Specialty (Rare) Metals in British Columbia, Canada

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Background Information

The term "rare metal" (RM) is not strictly defined. It refers to uncommon, nonferrous metals derived from geographically restricted areas. "Specialty metal" is used interchangeably with "rare metal", and the two terms are considered synonymous. Examples of rare metals include: tantalum (Ta), niobium (Nb), zirconium (Zr), hafnium (Hf), lithium (Li), beryllium (Be), gallium (Ga), germanium (Ge), and rare earth elements (REE). According to the International Union of Pure and Applied Chemistry (IUPAC, Recommendation IR-3.6.2, March 2004), the term "rare earth element (REE)" encompasses yttrium (Y), scandium (Sc) and the lanthanide series: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (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 (Simandl, 2010b).

On a global scale, RM mining is of minor importance relative to Cu, Ni, or Fe mining in terms of value and tonnage. However, the external trade balance of industrialized countries depends on RM availability. High technology industries cannot operate effectively without a secure supply of RMs at competitive prices. Although other materials can be substituted for several RMs, they are either more expensive or less effective. A number of countries, including the United States, consider several RMs essential for national security. Many RMs are critical for development of "green" technologies and for the reduction of global greenhouse gas emissions (eg. high power magnets for hybrid car drives, Li for energy storage). Several RMs are highlighted in the 2010 "Review of Critical Raw Materials for Europe", spearheaded by the European Commission. Table 1 describes the prices, uses and market information for selected RMs.

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

Rare Metal	Annual Production Estimate (1000's of tonnes unless noted otherwise)	Representative Price (US$ unless noted otherwise)	Main Producing Countries	Main Uses
Nb	62	Ferroniobium (65% Nb): $39/kg	Brazil (9%) Canada (7%)	Steel industry (76%, ferroniobium); Aerospatial/military applications (24% Super alloys)
Ta	1.16	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	Zr (metal): 1.3 million tonnes Zircon (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	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	0.20 - 0.25	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	124 (Rare Earth Element Oxides)	Bastnaesite concentrate: 70% leached, CIF Europe $2.25/lb. REOs (FOB China; bulk, 99%) in $/kg: Ce: 22-38; Eu: 575-585; La: 20-23; Nd: 48-49; Pr: 48-49	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	18	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	The main Cs mineral is pollucite produced at Bernic Lake (Tanco), Canada. This is transformed into Cs metal and rented to oil and gas drilling companies	Canada	Formate brines (high-density, low-viscosity drilling fluids), Atomic resonance frequency standard in atomic clocks, GPS satellites, internet, cell phone transmissions and aircraft guidance systems

The general public is fascinated by RMs and in particular REEs and by the fact that China controls the market (Simandl, 2010a). If we take REEs as an example, junior exploration companies are currently maintaining over 400 active 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 two operations are under construction (Intierra, 2011). Only the best will reach the production stage and remain economically viable over an extended period of time. REE availability and price trends may be affected when some of the advanced projects reach production. High potential exists for substantial tonnage of REE as a by-product of uranium and/or phosphate fertilizer production (Simandl *et al.*, 2011a, b, c). REE resources on the seafloor have recently received renewed attention (Kato *et al.*, 2011). Recent REE export restrictions imposed by China may be eliminated if it decides to protect its share of the market. Brazil is the main producer 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 may contribute to the reopening of Ta mines or development of presently uneconomic Canadian deposits.

British Columbia's deposits

The accompanying map shows the location and geological setting of known RM occurrences in British Columbia. It represents a good starting point for exploration work given that RM deposits commonly occur in clusters. The RM-bearing deposits in British Columbia can be loosely grouped into the following seven main geological categories based on the association between mineralization and host-rock or key lithological units:

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

These deposit classes are described below, and some background information is provided.

