Fluids in Subduction Zones: Production of Jadeite in Panoche Pass

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I. Introduction

The metagraywacke rocks of Panoche Pass are coherent exhumed rocks in the Franciscan Complex, a fossil subduction zone, in California. The majority of the metagraywacke in the region contains albite, calcite, quartz, phengite, chlorite, titanite and minor amounts of lawsonite. However, there are irregular shaped mappable regions of metagraywacke which contain jadeite, more abundant lawsonite, and rutile instead of titanite. Jadeite and lawsonite are diagnostic minerals for high pressure, low temperature conditions found within subduction zones. The occurrence of these minerals in these irregularly shaped map patterns, but not throughout the region, suggests a role for fluid in driving the formation of jadeite and lawsonite rather than temperature, pressure, or chemical composition. These two mineral assemblages suggest that the rocks experienced different fluid compositions during metamorphism. The loss of calcite from the jadeite-bearing rocks suggests that CO_2 is released during metamorphism which has implications for our understanding of the carbon cycle. This study uses point counting, EPMA major element oxide data, and the TWQ thermodynamic modeling database to determine fluid compositions in equilibrium with the minerals present and to quantify the amount of CO_2 released during metamorphism of the jadeite-bearing rocks.

Hypothesis: The formation of jadeite in these metagraywackes requires decarbonation reactions driven by H_2O-rich fluid infiltration.

Null Hypthesis: The formation of jadeite in these metagraywackes does not require decarbonation driven by H_2O-rich fluid infiltration.

5X
PPL

5X
XPL

II. Geologic Background

Figure 1: This is a map of Panoche Pass. The numbers represent the sample locations. The striped region represents the regions in which jadeite appears (Ernst, 2011).

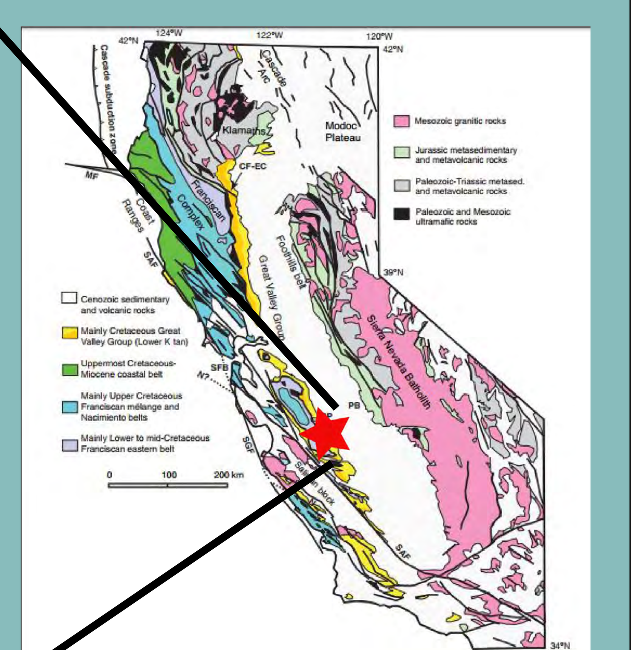


Figure 2: This is a geologic map of california. The colored regions outline the locations of the different belts of the Fransciscan Complex. (Ernst, 2011).

- Panoche Pass, located about 30 miles east of Monterey Bay, consists of coherent rocks that are found in the Diablo Range (a belt of the Franciscan Complex) (Ernst,1965). The Metagraywacke of Panoche Pass is divided into two different types of metagraywacke, jadeite-bearing, and jadeite-absent metagreywacke. P~ 6-8 kbar T~ 200-300 °C
- The jadeite-bearing metagraywacke occurs in irregular patterns
- Temperature, pressure and lithology cannot explain the patchy occurence of jadeite in Panoche Pass suggesting subduction zone fluid flow as the most likely cause of jadeite growth in these rocks.

III. Methods

Equilibrium fluid compositions were calculated for the jadeite-bearing metagraywackes using the thermodynamic program TWQ (Berman, 1991).

