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

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Keck Geology Consortium: Projects 2012-2013
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SANTA CATALINA ISLAND: GARNET QUARTZITE'S FROM THE CATALINA SCHIST IN THE VALLEY OF OLLAS

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Research Advisor: Stanley Mertzman

INTRODUCTION

Santa Catalina Island is located nearly 20 miles off the coast of Los Angeles County in Southern California. The primary set of rocks at this location, known as the Catalina Schist, comprises mélange material that is most likely altered from oceanic crust and sediments in subduction zones (Bebout, 2007). These metamorphic units were likely subducted as deep as 40 km (Grove, 2008). Reaching those depths permitted the Catalina schist to attain metamorphic grades that range from lawsonite-albite facies (~275 C, 0.5 GPa) to amphibolite facies (750 C, 1.2 GPa), which have been dated as Cretaceous in age (Penniston-Dorland, et al, 2011). These metamorphic suites also contain abundant evidence of metasomatism and the passage of fluids (Sorensen and Barton, 1987; Bebout and Barton, 2002). Thus, these rocks deserve examination due to their potential to expand the understanding of the geochemical evolution in the "forearc to subarc slab interface" of subduction zones (Bebout, 2007). This study may provide insight into what fluids are added along arcs, and how subducted rocks can add to the heterogeneity of the deeper mantle, according to Bebout (2007). Therefore, this paper focuses on the chemical similarities and the structural features of the sedimentary rocks - in this case garnet quartzite - along the Valley of Ollas. Most work has been done on the mafic blocks, and the work presented in this paper is the first done on the metasedimentary material.

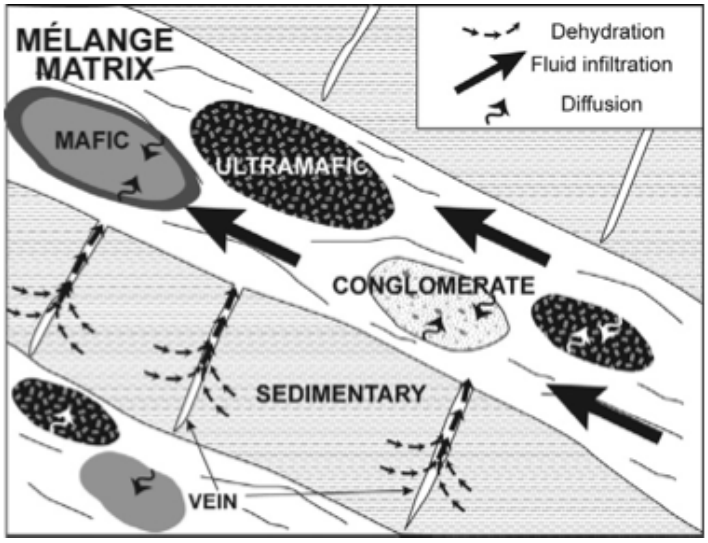

Figure 1. Schematic diagram illustrating the structural and lithologic character of rocks and fluid flow pathways and mechanisms in a mélange unit with the Catalina Schist (Penniston-Dorland, et al, 2011)

FIELD SITUATION

Santa Catalina Island, being composed of mélange material and later volcanic rocks, is difficult to geologically map. The Valley of Ollas is itself comprised mostly of mélange material and it is located within the amphibolite facies unit. Within this mélange zone exist random veins and blocks of garnet quartzite that display no clear orientation. So, it is difficult to determine stratigraphic direction. However, some locations of the valley show clear bedding in low-grade metamorphic material within the high metamorphic suite that contains interbedded garnet quartzite. All of these structures represent the dominant features that are found within the Valley of Ollas for the garnet quartzite sampled.

