be		082N 079
43	Laib Creek	Pegmatite/Granite	SHOW	Be		082FSE139
44	Laura	Pegmatite/Granite	SHOW	REE	Th	093O 021
45	Logtung Beryl	Pegmatite/Granite	SHOW	Mo, W		104O 016
46	Lower Jack	Pegmatite/Granite	SHOW	Be		--
47	Mathew Cr. (Peg1)	Pegmatite/Granite	SHOW	Be		082FNW273
48	Mathew Cr. (Peg2)	Pegmatite/Granite	PROS	Be	Ta	082FNE168
49	Mcconnell Beryl	Pegmatite/Granite	SHOW	Be		094D 114
50	Mica Mountain	Pegmatite/Granite	SHOW	Mica	kyanite, Be	083D 019
51	Midge Creek	Pegmatite/Granite	SHOW	Be		082FSE091
52	Mount Begbie	Pegmatite/Granite	SHOW	Tourmaline	Be	082LNE015
53	Mount Foster	Pegmatite/Granite	SHOW	Be		--
54	Mount George	Pegmatite/Granite	SHOW	Be		093G 066
55	Near Ash Mountain	Pegmatite/Granite	SHOW	Be		--
56	Peg	Pegmatite/Granite	SHOW	Cu	Be	092B 111
57	Rq Claims	Pegmatite/Granite	SHOW	Be		104N 074
58	Serpentine	Pegmatite/Granite	SHOW	Be		083D 029
59	Slocan2	Pegmatite/Granite	SHOW	Be		104N 074
60	Toby	Pegmatite/Granite	SHOW	Be		082FNW243
61	Ursa	Pegmatite/Granite	SHOW	Ce	Th, other REE	093O 041
62	White Creek	Pegmatite/Granite	SHOW	Be		082FNE159
63	Will	Pegmatite/Granite	SHOW	Ce	Th, other REE	093N 201
64	Woolsey Creek	Pegmatite/Granite	SHOW	Be		082N 078
65	Yellow Creek	Pegmatite/Granite	SHOW	Be		082M 168
66	Yellow Creek	Pegmatite/Granite	SHOW	Kyanite	Mica, Be	083D 007
67	Moose Creek	Peralkaline Intrusion-Related	DEPR	Nb	Ti, REE, Th	082N 027
68	Blue Jacket Creek	Placer/Paleoplacer	PAPR	Au	Pt, Fe, Ti, Zr	103F 026
69	Bugaboo	Placer/Paleoplacer	DEPR	U	Nb, Ti, Ta, Th, Fluorite, Zircon, REE	082KNE075
70	Bull Swamp	Placer/Paleoplacer	PAPR	Au	Magnetite, Fe, Ti, Zr	103G 001
71	East Creek	Placer/Paleoplacer	SHOW	U	Nb	082KNE006
72	Fife Point	Placer/Paleoplacer	PAPR	Au	Fe, Ti, Zr	103J 035
73	Forster	Placer/Paleoplacer	SHOW	U	Nb, REE, Th	082KNE005
74	Malloy Creek	Placer/Paleoplacer	DEPR	Nb	U, Th, Zr, Ce, Y	082KNE008
75	Mulvehill	Placer/Paleoplacer	SHOW	Th, REE, Silica		082LNE038
76	Oeanda	Placer/Paleoplacer	PAPR	Au	Fe, Ti, Zr	103G 002
77	Trident Cr	Placer/Paleoplacer	SHOW	Nb	U, Th	082M 077
78	Upper Bugaboo	Placer/Paleoplacer	PAPR	U	Nb, Th, REE	082KNE023
79	Vowell Creek	Placer/Paleoplacer	DEPR	Nb	U, REE, Th, Fe, Ti, Mn, V	082KNE007
80	Bighorn	Sedimentary Phosphate	PROS	Phosphate	Y	082GSE060
81	Cabin Creek (Cs)	Sedimentary Phosphate	PROS	Phosphate, REE		082GSE055
82	Cabin East	Sedimentary Phosphate	PROS	Phosphate	Y	082GSE025
83	Cabin G	Sedimentary Phosphate	PROS	Phosphate, REE		082GSE068
84	Ram A	Sedimentary Phosphate	PROS	Phosphate	Y, REE	082GSE063
85	Storm Creek	Sedimentary Phosphate	PROS	Phosphate	Y	082GSE061
86	Wapiti	Sedimentary Phosphate	DEPR	Phosphate		093I 008
87	Ash Mountain	Skarn	SHOW	W	Sn, Be	104O 021
88	Bischoff Lakes	Skarn	SHOW	Be		082M 162
89	Blue Light	Skarn	PROS	W	Sn, Be	104O 005
90	Daybreak	Skarn	SHOW	Sn	F, Be, W	104N 134
91	Haskins Mountain	Skarn	PROS	Ag	Zn, Pb, Sn, Cu, Be	104P 020
92	Jennings River	Skarn	SHOW	Fluorite	Be, Mo, W	104O 028
93	Low Grade	Skarn	SHOW	Be	Sn	104P 026
94	Samson	Skarn	SHOW	Zn	Pb, Ag, Cu, Nb, U	093J 001
95	Tin City	Skarn	SHOW	W	Sn, Be, Pb	082KNE071
96	Endako	Other	PROD	Mo, Cu, Zn	W, Bi, Be	093K 006
97	Gazoo - Southwest Stock	Other	SHOW	Mo	Be	104O 045
98	Heff	Other	PROS	Fe, Cu, Au	REE	092INE096
99	Karen	Other	SHOW	REE	Th	082LNE037
100	Massa	Other	PROS	Mo	Cu, Be	--
101	Northeast	Other	SHOW	Zn, Pb	Fe	104N 074
102	Ottawa Mine	Other	PAPR	Ag, Pb, Zn	Au, Cu, Be	082FN W155
103	Red Mountain	Other	DEPR	Au, Ag	Zn, Pb, Cu, Be	103P 086
104	Rexspar	Other	DEPR	U	Th, Fluorite, REE, Pb, Zn, Mo, Cu, W	082M 021
105	Riddle (Vent)	Other	SHOW	REE	F, Sr, Ba	082ENW071
106	Slide	Other	SHOW	Nb	U, Th, REE, V, Mo	082KNE066
107	Storie	Other	DEPR	Mo	Be	104P 069
108	Three G'S	Other	SHOW	REE	Graphite, other REE	082LNE018