- Point Counting: 1200 points were identified by using energy dispersive x-ray spectroscopy (EDS) on the electron probe micro analyser (EPMA).
- EPMA: Wavelength dispersive spectroscopy (WDS) was used to determine major element composition of titanite, albite, rutile and calcite in the jadeite-absent rocks and albite, jadeite, titanite, and rutile in the jadeite-bearing rocks.
- X-ray fluorescence (XRF): XRF was used for analysis of major and trace elements in the PANalytical 2404 X-ray fluorescence vacuum spectrometer at Franklin and Marshall College.
- CO_2 Analyses: . CO_2 content was measured by dissolving approximately 0.5g of sample with 3M HCl. The samples were reacted with the acid, washed 3 times, then dried in an 80-degree oven for 4 days. The difference in mass is interpreted to be the loss of the carbonate components in the rock.

IV. Results

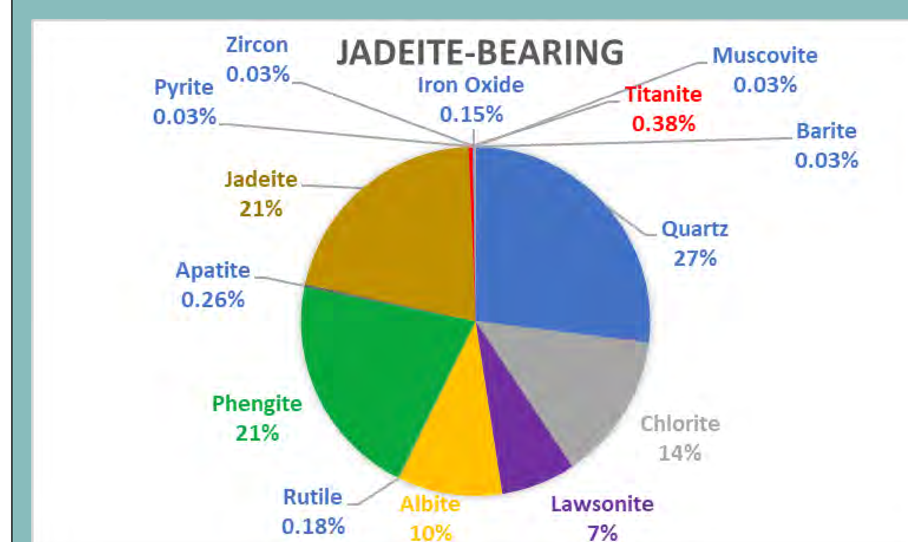


Figure 3: The combined point counting results from the three jadeite-bearing rocks are illustrated by this pie chart. It represents the sum of 3414 points.

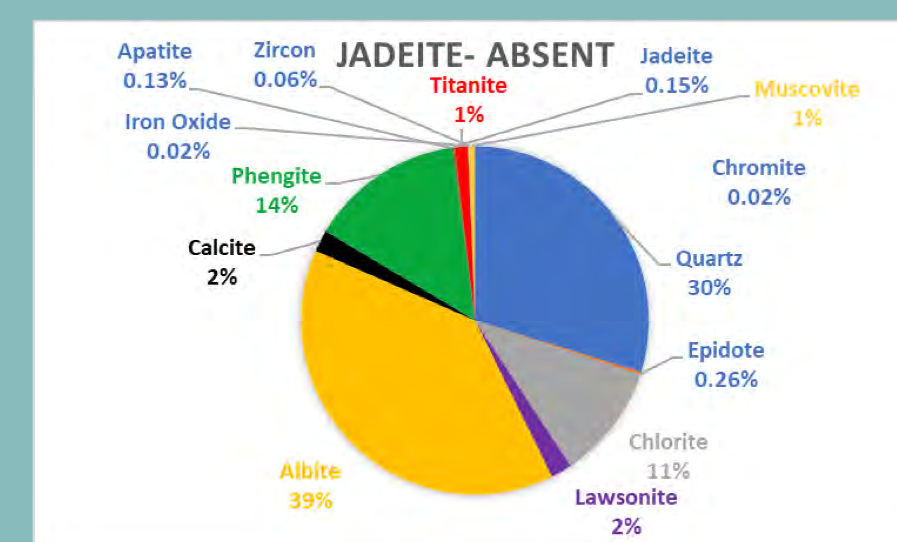


Figure 4: The combined point counting results from the four jadeite-absent rocks are illustrated by this pie chart. It represents the sum of 4619 points.

