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SUBDUCTION INITIATION OF GEOSCIENTISTS: KECK CATALINA II

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INTRODUCTION

Franciscan-like subduction-related metamorphic rocks (blocks of garnet-bearing blueschist and amphibolite) were recognized on Santa Catalina Island by the first half of the twentieth century (Woodford, 1924; Bailey, 1941). However, the modern era of Catalina geology began with detailed mapping and a tectonic model by Platt (1975). The metamorphic rocks of Catalina (sometimes referred to as the Catalina Schist) consist of mappable units of metsedimentary and ultramafic mélange that range from lawsonite-blueschist to amphibolite facies, with increasing grade correlated with structural height (Platt, 1975). Platt's initial subdivision of the island into blueschist, greenschist, amphibolite, and ultramafic units bounded by shallow dipping thrust faults (Fig. 1) has been refined, with the "greenschist" unit now defined as epidote amphibolite and epidote blueschist overprinted with greenschist-facies assemblages (Grove and Bebout, 1995).

The highest-grade amphibolite unit from Catalina records peak conditions of 7-12 kbar and 650-750 °C based on cation thermometry and fluid inclusion barometry (Platt, 1975; Sorensen and Barton, 1987). The unusually high temperatures and Barrovian-like assemblages of the highest-grade rocks became the basis for the interpretation that the Catalina Schist was formed in a nascent subduction zone. In this model, the amphibolite-facies rocks were formed at the initiation of subduction and recorded high temperatures due to proximity with the hot mantle wedge; the inverted metamorphic gradient of underthrust lower-grade units recorded the subsequent cooling of the trench (Platt, 1975; Cloos, 1985; Peacock, 1987). More recent analysis of detrital zircon ages from Catalina metasedimentary rocks has revealed that accretion of the Catalina Schist occurred over at least a 20 My period, with the lowest-grade units containing detrital zircons younger than the 115 Ma metamorphic age yielded by the high-grade rocks (Grove et al., 2008). Furthermore, a single garnet blueschist block (Fig. 1) found in the blueschist-facies mélange yielded high-error Rb-Sr and Ar-Ar ages of ~150 Ma suggesting that a pre-Catalina subduction zone existed in the region. The age of the garnet blueschist block was firmly established by a 155±8 U-Pb sphene age collected during the 2012 Keck project (Awalt et al., 2013). However, the P-T history of this key sample remains unconstrained, possibly due to multiple episodes of subduction as the Catalina trench become superimposed on the remnants of a thermally mature subduction zone through subduction erosion (Grove et al., 2008).

Santa Catalina Island has long been used as a field laboratory to investigate devolatilization and fluid flow in subduction zones. Petrologic, geochemical, and chronological constraints on Santa Catalina Island have been used to document extensive fluid flow and