Abbreviation	Status	Description
SHOW	Showing	Occurrences hosting minor in-situ mineralization.
PROS	Prospect	Occurrences documented as containing mineralization which warrants further exploration.
DEPR	Developed Prospect	Occurrences on which exploration and development have progressed to a stage that allows a reasonable estimate of the amount(s) of one or more of the potentially mineable commodities.
PROD	Producer	Currently producing mine. Occurrences from which one commodity or more commodities is being mined for commercial gain or benefit. This does not include large bulk samples for testing purposes.
PAPR	Past Producer	Past producing mine. Occurrences that are not currently being mined and have recorded production in the past. This does not include bulk samples for testing purposes.

The main, economically important, Ta ore minerals are tantalite ($(Fe,Mn)(Nb,Ta)_2O_6$; 42-84 % Ta_2O_5), columbotantalite ($(Fe,Mn)(Nb,Ta)_2O_6$; 20-50% Ta_2O_5), columbite ($(Fe,Mn)(Nb,Ta)_2O_6$; 1-40 %Ta_2O_5), wodginite ($Mn_4(Sn>Ta,Ti,Fe)_4(Ta>Nb)_8O_{32}$), microlite (Ta-rich mineral of the pyrochlore group) and strüverite (Simandl, 2002). Columbite-tantalite minerals are the most widespread of Ta-Nb minerals; in some occurrences they are replaced by fersmite or microlite. Information regarding traditional Ta/Nb resources and ore-dressing implications is summarized by Simandl (2002).