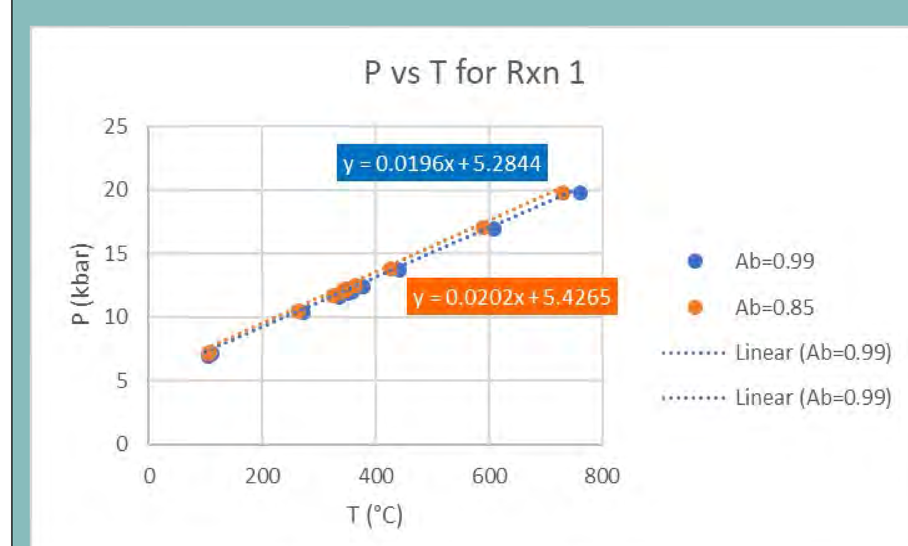


Figure 5: This graph displays the equilibrium pressure-temperature conditions calculated using the TWQ database using the range of plagioclase compositions (X_{Ab}) present in the rock. Jadeite is stable above the lines of equilibrium while albite is stable below them.

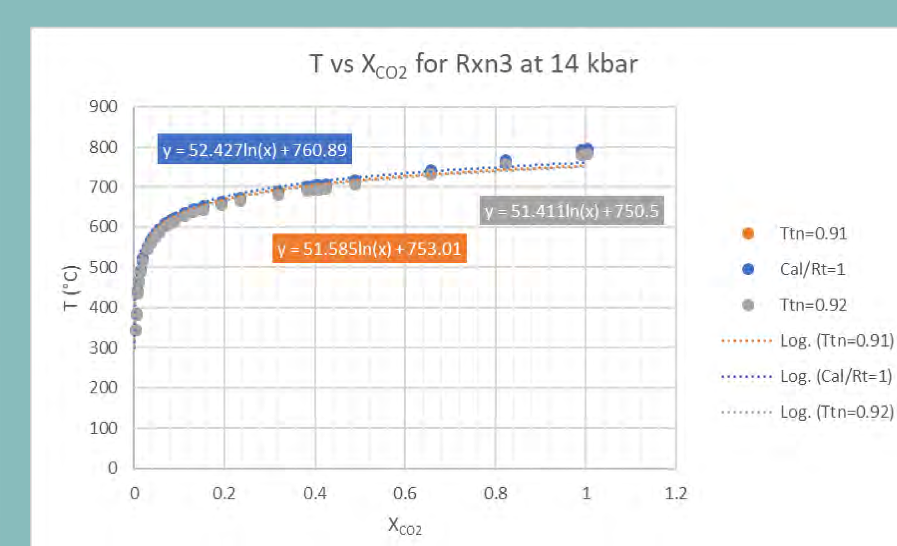


Figure 6: This graph displays the line of equilibrium above which, titanite and CO_2 are stable and below which, rutile, quartz and calcite are stable.

