2013 Geology Research Day

Abstract Volume

Department of Geological Sciences
California State University, Fullerton
Titan Student Union - Garden Café , April 26 2013

The Department of Geological Sciences at California State University, Fullerton is an interdisciplinary education and research community whose members are active mentors and role-models. Our mission is to provide a student-centered educational and research experience that emphasizes critical thinking, communication, and scientific citizenship.

'Research Day' is an extension of this mission, where students are afforded the opportunity to share their research findings and scientific experiences with faculty, student peers, friends, family, and members of the professional geological community in an informal and supportive environment. Thank you for participating in this year's event!

4th Annual Geology Research Day

California State University, Fullerton ~ Department of Geological Sciences

Titan Student Union Garden Café

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Assessing a late Triassic fossil sponge reef mound to further understand the shift from Paleozoic fauna to modern fauna

Mihai Agiu
Faculty Advisor: Professor Nicole Bonuso

This study will examine a fossil sponge reef mound recently located in New Pass Range, Central Nevada, in order to document reef dynamics for further understanding of how reefs became modernized. The reappearance of reefs in an ecosystem often serves as a marker for the end of recovery. After the end-Permian mass extinction (approximately 252 million years ago), in which about 96 percent of all marine species perished, secondary reef-building organisms, such as sponges, recovered initially as the primary reef-builders. Marine organisms from the past died out and new, more modern organisms took their place. The sponge reefs are intermediate between the "Paleozoic" fauna prior to mass extinction, and "modern" fauna. Understanding past extinctions and recoveries is significant because of current issues with global climate change and marine ecosystem degradation. Such information can be used in comparison with modern crises to help predict possible outcomes, and contribute to conservation initiatives to avoid large-scale changes in modern marine communities. Research methods include both field and laboratory procedures: A small, 10 meter high by 10 meter long reef preserved in limestone, will be documented by using a systematic grid-rock sampling scheme. Rock samples will be collected from locations where the grid lines intersect: approximately 25 samples. Rock thin-sections will then be produced to examine and document the fossils within the rocks. The efforts of understanding the shift from “Paleozoic” fauna to “modern” fauna will provide insight on marine ecosystem recovery.

Determining the Evolutionary History of Miocene Leatherback Sea Turtles Using Fossil Specimens from Orange County

Katrina Awalt
Faculty Advisor: Professor James Parham

The living leatherback sea turtle (Dermochelyidae) is a highly specialized and critically endangered species that represents the last representative of a once much more diverse group of sea turtles. From the Cretaceous to the middle Miocene many different species coexisted (Wood, et al., 1996), eventually dwindling to the single extant species currently alive today. The decline of leatherback diversity in the Miocene coincides with a major change in their shell. Most turtles have shells made up of approximately 50 bony plates, but leatherback shells are made of hundreds of interlocking bones called ossicles. Middle Miocene leatherbacks have thick shells with large ossicles, whereas extant leatherbacks have relatively thinner shells with more, smaller ossicles. Leatherbacks have a poorly studied evolutionary history, and through my research I hope to reach conclusions about when, and why leatherback diversity so sharply declined. Orange County has one of the best fossil records of leatherbacks, and I will be focusing on specimens collected during paleontological mitigation that are part of the collections of John D. Cooper Archaeological and Paleontological Center. These specimens are from the “Topanga” and “Monterey” Miocene formations (in quotes because the formation names

in Orange County need to be revised). While there have been multiple Miocene leatherback fossils discovered in California, only a single bone has ever been described (Gilmore, 1937). My research will consist of describing these fragmentary fossil specimens and using ossicle characteristics to determine where they fit into the evolutionary time line of leatherbacks. It is my hope that this new information will help to shed understanding on when leatherbacks began to experience a decline of diversity.

Gilmore, C.W. 1937. A new marine turtle from the Miocene of California. Proceedings of the California Academy of Sciences Fourth Series 23(10):171-174.

Wood, R.C., Johnson-Gove, J., Gaffney, E.S., Maley, K.F. 1996. Evolution and phylogeny of leatherback turtles (Dermochelyidae), with descriptions of new fossil taxa. Chelonian Conservation and Biology 2(2):266-286.

Fault orientations of the Sierra Nevada Frontal Fault zone in the vicinity of Lone Pine, California

Brian Gadbois
Faculty Advisor: Professor Phillip Armstrong

The eastern boundary of the Sierra Nevada Mountains is defined by a system of east dipping normal faults known as the Sierra Nevada Frontal Fault Zone (SNFFZ). It generally is assumed that these normal faults dip about 60 degrees east. Recent work by Phillips and Majkowski (2011) on the northern section of the SNFFZ near Bishop shows normal faults that dip 35-46 degrees - much less than assumed typical dips. Current models used to calculate long-term slip rates along the SNFFZ are based on a 60 degree fault dip. If fault dips are significantly shallower than 60 degrees, computed long-term horizontal extension rates will be significantly greater than initially assumed because the horizontal component of slip will be as much as two times greater than expected. Based on previous studies and my own field reconnaissance surveys, I hypothesize that SNFFZ normal faults near Lone Pine dip much shallower than 60 degrees. I will test this hypothesis by mapping and measuring faults and their orientations from fault surface exposures in Tuttle Creek canyon west of Lone Pine at the base of Whitney Portal. Data will be collected using basic field mapping techniques and detailed differential GPS measurements. Continuous fault mapping across ~300m of elevation change will allow the construction of 3-D fault planes, from which a dip can be derived.

