Evidence for Chemical Changes during Subduction Zone Metamorphism within the Catalina Schist

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Introduction

On Santa Catalina Island, California, the Catalina Schist consists of metamorphosed sedimentary and igneous rocks that were metamorphosed at sub-blueschist (lawsonite-albite) to amphibolite facies conditions (275°C - 750°C at 0.5 to 1.1 GPa) which correlates to subduction depths of 15 to 50km. Two locations (Figure 1) on the west side of the island have exposed meter-sized metaconglomerate blocks in a finer-grained mélange matrix that contain relict igneous clasts ranging in composition from felsic to mafic (Figure 2). These lawsonite-blueschist metaconglomerate clasts resemble unaltered igneous rocks but exhibit metasomatic alteration related to high P/T conditions.

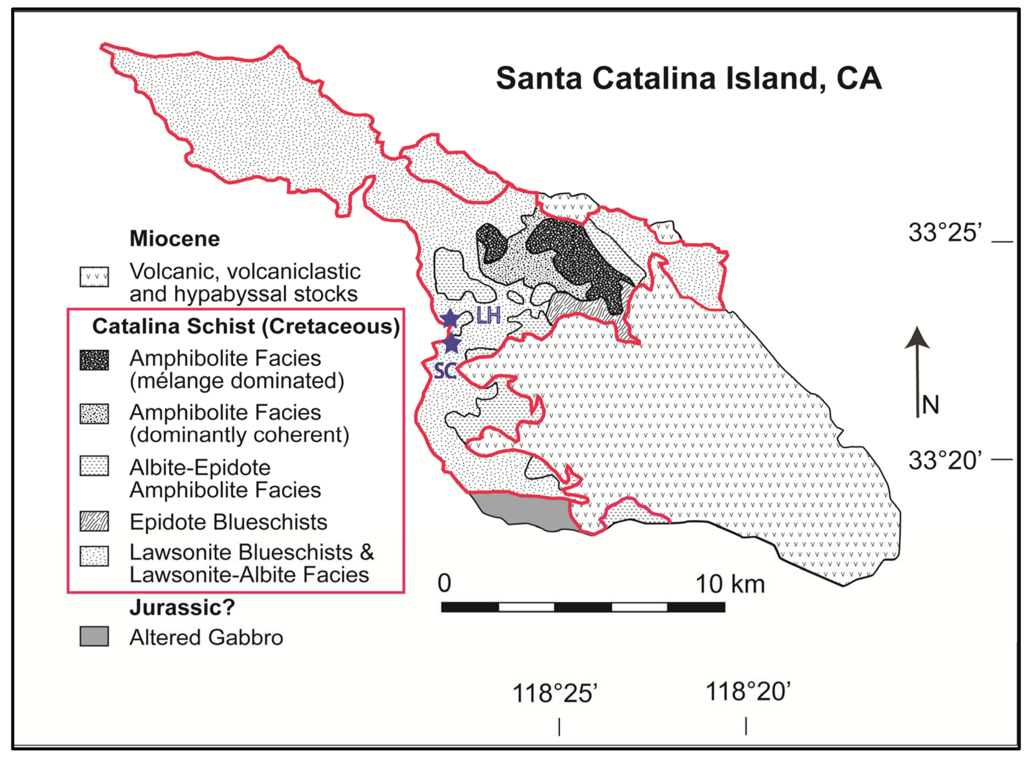


Figure 1: Geologic map of Santa Catalina Island with Catalina Schist outlined. Locations for this study noted with a star (After Grove and Bebout, 1995).

Veining (Figure 3) and alteration textures (such as metasomatic rind development) are pervasive in the Catalina Schist, providing evidence that there has been extensive fluid-rock interaction at within the subduction zone. A comparison of the major, minor, and trace element composition of the clasts to that of likely protolith material, the Willows Plutonic Complex, will give insight to the detailed chemical changes that have occurred in these rocks during subduction zone processes.

