41st Annual Graduate Student Colloquium

Fox Glacier, South Island, New Zealand; photo by Mouse Reusch

Sponsored by the
Department of Geosciences
March 30 -April 3, 2009

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The Graduate Student Colloquium is a forum where students present their research or research proposal to faculty, friends, and peers. The Colloquium is hosted by the Department of Geosciences and is open to graduate students involved in geoscience research. The colloquium format stimulates research discussion, allows students to practice for national meetings, and helps students improve their speaking skills. The Colloquium assists both the Department and Penn State to maintain and strengthen their reputations at national and international meetings for giving high quality talks and poster with visual appeal.

Schedule of Events

Opening Reception	10am March 30th	EMS Museum – ground floor Deike Bldg
Poster Viewing	10am March 30th –thru 12pm April 3rd	EMS Museum – ground floor Deike Bldg
Talk Session 1	10:30a-12:00p April 1st	541 Deike
Poster Judging	1:00-4:00p April 1st	EMS Museum
Talk Session 2	10:00a-12:00p April 2nd	541 Deike
Talk Session 3	9:00a-12:45p April 3rd	541 Deike
Special Talk	12:45p-1:45p April 3rd	541 Deike
Entropy and Grad Colloquium Prizes	May 1tst	VFW Hall

The Graduate Colloquium Committee wishes to thank the students for sharing their work and the faculty for giving constructive advice. The Committee also wishes to thank the Shell People Services division of Shell Oil Company and Chevron for their generous financial support, and the Department of Geosciences for hosting this Colloquium.

Graduate Student Colloquium Committee Members 2009
(the coolest committee):

Mouse Marie Reusch (chair)

Knut Christianson
Claire Fleeger
Hiroshi Hamasaki
Matt O'Donnell
Vicki Miller
Kris Peterson
Megan Pickard
Jon Schueth
and Dave Vacco

The Peter Deines Lectureship

The first place award for an oral presentation by a post-comprehensive PhD student is designated the Peter Deines Lectureship for the following academic year.

This award was started in 2004 to represent the tremendous amount of respect and admiration the graduate students in the Department of Geosciences had for Dr. Peter Deines, who that year was stepping down from the position of Graduate Program Chairman. Recipients of the honor are invited to give a department colloquium talk during the following academic year.

The department and the world lost a great man and wonderful person when Peter passed away on 2 February 2009. It is with great pride that the Graduate Student Colloquium continues the tradition born in 2004.

Past Recipients

2004-05: Margaret Benoit
2005-06: Shawn Goldman and Courtney Turich
2006-07: Christina Lopano
2007-08: Gavin Hayes
2008-09: Daniel Hummer

The Peter Deines Lectureship

Professor Emeritus of Geochemistry, Department of Geosciences, College of Earth and Mineral Sciences of The Pennsylvania State University.

Peter Deines (4/02/36 to 2/02/09) earned a Geologen Vordiplom at the Rheinsche Friedrich Wilhelms Universitaet, Bonn, Germany in 1959, an M.S. (1964) and a Ph.D. (1967) in Geochemistry and Mineralogy from Penn State University. Since 1967, and after 2004, as an Emeritus Professor, he was a member of the Geological Science Faculty of the Pennsylvania State University. He earned an international reputation for his geochemical research, teaching, and science administration. Recognition came in teaching awards, election to the University Senate, in which he served for 24 years, and election especially to Treasurer of the International Geochemical Society. In that office, he was so effective that he was awarded a unique Honorary Life Membership for his financial management of the society. He was a principal organizer of that Society's primary international meetings, the famous Goldschmidt Conferences.

With his gift for organization, he also served the Department of Geosciences on most of its committees and he served as its Graduate Program Chairman, while also administering committees for the College of Earth and Mineral Sciences, primarily for Scholarships. Most important was his commitment to the University Academic Senate, in which he served in 28 committee posts, including its Chair for 1990-91; and to the University, on 34 committees and commissions, including University Ombudsman since 2006. He also was elected President of the Faculty-Staff Club.

Dr. Deines' research centered on precise explanations of natural variations in stable isotope abundances as means of understanding geologic processes. Results were presented in lectures throughout the world and in over 60 published papers. His illustrated book, "Solved Problems in Geochemistry," was polished by his teaching of eight graduate courses and is available on the web especially for graduate students.

A 40-year member of the Nittany Valley Symphony, Peter will be missed for his finesse with violin and viola.