Summary

More than 100 RM occurrences are reported in BC. This compilation may serve as a starting point for those considering RM exploration programs in BC. There is uncertainty in the classification of some occurrences due to the scarcity of available information or the unusual nature of particular occurrences. The economic significance of many of these occurrences is poorly known because the size, shape, depth, grade, composition and orientation are not well defined. Based on currently available information, carbonatite-/syenite-related deposits are the most promising for the recovery of RMs, especially Nb and REE.

Aknowledgements

The original electronic version of the geological base map used for this compilation was provided by Pat Desjardins and was created by Yao Cui and Philip Erdmer (2009). Nick Brown contributed significantly to the original Specialty Metals database.

References

References associated with the left portion of this poster are available from the first author at George.Simandl@gov.bc.ca.

Selected Examples

Aley Carbonatite

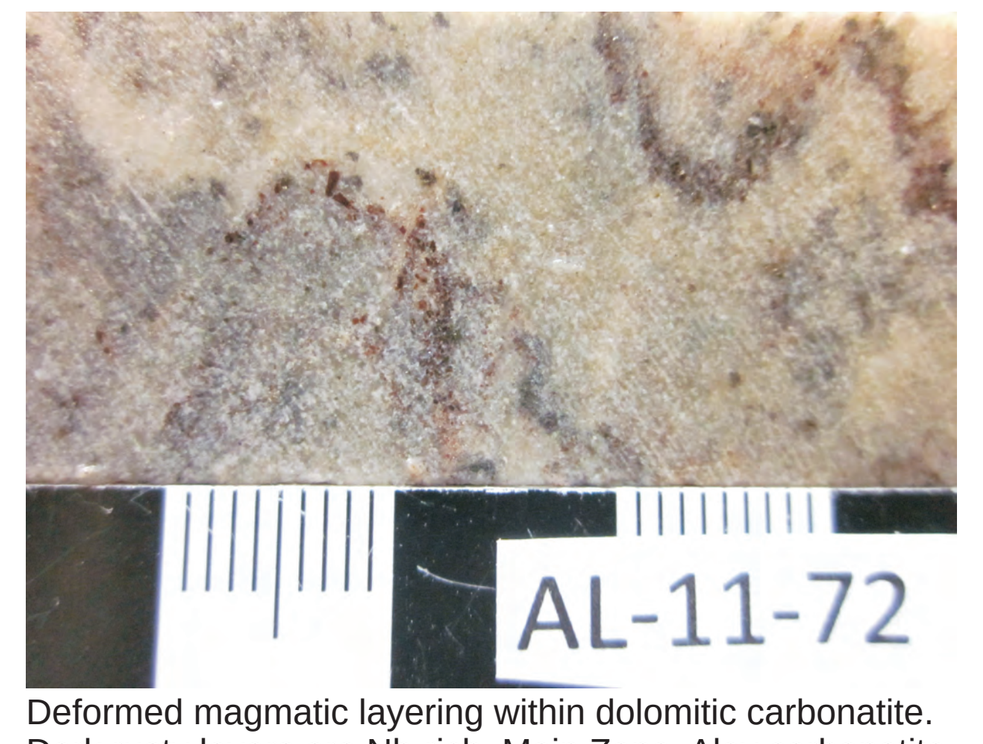
Taseko Mine Ltd.'s Aley Niobium Project is located 140 km north of Mackenzie. Aley has an inferred resource of 159 million tonnes grading 0.43% Nb_2O_5 based on Taseko's 2010 drilling program in combination with the historical drill data. The in-pit inferred mineral resource for the Central Zone of the Aley Deposit is summarized in the table to the right for a range of cutoff grades with the base case of 0.2 % Nb_2O_5 in boldface. Drilling on the property continued in 2011.