Geochemical analyses of Early Rhyolite and Rhyodacite from Dome 7403: Insights into post-caldera evolution of Long Valley caldera

Matthew Hutchinson
Faculty Advisor: Professor Brandon Browne

Long Valley Caldera formed 760,000 years ago following the catastrophic eruption of ~600 km^3 of compositionally zoned rhyolite known as the Bishop Tuff. In the 100,000 years following this eruption, ~100 km^3 of crystal-poor rhyolite referred to as the Early Rhyolite was erupted. Early Rhyolite magma is compositionally distinct from Bishop Tuff magma, with lower SiO_2 concentrations and higher Ba concentrations. Early Rhyolite lavas also contain quenched inclusions of andesite, suggesting that more mafic magma intruded the reservoir holding Early Rhyolite magma prior to eruptions. The only other post caldera “mafic” magma erupted within the ring fracture system of Long Valley is rhyodacitic and found as Dome 7403, a small plug of 100-m-thick lava found on the northeast floor of Long Valley. Does magma erupted from Dome 7403 also possess a magma mixing origin like the Early Rhyolite? This

project aims to compare the major and trace element compositions of Early Rhyolite lava, andesite inclusions in Early Rhyolite lavas, and rhyodacite from Dome 7403 as a way of examining the question of a common origin. Whole rock Ar-Ar dating of the Dome 7403 lava will also be completed as a means of evaluating the age of this unit, which will assist in our interpretation of the evolution of the Long Valley Caldera system.

Understanding the Orientation of the Sierra Nevada Frontal Fault System in the Vicinity of Lone Pine and Independence, CA

Garrett Mottle
Faculty Thesis Advisor: Professor Phillip Armstrong

Owens Valley in eastern California is a deep graben located between the Inyo and White Mountains to the east and by the Sierra Nevada Mountains to the west. The boundary between Owens Valley and the Sierra Nevada Mountains is the Sierra Nevada Frontal Fault System (SNFFS), which is a system of normal faults formed by crustal extension of the Basin and Range province. It generally is assumed in previous studies that the SNFFS normal faults dip steeply at ~60 degrees east. However, a recent study (Phillips and Majkowski, 2011) shows that the faults typically dip less than 50 degrees along the northern part of the SNFFS near Bishop. More recent work (Shagam 2011) near Independence shows that faults there dip 29-34 degrees east. My hypothesis is that faults farther south between Independence and Lone Pine dip shallowly (~30 degrees). I will test this hypothesis by mapping and measuring fault orientations of the SNFFS at George and Bairs Creeks using hand-held GPS and differential GPS devices at three fault exposures. The selected faults will have sufficient elevation exposure to allow for three-point analysis to determine their orientations in detail. This study will involve geologic mapping and the measurement of rock fractures in granite bedrock in order to evaluate the relationships between master fault dips and subsidiary faults and fractures in the footwall. Deliverables of this study will include a detailed map of a section of the SNFFS and a report discussing the data and conclusions found in this study.

Assessing the Dependency Between the Magnitudes of Southern California Earthquakes and the Magnitudes of Their Aftershocks

Daniel J. Philo and Alyssa Garcia
Faculty Advisors: Professors Kevin Nichols and David Bowman

Previous studies on the dependency of aftershock magnitude and mainshock magnitude have come to widely varying conclusions, with complete independence on one end (Davidsen and Green, 2011) and a positive correlation on the other (Lippiello et. al., 2008). This study will further investigate the dependency between aftershock and mainshock magnitudes by applying a model independent stochastic declustering (MISD) algorithm to a Southern California earthquake catalog. MISD will determine the probability that a given earthquake is either a mainshock or an aftershock of a previous earthquake. The average aftershock magnitude can then be computed for any given mainshock magnitude. This study aims to find if there is a positive correlation between the two (i.e., an increase in mainshock magnitude is accompanied by an increase in average aftershock magnitude). Preliminary data acquired by applying MISD to a global earthquake catalog suggests that there is a positive

correlation between mainshock magnitude and aftershock magnitude. This study will use a localized earthquake catalog to further refine these findings. MISD will be applied to three data sets from the Southern California Seismic Network (SCSN), covering the years 2003-2012. The first data set is reported in local magnitude, the second in moment magnitude, and the third data set prioritizes spatial accuracy by relocating epicenters using 3-D velocity modeling. MISD will also be applied to a synthetic earthquake catalog, where mainshocks and aftershocks are known. This will provide a standard to which the results from the three data sets can be compared. A further understanding of the dependency between mainshock and aftershock magnitudes is important for analyzing earthquake hazard. This study will allow for a more complete assessment of the potential risks of earthquakes and their aftershocks, which is especially important in earthquake prone Southern California.

Davidsen, J., and A. Green (2011), Are earthquake magnitudes clustered?, Physical Review Letter, 106, 108502; Lipiello, E., L. de Arcangelis, and C.Godano (2008), Influence of time and space correlations on earthquake magnitude, Physical Review Letter, 100, 038501

Mapping the enriched-mantle component of the Kern Plateau, Eastern Sierra Nevada, California

Elizabeth M. White
Faculty Advisor: Professor Diane Clemens-Knott

The Mesozoic Sierra Nevada batholith, located in eastern-central California, represents one of the most intensely studied batholith complexes in the world. Its overall composition is granodioritic, which likely formed by some differentiation process involving basaltic magma generated in the mantle wedge overlying the eastwardly subducting Farallon Plate. However, the likely complexity of the lithospheric mantle underlying the southwestern North American margin, as well as the continental crust into which the batholith was emplaced, resulted in a complicated amalgam of geochemical and isotopic compositions. The purpose of this study is to chemically characterize the most mafic rocks from the Sierra Nevada batholith since they best reflect the composition of the mantle-derived parental magma. Specifically, many whole-rock isotopic and geochemical analyses suggest that the magma genesis of the Sierra Nevada batholith is the result of juvenile crust formed from a depleted-mantle source. However, rock suites in the eastern batholith, such as those from the Lamarck Granodiorite, display distinct geochemical characteristics, which have been interpreted as reflecting magmatic contributions from an enriched-mantle source (Coleman et al., 1992). Significantly, use of the enriched-mantle derived magma in mass-balance calculations for the Mesozoic crustal growth event in the Sierra Nevada batholith considerably decreases the estimates of how much material was transferred from the mantle to the crust during the Mesozoic Era. A major argument against past studies, however, the scarcity of mafic rocks analyzed. The Kern Plateau is one of the few locations in the eastern Sierra Nevada Mountains where mafic rocks are exposed. In this project, I will first map and sample the Summit Gabbro. Then I will analyze the whole-rock chemistry using XRF and produce a petrographic description of mineral textures. My overarching goal is to locate the most chemically primitive (ideal target of Mg# = 65 to 72) Summit Gabbro facies, with the goal of characterizing the mantle-derived component involved in the differentiation of the eastern batholith. The results of this study will improve our understanding of crustal growth in continental margin arcs.

