The Petrography, Geochemistry and Mineral Chemistry of the Fir Carbonatite System, east-central British Columbia: An Update of Current Knowledge with Implications for deposit modelling

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1. Background

The Fir carbonatite system is hosted by strongly metamorphosed strata of the Horsethiefcreek group in the Monashee Mountains of British Columbia (Figure 1) and contains an indicated + inferred resource of approximately 60 Mt grading 190 ppm and 1500 ppm of Ta_2O_5 and Nb_2O_5, respectively (Technical Report on Mineral Resource Update; June, 2012). The carbonatites form a system of concordant and multiply folded sills that can reach up to 80 m in thickness. They are exposed at surface only in a few places (Figure 2) and the bulk of the available information was obtained from HQ drill core examination (>50 km drilled).

It is one of many carbonatite-alkaline rock occurrences in the Canadian Cordillera, which received much attention in recent years both from the petrologic and the economic points of view as the market conditions were favourable for commodities typically hosted by them. As a consequence the research on the petrogenesis of these rocks has expanded significantly during this time, certainly owing to the increased exploration activities which basically confirmed and extended the great diversity of this rock association. A generalization about their petrogenesis and mineralogy (i.e., ore potential and ore types) is only possible to a very limited degree and reliable analogies for deposits hosted by these rocks that would support and facilitate exploration work and resource modelling are scarce. A detailed examination of individual occurrences and deposits is therefore obligatory.

The petrogenetic studies of carbonatite-alkaline rocks in the Canadian Cordillera are particularly challenging because of the high degree of deformation and metamorphism (amphibolite facies), which certainly overprinted and modified primary magmatic features. These could contain information about processes that can form economic deposits of, for instance, Ta and Nb in carbonatites.

In order to produce a sufficiently accurate deposit model a wide range of structural and mineralogical information had to be acquired and implemented. This poster presents data obtained chiefly from drill core samples that were examined by thin section petrography, geochemistry and mineral chemistry analysis. The entire data set includes a range of different carbonatite facies and associated rock types, but the focus in this presentation lies on the dolomite carbonatite, which constitutes an estimated 90 vol.% of the deposit and is the main ore rock.

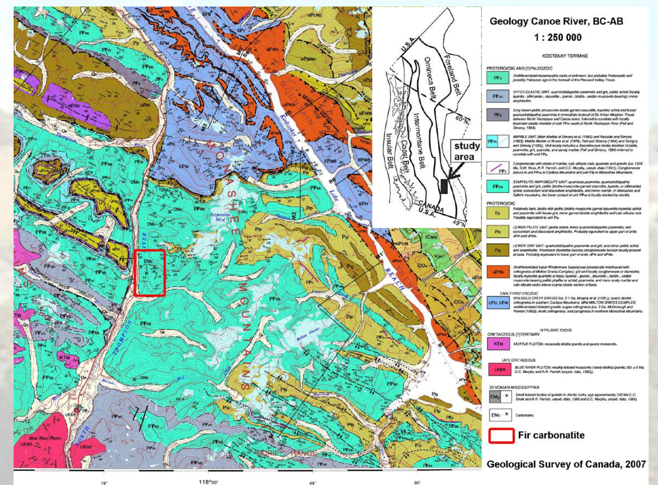


Figure 1: Geological map of the Monashee Mountains.

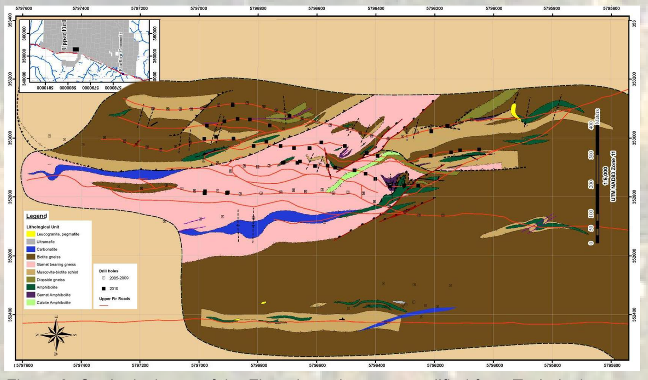


Figure 2: Geological map of the Fir carbonatite area; modified from Technical Report, June 2012.