COG % Nb_2O_5	Tonnes 000's	Grade % Nb_2O_5
0.1	187,743	0.39
0.15	172,151	0.41
0.2	**158,892**	**0.43**
0.25	146,437	0.45
0.3	127,481	0.47

COG: cut-off grade

Reference:
http://www.tasekomines.com/tko/Aley.asp

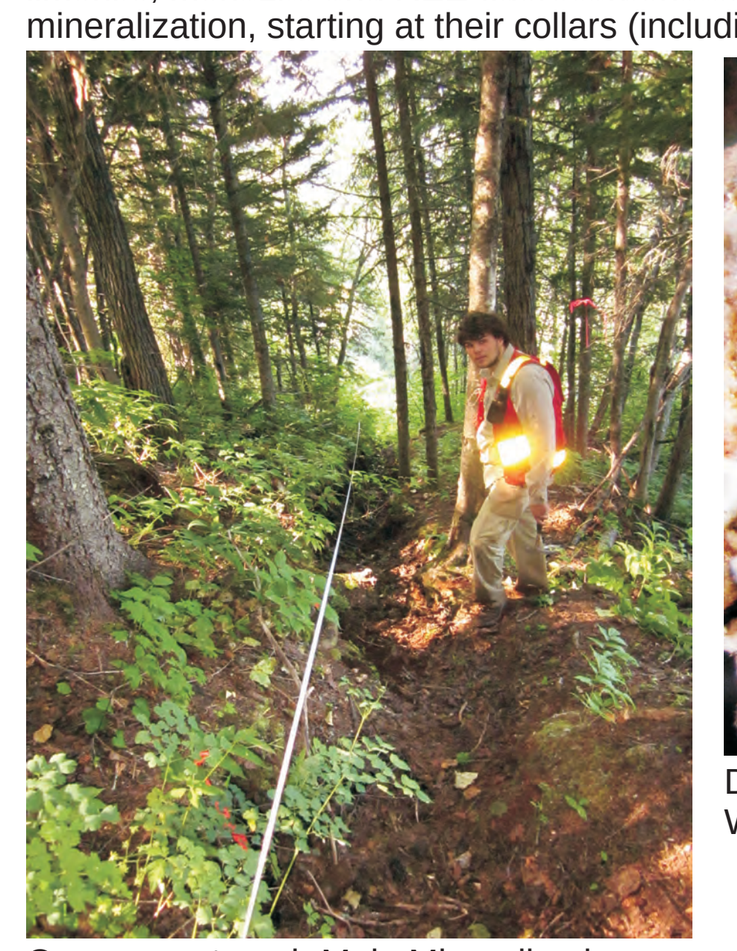

Drilling at the Main Zone, Aley carbonatite.