Coleman, D. S., Frost, T. P., Glazner, A. F. (1992) Evidence from the Lamarck Granodiorite for Rapid Late Cretaceous Crust Formation in California. Science, v 258, no. 5090, 1924-1926.

Did Alpine Glaciers Exist on Sugarloaf Mountain During the Last Glacial (San Bernardino Mountains, California)?

Alexandre Woodward
Faculty Advisor: Professor Matthew Kirby

Paleoclimatic research has shown that there have been four periods of alpine glaciation in the mountain ranges of Southern California during the last 22,00 years(Owen et al., 2003). The evidence is conclusive along the north facing lopes of Mt San Gorgonio within the San Bernardino Mountains. These sites of Alpine glaciation all two key characteristics: 1) a minimum glaciation height of of more than 9000' above sea level: and 2) a north or northeast facing slope. Sugarloaf Mountain of the San Bernardino Mountains is located approximately seven miles north of Mt San Gorgonio and shares these two key characteristics. It is hypothesized that an alpine glacier occupied the north facing slope of Sugarloaf Mountain. To test this hypothesis, a field research project is proposed. This project will involve: a) extensive field mapping: and b) a comparison of modern precipitation between the two sites. Features particular to alpine glaciation will be mapped with GPS, photographed, and described. Potential features include moraines, erratics, and striations. If the hypothesis is proven correct, future research separate from this project may include cosmogenic dating of specific glacial features. Evidence of glaciation, or lack thereof, will increase the knowledge of the past hydroclimatic conditions during the last glacial.

Undergraduate Thesis Category

Primary Productivity and Paleoxygenation Following the End-Permian Mass Extinction: A High-Resolution Geochemical Analysis of Griesbachian Sediments from the Canadian Sedimentary Basin (Alberta, Canada)

Elizabeth Agredano
Faculty Advisor: Professor Adam D. Woods

The recovery of primary producers following the End-Permian mass extinction (~252 Ma) is an inadequately studied niche of extinction recovery analysis. Although the recovery of primary producers set the foundation for ecological re-equilibration, most studies have instead focused on elucidating the recovery of macroflora and fauna. Thus, it is essential to quantify trends in the recovery of primary producers in order to better understand the way in which life rebounds after such a crisis. To that end, this study analyzed trace element variation in samples from a core extracted from the Lower Triassic (Griesbachian) Montney Formation of the Pedigree-Ring Border-Kantah River area, located within the Western Canadian Sedimentary Basin (WCSB) in modern day Alberta. Forty-four ~50mg samples from core 16-8-86/20W6 were examined for trace element concentrations using ICP OES (Perkin Elmer 7300 DV). Total organic carbon (TOC) contents of the samples were previously obtained using the Loss on Ignition method. The concentration values of trace element proxies for paleoxygenation and primary productivity were then compared to a world-average-shale for analysis. Preliminary results demonstrate relatively high concentrations of %TOC, Ba, Cu, Ni, and Zn, which are indicative of high

productivity levels across the Griesbachian, and therefore a rapid, robust recovery of primary producers. Relatively high concentrations of V and low concentrations of Mo suggest anoxic, but not euxinic depositional conditions. Reduced benthic oxygenation levels characteristic of the samples are likely the result of a combination of high productivity and a deep, anoxic ocean water mass impinging onto the continental shelves. The results of this study support recent hypotheses that suggest high primary productivity in the aftermath of the extinction, perhaps as the result of increased nutrient input to the oceans (Algeo and Twitchett, 2010), and suggest that high primary productivity and productivity-driven anoxia may have acted as a stressor during the recovery interval. This research, combined with trace element analysis of samples from additional cores and outcrops, will provide high-resolution pictures of temporal and spatial trends in primary productivity, as well as an overall understanding of how productivity is related to the environmental conditions that contributed to recovery from the End-Permian mass extinction.

Acknowledgements are made to California State University, Fullerton Louis Stokes Alliance for Minority Participation (Grant number NSF:HRD – 0802628), whose support for this work were invaluable

Assessing Potential for Geothermal Energy in Northern Thailand

Priyankaa Cid
Faculty Advisor: Professor Brady Rhodes

Northern Thailand is characterized by linear mountain ranges and steep sided valleys where northwest trending high-angle faults play a large role in the presence and potential for geothermal energy. Because of cooling magmatic bodies, remnant from the Shan Tai and Indo-China collision in the Permian to late Triassic, the heat source remains active allowing for many hot springs and geysers to be exposed at the surface. Related to these faults are a number of hot springs currently under investigation as a potential geothermal energy source. Surface temperature must be over 80^{o} C to be considered a high potential geothermal energy source. This study looks to implement a geothermal energy plant centered on the San Kampaeng hot springs, located in the Chiang Mai basin. The hypothesis I tested was: based on high temperature at depth, the San Kampaeng hot springs are thought to be a source of consistent high potential geothermal energy. In order to test this hypothesis I collected 5 water samples that were analyzed for calcium, quartz, sodium, potassium. Through calculating saturation indices I found the geyser subsurface temperature results consistent with previous studies. These results suggest a consistent high potential geothermal energy source that provides further support towards establishing a hydrothermal power-plant in San Kamphaeng.