2. Rock Textures

The most obvious structures observed in the drill core are textural differences (Figure "drill core", A-C) which can be a magmatic feature (porphyritic rocks, cumulates, etc) or the result of post-emplacement deformation.

A detailed examination of the textures and microstructures indicates that they formed under conditions where crystal-plastic deformation and grain boundary migration are the main deformational processes. The primary fabric is therefore interpreted as the result of high-grade metamorphism which transformed the original carbonatite into a carbonatite gneiss.

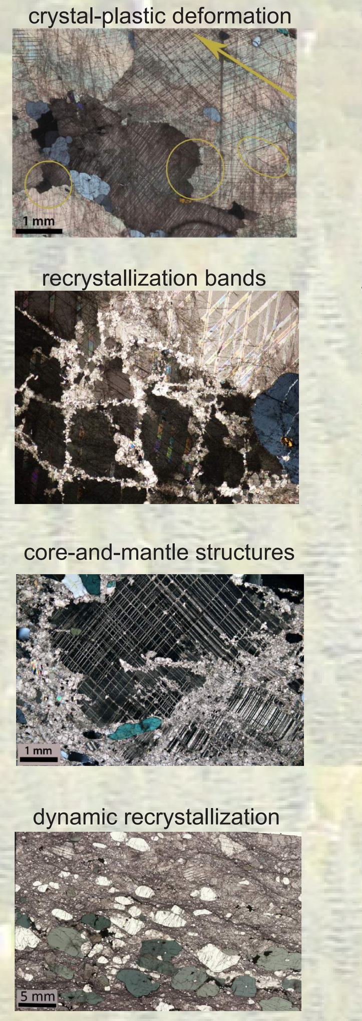
This gneissic carbonate rock was later overprinted by shear zones which developed in certain portions of the carbonatite. Characteristic microtextures are recrystallization bands, core-and-mantle-structures and an almost entirely dynamically recrystallized dolomite matrix (in order of increasing deformation intensity).

drill core

Textural classification: (A) gneissic; (B) porphyroclastic; (C) fine-grained, foliated.

core slab

thin section



Summary:

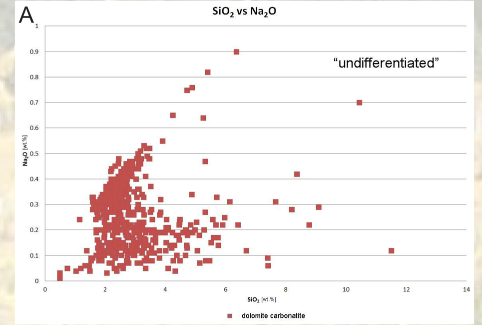
- observed textures are the result of metamorphism
- mylonitic shear zones post-date and overprint the metamorphic fabric
- they are large scale features that are traceable across the deposit,
- but texturally very heterogeneous

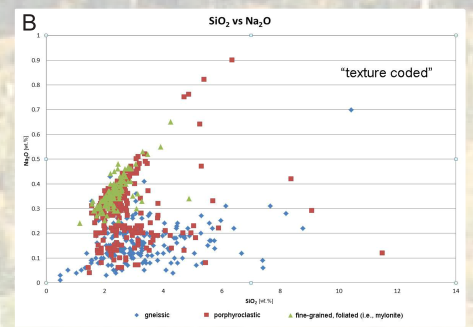
3. Whole Rock Geochemistry

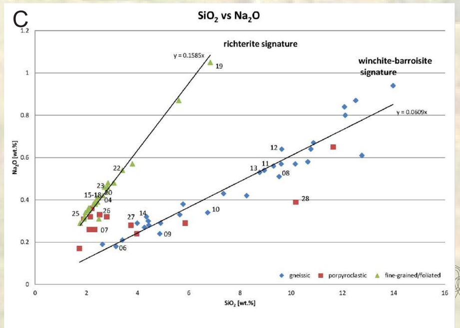
The data set that was collected during exploration work encompasses over 12,000 geochemical analyses for major- and trace-elements covering all relevant units of the deposit. Analyses from the dolomite carbonatite generally show a large scatter, but distinct clusters or trends are not very obvious and difficult to interpret without the help of more sophisticated methods.