The Willows Plutonic Complex on Santa Cruz Island is interated to be a fragment of an island-arc terrane. The lithology of the rocks exposed within the complex varies from leucotonalites to hornblende gabbros (felsic to mafic, respectively). This range in lithology is similar to the clasts in the metaconglomerate blocks on the lawsonite-blueschist facies of the Catalina Schist. This similarity in lithology is one of the reasons why the WPC is presumed to be a protolith for the Catalina Schist.

Objectives

Samples for this study will include a suite of samples characterized by Tenore-Nortrup (1995) and samples I collected from the Catalina Schist in January of 2012. For this research, I propose to:

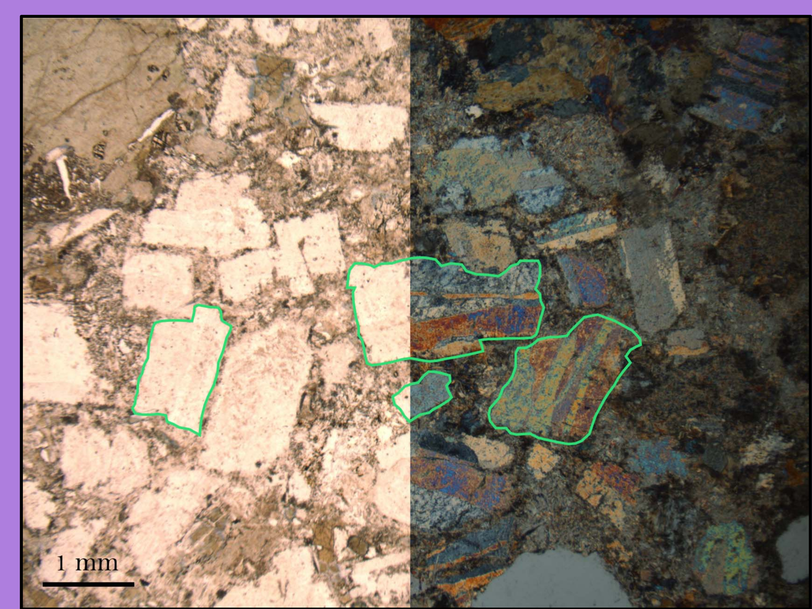
- Evaluate the hypothesis that the Willows Plutonic Complex (WPC) is a likely protolith for the metaconglomerate clasts by comparing the bulk-rock composition of relatively immobile major and trace elements of metamorphic igneous clasts to the bulk-rock composition of igneous rocks of the WPC;
- document the metamorphic reactions experienced by these rocks by examining minerals and replacement textures;
- determine the chemical changes and signatures left by the fluid interacting with these relict igneous clasts by making comparisons to this protolith, and;
- characterize which mineral phases or reactions are associated with the changes in composition.

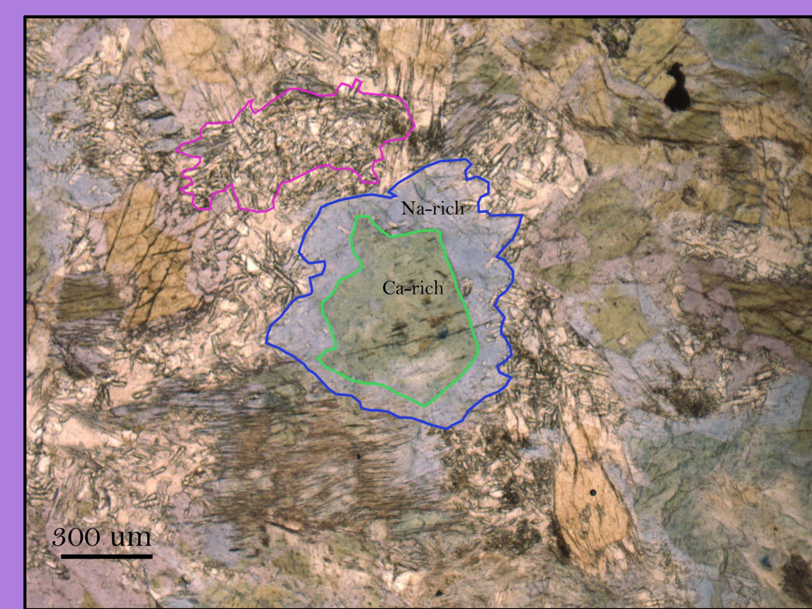
Hypothesis

H_0: There is no chemical difference between igneous rocks of the WPC and igneous clasts from the lawsonite-blueschist metaconglomerate blocks of the Catalina Schist

