Geologic setting of the Rock Canyon Creek REE-Fluorite deposit, British Columbia, Canada

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Abstract

The Rock Canyon Creek REE-fluorite deposit is in the Foreland Fold and Thrust belt of the Canadian Cordillera, 300 metres east of the Munroe Lake thrust fault which, in the deposit area, divides the Main Ranges from the Front Ranges of the Canadian Rocky Mountains. A literature review and preliminary fieldwork indicate that the deposit is hosted by Middle Devonian rocks of the Cedared and Burnais formations and consist mainly of dolostone, breccia, and laminated silty, calcareous gypsum. Fluorite-bearing outcrops extend across an area 3300 by 750 metres. The steeply dipping REE-fluorite zone was intersected by drilling. It may be more than 50 metres thick for more than 1100 metres along strike, and to a depth of 124 metres. It remains open along strike and dip, and its thickness locally exceeds 50 metres. Based on surface mapping and borehole logging, the deposit appears to be concordant with stratigraphy. Most of the mineralization occurs as breccias and fracture fillings in fluorite-impregnated dolostone. Fluorite concentrations vary from less than 1% to 13.5% by weight, and light REE (Ce+La+Nd) concentrations vary from trace to 2.8%. REE are hosted mainly by bastnasite-(Ce), parisite-(Ce), synchysite-(Ce), and REE-bearing phosphates. Ongoing work will focus on better characterizing the deposit to address questions about the origin of ore forming fluids and the temporal, structural, and stratigraphic relationship to Mississippi Valley-type and sparry magnesite deposits along the eastern flank of the Canadian Cordillera.

Location

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

M. Hoshino examining REE-fluorite mineralization

S. Kodama testing core from 2009 drilling campaign

Tectonic setting

The Rock Canyon Creek deposit (Fig. 1) is in the Foreland Fold and Thrust belt of the Canadian Cordillera (e.g., Gabrielse et al., 1991; Monger and Price, 2002). It lies in the footwall of the Munroe Lake thrust (Fig. 2), which divides the Main Ranges from the Front Ranges of the southern Canadian Rocky Mountains (Mott, 1989). Late Jurassic to early Tertiary thin-skinned folding and thrusting in the Rocky Mountains affected miogeoclinal and foreland basin sedimentary rocks deposited on top of crystalline Precambrian basement (e.g., Price and Fermor, 1985; Monger and Price, 2002). Several diatremes and intrusions in the region may be related to deep transverse basement structural features (McMechan, 2012). Such intrusions have not been recognized near the Rock Canyon Creek REE-fluorite mineralization.