Recovery of deep marine communities following mass extinction at the Permian-Triassic boundary

Crystal Cortez
Faculty Advisor: Professor Nicole Bonuso

Earth history has seen the extinction and recovery of many of its inhabitances due to global changes beyond any control. With global change occurring daily it is vital to record information about past extinctions as well as those organisms that were able to surpass similar crises. Such information can be

used as a comparison with modern crises and possible conservation plans can be produced. In this study an analysis was made of deep marine communities shortly after the world's largest mass extinction at the Permian-Triassic boundary around 251 million years ago. An assessment was made of the Fossil Hill Member, located within the Favert Formation where present day Nevada now lies. Geologic history shows this locality was once belonged to the back arc of the Somona Orogeny yielding deep marine sediments of the Middle Triassic. Rock samples were taken and made into thin sections in order to record rock types in addition to cataloging the biodiversity found within the samples. A stratigraphic column was produced in order to observe changes in communities through time. Analysis revealed that although several organisms were discovered, the abundance of bivalves was overwhelming. In addition, some species of foraminifera were observed which, have never been mentioned in the literature for this location. Additional detailed analysis is needed in order to classify the organisms down to the species level. However, the abundances and biodiversity found within the samples show that not only do we have organisms recovering from mass extinction but flourishing as well.

Petrology of Minaret Cone, Mammoth Mountain, CA

Blair Davidson
Faculty Advisor: Professor Brandon Browne

Approximately three dozen mafic vents surround Mammoth Mountain, a volcanic complex of 25-30 overlapping lava domes located in eastern California, including Minaret Cone on the northern flank. Mahood et al. (2010) determined an age of 94±9 ka based on $^{40}Ar/^{39}Ar$ analysis of Minaret Cone groundmass, which predates the 67-57 ka time period when the bulk of Mammoth Mountain lavas were erupted (Mahood et al., 2010). This study examines the mineralogy and chemical composition of basaltic material erupted from Minaret Cone. Minaret Cone lavas and scoria are plagioclase and clinopyroxene phyric with sparse olivine phenocrysts enclosed in an acicular groundmass composed mostly of plagioclase. Minaret Cone lavas and scoria yield bulk-rock trachybasaltic compositions that plot within the high-K calc-alkaline differentiation series, with 50.1-51.2 SiO_2, 1.58-1.69 TiO_2, 17.75-17.93 Al_2O_3, 8.20-8.49 Fe_2O_3, 5.42-5.81 MgO, 8.14-8.15 MnO, 8.77-8.99 CaO, 1.56-1.63 K_2O, 3.67-3.83 Na_2O, and 0.59-0.64 P_2O_5 (values in weight %). Modest modal olivine along with low concentrations of Ni (32-45 ppm) and Cr (42-73 ppm) require that Minaret Cone magmas are not primary mantle melts, but rather result from differentiation and assimilation in the lower crust. This interpretation is supported by trace element patterns in MORB-normalized spider diagrams, where Minaret Cone samples develop trends comparable to previously reported samples of Quaternary mafic lavas from the north moat region of Long Valley caldera (e.g., Bailey, 2004; Cousens, 1996). Interestingly, Minaret Cone samples share MORB-normalized trace element profiles to mafic enclaves contained in Mammoth Mountain trachyandesites and trachydacites in terms of immobile elements (e.g., Nb, Ce, Hf, and Ti), but are depleted in more mobile elements (e.g., K, Rb) compared to enclaves, suggesting that mafic magmas that intruded the Mammoth Mountain magma reservoir to form undercooled enclaves were more differentiated than those erupted from Minaret Cone.

Early to Late Holocene Paleoclimate Reconstruction Using Sediment Cores from Silver Lake, Mojave Desert, California

Holly Eeg
Faculty Adviser: Professor Matthew Kirby

This research project presents initial results from a sediment core extracted from Silver Lake in the Mojave Desert (3km north of Baker, CA). Silver Lake is the terminal playa lake for the Mojave River, which drains from the San Bernardino Mountains of southwestern, California. The project's objective is to reconstruct past hydrologic change using lake sediments from Silver Lake. The project consists of four hypotheses: 1) the region transitioned from a wet late glacial to a dry Holocene by (~9,450 cy BP); 2) the Holocene, although generally dry, is characterized by various amplitude wet-dry cycles; 3) intervals of wetter than normal climate at Silver Lake will correlate to those observed at Lake Elsinore (Kirby et al., 2010) and Lower Bear Lake (Kirby et al., 2012), which are located west of the Mojave Desert; and 4) a decrease in the average grain size reflect wetter than normal climates. To test these hypotheses, a multi-proxy methodology is proposed. This methodology will include a combination of qualitative and quantitative methods such as: sediment description, magnetic susceptibility, loss on ignition at 550^{o}C (total % organic matter), 950^{o}C (total % carbonate matter), and grain size. Understanding the Mojave Desert's paleoclimate provides insight to the frequency and amplitude of extreme weather patterns and wet-dry cycles. This information is of interest to geological hazard prevention organizations, land use agencies, and water management efforts.

