KECK GEOLOGY CONSORTIUM

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

April 2011
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2010-2011 PROJECTS

FORMATION OF BASEMENT-INVOLVED FORELAND ARCHES: INTEGRATED STRUCTURAL AND SEISMOLOGICAL RESEARCH IN THE BIGHORN MOUNTAINS, WYOMING
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EXPLORING THE PROTEROZOIC BIG SKY OROGENY IN SOUTHWEST MONTANA
Faculty: *TEKLA A. HARMS*, *JOHN T. CHENEY*, Amherst College, *JOHN BRADY*, Smith College
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INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO
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SEDIMENT DYNAMICS & ENVIRONMENTS IN THE LOWER CONNECTICUT RIVER
Faculty: *SUZANNE O'CONNELL*, Wesleyan University
Students: LYNN M. GEIGER, Wellesley College, KARA JACOBACCI, University of Massachusetts (Amherst), GABRIEL ROMERO, Pomona College.

GEOMORPHIC AND PALEOENVIRONMENTAL CHANGE IN GLACIER NATIONAL PARK, MONTANA, U.S.A.
Faculty: *KELLY MACGREGOR*, Macalester College, *CATHERINE RIIHIMAKI*, Drew University, *AMY MYRBO*, LacCore Lab, University of Minnesota, *KRISTINA BRADY*, LacCore Lab, University of Minnesota

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GEOLOGIC, GEOMORPHIC, AND ENVIRONMENTAL CHANGE AT THE NORTHERN TERMINATION OF THE LAKE HÖVSGÖL RIFT, MONGOLIA
Faculty: *KARL W. WEGMANN*, North Carolina State University, *TSALMAN AMGAA*, Mongolian University of Science and Technology, *KURT L. FRANKEL*, Georgia Institute of Technology, *ANDREW P. deWET*, Franklin & Marshall College, *AMGALAN BAYASAGALN*, Mongolian University of Science and Technology.
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LATE PLEISTOCENE EDIFICE FAILURE AND SECTOR COLLAPSE OF VOLCÁN BARÚ, PANAMA
Faculty: *THOMAS GARDNER*, Trinity University, *KRISTIN MORELL*, Penn State University
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KECK SIERRA: MAGMA-WALLROCK INTERACTIONS IN THE SEQUOIA REGION
Faculty: *JADE STAR LACKEY*, Pomona College, *STACI L. LOEWY*, California State University-Bakersfield
Students: *MARY BADAME*, Oberlin College, *MEGAN D'ERRICO*, Trinity University, *STANLEY HENSLEY*, California State University, Bakersfield, *JULIA HOLLAND*, Trinity University, *JESSLYN STARNES*, Denison University, *JULIANNE M. WALLAN*, Colgate University.

EOCENE TECTONIC EVOLUTION OF THE TETONS-ABSAROKA RANGES, WYOMING
Faculty: *JOHN CRADDOCK*, Macalester College, *DAVE MALONE*, Illinois State University
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Keck Geology Consortium: Projects 2010-2011
Short Contributions— Sierra Nevada Mountains

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ORIGIN OF MIGMATITIC ROCKS IN THE SEQUOIA PENDANT, SIERRA NEVADA, CALIFORNIA
MARY BADAME, Oberlin College
Research Advisor: Steve Wojtal

PLUTON-WALLROCK INTERACTION OF THE EMPIRE QUARTZ DIORITE, SOUTHERN SIERRA NEVADA: IMPLICATIONS FOR SKARN FORMATION IN THE MINERAL KING PENDANT
MEGAN D'ERRICO, Trinity University
Research Advisor: Dr. Benjamin Surpless

TEMPORAL VARIATION IN PLUTON-WALLROCK INTERACTION IN THE SIERRAN ARC
STANLEY HENSLEY, California State University, Bakersfield
Research Advisor: Dr. Staci Loewy

THE PETROGENESIS OF THE ASH MOUNTAIN INTRUSIVE COMPLEX: IMPLICATIONS FOR SIERRAN MAGMATISM
JULIA HOLLAND, Trinity University
Research Advisor: Ben Surpless

EARLY SIERRA NEVADA MAGMATISM EXAMINED USING SHRIMP-RG U-PB AGES AND TRACE ELEMENT COMPOSITIONS OF ZIRCONS FROM THE MINERAL KING ROOF PENDANT RHYOLITE UNITS
JESSLYN STARNES, Denison University
Research Advisor: Dr. Erik Klemetti