However, the combination of geochemical data with petrographic observations (textural classification) improves significantly the quality of geochemical plots as can be seen on the example of SiO_2 vs Na_2O (see plots A-C). The "texture coded" plot distinguishes the different fabric types within the data set where fine-grained foliated samples form a distinct trend (plot B).

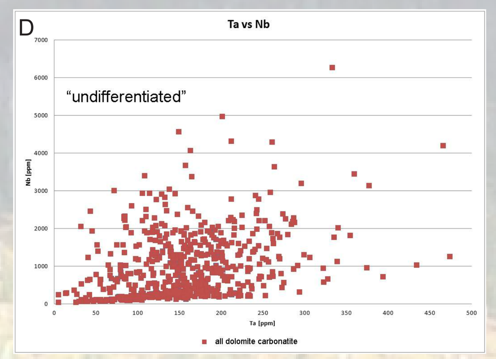
This geochemical feature is caused by the composition of the amphibole, which is the only major host of Na in this carbonatite. Plot C shows the "texture coded" whole rock geochemical analyses from drill core samples that were also collected for mineralogical work (sample numbers next to symbols). The trend lines correspond to the Na_2O/SiO_2 ratios calculated from electron microprobe analysis of the Na-amphibole species richterite and winchite-barroisite.

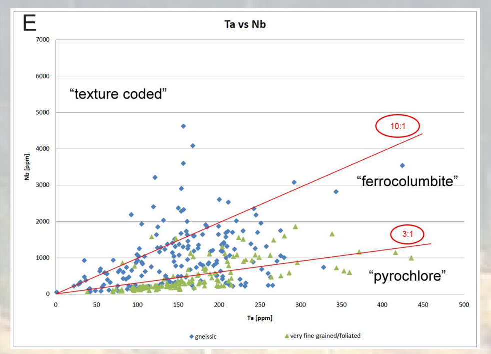






The "texture coded" plots can also be successfully used to distinguish between different ore types as shown in the plots below. The Nb-Ta mineralization occurs in the form of pyrochlore and ferrocolumbite which have Nb/Ta ratios of approximately 3 and 10, respectively. The data point distribution strongly suggests that the fine-grained foliated carbonatite contains pyrochlore whereas the carbonatite with a gneissic fabric has abundant ferrocolumbite.





Summary:

- **mylonitization was controlled by the composition of the dolomite carbonatite**
- **mylonitized carbonatite contains predominantly richterite and pyrochlore**
- **gneissic rocks carry winchite-barroisite and ferrocolumbite**

There are many more variations in the geochemical data set (e.g., P_2O_5, REE, MnO, Sr, etc.) which correlate well with mineralogical information and possibly indicate the presence of two different carbonatite facies.

The composition of dolomite (85 vol.% of rock; fabric controlling mineral) shows variations that probably also controlled its competency during shearing causing strain partitioning into specific zones.