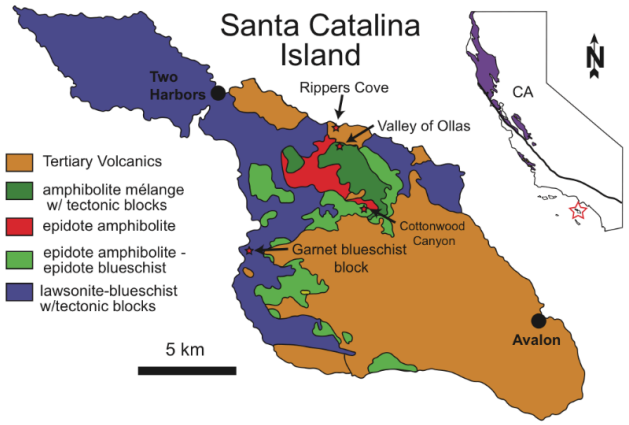

Figure 2. Aerial map of Santa Catalina Island demonstrating metamorphic suites with overlaying volcanics, and locations of where team members collected samples.

HAND SAMPLES, THIN SECTION AND XRD DATA

3.1 Hand Samples

One of the most obvious features that the garnet quartzite displays in hand sample is the distinct layering pattern of garnet. This feature is evident in almost all samples; it may have formed due to fluid diffusion through the sedimentary rock, as shown in figure 1 (Penniston-Dorland, et al, 2011). This will be explained further in the discussion section. Two collected hand samples are also believed to be rind material around the garnet quartzite blocks due to different mineral content in hand sample, such as higher concentrations of biotite and less quartz (XRF data from 1 of the 2 rind samples demonstrates chemical distinctions).

3.2 Thin Sections and XRD

After examining the hand samples, thin section analysis was done on 9 of the 14 samples collected. Each contained quartz, garnet (pyrope-almandine solid solution ± spessartine), phyllosilcates (chlorite ± oxybiotite ± muscovite), rutile, and amphiboles (tremolite-actinolite solid soultion ± cummingtonite ± gedrite). All amphiboles and phylosilicates phases were determined by petrographic analysis. Garnet was easily identified petrographically and its semi-quantitative chemistry was determined through XRD analysis. Most of the amphibole in the thin sections is either tremolite or cummingtonite, and rarely actinolite or gedrite. Phylosilicate minerals, especially chlorite, are found in every thin section. There are three additional important minerals found in the thin sections: sphene, feldspar, and zircon. Sphene appears in four different thin sections, and in one single example replacing rutile. Feldspar is found in just one thin section, which came from a sample thought to be a rind. Finally, zircon was found in a thin section containing zonation.

Besides the mineral assemblages, there were also structures and textures found in the thin sections that are worth noting. In particular, deformation features are evident in all thin sections. These features range from bending minerals to folding minerals. Another apparent feature in the thin sections are the layered garnets, as also observed in the hand samples. Within each layer of garnet there are hydrous minerals, such as amphibole and mica, which follow the lineation of the garnets. Some of the garnets in the thin sections also demonstrate heterogeneous structures. For example, in some thin sections there is obvious chemical differences in the garnets when their inner and outer cores are compared based on their color disparities in plane-polarized light. Then, in some thin sections, the inner cores are corroded, as opposed to their homogenous outer cores. These structural and mineralogical differences can be used to interpret chemical and physical changes from the inner to outer core.

GEOCHEMISTRY

4.1 XRF Data

All 14 samples that were collected in the Valley of Ollas had their major and trace element whole rock analysis prepared using X-ray fluorescence. From the 14 samples, 12 are garnet quartzite, while 2 represent the possible rind material. The garnet quartzite samples have varying silica concentrations that range from 67.38 % to 89.98 % (tab. 1). Other major elements that fluctuate in the garnet quartzite samples are aluminum, iron, magnesium, and manganese oxide concentrations. These variations are possibly related to the garnet phases. Another observation made when examining the data is the low concentrations of both sodium and potassium in the samples (tab. 1). The concentrations of these two elements are less than 1 % in each sample. After scrutinizing the dataset for the