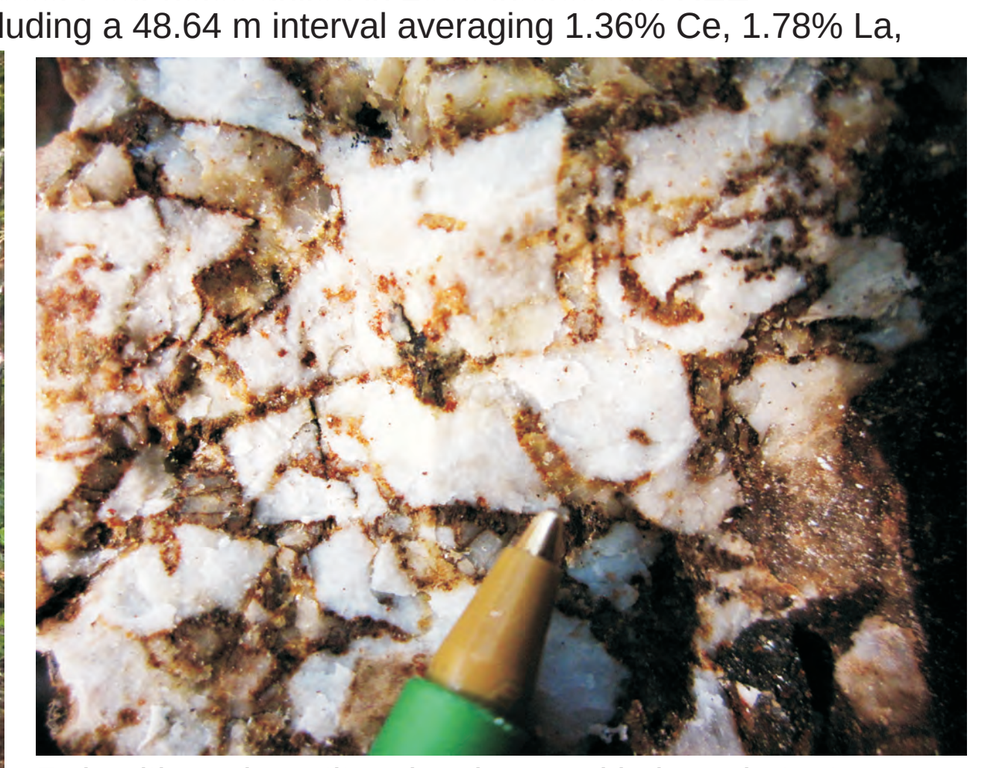


Deformed magmatic layering within dolomitic carbonatite. Dark rusty layers are Nb-rich. Main Zone, Aley carbonatite.

Wicheeda and Carbo properties

The Wicheeda Property, owned by Spectrum Mining Corporation, is located 80 km NE of Prince George. The "Main Zone" consists of mineralized dolomitic-carbonatite. In some drill holes this carbonatite transitions at depth into a silicocarbonatite (Graf, personal communication; Graf *et al.*, 2009). Minor constituents are K-spar, black biotite, corderite, pyrochlore, columbite, magnetite, pyrite, limonite, monazite and REE-fluorocarbonates. Four holes drilled in 2008 intersected REE mineralization, starting at their collars (including a 48.64 m interval averaging 1.36% Ce, 1.78% La, 0.13% Pr and 0.28% Nd for a combined REE content of 3.55% over 48.64 m). Spectrum conducted a followup drill program in 2009 and drilled 15 additional holes, 10 of which were drilled into the Main mineralized carbonatite around the 2008 drill holes that extended it's drill proven size considerably. This deposit remains open in all directions. Metallurgical work is in progress.


Overgrown trench Main Mineralized Zone, Wicheeda Lake area.


Dolomitic carbonatite, showing crackle breccia texture, Wicheeda carbonatite (Main Zone).

The Carbo property is located on the same trend as Wicheeda and is operated by Canadian International Minerals Inc. Latest drilling results from this property are available on the company website: http://www.cdnintlminerals.com/s/NewsReleases.asp?ReportID=493701


Pale-pink to white REE-bearing fluorocabonate veining, Carbo claim.

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Blue River Ta-Nb-bearing Carbonatites

A number of strongly deformed carbonatites, including the Fir, Upper Fir and Verity deposits, are located North of Kamloops, approximately 10 kilometres north of the town of Blue River and known to contain tantalum (Ta) and niobium (Nb). The Hodgie Zone deposit also contains vermiculite and is believed to contain REE mineralization at depth. According to the Commerce Resources Corp. website, the Upper Fir deposit contains an Indicated Resource of 36.35 million tonnes containing 195 ppm Ta_2O_5 and 1,700 ppm Nb_2O_5 and an Inferred Resource of 6.40 million tonnes containing 199 ppm Ta_2O_5 and 1,890 ppm Nb_2O_5. A total of 183 drill holes completed between 2005 and 2009 were used to develop the mineral resource, this estimate, according to a NI-43-101 technical report produced by Albert Chong and Tomasz Postolski (2011), is available at http://www.commerceresources.com/i/pdf/NI43-101Report-BlueRiver.pdf.


Main bulk sample area, Upper Fir carbonatite.


Nb-Ta-bearing pyrochlore group mineral, Upper Fir carbonatite.

