

Primary fersmite and the direct indicator mineral concept, Mount Brussilof, British Columbia

Introduction

Fersmite ([Ca,Ce,Na][Nb,Ta,Ti]₂[O,OH,F]₆) is a complex mineral, occurring commonly as a strongly metamict alteration product of pre-existing niobate minerals in carbonatites, alkaline and peralkaline intrusions, and rare element pegmatites. Most well-documented primary fersmite localities are found in Europe and correspond to 'alpine cleft', or 'alpine fissure' occurrences (open joints, vugs, and cavities partially filled with well-crystallized minerals) formed during metamorphism and uplift. Globally, fersmite is the third most important Nb-ore mineral after pyrochlore supergroup minerals and columbite-tantalite solid solution series minerals (Mackay and Simandl, 2014; Simandl et al., 2018). The physical and chemical properties of fersmite contribute to its effective use as a direct indicator mineral for carbonatites and related deposits.

At the Mount Brussilof magnesite deposit, sparry dolomite zones cut sparry magnesite (Simandl and Hancock, 1991). Primary fersmite is hosted by the sparry dolomite, occurring in vugs alone or together with sugary dolomite enclosed in the sparry dolomite. It occurs as accessory, black, acicular to platy, strongly zoned crystals up to 2 cm long or as smaller crystals (< 3 mm) commonly fractured and cut by late dolomite.

The objectives of this study are to: 1) describe the Mount Brussilof fersmite occurrence; 2) define the relationships between fersmite, sparry dolomite, and sparry magnesite; 3) characterize the compositional zoning observed in fersmite and present the most likely hypothesis regarding its origin; and 4) compare the physical and chemical properties of the Mount Brussilof fersmite to those of fersmite from carbonatite- and pegmatite-related deposits, furthering the value of fersmite as a direct indicator mineral.

Geologic setting

The Mount Brussilof deposit is 40 km northeast of Invermere. The spatial relationship between the Mount Brussilof magnesite deposit and Mississippi Valley-type (MVT) deposits such as Shag, Hawk Creek, Kicking Horse, and Monarch, and their position along the Kicking Horse rim was highlighted by Aitken and Mcllreath (1984), Simandl et al. (1992), and Paradis and Simandl (2017; 2018). At the Mount Brussilof mine, sparry magnesite is cut by sparry dolomite (Simandl and Hancock, 1991) and fersmi is hosted by sparry dolomite or by sugary dolomite



Fig. 1. Location of the Mount Brussilof magnesite mine and related fersmite occurrence.

enclosed in sparry dolomite. A close link is established between MVT Zn-Pb mineralization and sparry dolomite. Although this fersmite occurrence is too small to be of economic interest, it indicates migration of Nb-bearing fluids post-dating sparry dolomitization.

Fig. 2. Kicking Horse Rim, bound on the west by the projection of the Cathedral Escarpment. Mount Brussilof magnesite mine and selected MVT deposits. 1- Kicking Horse mine; 2- Monarch mine; 3-Hawk Creek prospect; and 4- Shag prospect. All are northeast of the Cathedral Escarpment and hosted by carbonate rocks deposited in shallow-marine environments (from Simandl et al., 1992).





Fig. 3. View of the Mount Brussilof Mine.



Fig. 4. Magnesite ore displaying 'zebra' texture.



Fig. 5. Sparry magnesite ore (pale grey) cross cut by sparry



Fig. 6. White sparry dolomite from the Kicking Horse Pb-Zn mine, BC. Fragments of fine-grained dolomite are rimmed by a mixture of sphalerite, pyrite and galena.













Fig. 11. Chondrite-normalized median, upper quartile, and lower quartile REE distribution for Mount Brussilof fersmite based on 189 spot analyses and for fersmite from Aley carbonatite (blue) from Chakhmouradian et al. (2015).



Fersmite ([Ca,Ce,Na][Nb,Ta,Ti]₂[O,OH,F]₆) is an orthorhombic mineral of the euxenite-group which share the formula AB₂O₆. The A-site is commonly occupied by Y, REE, Ca, Na, U, and Th, and the B-site contains Ti, Nb, and Ta.

Fersmite commonly occurs as a strongly metamict alteration product of pre-existing niobate mine in carbonatites (e.g., Aley Carbonatite), alkaline and peralkaline intrusions, and pegmatites.