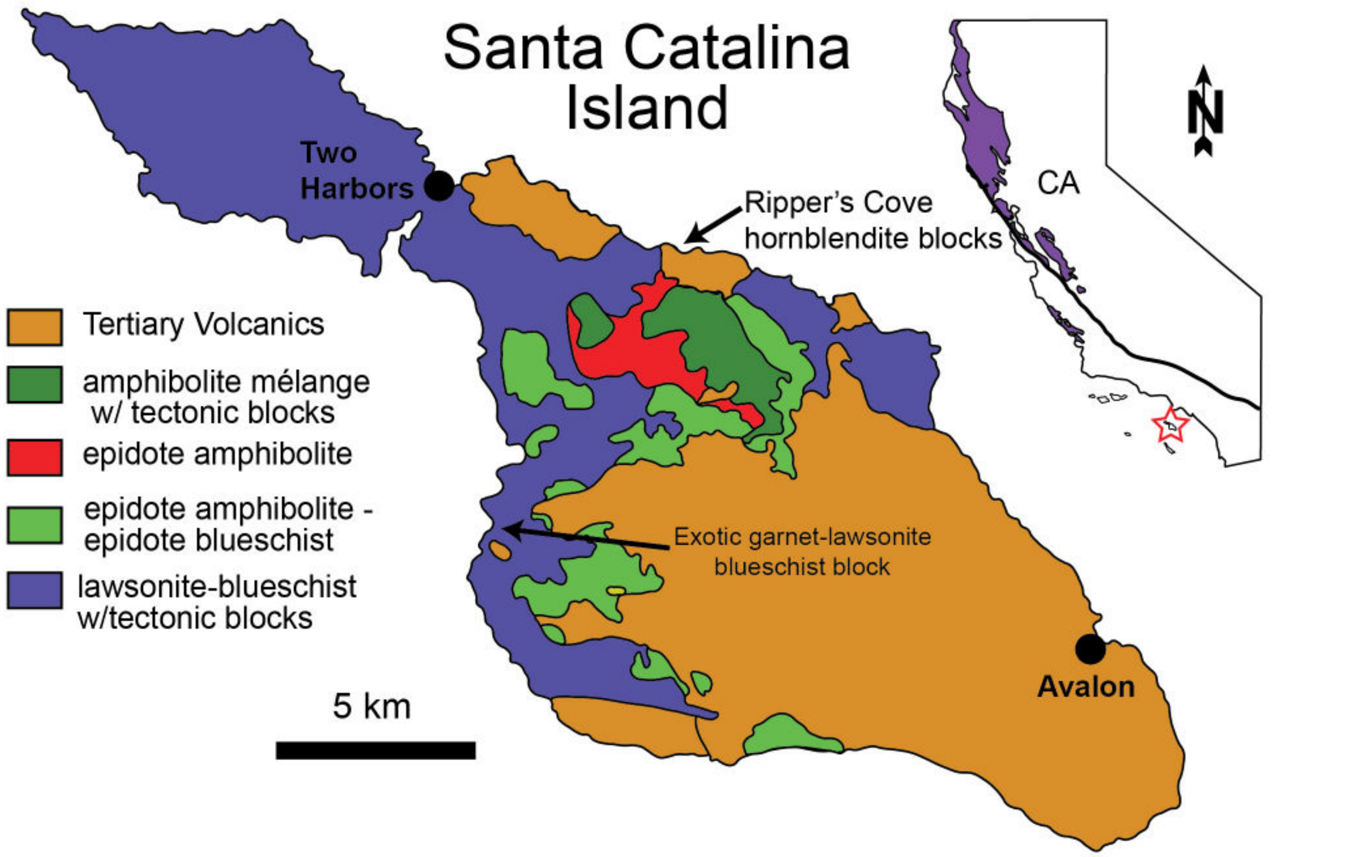

Figure 1: Geologic sketch map of Santa Catalina Island, California, modified from Platt (1975) and Grove and Barton (1995). The location of Catalina Island is shown in the red star on the inset map; the Franciscan Complex is shown in purple. The proposed study areas are shown in black rectangles.

metasomatism due to devolatilization of sediments during subduction (e.g., Sorensen and Grossman, 1989; Bebout, 1991; 2007; King et al., 2006, 2007). Many blocks in the amphibolite/ultramafic mélange have talc or tremolite metasomatic selvages or reaction rinds similar to those found in the Franciscan Complex. Unlike in the Franciscan, some of these selvages contain garnet that is compositionally different from that found in the blocks (Penniston-Dorland et al., 2013). In situ analysis of oxygen isotopes based on samples collected during the 2012 Keck Project has demonstrated that selvages contain garnet that grew both before and after rind formation (Leung et al., 2016). These garnets likely contain further information on the P-T history of rind formation and on the trace element composition of rind forming fluids.

In the summer of 2018, we undertook a nine-student Keck Gateway project using the geology of Santa Catalina Island, California as an introduction to the study of metamorphic rocks and metasomatism both in the laboratory and in the field. Students worked collectively on three projects using in situ analysis of major and trace elements in garnet to address questions of tectonics (timing of garnet vs. lawsonite growth in garnet blueschist, trace element zoning in amphibolite garnets with and without plagioclase) and metasomatism (major and trace elements in rind garnets). The project began with students joining Page, Buckle, and Flood on the Oberlin campus for two weeks. During this time, we had several local field trips and team-building exercises but had a primary focus on analyzing garnets from previously-prepared thick sections by SEM/EDS. By the end of the two weeks, major-element traverses of garnets from four different tectonic blocks from Catalina were completed, and targets were selected for trace-element analysis. At this point, the team flew to Los Angeles, joining Lackey for a week in the field that involved investigating field relations of the tectonic blocks already under study, limited new sample collection, and a digital mapping exercise on blocks in mélange. The final two weeks of the project were spent on the campus of Pomona College measuring trace-element compositions of garnet and lawsonite by laser ablation inductively-coupled mass spectrometry (LA-ICP-MS), measuring bulk-rock compositions by X-ray Fluorescence Spectrometry, analyzing data, drafting abstracts and posters.