H_1: Differences in major, minor and trace elements will be observed between protolith and sampled material due to fluid-rock interactions. Particularly, I expect to see enrichments in the large ion lithophile elements (LILE: Cs, Rb, Ba, Pb, Sr), fluid mobile elements (FME: LILE plus Li), and rare earth elements (REE).

Figures 2 and 3: Field photos of metaconglomerate blocks within the lawsonite-blueschist facies on Santa Catalina Island. Figure 2 (left) is smaller metaconglomerate block that illustrates the range in igneous lithologies that can be found in the blocks. Figure 3 (right)shows a cross cutting vein in a metaconglomerate, providing evidence that these rocks had interaction with fluids.





Figures 4 and 5: Photomicrographs of a portion of the lawsonite-blueshists clasts. Figure 4 (left) in both PPL and XPL shows the replacement reaction of phengite from feldspar (outlined in green). Both the habit and polysynthetic twinning of the feldspar is retained. Figure 5 (right) in PPL illustrates the rimming of the new Na-rich amphibole (blue) around a relict igneous amphibole (green). Lawsonite grains can also be seen (magenta).

Willows Plutonic Complex

The basis for the assumption that the WPC is the likely protolith includes the: (1) age of WPC (Jurassic) verses the Catalina Schist (Cretaceous) ; (2) geographic closeness; (3) similar lithologic suite of rocks in both the WPC and Catalina Schist; and, (4) presence of genetically related saussarite gabbros on Santa Catalina Island to altered gabbros on Santa Cruz Island. To evaluate whether the WPC is the protolith for the Catalina Schist, the bulk rock trace element data was collected using solution ICP-MS methods and was normalized to the unaltered igneous rocks in the WPC. Elements that are thought to be immobile, REE and high field strength elements (HFSE), were chosen to evaluate this question. The concentration of these immobile elements in the Catalina Schist and WPC are similar (Figure 6) and this provides more evidence that the rocks of the WPC could be the protolith for the metaconglomerate clasts.

