GEODAZE 2013 ABSTRACTS

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THE TIMING AND RELATIONSHIPS OF NA-CA AND K-CA ALTERATION TO GOLD SKARNS AT COPPER BAIN, NEVADA

Caleb King

Mapping of the Copper Basin area at Battle Mountain, Nevada, reveals widespread intense Na-Ca and K-Ca alteration, an unusual type of alteration in gold systems and heretofore unknown the major gold province of northern Nevada. New U-Pb zircon ages for igneous rocks in and around the deposits constrain the timing of alteration events to the Eocene (41-38 Ma) which is combined with observed crosscutting relationships to construct the time-space development of Copper Basin. The system begins with the emplacement of stocks and dikes exhibiting characteristic porphyry styles of alteration including potassic and sericitic alteration. At a time coeval with, or directly following these events in the distal parts of the system, Na-Ca alteration (scapolite-plagioclase-diopside-actinolite-garnet-titanite-epidote-allanite-clinozoisite) removes Fe, Cu and other metals and creates numerous plagioclase-actinolite-diopside-titanite cemented breccias. As these fluids evolve and attain higher temperatures in the proximal parts of the system, the early Na-Ca alteration is overprinted by higher temperature K-Ca alteration (Kspar-actinolite/tremolite-garnet-diopside-epidote-titanite-clinozoisite-rutile) that correlates with mineralization in the form of garnet skarns and breccias containing hypogene Cu-Fe sulfides and Fe Oxides. The importance of these alteration types were unrecognized and new mapping, mineralogical studies, and geochemistry suggests the fluids associated with these alteration types played a major role in ore formation.

The abundant Na-Ca and K-Ca alteration at Battle Mountain requires a re-examination of the ore-forming environment during the Eocene. These alteration types can be made several ways including the possibility of Eocene alkaline lakes providing an amagmatic fluid of high salinity, necessary for the formation Na-Ca alteration in depleted zones and K-Ca alteration in areas where metals are precipitated as ore. Understanding these relationships and the association of different fluids and types of alteration is key to understanding the emplacement and formation mechanisms of the immense endowment of metals in northern Nevada.
CONTRASTING TYPES OF FE- AND CU-MINERALIZATION, YERINGTON DISTRICT, NEVADA
Simone Runyon

Petrological and geological studies of carbonate-hosted Fe- and Cu-mineralization in the Yerington district, Nevada support that these contrasting deposits represent different parts, timing, and sources of Jurassic igneous-related hydrothermal systems. Tilting of ~90˚ by Tertiary extensional faulting allows study from the Jurassic paleosurface to ~7 km depth.

In the Yerington district, Mesozoic carbonate and clastic rocks host Cu-rich, Fe-oxide-poor skarn and replacement deposits (Ludwig, Mason Valley) and Fe-oxide-rich ± Cu, silicate-poor skarn (Pumpkin Hollow). This study adds new petrography, mapping, and geochemistry to compare Fe-oxide-rich systems over similar structural levels.

Magnetite-rich skarns are best developed in Mesozoic limestones; dolomite is locally present near both the Fe-oxide-rich and Cu-only skarn, but these are fundamentally calcic skarn and local dolomite cannot account for the abundance of magnetite. Observations of Fe-oxide-rich occurrences are consistent with zoning from proximal Na-Ca alteration in intrusive rocks (including intense endoskarn) into early gt-px-bi-plag hornfels and marble with superimposed Mt-replacement. Fe±Cu ore minerals dominate proximal assemblages with lesser andraditic garnet, diopsidic to salitic pyroxene, and later hydrous silicates. Most Fe-oxide and nearly all Cpy are deposited late. In this context the Minnesota mine and parts of Pumpkin Hollow are proximal. Distal Fe-oxide mineralization related to Na-Ca alteration occurs in the batholith ranging from deep Mt-Ap-Act to shallow Mt-Hm-Chl(-Cpy). Late granite porphyry dikes, similar to those related to porphyry-Cu mineralization and Cu-only skarns, postdate Fe-oxide mineralization and exhibit K-silicate alteration ± Cu. In contrast, the Ludwig area Cu-only skarns lack abundant Fe-oxide and are related in time, and possibly source, to the granite porphyry dikes.

The early intermediate phase of the batholith supplied heat that formed Fe-oxide-rich systems, and later granite porphyry dikes introduced fluids responsible for Fe-oxide-poor systems. Exposure of these contrasting carbonate-replacement deposits provides an opportunity to compare types, processes, and genetic models of skarn deposits.
This study contributes new U-Pb ages from zircon to better understand Laramide magmatism and associated mineralization in the Central Mining District (CMD), New Mexico. The CMD contains multiple igneous rock types in major and minor intrusive centers with distinctive mineralization (Santa Rita: porphyry and skarn Cu; Hannover: skarn Fe ± Zn, skarn and porphyry Cu; Copper Flat: breccia and skarn Cu ± Fe; granodiorite porphyry dikes: skarn Zn ±Cu ±Pb; North Star: unmineralized). Key samples were collected for U-Pb dating, 12 yielded zircons which were dated at the Arizona LaserChron Center.

The new dates are compatible (within error) with observed cross-cutting relationships. Nearly all ages range from 57.5 to 60.5 Ma. Quartz diorite sills formed first at 60.5 ± 1.3 Ma (3 samples); these have Na-Ca alteration and may relate to early Fe mineralization. The granodioritic Santa Rita (59.5 ± 1.5 Ma) and Hannover-Fierro (58.5 ± 0.9 Ma) stocks are associated with principal Cu deposits and Fe (magnetite) skarn and replacement mineralization. Felsic dikes, including granodiorite porphyry (58.5 ± 0.7 Ma), granite porphyry (58.3 ± 0.8 Ma), and quartz latite porphyry (59.0 ± 0.7 Ma) overlap in age but cut earlier intrusions; they are associated with Zn ±Cu skarn and replacement mineralization. The granite porphyry pluton at Copper Flat formed at (57.5 ± 0.7 Ma). An age of 47.4 ± 0.6 Ma on the North Star gabbroic plug suggests an independent, later phase of magmatism.

These results show that mineralization occurred over a short period. The absolute ages and their narrow range are unusual among Laramide porphyry copper districts in the southwest where mafic to intermediate magmatism is early and mineralized centers associated with the same complex may span 4-5 m.y. Well-constrained timing in the CMD and elsewhere is key to interpreting how magmatic evolution contributes to world-class mineralization.
TIME-SPACE RELATIONSHIPS AMONG MAGMATISM, ALTERATION, AND MINERALIZATION IN THE CENTRAL MINING DISTRICT OF SW NEW MEXICO

Cody-John Davis

The Central Mining District (CMD), located east of Silver City in southwestern New Mexico, contains multiple types of Cu, Zn and Fe mineralization related to several distinct intrusive suites. This study examines selected aspects of the multiple styles of mineralization and alteration as related to the several dozen igneous units identified and mapped in earlier work by USGS geologists and others. A goal of the project is better understanding of the time-space relationships between magmatism, hydrothermal alteration, and the different types of Cu, Zn or Fe mineralization. This is approached through mapping at scales of 1:500 to 1:2000, coupled with petrographic and electron microprobe analyses (EMPA) conducted at the University of Arizona.

Dominant alteration and mineralization can be broken into iron skarn, argillic, garnet-pyroxene skarn, and propylitic alteration, associated with early stock formation, subsequent Cu(+Mo) alteration of the Santa Rita (Chino) stock, later granodiorite dikes and apophyses with Zn(-Pb) mineralization, and late district-wide dike propagation, respectively. The types differ in their assemblages, distribution, geometry, and host rocks, but share associations between intrusive emplacement and mineralization, localization of alteration to dikes and their envelopes, vein orientations, and connections between types of dikes and specific mineral assemblages. Coupled with published results these reveal a link between early dikes and mineralization, structurally controlled fluid pathways, primarily magmatic fluid sources, and genetic relationships among the various stocks and dikes. The CMD has NNE and NW vein orientations, strong structural controls, sulfur-rich magmas, and dominant metals and grades in common with other Laramide districts in the SW USA. However, it differs in the diversity of deposits, abundance of intrusive rock types, late mafic phases, and intensity of supergene enrichment. This may reflect diversity in pluton composition, temporal and spatial distance between stocks, late magmatic injection, or distribution of preexisting structures with respect to pluton emplacement.
AN INTEGRATED VIEW OF JURASSIC IRON-OXIDE-RICH HYDROTHERMAL SYSTEMS, SOUTHEAST CALIFORNIA AND WESTERN ARIZONA
James Girardi

New field, lab, and compilation studies document numerous iron-oxide-rich hydrothermal systems associated with Jurassic igneous centers and exposed over ~7 km of the uppermost Jurassic crust of the Mojave Desert and nearby regions. These composite exposures illustrate diverse mineralization characterized by >50% Fe, sparse sulfides, and variable Cu-Au-V-LREE-P enrichments. They have acid altered tops and metal-poor Na±Ca altered bottoms. This region allows comparison of igneous-hosted Kiruna-type magnetite-apatite-actinolite occurrences with carbonate-hosted magnetite-dominated iron-skarns, and speculation on their connections with economically important iron-oxide(-copper-gold) (= IOCG) mineralization. The investigated iron-oxide occurrences are part of a larger belt in the southwest United States, and closely resemble the Jurassic-early Cretaceous IOCG deposits of the coastal central Andes.

Deep to intermediate exposures contain voluminous pluton-hosted Na±Ca alteration, and carbonate-hosted magnetite-andradite-diopside-epidote calcic-skarns (e.g. Iron Hat deposit, Marble Mountains), or magnetite-serpentine-spinel-clinohumite magnesian-skarns (e.g. Eagle Mountains district). Volcanic levels of exposure contain Na±Ca alteration, and shallower volcanic-sedimentary exposures contain hematite-rich, sulfide-poor, advanced argillic alteration (e.g. Sidewinder, Palen, Coxcomb Mountains). Kiruna-type mineralization is present at deep through shallow exposures, commonly structurally controlled, and crosscuts Na±Ca alteration (e.g. Iron Queen prospect, Palen Mountains). Minor Cu(-Au) sulfide mineralization is associated with Kiruna-type (e.g. Orange Blossom mine, Bristol mountains) and iron-skarn mineralization (e.g. Iron Chief mine, Eagle Mountains).

Synthesis of data from 50 iron-oxide districts and occurrences, many with minor Cu(-Au), reveals co-location, alteration, and mineralization similarities, suggesting similar origins for iron-skarn and Kiruna-type occurrences. In the Cordilleran context, arid paleoclimate, low-lying paleogeography, and evaporitic surficial fluid sources are common to the setting of middle-Mesozoic iron-oxide mineralization in North and South America. Cu(-Au) productivity differences may perhaps be explained by the presence of S necessary for sulfide formation, that was available for fluids of South American marginal marine organic-bearing volcanic-sedimentary basins, but not in North American inland intra-arc basins.
LOCALIZED SYNOROGENIC REMOBILIZATION OF CU-CO ORES IN THE CENTRAL AFRICAN COPPERBELT

Isabel Fay

This study compares the mineralogy and characteristics of discordant veins in mineralized and barren parts of the Tenke-Fungurume district of the Central African Copperbelt in order to assess whether the Lufilian orogeny (ca. 550-510 Ma) added Cu and Co to it or only remobilized metals already present. These are mainly carrollite-bornite-digenite-chalcopyrite disseminated in high-grade concentrations unevenly distributed through Neoproterozoic basinal strata disrupted and displaced by Lufilian thin-skinned thrusting. These strata contain multistage veins 1-15 cm wide, either crosscutting at >40° or parallel to shale-dolomite laminations along partings between them. Veins of both orientations consist of very coarse-grained dolomites partly or entirely replaced by quartz and dated by previous Re-Os work to the Lufilian orogeny. The vein sulfides comprise roughly the same mineral suite as the disseminated ores, but without their complex exsolution, replacement, and overgrowth relationships. Sulfides occur in veins only in areas where they also occur disseminated; veins elsewhere are barren. The vein sulfides’ volume, estimated from mapping and logging, is less than 1% of the district’s metal inventory.