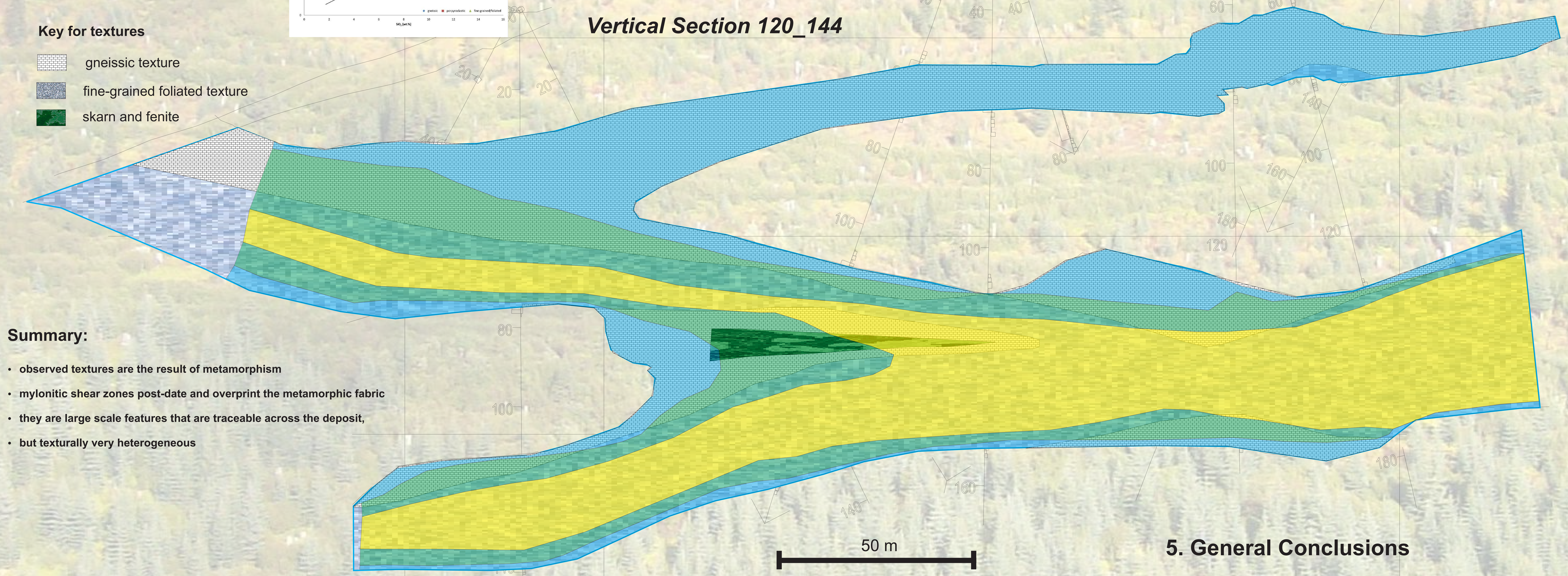
Vertical Section 120_144

Key for textures

- gneissic texture
- fine-grained foliated texture
- skarn and fenite

Key for Nb-Ta mineralization

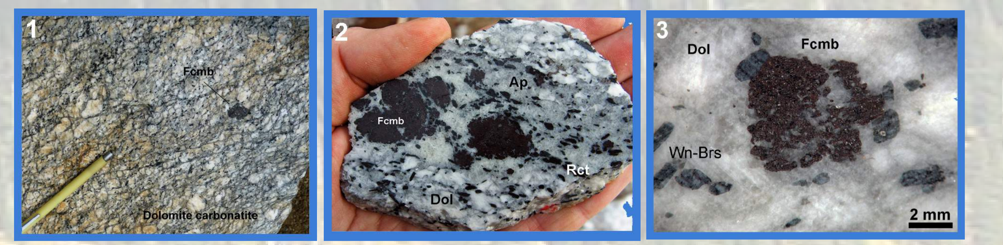
- ferrocolumbite zone (fcmb)
- mixed zone (pcl+fcmb)
- pyrochlore zone (pcl)



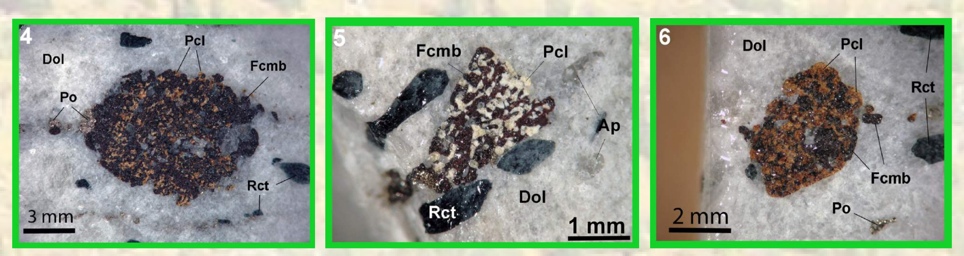
4. Mineral Chemistry - Pyrochlore

In order to develop the best possible process flow sheet for ore recovery and hydro-metallurgical processing it is important to understand the exact composition of the Nb-Ta ore. The Nb-Ta mineralization in the Fir carbonatite system is relatively simple and consists of pyrochlore and ferrocolumbite which, however, occur in several modes (see illustrations 1 - 9). This great variety cannot be detected in the geochemical data or resolved in textural logs but the end-members pyrochlore and ferrocolumbite are reasonably well distinguished.