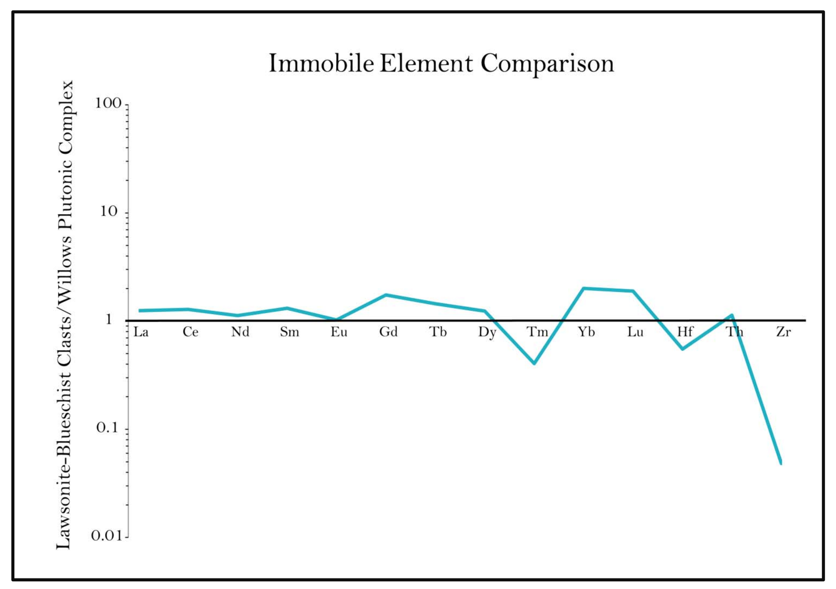
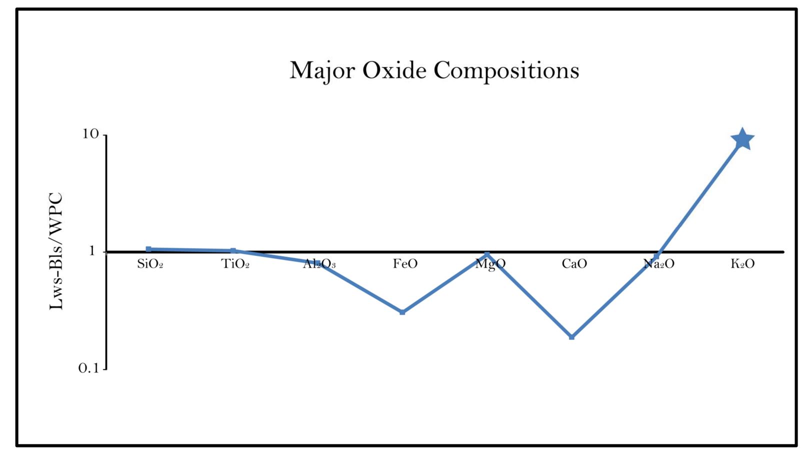
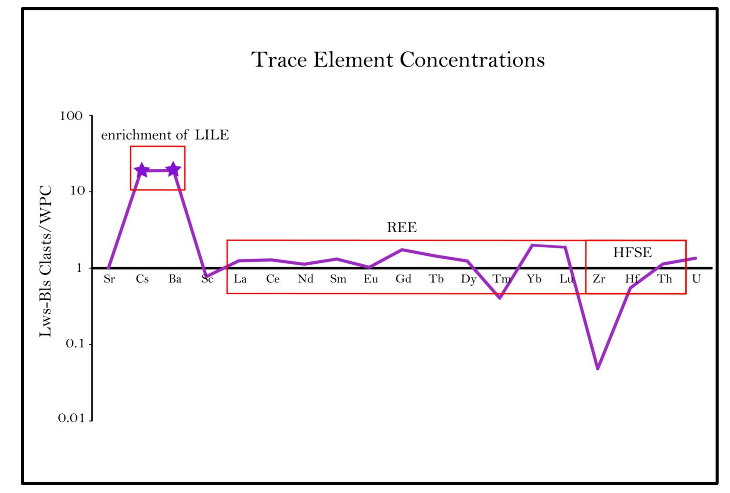


Figure 6: Rare earth element and high field strength element comparison of the lawsonite-blueschist clasts to the Willows Plutonic Complex (Sorensen, 1985).

Results

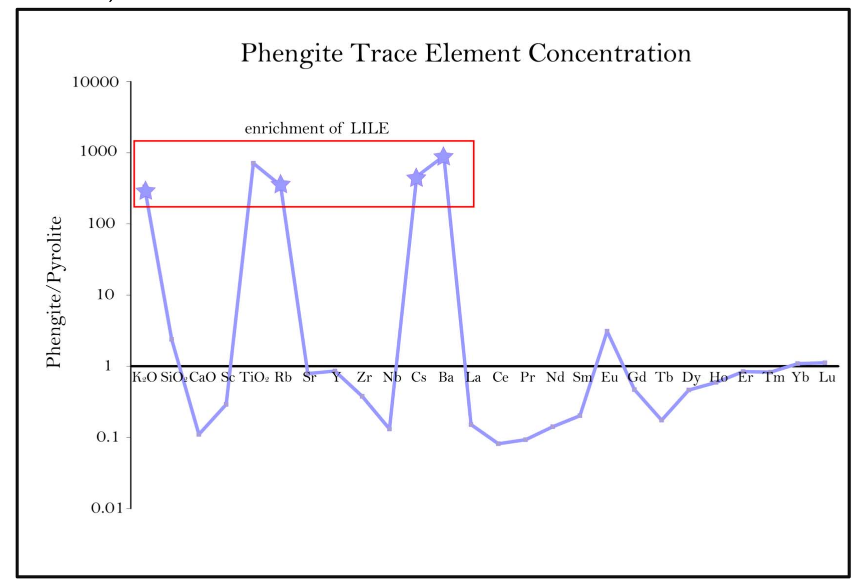
Using solution ICP-MS, whole rock data from the lawsonite-blueschist clasts of the Catalina Schist was collected. The results reflect a possible alteration by fluids due to the enrichment of fluid mobile elements relative to the likely protolith, the Willows Plutonic Complex. Most notable are the enrichments of K_2O (up to 4 wt%), Ba (up to 1698 ppm), Cs (up to 6.9 ppm), and Sr (up to 984 ppm) (Figure 7 and 8).