Geology of the Rock Canyon Creek area

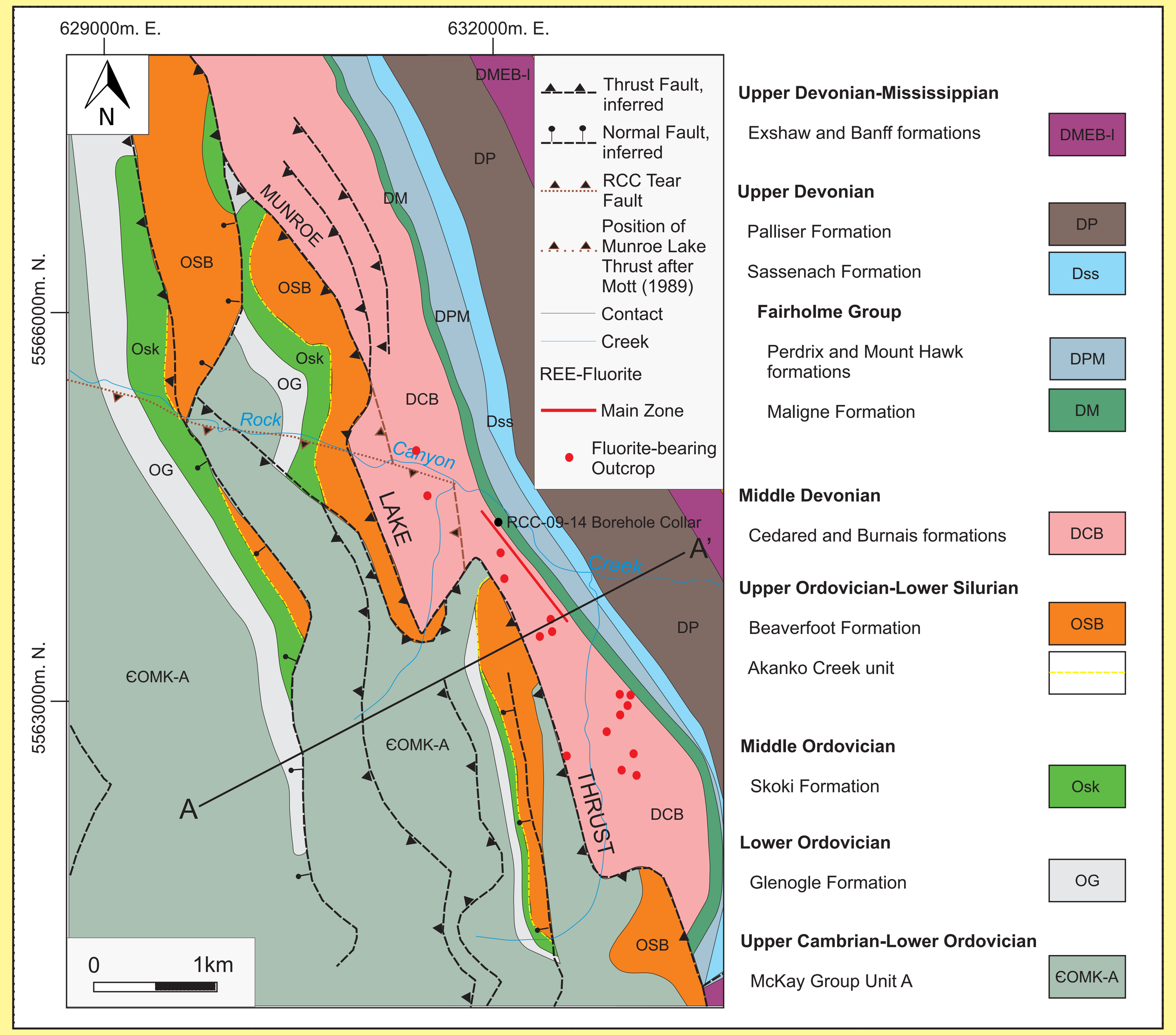

Fig. 2. Geological setting of the Rock Canyon Creek deposit. Modified after McMechan and Leech (2011). An alternative interpretation from Mott (1989) includes a west-northwest-trending fault (Rock Canyon Creek tear fault) in brown.