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. Carbonatites form plugs, dikes, sills and breccia zones and are associated with fenitization (Na, K, Fe alteration) and syenites. Carbonatites are known to contain economic concentrations of Nb (± Ta), LREEs and in specific cases also with 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). Carbonatites are commonly associated with syenite intrusions and both may be mineralized. The carbonatite-associated RM deposits in British Columbia that have received the most attention are the Aley (Kressal *et al.*, 2010; McLeach *et al.*, 2010), Upper Fir (Gorham, 2011), and Wicheeda Lake (Graf *et al.*, 2009), deposits. Both the Aley and Upper Fir carbonatites are potential sources of Nb and Ta; however, the two deposits differ in grade, mineralogy, and shape. The Wicheeda Lake deposit has seen less development than the other two, but can be described as a relatively high grade REE system (Graf *et al.*, 2009). A similar type of mineralization was encountered in shorter drill intersections on the neighbouring Carbo property. Occurences associated with nepheline syenite gneiss complexes are also included in this category.

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. The REE mineralization within these deposits is characterized by relatively flat chondrite-normalized patterns and may have negative Eu anomalies, as illustrated by examples from the Nechalacho project near Thor Lake, Northwest Territories (Williams-Jones, 2010) and the Strange Lake Complex on the border of Quebec and Labrador (Kerr, 2011). These deposits represent important sources of HREE and Y. Currently, HREE are primarily sourced in China, where they are derived from ion adsorption clay deposits. Peralkaline intrusion-related deposits may diversify the global supply of HREE and reduce reliance on Chinese exports if brought into production. Several large peralkaline intrusion-related RM deposits in Canada and elsewhere have reached advanced exploration stages; however, none of them is currently in production. Metallurgy of these is now better understood but remains challenging.

Ice River is a large peralkaline complex with the potential to host RM deposits. Most of this complex is located within Kootenay and Yoho National parks, where no development may take place.

Pegmatite/Granite

Granitic pegmatites are major sources of Ta, Li, Rb, Cs, Be, Sn and a number of other industrial mineral commodities (Sinclair, 1996). In general, these pegmatites are derived from a granitic source to which they are geographically and temporally 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 also 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. For example, the Tanco pegmatite (Manitoba, Canada) is more than 2 km long, 820 metres wide and over 100 metres thick, and the Bikita pegmatite (Zimbabwe) is about 2 km long and up to 230 metres wide. No Ta- or Li-enriched pegmatites of comparabledimensions are known to occur in British Columbia. Smaller pegmatites containing potentially economic concentrations of Li ± Be minerals in eastern Canada are currently in pre-feasibility stages. Information regarding pegmatite- /granite-related or other known Be occurrences in British Columbia is compiled by Legun (2004, 2005). Most of the British Columbia Be occurrences correspond to small aquamarine showings; however, Hellroaring Creek prospect was explored with Be production in mind.

Skarn

From the point of view of an economic geologist, skarns are contact metamorphic or metasomatic zones formed by mass and chemical transfer between igneous rocks and adjacent lithologies. Typical skarns consist of pyroxene, garnet, idocrase, wollastonite, actinolite, magnetite, hematite and epidote. The same mineral assemblages may also form from the interaction of silica-rich and carbonate-rich lithologies during metamorphism. Skarn deposits are important sources of gold, base metals, iron, tungsten and a variety of industrial minerals including garnet and wollastonite. Information regarding skarn deposits in British Columbia is summarized by Ray and Webster (1997). Several of the skarn deposits are described as containing notable concentrations of REE or beryllium. Beryllium-bearing skarns typically have a tungsten- or tin-affinity although some of them are classified as Zn-Pb or Mo skarns by Ray and Webster (1997). Tungsten and tin skarn deposits are characterized by Ray (1995a, b). The Heff deposit was originally described as a skarn (Ray and Webster 1997) but later referred to as a possible IOCG deposit (Ray and Webster, 2000).

Placer/Paleoplacer

Placers and paleoplacers are significant global sources of precious metals (especially gold, platinum and palladium), zircon, titanium oxides, Ta, monazite (REE-bearing) and gemstones. There are nearly 440 known placer/paleoplacers in British Columbia. They are classified either as 'marine' or 'surficial' placers, and at least 11 of them contain RMs. Marine and surficial placers are described by Levson (1995a, b). Marine placer deposits are located along the west coast of British Columbia and are reported to contain a variety of minerals including gold, ilmenite, rutile, cassiterite, PGEs, zircon, magnetite, gemstones, garnet, monazite and various industrial minerals (Levson, 1995a). It is not clear if there has been any attempt to determine concentrations of monazite or xenotime in these deposits.