Specimen	17A1	17A2	17B1	17D1	17(E1)	17F1	17B2	17C2	17C1	O5C-1	11A2	11A3	11B1	11B2
SiO2	88.41	85.55	85.30	88.42	72.84	85.36	86.70	55.29	75.56	68.76	89.98	67.38	84.64	80.69
TiO2	0.21	0.39	0.44	0.19	0.53	0.32	0.49	0.89	0.52	0.89	0.11	0.38	0.40	0.62
Al2O3	3.46	4.69	4.50	3.81	8.82	5.14	3.95	12.86	7.41	8.83	3.46	11.29	4.43	6.05
Fe2O3T	3.93	5.02	5.99	4.12	10.19	3.91	5.35	14.02	10.00	13.29	4.22	12.35	4.66	9.14
MnO	0.81	0.82	0.43	1.27	2.99	1.48	0.39	1.58	2.02	1.77	0.89	2.75	0.83	0.69
MgO	1.28	1.90	1.77	1.38	2.47	1.13	2.06	5.32	2.53	3.69	0.95	2.97	2.26	2.22
CaO	1.03	1.18	0.85	0.77	1.74	1.36	0.69	4.46	1.62	1.71	0.81	2.83	1.76	0.99
Na2O	0.00	0.28	0.00	0.00	0.03	0.21	0.00	4.52	0.03	0.05	0.00	0.16	0.12	0.00
K2O	0.06	0.18	0.08	0.03	0.28	0.92	0.20	1.09	0.38	0.41	0.09	0.47	0.08	0.01
P2O5	0.31	0.41	0.11	0.13	0.25	0.28	0.14	0.08	0.35	0.20	0.02	0.04	0.25	0.04
Total	99.50	100.42	99.47	100.12	100.14	100.11	99.97	100.11	100.42	99.60	100.53	100.62	99.43	100.45
LOI	0.30	1.13	0.28	0.28	0.81	0.61	1.04	2.41	1.02	0.23	0.28	0.69	0.27	0.15
Rb	<0.5	12.5	0.5	<0.5	6.2	7.0	7.1	22.1	5.5	16.3	1.3	6.7	0.7	<0.5
Sr	24	37	20	25	43	45	20	36	46	22	21	47	27	15
Y	45.1	45.8	47.8	35.3	40.8	89.9	49.2	46.0	51.2	45.3	38.2	93.7	42.9	38.4
Zr	59	116	105	61	122	189	86	149	103	150	87	270	82	136
V	77	104	96	58	137	120	87	305	226	357	57	147	79	179
Ni	68	157	41	65	93	115	105	175	124	190	49	133	104	47
Cr	77	150	64	95	151	256	151	303	156	205	67	170	158	152
Nb	2.5	6.3	6.6	5.1	11.6	2.3	7.1	8.2	7.8	7.0	0.8	1.6	6.3	2.4
Ga	2.3	3.4	2.4	3.2	6.1	6.0	2.8	12.1	6.4	11.5	2.4	6.2	3.4	4.8
Cu	23	33	20	32	17	89	67	211	347	46	28	70	19	137
Zn	16	23	12	16	72	58	17	141	93	203	21	58	24	48
Co	32	51	23	12	22	56	25	41	27	32	19	57	22	21
Ba	99	131	131	40	1063	301	101	291	310	2834	91	364	85	71
La	33	23	23	12	24	55	22	35	36	27	27	50	22	19
Ce	85	59	40	14	37	156	49	50	45	26	70	140	42	26
U	2.3	2.2	2.4	1.9	<0.5	2.7	2.2	<0.5	1.9	<0.5	1.6	2.3	1.3	1.3
Th	2.6	6.5	1.2	<0.5	<0.5	18.0	4.3	9.4	5.0	8.2	7.4	16.1	5.2	7.0
Sc	7	9	9	10	12	23	9	26	10	10	4	26	6	6
Pb	<1	<1	3	<1	5	<1	<1	<1	<1	11	<1	<1	<1	<1