Riddle Creek Sr-Ba-F-REE

Sr-Ba-F-REE mineralization within the Marron Formation outcrops 16 km SW of Summerland. The Riddle Creek erosional remnant contains intercalations of Tertiary lava flows with pyroclastic and sedimentary rocks. The Marron Formation consists of an assemblage of alkaline volcanic rocks that may be cogenetic with Coryell intrusions (Church, 1970; Currie, 1976).


Mineralized volcanic breccia, Maroon Formation.


Fluorite-rich REE-bearing lapili tuff, Riddle Creek.

The Riddle Creek area is known for U mineralization and was also explored for gold (Church, 2007; Morrison, 2001); however, Sr-Ba-F-REE mineralization reported by Morrison (2001) is spatially dissociated from U mineralization (Jerry Blackwell, 2012; personal communication). Fluorite is the main F-bearing mineral; however, Ba-, Sr- and REE-bearing minerals remain to be identified. Paragenesis is not established.

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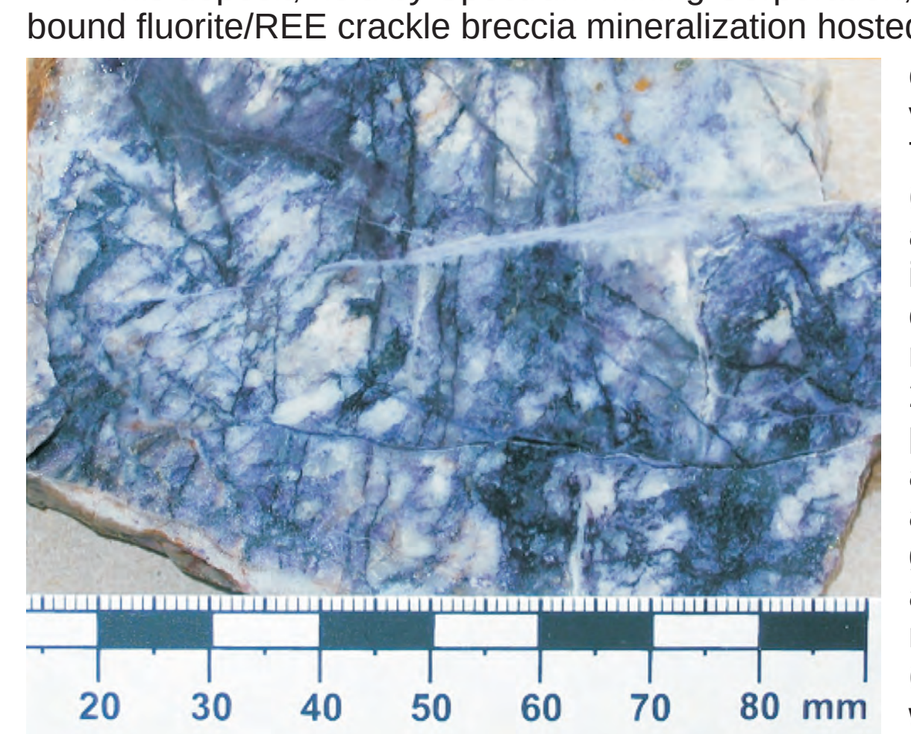
Rock Canyon Creek Polymetallic Deposit

This deposit, held by Spectrum Mining Corporation, is located 50 km E of Canal Flats. It is a strata-bound fluorite/REE crackle breccia mineralization hosted by mid-Paleozoic carbonates. The mineralization consists of disseminations and fine fracture filled veinlets of pyrite, fluorite and REE minerals. Twelve of the seventeen holes drilled in 2009 (1213 m) intersected the mineralized zone assaying 1-2% total REE and 3-5% F over an indicated strike length of 1200 m, a minimum width of 50 m and to a depth exceeding 100 m. It remains open to depth and along strike (Pighin, 2010). REE minerals, bastnaesite, gorceixite and parisite were reported by Hora and Kwong (1986) and Cominco. Follow up studies by Mcleod (1986) and Sampson *et. al*. (2001) did not confirm gorceixite or bastnasite but reported synchysite and goyazite. One sample from vein-type mineralization assayed 201 g/t Ag and 0.8 g/t Au (Graf, *ibid.*). Based on the coexistence of fluorite with REE's, this deposit is believed to be carbonatite related (Pell and Hora, 1987).