These features of the Lufilian veins are better explained by remobilization than by addition of metals. If added, metals would have been distributed in Lufilian veins everywhere, not just in those areas already mineralized. Remobilization was local only, since farther movement would have transported ores into previously unmineralized areas, and it was small in volume, since only a small fraction of the Copperbelt ores are in veins. These results contrast with two models recently offered for Copperbelt mineralization, which attribute much or all of the ore to Lufilian addition, and indicate that the Lufilian merely remobilized a small amount of preexisting ore over a short distance without substantially changing the distribution of Cu-Co mineralization.
MINERALOGICAL AND GEOCHEMICAL VECTORS OF GOLD MINERALIZATION AT THE HOYLE POND GOLD MINE, TIMMINS, ONTARIO
Jack Gibbons, Thomas Monecke, Nigel Kelly

In orogenic gold deposits, hydrothermal alteration of mafic volcanic rocks may be easily observed up to 10 m away from veins, while hydrothermal alteration of turbidites is rare, is difficult to observe, and is generally restricted to within 1 m away from veins. This study investigated hydrothermal wallrock alteration in the turbidite-vein zone (TVZ) of Goldcorp’s Hoyle Pond gold mine in Timmins, Ontario to constrain vein paragenesis and associated alteration in order to provide mineralogical and geochemical gold mineralization to Goldcorp vectors to support development of the TVZ.

Four hydrothermal alteration styles were identified in the TVZ. Rietveld XRD, short-wave infrared resonance, trace and major element geochemistry, and petrography were collectively used to identify and delineate the different styles of alteration: tourmalinization, sulfidation, hydrolytic, and carbonatization. Tourmaline and trace apatite compose a diffuse tourmalinization halo that is restricted to within 0.4 m away from veins. Arsenopyrite, pyrite, pyrrhotite, and chalcopyrite compose a sulfidation halo that extends up to 0.8 m away from veins. Muscovite replacement of albite composes a hydrolytic alteration style that extends up to 2.0 m away from veins. Ankerite and calcite compose a broad carbonatization halo that extends beyond the m-scale focus of this study. Within veins, native gold rims and is included within arsenopyrite and pyrite and occurs along the margins of tourmalinized, carbonatized, and hydrolytically altered wall rock fragments. This consistent textural association suggests that gold deposition occurred after tourmalinization, carbonatization, and hydrolytic alteration and broadly coeval with sulfide deposition.

Alteration zoning patterns identified in this study are too spatially restricted to gold-bearing veins to be an effective exploration tool but are useful in supporting development of the TVZ at Hoyle Pond and in constraining fluid-rock reactions at other turbidite-hosted, orogenic gold deposits.
A MULTI-DIMENSIONAL APPROACH TO UNDERSTANDING MICROPOROUS HETEROSILICATES
Shelby Rader, Aaron Celestian, Michael Powers

The sodic (Na-) form of the mineral sitinakite and the potassic (K-) form of the mineral umbite are two heterosilicates that have been synthesized and investigated for their catalytic and exchange properties. These properties are analagous with those of zeolites, but heterosilicate structures differ in having transition elements as essential components of their framework. Both umbite and sitinakite contain a series of 8-membered rings (8MR) running the length of the crystal, which are responsible for ion exchange. This process has been studied in situ using a collection of time-resolved XRD, Raman spectroscopy, and TGA/DSC. Sitinakite was analyzed for the ion exchange systems of Na→Cs and Na→H→Cs, while umbite was analyzed for the ion exchange systems of K→H→Gd, K→H→Eu, and K→H→Y.

Umbite exhibited significant structural changes for each of the ion exchange systems, with the 8MR showing conformational transformations due to the increased ionic radii and hydration spheres of the REE ions. Umbite was stable over a wide range of temperatures (0-1000°C) and chemical conditions (H- and REE- exchange), indicating likely structural integrity across a variety of environments applicable to industrial catalysis. Sitinakite exhibited similar behavior, displaying rapid shifts in peak position during both Raman and XRD analysis of ion exchange, indicating a symmetry change as Cs was taken into the crystal structure, causing the 8MR to become more circular. During ion exchange, up to four discrete polyhedra distortions, related to H2O swelling effects and structural changes, were noted and modeled, which was previously impeded by poorer resolution XRD. These results show the validity of a multi-dimensional approach to understanding ion exchange mechanisms in microporous materials. Umbite is currently under development as a strong oxidation catalyst over a wide variety of environments while sitinakite exhibits selective sequestration of Cs and Sr from aqueous solutions, an application related to radioactive waste remediation.
Tectonics and Geochemistry

LATE CRETACEOUS TRANSITION FROM FLEXURAL SUBSIDENCE TO DYNAMIC SUBSIDENCE
Clayton S. Painter, Barbara Carrapa

Regional isopach maps have been used in the past to quantify the magnitude and morphology of subsidence in the western Interior caused by the lithospheric loading by the Cordilleran Orogenic belt. These isopachs have been useful in tracking flexural wave migration from west to east and in identifying flexural-foreland-basin depozones (i.e., foredeep, forebulge, and back-bulge). Existing isopach maps mark a transition during the Late Cretaceous from flexural to dynamic subsidence and the subsidence profile changes from foredeep, forebulge and back-bulge depozones to a depocenter that is ~480 kilometers east of the thrust front, which cannot be replicated using flexural calculations. However, these existing broad regional isopach maps are often data limited, with only one to three data points per state.

Presented here are isopachs that span northern New Mexico, eastern Utah, Colorado and southern Wyoming using a total of 130 data points (i.e., geophysical well logs), giving much tighter data constraint. By doing so, we have refined the transition from flexural subsidence to dynamic subsidence to ~81 Ma, which correlates to the beginning of a large scale progradation of coarse-grained sediments in the foreland basin. In addition to refining the timing of the transition of subsidence styles, the morphology of the basin is also further constrained. Previously the dynamically driven depocenter appeared to be an east-west trending basin, but with higher data density, it appears to be a north-south trending basin. Flexural models are also presented for the flexural foreland basin when the wavelength of the flexural profile increases, which has caused disagreement in the past. Furthermore, the refined location and morphology of the Campanian, dynamically driven depocenter is consistent with the modeled position of the hypothesized Shatsky oceanic plateau at ~81 Ma, an oceanic plateau that has been proposed to be the cause of Late Cretaceous flat-slab subduction.
DETRITAL ZIRCON PROVENANCE OF CRETACEOUS THROUGH MID-TERTIARY STRATA OF THE FOUR CORNERS REGION, SOUTHWESTERN NORTH AMERICA
Mark Pecha, George Gehrels

A total of 3228 U-Pb laser analyses have been conducted on 32 detrital zircon samples of Cretaceous through mid-Tertiary strata from the Four Corners region of the southwestern United States. At least two representative samples were collected from each major unit in order to assess provenance and internal stratigraphic variability. The results indicate that two distinct changes in sediment provenance occur within this stratigraphic section: 1) from the Lewis Shale to the overlying Pictured Cliffs Sandstone, where the prominent Grenville aged zircons essentially disappear, 2) the transition from Fruitland Fm to Kirtland (and the younger units above) with the dominant influx of Yavapai-Mazatzal (~1.6-1.75Ga) aged zircons. This second transition is interpreted to reflect the unroofing of the surrounding Laramide basement blocks, predominantly the San Juan (Needle Mts.) and Nacimiento uplifts. Another prominent feature observed in the detrital zircon record is the dominant arc derived signature. Sediment input from the arc/arc region to the southwest is evident from at least the Lower Cretaceous Dakota Fm through the deposition of the Eocene San Jose Fm. This coupled with a pervasive Jurassic (150-170 Ma) arc signature illustrates that sediment was continuously entering the Four Corners region from the south-southwest during this time span. In order to assess the possible re-working of zircons from the Sevier thrust belt to the west or southwest, Kolmogorov-Smirnoff (K-S) statistical comparisons were made with both the Nevada and Sonora transects of the miogeoclinal DZ reference (Gehrels & Pecha, in review). The results indicate that after ~76 Ma and the deposition of the Cliff House sandstone, it is unlikely the Four Corners region received significant sediment input directly from the thrust front. Most of the units sampled contain zircons that record the maximum depositional age of their respective strata, which generally agree with published magneto or biostratigraphic ages.
PROVENANCE AND METAMORPHISM OF THE INDUS-YARLUNG SUTURE MÉLANGE NEAR LOPU KANGRI, TIBET
Kate Metcalf, Paul Kapp, Drew Laskowski, Devon Orme

The Indus-Yarlung Suture Zone (IYSZ) is the boundary between India and Asia and includes the preserved Asian forearc, the ophiolite, and the tectonic mélange. The mélange has long been considered the accretionary prism corresponding to the ophiolite to the north which obducted onto the Indian margin prior to India-Asia collision. Recent studies suggest that the ophiolite obducted onto Asia, placing the mélange on the south margin of Asia prior to collision. This interpretation is supported by Asian-affinity detrital zircon ages in the mélange, and requires that the suture between India and Asia is not north of the ophiolite, as previously thought, but south of the mélange. The question remains how far south, and what is the nature of the suture? Near Lopu Kangri, the mélange is composed of a mudstone matrix with blocks of basalt, chert, mudstone, metabasite, limestone, and sandstone. The majority of the blocks are deep water facies or consistent with oceanic crust, supporting the interpretation that the mélange is an accretionary complex formed by oceanic subduction. The Lopu Kangri range exhumes Indian-affinity material so that the mélange is exposed both northeast and southwest of the range. We present metamorphic facies and assemblages for samples on the northeast side of the range to help constrain P-T conditions experienced during subduction, collision, and post-collision.

Further southwest blocks gradually increase in size to slivers of measurable section and matrix decreases. Eventually the matrix is absent and strain is apparently taken up in incompetent layers within the slivers. If these slivers are Indian-affinity, this could mark the beginnings of collision as the continental margin of India entered the subduction zone. We present detrital zircon ages from samples of both the blocks and matrix on either side of the range to provide a better control on the location of the suture.
BASIN EVOLUTION AND EXHUMATION OF THE LATE CRETACEOUS-EARLY EOCENE WESTERN XIGAZE FOREARC BASIN, SOUTHERN TIBET
Devon A. Orme, Barbara Cararpa, Peter Reiners

Forearc basins are important data archives for understanding continental dynamics because they preserve the tectono-erosional record of continental margins before collision. This study focuses on the Cretaceous-Eocene Xigaze forearc basin in southern Tibet, which is exposed along ~600 km of the Indus-Yarlung Suture Zone between the Indian craton to the south and the Asian Lhasa terrane to the north. From late Cretaceous to early Cenozoic time, subduction of Neo-Tethyan oceanic crust beneath the southern margin of Asia accommodated the northward motion of the Indian craton and formed the Xigaze forearc basin. Following collision with India in the early Cenozoic, the basin transitioned from predominantly marine to non-marine sedimentation and was subsequently uplifted to a mean elevation of 5000 m. How this transition occurred remains unresolved. This study’s overall objective is to decipher forearc-basin and Indo-Asia continental-margin development from field sedimentology and stratigraphy, and detrital geo-thermochronology.

