Mineralogy of the Rock Canyon Creek REE-fluorite deposit, British Columbia, Canada

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Objective

The main objective of this study was to document mineralogy of the rare earth element (REE)-fluorite zone at the Rock Canyon Creek deposit. This zone was intersected by drilling along a strike length of 1100 metres and to a depth of more than 124 metres.
Detailed mineral identification was performed using SEM-EDS, Powder XRD, and Raman spectroscopy on selected mineralized samples from the drill hole RCC-09-14 which intersected high grade REE mineralization.

Rock Canyon Creek REE-fluorite deposit

- The Rock Canyon Creek rare earth element (REE)-fluorite deposit, about 90 km north-northeast of Cranbrook is in the British Columbia alkaline province (Fig. 1).
- Most of the 44 REE occurrences reported in British Columbia (Simandl et al., 2012) are in this province which consists of carbonatites,nepheline and sodalite syenites, ijolite series rocks, kimberlite, and many ultramafic and lamprophyre diatremes, breccias, and dikes (Pell, 1994).
- The Rock Canyon Creek deposit is hosted by Middle Devonian carbonate rocks of the Cedared and Burnais formations (Pell and Hora, 1986; Green et al., 2017).

Fig. 1. Location of the Rock Canyon Creek REE-fluorite deposit. The British Columbia Alkaline Province, as defined by Pell (1994), is shown in red.

Mineralized zone and position of drill holes

The main REE-fluorite mineralized zone (Fig. 2) was investigated at depth by 17 diamond drill holes totalling 1213.79 metres (Pighin et al., 2010).

The steeply dipping REE fluorite zone extends along strike for more than 1100 metres, to a depth greater than 124 metres; it remains open along strike and dip and, at least locally, is more than 50 metres thick.

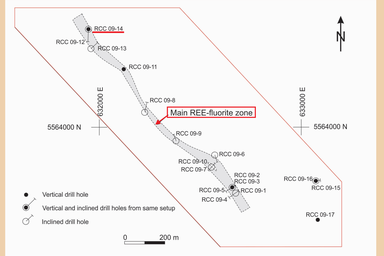

Fig. 2. Approximate vertical projection of the main REE-fluorite mineralized zone to the surface and locations of diamond-drill holes. Compiled from Pighin (2010). Mineralized zone is open at depth and along strike in both directions. Drill hole RCC-09-14, the main object of this study, intersected high-grade mineralization and is one of the two northernmost drill holes.

Analytical methods and results

In order to characterize REE mineralization we selected 38 samples from borehole RCC-09-14 and fifteen polished thin sections were prepared. Drill hole RCC-09-14 (up to 124.7 m) generally consists of dolostone and dolostone crackle breccia containing REE mineralization with accompanying fluorite and pyrite (Fig. 3). The detailed description is shown in Table 2.

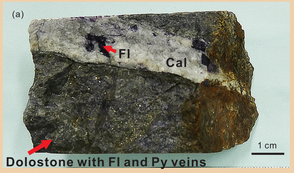

Fig. 3. Representative photograph of core sample in the Rock Canyon Creek. (a) Dolostone crackle breccia containing abundant fluorite (Fl) and pyrite (Py), cut by calcite vein containing coarse fluorite crystals.

X-ray diffraction analysis

Core samples, representing 3-metre drill core intervals, from drill hole RCC-09-14 were crushed, split, and milled to make powder samples for powder X-ray diffraction (Powder-XRD). Qualitative powder-XRD analyses were conducted on 38 powdered samples using the Rigaku Smart Lab X-ray diffractometer. The operating voltage and current were 40 kV and 200 mA, respectively, and samples were scanned from 3° to 70° 2θ at a step size of 0.02° and scan speed of 10° min⁻1.The result of XRD for drill hole RCC-09-14 is shown in Table 1.

SEM-EDS analysis

Following the qualitative analysis, quantitative analysis of minerals was conducted using SEM-EDS (JEOL JSM-6610LV). SEM-EDS analyses were carried out on 15 thin sections (Table 2). Cobalt (Co) standard was used for quantitative analysis. The minerals identified by SEM-EDS are shown in Table 2.

Table 1 List of minerals in drill hole RCC-09-14 detected by Power-XRD.

