GEODAZE 2005

33rd Annual Geosciences Symposium

PROGRAM AND ABSTRACTS

April 7th & 8th
Memorial Student Union - Ballroom A
University of Arizona

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Table of Contents

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We would also like to thank the session chairs and evaluators, as well as the many unmentioned students, professors, and staff who contributed their time and effort in assisting us with GEODAZE 2005.

Chairs' Welcome

Welcome to GeoDaze 2005! We would like to extend a special thanks to those of you who have made this year's symposium possible through your generous contributions. Now in its thirty-third year, GeoDaze is a student-run symposium designed to provide our graduates and undergraduates with a forum to present original research and receive feedback from industry, civic, government professionals, and academics alike. Over the last year our students and faculty have worked hard on a number of diverse research projects throughout the world. We are excited to showcase their results over the next two days.

As many of you know, our department is somewhat stratified between hard-rock and soft-rock geologists. The structure of Thursday's talks will be as follows: tectonics, structural geology, seismology, and economic geology from 9:15am-11:30am; a sampling of undergraduate research from 1:00pm-2:00pm; and a poster session from 2:00pm to 4:00pm. On Friday, the atmosphere will begin to heat up with Quaternary themed research talks from 9:15am-11:30am, followed by a shift into a sizzling climate of paleoenvironmental presentations from 1:00pm-3:00pm. We are pleased to welcome our keynote speaker, Dr. Maureen Raymo from Boston University and Woods Hole Oceanographic Institute, who will give a very cool address entitled "Causes of Ice Ages in Earth's History" from 3:00pm-4:00pm.

From 4:00pm-4:15pm we hope that you'll find the slide show of our department's activities throughout the last year to be uplifting. If not, tuff. Afterwards, the awards ceremony will release the year's stresses for many of our students with monetary prizes funded by our sponsors. The symposium will end with an eruption of Thank You's to our volunteers, friends, and alumni of the department whose support we certainly do not take for granite. Seismologist George Zandt and Department Head Susan Beck invite everyone to elastically propagate to their house in the Tucson Foothills for the annual GeoDaze party at 6:30pm.

Saturday morning we will converge for the ConocoPhillips Field trip, "Core Complex Geology along the Catalina Highway," lead by Jon Spencer of the Arizona Geological Survey. With his expertise in Arizona tectonics Dr. Spencer will explain the Catalina's geologic history and point out some gneiss outcrops. We hope you enjoy this year's symposium because geology rocks!

Sincerely,

Andy Frassetto & Toby Ault
(GeoDaze 2005 co-chairs)

Schedule of Events

Thursday, April 7th

Arizona Ballroom A (North)
Memorial Student Union

8:30 Coffee and Pastries

9:00 GeoDaze Welcome Address **Randy Richardson**

SESSION I

Tectonics, Structure, Geophysics, Economic Geology, and Undergraduate Talks

Session Chairs: Megan Anderson & Matt Fabijanic

9:15 Tibetan two-step: thermobarometry and cooling history of the Amdo basement
Jerome Guynn

9:30 Upper crustal deformation of the Linzhou area, southern Tibet, and tectonic implications
Shundong He

9:45 Crustal deformation and crust-mantle interaction in an active continental collision: east Anatolia
Arda Ozacar

10:00 An investigation of crust and upper mantle structure in Western Argentina utilizing local event receiver functions
Josh Calkins

10:15 Stratigraphy of the Arizona lithosphere: implications on regional Cenozoic tectonics
Andy Frassetto

10:30 Coffee Break

Session Chairs: Shannon Langdon & Becca Walker

10:45 Tertiary tilting and dismemberment of a Laramide magmatic-hydrothermal system, Pima Mining District, southern Arizona
William Stavast

11:00 Porphyry puzzle pieces: A new cross section through the Globe-Miami copper mining district, Arizona

David Maher

11:15 The Ertsberg mining district: on the right side of the tracks!

Stacie Gibbins

11:30 Lunch Break

Session Chairs: Lynnette Kleinsasser and Lynn Peyton

1:00 Alkali metasomatism in the southern part of the Pima mining district: chronicling a story of contrasting fluid sources

Erik Flesch

1:15 A receiver function study of the crustal structure of Toba caldera, Sumatra Island

Koichi Sakaguchi

1:30 Preliminary geochemical implications from the collaborative batholiths study of the Coast Plutonic Complex, British Columbia

Theresa Kayzar

1:45 A high resolution seismic study of the Kalya horst and platform: Long term paleoclimate drilling site survey in central Lake Tanganyika

L. Cody Helfrich

SESSION II

Posters

2:00 Coffee and Snacks

U-Pb ages of detrital zircons from quartzose eolianite in the Jurassic Mount Wrightson Formation, Santa Rita Mountains, Arizona

Joe Amar

Neotectonics and evolution of the Yenicaga Basin, Bolu – Turkey

Mehmet Serkan Arca

U-Pb ages of detrital zircons from lower Jurassic Nugget Sandstone of northern Utah

Erin Brenneman, Joe Amar

Detrital zircons in the Garta member of the Chinle Formation in northern Utah: Implications for upper Triassic paleodrainage patterns

Richard A. Brown, Benjamin M. Norton

Deposition of playa windblown dust over geologic time scales

Joe Cook, Jon Pelletier

Orientation in Raman Spectroscopy

Dembowski, R.F., Mooney, P.R., Fischer, T., Laetsch, T., Struthers, J.

Program impact on collaboration for advancing teaching technology and science (CATTS) fellows

N. English, N. Regens, J. Knight

Detrital zircons in upper Triassic strata of the upper Chinle and Dockum groups, New Mexico and Texas

Jennifer D. Fox, Kelley N. Stair, T.M. Lehman

Stable isotope analysis of ostracode valves: A record of climate change in the Bonneville Basin, Great Salt Lake, Utah

Helfrich, L.C., Balch, D.P., Cohen, A.S.

Magnetism and hydrothermal alteration of the Copiapo Batholith, northern Chile

Laura Huebner, Mark Barton, Eric Jensen

Comparison of detrital zircons in the fluvial Kayenta Formation (lower Jurassic) of southern Utah with detrital zircons from underlying and overlying eolian strata

Owen V. Hurd, Gregory R. Schmidt

In-situ clinopyroxene Sr isotopic analyses by LA-ICPMS; A test of mantle melting processes in the Big Pine volcanic field, California.

Theresa M. Kayzar, Kelley N. Stair, Mihai N. Ducea

Geochemical and isotopic characteristics of Mesozoic granitoid magmatism in the middle and lower Yangtze River Valley, China

Chao Li

Bottoms up! A rare view of the roots (~10 km paleodepth) of a productive Laramide porphyry copper system exposed in the Globe-Miami district, Arizona

David Maher and William Stavast

Preliminary results of the mineralogical analysis of the Obi Rakhmat Grotto and Paltau Cave Sediments, Uzbekistan.

Susan M. Mentzer

RRUFF Project: Raman Spectroscopy Database

Mooney, P. R., Campbell, C., Dembowski, R., Fischer, T., Kaur, B., Laestch, T., McCarthy, A., Minamyer, C., Norton, M. B., Origlieri, M., Reynard, J., Schmidt, G. R., Schrader, D., Shah, S., Struthers, J., Uchida, H., Zwick, J.

Using Raman Spectroscopy to Characterize Gemstones

Vera Sanderlin

Detrital zircons in northern Arizona of the fluvial Kayenta Formation (lower Jurassic) on the Colorado Plateau

Gregory R. Schmidt, Owen V. Hurd, Linette C. Ancha, Gerald, Bryant

Oriented Crystal Studies: Orienting Crystals

Schmidt, G. R., Uchida, H., Mooney, P. R., Downs, R. T., Lu, R.,

Alkali metasomatism in the southern part of the Pima Mining District: Field relationships and alteration assemblages

Tyler Vandruff, Erik Flesch, and Bill Stavast

Coupled basin evolution and metamorphic core complex exhumation in the southern Basin and Range Province, southeastern Arizona

Frank H. Wagner, III (Trey) and Roy A. Johnson

Strain partitioning and vertical-axis rotation across the Santa Rita fault zone in response to Cenozoic metamorphic core complex emplacement, Southeastern Arizona

Frank H. Wagner, III (Trey) and Roy A. Johnson

Friday, April 8th

Arizona Ballroom A (North)
Memorial Student Union

8:30 Coffee and Pastries

9:00 Welcome and Announcements

SESSION III

Quaternary Geology

Session Chairs: Stacie Gibbons and Jessica Conroy

9:15 Uranium-series dating and Middle Paleolithic hominid occupation in central Asia

Jennifer D. M. Wagner

9:30 Atmospheric circulation and paleohydrology change in late Miocene and Pliocene as recorded in the Linxia basin, northeast Tibetan Plateau

Majie Fan

9:45 Strontium isotopic analysis and petrographic study of a Nepali paleosol sequence: Quantification of silicate weathering

Amanda Reynolds

10:00 The search for a silver lining: Using Pb-isotopes to constrain the source of archaeological ores at La Isabela

Alyson Thibodeau

10:15 The evolution of scientist-teacher partnerships: A case study investigation

Becca Walker

10:30 Coffee Break

Session Chairs: Allison Drake and Tom Damassa

10:45 Quantitative assessment of debris flow deposition and reworking by the Colorado River, Grand Canyon, Arizona.

Brian Yanites

11:00 The integration of tree-ring and alluvial fan records of fire history at the Missionary Ridge Fire, Durango, Colorado

Erica Bigio

11:15 Correlation and chronostratigraphy of Pleistocene—Holocene tephras from the Bolivian Altiplano

Christa Placzek

11:30 Lunch Break

SESSION IV

Paleoclimatology, Climate, and Paleoecology

Session Chairs: Brian Yanites and Alyson Thibodeau

1:00 A new reconstruction of seventeenth century climate variability from the Western Indian Ocean using the coral genus Diploastrea

Thomas D. Damassa

1:15 Spectral analysis of Coral d18O Records in the Pacific and Indian Oceans: an examination of decadal and interdecadal variability

Toby Ault

1:30 Holocene precipitation variability in the Galápagos Islands

Jessica Conroy

1:45 Will future climate threaten the Sonoran Desert?

Allison Drake

Session Chairs: Heidi Barnett and Jessica Rowland

2:00 Reconstructing 31,000 years of vegetation dynamics in the northern Chihuahuan Desert: A packrat midden study from the Peloncillo Mountains

Camille Holmgren

2:15 Early to mid-Holocene climate in southern Arizona inferred from speleothem stable isotopes

Jennifer D. M. Wagner

2:30 Stable isotopic variations in columnar cacti: Are responses to climate recorded in spines?

Nathan B. English

2:45 Coffee Break

3:00 Keynote Address

Causes of Ice Ages in Earth's History
Dr. Maureen Raymo

4:00 Slide Show **Scott St. George & Tom Damassa**

4:15 Awards **P. Jonathan Patchett**

4:45 Thank You's and Invitation to Party

Saturday, April 9th

8:00 AM - 4:00 PM

Field Trip up the Santa Catalina Highway

(Sponsored by ConocoPhillips)

Meeting location: Gould-Simpson Building Loading Dock

Meet at the Gould-Simpson loading dock by 8:00 AM. Departure is expected at 8:15 AM. Contact Erin Gleeson at egleeson@email.arizona.edu to sign up for this trip.

Jon Spencer of the Arizona Geological Survey will lead the Geodaze 2005 field trip along the lower Catalina Highway in an exploration of the geologic features associated with the Catalina metamorphic core complex. The field trip will consist of three stops, two of which will involve short hikes on the southern flank of the Santa Catalina Mountains.

Stop #1: Drive to the Babad Do'ag parking lot. From there, cross the highway and walk along the Babad Do'ag trail while looking at excellent exposures of mylonitic rocks and at least one top-southwest shear-sense indicator for a round trip of about 1 km (0.6 mi).