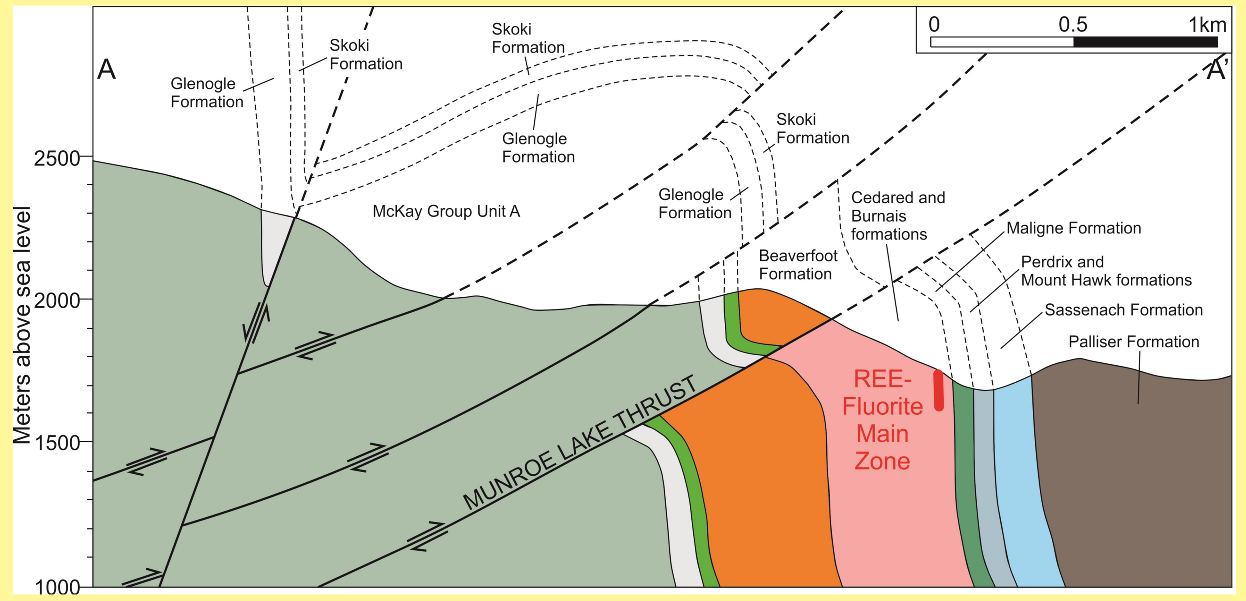

Fig. 3. Geological cross section of the Rock Canyon Creek deposit area. For section location and legend see Figure 2. No vertical exaggeration. Based on mapping by Mott (1989) and McMechan and Leech (2011).

Structural geology

The predominant structural elements in the area are northeast-vergent thrusts and folds (Figs. 2, 3; Mott, 1989; McMechan and Leech, 2011). Thrust faults, including the Munroe Lake thrust, are oriented northwest-southeast and dip shallowly to the southwest (Fig. 3). A normal fault west of the Munroe Lake thrust has a similar strike to the thrusts (Fig. 2), but dips steeply southwest (Fig. 3).

Mott (1989) proposed that a northwest-striking, south-dipping tear fault (Rock Canyon Creek tear fault) follows the trend of Rock Canyon Creek, based on the observation that the Beaverfoot, Skoki, and Glenogle formations are exposed at lower elevations on the north side of the creek than on the south side. Although this putative tear fault was not included in the McMechan and Leech map (2011), its projection may connect to the Munroe Lake fault 200 metres northwest of the main REE-fluorite zone (Fig. 2). Because of the possible importance of the fault to mineralization, future fieldwork will attempt to resolve if the fault exists or not.

Stratigraphy

Age	Name	Rock types	Thickness	Fossils
Upper Cambrian - Lower Ordovician	McKay Group Unit A	Limestone, dolostone, conglomerate and chert horizons	400 - 600 metres	Fossil debris including brachipod
Lower Ordovician	Glenogle Formation	Black shale and siltstone, quartz arenite, limestone and dolostone	< 75 metres	1-2% crinoid, graptolite, brachiopod, and gastropod fossil debris
Middle Ordovician	Skoki Formation	Dolostone with abundant chert nodules	150 metres	Silicified crinoid and brachiopod debris
Upper Ordovician	Akanko Creek	Dolostone and quartz arenite	< 10 metres	N/A
Upper Ordovician - Lower Silurian	Beaverfoot Formation	Conglomerate and dolostone	140 metres	Abundant coral, and silicified crinoids and brachipods
Middle Devonian	Cedared and Burnais formations	Dolstone, dolostone breccia, and evaporitic gypsum	75 - 100 metres	Fish fragments, gastropod, crinoid, and brachiopod debris
Upper Devonian	Fairholme Group	Lime mudstone, shale	100 metres	Up to 1% fossil fragments including conodont
Upper Devonian	Sassenach Formation	Siltstone, sandstone and argillaceous limestone	< 200 metres	N/A
Upper Devonian	Palliser Formation	Limestone and dolostone	600 + metres	Trace fossils (burrows)
Upper Devonian - Mississippian	Exshaw and Banff formations	Shale and lime mudstone	1000 metres	N/A

Table 1. Stratigraphy of the Rock Canyon Creek deposit area.

Breccias

Breccias in the Cedared and Burnais formations in Beaverfoot, Brisco, and Standford ranges consisting of angular fragments of limestone and dolostone in a sandy mudstone matrix, were interpreted by Belyea and Norford (1967) as the products of solution collapse. Similar breccias in the study area were also attributed to solution collapse (Mott, 1989; McMechan and Leech, 2011).

Breccia of uncertain origin coincides with the main mineralized REE-fluorite zone. The elongate shape of the breccia zone suggests that it may be either a fault related ('crackle fault breccia') or a 'cave-ceiling crackle breccia' related to stratabound paleokarst development. Regardless of its origin, this breccia appears to be the main structural control on REE-fluorite mineralization, and for pyrite and sparry dolomite mineral growth.

