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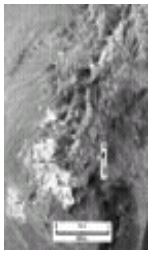
Research Interests

The application of conventional and laser microprobe stable isotope techniques for economic geology studies is my main area of research interest. I have also recently become involved in some very interesting geobiological and paloeclimatic studies in the past several years thanks to a number of collaborative studies undertaken with other UGA faculty and graduate students. We have an outstanding stable isotope facility here in Athens, with the ability to extract and analyze silicate oxygen (soon via a new laser system), carbonate carbon and oxygen, sulfide/sulfate sulfur, and mineral/water H/D isotopes for geologic studies. The stable isotope lab is also equipped with a laser microsampler for in-situ analysis of sulfide sulfur and carbonate carbon and oxygen isotope ratios. The original (ancient) system that I constructed when I arrived in 1991 has now been replaced with a state of the art computer controlled sampling system connected to a continuous flow inlet that was designed and constructed by Dr. Kristen Leckrone during her stay here as an NSF postdoc. Since I arrived in Athens in 1991, my students have worked on the following research projects:

1. Three students (Sandra Bezenek M.S. 1996, Frank Lieth M.S. 1996, Mustapha Kane Ph.D. 1996) worked on projects on the Dalnegorsk borosilicate skarn deposit, Far East Russia. These studies focused on both the regional scale geology of the central Primorye region from a metallogenic standpoint, as well as geochemical studies of the Dalnegorsk deposit itself. This deposit is the largest borosilicate skarn in the world, supplying over 80% of Russia's boron, and is also the largest wollastonite deposit in the world. We were able to determine the time-integrated history of the fluid system as it evolved from an initial magmatic-dominated system to a meteoric-dominated system with time. The fluid history was complex, however, with multiple cyclic intrusions causing the fluid composition to vary with time from magmatic- to meteoric-dominated regimes several times. This work involved field work in Russia as well as subsequent lab work here in Athens and at Oak Ridge National Lab

using the SIMS housed there. This project, the results of which were published in *GEOLOGY* in 2001, was a cooperative study sanctioned by a formal agreement between the Far East Geological Institute of the Russian Academy of Science and the University of Georgia. At left is a photo of the Primorye coast at Rudnaya Pristan, approximately 30 km east of Dalnegorsk.

2. Graduate student Greg Vaughan (M.S. 1995) worked on seafloor hydrothermal vents (blacksmokers) from several East Pacific Rise vent sites. Greg had the unique opportunity of getting some dive time on the ALVIN submersible at the 9-10º N site, where very recent volcanic activity (zero age) gave scientists the chance to see a submarine hydrothermal system born. Greg's research focused on the variation of sulfur isotope ratios within individual chimney walls. This work documented variable fluid compositions in these ephemeral vent sites, and has led to a better understanding of mid-ocean ridge hydrothermal fluid flow. He used the laser microprobe here in Athens for this work. The photo at left shows the blacksmoker chimney collected at the 21º N site that Greg concentrated on in his thesis. It is one of the largest chimney structures collected to date from a mid-ocean ridge site, and it currently resides here in Athens. Greg also did a substantial amount of work on improving the standardization procedure used for laser ablation stable isotope ratio measurement, and the results of that work was published in *American Mineralogist* in 1996.



3. Between 1995 and 2002 a number of students worked on mineral deposits here in the U.S. Langdon Mitchell (M.S. 1996) worked on the Viceroy Gold Castle Mountain adularia-sericite epithermal gold deposit in California. This system is unusual in the sense that it appears to be directly spatially related to and contemporaneous with the 15 my Linder Peak volcanic package that it ' s hosted in. These adularia-sericite systems almost always form distal to volcanic centers and 1-2 my after the cessation of volcanism, so Langdon's thesis is an important study that proves to be the exception to the rule from an ore deposit model standpoint. The top left photo is an aerial shot of the Castle Mountain property , and clearly shows the widespread, argillically-altered zone surrounding the centrally located pits representing the zone of focused fluid flow and gold mineralization. The results of Langdon ' s work were published in a *GSN Ore Deposits of the Cordillera* volume in 1996.

Grant Eager (M.S. 1998) focused on the Kennecott Ridgeway gold deposit in South Carolina. We led an SEG-sponsored fieldtrip here from the 1995 national GSA meeting, and many of the participants were hard pressed to say what sort of deposit Ridgeway was initially as it is now so structually deformed. Grant found that the sulfur isotope signature of the pyrite that is ubiquitous throughout the deposit is strongly suggestive of formation in a submarine hot-spring environment. These data, coupled with a number of critical field observations, will hopefully put the shear-zone vs. hot-spring debate to rest. The top right photograph shows a piece of high grade ore (upper, cm scale) and a photomicrograph (lower, field of view is 4.6 mm) of the same material which shows the strongly developed cleavage.

Julia Rosdeutscher (M.S. 1999) did her thesis on the Pikes Peak Mining Co. Grassy Valley gold deposit in Colorado. This deposit is hosted just outside the phonolitic breccias that comprise much of the diatreme in the middle of the Cripple Creek district (see lower left photo for a map of the district, including Grassy Valley), which is a famous and long-term gold producer. Julie was able to show that although the deposit is not hosted within the diatreme proper, it was still dominated by magmatic rather than meteorically derived fluids.