To examine the pre-collisional history of the Xigaze forearc, we present new stratigraphic sections, totaling 5 km thick, from a previously unexplored ~60 km segment of the Xigaze forearc, ~50 km north-northwest of Saga. Sedimentary facies of mid-Cretaceous to early Eocene deposits indicate a shoaling-upward trend and document the change from marine to terrestrial sedimentation. Within these sections, precise biostratigraphic age control is limited. Therefore, we use detrital zircon U-Pb geochronology to constrain the maximum depositional age of distinct stratigraphic horizons. Our results indicate that this method of chronostratigraphic control is robust in a forearc setting.

In order to determine the timing of exhumation of Xigaze forearc strata following collision, we utilize zircon (U-Th)/He thermochronology coupled with U-Pb geochronology. This method has the ability to distinguish between the exhumation history of the sediment source and that of the basin. Double-dated (U-Th/He and U-Pb) zircon crystals from eight samples in ~80 Ma deposits indicate that the basin was buried to depths greater than 7 km prior to exhumation and that basin exhumation occurred between 30-10 Ma.
Over the last few years we have calibrated the volcanic glass paleoaltimeter in the southern Central Andes of South America. Researchers can use volcanic glass as a proxy for paleoelevation because newly erupted volcanic glass absorbs meteoric water. The 2H/1H ratio, or δD referenced to Standard Mean Ocean Water, of meteoric water systematically decreases with increasing elevation. As there is little hydrogen present in volcanic glass initially, this meteoric parent water directly controls the δD value of the waters of glass hydration. Over the last few years we have demonstrated that volcanic glass faithfully reflects meteoric water compositions across >3000 m of elevation and can preserve primary isotopic information for >16 Myr. Here, we apply the volcanic glass paleoaltimeter, along with other datasets, to the reconstruction of paleoelevations in the Western Cordillera of northernmost Chile. The Chucal anticline is an excellent exposure of ~21.7 to 11.2 Ma syntectonic lake and floodplain sediments topped with massive ignimbrites. At a modern elevation of ~4300 m, the anticline is perched between the Western Cordillera and the Altiplano. Great debate surrounds when the Andes attained modern elevations and when the Altiplano became such a prominent high elevation plateau. δD results from volcanic glass as low as ~ -150‰, as well as parent water calculated from combining glass δD and lacustrine carbonate δ18O values, suggest that the western Andes of northern Chile stood at >3000 m by at least 17.5 Ma. Though perhaps not without controversy, this is another important pin in the reconstruction of Andean elevations and orogenic development throughout the Cenozoic.
EFFECTS OF U-TH-RICH GRAIN BOUNDARY PHASES ON APATITE HELIUM DATES
Kendra E Murray, Devon A. Orme, Peter W. Reiners

(U-Th-Sm)/He dates of multiple apatites from samples with a unique thermal history (e.g., typical hand-samples of crystalline bedrock) sometimes show larger dispersion than can be explained by known sources of date dispersion such as grain size, radiation damage, parent zonation, intragranular inclusions, or He implantation from primary adjacent phases. In two sample suites from the western United States with highly dispersed apatite He dates, we observe apatites with delicate micron-scale reddish-orange coatings rich in Fe, U, Th, and REE; these grain boundary phases (GBPs) are heterogeneous in thickness, grain coverage, and composition, and have effective U (eU) concentrations between 0 and >500 ppm. We model how the presence of such phases during the cooling history of an apatite would bias its measured U-Th/He date. The direction and magnitude of date bias is primarily a function of: (1) the host grain’s size, (2) the thickness and [eU] of the GBPs relative to the host grain, (3) the timing of GBP formation relative to the cooling age of the host grain, and (4) whether the GBPs are preserved and analyzed with the grain. When GBPs have 2-10 times more [eU] than the host apatite, they produce date bias up to 70% “too young” or >250% “too old”. Low-eU apatites are most susceptible to date bias, so GBPs generate negative date-[eU] trends in which the youngest dates could be interpreted as the sample’s maximum cooling age. Although the heterogeneity, variable preservation, and ambiguous formation age of GBPs precludes a general quantitative solution to this problem, our model is useful for demonstrating that observed date dispersions are consistent with the effects of U-Th-rich GBPs. For these troublesome datasets it is currently the best approach within the observations and measurements of routine apatite He dating.
The Central Andean Uplift and Geodynamics of High Topography (CAUGHT) project is an interdisciplinary project to investigate connections between lithospheric removal, crustal shortening and surface uplift in the northern Bolivia and southern Peru region of the South American Andean orogen. Forty seismic stations installed for the CAUGHT project were deployed between 13° and 18° S latitude, covering the transition zone where the Altiplano region pinches out in southern Peru, in an effort to better constrain the changing character of the crust and mantle lithosphere.

For this receiver function (converted wave) study, we have little coverage in the forearc and foreland, ~75 km spacing in most of the array, and a relatively dense ~20 km spaced profile along the Charaña-La Paz-Yucumo transect, the eastern portion of which is nearly coincident with the balanced cross-section of McQuarrie et al. (2008) which documented a total of 275km of upper crustal shortening. More than 1500 receiver functions have been calculated using an iterative deconvolution method, and stacked using the common conversion point (CCP) method, along profiles parallel to and nearly coincident to those used for the geologic shortening estimates. We identified arrivals for the Moho and generated a 3D map of crustal thickness underneath the array that reveals distinct characteristics for the 4 major tectonomorphic provinces. We observe variable crustal thicknesses beneath the Altiplano, ranging from 60 to 70 km, as well as significant differences in thicknesses (~10 km) beneath the similarly elevated Western and Eastern Cordilleras. The significant difference in crustal thickness with elevation suggests two possibilities; underthrusting of the Brazilian cratonic crust to provide flexural support or delamination of material from beneath the Altiplano and/or Eastern Cordillera.
RECEIVER FUNCTION RESULTS FOR THE PERUVIAN FLAT SLAB SUBDUCTION REGION
B.T. Bishop, Susan Beck, George Zandt

The subduction of the aseismic Nazca Ridge beneath southern Peru has been linked to the onset of thick-skinned deformation in central and southern Peru, as well as the termination of volcanism in the region. Previous studies in the region focused on local seismicity and provided limited constraints on the region’s crustal thickness and the depth to the subducted slab. New teleseismic receiver function results from the Peru Lithosphere and Slab Experiment (PULSE) have provided a more extensive and accurate constraint on the region’s crustal thickness and slab depth, as well as identified a number of anomalous low velocity interfaces at middle crustal depth that may be linked to the region’s history of former volcanism.
The central Andes in South America are characterized by along-strike variations in magmatism, upper crustal shortening, crustal thickness, and slab geometry that make it an ideal region to study the relationship between the subducting slab, the mantle wedge, and the overriding plate. We use finite frequency teleseismic tomography to image P-wave velocity variations in the mantle under the central Andes between 10°S to 30°S down to ~600 km. P- and PKIKP-arrivals were picked in multiple frequency bands for earthquakes at distances between 30° and 90° and between 155° to 180° from the array respectively. Results from the finite frequency tomography inversion show a clear trench-parallel fast velocity migrating away from the trench. This dipping fast anomaly, which penetrates the 410 km discontinuity, corresponds to the dipping Nazca slab under the central Andes. In the northern part of the study area, around 14°S, this fast anomaly bends away from the trench below 200 km depth correlating with the location of the Peruvian flat slab which results in the slab to descending into the mantle farther inland. The northern Altiplano is consistently underlain by slower P-wave velocities in the upper mantle while the upper mantle beneath the Subandean Zone is characterized by fast anomalies at shallow depths (<150 km) consistent with the presence of fast cratonic lithosphere. While this fast anomaly is consistently observed under the Subandean Zone, the western limit of this anomaly is variable, extending under the Eastern Cordillera at 14° and 16°S. Further south, slow anomalies are observed in the upper mantle under the Puna, APVC and the Los Frailes volcanic fields.
INVESTIGATING THE TECTONICS OF THE ANATOLIAN PLATE USING AMBIENT NOISE TOMOGRAPHY
Jonathan R. Delph, Susan L. Beck, George Zandt

The Anatolia Plate is part of the Alpine-Himalayan system and comprises much of Turkey and the Aegean Sea. The tectonics of the region is complicated, with an extensional regime in the west attributed to rollback of the African slab and a compressional regime in the east from continental collision of the Arabian Plate with Eurasia, forming one of the most cited examples of escape tectonics. We use Ambient Noise Tomography (ANT) to image crustal structure. This study uses cross-correlations from more than 150 seismic stations to measure surface wave phase velocities. The dispersive nature of surface waves gives us insight into vertical and lateral heterogeneities in the crust, with longer periods corresponding with greater depths. This method allows us to draw interpretations of the overall crustal structure as it varies with depth, using surficial geology as a constraint.

We find that suture zones related to the closure of the Tethyan Sea impose the most dramatic velocity variation throughout the study area. The Central Anatolian Crystalline Complex, composed mostly of crystalline basement, has high phase velocities at every frequency interval sampled. The phase velocities drop sharply across the Inner-Tauride and western Izmir-Ankara-Erzincan sutures that formed during the closure of the northern branch of the Neotethys Ocean. We also find a very slow anomaly in eastern Anatolia beneath a group of Neogene volcanoes, an area where it is thought that heat flow and elevations are high due to the influx of asthenospheric material into the region as a result of the detachment of the downgoing Arabian slab. Underthrusting of the Arabian Plate beneath Eurasia is also visible, and the amplitude of this anomaly decreases with depth, giving credence to a discontinuous Arabian slab. Another large slow anomaly appears beneath the Isparta angle, where teleseismic tomography and volcanics may indicate a slab tear.
The Central Andes of southern Peru, Bolivia, and northern Chile (between ∼10°S and ∼35°S) comprise the largest orogenic plateau in the world associated with abundant arc volcanism, the Central Andean Plateau (CAP). The goal of this continental-scale Ambient Noise Tomography (ANT) project is to image the vertically polarized shear-wave velocity (Vsv) structure of the CAP by incorporating broadband seismic data from ∼20 seismic networks deployed incrementally in the Central and Southern Andes from May 1994 through August 2012. Our major results include mapping a pervasive mid-crustal low-velocity body (<3.25 km/s) underneath the western portion of the CAP and a locally ultra-low-velocity anomaly (∼2.0 km/s) beneath the Altiplano-Puna Volcanic Complex (APVC). The presence of a large and laterality extensive low-velocity body suggests either a zone of partial melt (“mush”) associated with batholith formation at depth, a thermally weakened crust capable of lateral flow, or the presence of aqueous fluids. Working under the hypothesis that voluminous ignimbrites are the surface expression of batholith formation at depth as exemplified by the APVC, we combine our results with the locations of known Neogene ignimbrite eruptive centers and negative isostatic residual gravity anomalies and suggest the 3.25 km/s shear-wave velocity contour at 15 km depth generally outlines the extent of a Neogene to modern batholith. Previous work in Tibet, a region with thick crust analogous to the CAP, suggests a zone of mid-crustal radial anisotropy may separate horizontally and vertically polarized shear-wave velocities by as much as 20%. The effective isotropic shear velocity may be ∼10% faster than the 3.25 km/s we observe which would correspond to velocities expected of an isotropic granitic composition (∼3.6 km/s) at depth. Our interpretation of a large Neogene batholith associated with active volcanism revisits the idea of magmatic addition as a contributing mechanism to the growth of the western portion of the CAP.
POST-SEISMIC DEFORMATION FOLLOWING THE M7.2 APRIL 4, 2010 EL-MAYOR CUCAPAH EARTHQUAKE FROM GPS GEODESY
Joshua Spinler, Richard Bennett