Geology of the Nam Phrae Basin in Northern Thailand

Joseph Hawkins
Faculty advisor: Professor Brady Rhodes

Previous investigations into Thailand's geologic history have revealed a very dynamic history that is only recently being understood and interpreted. Thailand's overall formation was due predominantly to the collision of three terranes (the Shan Thai, Indo-China, and West Burma terranes); collisions occurring throughout the Permian and much of the Tertiary period, but a more detailed history is still necessary to piece together events, both spatially and temporally, occurring on a smaller scale throughout this time. During the month of January 2013 I mapped the Nam Phrae basin, a previously unmapped region along the south western edge of the Chiang Mai basin, roughly 4km long (north to south) and 1.5km wide (east to west) that was thought to offer clues into some of the deeper complexities of the regions geologic history. Thailand's basins are the result of extensional events related to stresses incurred from the nearby tectonic activity involving India's collision with Asia. In order to carry out the investigation, a field map was generated and basic geologic data collected in the basin including attitudes of bedding planes and faults, information about the environment of deposition and the provenance of the gravels that comprise the basin sediments. The Nam Phrae basin was found to be comprised largely of fluvial and lacustrine deposited gravels eroded from the mountains bounding the basin that are made of mylonites and gneisses capped by marine sediments. These older mylonites and gneisses are being exposed along a north-south trending normal fault that makes up the western boundary of the Chiang Mai basin, and eastern Nam Phrae basin. Within the

basin several normal faults were mapped, further implying a deformational history of extension. Lenses of coal roughly a meter thick each were described, implying periods of swampy or marsh environments not previously described in the geologic history of the region. This work and more like it is important in understanding and completing the geologic history of Thailand, as well as offering a better understanding of processes occurring or that have occurred elsewhere.

The Pyroclastic Surge Deposit of the ~680 yr BP Panum Crater Eruption, Eastern California

Zachary Haygood
Adviser: Professor Brandon Browne

Panum Crater represents the youngest eruption of the Mono-Inyo Volcanic Chain in eastern California (Sieh and Bursik, 1986). Previous work by Sieh and Bursik (1986) determined a stratigraphy for this eruption characterized by a throat clearing breccia overlain by a pyroclastic flow deposit ("dune" flow), pyroclastic surge deposit, a block-and-ash-flow deposit found locally to the northwest of Panum Crater, capped by a tephra ring deposit and a rhyolite lava dome. This study investigates the "pyroclastic surge deposit" horizon of this stratigraphy along flow-parallel transects with increasing distance from vent in terms of thickness, internal stratigraphy, and granulometry. Surge deposits within ~300 m of the crater rim are up to 4 meters thick and can be subdivided into 2 units, with a 3-meter-thick cross-bedded ash-rich unit at the base (P1) overlain by light beige ash-rich beds with cross-bedding and planar-bedding structures interbedded with 15 to 20-cm-thick reversely graded coarse-grained pumice lapilli and lithic fall deposits (P2). Surge deposits ~500 meters of the crater rim are 1 to 2 meters thick and can be subdivided into 3 units, with a dark beige fines-rich cross-bedded base unit (P1), a middle unit composed of beige fines-rich planar bedded layers interbedded with reversely-graded pumice fall (P2), overlain by a light tan fine-grained crystal-rich friable unit (P3). Surge deposits thin rapidly from 0.5 meters thick at distances of 700 meters from the crater rim to <4 cm thick at distances beyond 2 km from the crater rim. At these distances, only the upper friable and crystal-rich unit (P3) is observed. Granulometric analysis yields supportive data to the stratigraphic descriptions mentioned previously. For samples located ~500 meters from the Panum Crater rim, the percentage of fines decrease with stratigraphic height from 53% in P1 to 44% in P3, whereas median grain size increases slightly from 0.1 mm in P1 to 0.2 mm in P3. Sorting values range from 1.4 to 1.5 throughout the stratigraphy. We interpret this stratigraphy as the result of a dry, dilute, and turbulent pyroclastic density current (P1) followed by simultaneous deposition of fall and pyroclastic density current deposits (P2) capped by a co-ignimbrite ash fall (P3).

Age, provenance, and lateral variation of detrital zircon populations in the Peninsular Ranges forearc basin, Orange County, CA

Natalie Hollis
Faculty Advisor: Professor Diane Clemens-Knott

Late Cretaceous sediments of the Peninsular Ranges forearc basin were analyzed for U-Pb detrital zircon (DZ) data. These data display lateral and outcrop-scale variation in the proportions of zircons

derived from the arc and its metamorphic framework, as well as from extra-regional sources. Sandstone samples, exposed along the western flank of the Santa Ana Mountains, were collected along two traverses across the Late Cretaceous Ladd and Williams Formations: (1) a northern traverse along Silverado and Williams Canyons; and (2) a southern, along the Ortega Highway, ~23 km to the south. The Arizona LaserChron Center's LA-ICP-MS was used to measure the U-Pb dates of 87 to 99 DZs from each of six samples. Maximum depositional ages (MDA) estimated from the DZ data are compared to biostratigraphic estimates of sediment age. MDAs of the stratigraphically lowest sample (Baker Canyon mbr, Ladd Fm) from the northern and southern transects are indistinguishable (97.9±3.0 Ma (N); 97.0±1.6 Ma (S)), but are significantly older than the stratigraphic age of 91-89 Ma. Samples from the overlying Williams Fm (Schulz Ranch mbr) also exhibit differences between the estimated MDAs and stratigraphic age (83-75 Ma), as well as differences in MDA along strike: 97.3±1.4 Ma (N) and 88.5±1.4 Ma (S). Two samples of the stratigraphically highest unit, (Pleasants mbr, Williams Fm), also display lateral variations in MDA: 75.3±1.8 Ma (N) and 84.0±1.2 Ma (S), though both MDAs fall within the unit's stratigraphic age of 83-75 Ma. The stratigraphically lowest samples have the greatest amount of arc-derived DZs, while the stratigraphically highest sample contains a significant population of extra-regional DZs. Possible origins of these extra-regional DZs include ≈83 Ma plutons exposed in the northeastern Peninsular Ranges batholith and ≈75 Ma plutons exposed in western Arizona. These data suggest that the northern and southern drainage basins were isolated, with differing amounts of metamorphic framework contributing to the detritus. The mismatches between MDAs and stratigraphic ages suggest that the arc may have been dormant between ≈95 and 91 Ma, or possibly later (≈83 Ma) in the vicinity of Silverado Canyon. The appearance of extra-regional DZs in the Pleasants mbr indicates that the arc crest was breached by ≤83 Ma fluvial systems that transported zircons from Laramide-aged uplifts east of the Peninsular Ranges Batholith.