Stop #2: Return to the vehicles, drive further up the highway to the Prison Camp campground, and walk southward on the west rim of Soldier Canyon to look at the north side of the forerange arch. We will see several excellent indicators of top-northeast shear, opposite to the sense of shear on the south side of the arch, and will look at a pegmatite that cuts this mylonitic fabric. The round trip hike will be about 4 km (2.5 mi.), mostly off trail, with approximately 250 m (800 ft.) of total vertical ascent.

Stop #3: Return to the vehicles, drive to Geology Vista which is just above the Windy Point overlook on the Catalina Highway. This stop provides a spectacular view of the Tucson basin and surrounding ranges and will be the backdrop for a discussion of the tectonics of exhumation and the regional geology.

Session I Abstracts

Tibetan two-Step: thermobarometry and cooling history of the Amdo basement

Jerome Guynn
Department of Geosciences, University of Arizona

The Bangong suture zone marks the boundary between two terranes, Qiangtang and Lhasa, which make up southern Tibet. The two terranes are thought to have collided in the mid-Mesozoic. The suture zone stretches for over 2000 km across Tibet, but there is only a ~100 km long section where basement rocks are exposed. These rocks, the Amdo basement, comprise amphibolite-grade orthogneisses, paragneisses and metasediments. They were thought to have undergone high-grade metamorphism during the Cambrian, when the granitoid protoliths for the orthogneisses crystallized, and only low-grade metamorphism during the late-Jurassic/early-Cretaceous collision, which resulted in only minor shortening. Geochronology, thermobarometry and field mapping, however, indicate that a) very high-grade metamorphism occurred in the mid-Jurassic, b) the metamorphism may not be associated with the collision and c) the collision may have resulted in significant crustal shortening. U-Pb ages on titanite and Ar-Ar ages on hornblende provide ages of ~180 Ma that are representative of the time of upper-amphibolite metamorphism. Mica Ar-Ar cooling ages are ~165 Ma, indicating fairly rapid exhumation. However, Ar-Ar diffusion modeling ages on potassium-feldspar reveal that the Amdo basement remained in the middle crust until about 130 Ma, when it experienced another episode of rapid cooling. This two-part cooling history indicates that the metamorphism of the Amdo basement, as well as obduction of associated ophiolites, may have actually preceded a Cretaceous collision between Lhasa and Qiangtang, an interpretation supported by other geological observations. Extensive Cretaceous shortening is observed all along the Bangong suture, including in the area of the Amdo basement.

Upper crustal deformation of the Linzhou area, southern Tibet, and tectonic implications

Shundong He
Department of Geosciences, University of Arizona

Many hypotheses attribute the uplift of the Tibetan plateau to the Cenozoic Indo-Asian collision. However, geological data show that pre-collision deformation played important roles for shortening the Lhasa and Qiangtang terranes, of southern and central Tibet, respectively. Furthermore it is uncertain when collision-related shortening initiated in southern Tibet. Previous thermochronologic studies suggest that it may have been postponed until Oligocene time. This study focuses on the upper crustal deformation history of the Linzhou area, 80 km northeast of Lhasa, where both pre- and post-collisional structures are exposed. Volcanic rocks of the Linzizong Formation, which are

widely distributed and exposed in southern Tibet, yield U-Pb zircon ages ranging from 69-47 Ma. The age span of volcanism overlaps with the onset age of Indo-Asian collision, which is suggested to have occurred some time between the latest Cretaceous and the Eocene. In the Linzhou area, geologic mapping shows that there are large-displacement north verging thrust faults that cut Cretaceous rocks in their footwall bur which are overlain by the Linzizong Formation. These relationships demonstrate significant upper crustal shortening and denudation in southern Tibet before the Indo-Asian collision. In addition, there are south-directed thrust faults that cross-cut the Linzizong Formation, indicating syn-collisional shortening. $^{40}Ar/^{39}Ar$ thermochronological studies of K-spar from a monzonite intrusion, in the hanging wall of a post-Linzizong thrust fault, indicate rapid exhumation of the intrusion to upper crustal levels at ~40 Ma. This is the oldest Cenozoic exhumation event documented in southern Tibet and may mark the time when the leading edge of the Indian lithosphere underthrust this region of the Tibetan plateau.

Crustal deformation and crust-mantle interaction in an active continental collision: east Anatolia

Arda Ozacar, George Zandt, Hersh Gilbert, Susan Beck
Department of Geosciences, University of Arizona
Email: oxacar@geo.arizona.edu

Conceptual models of orogens often invoke an evolution of deformation style from tectonic escape of coherent lithospheric blocks to crustal thickening involving intra-crustal flow, or vice versa. In this respect, the Eastern Turkey Seismic Experiment (ETSE) provides an important opportunity to study crustal deformation and crust-mantle interaction beneath an active continental collision. Receiver function analysis indicates a change in crustal structure between the Arabian platform and East Anatolian plateau. Beneath the platform, crust is relatively thin (~35 km) and exhibits a strong mid-crustal discontinuity (~25 km). Beneath the plateau, crustal thickness increases towards north reaching up to 48 km and crust exhibits low velocity zones. The crustal Vp/Vs ratios are low at the suture (~1.68), high across the North Anatolian fault and near young volcanic units (~1.87). Such high values near young volcanism can be explained by the presence of partial melt. Near the suture, we also constrained a layered Vp/Vs model that has a low average (1.68) for the whole crust but a high average (1.80) for the upper crust. Indeed this suggests the lower crust as the source of low Vp/Vs at the suture. In the central region of the plateau, the fast directions of SKS splitting and Pn anisotropy are parallel to each other but at high angles to the GPS motions suggesting a crustal layer that accommodates the differential motion between surface and upper mantle. In such a case, we would expect this layer to impose an anisotropic lineation. To test this idea, crustal anisotropy on a representative station is modeled by a ray-based approach using a global minimization technique. Inversion results show south-dipping (34º) fabric with a strong anisotropy (25%) near the base of the crust, which agrees with a relatively slow mantle flow towards SW.

An investigation of crust and upper mantle structure in Western Argentina utilizing local event receiver functions

Josh Calkins
Department of Geosciences, University of Arizona
Email: jcalkins@geo.arizona.edu

Images of the crust-mantle boundary and crustal structure obtained using the traditional analysis of teleseismic receiver functions (RFs) exhibit an unusually weak P-S conversion from the Moho in Western Argentina, where the subducting Nazca plate temporarily flattens out beneath the overriding South American plate. In order to better estimate depth to the Moho and search for mid-crustal impedance contrasts, we calculate and stack receiver functions using approximately 45 local earthquakes occurring in the downgoing slab between December of 2000 and February of 2001. The events occurred over a depth range of 76 to 165 km and were all within 128 km horizontal distance of the recording station and thus traveled with ray parameters less than .09 s/km. Radial receiver functions are calculated at a temporary broadband seismic station located near San Juan, in the region where the Precordillera transitions eastward to the Sierras Pampeanas. Plots of stacked RFs as a function of ray parameter show a strong signal from the Moho at 7 seconds corresponding to a depth near 50 km, as well as conversions from interfaces within the crust at depths of ~ 20 and 35km. The observed Moho depth is in good agreement with estimates made using Pn apparent phase velocities along a transect through tectonically similar terrain 200 km to the north. Furthermore, analyses of shallow and deep seismic reflection profiles by other workers have also revealed complex crustal structures and depth to Moho estimates in the 50 km range.

Stratigraphy of the Arizona lithosphere, implications on regional Cenozoic tectonics

Andy Frassetto, Hersh Gilbert, George Zandt
Department of Geosciences, University of Arizona

The Consortium for Arizona Reconnaissance Seismic Experiment broadband array samples lithosphere across the Basin and Range (BR), parts of the Arizona Transition Zone (ATZ), and Colorado Plateau (CP). Our observations aim to further distinguish the structural difference between the relatively stable CP and significantly extended BR. We use receiver functions to extract kilometer scale seismic structure in the form of Ps converted phases from teleseismic earthquake recordings. The results reveal distinct differences between the three regions including variations in crustal thickness, sharpness of the Moho transition, low velocity zones, and muted amplitudes. All BR receiver functions show a high amplitude Moho with crustal thicknesses of ~30 km. In contrast, data from CP and ATZ stations reveal a significantly stratified mid to lower crust with a deeper Moho at ~40 km. At stations WUAZ and KNTH two prominent Ps phases of comparable amplitude occur at approximately 40 and 50 km. These results raise the possibility of a layered Moho boundary or mafic material in the lower crust beneath

the ATZ. Common to all stations sampling the CP and ATZ, a substantial low velocity layer appears to underlie the region at ~60 km depth.

Receiver functions from CP stations WUAZ and ZIZZ contain a shallow, high amplitude, negative polarity arrival at 1.5 s following the direct P wave. These stations are located near the San Francisco and Springerville Pliocene to Holocene age volcanic fields. These observations result from the top of an anomalously slow shear wave-speed layer. Receiver function amplitude at WUAZ varies significantly with direction, and southwesterly azimuths are characterized by muted Ps phases that display no moveout as a function of distance. These data sample the crust beneath the ~1000 year old Sunset Crater. A preliminary forward model shows that shear wave-speeds of ~2.25 km/s at ~9-15 km depth produce a synthetic receiver function that matches the observed negative arrival. We believe that this phenomenon may result from the presence of a partially crystallized melt body beneath the San Francisco volcanoes.

Tertiary Tilting and Dismemberment of a Laramide Magmatic-Hydrothermal System, Pima Mining District, southern Arizona

William Stavast
Center for Mineral Resources, Department of Geosciences, University of Arizona
Email: wstavast@geo.arizona.edu

Faulting and rotation of the crust can yield greater three-dimensional exposures. In turn, this can lead to a better understanding of the dynamics of igneous and hydrothermal systems, with applications to mineral exploration. In the Pima Mining District, the Ruby Star Granodiorite (~64 Ma) is widely recognized as being responsible for porphyry copper mineralization at the Sierrita-Esperanza deposit (Aiken and West, 1982; Titley et al., 1986). Uncertainty persists, however, regarding the amount and character of dismemberment and tilting of rocks in the district. This study uses geologic relationships (including results of new geologic mapping of rock types and hydrothermal alteration; see also Vandruff et al. and Flesch et al., this volume), paleomagnetism, and hornblende geobarometry to quantify the amount and direction of tilting.

Several lines of evidence indicate that the district has been tilted 50-60° to the south. First, the Cretaceous Demetrie Volcanics and the Tertiary Helmet Fanglomerate (32-28 Ma) dip 60° to the south, although younger units dip less steeply. Second, the ages of strata become younger to the south. Third, alteration around the Sierrita-Esperanza deposit exhibit deeper alteration styles (e.g., Na(Ca) alteration) to the north and shallower alteration styles (e.g., sericitic alteration) to the south. Fourth, paleomagnetic studies (11 sites) from tuffs, granites, and dikes (~60-70 Ma) indicate a rotation of ~48° along an axis of N50E. Fifth, 15 samples of the Ruby Star Granodiorite distributed throughout the district have been analyzed for Al-in-hornblende barometry (Anderson and Smith, 1995), and results represent paleodepths of 2 to 12 km. Repetition of geologic features and the patterns of the geobarometric results indicate that the pluton has been dismembered into at least three major structural blocks, and the paleodepths increase to the north in each block. We conclude that the present surface represents an oblique section through the magmatic-hydrothermal system.

Porphyry puzzle pieces: A new cross section through the Globe-Miami copper mining district, Arizona

David Maher
Center for Mineral Resources, Department of Geosciences, University of Arizona

The Globe-Miami (G-M) area, ~100 km north of Tucson, lies in an area that is extended by middle Tertiary normal faults. The region has a complex history of marine and terrestrial sedimentation, erosion, magmatism, hydrothermal alteration, and compressional and extensional deformation and related sedimentation that spans 1.8 billion years. These events create a wealth of distinctive geologic geometries—intrusive and hydrothermal features and various unconformities and faults—that provide numerous three-dimensional relationships.