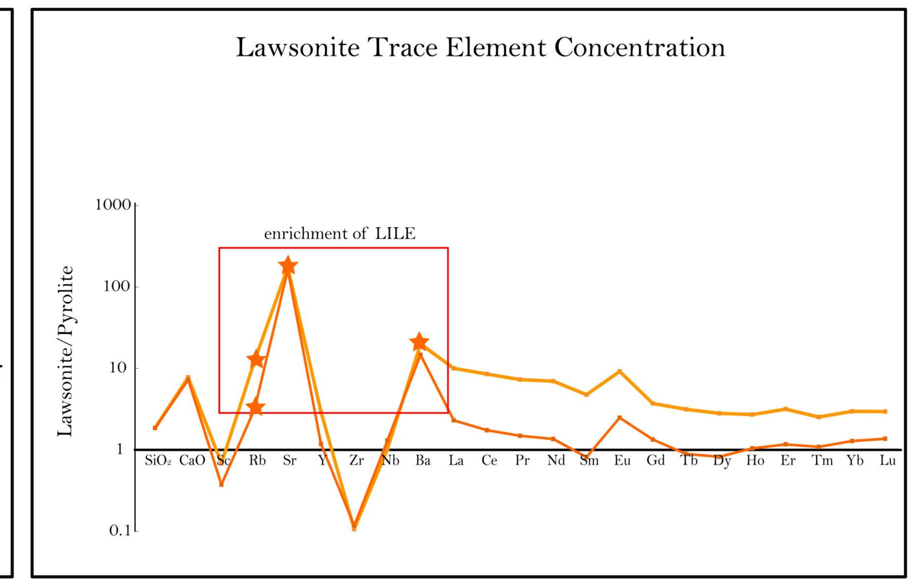




Figures 7 and 8: Figure 7 (left) shows major oxide composition of the lawsonite-blueschists compared to the Willows Plutonic Complex (WPC), with an enrichment of K_2O. Figure 8 (right) shows trace element concentrations in samples from the lawsonite-blueschist clasts relative to the WPC.

The enrichment of these large ion lithophile elements in the new hydrous metamorphic minerals offers more evidence that these rocks are being altered by fluid. Furthermore, the enrichments seen in the bulk rock data can be attributed to the presence of new minerals and the enrichment of specific elements in these minerals. Phengite and lawsonite, for example, are abundant in these samples, and because these phases are hosting LILE they could be the cause of the enrichment in the conglomerate clasts (Figure 9 and 10).





Figures 9 and 10: Figure 9 (left) shows trace element concentration in phengite normalized to pyrolite. Starred elements are the some of the LILE. Figure 10 (right) shows trace element concentration in lawsonite normalized to pyrolite. Two different lawsonite groups were measured, indicated by separate trace concentration patterns. Starred elements are two LILE, Sr and Ba.

To determine the uncertainty of my measurements, the relative standard deviation (RSD) was calculated for all elements collected during analyses. The RSD was used for each element to: determine the accuracy of the measurement, how much variance there is, and how small/large the standard deviation is to the average value. To show that a given element from the lawsonite-blueschist clasts are enriched/depleted relative to the WPC, the measured values should fall outside of the 2σ values for the WPC.

Acknowledgements

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