Geology of the deposit

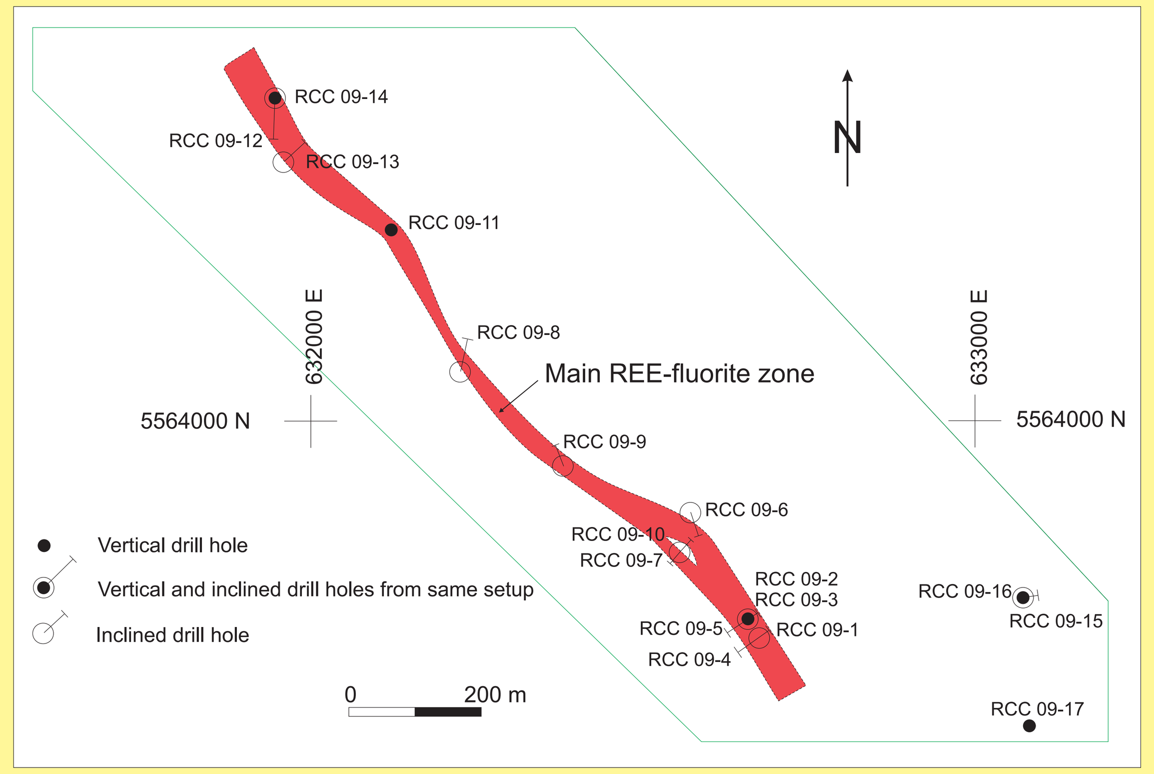

Fig. 4. Projection of REE-fluorite zone to surface and diamond drill hole locations. From Hoshino et al. 2017.