The 2010 April 4 Mw 7.2 El Mayor-Cucapah (EMC) earthquake is the largest event to occur along the southern San Andreas fault system in nearly two decades. We use 201 GPS velocity estimates from regional sites to model the crustal velocity field of southern California, USA, and northern Baja California, Mexico, prior to the EMC earthquake. In the year following the EMC earthquake, the EarthScope Plate Boundary Observatory (PBO) constructed eight new continuous GPS sites in northern Baja California, Mexico. We used our velocity model, which represents the period before the EMC earthquake, to assess postseismic velocity changes at the new PBO sites. Time series from the new PBO sites, which were constructed 4-18 months following the earthquake do not exhibit obvious exponential or logarithmic decay, showing instead fairly secular trends through the period of our analysis (2010.8-2012.5). The weighted RMS misfit to secular rates, accounting for periodic site motions is typically around 1.7 mm/yr, indicating high positioning precision and fairly linear site motion. Results of our research include new fault slip rate estimates for the greater San Andreas fault system, including model faults representing the Cerro Prieto (39.0±0.1 mm/yr), Imperial (35.7±0.1 mm/yr), and southernmost San Andreas (24.7±0.1 mm/yr), generally consistent with previous geodetic studies within the region. Velocity changes at the new PBO sites associated with the EMC earthquake are in the range 1.7±0.3 to 9.2±2.6 mm/yr. The maximum rate difference is found in Mexicali Valley, close to the rupture. Rate changes decay systematically with distance from the EMC epicenter and velocity orientations exhibit a butterfly pattern as expected from a strike slip earthquake. We infer a strong lower crust overlying a relatively weak uppermost mantle for the study region from initial post-seismic deformation modeling using a three-layer viscoelastic model.
A REVISED PALEO-RECONSTRUCTION OF THE EQUATORIAL ATLANTIC FROM NEW MAGNETIC, GRAVITY, AND SEISMIC REFLECTION DATA, OFFSHORE GUINEA
Russ Edge

The Guinea margin, situated within the Equatorial Atlantic represents the final point of separation between Africa and South America during Triassic to Cretaceous rifting to form the North and South Atlantic. Despite being in such a tectonically interesting region, relatively little data have been published about the Guinean continental margin. Consequently, prior plate reconstructions within the Equatorial Atlantic lack sufficient detail to provide a fully reasonable explanation for the complex rift structure observed within new 2-D and 3-D seismic datasets. New observations drawn from the seismic data, and local gravity and magnetic data, permit development of a new paleo-reconstruction model across the Guinea Plateau using the interactive GPlates software. Restoring the now-stretched continental crust to its pre-rift configuration and providing information on fault kinematics based on displacement timing facilitate a more accurate reconstruction. Furthermore, using magnetic reversals, fracture zones have been extended farther towards the continental margin and mapping of hot-spot tracks within the Tertiary have helped constrain more accurate plate motions. The creation of this more detailed Equatorial Atlantic plate reconstruction aids in better understanding of rift evolution, and presents opportunities for increased insight into how global oceanic circulation patterns and climate change are affected by tectonic activity.
POST-RIFT EXTENSION AND VOLCANISM ON THE GUINEA PLATEAU, WEST AFRICA – LINKED TO GRIMALDI-BATHYMETRISTS SEAMOUNT MAGMATISM?
Noah McDougall

Systems of fracture zones with two distinct orientations converge at the Guinea Plateau, West Africa and control the geometry of the continental margin; One fracture zone orientation formed as a result of the opening of the North Atlantic Ocean and the other from the opening of the South Atlantic Ocean. Crustal weaknesses associated with formation of these fracture zones may continue onto the Guinean continental margin as evidenced by alignment of post-rift volcanism with the synrift fracture zones. Detailed mapping on the Guinea Plateau using 3-D seismic data provided by Hyperdynamics Corp. highlights cylindrical features that are capped by a Late Paleocene unconformity. Most of these seismic anomalies range up to 2 km in diameter, but one 20-km-diameter feature covers the northwestern corner of one of the 3-D seismic surveys. High seismic amplitudes, non-diapiric morphologies, and onlap onto the flanks suggest these features were created by extrusive volcanic events. This interpreted volcanic field correlates with the trend of the Grimaldi-Bathymetrists seamount chain that follows the North Atlantic Guinea Fracture Zone. The interpreted age of the volcanic field on the plateau is consistent with the increasing ages of Late Paleocene and younger seamounts toward the east; in addition, the large 20-km feature is on the same order of scale as the seamounts. A northeast-trending Late Cretaceous to Late Paleocene horst-and-graben fault network, linked to the Late Paleocene magmatic event, continues across the two 3-D seismic surveys, which are separated by ~100 km. This implies a regional mechanism for the post-rift extension rather than purely gravitational relaxation toward the continental margin.
Geomorphology

DISTINGUISHING VOLCANIC AND FLUVIAL ACTIVITY IN MANGALA VALLES, MARS VIA GEOMORPHIC MAPPING
Amber Keske, Alfred McEwen

Mangala Valles is a 900 km-long outflow system extending from the Martian southern highlands toward the northern lowlands west of the Tharsis bulge. Until recently, it was widely accepted that the flow features observed in Mangala Valles are the result of one or more catastrophic flooding events, likely by igneous disturbance of massive aquifer sources. Such ideas have been supported by the presence of obvious streamlined features that can be easily identified using relatively low-resolution images such as those returned by Viking. However, recent ideas suggest that the system could have been carved by thermomechanical erosion by voluminous lava flows, or a hybrid hypothesis where the valley was initially carved by aqueous processes and later modified by volcanic erosion and deposition. To investigate this, we are mapping geomorphic units using primarily MRO Context Camera (CTX) images in JMars, which serves as the mapping tool and the main source of geographic information. Our goal is to interpret each mapped unit as having a fluvial, volcanic, or other origin. Fluvial units might be distinguished by boulder deposits, but are extremely rare on Mars as the channels are often covered by lava flows. Lava flows tend to form smooth plains with lobate boundaries, and contain features suggestive of lava inflation. An overlay of an age map from Basilevsky et al. (2009) reveals that several of the units we have thus far interpreted as lava flows are relatively young (~1 Ga), and that there are also much older units (~3.5 Ga) that were cut by the channels. This is consistent with one or more aqueous outburst events early in Mangala’s history followed much later by a phase of extensive plains volcanism which partially or completely filled its channels. Previous interpretations of relatively young fluvial activity may instead be explained by relatively young lava flows.
Wildfires can have drastic effects on the erosional and ecological regimes of mountainous landscapes. The measured increase in severity, frequency, and duration of wildfires in the western U.S. over the last few decades has motivated efforts to understand and quantify post-fire erosion and the recovery of vegetation on the landscape. Conceptual models state that the recovery of the landscape follows an exponential trend, but these models lack supporting data and explanatory processes. In this study we test the conceptual recovery model by using bi-annual LiDAR scans, including both airborne laser scanning (ALS) and terrestrial laser scanning (TLS), over two years to document the formation and evolution of two debris-flow fans located below small (<1 km2) upland catchments burned by the Las Conchas fire in 2011. These methods are also used to monitor vegetation recovery and soil erosion within a nearby small upland catchment that was also burned by the Las Conchas fire. Differencing of the LiDAR datasets indicate that net surface change (deposition-erosion) decreased between LiDAR scans. Field observations and LiDAR datasets also indicate that, following initial formation, the debris-flow fan surface is modified by subsequent streamflow and related processes such as scouring, headcutting, gullying, and channel capture. In the upland catchment, percent vegetation cover increased over the same 2-year monitoring interval. Our study shows that immediately following wildfire, post-fire erosion is greatest, but decreases quickly as less material is conveyed to the outlet and the fan is reworked. Increase of vegetation cover and stabilization of channel features in the upland catchment and on the fan surface may explain the observed decrease in sediment movement over time. This study provides quantitative data and observable processes to support the conceptual ideas of post-fire recovery.
Climate and Paleoclimate

MODELING THE POLLEN AND VEGETATION RELATIONSHIPS FOR COMPARING SIMULATED VEGETATION WITH FOSSIL POLLEN DATA
Yao Liu, Stephen Jackson, Christopher J. Paciorek, Kiona Ogle

Fossil pollen records are used to infer past vegetation dynamics. Modeling the relationships between pollen assemblages and vegetation composition can (i) improve the theoretical understanding of the vegetation-sensing properties of pollen records, and (ii) facilitate quantitative comparison between model-simulated past vegetation composition and fossil pollen records. We built a Bayesian statistical model to characterize the relationship between pollen and vegetation, using a dataset of paired surface-pollen samples and surrounding vegetation within 1 km radius at 33 small lakes (< 2 ha) in the northeastern US. In our model, we partitioned the effect of vegetation on pollen into “local” and “background” sources. The 1 km-radius distance-weighted vegetation survey data around the lakes was used to inform the local pollen source. We used Forest Inventory Analysis (FIA) data to inform the background pollen source. Differential pollen productivities among taxa were modeled with a set of taxon-specific scaling parameters. The vegetation influence on pollen was modeled as a function of distance, while accounting for the anisotropic effect of prevailing wind direction.

We obtained estimates and associated uncertainties for taxon-specific productivity and the distance-effect parameters. Among 13 common taxa in the northeastern US, the productivity scaling parameters are highly variable – with a 200-fold difference between the estimated mean of the least and the most productive taxa. Uncertainties in the productivity-scaling parameters vary among taxa, possibly due to the taxonomic resolution of pollen data. The taxon-specific distance-effect parameters also differ significantly among some taxa, and are generally consistent with the expected distance effects based on pollen-grain sizes. We are applying the fitted statistical model to convert a simulated time-series of vegetation during the Holocene into pollen records from the northeastern US. In sum, this work is providing (i) better estimates of key parameters for the pollen-vegetation relationship, and (ii) a vehicle for comparing simulated vegetation with actual fossil pollen records.
A GLOBAL ASSESSMENT OF CLIMATE-DRIVEN VEGETATION CHANGE FROM THE LAST GLACIAL MAXIMUM TO PRESENT
Connor Nolan, Stephen Jackson, Jonathan Overpeck, Simon Brewer

Climate projections for the next 100 years include major increases in average global temperature that are likely to cause changes in plant community composition and structure across the globe. Characterizing the magnitude of impending climate-driven vegetation changes is important for conservation planning and adaptation, but difficult because climate-driven vegetation change is the result of interacting processes operating on multiple spatial and temporal scales. While we do not understand all of the processes involved, we do have paleoecological records from all vegetated continents that offer a proxy record of the vegetation during the last glacial period (defined here as 14,000 to 21,000 years before present) which we can use to assess past vegetation change. Panels of regional experts compiled all available pollen and plant macrofossil records with coverage during the last glacial period. Then, for each site the experts compared glacial period vegetation to modern (or late Holocene) vegetation and assessed the magnitude of vegetational change, in terms of species composition and physiognomy (e.g. grassland vs. deciduous woodland vs. coniferous forest), and the role of the climate change since the last glacial period in driving the observed changes. Our results illustrate the spatial variability of vegetation response to this magnitude of climate change, including whether the plant communities of any area have remained unchanged since the last glacial period. This project represents the first global-scale analysis and synthesis of climate-driven vegetation change since the last glacial period and will provide an important framework for future conservation efforts and decision-making.
LATEST PLEISTOCENE PALEOHYDROLOGY OF WILCOX BASIN, SOUTHEASTERN ARIZONA: PALEOClimATIC IMPLICATIONS FOR WESTERN NORTH AMERICA
Andrew Kowler, Jordon Bright

