DEPARTMENT OF GEOLOGICAL, ENVIRONMENTAL, AND PLANETARY SCIENCES

Lithium Diffusion Experiments on Grossular Garnet

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Background

- Timescales for metamorphic fluid flow events are not well understood.
- It is important to be able to understand the geologic processes involved with fluid, as it is the cause of the melting beneath arc volcanoes, and ore deposits are created when elements dissolved in fluid traveling through rocks are precipitated.
- The way to measure how fluid interacts with rocks is by measuring the diffusivity of elements from the fluid into minerals in the rocks.
- Specifically, this study will determine the diffusivity of Li within garnet to achieve this goal.

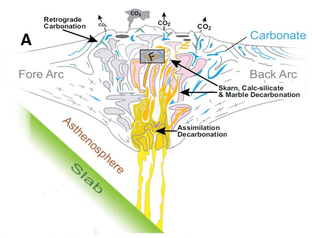


Fig. 1: Fluid-Rock Interactions
The path of fluid that causes decarbonation reactions in yellow. Fluid removes CO_2 from mineralogy, which escapes as a gas at the surface or gets reincorporated into the mineralogy with retrograde carbonation. (Ramos et al., 2020)

Introduction

- Garnet is abundant and preserves chemical zoning
- Lithium is a rapid diffuser and is fluid mobile
- Measurement of lithium diffusion profiles in garnet can tell us about fluid flow duration and periodicity (Penniston-Dorland et al., 2020)
- Work on almandine-pyrope rich garnet indicates Li diffuses via two separate mechanisms.
- Diffusivities on the order of 10^{-19} for the faster mechanism and 10^{-20} for the slower (D unit: $^{m^2}/_{s}$) (Hoff, 2025).
- Sample: Jgros (91% grossular) Jeffrey Mine, Asbestos, QC

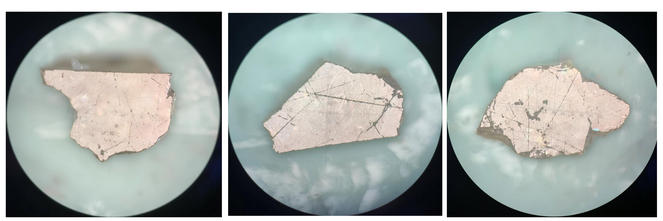


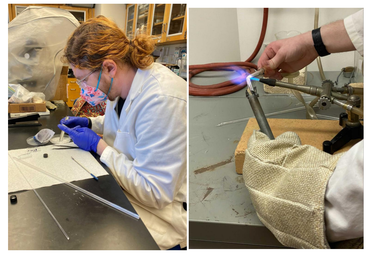
Fig. 2: Samples
Left side is Jgros 2-week, middle is Jgros 3-week, and right side is Jgros 4-week. Pictures taken using a reflected light microscope.

Hypothesis

Hypothesis: Lithium will diffuse more slowly within grossular than other primary end members of garnet.
Null-Hypothesis: Lithium diffuses at the same rate or faster in grossular than other primary end members of garnet.

Methods

- Jgros grains are polished and cleaned
- Polished grains are inspected for any fractures, inclusions or scratches
- 3 charges are filled with powdered spodumene, and 2 Jgros samples
- Charges are placed in furnace at 650˚ C
- One charge removed after 2, 3, and 4 weeks
- One sample from each duration and the starting Jgros were analyzed using a depth profiling LA-ICP-MS method



Figs. 3,4: Filling and sealing the charges
On the left (fig. 3), I am filling the charges with spodumene and 2 Jgros samples each. On the right (fig. 4), I am sealing the fused quartz tube under a vacuum to remove any air from the tube.

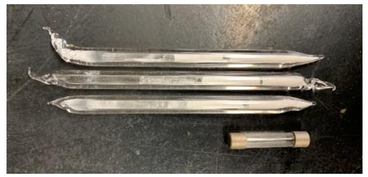
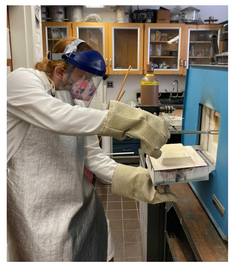


Fig. 5: Experiment Charges
Sealed fused quartz tubes with a fuse for scale. Each tube is ~10 cm long, and filled with Jgros samples surrounded by the lithium source.





