PROCEEDINGS OF THE TWENTY-SIXTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2013
Pomona College, Claremont, CA

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KECK GEOLOGY CONSORTIUM
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INTRODUCTION

The Catalina Schist is a rock unit that has received attention for its complicated tectonometamorphic history. Tectonically, it has been described as a subduction zone assemblage with a mix of island arc igneous and sedimentary origins (Grove et al., 2008). It includes a mélange zone of blocks and matrix as well as zones of coherent rock units that have been studied for decades as a natural laboratory of geochemical evolution within a subduction zone (Platt, 1975; Sorenson, 1987; Bebout 1989). Isolated blocks of garnet amphibolite occur in the mélange. While the high temperatures needed to produce garnet amphibolite seem anomalous to a subduction zone setting, the presence of blueschist facies rocks in the mélange matrix, which can only be formed under the high-pressure, low-temperature conditions of subduction zones, confirms a subduction history. Many of the isolated garnet-amphibolite blocks are encircled by mineralogical rinds. Several of the amphibolite blocks and rinds were collected and studied in an attempt to determine the metamorphic history of the material.

Material that has been metamorphosed in the conveyor belt of a subduction zone is uplifted back to the surface as more material is fed into the system. The product is a mélange of ground material (matrix) surrounding some remaining larger blocks, such as the samples in this study. The block texture of the samples collected in the field suggests that these amphibolites were likely exposed to subduction conditions. Subduction zone environments juxtapose materials with disparate chemical compositions such as sedimentary and mafic rocks. These materials are subjected to high pressures and elevated temperatures that generate hydrous fluids through metamorphic reactions. Indeed, subduction zones create large volumes of water due to those metamorphic reactions (Bebout, 2012). The hydrothermal fluids released by metamorphic reactions have the ability to transport and redistribute elements among the subduction zone rocks, changing their chemical compositions (Penniston-Dorland, 2011).

This study sought to determine why there are reaction rinds on Catalina Island amphibolite blocks. Are the rind layers the result of a chemical reaction with the mélange zone matrix and subsequent chemical diffusion? Are they the result of the physical process of mechanical mixing (Penniston-Dorland et al., 2011) during uplift? To what extent were fluids involved in this process, and did fluids introduce new materials to the reaction (as proposed by Sorenson and Bebout, 1987; Bebout and Barton, 1989)? To answer these questions, this study focused on three coarse-grained blocks of garnet-amphibolite from Ripper's Cove, Catalina Island (Fig. 1, Page et al., this volume). The samples were divided by material into core and one or more concentric rinds (Fig. 1). Two of the three samples exhibited garnets in both the core and rind materials. A garnet-hornblende thermometer, using rind and core garnets (using both garnet cores and rims) and hornblendes, was applied where possible.

Fig. 1 Magliozzi with Sample RIP 4 at Ripper's Cove, Catalina Island. Chisel is resting above the garnet-amphibolite block RIP4A with lower end touching primary rind layer RIP4C. Magliozzi's hand is resting on secondary rind material RIP4C.

Previous work

All units of the Catalina Schist, from blueschist to amphibolite facies metasedimentary, metamafic and meta-ultramafic rocks, show veining and alteration that reflect fluid transport and metasomatism during prograde metamorphism and uplift. Host-rock and vein mineralogy and whole-rock composition demonstrate large-scale chemical redistribution, especially of Si and alkali elements (Bebout, 1989). Bebout's 1989 isotopic studies of the metasomatic events of the Catalina Schist found that the likely source of metasomatic fluids is lower temperature, devolatilization reaction fluids from other, sediment-rich parts of the subduction zone. Though he does not discuss block and rind textures, it can be inferred that such processes could produce or chemically modify rinds on amphibolite blocks.

Penniston-Dorland et al. proposed in 2011 that an early episode of mechanical mixing between mafic block and melange materials allowed for the formation of rind materials. She states that garnet growth in both block and rind materials occurred after mechanical mixing, and that fluid infiltration caused alteration of garnet to chlorite and the growth of white micas. These conclusions were drawn from rind concentrations of Cr, Ni, Zr, Al_2O_3, TiO_2, FeO, and possibly CaO, MgO, Na_2O, and Sr, as well as increases in SiO_2, K_2O, Li, and Ba, which reflect mobility of elements during later stage fluid infiltration (Penniston-Dorland et al. 2011). This earlier work describes a primary rind layer on garnet-amphibole blocks. Conversely, this study observed multiple layers of concentric rinds with unique textures and assemblages in each layer.

METHODS

Field methods

Samples were collected from Ripper's Cove, Santa Catalina Island during two visits to the location in July, 2012.