STABLE ISOTOPE GEOCHEMISTRY OF MARBLES IN THE KINGS SEQUENCE, SIERRA NEVADA, CA
JULIANNE M. WALLAN, Colgate University
Research Advisor: William H. Peck

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ORIGIN OF MIGMATITIC ROCKS IN THE SEQUOIA PENDANT, SIERRA NEVADA, CALIFORNIA

MARY BADAME, Oberlin College
Research Advisor: Steve Wojtal

INTRODUCTION

In the Sequoia Pendant, migmatites formed from biotite schist of the Kings Sequence are directly adjacent to undeformed intrusions of the Ash Mountain Complex. Migmatization may have occurred as a result of heating and ductile flow created by intrusion of the Ash Mountain Complex. Alternatively, melt generation by migmatization may have produced the more felsic components of the Ash Mountain Complex. A third hypothesis is that migmatization occurred prior to and independent of local magmatism. Migmatites were studied to evaluate when and under what conditions they formed with respect to the rest of the Sierran Arc. Partial melting exhibited in the migmatitic rocks may help to explain the diversification of the Sierran magmas.

GEOLOGIC BACKGROUND

The Kings Sequence is comprised of a group of distinct metamorphic pendants, and runs along 250 km of the southern Sierra Nevada batholith (Saleeby and Busby, 1993). The Kings Sequence contains Upper Triassic to Early Jurassic rocks of marine origin. The pendants grouped in the Kings Sequence consist of quartzite, marble, schist, and mafic and silicic metavolcanic rocks.

The Sequoia Pendant of the Kings Sequence crops out along the Marble Fork of the Kaweah River exposing migmatitic biotite schists. The migmatites are in close proximity to the Fry's Point granite, supporting a hypothesis for the cause of migmatization. Mafic components (mostly diorite) associated with the Fry's Point pluton partially melted the adjacent sedimentary rocks, causing migmatization of the Marble Fork biotite schists. Deeper portions of the Sequoia Pendant melted to produce the Fry's Point granite, which intrudes both the diorite and the biotite schist in the Marble Fork region.

METHODS

Fieldwork in Sequoia National Park, California was conducted during the summer of 2010. Samples of the migmatitic biotite schists of the Sequoia Pendant were collected. Two samples were processed for zircons, which were analyzed at the SHRIMP laboratory at Stanford University for age and trace element concentration. The zircons analyzed were imaged using a cathodoluminescence detector attached to a scanning electron microscope (SEM-CL) to characterize their internal structures. Some samples were also fused and analyzed for whole rock major and trace element data using the XRF laboratory at Pomona College. Thin sections were made of most samples, carbon-coated and analyzed using petrographic microscopy and scanning-electron microscopy with energy dispersive x-ray spectrometry (SEM/EDS). SEM/EDS analysis of the migmatitic biotite schists generated elemental compositions of mineral phases.

SHRIMP-RG U/PB ANALYSIS

The migmatite samples processed yielded few zircons. SHRIMP-RG U/Pb analyses of six zircons yielded a range of ages from 1800-105 Ma. Figure 1 shows SEM-CL images and dates of the zircons. The youngest zircon yielded a ^{207}Pb corrected ^{206}Pb/^{238}U age of 106.4±1.4Ma, within error of the 105.5 Ma age of the Fry's Point granite (Holland, this volume). It has euhedral form and prismatic terminations suggesting magmatic growth, potentially during migmatization of host biotite schist. In addition, zircon from the Fry's Point granite commonly contain inherited cores. One such core was dated at 1088.7 Ma, indicating the granite likely incorporated a component of the metamorphosed