My new synthesis utilizes these relationships as structural piercing points to construct new cross sections in the G-M district. Consistent dips in pre-middle Tertiary unconformities and dips of synextensional sediments indicate that the area lies in a structural tilt domain dominated by several crosscutting sets of down-to-the-east normal faults that caused ~60° westward tilting of crustal blocks. This tilt domain is younger than, but overlaps in space and time with, a domain to the south and west characterized by down-to-the-west faults. Present-day map view approximates a series of repeated pre-extensional crustal cross sections in which piercing points show the G-M district underwent about 200% extension in a N60°E orientation.

The numerous Laramide porphyry copper occurrences, all of which are demonstrably fault bound, lie in belts aligned N60°E. Cross sections along these belts show that, from west to east, alteration changes from assemblages representing deeper, higher temperatures to shallower, lower temperatures (Maher and Stavast, this volume). As a result, the numerous piercing point relationships coupled with observations of alteration and mineralization in the district, can be used as a predictive tool to identify fault-bound portions of deposits that may lie hidden beneath large areas of post mineral cover in the G-M area. Tilt domains that formed by multiple generations of faults, which overlap in space and time, are difficult to reconcile with models involving simple shear zones.

The Ertsberg Mining District: On the Right Side of the Tracks!

Stacie Gibbins and Spence Titley
Email: sgibbins@geo.arizona.edu

The island of New Guinea is the consequence of a tortured tectonic history. It is the result of an Eocene-initiated oblique convergence between the northern margin of the Australian Craton and the Pacific and Philippine–Caroline Plates. This resulted in the accretion of oceanic and arc terranes on the northern margin of New Guinea, and a prolonged period of active margin tectonics and magmatism. Two episodes of magmatism have been recognized on New Guinea: a Miocene and Pliocene pulse. A number of porphyry Cu-Au deposits have been discovered in the Mobile Fold and Thrust Belt on the island, and are associated with both magmatic episodes. The Ertsberg Mining

District, Irian Jaya, boasts the highest Cu and Au resource of the known mineral deposits on the island.

Compilation and comparison of whole rock geochemistry, radiogenic isotopes, absolute age data, igneous rock compositions and structural setting is used to explore which factors appear most influential in endowing such a high metal concentration in the Ertsberg Mining District. Preliminary results suggest magma source for the igneous rocks in the Ertsberg Mining District to differ significantly from the source responsible for other mineral deposits on the island; igneous rocks in the district have a significant Archean-Proterozoic lower crust source, whereas igneous rocks associated with other mineral deposits on the island have a depleted mantle source.

Alkali metasomatism in the southern part of the Pima Mining District: chronicling a story of contrasting fluid sources

Erik Flesch, Tyler Vandruff, and William Stavast
Center for Mineral Resources, Department of Geosciences, University of Arizona,
Email: eflesch@geo.arizona.edu

Broad white swaths of Na(Ca) hydrothermal alteration in Ruby Star Granodiorite occur on the southern part of the Pima Mining District east of the Sierrita Mountains within an 11-km^2-zone). These zones are structurally deeper than (Stavast, this volume) and lateral to intense K and acid alteration associated with the Sierrita-Esperanza porphyry copper deposit (Titley et al.,1986). Na(Ca) alteration is of interest because it occurs in many geologic settings and may be important in some ore-forming systems (cf. Huebner et al., this volume). This study uses mineralogical characterization and geologic mapping to constrain the spatial and temporal distribution of Na(Ca) and K alteration in relationship to magmatic events and alteration types/vein assemblages. These results (Vandruff et al., this volume) constrain the parentage of Na(Ca) and K metasomatism, respectively, i.e. whether their fluid donors were from magmatic or external sources.

Multiple phases of the Ruby Star Granodiorite intruded Mesozoic igneous rocks (to west) and Paleozoic-to-Laramide strata (to east). Na(Ca) alteration is observed deep in the Ruby Star and resulted from leaching of potassium and enrichment in sodium and calcium; whereas K-altered Ruby Star (overlapping with ore) resulted from potassium enrichment. Na(Ca) alteration is observed to postdate two Ruby Star intrusions and associated instances of K-alteration. The Na(Ca) is cut by Laramide latite dikes; the latites in turn are overprinted by subsequent Na(Ca) alteration. K metasomatism is generated by cooling of fluids at relatively high temperatures. In contrast, Na(Ca) alteration may be caused either by heating of fluids or by circulation of sodium-rich fluids. Na(Ca) alteration developed preferentially on the eastern side of the system, which is adjacent to Paleozoic sedimentary rocks that contain evaporite horizons. Because of this geometry, we infer that incursion of a sedimentary brine, driven by magmatic heat, spawned Na(Ca) alteration in this district.

A receiver function study of the crustal structure of Toba caldera, Sumatra Island

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Toba caldera complex is located in northern Sumatra and is one of the largest known Quaternary caldera complexes. The present depression formed 74,000 years ago during an eruption of more than 2800km^3 of silicic pyroclastics over an area of at least 4 million km^2. Interest in this region has increased since the eruption of the Dec 26, 2004, M9.0 N.Sumatra earthquake, located ~300km west of the Toba caldera.

We investigate the Toba caldera complex and the subducting Australian plate utilizing receiver functions to better understand the deep structure of the caldera system and its relationship to the adjacent subduction zone. The receiver functions are produced by seismic data from two permanent stations and 16 temporary stations that were deployed within the Toba caldera as part of a PASSCAL deployment called TOBA project. A permanent station (PSI) is also operated within the caldera, ~400km inland from the Sunda trench to the east. The other permanent station is located near Singapore, on the southern tip of the Malay Peninsula, ~800km from the trench.

The preliminary receiver functions from the TOBA project stations and PSI station exhibit strong P-s conversions at ~ 2.5 s, ~5s and ~10s. The most prominent is the 5s arrival and this arrival is most likely from the Moho with its depth of 28 to 42 km, deepest in the center of the caldera at the highest elevation in this region. The crustal Vp/Vs is estimated to be 1.70 ~ 1.98 and the values tend to be higher near the center of the caldera. The shallower arrival is usually preceded by a negative arrival from the top of a low velocity zone, probably a partially crystallized sill. We also observed a possible arrival from the subducting slab at ~80km depth. In contrast, the receiver functions from station BTDF in Singapore show very simple structure with a distinct arrival at ~32 km depth that is interpreted as the Moho.

Preliminary Geochemical Implications from the collaborative BATHOLITHS study of the Coast Plutonic Complex, British Columbia

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Geochemical characterization of the Coast Plutonic Complex of British Columbia is a key piece of the larger BATHOLITHS interdisciplinary study; this project is aimed at understanding the origin and evolution of large Cordilleran magmatic arcs. Samples were collected along two transects in the study area; a northern transect along Douglas Channel and a southern transect along Dean/Burke Channels, the latter of which has been analyzed. Major, trace, and isotopic data collected in the first year of study estimate the average chemical composition of the Canadian Cordillera to be granodiorite to quartz-diorite, which is slightly more felsic than other North American Cordilleran arcs. In addition, the data allow us to characterize the depth and composition of source regions of

melting and residual material that would have been produced during melt generation. Relatively flat REE patterns lacking abundant Eu anomalies suggest the lack of large components of either garnet or plagioclase in melting residues. Rather, it is postulated that pyroxenes and amphiboles may play a greater role in the residual component of the southern Coast Plutonic Complex. Initial Sr values (0.7032 to 0.7042) and positive εNd values (2.9 to 6.0) suggest that the southern Coast Plutonic Complex represents juvenile crustal additions, while elevated $\delta^{18}O$ values (7.4 to 11.5‰) also require a significant contribution to the arc from crustal material. Future goals proposed from these preliminary data include investigating the cause of potential magmatic flare-up events and the role of a thickened crust, as well as evaluation of the potential for convective removal of a residual root beneath the Coast Plutonic Complex.

A high resolution seismic study of the Kalya horst and platform: long term paleoclimeate drilling site survey in central Lake Tanganyika

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Lake Tanganyika, located in the western branch of the East African Rift, is an elongated basin which formed as a result of regional extension (Tiercelin and Mondeguer, 1991). The lake provides the ideal setting for characterizing the complex kinematics and sequence stratigraphy associated with an active rift system (Cohen et.al, 1993). Further, Lake Tanganyika has the potential of containing a continuous paleoclimate record of the southern hemisphere, on the order of several million years. Our work focuses on the central part of Lake Tanganyika; just south of Mahali Mountains in the Kalya region, where two opposite-polarity half grabens are separated by a topographic high: the Moba – Kalya Horst (Rosendahl et.al, 1987). The Kalya Horst, described as a high relief accommodation zone and imaged by earlier Nyanza Project bathymetric surveys, is believed to be deep enough to have not been affected by low lake stands yet high enough to be isolated from terrestrial input (Brislen, 2001; Henderson and Gans, 2000). By using high frequency reflection seismology this study was able to show that the Kalya Horst Ridge is a continuous topographic high, not bisected by major transverse faults and bordered to the north by two srike-slip faults. Further, two regional climate fluctuations are shown as major erosional unconformitys both defining and within sequences. Finally, this study located a potential drill site on the Kalya horst containing an undisturbed record of climate change in Africa for the last million years.

Session II (Poster abstracts)

U-Pb ages of detrital zircons from quartzose eolianite in the Jurassic Mount Wrightson Formation, Santa Rita Mountains, Arizona

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Quartzose eolianite is interbedded with Jurassic (185-170 Ma) volcanic rocks of the Mount Wrightson Formation in the Santa Rita Mountains of southern Arizona. An eolianite lens sampled from the upper member of the Mount Wrightson Formation on Cave Creek contains detrital zircon grains of both Mesozoic (27%) and older ages. Zircon grains were dated by laser ablation ICPMS using a beam diameter of 50 microns. After analysis, 15 of 100 grains were removed from the study because of either >20% age discordance or poor analytical precision, leaving 85 reliable analyses. The Mesozoic grains (n=23) are dominantly Middle Jurassic to Late Triassic in age (176 and 221 age peaks on frequency curve), and were probably derived from the Cordilleran magmatic arc of which the Mount Wrightson volcanic rocks are a part. Pre-Mesozoic zircons include grain populations similar to those in Jurassic erg sands of the Colorado Plateau, and probably represent sediment blown into the Cordilleran arc from sand seas lying to the north. The most abundant pre-Mesozoic grains are Grenvillian (n=22), 840-1260 Ma; pre-Grenvillian Mesoproterozoic (n=12), 1320-1500 Ma; and Paleoproterozoic (n=18), 1600-2000 Ma. Minor Archean grains (n=6) are also present, as are Paleozoic and Pan-African grains (n=7). The Precambrian grains reflect derivation from various parts of the Laurentian craton lying to the east of the Cordilleran magmatic arc. Admixture of the arc-derived Mesozoic zircon grains and the craton-derived pre-Mesozoic zircon grains is expected from the depositional setting of the Mount Wrightson eolianites.

Neotectonics and evolution of the Yenicaga Basin, Bolu – Turkey

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The Yenicaga Basin, located along the North Anatolian Fault System, is interpreted to be a fault-wedge basin with the North Anatolian Fault System's master strand, the Gerede Fault, cutting across the basin itself. The basin and its surroundings contain both paleotectonic rock units and neotectonic rock units. Paleotectonic units, which are deposited or formed during prior tectonic regimes, comprise several formations. The most important of these is the Upper Miocene-Lower Pliocene Eskipazar formation which plays an important role in the understanding of the evolutionary history of the basin. The main Neotectonic unit deposited under control of the present tectonic regime is the Plio-Quaternary Betemurlu formation. The Betemurlu formation unconformably overlies the paleotectonic Eskipazar formation throughout the study area

and the unconformity separating these two units corresponds to the time interval during which the paleotectonic stress regime changed into the neotectonic stress regime. Thus, the onset age of the strike-slip neotectonic regime in the study area is Late Pliocene (~ 2.6 Ma). Common basin-margin-bounding faults of the Yenicaga Basin are the Asagi Kuldan fault, the Aksu fault, the Izmirli fault set, the Saraycali fault, the Degirmen fault set and the Hamzabey fault set. These fault systems display well-preserved fault scarps in places. Morphological expressions of these faults and their geometrical relationships with the local stress regime indicate that these faults are mainly strike-slip and oblique-slip faults. Morphotectonic expressions of the faults exposed within the study area indicate that these faults remain active. Most of the population centers within the study area are located on water-saturated, loose basin fill near the active faults. Hence, these population centers are open to future earthquake hazards.