Wednesday Morning Talks

TIME	PRESENTER	ADVISOR	TITLE
10:30	Clayton Magill	Kate Freeman	Environmental Variability During a Time of Rapid Hominin Speciation, ca. 1.80 Ma
10:45	Patrick Applegate	Richard Alley	Effects of Sampling Criteria on the Distributions of Cosmogenic Exposure Dates From Degrading Moraines
11:00	Brett Carpenter	Chris Marone	A Preliminary Look at the Creeping Section of the San Andreas Fault in Central California: Insights From Fault Cuttings, Outcrop Samples, and Synthetic Mixtures
11:15	Fred Tugume	Andy Nyblade	The Depth Distribution of Seismicity at the Northern end of the Rwenzori Mountains: Implications for Heat Flow in the Western Rift, Uganda
11:30	Mouse Marie Reusch	Andy Nyblade	Constraining the Depth Extent of the Cameroon Volcanic Line Anomaly

Environmental Variability During a Time of Rapid Hominin Speciation, *ca*. 1.80 Ma

Clayton Magill
Dr. Katherine Freeman
Pre-comps

Leading modern hypotheses of hominin evolution directly link environmental variability and times of rapid speciation. Specifically, African aridification trends during the Plio-Pleistocene show a strong correlation to hominin diversity patterns; however, the timing and mechanism(s) governing the influence of climate on our ancient ancestors is poorly understood.

We hypothesize moisture balance and plant functional groups in the 'Cradle of Mankind' covaried with Milankovitch solar insulation patterns during the Plio-Pleistocene. Cenozoic marine records indicate East African climate is paced by orbital variations in solar flux and its impact on monsoonal circulation. Moreover, lithostratigraphic sections from Olduvai Gorge, Tanzania demonstrate precessional (*ca.* 21 kyr) forcing of lacustrine facies during the early Pleistocene. Regional pollen and soil carbonate $\delta^{13}C$ records from this time show significant variability and broadly suggest changing C_3 to C_4 ecological regimes, but data are low-resolution, poorly constrained and show evidence of diagenetic alteration.

Here we report bulk organic $\delta^{13}C$ and molecular $\delta^{13}C$ and δD data from perennial lacustrine sediments found in Olduvai Gorge. Bulk carbon isotopic analyses range ~8‰ and cycle between *ca*. -17‰ and -26‰ in concert with calculated regional insolation during the Plio-Pleistocene. Compound-specific carbon isotopic signatures of plant-derived (*n*-C_{29} and *n*-C_{31}) alkane biomarkers also fluctuate between ~-24.9 and -33.9‰, while algae-sourced (*n*-C_{17}) molecules show a more consistent value near *ca*. -26‰. Interestingly, δD values for the algal-derived *n*-C_{17} alkane are enriched (-65‰) and depleted (-139‰) during times of higher and lower solar flux, respectively.

We interpret these results as evidence of pronounced East African ecological and hydrological variability during the Plio-Pleistocene governed by equatorial insolation patterns. Dramatic swings between woodland C_3 and grassland C_4 vegetation accompany precessional planetary movement and likely reflect its impact on regional evaporation/precipitation ratios. We believe increased terrestrial evaporation and decreased water availability during times of higher radiation drove shifts towards arid-adapted vegetation, and vice versa. Within this dynamically changing landscape, hominins may have experienced significant adaptive pressures related to resource acquisition and environmental acclimation that influenced natural selection processes.

Effects of Sampling Criteria on the Distributions of Cosmogenic Exposure Dates From Degrading Moraines

Patrick J. Applegate
Richard B. Alley
Post-comps

Cosmogenic exposure dating has been used repeatedly to determine the ages of moraines thought to be associated with abrupt climate events, especially the Younger Dryas cold reversal (12.8- 11.6 ka). The spatial distribution of moraines associated with abrupt climate events provides information on the mechanisms responsible for the changes. However, only a few samples can usually be collected from any one moraine; the dates are expensive, and the chemical processing is time-consuming. Therefore, field workers select samples that appear most likely to reflect the true age of the moraine. Boulders that have fresh surfaces and stand at least a meter above the moraine crest are generally preferred. In this study, we use a Monte Carlo-based model of nuclide production in boulders on a degrading moraine to assess the influence of these sampling criteria on the inferred age of the moraine. We first invert the model against a set of exposure dates from the Waiho Loop moraine in New Zealand. This inversion yields realistic values of the model parameters (moraine age, initial moraine height, initial moraine slope, and topographic diffusivity) for late-glacial moraines. We then run the model in a forward sense, generating a probability distribution of exposure dates predicated on these parameter estimates. Next, we subsample this probability distribution using each of the two sampling criteria mentioned above. Our results suggest that sampling tall boulders is a reasonable strategy for selecting samples for cosmogenic exposure dating, but that sampling fresh boulders tends to lead to exposure dates that underestimate the ages of moraines. This conclusion is only true for moraines that have lost several meters of material from their crests over their post-depositional histories.

