



New investigations of the REE-Nb carbonatite deposits of southern Ravalli County, Montana, USA



Sarah Risedorf¹, Christopher H. Gammons¹, Peter Meistrick²

¹Montana Technological University, Butte; ²U.S. Critical Materials, Salt Lake City

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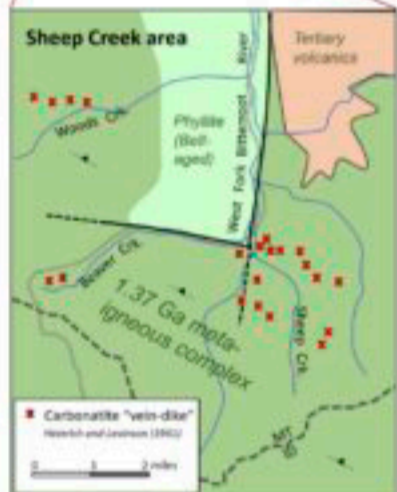
Purpose of Study

Domestic sources of REE's and critical metals are needed to support U.S. energy independence and the transition to a green economy. This study is looking in more detail at carbonatite-associated REE-niobium deposits in the Sheep Creek area of SW Montana. These deposits have been known since the 1960s (Crowley, 1960; Heinrich and Levinson, 1961), but very little modern work has been conducted since.

Location and Geology



Sheep Creek (circled) is located within the Montana-Idaho Alkalic Belt (MIAB). The MIAB contains several alkaline igneous complexes and REE-Th-rich mineral deposits.



Dozens of small carbonatite occurrences exist in the district. They are located within a 1.37 Ga meta-igneous complex consisting of amphibolite, biotite-hornblende gneiss, diabase, and augen gneiss. This suite of rocks extends to the SE into Idaho where similar REE-Nb-rich carbonatites exist. Meta-sedimentary rocks of the Belt Supergroup and Tertiary volcanic rocks to the north are unmineralized. The age of the carbonatites is up for debate, and will be addressed in further work.

Mineralogy

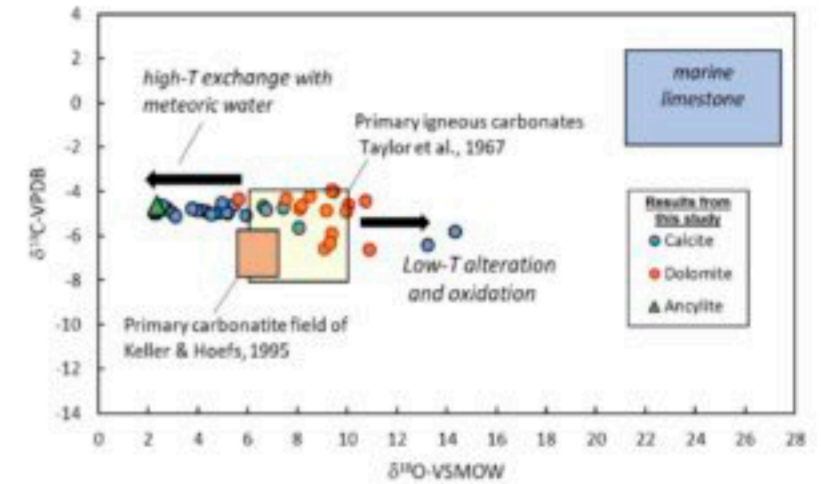


Most common matrix minerals
Calcite, dolomite, quartz
Barite, apatite, magnetite
Actinolite $\text{Ca}_2(\text{Mg,Fe})_7\text{Si}_8\text{O}_{22}(\text{OH})_2$
Phlogopite $\text{K}(\text{Mg,Fe})_3(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$
Celsian $\text{BaAl}_2\text{Si}_2\text{O}_8$

Most common REE-Nb minerals
Allanite $(\text{Ca,REE})_2(\text{Al,Fe})_2\text{Si}_2\text{O}_7(\text{OH})$
Ancyrite $(\text{REE})\text{Sr}(\text{CO}_3)_2(\text{OH})\cdot\text{H}_2\text{O}$
Bastnaesite $\text{Ce}(\text{CO}_3)_2\text{F}$
Monazite $(\text{REE})\text{PO}_4$
Columbite $\text{Fe}(\text{Nb,Ti})_2\text{O}_6$
Nb-rich rutile $(\text{Ti,Nb})\text{O}_2$
Aeschynite $(\text{REE})(\text{Nb,Ti})_2(\text{O,OH})_6$
Unidentified REE-(Nb) silicates

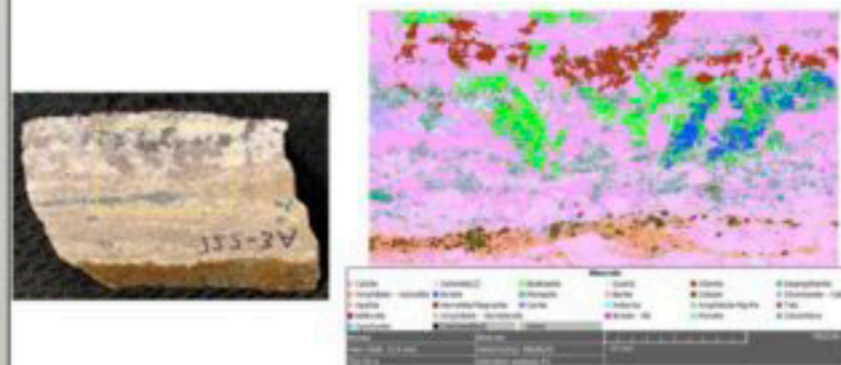
Sulfide minerals
Pyrite, pyrrhotite, chalcopyrite, molybdenite, siegenite, cobaltite