U-Pb ages of detrital zircons from lower Jurassic Nugget Sandstone of northern Utah

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Previous analyses of Permian and Jurassic eolian sandstones on the Colorado Plateau of southwest Laurentia have yielded U-Pb ages that fall into six populations of widely different ages from Paleozoic to Archean. Further analyses conducted on Jurassic eolian sandstones including the Nugget Sandstone have yielded similar zircon age populations. The Lower Jurassic Nugget Sandstone of northern Utah is quartz-rich eolian sandstone equivalent in age to the Glen Canyon Group farther south. The sample was collected near Thistle, Utah from the upper Nugget Sandstone, a white eolian sandstone with massive cross-bedding that overlies redbeds and underlies the Twin Creek Limestone. U-Pb ages were determined for 100 individual detrital zircon grains using a LA-MC-ICPMS (Laser-Ablation Multi-Collector Inductively Coupled Plasma Mass Spectrometer) with a beam diameter of 35 microns. Analyses that were >20% discordant or had >10% uncertainty were removed from consideration. An age-probability plot of the remainder (n=85) displays the following age populations: 240-540 Ma (Paleozoic), n=21; 580-780 Ma (Pan-African), n=12; 860-1260 Ma with a peak near 1080 Ma (Grenvillean), n=29; 1300-1520 Ma (Mesoproterozoic), n=6; 1560-1860 (late Paleoproterozoic), n=10; >1860 Ma (early Paleoproterozoic and Archean), n=7). The main provenance of the Nugget Sandstone is interpreted to have been the Appalachian orogen. Nearly three-quarters of the zircons plotted fall within three age populations (Paleozoic, Pan-African, Grenville) derived from bedrock of ages known to be widespread within or bordering the Appalachian orogen but rare or absent elsewhere in North America. This inference coincides with previously published conclusions regarding the provenance of Permian and Jurassic eolian sandstones on the Colorado Plateau. The age probability plot for the Nugget Sandstone is closely analogous to plots for the Wingate Sandstone and Navajo Sandstone of the Glen Canyon Group at North Wash in southern Utah. Paucity of Mesoproterozoic and late Proterozoic grains (n=16 combined) indicates that Precambrian sources within the Yavapai-Mazatzal age belt of the nearby

Ancestral Rocky Mountains province contributed only minor detritus to the Nugget Sandstone.

Detrital zircons in the Garta member of the Chinle Formation in northern Utah: Implications for upper Triassic paleodrainage patterns

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Detrital zircons were separated from a sample of conglomeratic fluvial sandstone collected near the base of the Gartra Member of the Chinle Formation near Vernal in northeastern Utah. U-Pb ages were determined for 95 individual zircon grains using laser ablation ICPMS with a beam diameter of 50 microns. Analyses of five grains were rejected due to >20% age discordance, leaving 90 grains that yielded reliable results. There are three main age populations of zircon grains in the Gartra sample: 480-580 Ma, 1320-1480 Ma, and 1600-1780 Ma. Subordinate numbers of grains are present in the age ranges of <480 Ma (n=3, Paleozoic), 620-760 (n=2, Pan-African), 880-1220 Ma (n=13, Grenville), and >1780 Ma (n=8, Paleoproterozoic and Archean). Approximately 40% of all the grains (n=36) lie within the 480-580 Ma age range, and half of that group have ages of approximately 520 Ma (Early Cambrian). The two other main age groups, with frequency peaks at 1433 Ma and 1715 Ma and making up approximately a third (n=29) of the total grain population, could have been derived from Precambrian rocks forming the cores of uplifts within the Ancestral Rocky Mountains to the southeast in Colorado, and Gartra paleocurrents imply derivation of detritus from the southeast. The prominent Cambrian zircon grains (~520 Ma) suggest derivation, however, from the Amarillo-Wichita uplift lying 750-1000 km southeast of the collecting locality. Their presence in the Gartra Member implies that a paleodrainage system with headwaters in the Amarillo-Wichita uplift passed through the Ancestral Rocky Mountains province to exit as the Eagle paleoriver responsible for deposition of the Gartra Member. Alternately, the Cambrian zircons could perhaps have been recycled from Paleozoic strata of the central Colorado trough that might have been derived in part from the Amarillo-Wichita uplift. In that case, the inferred Late Triassic transport distance would be reduced.

Deposition of playa windblown dust over geologic time scales

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Desert pavements are characteristic features of low elevation, long undisturbed arid environments with a steady supply of windblown dust. The characteristic interlocking monolayer of pebble-sized and larger clasts overlies a matrix of fine grained eolian silt derived from the deposition of airborne particles over time. Characteristically, the thickness of the silty A horizon has been used as an indicator of pavement age. It has also been suggested that pavements located in proximity to a large dust source may exhibit more rapid A horizon development due to the locally higher eolian silt concentration. In this study we test this theory by measuring the thickness of the A

horizon in pavements of various age and distance from a major dust source, Franklin Lake Playa in the Mojave Desert. To better understand the physical processes controlling deposition, field observations were then compared with a numerical model designed to describe the spatial distribution of windblown deposits through geologic time. Modeled zones of high eolian deposition correspond with observed areas of higher A horizon thickness. Measurements of silt-dominated A horizons demonstrate a significant increase in thickness near the playa and a relatively rapid decrease to a uniform regional "background" thickness farther from the source. Additionally, the youngest pavements exhibit very thin A horizons regardless of distance from the playa while the oldest pavements observed demonstrate a decrease in A horizon thickness that deviates from the expected trend of increasing thickness with age. These observations suggest there is a minimum time or threshold that must be reached in order for significant silt thickness to develop even in areas of high windblown silt concentration. We also suggest the high degree of hillslope diffusion and pavement degradation observed in the oldest surfaces results in a deflation of an otherwise thick A horizon.

Orientation in Raman Spectroscopy

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Polarized Raman spectroscopy on oriented samples records the vibrations of chemical bonds into a spectrum that can be related to the crystal structure. Because of the difficulty in measuring Raman in precise orientations there have only been a few attempts to study this relationship. The goal of our study is to take an unknown, unoriented sample, identify it and determine its orientation with one spectrum analysis. This is of particular importance in the Martian environment where rock forming mechanisms and textures can be inferred from the Raman data, without the need to return any mineral samples. In the general procedures of this experiment, an oriented crystal is mounted on a pin, polished, and placed onto the rotational spectrometer stage which allows precise rotation around the axis of the laser. We then take spectrum shots from 0º to 90º, rotating 10º between each shot. The procedure is then repeated along all appropriate crystallographic axes.

We examined the Raman spectra of beryl, which has hexagonal symmetry. When collecting data down the c-axis, regardless of polarization, the same Raman spectrum was obtained, consistent with hexagonal crystal structural. Next, spectra were collected with the polarized laser pointed down the a, a*, and b axes. The results were again identical with each other, consistent again with hexagonal symmetry. However, when the laser is oriented along the a axis and the polarization is changed from c to the a-b plane, complex variations in peak intensities are observed. These variations will be analyzed to understand their systematics. These observations are assumed to hold for all hexagonal minerals, and hopefully run congruent with symmetrical assumptions about other crystal structures. Other analysis will be performed to determine the correlation of orientation effect with respect to crystallographic structure and symmetry.

Program impact on collaboration for advancing teaching technology and science (CATTS) fellows

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The University of Arizona's Collaboration for the Advancement of Teaching Technology and Science (CATTS) was formed 4 years ago for the purpose of teaming university graduate and undergraduate science students with local K-12 teachers to enhance science teaching at all grade levels. This NSF-funded GK-12 program has been remarkably successful at training university students to use exemplary science education materials and to enable them to work within the culture of K-12 classrooms.

CATTS provides immediate and lasting impacts on the students who participate in the program. This poster 1) highlights the immediate impacts of a CATTS fellowship on participants, and 2) presents data from exit and post-program interviews of CATTS Fellows of lasting impacts. The interviews suggest that students who participated in the CATTS program are more likely to consider a career in science related K-12 education or public outreach (32% of respondents listed this as the primary lasting impact), are helped considerably in their hunt for jobs after completing a CATTS Fellowship (21%) and have improved their teaching ability over the year (21%). Other lasting impacts include personal growth and improved success in obtaining scholarships and grants.

Detrital zircons in upper Triassic strata of the upper Chinle and Dockum groups, New Mexico and Texas

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Detrital zircons were sampled from Upper Triassic fluvial sandstones in the Trujillo Formation of the upper Chinle Group in northeast New Mexico and the Trujillo and Cooper Canyon Formations of the upper Dockum Group in northwest Texas. The Trujillo and Cooper Canyon Formations of the Dockum Group were collected in the headwaters of the Red and Brazos Rivers near the eastern escarpment of the Llano Estacado, and the Trujillo Formation of the Chinle Group was collected west of Conchas Reservoir near Tucumcari. From the three samples, U-Pb ages of 276 detrital zircon grains were determined by laser ablation ICPMS using a beam diameter of 35 microns. Analytical data were filtered to exclude zircon grains with >20% age discordance or poor precision, leaving 244 reliably dated grains. The zircon grains range dominantly from 200 Ma to 2000 Ma in age, with a few Archean grains present in the Trujillo samples. Northwest-directed paleocurrent trends in the upper Dockum Group of west Texas imply a provenance lying to the southeast, and a prominent age spike of 220-280 Ma in all three samples probably reflects derivation of detritus from granitic rocks of the Permian-Triassic magmatic arc in eastern Mexico. Older grains in the age range of 380-700 Ma represent Paleozoic and Pan-African detritus possibly derived from reworking of

Appalachian-derived detritus in strata exposed within the Marathon segment of the Ouachita orogenic belt in southwest Texas and adjacent Mexico or from the unexposed core zone of the Ouachita orogen. A prominent age spike of mid-Paleozoic grains (~400 Ma) in the Cooper Canyon Formation, which is younger than the Trujillo Formation, probably signifies erosional unroofing of the core of the Ouachita system over time. Nearly a third of the detrital zircons in each of the three samples were derived ultimately from bedrock sources of Grenvillian age (900-1250 Ma) along the flank of the Appalachian-Ouachita orogen or in eastern Mexico, but were possibly reworked from Ouachita sedimentary assemblages. The Dockum Trujillo sample also displays a prominent mid-Proterozoic age spike (1250-1500 Ma) suggesting ultimate derivation from anorogenic granite of southwestern Laurentia, with or without recycling through Paleozoic strata.

Stable isotope analysis of ostracode valves: A record of climate change in the Bonneville Basin, Great Salt Lake, Utah

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A continuous 120m drill core from the Great Salt Lake (GSL) of Utah in August 2000, provides an important regional paleoclimate archive covering the last ~250ka. Initial paleoclimate and paleoecological studies, performed at ~2ka resolution on core GSL00-4, showed hydrologic fluctuations in the Bonneville Basin between three states: shallow saline/hypersaline lake, saline/freshwater marsh, and deep freshwater lake (Balch et al., 2003 and submitted). U-series and tephra correlations established by Dean et al (2002), combined with biostratigraphic and C-14 data (Balch et al, submitted) permit correlations between lake level and the marine oxygen isotope record. Delta O-18 and delta C-13 results presented here, obtained from bulked samples of the ostracode *Limnocythere staplini*, and brine shrimp fecal pellets provide further evidence of the magnitude and abrupt nature of hydrological changes in precipitation/evaporation ratios of the GSL region. Major isotopic excursions of up to 12 per mil delta O-18 occur between 250-2ka, reflecting alternations between long residence time saline lakes and short residence time freshwater marshes. In contrast, relative Holocene isotopic stability (about 2 per mil O-18 variation) suggests relatively uniform hydrologic conditions.