Lacustrine and paleospring deposits in Willcox Basin, southeastern Arizona record the timing of dramatic paleohydrologic changes that characterized the last glacial-interglacial transition. Extensive paleospring activity from 19.3-19.0 ka cal BP (ka) may have been accompanied by lowstands of Paleolake Cochise, followed by a relatively dry interval that lasted until the first of several major lake transgressions that occurred throughout the remainder of the Pleistocene. Several humid intervals occurred following a dramatic reduction in effective moisture at the onset of Bolling-Allerod warming, but the replacement of extensive wetlands by spatially restricted ephemeral seeps and desiccation of the valley floor did not occur until as early as 10.8 ka. Comparison of marine records with well dated lacustrine records from western North America (WNA) reveals a close coupling between abrupt paleohydrologic changes and massive discharges of glacial meltwater and sea ice into the North Atlantic during the Heinrich 1 stadial (~17.5-14.5 ka) and the Younger Dryas. While the triggers of these changes are apparent, the teleconnective mechanisms responsible for them remain poorly understood; further, efforts to develop a regionally coherent reconstruction of past atmospheric circulation are currently hindered by a paucity of paleohydrologic data south of 35oN from the southern Basin and Range SBAR. While it is clear that the dynamic interplay between northern Hemisphere ice sheets and the Meridional Overturning Circulation triggered major hydroclimatic responses throughout WNA and elsewhere following the last glacial maximum, spatial and temporal variability in their magnitude and direction--as well as the causes of this variability--remain a mystery, and should be the focus of future investigations. Toward this goal, the results presented herein comprise the most detailed account of hydroclimatic variability in the SBAR region and thus shed new light on the nature of atmospheric circulation across WNA during the most dramatic warming episode in recent geologic history.
Characterizing the climate history of mountain regions is critical for understanding the natural variability in their environment and the potential impacts due to climate changes in to the future. New high-resolution records from an alpine lake (Blue Lake) in the south San Juan Mountains, CO reveal 4500 years of local productivity and temperature variability. Records were developed with two sediment cores and using loss on ignition (LOI), and micro-scanning Xray-fluorescence (µXRF). Comparisons of total organic matter content (TOC) between two cores shows strong covariability. The TOC record reflects a combination of algae productivity within the lake as well as organic material washed into the lake through time. The µXRF records reveal sediment elemental compositions through time. Variation can be primarily attributed to material with the washed in or blown in from surrounding areas and, also diatoms within the lakes that produce shells of silica. Using titanium-silica ratios, we can estimate the contributions of the silica that was washed into the lake versus the silica produced biogenically. The biogenic silica signal is strongly coherent with periods in the LOI record, but also shows some discrepancies. These new records will contribute to previous work done with sediment cores from a neighboring lake (Fish Lake) and, can offer an interesting contrasts regarding the past climate as recorded by different lakes within one area.
A 3000-YEAR-LONG RECORD OF SOUTHWESTERN DUSTINESS
Cody Routson, Jonathan Overpeck, Connie Woodhouse

Airborne dust in the arid southwest United States has important implications for drought, snowpack and water resources. Dust storms are entrained from Southwestern deserts by spring winds and westerly storm systems and deposited on the snow-covered Rocky Mountains. These dust-on-snow events reduce albedo and cause the snowpack to absorb more heat, accelerating ablation and subsequently reducing available runoff, a critical water resource for the environmental, and the agricultural, industrial, and municipal water uses. To characterize the long-term variability and natural risk of Southwest dustiness, we have developed a 3000-year-long, sub-decadal resolution, record of dust deposition from lake sediments using multiple sediment cores from two lakes in the south San Juan Mountains, Colorado. We used μX-ray-fluorescence (μXRF) to analyze the elemental composition of our sediment. We also analyzed local bedrock and dust deposited on local snowpack to constrain dust-input end-members for our site, and employed an end-member mixing method to calculate the fraction of wind deposited dust in our lake sediment through time. We also developed an independent high-resolution grain size record from the same sediment cores, which shows dust grain size concentration corroborates our μXRF dust record. Our new record shows increased dustiness associated with recent land disturbance, drought, and livestock grazing, consistent with previous work in the region. Our record also shows increases in medieval period (~900-1300AD) dustiness, as well as anomalously high dust between 200 BC and 800 BC. Combined with annually resolved tree-ring based drought reconstructions, our new record provides key insight into relationships between Southwestern aridity and dustiness. As global temperatures rise and the Southwest shifts toward a more arid landscape, understanding the relationship between dustiness, drought, and water resources will become ever more imperative.
Understanding the range of monsoon variability in the southwestern United States during the late Holocene requires information from diverse paleoclimate archives. As a complement to regional tree-ring records, which have been used to reconstruct precipitation over the last few centuries, we present new 3500-year long high-resolution (~4.5 years/sample) oxygen isotope records from two southern Arizona caves: Cave of the Bells (COB) and Ft. Huachuca Cave (FHC). Monitoring at COB over the last decade shows dripwaters largely come from winter rainfall, but strong monsoons can affect the average dripwater oxygen isotopic value. Monitoring at FHC has been less frequent, but also highlights the dominance of winter precipitation on the overall moisture balance of the cave. We therefore interpret higher values in the speleothem records as a strengthening of the North American monsoon relative to winter cyclonic activity. Both speleothem records well constrained chronologically, which should provide robust information about local decadal-scale precipitation fluctuations at each cave site. On timescales shorter than a few centuries, however, the COB and FHC records are neither significantly correlated nor coherent with one another. Extensive Monte Carlo age-modelling rules out the possibility that inter-site differences reflect errors in the chronologies of the two records, and instead suggests that COB and FHC are fundamentally discordant on shorter timescales (10 to 300 years). We argue this disagreement is mostly due to spatially heterogeneous rainfall in the arid Southwest during summer. Cave processes, such as the kinetics of calcite precipitation at the speleothem site, may also play a role in either or both caves. On longer timescales (300 to 1000 years), the COB and FHC records are in better agreement with one another, and they show that the North American monsoon has weakened over the past 4000 years.
Geoscience Education

WHY SO FEW HISPANICS MAJOR IN GEOSCIENCE
Philip J. Stokes, Karl Flessa, Roger Levine

Geoscience has the fewest underrepresented minority students of any STEM field. Prior research has attributed the poor diversity to sociocultural factors, but no quantitative study has explored how the experiences of white and Hispanic majors in geoscience differ. We interviewed 29 geoscience students at the University of Arizona and identified 881 "critical incidents" that affected their choice of an undergraduate major. Using the Critical Incident Technique, incidents were grouped into three major categories: college, K-12, and out-of-school factors. We compared the reported frequencies of critical incidents between white and Hispanic students. Both groups reported similar numbers of positive outcome critical incidents but Hispanic students reported significantly more negative critical incidents. Critical incidents involving college familial factors were the driving mechanism behind this difference. These differences suggest that family members of Hispanic geoscience students have a greater involvement in, and perhaps a greater skepticism of, their child’s choice of a geoscience major. We also found that Hispanic students reported significantly fewer critical incidents involving out-of-school outdoor experiences. Barriers need to be identified before they can be removed. We found two: skepticism from families and limited outdoor experiences.
POSTER SESSIONS

Climate, Paleoclimate, Paleoecology, and Paleontology

G01: PALEOCLIMATE AND PALEOENVIRONMENTAL RECONSTRUCTION OF LAKE MALAWI, EAST AFRICA [SITE MAL05-2A] OVER THE PAST 75 KA
Wan Fadhilah Wan Mohd Hanizan, Andrew S. Cohen

Lake Malawi lies within the Malawi Rift, which represents the southernmost section of the Western Rift in East Africa. The analysis of the basin using the sediment drill core records obtained in 2005 from drill site MAL05-2A of Lake Malawi provides a detailed record of climate and other environmental changes in the region covering the past ~75 kyr. In this study, we analyzed the coarse sieve fraction (>61µ) of sediment samples to reconstruct environmental history. Sieve samples of the drill core were collected at 50 cm intervals from 39.7 mblf to the surface (~1-kyr resolution). We counted the core for paleoecological indicators (preserved charcoal, the green alga Pediastrum, fish bones/scales and ostracode abundance), as well as environmentally significant mineralogical indicators (vivianite, mica, and other terrigenous sand grains). Variations in these counts throughout the drill core will be used to determine the changes in regional climate and lake environment/level over the past 75 kyr. Preliminary analysis shows a lack in ostracodes and an increase in vivianite abundance within the upper 10 m of the drill core, demonstrating a deep, stratified lake with anoxic conditions through much of the water column of the lake, which prohibits benthic ostracodes and enhances vivianite formation.
A 43cm gravity core NP05-TB40 GC1 0-43cm was collected at 4° 52.563'S, 29° 36.183'E near the town of Kigoma on Lake Tanganyika by the Nyanza Project in 2005, in 76 meters water depth. The core was collected for high-resolution environmental reconstruction using a MUCK corer. We analyzed this core at 1cm intervals over its entire length. Water mass of each centimeter interval of the 43.0 centimeter core was determined. Our paleoecological study of the core involved making counts of fossil materials (fish bones, fish scales, ostracodes, charcoal, insects, and molluscs) which have proven useful in prior studies of Lake Tanganyika for the interpretation of paleoclimatic and paleoecological history of the core location. Our data is normalized as abundances of fossils per gram of dry weight sediment for standardization. Fish bones and fish scales throughout the core are being used to detect the changes in fish abundance productivity in this area of the lake, which may be changing as a result of either climate change or fishing pressure. Charcoal and insect abundances will be useful in interpreting periods of climate change and fire frequency in the region. The multiple species of ostracodes and molluscs and their presence in particular intervals will be useful for inferring benthic environments and lake level changes.
Climate within the tropics is rapidly changing, but the effect of such changes on the geosphere is relatively unknown. It is likely that biogeochemical cycles will be profoundly affected due to the climatic influence on weathering, pedogenesis, and mineral transformation. Although conceptual source-to-sink models exist to evaluate these changes for tropical rift basins, the lack of long sediment records prevents detailed examinations. We use pollen, charcoal, grain size, and clay mineralogy data from Lake Malawi, southeast Africa, to examine relationships between climate, vegetation, and sedimentation over the Penultimate Glaciation (PG) and Last Interglacial Period (LIG).

We show that insolation and high-latitude temperature drives changes in vegetation that are critically important to patterns of weathering and accumulation of siliciclastics. Forest expansion occurs during insolation maxima, however, the vegetation assemblages and clastic input differ from peak to peak. During the PG, high insolation results in silty detritus when dense tropical seasonal forest and afromontane forests dominated the lowlands. In contrast, an LIG insolation maximum results in sandy input coeval with open, drought-tolerant miombo woodlands. Pronounced fires seem to have further conditioned the landscape for sediment transport and mass wasting at this time of enhanced summer rainfall. Clay minerals analysis shows a similar pattern to the vegetation record, with high values of kaolinite:smectite indicating heavy leaching during the moister forest phase. During the LIG, leaching was variable and reduced under a more seasonal climate. During low insolation periods, extreme aridity led to expansion of grasslands and semi-desert trees with Somali-Masai affinities. Clay minerals were dominated by smectite, suggesting very low chemical weathering. This study points to a strong influence of vegetation composition and structure on the intensity of weathering in the tropics. Furthermore, this complex interplay of ecology and sedimentology is likely to greatly alter in response to future climate change.
The purpose of this study is to help determine whether sequence stratigraphic parameters can be predicted using sample sizes. Length of hinges and overall body size of the bivalve species *Lentidium mediterraneum*, the most common species in this fossil assemblage, were measured to determine whether there is correlation in body size ratios through changing environment and time periods.