Table 1. X-ray fluorescence data for 14 samples; 12 garnet quartzites and 2 possible rind samples.

garnet quartzites, the possible rind samples (17B2 and 17C2) were analyzed and compared to the blocks that they are associated with (17B1 and 17C1). From the samples, 17B2 has a similar bulk composition to 17B1, however 17C2 contains some variation in its bulk composition compared to 17C1. When both datasets are compared, 17C2 has a lower silica concentration, 55.29 %, than 17C1 (75.56 %). Sample 17C2 is also higher in aluminum, iron, magnesium, calcium, sodium and potassium (tab. 1). However, due to only one sample showing such chemical differences, the results are inconclusive.

4.2 ACF and AFM Diagrams

The 14 samples are plotted onto an ACF and an AFM diagram using the XRF data sheet in table 1. For the ACF diagram (fig. 3) all samples plot closer to the A and F components and away from the C component due to the samples containing higher concentrations of aluminum, iron and magnesium. What can also be seen is that the bulk composition of the samples plot closer to the alumina apex than the mineral assemblages connected with tie lines would make

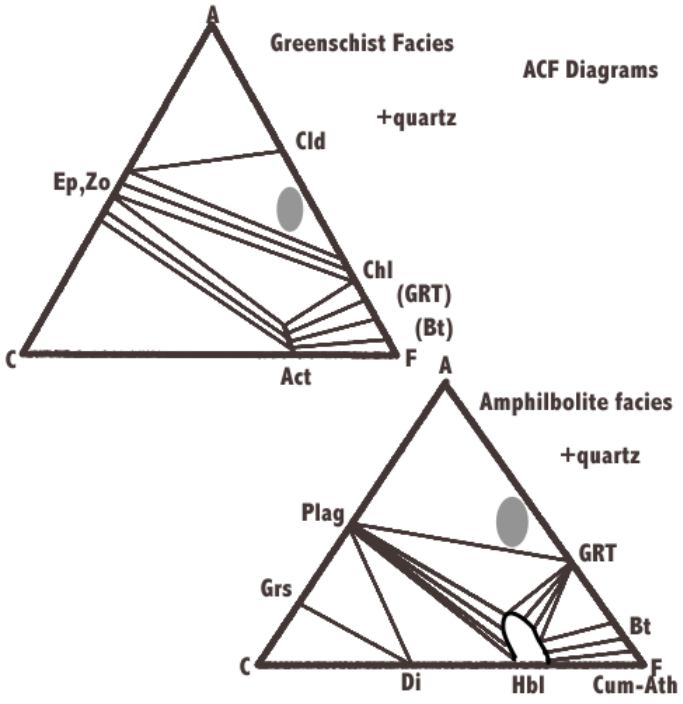

Figure 3. ACF diagrams demonstrating the mineral assemblages, and the composition range of common garnet quartzites in the Valley of Ollas. (Winter, 2010).

you think. A possible reason for this could be the heterogeneity of the samples. This could have occurred due to sedimentary material being metamorphosed, and causing the permeability of the material to decrease, thus restricting the ability of aqueous fluid to homogenize the material equally. The diffusion of water through the linear fabrics of the garnets would have allowed a chance for equilibrium to occur and form the mineral assemblages that are plotted. However, the samples in the AFM diagram, figure 4, do plot within the mineral assemblages presented on the diagram. These samples have tie-lines between garnet, biotite solid solution, and chlorite solid solution.