Magnetism and hydrothermal alteration of the Copiapo Batholith, northern Chile

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The Copiapo batholith (110-120 Ma) is associated with Candelaria and other Fe-oxide[-Cu-Au] deposits. Our unpublished mapping reveals a complex story of multiple, superimposed igneous and hydrothermal episodes, from which we are developing an extensive digital compilation of rock types and hydrothermal alteration. This compilation

allows correlation and analysis of regional magnetic data (courtesy of Phelps Dodge) with field data on magnetite abundance and alteration types and with our newly measured magnetic susceptibilities. A better understanding of the relationship between aeromagnetic patterns and the mapped geology aids mineral exploration and understanding the evolution of the Chilean coastal batholith.

The regional magnetic signature of the batholith varies greatly and lacks a simple correlation with rock type. To understand these complex magnetic patterns, we are making new susceptibility measurements on well characterized hand samples. Susceptibility changes systematically with alteration type over several orders of magnitude. Variation in the magnetic signature results from: (1) differences in the primary igneous magnetite contents, (2) destruction of original magnetite by oxidation to hematite, sulfidation to pyrite, or removal by leaching; and (3) addition of magnetite by iron metasomatism and magnetite precipitation, by creation of new magnetite by oxidation of other iron-bearing silicates or by reduction of earlier hematite.

We find that patterns in magnetism (highs and lows) are broadly consistent with the mapped 2-D distribution of rock types after taking into account alteration type and abundance. In detail, a better 3-D understanding can be achieved only by combining geophysical data and geological constraints on magnetite abundance and hydrothermal alteration. Moreover, superposition of events thoroughly complicates any interpretation of the origin of magnetic patterns. Incorporating the time element (i.e., 4-D), therefore, is key to unraveling the origin of this complex system and, hence, the controls on Cu-Au mineralization. The ultimate story will be anything but simple.

Comparison of detrital zircons in the fluvial Kayenta Formation (lower Jurassic) of southern Utah with detrital zircons from underlying and overlying eolian strata

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Detrital zircon grains for this study were collected from the Kayenta Formation of the Glen Canyon Group in North Wash southeast of Hanksville (Utah) on the Colorado Plateau. U-Pb ages for 100 detrital zircon grains were determined individually by LA-ICPMS using a beam diameter of 50 microns. Due to >20% discordance or poor precision, 7 grains were removed from consideration, leaving 93 reliable analyses. The majority of the zircons fall into three main age populations: 240-300 Ma (12%), 400-540 Ma (12%), and 1020-1340 Ma (32%), with specific frequency peaks at 259 Ma, 447 Ma, and 1082 Ma. The remaining zircons fall primarily into four subordinate age clusters: 780-960 Ma, 1380-1460 Ma, 1580-1720 Ma, and 2640-2720 Ma. The age distributions and frequency peaks of most detrital zircons in the Kayenta Formation closely resemble those in eolianites of the underlying Wingate Sandstone and the overlying Navajo Sandstone within the Glen Canyon Group. Reworking of eolian sand into the Kayenta fluvial system was the likely source of these zircon grains. The zircon age spike in the 240-300 Ma range, present in the Kayenta Formation but absent from both the Wingate and Navajo sandstones, suggests a Kayenta provenance partly in the Permian-Triassic East Mexico arc to the southeast. Paleocurrent directions in the Kayenta Formation of

southern Utah indicate primary flow from the east but subordinate flow from the southeast as well. The Kayenta sample contains less quartz (74%) than either the Wingate or Navajo (82% and 85% respectively), and more lithic fragments (9%) than either Wingate or Navajo samples (4% in each case). The petrographic difference suggests a contribution of less quartzose and more lithic sand to the Kayenta fluvial system from 240-300 Ma source rocks that did not contribute to underlying and overlying eolian systems. Eolian reworking of fluvial sand could increase quartz content and reduce lithic content, but could not eliminate 240-300 Ma zircon grains which are absent from Wingate and Navajo eolianites.

In-situ clinopyroxene Sr isotopic analyses by LA-ICPMS; A test of mantle melting processes in the Big Pine volcanic field, California.

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Mantle melting processes can be directly studied from xenoliths brought to the surface by well exposed basaltic lava flows in the Papoose Canyon of the Big Pine Volcanic Field, CA. High concentrations of MgO(~10 wt. %), as well as Sr and Nd isotopic ratios of Papoose Canyon basalts suggest that no crystal fractionation or crustal assimilation occurred to alter the Papoose primary magmas. However, trace elements and radiogenic isotopes demonstrate unambiguously that two distinct mantle melt sources and their mixtures are responsible for the compositional diversity in the Papoose Canyon flows. The two end member sources are compositionally peridotite and pyroxenite. There are two physical mechanisms that can lead to the observed chemical compositions in the lavas: (1) melt mixing between peridotite-derived melt and pyroxenite-derived melt and (2) solid melt interaction in which pyroxenite melts are modified chemically by interactions with a peridotite solid matrix; it is also possible, although less likely, that peridotite-derived melt interacted with a solid pyroxenite.

Big Pine lava flows contain peridotitic and pyroxenitic xenoliths that are proxies for the end-member source rocks for melting. Chromatographic models involving a pyroxenite melt percolating though a peridotite matrix predict that the solid develops a disequilibrium trace element and isotopic profile within the clinopyroxene, whereas melt mixing typically does not. The problem is that isotopic heterogeneities develop on a scale of hundreds of microns at most and cannot be resolved through conventional isotopic (TIMS) analyses. In order to test between these models, we will use Sr isotopes as a tracer, and apply a technique of measuring spatially controlled domains within clinopyroxene crystals: laser ablation multicollector ICP-MS. Preliminary experiments in the ISOPROBE laboratory at the University of Arizona demonstrate the feasibility of measuring Sr isotopes on low-Rb phases (calcite, plagioclase, clinopyroxene) down to spot sizes of 50 microns. Sections from six xenoliths were cut to 100 micron thickness and examined using laser ablation MC-ICP-MS.

Geochemical and isotopic characteristics of Mesozoic granitoid magmatism in the middle and lower Yangtze River Valley, China

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Yanshanian (160-100 Ma) granitoid magmatism of the middle and lower Yangtze River valley in east-central China is associated with more than 200 polymetallic (Cu, Fe, Au, Mo, Ag, W, Zn, Pb) deposits, forming one of the most important metallogenic belts in China. Patterns in magmatism and mineralization have been recognized and emphasized since the 1950s by Chinese geologists. This study synthesizes the published geological and geochemical characteristics and investigates the controls on Yanshanian magmatism and igneous-related metallogeny eventually leading to a comparison to other convergent margins in the circum-Pacific.

Yanshanian intrusions vary from gabbro to granite, but mainly are quartz monzodiorite, granodiorite, and granite. The ore deposits are contemporaneous with magmatism and their type correlates closely with igneous compositions. Copper ore deposits are primarily related to calc-alkaline complexes of early Yanshanian in the west; iron ore deposits are predominantly related to subalkaline-alkaline intrusions of late Yanshanian in the east. The SiO_2 content ranges from 45 to 77 wt %, principally between 52 and 72 wt %. The complexes are predominantly metaluminous with lesser weakly peraluminous. The complexes are alkaline to subalkaline and medium to high K. The Yanshanian intrusions have consistent and similar REE patterns: 1) high ΣREE (78-382 ppm); 2) enriched LREE ($(La/Yb)_N$ 2-49, mainly 15-40); and 3) minor Eu anomalies from 0.7 to 1.2. The Yanshanian intrusions have initial $^{87}Sr/^{86}Sr$ of predominantly 0.705 to 0.709, and □Nd of -6.5 to -16.3. These geochemical features imply that Mesozoic granitoids of the middle and lower Yangtze River valley came from a mixture of upper mantle and crustal sources. The differences between types of ore deposits may be due to differences in magmatic fluid compositions, as well as the nature and abundance of external fluids.

Bottoms up! A rare view of the roots (~10 km paleodepth) of a productive Laramide porphyry copper system exposed in the Globe-Miami district, Arizona

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Several porphyry copper deposits and prospects occur in and around the Schultze Granite, a composite, felsic Laramide pluton that crops out over ~50 km^2 in the Globe-Miami-Superior region. New interpretations of the middle Tertiary extensional structure in the area indicate many of the deposits and prospects (n>25) are dismembered and tilted portions of perhaps as few as four, large, magmatic-hydrothermal systems. The dismemberment has telescoped the rocks in the vertical sense such that many crustal levels of the systems have been exposed across the present-day land surface. Our new

mapping (1:200), combined with a new structural interpretation (Maher, this volume), provides insights into the deepest levels of known, productive systems.

Several piercing points establish displacements of faults across the Globe-Miami district. We recognize one area, exposed along Pinto Creek in the west-central portion of the district, to be the deep levels or "roots" of the well-mineralized Miami-Inspiration porphyry copper system. Hornblende geobarometry on a nearby sample yielded a paleodepth of 10 km. Within the center of the hydrothermal system, the deep levels contrast with the shallower levels. We observe dominantly phaneritic rocks rather than porphyries; alternating ductile and brittle deformation rather than mainly brittle deformation; variable vein and dike orientation rather than consistently oriented, sheeted veins; alteration dominated by K-feldspar and muscovite rather than biotite and sericite; and sparse rather than abundant sulfides.

The alternating ductile and brittle character exhibited by the dikes and veins at deep levels may reflect transient changes in the evolving magma chamber and correlate with episodic hydrothermal fluid release and/or introduction of new magma. Ultimately, these deep-level rocks potentially allow us to understand magma chamber dynamics, to recognize faults that were active during Laramide arc magmatism, and to explore paleo-upwards in the crust for economic mineralization in these structurally complicated regions.

Preliminary results of the mineralogical analysis of the Obi Rakhmat Grotto and Paltau Cave Sediments, Uzbekistan.

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Obi Rakhmat Grotto is a Pleistocene rockshelter located in the Western Tien Shan mountains of Central Asia. Paltau Cave is a nearby active karst system that contains artifacts tentatively dated to the late Pleistocene through mid-Holocene. Both contain thick stratigraphic sequences rich in cultural materials and human remains. A geochemical study was undertaken in 2003 and 2004 to determine the preservation potential for hominid remains at Obi Rakhmat. Fourier transform infrared analysis of sediment samples reveals that the Obi Rakhmat sequence maintains a favorable environment for bone preservation, while the lower Paltau Cave sequence does not. The Obi Rakhmat sediments are composed of clays and carbonates with local concentrations of stable apatite. The Paltau sediments contain, among other minerals, authigenic taranakite, which is indicative of the diagenesis of clays, carbonates and sometimes bone in the presence of phosphate-rich groundwater.

RRUFF Project: Raman Spectroscopy Database

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Raman spectroscopy was first discovered in 1928 when Sir C.V. Raman wrote: "When a beam of monochromatic light is scattered by a transparent liquid, the scattered light contains frequency of very low intensity not present in the incident radiation." Although Raman's work was recognized for its direct application to the quantum theory of light, its usefulness as an identification tool was not realized until a suitable monochromatic light source (laser) was developed.

Since the advent of lasers, Raman spectroscopy has been used extensively, but due to cost of equipment, the technology has been restricted to the research lab environment. Seeing the potential of Raman as a versatile identification tool, Downs and Denton were funded by NASA to develop a miniature Raman device for the 2009 Mars rover. It was recognized that the miniaturization of the Raman spectrometer would make it suitable as a handheld device for use in identifying phases for homeland security, drug enforcement, gemstone identification etc.