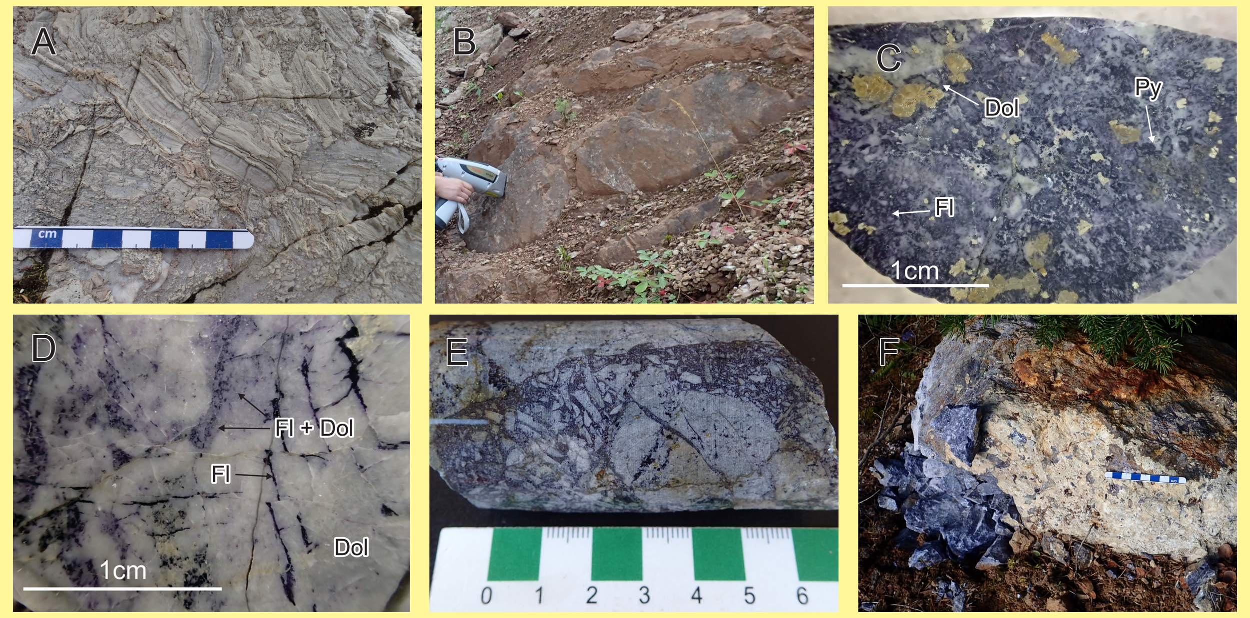

Fig. 5. a) Intraformational breccia composed of evaporitic laminated gypsum of the Cedared and Burnais formations, weathered surface. **b)** REE-fluorite-bearing dolostone, the main zone, displaying characteristic red-brown weathering. **c)** Representative sample of mineralization consisting of purple fluorite (Fl) and pyrite (Py) in grey dolomite (Dol). REE-bearing minerals cannot be identified at this scale; however sample contains 1.8 weight % of Ce, La, and Nd combined. **d)** Example of 'crackle breccia' cemented by fluorite in the right portion of the photograph; open spaces filled by fluorite and dolomite (Fl + Dol). **e)** Monolithic dolostone breccia; larger fragments are cut by fluorite filled fractures; purple matrix of the breccia consists of fluorite, dolomite, barite, and pyrite. **f)** Fluorite-rich boulder suspected to contain cryolite found near the northwestern end of the main REE-fluorite zone.

		Mineral	Formula	Sources
In-situ	Gangue	Calcite	$CaCO_3$	4
		Dolomite	$CaMg(CO_3)_2$	3,4
		Ferroan Dolomite	$CaMg(CO_3)_2$	3
		Pyrite	FeS_2	2,4
		K-Feldspar	$KAlSi_3O_8$	3,4
		Quartz	SiO_2	3,4
		Rutile	TiO_2	3
		Magnetite	$Fe^{2+}Fe^{3+}{}_2O_4$	2
		Apatite	$Ca_5(PO_4)_3(F,Cl,OH)$	3,4
		Hematite	Fe_2O_3	3,4
	Ore	Fluorite	CaF_2	2,3,4
		Barite	$BaSO_4$	2,3,4
		Bastnaesite	$(Ce,La,Y)CO_3F$	4
		Pyroclore	$(Na,Ca)_2Nb_2O_6(OH,F)$	3
		Parisite	$Ca(Ce,La)_2(CO_3)_3F_2$	2,3,4
		Synchysite	$CaCe(CO_3)_2F$	3,4
		Monazite	$(Ce,La)PO_4$	4
		Sphalerite	$(Zn,Fe)S$	3
		Galena	PbS	3
		Cerussite	$PbCO_3$	3
		Smithsonite	$ZnCO_3$	3
In-situ & Float	Gangue	Dolomite	$CaMg(CO_3)_2$	1,3,4
		Pyrite	FeS_2	1,2,4
		K-Feldspar	$KAlSi_3O_8$	1,3,4
		Quartz	SiO_2	1,3,4
		Rutile	TiO_2	1,3
	Ore	Bastnaesite	$(Ce,La,Y)CO_3F$	1
		Fluorite	CaF_2	1,2,3,4
		Barite	$BaSO_4$	1,2,3,4
Float	Gangue	Limonite	$FeO(OH)\cdot nH_2O$	1
		Illite	$(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$	1
		Prosopite	$CaAl_2(F,OH)_8$	1,3
		Kaolinite	$Al_2Si_2O_5(OH)_4$	1,3
		Talc	$Mg_3Si_4O_{10}(OH)_2$	1
		Muscovite	$KAl_2(AlSi_3O_{10})(F,OH)_2$	3
		Elpasolite	K_2NaAlF_6	3
		Goyazite	$SrAl_3(PO_4)(PO_3OH)(OH)_6$	3
	Ore	Gorceixite	$BaAl_3(PO_4)(PO_3OH)(OH)_6$	1
		Cryolite	$Na_3{\bullet}AlF_6$	3
		Ag-Sn-Te-S phase	$Ag_8Sn(TeS_2)_2$	3