A Preliminary Look at the Creeping Section of the San Andreas Fault in Central California: Insights From Fault Cuttings, Outcrop Samples, and Synthetic Mixtures

Brett M. Carpenter
Chris Marone
Post-Comps

I report on experiments designed to explore the mechanical behavior of the main creeping strand of the San Andreas Fault at Parkfield; as identified by the SAFOD project. Experiments were conducted on material from the “MD 10830 ft.” cored interval, surface samples of rock formations surrounding the borehole, and synthetic mixtures designed to investigate the role of talc and serpentinite in fault behavior.

Experiments were conducted in a servo-controlled, double-direct shear apparatus. The majority of experiments were conducted in a true triaxial pressure vessel, however, a subset of experiments were performed outside the pressure vessel at room temperature and humidity. Vessel experiments were conducted under constant confining (6 MPa) and pore (5 MPa) pressures. Pore water consisted of a mock pore water solution with NaCl, $CaCl_2$, and KCl added based on SAFOD water chemistry reports.

Cuttings data show a significant decrease in frictional strength from 0.35 outside of the fault, to 0.21 within the fault. Outcrop experiments on comparable rock types under dry conditions result with coefficients of friction of ~0.6. Synthetic gouge experiments indicate that > 50% of talc/serpentinite by weight is required to influence fault behavior. These results indicate that the fault is a zone of weakness in an otherwise strong crust.

Velocity stepping and slide-hold-slide tests indicate that the rocks exhibit slip-rate and history-dependent friction behavior similar to that documented for simulated fault gouge. A sudden increase in load point velocity results in an immediate increase in friction followed by a displacement-dependent decay to a new steady-state level. Velocity stepping tests show that cuttings from the cored interval are velocity strengthening, consistent with a creeping fault. Slide-hold-slide tests on the same cuttings show a significant decrease in healing (healing rates near 0) within the fault zone, which indicates that the fault doesn’t restrengthen between creep events. Similar behavior is seen in synthetic mixtures containing talc.

The Depth Distribution of Seismicity at the Northern end of the Rwenzori Mountains: Implications for Heat Flow in the Western Rift, Uganda

Fred A. Tugume
Andrew Nyblade
Pre-comps

In this study, data from a 6-month deployment of seismic stations around the northern end of the Rwenzori mountains have been used to investigate the depth extent of seismicity and its implications for heat flow in the Western branch of the East Africa rift system in Uganda. Previous seismicity studies of the Western branch in Uganda show earthquake nucleation at depths greater than or equal to 40 km suggesting that heat flow from the rift is not elevated. However, terrestrial heat flow measurements for the Western branch in Tanzania are high (~109mWm^{-2}), similar to high average heat flow in the Eastern branch of the East African Rift System in Kenya (100mWm^{-2}).

To investigate further the depth extent of seismicity in the Western branch, seismological data were collected and analyzed to obtain accurate hypocenters using both standard and double difference location algorithms. Focal mechanisms were also obtained to place constraints on the local stress regime. Results show that seismicity is concentrated along the major border faults of the Rwenzori horst, suggesting an eastward dip on the Ruimi-Wasa Fault and a northwestward dip on the Toro-Bunyoro Fault. Fault motions are predominantly normal, with strike slip motions between the Ruimi-Wasa and Toro-Bunyoro Faults. The observed depth distribution of seismicity peaks at 16 km depth and extends to 31 km. Strength envelope models indicate that heat flow in the range of 54 mWm^{-2} to 66 mWm^{-2} is required to explain this result. A heat flow of 54-66 mWm^{-2} is similar to heat flow in other mobile belts in East Africa away from major rift valleys, and is much lower than the high heat flow reported for Eastern branch in Kenya or the Western branch in Tanzania. Therefore, heat flow around the Rwenzori Mountains does not appear to be elevated. This finding does not preclude the possibility of a deep seated (i.e., mantle) thermal anomaly beneath the rift, which simply may not have had sufficient time to reach the surface.