STUDENT PROJECTS

An investigation of the Catalina garnet-blueschist: Major and trace element composition and zoning in garnet and lawsonite from multiply subducted block

Blaize Adler-Ivanbrooke, Juan Esparza, Sarah Hampton

As described above, a large garnet-lawsonite blueschist block with an anomalously old age is a key sample in understanding the tectonic history of Catalina. Preliminary attempts at thermodynamic modeling in order to reconstruct the pressure-temperature evolution of the rock did not succeed in reproducing the observed metamorphic assemblage. One possibility is that the garnet and dated sphene formed in an early metamorphism at 155Ma, and the lawsonite and glaucophane recrystallized in a second lawsonite-blueschist metamorphism after 115Ma. This is consistent with color zonation in glaucophane (Awalt et al., 2013). Detailed petrography by electron microscope revealed that lawsonite is texturally late, and, in particular, exists as veins that crosscut resorbed garnet adding further credence to a multiple-subduction origin (Adler-Ivanbrooke et al. (2018). Elevated Heavy Rare Earth Element (HREE) content in both late lawsonite and early garnet suggest that lawsonite grew at the expense of garnet or with a metasomatic source of HREE (e.g., Mulcahy et al., 2014). Garnet exists only in a m-thick band through the block, and whole rock geochemistry of multiple samples across the block show that this is not because of compositional differences and is likely due to preservation of garnet only within the core of the block.

Major and Trace Element Zoning in Garnets of Unusual Size from Blocks Hosted by Ultramafic Mélange, Santa Catalina Island, California

Amani Canada, James Karroum II, Lorena Paras

Most Catalina garnet-hornblende rocks contain no plagioclase, however, the presence of plagioclase and granitic veins in some blocks led Sorensen and Barton (1987) to conclude that all garnet-hornblende rocks are residuum from the partial melting of a basaltic precursor during subduction initiation. Canada et al. (2018) compared the major and trace-element zoning patterns in three garnet-hornblende blocks: two (one plagioclase-bearing) with typical garnet sizes for the island (<5mm diameter), and a third unusual plagioclase-bearing sample containing ~3cm diameter garnets collected during the 2012 Keck project.

Garnets from all three samples were found to have similar major and trace-element zoning patterns, suggesting a similar bulk composition and P-T evolution for mafic blocks with or without plagioclase, supporting the notion of the absence of plagioclase being due to melt extraction. Unlike the single existing published analysis of trace elements in Catalina (Sorenson and Grossman, 1989), HREE were not found to increase in the rims of garnets, however, Cr did increase in some garnet rims, perhaps due to metasomatism from a mantle-source.

Major and trace element analysis of garnet crystals from a hornblendeite block and rind on Santa Catalina Island, CA: Insights into metasomatic processes in subduction mélange

Nathaniel Bess, Eric Hasegawa, Paige Voss

Leung et al. (2016) documented three different generations of garnets in a single rind sample from one block on Catalina, first described by Penniston-Dorland et al., (2013). Three students worked collaboratively to describe the mineralogy of a block and two samples of garnet-bearing rind (Fig. 2). Bess et al. (2018) showed that, similar to the oxygen isotope record, different populations of garnets in block and rind show different trace-element patterns. Metasomatic rinds have two different generations of garnet, mm-scale crystals that have core major and trace-element compositions similar to the block garnet. Rims on large rind garnets differ from the rims of block garnets, but are similar in major and trace elements to a second generation of 100µm-scale

Figure 2: Students draw and photograph a tectonic block of garnet hornblendite with actonite-chlorite rind at Ripper's Cove, Santa Catalina Island, California.

garnets found in quartz veins that cut the rind.

Collectively, the three groups were able to provide the community important new trace-element data on garnets to the study of metamorphism and metasomatism on Santa Catalina Island. These data help shed new light on slab-melting within nascent subduction zones, and help add more evidence for the idea of multiple episodes of subduction within the subduction mélange channel. In undertaking this research students gained valuable field and laboratory skills as well as participating in many discussions on the different careers available to geologists and the importance of and challenges inherent in increasing diversity in the geosciences.

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