Table 2. Mineralogy of the Rock Canyon Creek deposit. Sources: 1 - Hora and Kwong (1986), 2 - Pell (1992), 3 - Samson (2001), and 4 - Hoshino et al. (2017).

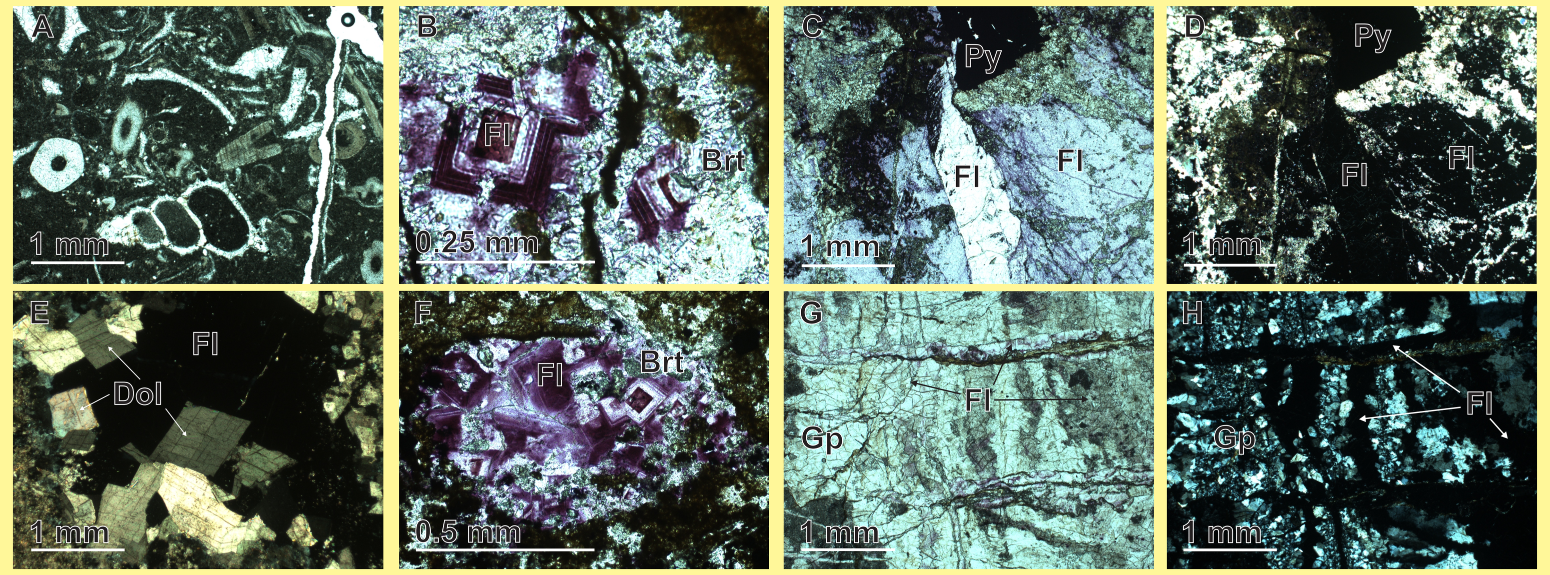

Fig. 6. Photomicrographs from selected mineralized and unmineralized samples from the Rock Canyon Creek area. **a)** Unmineralized Middle Devonian fossiliferous dolostone adjacent to the deposit; Plain polarized light (PPL). **b)** Open-space filling textures displayed by cubic fluorite (Fl) and barite (Brt) (PPL). **c)** Light purple fluorite cut by colourless fluorite adjacent to coarse pyrite (Py) grain (PPL). Cross-cutting relationship indicates multiple generations of fluorite. **d)** Same field of view as in C in cross-polarized light (XPL) displaying isotropic extinction of colourless and purple fluorite, and opaque pyrite. **e)** Euhedral sparry dolomite in open-space filling texture (XPL). Black (isotropic) material surrounding sparry dolomite is fluorite. **f)** Open-space filling cubic fluorite intergrown with barite in a VUG (PPL). **g)** Colourless to light-purple flourite veinlets cutting finely laminated evaporitic gypsum (Gp) of the Cedared and Burnais formations which host the deposit (PPL). **h)** Same field of view as in G in XPL displaying fluorite veinlets cross-cutting and running parallel to laminated gypsum of the ore-hosting Cedared and Burnais formations.

Genetic considerations

The Rock Canyon Creek REE-fluorite deposit has historically been viewed as a being related to a carbonatite source (Graf, 1985; Hora and Kwong, 1986; Pell and Hora, 1987; Samson et al., 2001). Disseminated fluorite–REE mineralization was regarded as a result of interaction between F- and REE-bearing hydrothermal fluids of unspecified origin with carbonate wall rock (Gagnon et al., 2003). Differences in fluorite composition were interpreted either as progressive mixing of hydrothermal fluids or interaction of fluids with the country rock (Gagnon et al., 2003).

Although the deposit is in the British Columbia alkaline province (Pell, 1994), it is unusual in that it is not spatially associated with outcrops of carbonatite or alkaline rocks. Furthermore, it lacks primary monazite, although secondary monazite was recently reported in shallow drill core by Hoshino et al. (2017) from drill hole number RCC-09-14 (Fig. 2). Similarities between the Rock Canyon Creek REE-fluorite deposit, Mississippi Valley-type (MVT; e.g. Shag, Monarch, Kicking Horse, Munroe), and sparry magnesite deposits (e.g. Mount Brussilof Mine and related occurrences) in southeastern British Columbia were noted by Paradis and Simandl (2016). All the above deposits are in