Bivalve samples were obtained from a series of 9 sediment cores from the Po Plains of Italy, representing two transgressive/regressive cycles from the Upper Pleistocene and Holocene periods. Core material was dated using C14 dating, micropaleontology (using pollen, forams, and ostrocods) and AAR geochronology. The sediment cores were then sieved to remove clay and mud, leaving the sample mollusks, of which 68,994 total specimens representing 129 genera and 241 species were collected.

A binocular scope with an eyepiece graticule was used to measure 180 undamaged samples. Statistics of averages of anterior-posterior widths and lengths of samples from many layers were compiled using Excel and PAST Ver. 2.14. These averages and standard deviations were compared with average hinge lengths of the samples to determine whether species size correlates with hinge length across changing time periods and environments.

Similar to preliminary work, there appears to be a linear relationship between body width and hinge length, and between width and height, throughout the samples studied. A larger variety of sizes was studied and several samples of other species were also measured to compare them as well. The other bivalves appear to continue the linear relationship seen in *Lentidium mediterraneum*. 
Geophysics

G05: BUILDING A REGIONAL VELOCITY MODEL FOR OFFSHORE GUINEA BASED ON 2-D AND 3-D SEISMIC VELOCITY DATA
Saba Keynejad

Seismic data acquisition takes place in the time domain, whereas subsurface interpretation, reservoir evaluation, and geological modeling of the Earth are properly handled in the depth domain. A velocity model of the subsurface is the key element that connects these domains and permits conversion of seismic time images to more geologically useful depth images. Multiple vintages of 2-D seismic reflection time data cover a very large area (135,000 km2) of the Guinea Plateau off the coast of West Africa. Also within this zone are two modern 3-D reflection surveys covering a total area of less than 3900 km2 that have been depth migrated with good velocity control. Linking interpretations based on the time-domain 2-D data with those developed using the depth-domain 3-D data is the challenge. Only some of the 2-D profiles have available velocity information, and the velocities (from data processing) are irregular and inconsistent even at line intersections. Converting individual 2-D profiles to depth introduces considerable vertical and lateral “misties,” and converting other 2-D lines to depth is not feasible without a regionally consistent velocity model. To enable depth conversion of the 2-D data and horizon interpretations, I constructed a regional velocity model using edited stacking velocities from 111 2-D lines. This model covers the area containing 124 2-D seismic lines and the two 3-D seismic surveys. Inconsistent velocity functions are edited based on adjacent velocity information and matching stratigraphic horizons. Regional smoothing increases lateral and vertical consistency, and time-to-depth conversion of the velocity model permits incorporation of the 3-D velocity data (which is in depth) to increase model accuracy. The integrated model then is used to convert interpreted geological features, such as faults and geological horizons, to depth.
The western margin of the North America was formed during the Late Proterozoic when a major rifting event occurred. The series of tectonic events, crustal uplifting and subsidence in western North America continue to be active until today as evidenced by the San Andreas Fault, Cordilleran magmatic arc and Sierra Nevada uplift. This complex history has produced a similarly complex lithosphere beneath the western North America, with appreciable variation in seismic wave speed apparent in tomographic images. The PBO GPS network provides the first images of the vertical field for this region. Significant uplift and subsidence are observed at rates of the order of 1 mm/yr or more. We investigated the pattern of the vertical crustal motion in light of the upper mantle P-wave speed, and the topography of the western North America to explore the potential explanations for the vertical motions. We found that there is a remarkable correlation between the vertical velocity, seismic wave speed and elevation at long wavelengths. The correlation appears to correspond to the portions of the continent that are underlain or not underlain by oceanic subducted slab. Important questions that we are addressing with this regional study include: 1. What are the observable patterns, which signify changes and geologic features in western North America? 2. What are the plausible explanations for the patterns observed? Could it be due to the mantle dynamics?
This study comprises 118 discrete Miocene volcanic flows from the eastern Columbia River Basalt Group (CRBG) with the aim of testing the distributions of geomagnetic field directions as predicted by several geomagnetic field models. This is important because little is known empirically about the behavior of the geomagnetic field prior to the last 5 million years. The results of this study will also allow us to extend the temporal coverage of the geomagnetic field models. The rock magnetic analysis of these samples shows that the primary magnetic directions are uniformly carried by titanomagnetite, indicating that the magnetic behavior of the samples reflects the magnetic field, not their magnetic mineralogy. To reduce systematic bias, the sites were analyzed as ungrouped and grouped site directions, and outliers were removed with visual inspection, and with systematic cutoff criteria. The overall paleomagnetic directions of the flows are southerly and up, and northerly and down. Furthermore, deviating directions are also present, possibly due to excursions as part of secular variation, or as intermediate transitions between reversed and normal polarity intervals. No new rock ages were necessary for this study due to previous extensive and reproducible geochronological analyses. Additionally, integrating the Miocene ages of the flows and their corresponding paleomagnetic directions allows one to observe the evolution of the paleosecular variation through the Neogene, because it can be compared with the published characteristics of the geomagnetic field in the last 5 million years. Elongation results coincide with those predicted from the TK03.GAD model, but not the CJ98.GAD model. However, when comparing our dispersion results, they do not conform to the TK03.GAD, CJ98.GAD, and CP88.GAD models, which underpredict the dispersion values. Thus, this suggests that, although the geomagnetic parameters in general agree with these models, they require some refinement to accommodate the differences during the Miocene.
Development of soils in young drainages with fresh rock exposures is a complex process of chemical and mechanical weathering, and is influenced by soil moisture content, water transit time, temperature variations (due to climatic effects and sun exposure) and other factors. The mean transit time for water is observed to be a function of slope aspect, with north-facing drainages having systematically longer residence times for water, which also indicates deeper water-flow pathways. One hypothesis for this relationship is that soils are systematically deeper on north-facing drainages as a result of lower radiant forces due to diminished northern-hemisphere sun exposure on north-facing slopes. We use shallow seismic refraction surveys to constrain soil thickness in stream valleys on north- and south-facing drainages within the Valles Caldera National Preserve (VCNP), New Mexico. Redondo Peak, the VCNP's most prominent peak, provides two contrasting drainages: the geomorphically broad south-facing Lajara catchment and the narrower north-facing Jaramillo catchment. Analyzing first-breaks picks from seismic records with time-term and reciprocal-method inversion techniques allows us to generate three-layer velocity-depth profiles by distinguishing the depths of prominent refractors. Using turning-ray tomography within SeisImager/2D software (OYO Corporation/Geometrics), we develop laterally varying two-dimensional velocity cross-sections. Our preliminary results show that the north-facing slope of the Jaramillo drainage has a greater depth to bedrock than its south-facing counterpart, supporting the hypothesis that soil thickness is linked to water transit time and slope aspect. Shallow-subsurface seismic refraction models provide constraints for future investigations of critical-zone processes and hydrologic modeling by providing depth-to-bedrock measurements where soils are too deep for easy measurement by manual digging.
Geomorphology and Geoarchaeology

G09: GEOMORPHIC RESPONSES TO HOLOCENE CLIMATE VARIABILITY IN A LITTLE COLORADO RIVER HEADWATER TRIBUTARY IN WEST-CENTRAL NEW MEXICO

Jill Onken

The Holocene alluvial record of Carrizo Wash, a Little Colorado River headwater tributary, reveals a complex history of deposition and erosion that appears to be driven primarily by climate change. More than 140 radiocarbon dates provide chronometric control for the stratigraphic framework, which includes eleven allostratigraphic units. Late Holocene (post-4500 cal yr BP) deposits dominate the alluvial fan record in piedmont areas, whereas valley fill along the main trunk of Carrizo Wash consists primarily of middle Holocene (8500–4500 cal yr BP) alluvium.

A shift from winter-dominant precipitation during the early Holocene to middle Holocene conditions of consistently cold, dry winters and hot, moist summers likely resulted in sparser vegetation cover because of decreased effective moisture. Sediment-laden surface runoff was flushed from uplands and piedmonts by localized, intense monsoon storms to accumulate as valley fill in the upper reaches of Carrizo Wash.

Climatic conditions during the late Holocene became more variable with the intensification of the El Niño-Southern Oscillation (ENSO) climatic pattern. Decreased summer and increased winter insolation contributed to cooler, drier summers and warmer, wetter winters with widespread lower intensity storms, which generally resulted in greater effective moisture. Pulses of late Holocene alluvial fan deposition resulted in 5–8 meters of piedmont aggradation, most of which occurred 3800–3200 and 2700–2000 cal yr BP. In contrast, late Holocene valley aggradation was minimal, presumably because denser vegetation cover reduced the sediment load of runoff reaching the main stream trunk. Localized cienega and spring deposits imply especially wet conditions from 2500–1600 cal yr BP. Infilled paleochannels indicate past channel entrenchment 4800, 1100, and 600 cal yr BP (and possibly also 2500 and 1500 cal yr BP) that probably represents geomorphic responses to rapid shifts from especially dry to wet conditions characteristic of late Holocene climate variability.
Fluvial megafan deposition environments are important to the stratigraphy of retroarc foreland basins. The deposits of megafans are commonly the dominant architectural elements that build stratigraphic sequences of the foredeep depozone. As a consequence, a robust understanding of these sediments may be critical for effective natural resource exploration, as well as elucidating ancient hydrology, depositional patterns, and tectonic processes. The goal of this project is to use actualistic data to further our understanding of fluvial megafans in the central Andean foreland deposystem.

The study site for this project is the low-gradient Río Bermejo megafan of northern Argentina (Chaco foreland basin). The geography of the Río Bermejo watershed was analyzed using ArcGIS, in order to assess the potential controls on sediment generation and deposition in the Bermejo megafan. Key components of the GIS database included: watershed delineation, geology, topography, climate, and vegetation maps. A comprehensive suite of modern sediments from across the Río Bermejo watershed was also analyzed to determine composition and provenance characteristics, using classic thin section petrography (Gazzi-Dickinson method; n=43), detrital zircon geochronology (n=5), and x-ray diffraction derived clay mineralogy (n=15).