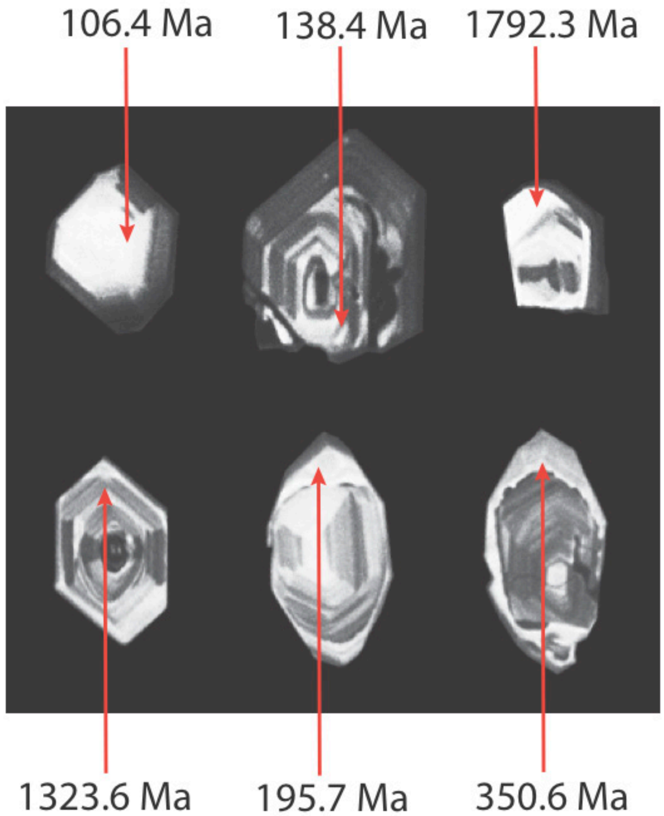

Figure 1: SEM-CL images of zircons yielded from two migmatite samples. Spot placements of SHRIMP-RG U/Pb detector are indicated by arrows. Ages are 207 corrected $^{206}Pb/^{238}U$ Ages. Zircons are approximately 40 µm across.

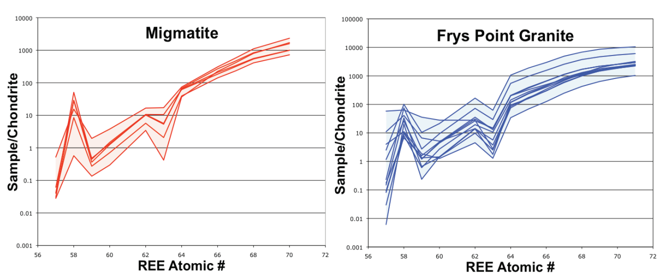

Figure 2: REE profiles of zircons yielded from migmatized biotite schists and Fry's Point granite. REE compositions were attained using SHRIMP-RG U/Pb analysis.

sedimentary rocks.

Another zircon yielding an age of 138.4±1.0 Ma gives a maximum depostitional age for this portion of the Kings Sequence consistent with other minimum ages yielded from rocks in the pendant (see Hensley, this volume). The SHRIMP-RG U/Pb age data suggest that the samples analyzed were deposited and drawn into the middle crust between 138.4±1.0 Ma, minimum depositional age, and the 106.4±1.4 Ma, the age of migmatization.

Trace element analysis of the zircons yielded from the migmatitic biotite schist and the Fry's Point granite further indicated the link between the two. Figure 2 shows REE profiles of both. The similarity of the REE patterns supports incorporation of the biotite schist, or partial melts thereof, into the granite magma.

PETROGRAPHY

The major minerals identified using a petrographic microscope and an SEM were hornblende, biotite, quartz, monazite, plagioclase, ilmenite, and apatite. The migmatitic biotite schists are composed of the three phases, the leucosome, melanosome, and paleosome. Figure 3 shows typical boundaries between the three phases. Leucosomes are primarily composed of quartz and plagioclase, with some monazite and apatite. Irregular quartz-feldspar boundaries in the leucosomes, with individual grains exhibiting cuspate and spikey extensions indicate melt solidification and lower nucleation rates (Holness, 2008). Melanosomes contain biotite, ilmenite and small amounts of hornblende. Paleosomes are intermediate in character between leucosomes and melansosomes and are interpreted to be host rock unaffected by migmatization

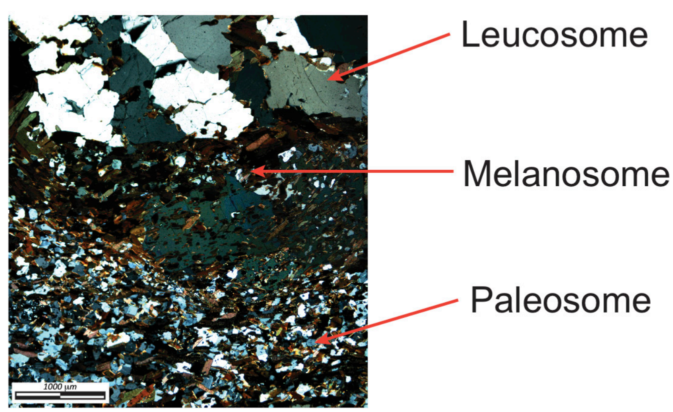

Figure 3: Photomicrograph of migmatized biotite schist exhibiting typical boundaries between leucosome, melanosome, and paleosome. Leucosome of sample illustrates irregular quartz-feldspar boundaries and cuspate extensions of individual grains.