Depth (m)	Dol	Cal	Fl	Brt	Py	Mc	Qtz	Ap	Bas	Mnz
1-6	+++	+	++	++	+		+		++	+
6-9	+++	++	++	+	++	+	+			
9-12	+++	++	++	+	++	+				
12-15	+++	++	++	+	++		+			
15-18	+++		++	+	+				++	
18-21	+++		++	++	+		+		++	
21-24	+++		++	++	+				++	+
24-27	+++		++	+	+				+	
27-30	+++		++	+	+				+	
30-33	+++		++	++	+				++	
33-36	+++		++	+	++		+		++	
36-39	+++		++	+	+	+	+		+	
39-42	+++		++	+	++	+	+			
42-45	+++		++	+	+	+	+		++	
45-48	+++		++	+	+		+			
57-60	+++		++	+	+		+		+	
60-63	+++		++	+	+	+	+		+	
63-66	+++		++	+	++		+			
66-69	+++		++	+	+		+		+	
69-72	+++		++	+	++		+		+	
72-75	+++		++	+	+		+			
75-78	+++		++	++	+		+			
78-81	+++		++	+	++		+			
81-84	+++		++	+	++					
84-87	+++		++	+	++		+		+	
87-90	+++		++	+	++		+			
90-93	+++		+	+	++					
93-96	+++		+	+	++					
96-99	+++		+	+	++		+			
99-102	+++		+	+	+		+			
102-105	+++		++	+	++		+			
105-108	+++		++	+	++		+			
108-111	+++		++	+	++		+			
111-114	+++			+	++		+			
114-117	+++		++	+			+	+	+	
117-120	+++		++	+			+		++	
120-123	+++		++	+			+		++	
123-124.7	+++		+	+			+	+	++	

Dol: dolomite, Cal: calcite, Fl: fluorite, Brt: barite, Py: pyrite, Mc: microcline, Qtz: quartz, Ap: fluoraopatite, Bas: bastnasite, Mnz: monazite
+++ : peak high, ++ : peak middle, + : peak low

Table 2 REE minerals in drill hole RCC-09-14 detected by SEM-EDS. +++ major, ++ minor, + trace

Drill Hole	Rock Type	Microscopic observations	REE minerals	Other minerals	REE content
RCC-09-14_1	Dolostone (Fe oxide-stained), weathered	fg dolomitic limestone; REE carbonates and phosphates with pyrite, fluorite and barite; late calcite vein	REE carbonate++, REE phosphate+++	dolomite+++, barite+++, fluorite++, calcite++, pyrite+	high
RCC-09-14_2.8	Fluorite-bearing Fe oxide stained dolostone breccia	altered cg dolomitic limestone; REE carbonates and REE phosphate occur with pyrite, fluorite and barite; late calcite veinlets	REE carbonate++, REE phosphate+++,	dolomite+++, barite++, fluorite+++, calcite++, pyrite+	high
RCC-09-14_5.8	Fluorite-bearing, Fe oxide stained dolostone	fg dolostone, REE carbonates and phosphates occur with pyrite, fluorite and barite; late stage fg pyrite aggregates; calcite vein is the latest	REE carbonate++, REE phosphate+++	dolomite+++, barite++, fluorite+++, calcite++, pyrite+++	moderate
RCC-09-14_6.75	Fluorite-bearing, pale gray dolostone cut by calcite vein.	contact of altered fg dolostone with calcite vein; REE carbonates occur with pyrite, fluorite and barite; late veinlets consisting of fg pyrite aggregates	REE carbonate+	dolomite+++, barite++, fluorite+++, calcite+++, pyrite++	low
RCC-09-14_8.15	Fluorite-, pyrite-bearing pale gray dolostone cut by calcite vein	contact of altered fg dolostone with calcite vein. REE carbonates occur with pyrite, fluorite and barite; late veinlets containing fg pyrite aggregates	REE carbonate+	dolomite+++, barite+, fluorite+++, calcite+++, pyrite+++, K-feldspar+	low
RCC-09-14_8.5	Fluorite and pyrite-bearing whitish limestone, calcite vein	altered cg dolostone. REE carbonates and REE phosphates occur with pyrite, fluorite and barite; late veinlets containing fg pyrite aggregates	REE carbonate+, REE phosphate+	dolomite+++, barite+, fluorite+++, calcite+, pyrite+++	low
RCC-09-14_37.3	Fluorite-bearing dolostone; cut by cg calcite vein	altered fg dolostone; REE carbonates and phosphates with fluorite, barite, and pyrite	REE carbonate+, REE phosphate+	dolomite+++, barite+++, fluorite+++, quartz++, K-feldspar++, calcite+, pyrite++	low
RCC-09-14_40.4	Fluorite- and pyrite-bearing grey limestone	altered fg dolomitic limestone; apatite grains are cut by fluorite-filled fractures		dolomite+++, barite++, apatite+++, fluorite+++, quartz++, K-feldspar++, pyrite+++	low
RCC-09-14_69.6	Fluorite- and pyrite-bearing grey dolostone, calcite veinlets, with massive pyrite	altered fg dolostone; REE carbonates occur with fluorite, barite and pyrite. Late veinlets containing fg pyrite aggregates	REE carbonate++	dolomite+++, barite++, apatite+++, fluorite++, quartz++, K-feldspar++, pyrite+++	moderate
RCC-09-14_80.1	Fluorite- and pyrite-bearing grey dolostone	altered fg dolostone; REE carbonates and phosphates occur with fluorite, barite, and pyrite; apatite is common; late fg pyrite aggregates	REE carbonate++, REE phosphate+	dolomite+++, barite++, apatite +++, fluorite++, K-feldspar++, pyrite+++	moderate
RCC-09-14_108.6	Fluorite and pyrite-rich grey dolostone	fg dolostone; REE carbonates accompanied by fluorite, pyrite and barite; fg pyrite aggregates	REE carbonate+++, REE phosphate+	dolomite+++, barite++, fluorite++, pyrite+++	high
RCC-09-14_120	Whitish dolostone	cg dolostone; REE carbonates and phosphates occur with fluorite, pyrite, and barite; apatite is common	REE carbonate++, REE phosphate+	dolomite+++, barite++, fluorite++, pyrite+++	moderate
RCC-09-14_121.2	Whitish dolostone	fg dolostone; REE carbonates and phosphates occur with fluorite, pyrite, and barite; apatite is common; fg pyrite aggregates; late calcite veinlets	REE carbonate+++, REE phosphate+	dolomite+++, barite++, apatite +++, fluorite++, pyrite+++	high
RCC-09-14_121.6	Fluorite-bearing whitish dolostone	cg dolostone; REE carbonates and REE phosphates with fluorite coexist pyrite and barite; fg pyrite aggregates; late calcite vein	REE carbonate+++, fluorite+++, REE phosphate+++	dolomite+++, barite++, fluorite++, pyrite+++	high
RCC-09-14_124.7	Whitish dolostone	cg recrystalized dolostone; REE carbonates with fluorite, pyrite and barite; apatite is common	REE carbonate+++	dolomite+++, barite++, apatite +++, fluorite++, pyrite+++	high