To support this device, the RRUFF project is assembling and maintaining an online database for search/match processing of data. In accordance with our private sponsor, the database will be established as a free service to the public. Each sample is screened for quality Raman spectra, sufficient for inclusion in the database. Samples are then run though a gambit of experiments including: X-ray powder diffraction (confirm identity), single crystal X-ray diffraction (orientation, and full crystal structure to elucidate cation site occupancies), electron microprobe analysis (determine chemistry), and Raman spectroscopy on oriented crystals. Details for each sample including locality and photographs are posted with experimental data, all available to download.

The goal of the project is to have data for every known mineral species, and an automated search/match engine to identify an unknown sample so minerals can be identified in about 10 seconds.

Using Raman Spectroscopy to characterize gemstones

Vera Sanderlin

Gemstones can be identified, authenticated, and their location of origin may be determined by Raman spectroscopy. With so many variations it is difficult to ascertain identification and establishment of authenticity of gems simply with visual techniques. In modern gemology there are increasingly more 'treatments' that are being used on stones and minerals to falsify, create, and enhance gem color to make them appear more valuable. Most purchasers of jewelry are not educated in gemology or mineralogy concepts and therefore not aware of the visual methods for detecting non-authentic stones and are susceptible to being sold synthetic or artificially enhanced gemstones under false pretenses by a vendor. Some enhancements done to gems are not always visible to a

certified gemologist either. This is where further scientific methods of gemstone identification can be useful. Raman spectroscopy may be used to identify and verify the authenticity of a natural versus a synthetically created stone.

In some gems the data generated from the spectrum can direct you to a regional provenance. These gemstones are uniquely identified by a display of variation in Raman spectrum peaks that can be a 'signature' for a specific locality. For example, the location of an emerald can be determined by looking at the spectra of deuterated water vibrational peaks. Unfortunately the origin of a diamond can not be determined by these spectral variations. To date there has been no successful method of determining location for the origin of diamonds.

The general technique of Raman spectroscopy applicable to gemstones is presented. Various spectra are used to demonstrate the technique of identifying gems. Support for synthetic versus natural gemstones is presented to demonstrate the technique applied to authenticity. Examples for the ability of Raman spectroscopy to aide in the differentiation, however slight, of spectra to determine origin of location in some stones is also exhibited to establish the use of Raman spectroscopy for the characterization of gemstones.

Detrital zircons in northern Arizona of the fluvial Kayenta Formation (lower Jurassic) on the Colorado Plateau

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Detrital zircon grains (n=100) per sample of the Kayenta Formation (Lower Jurassic) were collected in the southern section at Moenkopi Wash just outside of Tuba City in northern Arizona, eastern outcrops near the Delores River in Western Colorado, where paleocurrent indicators record flow from the northeast, and at North Wash in southern Utah. Paleocurrent indicators contained in the Moenkopi and North Wash samples suggest a flow from the southeast. Detrital zircon grains were analyzed individually by LA-ICPMS using a beam diameter of 50 microns. Four grains from Moenkopi, ten from Delores River, and seven from North Wash were removed from consideration due to >20% discordance or poor precision, leaving 96, 90, and 93 reliable analyses respectively. The ages gathered suggest varied detrital zircon populations include prominent clusters of Permian-Triassic grains (4%-7% with frequency peaks at 240-260Ma), Paleozoic and Neoprotrozoic grains (16%-23% in the range of 340-680 Ma), and Grenville derived grains (38%-58% in the range of 880-1340 Ma). Subordinate clusters include middle Proterozoic (5%-8% at 1360-1480 Ma), early Proterozoic (6%-12% at 1580-1920 Ma), and Archaean (2%-4% at 2700-2900 Ma) grains. Distant transport or recycling is indicated for most of the grain populations, with Paleozoic-Grenville grains, probably derived from the Appalachian-Ouachita orogen, and Permian-Triassic grains possibly derived from the east Mexico arc. Only 10%-20% of the detrital zircon grains could have been derived from the Yavapi-Mazatzal basement belt of southwest Laurentia.

Oriented crystal studies: Orienting crystals

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Raman spectroscopic and X-ray diffraction studies have been performed since the early1900's. These techniques have redefined the way the scientific community looks at crystal structures. It is now possible to perform oriented Raman spectroscopic studies by orienting crystals on a machine that has been dubbed "The Orienter". The process for orienting crystals is fairly straight forward. A crystal as large as 50 mm is mounted on a goniometer head and placed in our Bruker X8 Single-Crystal Diffractometer. Several scans are taken in a wide range of orientations, and the locations of diffraction spots are recorded. The spots are indexed andtheir locations determined. An orientation matrix is then constructed that transforms crystallographic indicies to laboratory Cartesian space. The matrix is then exported into a data file. The crystal is then placed on The Orienter and the matrix is loaded into a special computer program that computes the motor steps needed to drive the crystal so that a given crystallographic vector is aligned to the pin, and another crystallographic vector is aligned perpendicular to the flat. When the motors have been driven to their respective places, the pin is then aligned in a unique way with the crystal. The pin is slowly pushed up towards the crystal until it barely makes contact. Once in contact, optical adhesive is applied and set with a UV light. The oriented crystals are then analyzed with the Raman spectrometer to record the vibrational spectrum. After careful analysis of the oriented spectra, it is possible to compute all thermodynamic properties, or even seismic properties of a mineral.

Alkali metasomatism in the southern part of the Pima Mining District: Field relationships and alteration assemblages

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The southern part of the Pima Mining district contains an obliquely south-tilted crustal section (see Stavast, this volume) containing multiple granodioritic intrusions that span ~60 Ma to ~74 Ma. These intrusions generated potassic, sodic-calcic, chloritic, and sericitic alteration and, in the southern and structurally shallower part of the area, they created the Sierrita-Esperanza porphyry copper deposit. This work builds on earlier studies around Sierrita-Esperanza (Aiken and West, 1982; Titley *et al.*, 1986), investigating the alteration of the structurally deeper part of the system and its relationship to the igneous evolution.

Alteration within the area studied mainly falls into two broad categories: sodic(calcic) and potassium silicate, with minor sericitic alteration. The sodic(calcic) alteration is characterized by the alteration of igneous feldspars to plagioclase or epidote and the formation of sphene, actinolite, and chlorite in the place of original mafic minerals. Elongate domains (e.g., 10s X 100s m) of sodic-(calcic) alteration zone outward from mafic-destructive, plagioclase-rich cores with actinolite veinlets to margins with

epidote±actinolite±chlorite veins. Sodium and calcium are added and iron and potassium are removed as demonstrated by the mineralogical changes and by whole rock analyses. The potassium silicate alteration is characterized by plagioclase altering to alkali feldspars and the mafics becoming biotitized. In contrast to the swaths of sodic-(calcic) alteration, potassium silicate alteration occurs as 1- to 10-mm wide envelopes on quartz and magnetite veinlets.

Sodic-(calcic) alteration is most abundant on the eastern and structurally deeper parts of the system, whereas potassium silicate alteration is best developed in the south-central part of the intrusive complex and extending southward into the Sierrita-Esperanza deposit. Crosscutting relationships among veinlets, alteration zones, and intrusions demonstrate at least two cycles of potassium silicate and sodic-(calcic) alteration. In a companion abstract (Flesch et al., this volume), we consider the significance and alternative origins of these results.

Coupled basin evolution and metamorphic core complex exhumation in the southern Basin and Range Province, southeastern Arizona

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Records of lithospheric extension and mountain-range uplift are most continuously contained within syntectonic sedimentary rocks in basins next to large structural culminations. Adjacent to the Santa Catalina-Rincon metamorphic core complex, stratigraphic-sequence geometries evident in seismic reflection data within the Tucson Basin suggest a two-phase basin-evolution coupled to core-complex emplacement and uplift. Early extensional deformation took place along the low-angle Catalina detachment between 28-20 Ma. This extension involved rapid denudation of the footwall, bringing mid-crustal material to a level at or near the surface. Mini-basins developed adjacent to the core complex by brittle high-angle faulting in the hanging wall of the detachment system. These mini-basins record syntectonic deposition and served as catchments for footwall-derived volcanic and pre-mid Tertiary sedimentary units, with no sediment input from the adjacent core complex. Late-stage uplift of the Catalina core complex occurred during mid-Miocene to Pliocene Basin and Range extension. Forming simultaneously to core complex uplift, the main Tucson Basin began to subside symmetrically, filling the evolving basin largely with mylonitic granites. We examine several models that support the hypothesis that late-stage core complex uplift occurred as the result of flexural uplift of the footwall in response to high-angle normal faults that formed around the flanks of the dome. Additionally, we propose basin subsidence was coupled to Catalina core complex uplift through the transport of mid or lower crustal material from beneath the Tucson Basin towards the uplifting dome.

Strain partitioning and vertical-axis rotation across the Santa Rita fault zone in response to Cenozoic metamorphic core complex emplacement, Southeastern Arizona

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Recent reprocessing and interpretation of industry seismic reflection data collected in the 1970's around southern Arizona have illuminated subsurface features related to Cenozoic crustal extension. Within the northern Tucson Basin, the Catalina detachment fault dips at 23-35 degrees to the southwest off of the western flank of the Catalina-Rincon Metamorphic Core Complex. In the southern portion of the basin, the Santa Rita normal fault dips 15-20 degrees to northwest from the western flank of the Santa Rita Mountains and is cut by the Catalina detachment beneath the central Tucson Basin. The orientation of the Santa Rita fault is problematical, in that it is oriented nearly perpendicular to extension directions in the region. Of importance, however, is the Santa Rita fault's location in an area that borders zones of differing amounts of crustal extension, with a zone to the north of extreme crustal extension on the order of 100% or more across the Catalina / Rincon metamorphic core complex, and the area to the immediate south that has experienced moderate crustal extension of perhaps 30%. One possible explanation for the Santa Rita fault could be mountain-range-scale block rotations transferring strain between these extensional domains. Preliminary finite element modeling supports this hypothesis, with maximum principle stresses oriented favorably for oblique extension across the Santa Rita fault. This is supported by field observations of kinematic indicators, on a presumed surface exposure of the Santa Rita fault, that show orientations nearly parallel to those predicted through modeling. Additionally, paleomagnetic data in the Cienega gap area suggests counterclockwise rotation of units about a vertical axis, again consistent with modeled results, although more paleomagnetic data are necessary to confirm this rigorously.

Session III Abstracts

Uranium-series dating and Middle Paleolithic hominid occupation in Central Asia

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Although Central Asia was a "corridor" connecting hominid populations of northern and western Asia during the Paleolithic, sites in the region have added little to discussions of late Pleistocene hominid behavior and migrations. A major contributing factor to this silence has been the near absence of reliable chronological data, especially radiometric dates. Addressing this issue has been a principal objective of the joint Russian-Uzbek-American archaeological project at Obi-Rakhmat, a rockshelter in the Tien Shan Mountains, northeastern Uzbekistan. Having yielded an abundant, blade-rich Middle Paleolithic industry, faunal remains and several teeth and cranial fragments provisionally attributed to *Homo sapiens*, this deeply stratified site is uniquely suited to play a critical role in establishing the chronology of regional hominid occupation. AMS radiocarbon dates on charcoal mostly exceed 40,000 years old and should be regarded as minimal age estimates. U-series dates on travertines interbedded with Obi-Rakhmat cultural horizons can provide an independent chronometer extending back ~350,000 years. However, these travertines contain a large amount of silicate detritus and likely "hydrogenous" thorium which must be accounted for to obtain an accurate age. We used a trio of techniques to address this problem. First, we attempted to select material with as little apparent detrital material as possible and physically removed it by selective dissolution of the carbonate. Second, isochrons were constructed from multiple leachates from one horizon in an attempt to characterize the initial $^{230}Th/^{232}Th$, which can be used to correct single sample ages. Finally, to confirm ages obtained using this correction, they were compared with an age obtained from an isochron of a series of total sample dissolutions from one horizon. Applying reasonable corrections indicates that the cultural deposits are between 70,000 and 100,000 years old. This result, supported by very preliminary ESR (electron spin resonance) results on ungulate teeth, supports an older chronology for the Middle Paleolithic cultural sequence in Central Asia.