RM-bearing surficial placers are found in southeastern British Columbia. They are located near areas of alkaline igneous activity and are characterized by a Nb, U, Th , ± REE , ± Ta, ± Zr assemblage. Some of these placers were originally staked for uranium during the post-World War II uranium rush. More RM-bearing placers will be discovered in British Columbia. Most heavy minerals associated with gold are discarded and are not routinely analysed for REE, Nb or Ta, and some of them may contain non-negligible concentrations of RM-bearing minerals.

Sedimentary Phosphate

World-wide recovery of REE from phosphate rocks was considered or attempted by several companies in the 1960's and 70's. In those years, market conditions precluded long-term commercial success. However, the current market conditions may make recovery of REE from phosphate rock commercially viable (Simandl *et al.* 2011c). The metallurgical procedures for REE recovery during phosphate fertilizer manufacturing are described by Hibashi (1985). Commercial REE production from phosphate rock (Habashi, *ibid.*), most likely apatite concentrate, took place between 1965 and 1972 in Finland by Kemira Oy. Other papers considering extraction of REE during phosphate fertilizer manufacturing include Ionescu *et al.* (1980), Lounamaa *et al.* (1980), Kijkowska (1980) and Fidelis (1980).

In British Columbia, some upwelling-type phosphate deposits (Simandl *et al.* 2011a, b) are known to contain significant quantities of REEs (Pell, 1994; Simandl *et al.*, 2011d). 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 British Columbia. A summary of information concerning sedimentary phosphate deposits in British Columbia and their REE content is given by Butrenchuk (1996) as well as by Simandl *et al.* (2011a, b, c).

Other Deposits

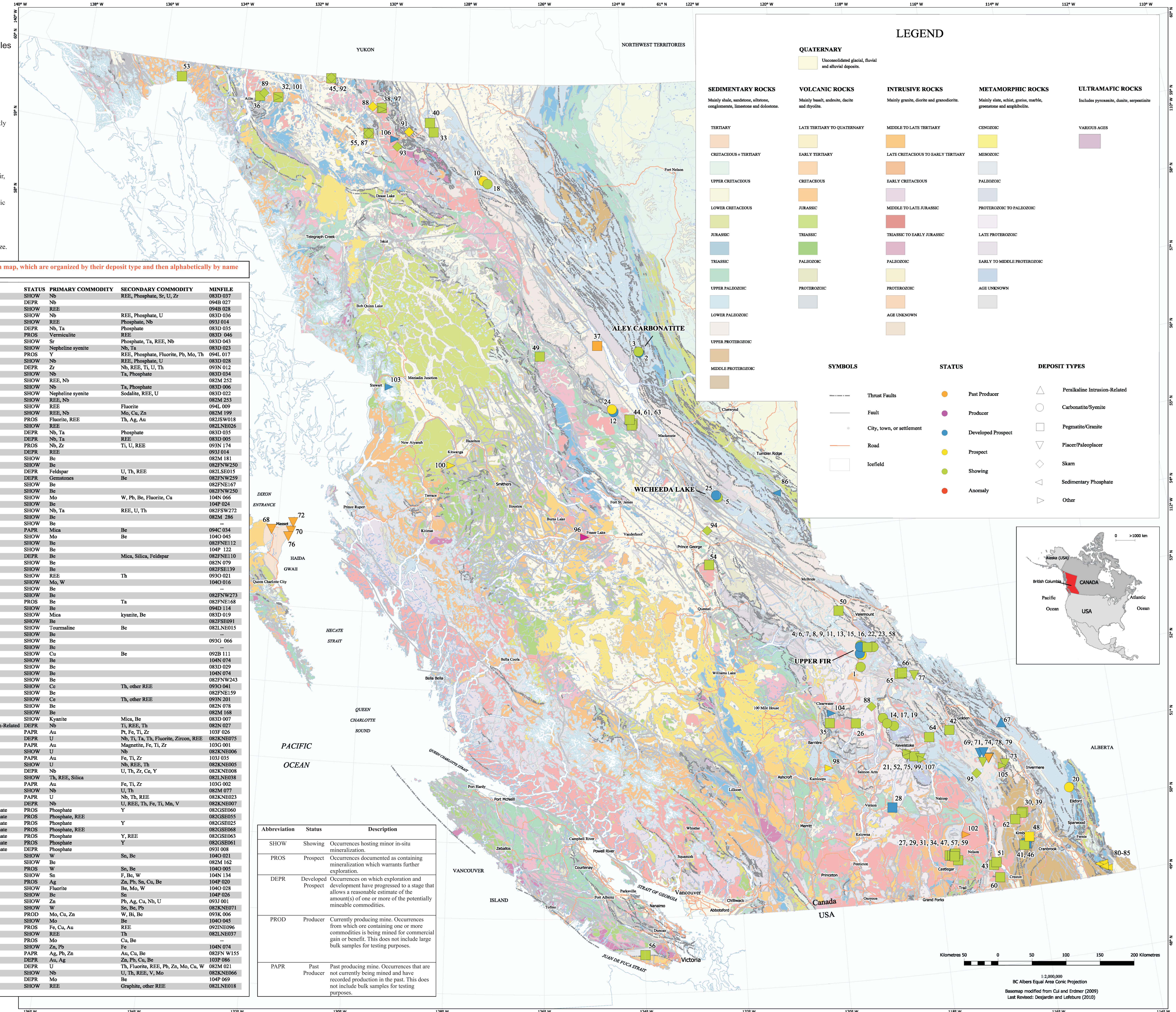
Several deposits, for example Rexspar, which was previously investigated as a potential source of fluorospar and uranium and is associated with metavolcanic rocks, do not fit particularly well in any of the above deposit types (Preto, 1978). Other occurrences were assigned to more than one deposit type. 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.