Initial results indicate that three distinct upstream “regions” feed sediment and water to the Bermejo megafan: (1) the Río San Francisco region; (2) the Río Bermejo headwater region; and (3) the Santa Barbara massif region. Parent lithologies, slope, type and extent of plant life, precipitation, and discharge characteristics vary markedly across these regions. It appears likely that the composition and age of sands and the mineralogy of clays in the Bermejo megafan reflect these upstream controls. Further analysis will expand our understanding of the modern Chaco foreland basin in general and the sediment budget for the Bermejo megafan in particular.
This poster highlights the results of the first soil-stratigraphic investigation at Yangguanzhai, a Middle Neolithic site in the Wei River Valley of north-central China. There are two major occupations evident at the site: 1) an intensive middle-Neolithic occupation, thought to date to 5,500 calendar years B.P. based on ceramic typology, and 2) a later Han dynasty occupation (~2,500 calendar years B.P.). These archaeological zones are found in association with two main soil units, which reflect paleoenvironmental conditions during their formation. The Neolithic soil in these profiles is thick, dark brown, and well-developed, while the upper Han soil is thinner, light brown and less structurally developed. Between these buried soils is unweathered sediment, which may have resulted from heightened flooding and floodplain deposition, and is thus indicative of landscape instability and increased sediment supply to this portion of the Wei River Valley. The Neolithic soil may also reflect greater vegetation density on the landscape, as inferred by its dark brown color and higher organic matter content. Based on field observations and corresponding laboratory analysis, it is clear that the inhabitants of Yangguanzhai experienced dramatic paleoenvironmental change over the course of the middle and late Holocene. Additionally, such paleoenvironmental shifts may have prompted site abandonment between the Neolithic and Han periods, as there is little archaeological evidence for occupation in this interval. Overall, this research enhances understanding of paleo-environmental conditions over the course of site occupation and elucidates paleoenvironmental shifts that likely affected human behavior, such as land use and settlement patterns.
G12: A PETROGRAPHIC ANALYSIS OF WEEDEN ISLAND POTTERY TO DETERMINE THE PROVENANCE OF SACRED AND SECULAR WARES
Erin Harris-Parks

The Weeden Island tradition of A.D. 250-900 stretched from north Florida to south Georgia and Alabama and is best known for a ritual complex involving mound construction, ancestor veneration, and the caching of elaborate pottery. Surprisingly, research on the provenance of Weeden Island pottery has determined that both nonlocal ornate vessels and plain local village wares are cached within the context of ceremonial mounds. The purpose of this study is to determine if a correlation can be established between functional type and provenance, based on both formal and petrographic analysis of local and nonlocal vessels. To accomplish this, selected vessel types were analyzed via petrographic microscope to distinguish between different clay sources. An assemblage of pottery collected from a burial mound at Hog Island (8LV2/7), curated at the Florida Museum of Natural History, was analyzed by paste, type, form, thickness and orifice diameter. Twenty-five representative thin sections were analyzed for accessory mineral content, grain size and composition to establish nonlocal provenance. Petrographic analysis revealed that both local and nonlocal clay sources could be differentiated based on the presence and abundance of micas, heavy minerals, sponge spicules, diatoms and phytoliths. It was concluded that multiple distinct local and nonlocal clay sources were present in the sample. The characteristics of these groups were seen in multiple vessels suggesting several distinct localities of high production and possible craft specialization. These analyses also showed that there is a relationship between historical type of pottery and provenance as well as, between type and form.
Structure and Tectonics

G13: THE KHAIRENITAR KLIPPE IN CENTRAL NEPAL
Edward Cross, Peter DeCelles, Tank Ojha

The Himalayan fold-thrust belt consists of a series of south-verging thrust sheets. This research focuses on the Greater Himalayan Sequence (GHS), which is thrust over the Proterozoic Lesser Himalayan sequence and unmetamorphosed foreland basin deposits. The GHS in eastern Nepal and Bhutan reaches nearly all the way to the front of the range, but in most of Nepal and India, it is exposed in isolated erosional klippen. Researchers had believed that there was a 150-km gap in central Nepal with no klippen, but field work conducted in this “gap” during this previous December and January identified a klippe—here named after the town of Khairenitar on which it sits—of GHS rocks that had been previously misidentified. This project will use detrital geochronology to produce a map and balanced cross-section, significantly improving our understanding of the structure and stratigraphy of central Nepal.

Zircon (U-Th)/He thermochronology records the age at which a zircon crystal moved through the closure temperature for Helium, usually around 180°C. Data produced with this technique will inform discussions of along-strike variability of the Main Central Thrust (MCT), upon which The Khairenitar Klippe sits, with ramifications for a range of processes including monsoon intensification and foreland basin development.
The mid-Cenozoic Liuqu Conglomerate was deposited during the early Miocene in alluvial fan and coarse-grained fluvial deposystems. The Liuqu basin formed between ophiolitic mélanges (to the south) and uplifted Cretaceous forearc deposits (to the north) along the central, 1000 km long segment of the Indus-Yarlung suture zone in southern Tibet. Sedimentological analysis shows the unit to be composed of mixed fluvial and sediment-gravity flow lithofacies assemblages, locally punctuated by mature paleosols of mainly vertic character. Structural and architectural analysis indicate that the Liuqu Conglomerate was deposited in a contractional setting. Paleocurrent and provenance data demonstrate that sediment was transported northward from the hanging wall of a GCT related thrust system that forms the southern limit of Liuqu outcrops. Detrital zircon U-Pb ages cluster around 80-110 Ma ($\varepsilon$Hf = -23.5 – 14.6), 120-135 Ma ($\varepsilon$Hf = -12.6 – 13.1), 500-600 Ma ($\varepsilon$Hf = -26 – 3.4), and 1100-1200 Ma ($\varepsilon$Hf = -27.6 – 2.9), requiring input from both Asian and Indian sources. The youngest detrital zircon U-Pb ages obtained from the Liuqu Conglomerate are ca. 18 Ma, providing a maximum depositional age. Analysis of paleosol carbonates yielded δ13C values between -12‰ and -8‰, indicating deposition in a well vegetated setting; this is consistent with mature paleosols preserved in this unit. Oxygen isotope composition of these carbonates was reset by burial processes. Together these results indicate that (a) the India-Asia collision was well underway by the time of Liuqu deposition (no later than 18 Ma). (b) Deposition occurred under paleogeographic and/or paleoclimatic conditions that promoted intense weathering on Liuqu floodplains and alluvial fan margins. (c) Deep tectonic burial caused the resetting of oxygen isotopes within soil carbonates, and (d) the Liuqu Conglomerate may represent the southern, lateral equivalent of the Gangrinboche Conglomerate exposed ~20 km to the north.
The Eastern Cordillera and Santa Barbara thrust systems of northwest Argentina exhibit a well-known transition in structural styles due to contrasting subduction dynamics. To the north, the Bolivian Andes are characterized by thin-skinned deformation attributed to simple shear and normal subduction (30°). To the south, the Sierras Pampeanas are characterized by thick-skinned deformation associated with pure shear and flat subduction. However, thrust belt evolution in northwest Argentina is controlled by inversion of the Cretaceous Salta rift. There, the Eastern Cordillera is characterized by high-angle reverse faults that involve Precambrian-Cambrian crystalline and metamorphic rocks and Cretaceous rift sedimentary rocks. The Santa Barbara system is the frontal thrust belt; characterized by steep, west-verging reverse faults uplifting large blocks of Paleozoic-Cenozoic sedimentary rocks. Both the Eastern Cordillera and the Santa Barbara system are controlled by reactivated normal faults associated with the Cretaceous Salta rift, a complex of extensional basins, beneath the modern foreland basin. Total shortening estimates are currently ~70 km, which compares to estimates of 300-330 km in Bolivia and 30-120 km in the Sierras Pampeanas. Field-mapping performed in the Eastern Cordillera and Santa Barbara thrust belts between 25°-26°S and 65°-66°W shows that inversion of the Salta rift is characterized by basement-involved fault propagation folding. A balanced cross-section through the Calchaquí and Lerma Valleys gives ~40% shortening (28 km for a 71 km portion of the thrust belt). To determine if the thrust belt formed in- or out-of-sequence, samples are being processed for apatite (U-Th)/He dating. Previous studies (e.g., Carrapa et al., 2011) document that (U-Th)/He dating is a usable proxy for the age of exhumation of thrust sheets in the region, and document sequential propagation of exhumation (and inferred deformation) from ~14 to 3 Ma; however, some authors argue for erratic, out-of-sequence deformation based on sediment architecture and facies associations.
The tectonic and climatic regimes that characterize the Andes of South America vary both along strike and perpendicular to the mountain belt providing a natural laboratory that facilitates the study of the relative effect of climate and tectonics on erosion. The orographic barrier created by the Andes alters the precipitation patterns on either side of the orogen while regional climate patterns change along strike. The northern region is characterized by high precipitation on both sides of the Andes whereas in the central region the east side receives high precipitation, but the west side lies in a rain shadow. In the southern region, the westerlies produce high precipitation on the western side of the Andes with low precipitation on the eastern side. The north, central, and southern regions are characterized by similar large scale tectonics, but different structural styles.

Analyzing three key transects from the north, central, and southern region provides the opportunity to investigate the following hypothesis: Climate controls erosion in the Andes and affects the morphotectonic architecture (shape and structural style) of the orogenic system. This poster will address proposed analytical methods, expected results, and goals of a project addressing this hypothesis. For example, samples from the northern transect should indicate stronger erosion (higher precipitation) than samples from the central transect despite the fact that shortening is maximum at ~20°S. This problem will be addressed analytically by using thermochronology, specifically apatite fission track analysis, of modern river sands draining three east-west transects across the Andes that correspond with changes in precipitation patterns. On the first order, this study will address the impact of both climate and tectonics for each regional setting (north, central, south). This provides a better context for the second order question: a comparison between the relative impact of climate and tectonics on erosion in varying settings.
G17: FAULT ROCKS OF TANQUE VERDE WASH, TUCSON, AZ
Warren Allen

At the western extreme of the Tanque Verde Wash in the Catalina Range near Tucson, AZ a variety of dark dense rocks have been identified as cataclasite, ultracataclasite or pseudotachylites. My study is to determine the existence of pseudotachylites and the possibility of dating the events that formed these fault rocks. My study includes field observations mapping and measurements of the macro-structures and thin-section petrological analysis of key sample locations as well as other scientific methods.

Tanque Verde Wash is located in a low saddle area that is in a NE-SW wash cut in the Catalina Mountains. The dominant lithology is mylonitic gneiss that exhibits ductile and brittle deformations. The basic geomorphology is formed by the kinematics of the up-lift, doming of the Catalina range and the corrugation due to the Poisson effect of the NE-SW trend. The low saddle of the Tanque Verde Wash is low point of such a corrugation.

My study focuses on a region near the west extreme where the wash drains out onto the Tucson basin extending upstream ~ 1 km to an exposed detachment fault. The dominant lithology of mylonitic gneiss along strike (~240°) exhibits a lobate pattern of folded mylonite in lit-par-lit packages. Some of the surface is skinned with a fault generated rock that have a glassy surface with stepping down texture to the SW. Hand samples reveal faint foliation patterns that have been severely deformed and smeared out. The colors range from shiny black to dull dark gray. Sections of the granite in the vicinity of the suspected fault rocks have a web pattern of dark material similar to the fault rocks. Several injection veins have been observed as well as more mafic inclusions.
Recently, a study of the Catalina detachment fault zone was conducted. The goal of this study was to assess the control that an ultramylonite shear zone within the Catalina-Rincon metamorphic core complex had on the detachment and sub-detachment faults there. As one part of the study, GPS data were collected on the Catalina detachment fault surface, the Javalina sub-detachment fault surface and in the ultramylonite shear zone. Each data-set was modeled as a plane in three dimensions and an inverse problem was solved to estimate the fault plane and ultramylonite shear zone plane geometries. Strike and dip values for the three best-fit planes were calculated and used to show that the three zones are nearly parallel in orientation.
The Santa Catalina Mountain range is located North and Northeast of Tucson. Its uplift is composed of a metamorphic core complex similar to the North American Cordillera. The plutonic and metamorphic rocks are known to range in age from Proterozoic to mid-Tertiary. In September 2012, two undergraduate geology students collected sand deposits from the Campbell Wash (East) and the Agua Caliente Wash (West) before they feed into the Rillito riverbed. Detrital zircon geochronology applied to these samples with a Mass Spectrometer connected to an Excimer laser served to compare results from present day streams with the rock data that has already been recorded for their respective headwaters in the Catalinas.

The dating results in the samples confirm the existence of Pinal Schist (~1650 Ma), Oracle Granite (~1442 Ma), Leatherwood Diorite (~74 Ma), and Wilderness Leucogranite (~44 Ma) in the headwaters of the two respective washes. However, the results of the Campbell Wash reveal the presence of a mid-Jurassic granite (~171 Ma) while no such outcrop has been recorded in its headwaters. The closest outcrop is the Squaw Gulch Granite in the Mount Wrightson Formation on the Southern West side of the Tucson basin.

Furthermore, in the results for both the Campbell and the Agua Caliente washes evidence of a young igneous rock (~25 Ma) has been uncovered, while the closest similar age outcrop recorded is on the North side of the Catalina Mountain Range (Catalina Granite).