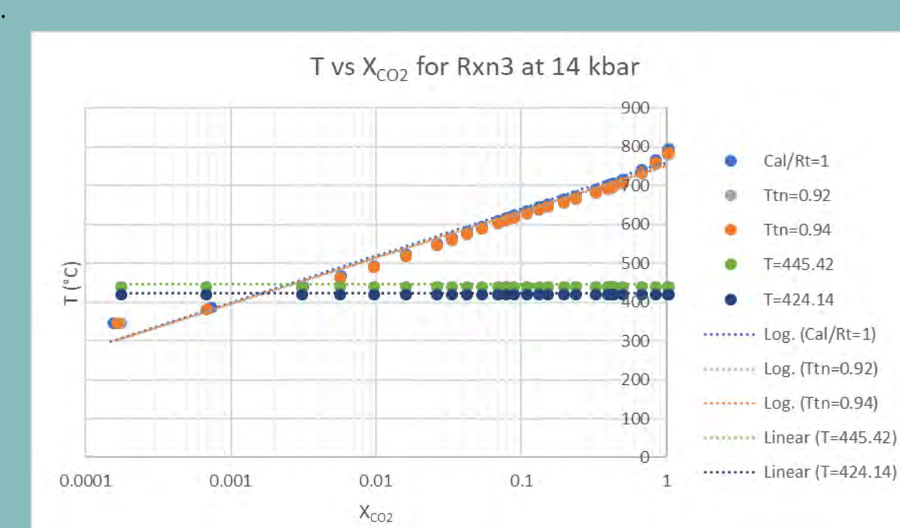
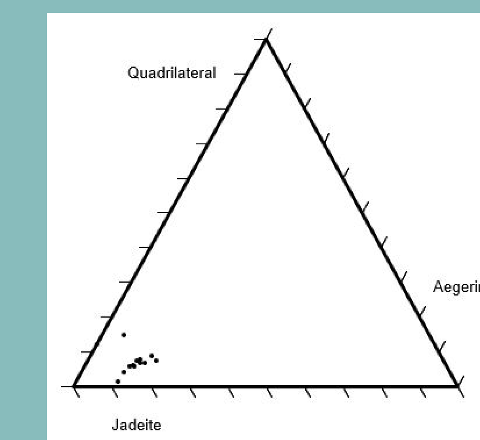


Figure 7: : The horizontal lines represent the stability of reaction 1, the inclined lines represent the stability of reaction 3. The intersection of these line sets represents the required fluid composition for metamorphism. X_{CO2} =0.0025

V. Discussion



- Mineral reactions that occurred in the rocks were determined by comparing the mineral modes in the jadeite-absent samples to those in the jadeite-bearing samples:

(1) $NaAlSi_3O_8 = NaAlSi_2O_6 + SiO_2$
Albite = Jadeite + Quartz

(2) $2\ Ca_2Al_3Si_3O_{12}(OH) + CO_2 + 5\ H_2O = 3\ CaAl_2Si_2O_8.2H_2O + CaCO_3$
2 Epidote + CO_2 + 5 H_2O = 3 Lawsonite + Calcite

(3) $CaTiSiO_5 + CO_2 = TiO_2 + CaCO_3 + SiO_2$
Titanite + CO_2= Rutile + Calcite + Quartz

(4) $Mg_4Al_4Si_2O_{10}(OH)_8 + 6\ CaCO_3 + 10\ SiO_2 = 4\ CaMgSi_2O_6 + 2\ CaAl_2Si_2O_8.2H_2O + 6\ CO_2$.
Chlorite + 6 Calcite + 10 Quartz = 4 Diopside + 2 Lawsonite + 6 CO_2

- Mineral modes were used to constrain the amount of reaction (on average) that occurred between the jadeite-absent and jadeite-bearing rocks. This is referred to as reaction progress and is calculated as $\xi=\Delta n/(\nu)$ (Rice and Ferry, 1982). Δn= change in moles of minerals. (ν) = stoichiometric coefficient. Minerals used to constrain ξ were: Rxn 1: jadeite; Rxn 2: epidote; Rxn 3: rutile; Rxn 4: calcite.
- Calculated lost CO_2 based on these calculations was 0.07 moles/100cm3.
- Estimated lost CO_2 using CO_2 analyses was 0.097 moles/100cm3. Calcite was consumed and CO_2 was lost by decarbonation reactions.
- The thermodynamic calculations of reactions 1 and 3 show that a fluid with a composition of X_{CO2}=0.0025 was necessary for this system to be in equilibrium and for jadeite and lawsonite to grow.

VI. Conclusion

- Point Counting and CO_2 analyses suggest loss of CO_2 due to reactions between jadeite-absent and jadeite-bearing rocks
- Equilibrium fluid composition is H_2O-rich (X_{CO_2}<0.025)
- Results confirm the hypothesis that loss of CO_2 was driven by infiltration of H_2O-rich fluid.
- By quantifying the loss of CO2 from the slab we can estimate the CO2 contributed to the mantle and better understand the global carbon cycle.

VII. Acknowledgements

I would like to thank my advisor Dr. Sarah Penniston-Dorland and her grad students Kayleigh Harvey, Nivea Magalhaes, and William Hoover for their assistance throughout this project, Dr. Phil Piccoli for assisting with data collection, and Dr. Alan Jay Kauffman for assisting with CO_2 analyses.

VIII. References

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