Figs. 6,7: Placing the charges in the furnace
Above (fig. 6), I am placing the charges into the furnace while wearing fire safety gear. To the right (fig. 7), is a picture of the charges within the furnace

Analysis

- LA-ICP-MS data were exported and analyzed using Iolite software to generate a table of lithium concentration as a function of time.
- Conversion rate of 0.7 µm/s is used to convert the time to depth. An average measured diffusion profile is made for each Jgros experimental run product (ERP).
- The diffusion equation used:

$$C = C_{S1} + (C_{i1} - C_{s1})erf\frac{x}{\sqrt{4D_1 t}} + C_{S2} + (C_{i2} - C_{s2})erf\frac{x}{\sqrt{4D_2 t}}$$

  - CS is the concentration of Li at the surface (ppm), Ci is the internal concentration of Li (ppm), x is depth (m), t is time (s), and D is diffusivity ($^{m^2}/_{s}$)
- Uncertainty is calculated using the standard deviation of the average profiles, addition error propagation is used for the overall average uncertainty

Results

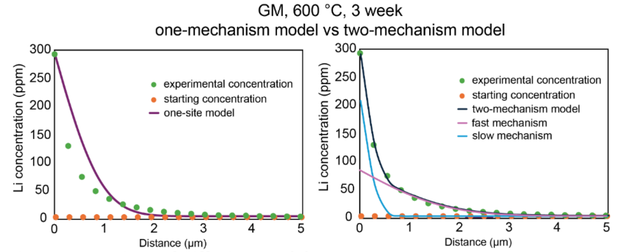


Fig. 8: Comparison of Diffusion Models
Comparison of one-mechanism (left) and two-mechanism (right) diffusion equation models (Hoff, 2025). The two-mechanism model has a better fit.

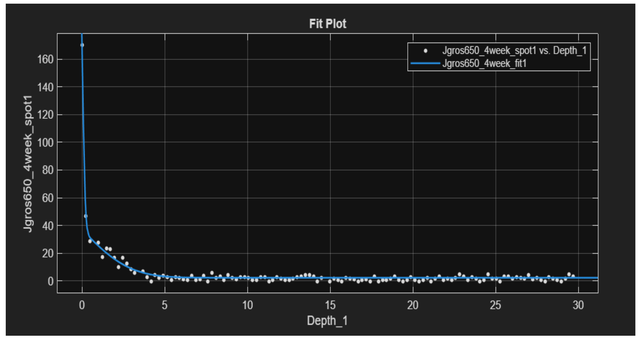


Fig. 10: Two-Mechanism diffusion Model
Example of a diffusion profile modeled in MATLAB software of a Jgros ERP for the 4-week duration. White dots the are concentration of Li (ppm) at the calculated depth. Blue line shows the modeled diffusion profile.

	D1 (m^2/s)	StDev D1	D2 (m^2/s)	StDev D2
2 week	3.51E-18	3.07E-18	1.81E-19	3.40E-19
3 week	3.65E-18	3.70E-18	4.94E-19	7.49E-19
4 week	2.90E-18	2.95E-18	2.46E-19	3.55E-19

Fig. 11: D Values Across Traces
Calculated diffusion rates and standard deviation across the 6 Jgros ERP for each duration. Addition error propagation for StDev was used as overall error in Figs. 12,13.

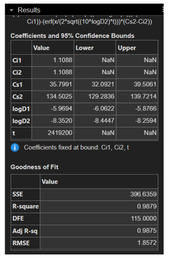
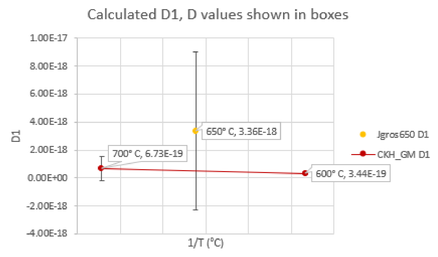
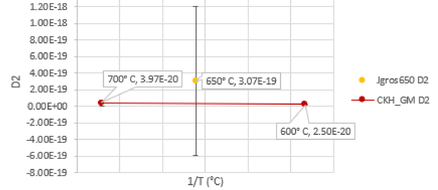


Fig 9 (left): Results Field in MATLAB: Top of the table displays values given to variables, Log(D1) and Log(D2) and 95% confidence bounds. Bottom of the table shows the goodness of fit for the modeled profile. The software adjusts the values of variables to minimize the R-square value.





Figs. 12,13: Arrhenius Diagrams
Upper figure (fig. 12) showing D2 versus 1/T to easily visualize relationships between D values. Lower figure (fig. 13) shows D1. Both compare average slow and fast D for Jgros to average slow and fast D of a pyrope-almandine sample from Gore Mountain, NY (CKH_GM). Data for CKH_GM was gathered by Dr. Hoff (Hoff, 2025). A higher D value means a faster diffusion rate.

Conclusion

- The ranges of Jgros D1 and D2 overlap with the D1 and D2 values for CKH_GM, which is a pyrope-almandine garnet.
- This data does not support the hypothesis that Li would diffuse slower in grossular garnet than other garnet species.
- Garnet chemistry is not a determining factor for the diffusivity of lithium in garnet.

References

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