REE-fluorite crackle breccia in dolostone matrix.

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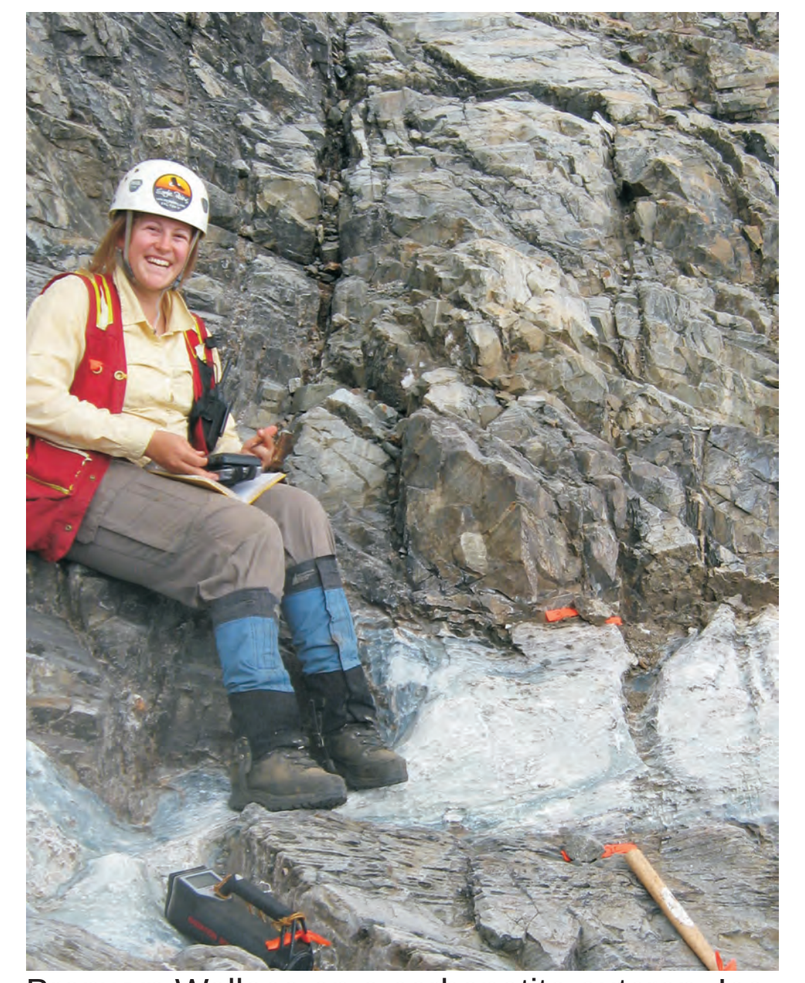
Ice-River Peralkaline Complex

The Ice River property is located 45 km E of Golden, B.C. It is accessed by helicopter; however, a Forest Service road does reach within 5km of the property boundary. The Ice River Complex is the best known (if not only) peralkalkaline complex in British Columbia. Its geology is described by Currie (1976) and Peterson and Currie (1994). Most of the complex is located within parks; however, one area outside of park boundaries is being explored by Eagle Plains Resources Ltd. for Nb, REEs, industrial minerals and base metals. According to Wallace and Brown (2009), at least one in-situ sample exceeds 26000 ppm of total REEs, with 24 samples over 5.6 km returning greater than 3000 ppm total REE. The highest Nb assay is 3923 ppm Nb and thirty-four samples over 5.6 kilometeres have returned greater than 600 ppm Nb. The most anomalous is associated with strongly zeolitized syenite and carbonatite dykes and related host rock.


Bronwyn Wallace on a carbonatite outcrop, Ice-River area.

References:
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