Optical light microscopy

Samples were cut and polished into thin sections at Oberlin College by specialist laboratory technician. Thin sections were examined using optical light microscopy using petrographic microscope techniques to obtain mineral assemblage and textural observations.

Scanning Electron Microscopy (SEM), Energy-Dispersive X-ray Spectroscopy (EDS)

Selected carbon-coated thin sections were examined using scanning electron microscopy to identify crystal grains of interest. The FEI Quanta 400 SEM was standardized using mineral standards analyses in conjunction with the RZAF procedure of standardization. Analyses were collected at 20 kV with a 2.5 nA beam current. EDAX TEAM (Texture and Elemental Analytical Microscopy) and EDAX GENESIS software packages were used to confirm mineral assemblage as well as to collect and quantify major element chemistry analyses.

RESULTS

Sample descriptions

RIP1: Rock sample composed of block + three rind layers

RIP1A

This sample is composed of garnet-amphibolite block material with a mineral assemblage of garnet (30%) and hornblende (65%). Garnet size is large, from 1500

to 2000 μm in diameter. Garnet inclusions include epidote, zoisite, chlorite, and quartz. Garnet inclusions vary texturally, with larger central inclusion grains at the core surrounded by powdery inclusions toward the rim (Fig. 2). Some inclusions are cut by quartz "veins." Accessory minerals include rutile and apatite.

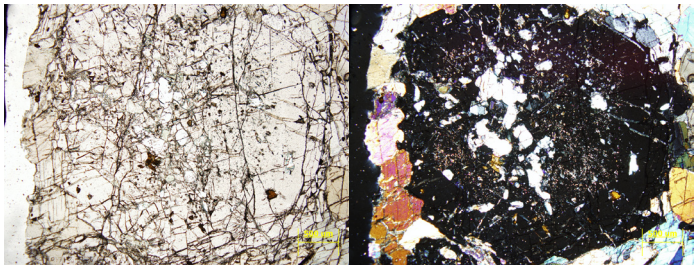

Fig. 2 Sample RIP1A under PPL (left) and XP (right). Focused on garnet with larger inclusions toward the center and powdery inclusions toward the rim.

Fig. 3 Sample RIP1C in field. Larger garnets surrounded by amphibole toward top of image, smaller garnets embedded in quartz near Chapstick.

RIP1B

This sample is composed of the first rind layer, occurring between RIP1A and RIP1C. The amphibole is more greenish in color and occurs in a mineral assemblage of chlorite (30%), phengite (20%), and amphibole (50%). No garnets were found in this sample. Accessary minerals include rutile and apatite. The thin section is quilt-like in texture, with equal-sized grains of amphibole and mica distributed throughout.

RIP1C

This sample is composed of the secondary rind layer, distinct from RIP1B or RIP1D. The mineral assemblage is garnet (30%), chlorite (15%), amphibole (35%), phengite (15%), quartz (5%). Phengite grows around chlorite. Two different sizes of garnets with similar chemical composition are found in this sample (Fig. 3). Smaller garnets are approximately 500μm in diameter, larger garnets range from 1500 to 2000μm. Smaller garnets are surrounded by quartz, focused on boundaries between quartz crystal grains, and contain few to no inclusions. Larger garnets contain inclusions of quartz, zoisite, and epidote. Accessary minerals include rutile and apatite.

RIP1D

This sample is the tertiary rind layer to garnet-amphibolite block material RIP1A. The mineral assemblage includes garnet (20%), chlorite (20%), amphibole (50%), quartz (10%). Garnets are replaced by chlorite and are approximately 1500μm in diameter. Accessory minerals include rutile and apatite.

RIP4: Rock sample composed of block + two rind layers

RIP4A

This sample is composed of garnet-amphibolite block material containing the mineral assemblage of garnet (35%), chlorite (10%) and hornblende (55%). Garnet size is large, from 2000 to 2500 μm in diameter. Garnet inclusions are also generally large and include epidote, chlorite, and quartz. Garnet inclusions vary texturally, with larger central inclusion grains at the core surrounded by powdery inclusions toward the rim. Chlorite rims or replaces garnets. Accessory minerals include rutile.

RIP4B

This sample is composed of the first rind layer, located between RIP4A and RIP4C. The amphibole is lighter in color than in RIP4A. The mineral assemblage is

chlorite (20%), garnet (10%), phengite (20%), and amphibole (50%). Garnets are highly altered and may be completely surrounded by chlorite. Accessary minerals include rutile and apatite. The thin section is quilt-like in texture, with equal-sized grains of amphibole and mica distributed throughout.

RIP4C

This sample is composed of the second rind layer, distinct from RIP4A or RIP4B. The mineral assemblage is chlorite (70%) and albite (30%). No garnets were found in this sample.

