Effect of Depth on Metamorphic Decarbonation in the Sierra Nevada Batholith: Isotopic Analysis of Carbon and Oxygen

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Introduction

CO_2 degassing in metamorphic environments is shown to be a significant input flux in the global carbon cycle, having critical environmental implications and perturbing Earth's climate (Stewart and Shimizu, 2026). The Sierra Nevada batholith is a compelling area to study as the existing calcareous rocks underwent contact metamorphism in its expansive region (Kerrick, 1970). While we know that metamorphism releases CO_2 it remains unconstrained if and how the amount of CO_2 released is depends on the depth at which metamorphism occurred. In the southern part of the Sierra Nevada batholith, different depths of igneous emplacement (from >8 kbar to 3 kbar according to Nadin and Saleeby, 2008) are exposed at the surface. This makes the Sierra Nevada batholith an ideal place to study the effects of depth on CO_2 release.

We are analyzing the Sierra Nevada Batholith region by analyzing the effect of pressure on Carbon and Oxygen isotopes, as well as the difference in isotope values in individual hand samples.

Geologic Setting

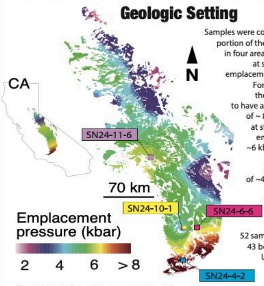


Figure 1. Map of the Sierra Nevada Batholith

Samples were collected across a >100 km portion of the Sierra Nevada batholith in four areas. The samples collected at stops 1 through 4 were at emplacement pressures of >8 kbar. For purposes of this project, these samples are assumed to have an emplacement pressure of ~ 8 kbar. Samples collected at stops 5 through 8 were at emplacement pressures of ~6 kbar. Samples collected at stops 9 and 10 were at emplacement pressures of ~4 kbar. Samples collected at stop 11were at emplacement pressures of ~7 kbar.

52 samples were collected with 43 being kept at Florida State University. Some samples wre drilled in multiple areas, for a total of 56 samples.

Carbon and Oxygen Isotope Behavior

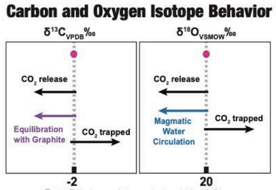


Figure 2. Carbon and Oxygen Isotope Value Shifts.

The isotope values of $\delta^{13}C$ and $\delta^{18}O$ vary for a wide range of reasons. CO_2 release at high temepatures may drive residual $\delta^{13}C$ and $\delta^{18}O$ to more negative values. The equilibration with graphite also drives $\delta^{13}C$ isotope values to be more negative. The addition of meteoric/magmatic water drives $\delta^{18}O$ isotope values to be more negative. When $\delta^{13}C$ and $\delta^{18}O$ isotope values become more positive, it is because there is CO_2 trapped in the system.

Results

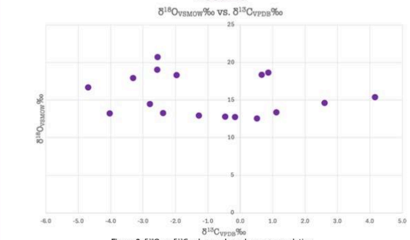


Figure 3. $\delta^{18}O$ vs. $\delta^{13}C$ values, values show no correlation

Out of the 56 samples that were run through an IR-MS at the National High Magnetic Field Laboratory, 17 gave sufficient carbonate data to analyze. The resulting data are plotted in Figure 3, and were found to have no correlation between the $\delta^{18}O$ and $\delta^{13}C$ isotope values. The samples collected at the pressure emplacement of ~4 kbar provided no carbonate data. No evidence of a decarbonation relationship is found along the length of the Sierra Nevada Batholith. The $\delta^{13}C$ isotopes have a wide range with no discernable relationship with pressure.

SN24-6-6

Sample	$\delta^{13}C$ ‰	$\delta^{18}O$ ‰
A	-4.68	16.6530
B	2.62	14.6066

SN24-4-2

Sample	$\delta^{13}C$ ‰	$\delta^{18}O$ ‰
A	-2.8	14.4557
B	-4.02	13.2156

Two different sections of the SN24-6-6 and SN24-4-2 samples were drilled for isotopic analysis. These different sample sections were chosen because there are visibly different minerals within these hand samples. The $\delta^{13}C$ and $\delta^{18}O$ isotope values from each drilled section in the hand samples show variations within centimeters. It can be deduced that there was only very local isotopic equilibrium reached in the system, making the hand samples heterogeneous rather than homogenous. These differences in isotope values could be due to numerous factors, including whether fluid infiltrated the system, the distribution of graphite, or the proximity to magmatic intrusions.

Pressure and Oxygen

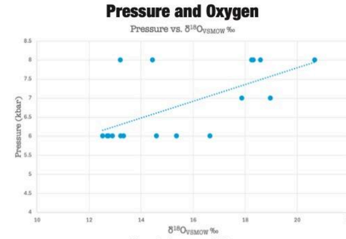
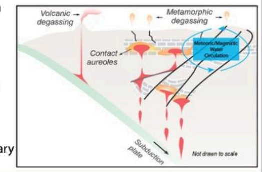


Figure 4. Pressure vs. $\delta^{18}O$

A positive correlation was found between pressure and the $\delta^{18}O$ isotope values. The higher the pressure, the higher the $\delta^{18}O$ VSMOW value. The low pressures correspond with shallower depths of emplacement, and it can be suggested that enhanced magmatic water circulation in contact aureoles could be one of the causes of the $\delta^{18}O$ depletion in shallower depths. Magmatic water circulation and infiltration is when water escapes from the magma chamber and flows through the nearby carbonate sedimentary rocks.



Conclusion

- No correlation between $\delta^{18}O$ and $\delta^{13}C$ isotope values
- No evidence of a relationship between pressure and $\delta^{13}C$
- Significantly negative $\delta^{13}C$ values (possible equilibration with graphite)
- Positive correlation between pressure and $\delta^{18}O$
  - Due to magmatic water infiltration
- Hand samples are heterogeneous, very local equilibrium was reached in the system

References

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