Primary fersmite is less common and forms tabular, blade-shaped, or acicular crystals. Such crystals are black, dark brown, or lemon-yellow to yellow-brown, and their luster varies from resinous to subvitreous or submetallic. Dark colored crystals are nearly opaque, fluoresce yellow-green to bluishgreen under shortwave and longwave ultraviolet light, and have a pale blue cathodoluminescence. We locumented localities containing prismatic fersmite crystals correspond to by Niggli et al. (1940) as open joints, vugs and other cavities partially filled with well-crystallized, commonly euhedral minerals formed during metamorphism and uplift of mountain belts.



Fig. 7. Coarse fersmite crystals (Fsm) lining cavity in sparry dolomite (Dol). Quartz (Qtz) and phosphate (Pho) are also present. Mount Bruss mine, British Columbia. Scale in centimetres.

Fig. 8. Reflected light photomicrograph of zoned fersmite (Fsm) crystals enclosed in sparry dolomite (Dol), reflected light. Late dolomite (Dol2) fills fractures in fersmite. Mount Brussi



Fig. 9. Ca-Nb-Ta x 10 compositions in weight proportions of fersmite from the Mount Brussilof mine (red), carbonatite (blue), pegmatite (pink), and placer (green) deposits. Pegmatite-associated fersmite shows a wider variation in Ta content relative to carbonatite-hosted fersmite. The Mount Brussilof fersmite has a higher Nb/Ta ratio and shows wider variation along the Nb-Ca axis relative to carbonatiteand pegmatite-hosted fersmite. From Simandl et al. (2019).

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Fig. 10. Compositional LA ICP-MS maps of fersmite grains from Mount Brussilof mine. Zoning may reflect variations in fluid composition during crystallization. Colour scales are linear with minimums and maximums defined by the median ± 3 standard deviations. Note that this implies that some pixels are below and above the color extremes. Scale is shown on Na and Tb maps applies to all maps. Concentrations are in ppm unless noted otherwise.



Potential use of fersmite as a direct indicator mineral

Definitions:

elements that occur in close spatial association with a targeted deposit, forming a broad halo, and can be easily detected by common analytical methods.

Indicator mineral: A transported mineral indicating a specific type of mineralization, hydrothermal alteration, or lithology. Its physical and chemical characteristics, including high density, facilitate its preservation and identification and allow it to be readily recovered at the parts per billion level from sample media such as till, stream sediments, or soil, thereby producing large exploration targets (McClenaghan, 2005).

Direct indicator mineral: An indicator mineral containing high concentrations of pathfinder elements characteristic of a targeted deposit.

Direct indicator mineral concept:

The direct indicator mineral concept uses traditional geochemical methods to screen samples, followed by QEMSCAN analysis of samples found to have anomalous concentrations of pathfinder elements (Simandl et al., 2017).



Fig. 12. The direct indicator mineral concept is a two-step method that provides the interpretive power of geochemical and indicator mineral surveys without expensive and time-consuming traditional indicator mineral surveys involving hand picking.

Brussilof, British Columbia. British Columbia Ministry of University Energy, Mines and Petroleum Resources, British Columbia Geological Survey



Fersmite as a direct indicator mineral:

Fersmite has the physical and chemical properties required for use as a direct indicator mineral in conjunction with pyrochlore supergroup minerals and minerals of the columbite-tantalite solid solution series as documented by MacKay et al. (2016) and Simandl et al. (2017). Its usefulness may extend t exploration for peralkaline intrusions and pegmatite-related deposits. More data are needed to produce more robust discrimination diagrams.

Summary

1) The Mount Brussilof fersmite occurrence is characterized by strongly-zoned, euhedral crystals growing on the walls of cavities or enclosed in a dolomite matrix. It shares similarities with niobate mineral occurrences reported in 'alpine clefts' and differs texturally from fersmite observed in carbonatite-related N mineralization. Although this fersmite occurrence is too small to be of economic interest, it suggests that Nb and REE were locally transported in fluids along permeable, structurally controlled zones along the Kicking Horse rim in southeastern British Columbia.

2) Zoning in the Mount Brussilof fersmite crystals may reflect variations in the composition of fluids from which they formed.

3) The higher concentrations of LREE in the Aley carbonatite fersmite relative to the Mount Brussilof fersmite most likely reflects relative concentrations of LREE in these fundamentally distinct fersmite-forming systems.

4) Fersmite can be successfully used to complement minerals of the pyrochlore supergroup and minerals of the columbite-tantalite solid solution series as a direct indicator mineral for deposit targeting.

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