RIP5: Rock sample composed of block + one rind layer

RIP5A

This sample is composed of garnet-amphibolite block material. The mineral assemblage is garnet (35%), phengite (10%), hornblende (55%), and quartz. Garnet size is large, from 2000 to 2500 μm in diameter. Garnet inclusions are also generally large and include chlorite and quartz. Garnet inclusions vary texturally, with larger central inclusion grains at the core surrounded by powdery inclusions toward the rim. Accessory minerals include rutile and sphene.

RIP5B

This sample is composed of a primary rind layer, surrounding RIP5A. The mineral assemblage is amphibole (70%) and chlorite (25%). No garnets were found in this sample. Amphibole crystals are very uniform in size. Accessary minerals include rutile and sphene, including very large sphene crystals (2500μm in length).

Chemical Compositions

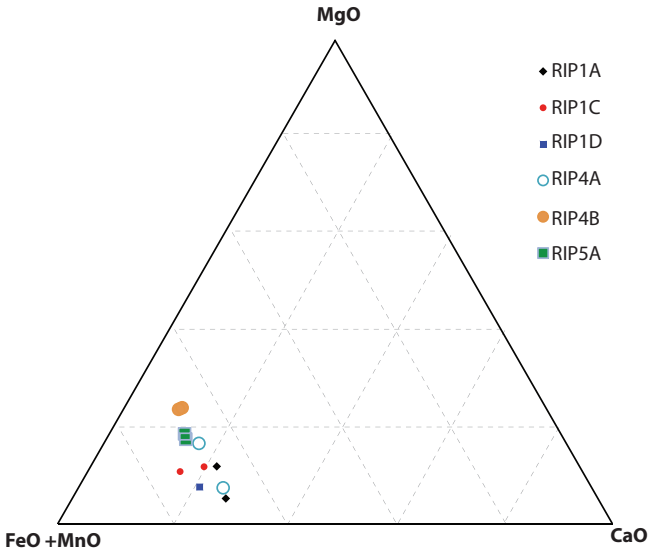

Fig. 4 Garnet composition diagram for all garnet-bearing samples in study. Data collected using FEI Quanta 400 SEM, quantified using TEAM software and Smith College mineral standards.

Representative Block Garnet Core (RIP1A)

Elem	Wt	%
MgO	4.53	7.36
Al2O3	22.33	14.33
SiO2	38.87	42.31
CaO	9.51	11.09
MnO	0.99	0.92
FeO	26.36	24
Total	102.6	100

Representative Block Garnet Rim (RIP1A)

Elem	Wt	%
MgO	5.82	9.51
Al2O3	22.25	14.37
SiO2	38.7	42.39
CaO	7.8	9.15
MnO	0.68	0.63
FeO	26.14	23.95
Total	101.39	100

Representative Block Amphibole (RIP1A)

Elem	Wt	%
Na2O	1.73	1.65
MgO	15.17	22.29
Al2O3	11.41	6.63
SiO2	49.6	48.9
K2O	0.27	0.17
CaO	10.85	11.46
FeO	10.81	8.91
Total	99.83	100

Table 1 Representative garnet core and rim compositions as well as amphibole composition from sample RIP1A. Data collected using FEI Quanta 400 SEM, quantified using TEAM software and Smith College mineral standards. Used in garnet-hornblende thermometer calculations.

Thermometry

Application of garnet-hornblende thermometry (Ravna et al., 2000) yielded temperatures of 205˚C using the garnet core compositions, and 216˚C using the garnet rim compositions, both paired with hornblende matrix compositions of sample RIP1A (Fig. 2).

DISCUSSION

Past work has indicated that garnets grew after mechanical mixing between garnet-amphibolite blocks and matrix material, followed by fluid infiltration that caused the retrograde growth of chlorite. The first part of this hypothesis is supported here by a higher concentration of chlorite in exterior rind layers, where water flowing through the matrix would have easier access. The difference in size of garnets, particularly in sample RIP1C, may indicate two different stages of garnet growth, which has not been previously discussed. Because smaller garnets appear to be concentrated in quartz vein-like sections, the secondary period of growth may have occurred following fluid alteration that produced quartz veins. This is supported by earlier work claiming large-scale chemical redistribution of Si (Bebout et. Al 1989).

Garnet-hornblende thermometry yielded temperatures lower than those necessary to form garnet-amphibolite blocks. This likely indicates a lack of equilibrium between the amphibole and garnet, which may reflect greater fluid alteration of amphiboles than garnets.

Future work for this study includes an examination of quartz fluid inclusions found in the rind layer of sample RIP1D.

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