Students Christian Schrader and Berkley Tracy completed their Masters projects in 2001 working on a large porphyry system in Alaska. We spent about a month during the summer of 1998 at Lake Iliamna, Alaska, working on core samples from the Pebble Cu-Au porphyry deposit. Cominco American Exploration funded this project. Christian worked on the geochronology and geochemistry of the multiple intrusive phases extant within the area, while Berkley focused on a combined fluid inclusion/barometry/structure problem that involved a significant amount of three dimensional modeling. It's a huge deposit, and both of these projects could easily have been expanded into Ph.D. dissertations. The photo at the lower right shows Christian and Berkley styling on the back of the Iliamna Lake Lodges' 900 HP jet boat that took us for a run up the Newhalen River that runs into Lake Iliamna.

4. Graduate student Fred Andrus completed his M.S. under the direction of Dr. Betsy Reitz (UGA Anthropology) working on the stable isotope geochemistry of oysters and clams from the Georgia coast and his Ph.D. under my direction, and is solely responsible for dragging me kicking and screaming into the archeological and climatological realm. Now a professor at the University of Alabama, Fred made some major breakthroughs, and in particular his work that has shown that sea surface temperature (SST) and El Nino is clearly recorded in oxygen isotope profiles in Peruvian sea catfish otoliths (aragonite "earstones" in fish) collected during the 1997-1998 ENSO event. Otoliths from the same species of catfish excavated from archaeological sites in northern Peru show that SST's were warmer prior to 5000 BP than today. The results of this research are now published in *Science, Paleoceanography*, and the *Journal of Archeological Science*. The photo at left shows Fred at the Ostra site south of Trujillo near the Santa river in Peru.

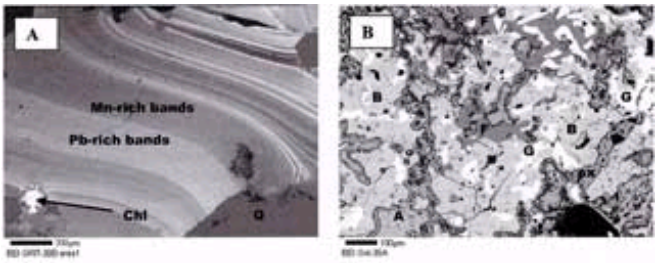


Figure 1: Backscatter electron images (BEI) of Betty O'Neal mine samples. A) Chlorargyrite (chl) grain in banded lead-manganate (e.g. coronadite) surrounded by quartz (q). B) Ag-rich fahlore (F) intergrown with bournonite (B), galena (G), acanthite (A), and oxidized bournonite (ox).

5. Chris Kelson worked with PlacerDome USA on an investigation of the Hilltop mine and surrounding areas in the Battle Mountain district, Nevada. He completed his Ph.D. in 2006 and is now an assistant professor at SUNY-Potsdam. Chris ' research focused on the timing of intrusion and mineralization in the Hilltop district. Chris spent several summers in Nevada working on the numerous mines and prospects in the district, and a great deal of time here in Athens doing stable isotope, fluid inclusion, and age dating on a huge suite of samples. The figure shows some of the nice sulfosalt-rich material Chris worked on from the Betty O ' Neal mine, one of the many interesting mineralized areas within the Hilltop district. The results of this research have already been published in a *GSN Ore Deposits of the Cordillera* volume, and are now in submission to *Economic Geology*.

6. Elizabeth Hollingsworth just completed her M.S. working on elucidating the nature of the fluid flow system in the Uzon caldera, Kamchatka. This project is an NSF funded study to evaluate the relationships between hydrothermal fluid flow and microbiological consortia that live in hot spring systems. Elizabeth spent a field season in the caldera collected a large suite of water, sediment, and rock samples, and subsequently collected a large amount of sulfur isotope data from those samples. She was able to constrain quite nicely the origin, migration, and ultimate fate of sulfur as it released from the magma chamber beneath the caldera, migrated upward, and then interacted in a myriad of ways at the surface, including becoming available to numerous microbial organisms. This work is now in submission at the *Journal of Volcanology and Geothermal Research*. The photo shows Elizabeth and

colleagues working in the East Thermal Field, with Mt. Uzon in the background. Elizabeth just completed her first tour as a geologist working at the Green ' s Creek massive sulfide mine in southeast Alaska, and is currently mushing dogs for tourists in Chena Hot Springs near Fairbanks.

All these students have done outstanding jobs and have gone on to a variety of careers in academia and industry. In the process of doing their research they became quite savvy at doing a host of different things, and I have benefited more than they know from all wonderful things they have learned. I am now beginning a year long formal Study in a Second Discipline program here at UGA, during which time I hope to morph somewhat into a geobiologist, while retaining my ore deposit roots. We will continue our Kamchatka hot spring work, with exciting new projects on the horizon focused on nitrogen and sulfur cycling in hot springs, as well as the biogeographic distribution of various microbial consortia within active caldera settings.

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