Carbonate Isotopes



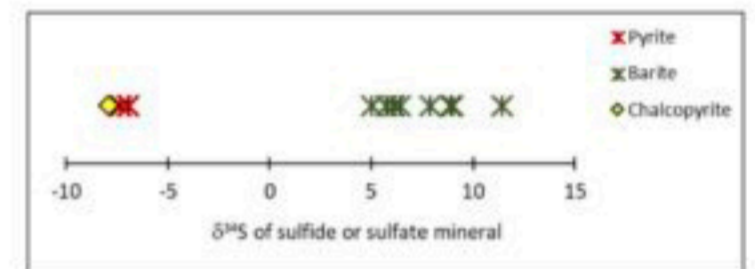
Most dolomite-rich carbonatite samples at Sheep Creek have C- and O-isotope values that plot near or within the primary igneous carbonate field of Taylor et al. (1967). The calcite-carbonatites, as well as one ancyrite-rich sample, have similar $\delta^{13}\text{C}$ values as the dolomites, but are depleted in $\delta^{18}\text{O}$. This type of pattern could be explained by high-temperature (> 200°C) interaction with meteoric water (see Andersen et al., 2019). Carbonatites that have been strongly weathered and oxidized have heavier $\delta^{18}\text{O}$ values due to low temperature isotopic exchange with groundwater.

Scanning Electron Microscopy



Automated SEM-EDS data are being collected using TIMA. In this thin section, 24 minerals were identified, although some of the rare minerals need confirmation with EPMA. The main REE minerals in this sample are allanite (red), bastnaesite (bright green), monazite (dark green), and a REE-(Nb)-silicate (blue), possibly biraite or chevkinite.

Sulfur Isotopes

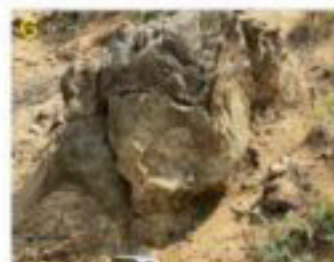


The S-isotopic composition of barite (n = 8) range from +5 to +11.4 ‰, as compared to 1 chalcopyrite and 3 pyrite samples, which range from -6.9 to -7.9 ‰. The isotopic separation between coexisting sulfide and sulfate minerals is consistent with equilibration at temperatures between 400 and 550°C. This temperature range may represent the magmatic/hydrothermal transition for the cooling carbonatite magmas at Sheep Creek.

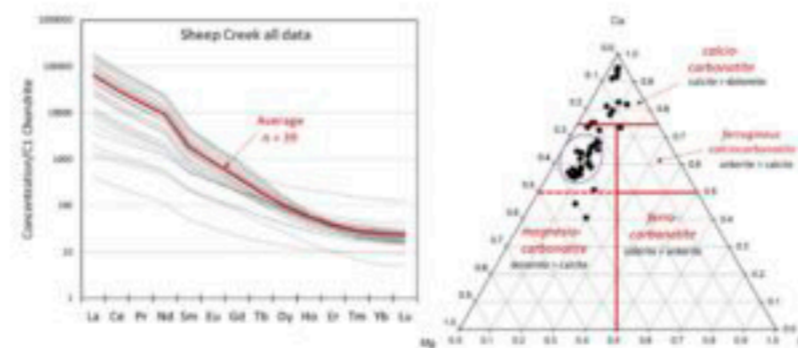
Rock types



Photos A, B, and C show how the carbonatites crop out in the field. The rusty weathering, dike-like carbonatites are often flanked by a biotite-rich fenite envelope (labeled above). Photos D, E and F are three distinct rocks of the meta-igneous complex. Veinlets cutting diabase in E are actinolite rich. Photo G (right) shows strong deformation of a carbonatite body along with fenitized (biotite-rich) wallrock.



Geochemistry



During the 2021 field campaign, 40 bulk samples of different outcrops of carbonatite and altered wallrock were sent to Activation Laboratories (Actlabs) for major and trace element analyses. The left diagram shows a very strong enrichment in the light REE (La through Eu), with no obvious Ce or Eu anomalies. In terms of their bulk chemistry, the samples show a cluster of dolomite-rich compositions (purple circle, right diagram) with a trend towards the calcite endmember that corresponds to higher REE concentrations.

Further Work

With funding from an Army Research Lab grant to MTU, I hope to complete the following tasks in Year 2:

- More automated SEM-EDS (CAMP lab, MTU)
- LA-ICP-MS and electron microprobe analysis (USGS lab, Denver)
- Geochronology, including Re-Os of molybdenite and ⁴⁰Ar-³⁹Ar of biotite.

References

Andersen, A.K., Larson, P.B., Cosca, M.A. (2019) C-O stable isotope geochemistry and ⁴⁰Ar/³⁹Ar geochronology of the Bear Lodge carbonatite stockwork, Wyoming, USA. *Lithos*, 324, 640-660.
Berg, R. B., 1977, Reconnaissance geology of southernmost Ravalli County, Montana: MBMG Memoir 44, 39 p.
Crowley, F. A., 1960, Columbian-rare-earth deposits, southern Ravalli County, Montana: MBMG, Bulletin 18, 47 p.
Gammons, C. H., 2020, The Montana-Idaho Alkalic Belt: An exploration target for critical metals and industrial minerals: MBMG Special Publication 121, 151-157
Heinrich, E. W., and Levinson, A. A., 1961, Carbonatic niobium-rare earth deposits, Ravalli County, Montana: *American Mineralogist*, v. 46, p. 1424-1447.
Taylor Jr., H.P., Frechen, J., Degens, E.T. (1967) Oxygen and carbon isotope studies of carbonatites from the Laucher See District, West Germany and the Alno District Sweden. *Geochim. Cosmochim. Acta* 31, 407-430.