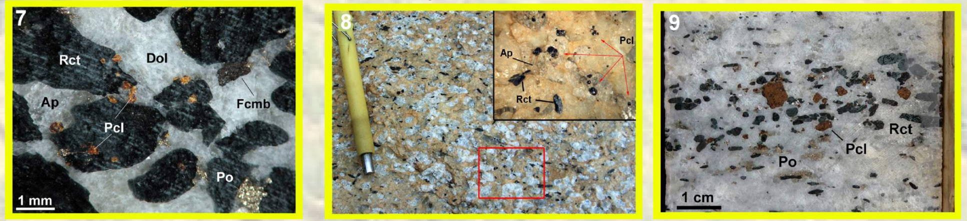
Ferrocolumbite



Pyrochlore and Ferrocolumbite



Pyrochlore



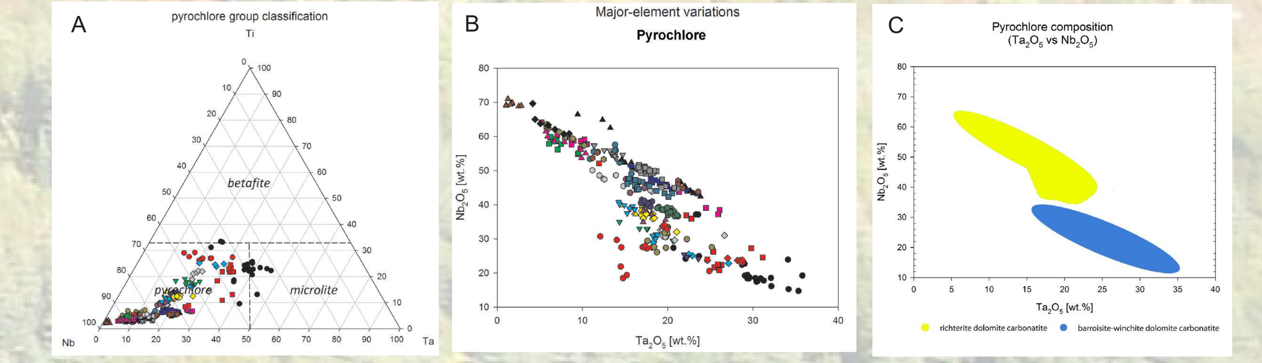
Mineral abbreviations for all illustrations: Ap = fluorapatite, Dol = dolomite, Fcmb = ferrocolumbite, Po = pyrrhotite, Rct = richterite, Wn-Brs = winchite - barroisite.

Although the Nb-Ta mineralization includes two phases, the emphasis lies on the pyrochlore which is the main host of Ta in the Fir carbonatite. It has a wide range in composition and covers a large portion of the pyrochlore classification diagram (diagram A) and the entire compositional trend of magmatic pyrochlore with respect to Nb and Ta (plot B below).

The composition, however, is far more restricted within the various modes which are often associated with carbonatites with a particular texture or amphibole species:

The pyrochlore with the highest Ta concentrations (i.e., microlite) is predominantly found in gneissic, winchite-barroisite-bearing carbonatites where it forms minute inclusions in ferrocolumbite (blue in plot C below). This mode is volumetrically of minor importance.

The majority of the pyrochlore mineralization forms abundant discrete crystals from 100 µm to 5 mm in size which are found in the often mylonitized, richterite-bearing dolomite carbonatite (yellow in plot C below).



5. General Conclusions

- **the availability of large amounts of data routinely collected during resource development can be utilized to improve the level of confidence of the deposit model**
- **geochemical data can now be fairly well correlated with mineralogical information and implemented in the deposit model**
- **the presence of two major carbonatite facies with different mineralization types suggests a magmatic origin of these features which encourages further petrogenetic studies on this deposit.**

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