There are several other deposits with the IOCG affinity in British Columbia, although they appear to have relatively low REE content. This does not mean that IOCG deposits are not important as potential REE sources. Olympic Dam deposit (Australia) is probably the most important IOCG deposit. In addition to Cu, U, Fe, Au, and Ag, it also contains substantial concentrations of REEs that are not currently recovered, but may be in the future.

Table 2: Descriptions of deposits depicted on map, which are organized by their 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	Slide	Other	SHOW	Nb	U, Th, REE, V, Mo	082KNE066
106	Storie	Other	DEPR	Mo	Be	104P 069
107	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 ore containing one 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.



Applied Mineralogy and Metallurgical Considerations

Metallurgy (including related technical, environmental and economic aspects) is often more important than geological and geotechnical constraints on the development of RM deposits. It should not be overlooked during the early assessment of all RM projects.

All the universal (including textural and grain-size) 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 have relied historically, or still 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 contain higher thorium concentrations. From that point of view they are considered slightly more difficult to separate (especially in developed countries). Good examples of past producers 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 (at competitive cost). There is currently no commercial production of REE from silicates. However, recent press releases of Canadian and Australian companies suggest that over the last few years significant progress has been achieved. Recovery of REE as a by-product of phosphate fertilizer does add some complexity to existing fertilizer plant circuits; however, it should not interfere with production. Similarly, HREE recovery from uranium ores is a relatively well established procedure previously used in Canada.

Principal niobium 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 ($(Ce,Na,Ca)_2(Ti,Nb)_2O_6$). The main, economically important, tantalum 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 British Columbia. This compilation may serve as a starting point for those considering RM exploration programs in British Columbia. 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 significance of many of these is poorly known because the size, shape, depth, grade, composition and orientation are not well defined. Future research could address these uncertainties for selected deposits in order to develop a more comprehensive understanding of RM occurrences in British Columbia. Based on currently available information, carbonatite/syenite-related deposits are the most promising for the recovery of RMs, especially Nb and REE, and should be given priority.

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