Atmospheric Circulation and Paleohydrology Change in Late Miocene and Pliocene as Recorded in the Linxia Basin, Northeast Tibetan Plateau

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While a large body of literature exists on the Red Clay/Loess sequence (8Ma – present) in China, few sedimentary records extend back into the middle Miocene. The well-dated record of the Linxia basin, northeast corner of the Tibetan Plateau, is therefore particularly valuable for studies of both Plateau uplift and Asian monsoon history. The Linxia Basin is a flexural foreland basin at the northeastern margin of the Tibetan Plateau. This study focuses on the sedimentology and geochemistry of the interval between 13.1 and 4.4 Ma, showing that the depositional environment evolved from deltaic to lacustrine to fluvial. After 6.0 Ma, eolian sediments accumulated in the floodplain in the basin center while the proximal region remained lacustrine.

Grain size profiles and neodymium isotope data suggest that loess is deposited in the basin throughout this time interval, and we recognized two eolian input components in the Linxia Basin. Modern analogues suggest these two components are controlled by the westerlies and winter monsoon wind intensity. The long-term balance of these two eolian components suggest that 13.1 to 8.0 Ma is characterized by a gradual increase in the westerlies with little change in the intensity of the winter monsoon; from 8.0 to 4.3 Ma the westerlies weaken and the winter monsoon intensifies.

Carbonate $d^{18}O$ and mineralogy have been affected by meteoric water $d^{18}O$, lacustrine evaporation, and early diagenesis and show strong cycles in water balance of the lake system up to 8.0 Ma, culminating in strong aridity at 8.0 Ma. Organic carbon $d^{13}C$ indicates a lack of C4 plants in the lake catchment or eolian source region before 4.4 Ma. The changes at 8 Ma suggest a significant Plateau uplift event at that time, although the pattern is not a modern one between 8 and 4.4 Ma. This may indicate significant plateau development occurred after 4.4 Ma

Strontium isotopic analysis and petrographic Study of a Nepali paleosol sequence: quantification of silicate weathering

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Many studies link uplift and subsequent weathering of the Himalayas to changes in the $^{87}Sr/^{86}Sr$ ratio of the oceans during the Neogene. Researchers generally invoke silicate mineral weathering to explain the high $^{87}Sr/^{86}Sr$ ratios of Himalayan rivers and global CO_2 drawdown during the Cenozoic. Other, more recent research, suggests that carbonate, not silicate, weathering dominates the $^{87}Sr/^{86}Sr$ ratio of Himalayan rivers, and that the high fluxes of organic matter to the Bengal Fan accounts for part of the Cenozoic

CO_2 drawdown. Examination of weathering processes in carbonate-free drainages and geochemistry of marine fan sediments has lead to a better understanding of Himalayan silicate weathering flux. However, the Himalayan system where the maximum amount of silicate weathering is occurring (floodplains) has yet to be quantified. In this study, we use buried paleosols in the Siwalik Group to quantify mass losses of major and minor elements, including Sr, due to Himalayan weathering during the Neogene. These paleosol archives allow us to estimate the relative contribution of silicate weathering (and hence CO_2 drawdown) in the Himalayan foreland.

The search for a silver lining: Using Pb-isotopes to constrain the source of archaeological ores at La Isabela

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Established in January 1494 by Christopher Columbus, La Isabela was the first European settlement in the New World. The settlement was situated on the northern coast of the present day Dominican Republic and the archaeological remains of the town constitute an independent source of information about Columbus' second voyage to the Americas. This study looks at the circumstances under which silver-bearing lead ore (galena) was smelted and refined at La Isabela, an activity not described in written accounts of the voyage. Approximately 100 kilograms of pure galena and 200 kilograms of lead silicate glass were recovered from the remains of a crude furnace constructed at the site. Metallurgical evidence implies that galena was smelted to produce lead metal, which was subsequently refined to extract silver within it. The lead silicate glass found at the site is a waste product of this refining procedure. This study uses Pb isotope ratios to determine the original source of the ore. Because the isotopic signature of Pb varies between potential source areas, the measurement of Pb isotope ratios constrains possible sources of the galena. The isotopic composition of lead in 12 galena samples and two lead silicate glass samples was measured by MC-ICP-MS. The results suggest that the galena was derived from a single region. Originally conceived as a way to identify locations where Columbus and his fleet prospected for silver in the Caribbean, this study instead concludes that pure galena was transported to La Isabela from Spain.

The Evolution of Scientist-Teacher Partnerships: A Case Study Investigation

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Partnerships between scientists and teachers bring individuals from different work environment cultures together to share information, make mutual decisions, achieve common goals, and contribute resources and skills (Gomez et al., 1990.) Because of differences between the cultures of science and teaching, building productive, durable partnerships is typically difficult.

CATTS (Collaboration to Advance Teaching Technology and Science) is an NSF GK-12 fellowship program that establishes partnerships between graduate and undergraduate CATTS fellows and K-12 teachers. Ideally, these sustainable relationships will increase each partner's knowledge and skill in inquiry-based teaching, the quality and quantity of math and science taught, and the likelihood of initiating future partnerships. We used a case study approach to investigate the dynamics of partnership development in the context of CATTS and why some partnerships evolve successfully and others do not. Data were obtained using classroom observations, journals, surveys, and interviews with fellows and teachers.

We found commonalities among case studies that allowed us to identify patterns in partnership evolution, attributes of successful and unsuccessful partnerships, and barriers to their formation. Specific shared goals and expectations were essential, but flexibility was also important as the goals and expectations evolved over time. Role definition was an iterative process that required frequent communication and feedback between partners. Establishing hierarchical roles resulted in intimidation and breakdown of communication.

The best partnerships involved a division of labor in the classroom and in planning and collaboration in which each partner's strengths were utilized to supply scientific and pedagogical resources. Investment in the partnership varied as the partnership progressed but was strongest when both partners felt as though their individual contributions were welcomed and appreciated. Successful partnership evolution and sustainability requires the blending of the K-12 and university cultures, mutual investment, and the fulfillment of basic partnership criteria.

Quantitative assesment of debris flow deposition and reworking by the Colorado River, Grand Canyon, Arizona.

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Quantification of debris fan volume and surface area is needed to explore the dynamic relationship between the regulated Colorado River and the debris fans that line the corridor of Grand Canyon. Photogrammetically derived digital terrain models (DTMs) were produced from aerial photographs dating back to 1965. The DTMs were processed and analyzed for accuracy, volume, and surface area. The surface derivatives were compared with daily discharge of the river to asses the effect of river regulation on debris fan form. The results confirm that 1) the accuracy of photogrammetric DTMs is sufficient to provide an annual assessment of debris fan morphology and 2) the reworking of debris flow deposition is dependent on river discharge.

The integration of tree-ring and alluvial fan records of fire history at the Missionary Ridge Fire, Durango, Colorado.

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The Missionary Ridge Fire burned through more than 70,000 acres of forest near Durango, Colorado, in June of 2002. Several debris flow and flood events following the fire incised older alluvial fan sediments throughout the burned area. This study focuses on one watershed where 3,000 years of fire-related depositional events have been preserved in the alluvial fan sediments. We use the recently exposed sediment record to compare the frequency and type of post-fire depositional events with tree-ring records of fire in the same drainage. Tree-ring records indicate that fire spread as frequent low severity surface fires, with patches of crown fire occurring at longer intervals. The aim is to assess how the geomorphic response to past fires correlates with the fire behavior determined by the tree-ring record over the past 300 years. The integration of both records allows for a fuller understanding of the frequency, extent and severity of fires throughout the late Holocene. This research provides a new context for comparing the recent large and severe fires in the Southwest and their resulting geomorphic response with estimated fire behavior over the past three millenium.

Correlation and chronostratigraphy of Pleistocene—Holocene tephras from the Bolivian Altiplano

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Tephras provide important isochrons for paleolimnologic, geomorphic, and archeological studies. Despite the widespread occurance of late Quaternary tephras on the Bolivian Altiplano few of these deposits have been previously recognized either on the landscape or in paleolakes sediment cores. We document the presence of thin (cm-thick) distal tephras in Quaternary lacustrine and alluvial deposits. The composition of the comprising glasses and pheonocrysts were determined by electron microprobe analyses. Each tephra has a diagnostic major element geochemistry, and some tephras could be traced across a broad geographic region. Tephras from Northern Chile and previously documented tephras from Southern Ecuador are also examined for possible correlations. $^{40}Ar/^{39}Ar$ dates provide a chronology for older tephras and document the presence of Altiplano paleolakes as early as 1.9 Ma. Organic material associated with ash beds in paleolake or paleowetland deposits provide good constrains on the age of Late Glacial--Holocene tephras. Stratigraphic context provides relative age constraints on undated tephras. This tephrachronology provides a basis for future Late Quaternary stratigraphic studies on the Bolivian Altiplano.

Session IV Abstracts

A new reconstruction of seventeenth century climate variability from the western Indian Ocean using the coral genus *Diploastrea*

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Interannual to interdecadal rhythms of tropical climate variability have been observed in both instrumental datasets and proxy records of paleoclimate. Particular attention has been given to the changing nature of these oscillatory patterns concomitant with the El-Niño/Southern Oscillation (ENSO) system. Subtle adjustments in the dominant quasi-periodicities of the ENSO phenomenon may produce substantial climatic impacts at human time scales across many ENSO teleconnected regions, including the Western Indian Ocean (WIO). It is therefore critical to determine the full range of ENSO variation at these locations in terms of its representative spatial, temporal, and frequency domains. To do so requires continued extensions of the paleorecord into the past. The coral *Diploastrea heliopora*, owing to its slow rate of growth, affords an opportunity to obtain substantially longer records of oceanic variables than those currently produced using the genus *Porites*. We first use a monthly-resolved oxygen isotope ($\delta^{18}O$) record of 20th century climate variability from the Mafia Island archipelago, Tanzania, to demonstrate the validity of this new archive. Statistical tests reveal considerable coherency between our $\delta^{18}O$ record and both local sea surface temperatures and other coral $\delta^{18}O$ time series within the WIO basin. Over the 20th century, our $\delta^{18}O$ record also captures a secular warming trend and displays significant power at ENSO-band periodicities (3-6 years). To emphasize the utility of *Diploastrea* in assembling multi-century paleoclimate datasets we present a similarly constructed century-long bimonthly record of WIO climate that spans much of the 17th and early 18th centuries. Relative to the modern period, the 17th century contains a pronounced interdecadal signal, and exhibits similar, although slightly weakened, variance within the ENSO band. We consider possible influences of decreased solar irradiance during this time (the Maunder Minimum) on climatic variability across the tropical Indo-Pacific. These results offer a rare glimpse of natural fluctuations in the response of the WIO to ENSO, changes in mean environmental conditions, and the interplay between the two, within a preanthropogenic setting.

Spectral analysis of coral $\delta^{18}O$ Records in the Pacific and Indian Oceans: an examination of decadal and interdecadal variability

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The El Niño/Southern Oscillation (ENSO) determines much of the interannual climate variability seen in the tropical Pacific Ocean Basin. Recently, patterns of ENSO-like variability operating at decadal to inter-decadal timescales have been identified. Characterizing these patterns beyond the instrumental period of record is important for determining the full range of variability of the ENSO system. Understanding that variability is important for determining the potential role of anthropogenically induced warming.

This study uses Singular Spectrum Analysis (SSA) and Empirical Orthogonal Functions (EOF) to identify spatial and temporal structures in nineteen annually resolved coral oxygen isotope records from the tropical Pacific and Indian Ocean (between 40°E and 90°W; 30°S and 30°N). SSA is used to determine the structure and length of periodic components within individual time series. EOF analysis extracts common patterns of variance between time series. Using the results of SSA, raw time series are divided into two groups depending on the frequency of their dominant oscillatory components: one with decadal (9-14 years) oscillations and ones with interdecadal (18-24 years) oscillations. EOF analysis is then used to check for spatial coherency.