DISSCUSSION

From petrographic analysis of garnet quartzite thin sections, it is apparent that the garnet comprises ~15 % to 20% of the average quartzite bulk composition. Thus, XRD analysis seemed appropriate to determine the rudimentary composition of the garnet that is modally important in these quartzite samples. The XRD data suggested an almandine-pyrope solid solution and, further, the XRF data for a number of samples suggests perhaps a non-trivial amount of sperssartine present in the solid solution as well. Using the XRF bulk rock chemistry, ACF, and AFM diagrams were constructed and they suggest the garnet (figs. 3, 4 and tab. 1) is more almandine-rich. All of the samples plot closer to the iron component on each diagram. The XRF also presents higher concentrations of iron than magnesium. Evidence for this is the higher concentrations of manganese in XRF data, and the fact that there are no traces of other manganese-bearing minerals in the thin sections.

The garnets in hand samples and thin sections also demonstrate clear layering. As mentioned above, this feature could have formed from the diffusion of water as shown in figure 1. As the sedimentary material began to metamorphose, the permeability of the rock dropped, which could have caused the aqueous fluid to diffuse in these linear fashions. Rising temperatures/pressures and soluble ions diffusing from the sediments could have created a suitable condition for garnet formation. The assumption of soluble ions is supported by the low concentrations of magnesium, calcium, sodium, and potassium in the XRF data. What also supports this idea is the abundance of

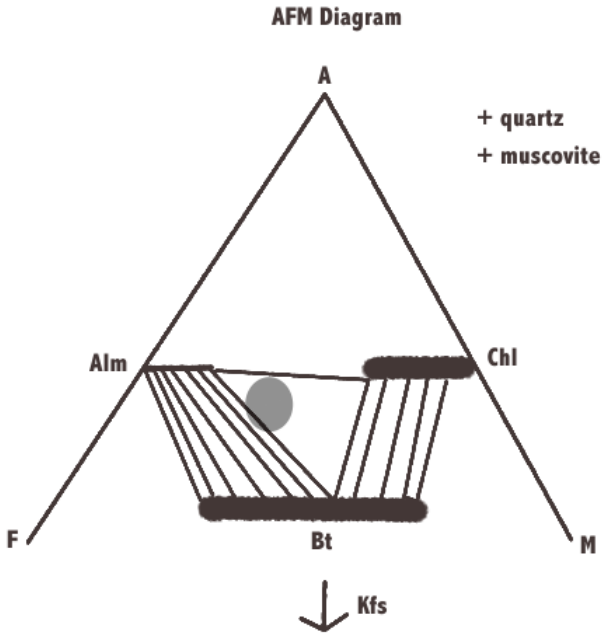

Figure 4. AFM diagram demonstrating the mineral assemblages, and the composition range of common garnet quartzites in the Valley of Ollas (Winter, 2010).

hydrous minerals that follow the path of the garnets, as they could have also formed from the diffusion of the aqueous fluid.

Petrography reveals the presence of both rutile, more abundant, and sphene, less abundant of the two minerals. The presence of the sphene may have geochronologic importance. According to Zack et al, (2010) it may be possible to determine the age of the metamorphic reactions that led to the formation of sphene if the reactions fit four criteria. These are: 1) visible overgrowth textures of sphene on rutile, 2) newly grown sphene that is datable (elevated concentrations of U, low common Pb), 3) no inherited Pb from precursor minerals for evaluation, and 4) newly grown sphene formed below its closure temperature. If these criteria are met with rutile containing a low concentration of U, the growth of sphene may be interpreted as a direct result of a U-enriching metasomatic event. Rutile's lack of U would make it impossible for the sphene to derive its higher concentrations of U from it, thus making it obvious that a U-rich fluid must have infiltrated the material. Within one thin section there is an

appearance of an overgrowth texture, but within other thin sections there are signs of rutile and sphene associations. Therefore, using the criteria mentioned above can date these samples. Additional future geochronologic projects could focus on investigating zoned zircon, biotite, and muscovite in the sample. The zoned zircon would likely be most illuminating because it holds the potential of unraveling a series of discrete events, the secret being held in each of the reaction rims preserved in the zircon crystal. Determining age-dates for these minerals would provide a useful constraint on the timing of the one or more events of metasomatism that affected the garnet quartzite of Santa Catalina Island.

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