- **Identified minerals:** dolomite, fluorite, quartz, K-feldspar, barite, apatite, pyrite, REE-bearing fluorocarbonates [(bastnäsite-(Ce), parisite-(Ce) and synchysite-(Ce)], and REE phosphates [monazite-(Ce) and crandallite group minerals].
- REE-bearing fluorocarbonates were identified in 14 samples, and REE phosphates in 9. Both REE carbonates and REE phosphates are commonly spatially associated with pyrite, barite and fluorite (Figs. 4a-f).
- Representative chemical compositions of REE minerals are summarized in Table 3.

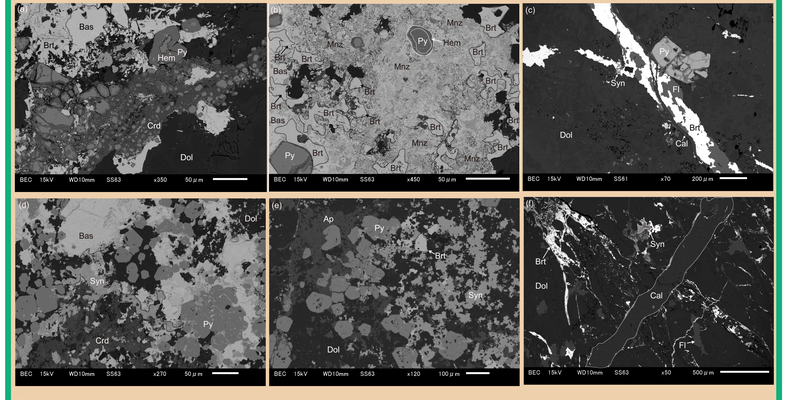

Fig. 4. Back-scatter-electron images of representative textures in drill hole RCC-09-14. **a)** RCC-09-14-1 m, bastnäsite-(Ce) with pyrite, hematite, barite, and crandallite. **b)** RCC-09-14-1 m, mixture of monazite-(Ce), bastnäsite-(Ce) and barite. **c)** RCC-09-14-1 m, late calcite-filled hairline fractures cut fractures filled with fluorite and barite. **d)** RCC-09-14-80.1 m, pyrite aggregates with bastnäsite-(Ce), crandallite and synchysite-(Ce). **e)** Euhedral pyrite aggregates with altered apatite, synchysite-(Ce) and barite in dolomite. **f)** RCC-09-14-121.2 m, late calcite veins cut barite and synchysite-(Ce) vein. Dol: dolomite, Fl: fluorite, Py: pyrite, Hem: hematite, Brt: barite, Bas: bastnäsite, Syn: synchysite, Crd:crandallite group mineral, Ap: apatite.