As the sedimentary samples were taken on the top layer of modern day sediment, this strongly suggests that there has to be uncovered outcrops present in the actual headwaters of the Campbell Wash and the Agua Caliente Wash.

Assuming that all methods were carried out accurately without technical problems, the next step would be to go in the headwaters of the Campbell Wash and look for outcrops that could contain Catalina Granite. Additional samples would be U-Pb dated and possibly would refute or confirm the hypothesis of its location.
G20: U-PB GEOCHRONOLOGY OF DETRITAL ZIRCONS FROM THE
CAMPBELL AND AGUA CALIENTE WASHES
Westin Skillings, Patricia Matille

The mountain range in northern most Tucson is the Santa Catalina Mountain Range. This particular mountain range was formed due to faulting from regional tension from the nearby San Andreas Transform fault in South West America. This situational uplift has exposed a combination of metamorphosed and ingenious rock which are the center points of our research.

Our studies were carried out to determine the detrital zircon dates from samples taken from the Rilito River (Campbell Wash) and the Ague Caliente Wash (North East Tucson). With these samples properly dated we would be able to construct a more accurate geologic map of these mountains and interoperate the change in flow patterns from yearly precipitation.

Our studies were done through acquiring several pounds of sand from both washes which were filtered with a 200 micron mesh. The samples were then taken to the Rock Room of the University of Arizona’s Geology Department where minerals were further separated. After this beginning process the samples were then taken to the Mineral separation lab were magnetic material was removed. Next the sample was sent through Methylene Iodide, a heavy liquid in which zircons can be effectively separated for dating methods. The samples were then mounted and imaged and sent through the Mass Spectrometer in the LazerChron Center.

Our results founded that the most abundant formation in the Santa Catalina’s are; a igneous formation Oracle Granite (1442 ma) and Metamorphic formation Pinal Shicst (1650 ma). The confirmation of Leatherwood Diorite (~74 Ma) another igneous body was also made. Possibly the most interesting discovery was the founding of Catalina Granite a 141 million year old igneous body that has never been previously recorded in the southern side of the mountain range, though it has been discovered exclusively to the northern side. This suggests that either there is indeed undiscovered formations of Catalina Granite on the Northern side of these mountains or the flow of drainage patterns changed dramatically less than 141 million years ago.

Though both scenarios are equally likely the next steps to this research is to discover the possible outcrops of Catalina Granite or discover how and why the drainage patterns from the mountains changed.
Rivers are responsible for the distribution of sediment from igneous bodies to riverbeds. Zircon crystals found in the sediment are used to determine the ages of the sediment. A group of three undergraduate UA Geoscience students collected samples from the Santa Cruz River. Using U-Pb dating, we can determine the exact age of the Zircon crystals and the rock formations where they originated.

The majority of our zircon crystals are from the Jurassic period with a peak in the middle Jurassic, the Bajocian age (169 Ma). The prevailing bulk of the crystals are from 63 Ma the early Paleocene Period. The sediment likely originated from a granite body near the Sierrita Mine. The youngest crystals are from the Oligocene period, 26 Ma, and they likely originated from the Tucson Mountain’s intrusive Granite.

With this information, geologists can speculate the origin of the sediments, the river’s path throughout history, and can determine how the sediments traveled to their current position. Through sediment traveling through the Santa Cruz River we can determine the origin of the sediment and the time when the igneous bodies formed.
The Central Mountain Province of Arizona is home to the Salt River Canyon. The Central Mountain Province is bordered by the Mogollon Rim, and the Colorado Plateau, and includes the White Mountains, and Ruin Granite downstream. Headwaters bring sediment from the White Mountains and the Colorado Plateau. The Salt River Canyon collection site includes a large stratigraphic sequence including recent volcanism, Mogollon rim gravel, Dakota Sandstone, Supai, and the Apache Group. The area may have also experienced a drainage reversal in the last 30 million years. From collecting samples in this area we were able to determine the ages of the zircons using a Mass Spectrometer connected to an Excimer laser in the University of Arizona LaserChron Center. Utilizing U-Pb dating, the age of our sample was determined to range from 93.7 Ma-3142 Ma. The sample included 93-220 Ma, 400-450 Ma, 1400 Ma-1800 Ma, 2500 Ma-3200 Ma. The ages of some of the zircons were unexpected as there were no local sources that coincided with those ages. To determine the possible sources of zircon ages not located in the local area, the paleography of North America needed to be examined. The age range of 400-450 Ma represented in our sample shows that the area contains zircons related to the Paleozoic when the Appalachian Mountains were North America's continental divide. Zircons ages 2400 Ma and older are likely from the Wyoming or Superior Craton. 93Ma- 220 Ma zircons do not originate from local volcanism and are likely windblown from the Sierra Nevadas. Arizona contains many 1400 Ma to 1800 Ma igneous rocks and these ages are most likely local. However, if we look for the closest possible source we find the Ruin Granite located downstream from our collection site. A Late Eocene alluvial plain was deposited by NE flowing streams creating an arkosic sandstone known as the Mogollon Rim Formation. Analyses of zircons from the Salt River Canyon suggest that the collection site had a long and complex history which included the delivery of source material from many areas of North America.
The Connecticut River, the largest river in New England, cuts through New Hampshire’s White Mountains and the Upper Appalachian Mountains and carries sediment from the Grenville Orogeny to the Atlantic Ocean. Zircons in the sediment taken from this river were analyzed in the University of Arizona’s LaserChron Center using the Mass Spectrometer and Excimer Laser. The zircons ages, derived from lead and uranium ratios, revealed the age of the sediment to range from 400 Ma and 900 Ma -1400 Ma. These ages can be used to determine the tectonic environment in which the rock that contains the zircons was formed in. After reviewing the tectonic events in North America during the Late Ordovician period, it is clear that the formation of Pangea, which involved the collision of Gondwana and Euroamerica, created the Appalachian Mountains and the zircons aged at 400 Ma. Going farther back into New England’s geologic history, it can be observed that the formation of Rodinia created the Grenville Orogeny and formed the zircons aged at 1400 Ma. Sediment from the igneous and metamorphic rocks of New England can be found in the Connecticut River, and when the sediment is analyzed using geochronology its age can be determined.
Planar deformation features in common minerals have been used as indicators of bolide impacts in the geologic record. While diagnostic shock features in quartz and feldspar are well-known and easily recognizable, similar planar deformation features in mafic minerals are much more difficult to identify optically. Thus, spectroscopy may serve as a better tool for shock analysis of such minerals. Raman spectroscopic analysis of shocked quartz and feldspar has revealed that Raman peaks tend to be broader for shocked crystals than those of their corresponding unshocked parent species. Does Raman spectroscopy reveal broadened peaks in shocked mafic minerals as well? Gabbro samples, provided by Planetary and Space Science Centre of the University of New Brunswick, from Sudbury (1859 Ma), Slate Islands (450 Ma), Brent (395 Ma), and Haughton (39 Ma) impact sites were analyzed, and evidence of peak broadening was positively identified in samples from at least two of these impact sites. In samples that demonstrate shock, the broadening of the Raman peaks of the shocked mafic minerals were evaluated and measured. X-ray diffraction patterns and optical analysis of these minerals may additionally aid in understanding the effects of shock on the crystalline structure of the minerals of interest.
The Providencia Canyon watershed, located in the Patagonia Mountains, southeastern Arizona, contains eight relatively small abandoned mine sites that are of concern to managers of the surrounding aquatic ecosystem. Past mining practices have been shown to cause changes in aquatic geochemistry—lower pH and elevated metal concentration, that can lead to a decrease in biodiversity of aquatic organisms. We sampled intermittent tributaries in the watershed draining disturbed areas which demonstrated erosional features that suggest possible heavy metals dispersion and contaminants leaching. Minor workings are common in the area due to scattered mineralization that occurred in the form of minor localized veining than included seams in fissures, joints, sheeting planes and other fractures in the rock. Of particular interest is the Four Metals Mine which is the largest disturbed site in the watershed and directly intersects the central, main tributary in the watershed. The Four Metals Mine was active during the early turn of the century and small amounts of gold, silver, lead, zinc, antimony, molybdenum, and tungsten were extracted. Water samples were collected from the surrounding area and field tested for specific conductance, pH, TDS, and alkalinity. The samples were chosen to represent surrounding background geochemical signatures as well as those that are potentially impacted from contact with mine waste rock, tailing impoundments, and mineralized bedrock. Corresponding sediment samples were taken to further characterize the area. The samples were submitted for trace element analysis by inductively coupled plasma mass spectrometry (ICP-MS) and ion chromatography methods, which included, but was not limited to arsenic, cadmium, copper, gold, iron, lead, silver, sulfate (SO4-) and zinc. This study will examine possible impacts of the abandoned mine lands remains on the Providencia Canyon watershed such as eroded, uncontained waste rock and tailing piles, and mineralized rock on the water quality of the watershed.
The path of magma ascending through the crust may be influenced by preexisting faults and regional stresses, resulting in the alignment of volcanic vents at the surface. However, it can be difficult to determine visually if centers of volcanic vents have a preferred alignment or are randomly distributed. If volcanic centers are treated as point data, the two-point-azimuth statistical method (TPA) can quantify whether the azimuths defined by all pairs of observed points are statistically different than that expected from randomly located points. TPA analysis also attempts to correct for non-homogeneity and biases inherent in the overall shape of the data. Circular features, suspected to be of volcanic origin and revealed in 3D seismic reflection data from near the continental shelf edge of the rifted margin of West Africa, were tested for alignment. Inferences of how these suspected volcanic features are emplaced, whether through preexisting faults or through rift-related faults, can aid in assessing reservoir risk. In general, TPA analysis indicates a WNW alignment of the circular features for the West African data, a trend that is distinctly different than the observed sets of NS- and NE-striking faults and more in line with rift-related faulting. Cinder cones and maars of the southeastern Arizona Pleistocene San Bernardino volcanic field were also tested for alignment. These data act as known volcanic features to be tested with the TPA method. Furthermore, the results can be compared to strains determined from GPS geodesy in future work. TPA analysis of the volcanic centers of the San Bernadino volcanic field indicates an approximate trend of N15E. This is similar to the trend of the basin-bounding faults and is more northerly than the strikes of intra-basin faults found in previous work, which were based on visual alignments of subsets of volcanic centers, gravity data and surface mapping.
Saturday Science Academy (SSA) is an academic outreach event held each year at the University of Arizona. With a variety of hands-on educational activities and demonstrations, SSA has attracted hundreds of participants over the past two years. The target audience of SSA is local middle and high school students from underrepresented minority groups who attend schools that do not emphasize geosciences in their curriculum. Hispanic and Native American students typically comprise the majority of participants in SSA. SSA is supported by the Department of Geosciences at the University of Arizona, The Arizona Mathematics Engineering Science Achievement (MESA), and The Southern Arizona Geosciences Union for Academics, Research and Outreach (SAGUARO).

To better understand the effect of SSA on local students, evaluation surveys were administered to participants at the 2009, 2010 and 2011 SSA events. Fossils and other prizes were used as incentives to encourage students to complete the surveys. In 2011, 112 surveys were collected from participants both before and after SSA. Program effectiveness was assessed through comparisons of participant’s pre-and post-SSA responses. Preliminary results suggest that SSA is effective in improving the perception of geosciences amongst both white and minority student groups yet there are differences in SSA’s effectiveness in reaching each group. Such differences can be seen through the responses to the statement ‘Geosciences are interesting’ where Hispanic students largely agree with the statement, while Native American students largely disagree with it.