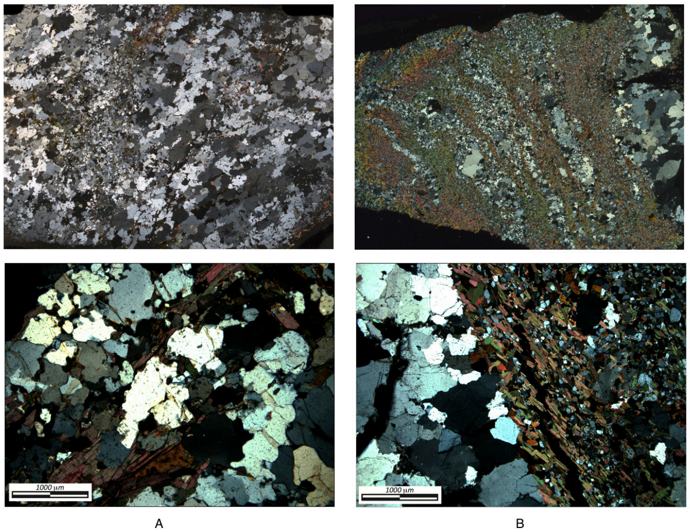

Figure 4: Scans and photomicrographs of two thin sections. Thin section A is 84% leucosome, 3% melanosome, and 13% paleosome. Thin section B is 63% leucosome, 23% melanosome, and 14% paleosome.

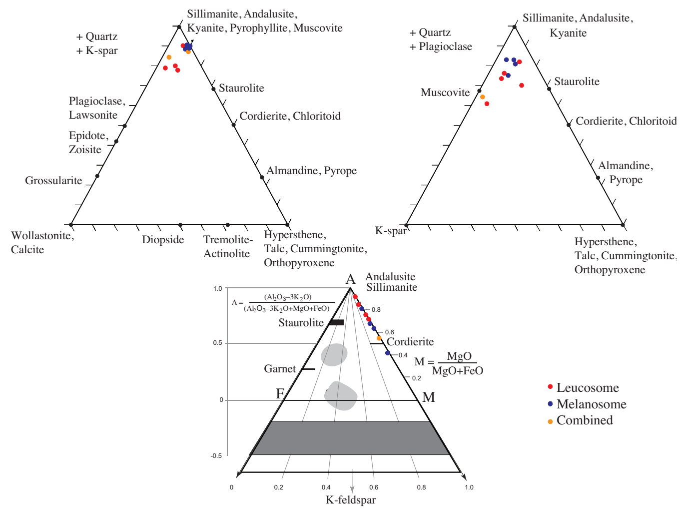

Figure 5: Three triangular plots (ACF, AKF, and AFM) indicating geochemistry of samples and formation of migmatites at lower grades.

(Winter, 2001). The samples range in their compositions of the three phases: 56-84% leucosome, 2-23% melansome, and 13-26% paleosome. Samples with a greater percentage of melanosome (>10%) have oriented biotite crystals and more linear melanosome-leucosome boundaries. Figure 4 shows scans and photomicrographs of two thin sections that exemplify the two textures described. Samples with lower percentages of melanosome have very fine-grained and scattered biotite, a reaction texture indicating the breakdown of biotite.

Bulk composition of the leucosome and melanosome domains is distinct. Figure 5 shows ternary diagrams of whole rock major element data: ACF, AKF, and AFM. The leucosomes have high silica content, but do not appear to be equivalent to a granitic melt composition. The AFM diagram demonstrates the almost identical behavior of the iron and magnesium components, indicating their pressure and temperature were lower than most metamorphosed pelitic rocks. In addition, the ACF and AKF diagrams do not show major element data consistent with high-grade mineral assemblages.

DISCUSSION AND CONCLUSIONS

The links between the Fry's Point granite and the migmatitic biotite schists of the Marble Fork region indicate migmatization was not independent of magmatism. Corresponding SHRIMP-RG U/Pb ages of the youngest migmatitic zircon and the majority of zircons from the adjacent Fry's Point granite suggest the two formations are coeval. The inherited zircon cores in the Fry's Point granite and the similarity of the REE profiles of the zircons yielded from the migmatites and granites indicate the granite magma likely incorporated metamorphosed sedimentary rocks during its formation.

The mineral assemblages observed as well as the absence of garnet, andalusite, cordierite, staurolite, and other high-grade minerals suggest that the rocks were metamorphosed at a low-grade. In addition, the analogous behavior of the iron and magnesium components indicate the migmatites were formed at a lower temperature and pressure than expected of typical pelites. Had these characteristics of the migmatitic biotite schists been the result of metamorphic retrogression, mineral alterations such as biotite to chlorite and feldspar to mica would have been observed.

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