Table 3 Representative compositions of REE-bearing minerals from RCC-09-14.

	RCC-09-14-1m			RCC-09-14-5.8m			RCC-09-14-80.1m				RCC-09-14-108.1m	RCC-09-14-121.2m		
wt %	Bastnäsite	Synchysite	Monazite	Synchysite	Monazite	Crandallite	Bastnäsite	Synchysite	Synchysite	Crandallite	Bastnäsite	Bastnäsite	Synchysite	Crandallite
P			13.03		12.33	9.92				11.55				11.25
Si														
Al			6.35		5.33	16.76			0.51	17.88				17.77
Na														
Mg														
Ca		14.42	1.6	14.56	1.33	6.13	1.76	15.53	14.37	3.35	2.81	1.19	11.19	2.3
Sr	1.63		2.82		3.09	5.49				6.22	1.01			10.74
Mn														
As														
Fe														
Ba														
Y				2.13										
La	19.81	12.82	14.15	11.16	15.69	9.83	8.72	5.23	13.85		19.05	24.93	20.23	3.5
Ce	33.83	23.35	21.69	23.82	22.64	8.31	24.31	17.68	19.18	6.37	27.92	32.44	24.09	3.7
Pr	3.38			2.92			4.72					2.81		
Nd	10.6	6.95	5.32	10.21	5.72		24.06	18.5	9.49		8.69	8.32	8.34	
Sm							2.84							
Th		1.89			1.54		2.3	2.82	3.34		6.88			
O	22.43	33.72	34.28	28.64	31.55	35.78	22.85	33.49	33.27	52.79	24.55	21.58	29.18	48.68
S			0.76		0.78	1.59				1.85				2.07
F	8.33	6.86		6.56		6.18	8.43	6.74	5.99		9.09	8.73	6.96	
Total	100.0	100	100	100	100	100	100	100	100	100	100	100	100	100

Discussion

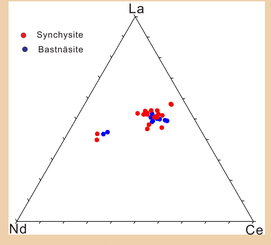

Fig. 5. La-Ce-Nd diagram of bastnäsite and synchysite in the Rock Canyon Creek deposit. There are two distinct clusters (high-La and high-Nd).

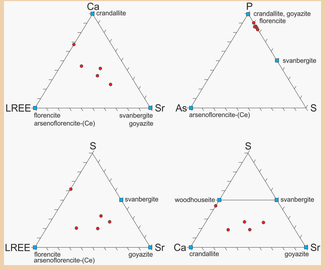

Fig. 6. Ternary diagrams of crandallite group minerals from the Rock Canyon Creek.

Conclusions

- Mineralization consists of dolomite, fluorite, quartz, K-feldspar, barite, porous apatite, pyrite, REE-bearing fluorocarbonates [bastnäsite-(Ce), parisite-(Ce), synchysite-(Ce)], and REE-bearing phosphates [monazite-(Ce), crandallite group minerals] in various proportions.
- Barite and fluorite veinlets and those containing REE minerals, fluorite, barite and pyrite are cut by calcite-filled fractures. Cross cutting relationships and replacement textures suggest that REE-bearing carbonates, fluorite, barite and pyrite are of hydrothermal origin.
- The monazite-(Ce) grains contain Al, and Ca, suggesting that monazite-(Ce) is altered or formed in the supergene environment.
- Presence of uncommon Nd-rich bastnäsite and Nd-rich synchysite may have important genetic and economic ramifications

Acknowledgments

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References

- Pell, J., 1994. Carbonatites, nepheline syenites, kimberlites and related rocks in British Columbia. British Columbia Ministry of Energy, Mines, and Petroleum Resources, British Columbia Geological Survey, Bulletin 88, 44p.
- Pell, J., and Hora, Z.D., 1986. Geology of the Rock Canyon Creek fluorite/rare earth element showing southern Rocky Mountains (82J/3E). In: Geological Fieldwork, 1986,British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 1987-1, pp. 255-258.
- Pighin, D.L., 2010. Assessment Report Rock Canyon Property, British Columbia Geological Survey Assessment Report 31435. 109p.
- Simandl, G.J., Prussin, E.A., and Brown, N., 2012. Specialty metals in Canada. British Columbia Ministry of Energy, Mines and Natural Gas, British Columbia Geological Survey Open File 2012-7, 48p.