Upper Mississippian-Pennsylvanian-Permian Metasomatism Analysis Using Samples from Slaughterhouse Springs, California

Taylor Kennedy
Faculty Advisor: Professor Brandon Browne

The purpose of this project is to analyze the bird spring formation for precious metals. Using mineralization and geochemical analysis I propose to characterize the ore mineralization of Pennsylvanian Bird Spring Formation (Pbs). (Pbs) has undergone metamorphism along the (1) high angle Slaughterhouse Fault and (2) Mid Hills quartz monzonite of the Cretaceous Teutonia batholith in the New York Mountains near Slaughterhouse Springs, California. Comparing the analysis of mineralization and geochemical data of the Bird Springs Formation as a result of faulting-induced metasomatism and contact metamorphism will yield valuable insight into our understanding of how metasomatic ore deposits are related to contrasting geological phenomena. With a better understanding of how ore deposits develop it will improve our ability to locate and develop mineral resources.

Analysis of Melt Inclusions and Chemical Content of Plagioclase and Amphibole Phases From Basaltic Inclusions From the 2006 Eruption of Augustine Volcano, Alaska

Laurel Morrow
Faculty Adviser: Professor Brandon Browne

This study examines basaltic enclaves within andesite erupted from Augustine Volcano's 2006 eruption. Geophysical data collected throughout the eruption indicate that an intrusion of basaltic magma into the andesite chamber triggered the eruption; post-eruption petrological study confirms this. The goal of this research is to determine pre-eruptive storage depths of magma erupted in 2006 by melt inclusion analysis from plagioclase crystals, as well as chemical composition analysis of amphibole phases using Ridolfi's 2010 Amphibole calculation spreadsheet. Composition analysis of amphibole data has indicated that two to three populations of amphibole exist, and that all amphibole originates either from basalt or gabbroic magmas, and not host magmas. Amphibole phases record melt temperatures between 698°C and 791°C, and pressures of formation of 390 to 81 MPa. Plagioclase melt inclusion analysis using the water by difference method to determine wt% water content has shown that plagioclase crystal formation occurs at depths ranging from 5-6 and 2-3 km.

Palaeocurrents and provenance of the Mae Rim Formation, Chiang Mai Basin, Northern Thailand

Dalin Nguyen
Advisor: Professor Brady Rhodes

The Mae Rim Formation (MRF) consists of fluvial sandstone and conglomerate that was shed off the rising Western Ranges Metamorphic Complex (WRMC) and its tectonic cover of low- grade metamorphic rocks of the Shan Thai terrane. Previous published data on the palaeogeography of the MRF, including palaeocurrent and provenance data, have been limited because of poor exposures and heavy weathering. In this project, I proposed to collect palaeocurrent and provenance data from the new and numerous road cuts on the campus of Chiang Mai Rajabhat University, Northern Thailand. Knowing if the MRF newly exposed in the Rajabhat road cuts consists of clasts from the Shan Thai terrane, or rocks from the WRMC constrains the timing of deposition compared to exhumation of the Western Ranges. To better understand the palaeogeography of the Rajabhat MRF, we also need to know the depositional flow direction. I hypothesized that the Rajabhat MRF would contain clasts exclusively from the Shai Thai terrane, and the palaeocurrent will have flowed from NE to SE off the rising Western Ranges. To test this hypothesis, I: 1) described the MRF exposed in these road cuts and measured its orientation, and the orientation of any cross- cutting faults; 2) measured the orientation of imbricate cobbles in MRF conglomerate for palaeocurrent analysis; 3) counted at least 100 clasts at each study site in the MRF to determine the distribution of lithologies represented; 4) determined palaeocurrent directions by plotting rose diagrams of clast orientations on OSXStereonet; 5) determined the provenance by plotting pie charts of clast compositions, and matching them to lithologies exposed in the Western Ranges. The results of this study helped confirm the palaeogeographic setting and timing of the deposition of the MRF relative to the WRMC's exhumation.

Reconstructing Late Holocene lake level using cores from Zaca Lake, California

Lilian Rubi
Faculty Advisor: Professor Matthew Kirby

This study focuses on two littoral cores extracted from Zaca Lake: Z2 (2.25 m water depth; 112 cm core length); and, Z3 (3.6 m water depth; 120 cm core length). Zaca Lake, located approximately 70 km east of Pacific Ocean, is well positioned to record ocean-atmosphere dynamics and its effect on coastal hydroclimates. The primary objective of this study is to use data from the two Zaca Lake sediment cores to reconstruct late Holocene lake level change. The working hypothesis states that the Little Ice Age (LIA: ~1300-1800 A.D.) was wet with high lake levels; whereas, the preceding Medieval Warm Period (MWP: ~800-1050 A.D.) was dry with lower lake levels. To test this hypothesis, a multi-proxy approach is used including analyses such as: core descriptions, magnetic susceptibility, LOI 550 °C (% organic matter), 950°C (% carbonate), grain size, and microfossil counts. Discrete terrestrial organic materials were sampled at three depths and used for AMS 14C dating. These dates indicate that both cores span the past 600 cy BP (ca. 1350 A.D.). This time frame encompasses the end of the MWP and the entire LIA. Documenting the variability of lake level allows us to anticipate and prepare for future changes in the hydrological variability of a region, which is especially important in drought-prone regions.