The initial grouping of time series based on SSA results seems to indicate that those corals with decadal patterns of variability are generally found close to the equator while corals with interdecadal signals are located more poleward. EOF analysis of the decadal group supports the initial division by revealing that the 9-14 year pattern of variability is coherent with most sites within the group. Similarly, a coherent pattern of variance in the interdecadal group exists with an18-24 year dominant oscillatory pattern.

When all nineteen coral records are grouped together, results from EOF analysis yield two linearly independent patterns of variability. One is characterized by decadal oscillations and acts most strongly on the decadal group from above. The other is characterized by low frequency variance and affects the inter-decadal group and not the decadal group. The consistency of results between tests is remarkable given that they are all independent procedures applied to raw data.

These results are consistent with those found by Tourre *et al.*; namely, that lower frequency patterns tend to occur at higher latitudes. Since the set of coral records seems to track the temporal and spatial structure of these low frequency patterns in the 20th century, they should be useful for determining the nature of decadal and interdecadal variability in past centuries.

Holocene precipitation variability in the Galápagos Islands

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The El Niño-Southern Oscillation is the world's largest source of interannual climate variability, imparting wide-ranging effects, both positive and negative, to many parts of the globe. Knowledge of how ENSO operated in the past is fundamental to predicting future El Niño events and understanding how anthropogenic climate change will alter El Niño frequency and intensity. The Galápagos Islands lay geographically in the ENSO "center of action," where most major precipitation variation can be attributed to El Niño and La Niña events without the burden of teleconnections. A sediment core from El Junco, a closed basin lake in the highlands of San Cristóbal Island, shows variability in lake level through the Holocene. El Junco receives more precipitation during El Niño events, raising lake level, and less precipitation during La Niña events, lowering lake level. The diatom population of El Junco responds to this change, with a greater population of the planktonic species *Frustulia rhomboides* var. saxonica, *Brachysira serian*s var. brachysira, and *Pinnularia biceps* found in the lake during high stands, and a greater population of the benthic species *Encyonema minutum* and *Eunotia pectinalis* found in the lake during low stands. Planktonic versus benthic diatom abundances throughout the El Junco core can thus be interpreted as a function of lake level. In the last two centuries, lake levels remained high, suggesting more El Niño events or a stronger El Niño background state. Through most of the last millennium, lake levels remained low, implying more La Niña events or a more La Niña background state. The El Junco diatom record also compares well with annual coral records from the Pacific, which show an intensification of El Niño activity during the 20th century.

Will future climate threaten the Sonoran Desert?

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The interactions of climate variability, fire, and nonnative species will play a significant and complicated role on future vegetation change in the southwest. Increasing global CO_2 levels are predicted to create unprecedented changes in global temperature and precipitation regimes. Global climate models can forecast how temperatures and seasonal precipitation might change, but inconsistencies between model results leave wide ranges for potential regional climatic changes across the globe. Arid ecosystems are expected to be very sensitive to changes in moisture and nutrient availability. The primary objective of this study was to evaluate the impacts of climate variability, wildfire risk, and human activities on the vegetation dynamics in three desert grassland communities in southeastern Arizona. A plant-soil ecosystem model, Century, was parameterized for dominant soil types and plant functional groups along an elevation gradient in southeastern Arizona. The model was validated using observational measurements of above-ground plant biomass and a satellite derived Normalized

Difference Vegetation Index (NDVI). Climate change simulations included isolated effects of increased temperature, the combined effects of increased temperature with altered seasonal precipitation, extreme drought conditions, and the impacts of fire and grazing management regimes. Growing phenology of vegetation under current-climate simulations shows high correlation with NDVI values, as well as with ground-measured values of annual production. Climate change simulations show greatly increased production under wetter conditions, and decreased production under isolated warming and extreme drought conditions. Results have implications for nonnative grasses, fire risk and fire dynamics, ecosystem structure and composition, biodiversity, and by extension, rangeland management, urbanization, road construction, water supply, and human health.

Reconstructing 31,000 years of vegetation dynamics in the northern Chihuahuan Desert: A packrat midden study from the Peloncillo Mountains.

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Although plant macrofossils preserved in packrat middens have proven to be a valuable source of biogeographical data in the arid southwest, there has been a conspicuous gap in packrat midden coverage in the semidesert grasslands that separate the northern Chihuahuan and Sonoran Deserts north of the USA/Mexico border. This study presents a 31,000 ^{14}C yr record of macrofossils and pollen from packrat middens in the Peloncillo Mountains along the Arizona-New Mexico border. Today these elevations are dominated by a mixture of semidesert grassland and Chihuahuan and Sonoran Desert shrubs, including a disjunct population of jojoba (*Simmondsia chinensis*). Between 31,000-13,000 ^{14}C yr BP, rocky areas just above playa lakes supported *Pinus edulis*, *Juniperus osteosperma*, *Juniperus* cf. *coahuilensis, Quercus turbinella* and a rich understory of summer-flowering C_4 annuals and grasses, indicating abundant summer rains and relatively warm summers. After ~13,000 ^{14}C yr BP, *P. edulis* declined in abundance and disappeared briefly at 12,000 ^{14}C yr BP, coincident with other records of regional aridity during the Bølling-Allerød. *P. edulis* rebounded briefly at 10,500 ^{14}C yr BP during the Younger Dryas before disappearing along with other mesic woodland species sometime after 10,300 ^{14}C yr BP. The few middens dating from the early to middle Holocene (10,000-4000 ^{14}C yr BP) indicate wetter-than-present conditions at the beginning of themiddle Holocene followed by a general drying trend. The 35 middens from the late Holocene detail the sequential arrival of increasingly xeric species. The absence of the Sonoran Desert shrub *Simmondsia chinensis* from all midden macrofossils suggests local populations may be derived from recent long distance (~100 km) dispersal from more extensive populations to the north or west.

Early to Mid-Holocene climate in Southern Arizona inferred from speleothem stable isotopes

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We have collected three stalagmites from Cave of the Bells (elevation 1700 m) located ~75 km southeast of Tucson, Arizona on the northeast side of the Santa Rita Mountains. Initial high resolution (<10 years) $\delta^{18}O$ data from a Holocene stalagmite dating from ~4.5-8.2 ka (Uranium-series chronology) show pronounced century-scale variability and mean values comparable to early Holocene levels found in a sample dated ~10-55 ka. Factors controlling speleothem $\delta^{18}O$ at this site include: temperature of precipitation (~+0.72‰ per 1°C), amount of precipitation (~-0.26‰ per 10 mm), temperature of calcite formation (~0.24‰ per 1°C), and seasonality (more negative values in winter). Overall an increase in stalagmite $\delta^{18}O$ reflects warmer/drier conditions and perhaps a greater infiltration of summer precipitation. Records derived from speleothems have the potential to fill key gaps in the paleoclimate history of the Southwest.

Stable Isotopic Variations in Columnar Cacti: are Responses to Climate Recorded in Spines?

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The behavior of the North American monsoon (NAM), particularly with respect to times of continental drought and its relationship to the Pacific-North American (PNA) teleconnection pattern and the El Nino/Southern Oscillation (ENSO) is of great interest to paleoclimatologists and water managers. Saguaro cacti (*Carnegiea gigantea*) and other columnar cacti in North and South America are long-lived and have the potential to record climate variability on land with high temporal and spatial resolution. The vertical sequence of spines on the saguaro's exterior represents a high resolution (4 to 6 per year), and long (over 150 years) record of environmental change.

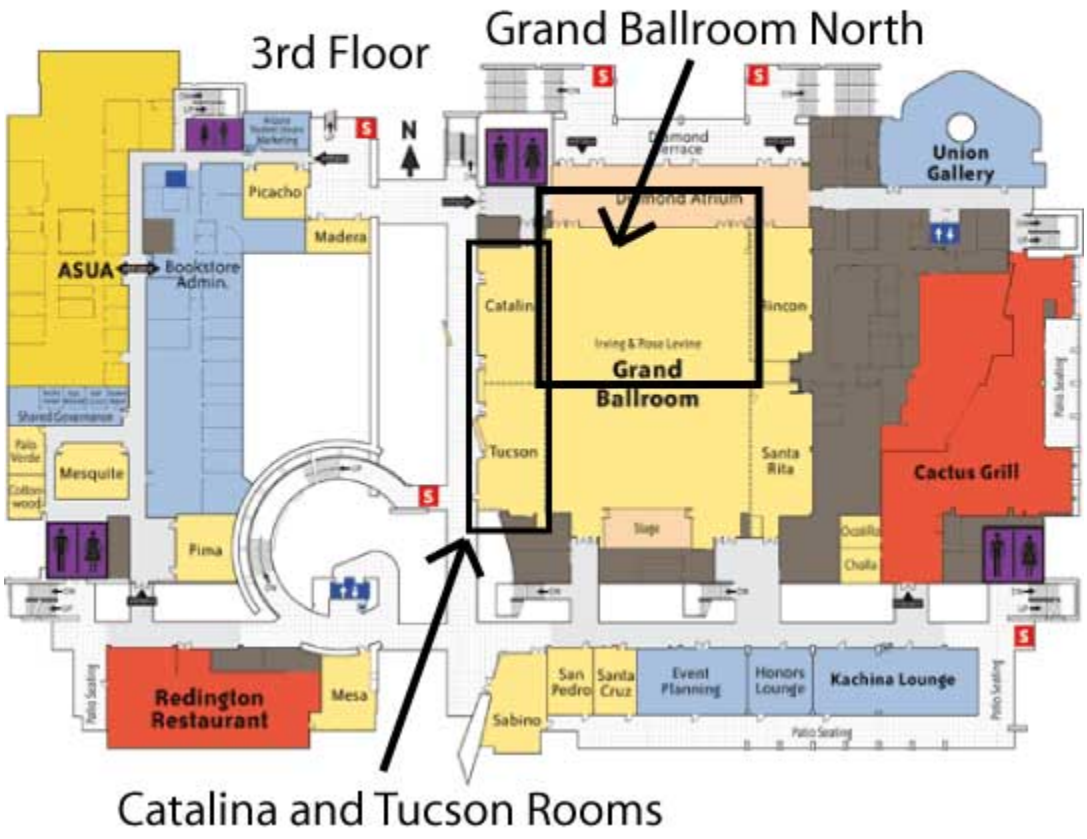
We present results from an experiment where we tracked the oxygen isotopic values in the source waters, stem tissue waters and spine tissue for three treatments over the course of 5 months. We also present the rationale for a new method to determine the growth rate of columnar cacti using the radiocarbon bomb spike. Our measurements reveal that oxygen and hydrogen isotopic variation among the sequentially produced and persistent spines covering the saguaro body record fluctuations in saguaro water balance.

The development and refinement of saguaro spines as climate records will serve as the basis for obtaining climate records from other species of columnar cacti in North

and South America. The role of the tropics in global climate change is poorly understood and precise chronologies of tropical climate change are needed to place empirical constraints on competing theories and models. In particular, the use of continental records from columnar cacti from coastal and Altiplano South America could identify ENSO periods in the last century and provide empirical constraints on the inputs of Atlantic (monsoonal) versus Pacific (winter) moisture to the Altiplano during ENSO and other important climatological phenomena.

Map of the Student Union

GEODAZE will be held on the 3rd Floor of the Student Union. This is one level up from Ground Level.



Map to GEODAZE party

Directions to Beck/Zandt house: 4535 W. Camino Nuestro

From the University, W on Speedway, N on Silverbell, W on Sweetwater. Just past Robin Elementary school, turn N onto Oxbow (dirt road), past speed bump turn left onto Nuestro. At "Y" keep left until you reach driveway of tan Santa Fe (4535 on lamppost). (Please note the star on the map below is not quite in the correct place).