Paleozoic shelf carbonate rocks, which extend along the length of the Canadian Cordillera, and were likely generated by mineralizing processes operating in the absence of nearby magmatic sources of metals and heat. All of these deposit types are associated with breccias and zones of hydrothermal sparry carbonates, such as magnesite, calcite, and saddle dolomite, and contain sulphides (Paradis and Simandl, 2016). Furthermore, Pell (1994) reported that the Rock Canyon Creek deposit was discovered as a result of geochemical exploration for MVT Zn-Pb deposits. Thus basinal fluids may have been responsible for, or at least partially contributed to, the formation of REE-fluorite mineralization at Rock Canyon Creek.

Possible links between the MVT and magnesite deposits and Rock Canyon Creek will be tested by future studies directed at establishing lithological, textural, mineralogical and geochemical parameters, depositional conditions, mineralization ages, provenance of metals and sulphur, tectonic and structural controls, and variations in the C and O isotopes in carbonate rocks. Conceivably, Rock Canyon Creek mineralization may record interaction between carbonatite-related and basinal fluid mineralizing systems.

Ongoing / Future work

Samples collected in 2016 are being analysed for major and trace elements including REE and fluorine and mineralogical studies are in progress. Our future work, focussing on generating a dataset to enable comparisons with magnesite and MVT deposits in the area, includes the following:

- Fieldwork to determine the extent of the brecciated and mineralized zones, document changes in brecciation style, and establish the distribution and intensity of sparry dolomitization adjacent to the main mineralized zone.
- Developing a three dimensional model of the deposit based on geochemical analyses of core samples.
- Detailed petrography and mineral chemistry using the scanning electron microscope (SEM) and electron microprobe.
- Laser Ablation-ICPMS studies for trace element analysis ± fluid inclusion studies of fluorite to test for covariation in REE composition of fluorite, and temperature of the fluid.
- S-isotopes of sulphides and barite, and O, C and Sr isotopes of carbonate rocks.
- Re-Os (pyrite) and U-Pb (monazite) geochronology.
- Study of co-variation between fluorite, sulphur, major and trace elements relative to concentrations of REE.
- Comparison of REE normalized patterns of weathering-enriched mineralization relative to those corresponding to fresh mineralization.

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For references please see:

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