Trace Element Analysis and Productivity Rates of the Permian-Triassic Extinction from Ute, Nevada

Shawn Sullivan
Faculty Advisor: Professor Adam Woods

The end of the Permian event (~252 My) was marked by an extinction that proved greater than any mass extinction of the past 600 million years. The Permian-Triassic mass extinction had an estimated loss of 85 percent of marine genera 70 percent of terrestrial genera. Understanding environmental conditions and the timing of the reestablishment of primary productivity after a mass extinction such as the Permian – Triassic crisis is key to understanding the recovery of many organisms. 25 samples were taken from the Spathian (uppermost Lower Triassic) Virgin Limestone (Moenkopi Formation), from Ute, Nevada for geochemical analysis. The Virgin Limestone at Ute is comprised of interbedded red and green shales and limestone beds (primarily packstones and grainstones) that are fossiliferous (primarily bivalves, gastropods and phylloid algae), often oolitic, and commonly contain so-called anachronistic facies (i.e., fabrics and features that are more common prior to the Ordovician). The limestone units were previously examined in detail (Woods, in revision), and the purpose of this study was to determine the relationship of the interbedded shales with the limestone units. Shale samples were analyzed using a Perkin-Elmer 7300 DV ICP-OES to determine specific trace elements contents and calculating the enrichment factors, which then can be used to better understand environmental conditions, primary productivity, and sedimentology during deposition. Vanadium, molybdenum, cobolt, chromium, and manganese values indicate that oxygen levels within the shale beds range from oxic to dysoxic , while barium, copper, nickel, phosphorus, and zinc values suggest that the oxic waters were associated with low productivity. Clay content relates to the aluminum, titanium, and zirconium.

Clay content seems to relate the amount productivity, the lower the clay content the higher the productivity. Magnesium values are typically low, while calcium values are high indicating that the shales are rich in calcite as opposed to dolomite. Geochemical data analysis suggests that during the time of deposition on the shallow, near shore environment the water was mostly oxygenated with few anoxic events and low productivity during shale deposition. Little peaks in data below 1.0 on graphed data indicate low oxygen events. Low productivity in the shally layers could be a result of the shallow depth where sediment is being deposited, or organic material is not properly preserved in low oxygen events. As mentioned above, the oxic and anoxic shales are interbedded with fossiliferous limestones that often contain anachronistic facies. Anachronistic facies are often associated with the inorganic or microbial precipitation of calcium carbonate, which has been attributed to the upwelling of anoxic, alkaline deep waters and the results of this study support this hypothesis by demonstrating the close juxtaposition of anoxic waters and anachronistic facies with each other.

Landslide Hazards in the Pai Valley, Northern Thailand

Kelly Shaw and Dylan Garcia
Faculty Advisor: Professor Brady Rhodes

In this study we look at past mass wasting events in the Pai Valley of Northern Thailand to better understand the size of previous slide events. Pai Valley is in the northernmost region of Thailand, approximately 20 miles south of the Burmese border. The climate in this part of southeast Asia is tropical and monsoonal with distinct wet and dry seasons. Knowing the frequency and size of prehistoric debris flows in the Pai Valley is significant because of the population living on these slides. Pai Valley residents have been building their homes on top of the suspected debris flow area. Future debris flows could be catastrophic for the valley, including major loss of life. We hypothesize that in the past there was a massive debris flow that originated west of the valley. Our research suggests that these are likely “Torrent Slides,” or “Long Slides.” We believe this because these are channelized slides that are found in mountainous terraines such as those found in the Pai region. Given the tropical setting of the area, we presume these slides were triggered by excessive rains or unseasonably wet periods. Through satellite imagery and on the ground mapping we determined at least two slide events and possibly a third. The mapping process involved driving and looking for locations with boulders versus bedded areas. When we determined the end of the boulder section and beginning of bedding, we plotted the location on our map. We continued until we had the boundaries of the slide determined. Clast counts were performed at a number of locations within the slide area. At each location an average of 50 clasts were counted, classified and measured. Sizes ranged from sand grain to 16 meters. The main lithologies of the clasts were granite and sandstone, consistent with a source to the west. There was no clear variation in the weathering of clasts within the slides, suggesting that the debris flows might have occurred within a short time period. Our mapping suggests the occurrence of at least 2 and possibly 3 slide events.

Graduate Proposal Category

Paleoclimatic Reconstructions Using Combined Sedimentological and Geophysical Methods from Abbott Lake, California

Christine Hiner
Faculty Advisor: Professor Matthew Kirby

Abbott Lake is located in the Santa Lucia Range of Monterey County, approximately 20 km east of the Pacific and 246 km south of San Francisco, CA. As one of only a few natural lakes between southern and central coastal California, Abbott Lake fills an important geographical gap for reconstructing the region's paleoclimatic history. This projects objective is to reconstruct the hydrologic variability of Abbott Lake and compare to previous regional records to observe spatial and temporal climatic changes. To achieve this objective, a multi-faceted methodology is proposed. These methods include: surface mapping, topographic profiles, sediment core analyses, radiocarbon dating, and seismic reflection data. In all these data will help to reconstruct the hydrologic history for Abbott Lake. It is of particular interest to examine the timing of hydrologic change across the region in comparison to the new Abbott Lake record. This research will also evaluate the hydrologic phasing of events between Abbott Lake and other sites such as Zaca Lake, Owens Lake, Lake Elsinore, and Lower Bear Lake. Finally, this project will seek to understand the forcings that drive hydrologic change over various timescales.

Deciphering biotic responses to rapid climate change at the Plio-Pleistocene Boundary

Bethany Malenick
Faculty Advisor: Professor Nicole Bonuso

The Pliocene-Pleistocene is a dynamic period for taxonomic loss and origination precipitated by an extinction event beginning 2 million years ago. In addition to the extinction, a dramatic climate change occurred as a result of the closing of the Panama Isthmus, which altered ocean circulation patterns and redistributed nutrients and sea surface temperature (SST). This study is the first to examine the pattern of extinction and origination within the eastern Pacific. I hypothesize that diversity and faunal abundance will decrease across the Plio-Pleistocene boundary in response to decrease SST and nutrient availability. I predict these rates will be comparable to previously calculated rates from the western Atlantic. Fieldwork will be conducted in Orange and San Diego counties from the Fernando and San Diego Formations. To test these hypothesizes I will use: Body Fossil Analysis, Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), Stable Isotope Analysis, and Multivariable Statistical Analysis. Understanding biotic responses to climate change during recent geological time affords key insight for modeling and planning for future anthropogenic climate change. The Plio-Pleistocene boundary provides a unique laboratory to examine how environmental change affects life on Earth and can provide direct insights into our present-day biodiversity crisis for two reasons: 1) many Plio-Pleistocene taxa are extant thus providing a direct prediction of how modern taxa might respond to rapid climate change; and 2) the proposed environmental analyses provides a more rigorous and detailed analysis then previous studies thus providing a more direct comparison with modern climate patterns.

Graduate Research Category

Thermochronologic constraints on megathrust splay faulting in the transition from strike-slip to convergence in the southern Prince William Sound, Alaska

Kelly M. Ferguson
Faculty Advisor: Professor Phillip A. Armstrong

Deformation related to the transition from strike-slip to convergent slip during flat-slab subduction of the Yakutat microplate has resulted in regions of focused rock uplift and exhumation. In the St. Elias and Chugach Mountains, faulting related to transpressional processes and bending of fault systems causes rapid exhumation. Underplating below the syntaxial bend farther west in the Chugach Mountains and northern Prince William Sound (PWS) causes focused, but less rapid, exhumation. Farther south in the PWS, plate boundary deformation transitions from strike-slip to nearly full convergence in the Montague Island (MI) and Hinchinbrook Island (HI) region, which is ~20 km above the megathrust between the Yakutat microplate and overriding North American Plate. Montague and Hinchinbrook Islands are narrow, elongate, and steep, with a structural grain formed by several megathrust fault splays, some of which slipped during the 1964 M9.2 earthquake.

We present 32 new apatite (U-Th)/He and 25 new apatite fission-track ages from the MI and HI region. Most AHe ages are <5 Ma, with some as young as 1.0 Ma. AHe ages are youngest at the SW end of MI, where maximum fault displacement occurred on the Hanning Bay and Patton Bay faults during the 1964 earthquake. AFT ages range from ~5 Ma to ~20 Ma and are also younger at the SW end of MI. Exhumation rates based on AHe ages, computed assuming a constant geothermal gradient of 20 deg C/km, are as high as ~4 mm/yr at the SW end of MI and decrease to the NE. Similarly, exhumation rates from AFT ages are as high as 1.3 mm/yr to the SW and decrease to the NE. These ages and exhumation rates indicate that the MI and HI region is a narrow zone of intense deformation probably related to duplex thrusting along one or more megathrust fault splays. We interpret the rates of rock uplift and exhumation to have increased in the last ~5 My, especially at the SW end of the island system and farthest from the region dominated by strike-slip and transpressional deformation to the NE. The narrow band of deformation along these islands likely represents the northwestern edge of a broader swath of plate boundary deformation between the MI/HI region and the Kayak Island fault zone.

Zircon hafnium and oxygen isotopic analysis of Sierra Nevada gabbros: Evidence for major compositional variation in the Mesozoic mantle

Michelle Gevedon
Faculty Advisor: Professor Diane Clemens-Knott

Hafnium isotope (εHf) analyses of zircon separated from gabbros confirm the existence of compositional variation within the mantle source region of the Mesozoic Sierra Nevada arc. Oxygen isotope ($\delta^{18}O$) values of these zircons indicate this heterogeneity originated in the mantle. Most zircon isotopic studies focus on granitoids, and non-mantle-like values are often interpreted as reflecting

variable crustal input during magma differentiation. In contrast, gabbros are better suited for discerning geochemical variations originating in the mantle because mafic rocks have undergone minimal differentiation.

Zircons were separated from 7 gabbros collected from two locations at ~36° N latitude, close to the western and eastern edges of the Sierra Nevada batholith (SNB) ~100 km apart. The Stokes Mountain region of the western SNB is an ideal site for a zircon Hf-O study because previous work has documented variations within whole rock O-Sr-Nd isotopic values likely attributable to small-scale mantle heterogeneity. Zircon eHf data from these western Early Cretaceous gabbros range from +15.9 to +2.7 ε-units, with the highest e-values approaching that of the modeled Cretaceous depleted mantle. In stark contrast, zircons from the late Jurassic Summit Gabbro of the eastern SNB Kern Plateau have εHf values ranging from +0.3 to -11.4 ε-units. Typical mantle-like zircon $\delta^{18}O$ values (i.e. +5.0‰ to +5.6‰) in both the western and eastern gabbros rule out the possibility that the ~27 ε-unit Hf variation is due to variable crustal assimilation. The disparity in εHf values suggests heterogeneity was present in the SNB mantle source region as early as the latest Jurassic, and supports earlier proposals for an enriched mantle end-member below the eastern arc flank.

Minor zircon $\delta^{18}O$ variation suggests the limited role of hydrothermally- or metasomatically-altered source material in the production of these gabbros. Within the western zircon population, $\delta^{18}O$ varies from typical mantle to values elevated by ~1‰. In contrast, the $\delta^{18}O$ of the eastern zircon population varies from typical mantle signatures to values lowered by ~1‰. The magnitude and depth of such an interaction is constrained by the undifferentiated character of the gabbroic host magma.

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