Constraining the Depth Extent of the Cameroon Volcanic Line Anomaly

Mouse Marie Reusch
Andrew Nyblade
Post-comps

Linear volcanic chains without age progression present challenges to current models of mantle dynamics. This study presents results from a seismic experiment to investigate the origin of the Cameroon Volcanic Line (CVL). The CVL is a 1600km feature traversing both continental Cameroon in West Africa and the offshore islands of Bioko (part of Equatorial Guinea), Sao Tome and Principe, and the offshore Annobon (also part of Equatorial Guinea). The CVL is a fairly linear feature, suggestive of the movement of the African plate over a stationary hotspot, but the volcanic rock ages of the CVL range from 42Ma to the present (with present volcanism occurring in the center of the line at Mt. Cameroon), contrary to what would be expected from a stationary hot spot. Several hypotheses have been proposed for the formation of the CVL such as multiple plumes, lateral flow from the Afar depression, and edge-flow convection initiated by the temperature differences between the mantle and the nearby Congo Craton.

The Cameroon Seismic Experiment was deployed in Cameroon from January 2005 to January 2007, with 8 stations active the first year and an additional 24 stations installed in January 2006. The data from the 32 broadband seismometers has been used for a body-wave tomography study to examine upper mantle structure. Results from P- and S-wave travel time tomography show a steep-sided linear low-velocity anomaly directly beneath the CVL that extends from shallow mantle depths to at least 350km. 3D results from the stacking of receiver functions to image mantle transition zone discontinuities suggest that this anomaly does not continue to greater than 500km depth. These findings suggest that the anomaly requires a formation model invoking a linear sheet-like thermal upwelling in the upper 400km of the mantle.

Wednesday PM Posters

PRESENTER	**ADVISOR**	**TITLE**
Brett Carpenter	Chris Marone	Time-Dependent Strengthening Rates in Simulated Fault Gouge and Implications for Fault Zone Processes
Alicia Cruz-Uribe	Maureen Feineman	Ages of Sevier Thrusting From Dating of Metamorphic Garnet Using the Lu-Hf
Katherine Dawson	Jenn Macalady & Kate Freeman	Anaerobic Biodegradation of Isoprenoid Biomarkers by a Denitrifying Microcosm
John Fegyversi	Richard Alley	Using Bubble Number-Densities of WAIS Glacier Ice as Both a Paleoclimatic and Accumulation Rate Reconstruction Tool: Methods and Current Findings
Claire Fleeger	Peter Heaney	Cesium Sequestration With Birnessite at a High pH
Brad Kuntz	Kamini Singha	Quantifying the Processes Controlling Turbulent Flow During Pumping Tests
Rachel Lauer	Demian Saffer	The Impact of Splay Faults on the Fluid Budgets of Subduction Zones: a Modeling Approach
Kristin Morell	Don Fisher	The Impact of Splay Faults on the Fluid Budgets of Subduction Zones: a Modeling Approach
Gabriel Mulibo	Andy Nyblade	The 1994-1995 Earthquake Swarms in Northern Tanzania and the Role of Diking Versus Faulting During Early Stages of Rift Development
Caroline O'Hara	Pete LaFemina	Evolution of a Ridge-Transform Intersection, Northern Iceland
Kris Peterson	Peter Heaney	To be announced
Margaret Popek	Demian Saffer	Topographically-Driven Fluid Flow Through a Heterogeneous Permeability Subsurface: Implications for Surface Heat Flow Near Parkfield, CA
Andrew Rathbun	Chris Marone	Experimental Constraints on Frictional Heat Generation and the Earthquake Energy Budget
Luke Zoet	Sridhar Anandakrishnan	Regularly Spaced (in Time) Seismic Events Originating From Beneath David Glacier in the Transantarctic Mountain Range of Antarctica

Time-Dependent Strengthening Rates in Simulated Fault Gouge and Implications for Fault Zone Processes

Brett M. Carpenter
Chris Marone
Post-Comps

The frictional behavior of tectonic faults is ultimately a product of asperity contact processes, fault zone fabric, and granular processes in gouge zones. Contact area evolution likely exhibits significant control on overall fault stability by influencing 1) healing during the interseismic period, 2) rate-dependent friction, and 3) restrengthening at short time scales of dynamic rupture. We report on a series of slide-hold-slide tests conducted on simulated fault gouges, to explore the role of gouge mineralogy on the evolution of contact area and associated fault healing at intermediate time scales. We conducted friction experiments in a double-direct shear configuration, under room conditions using four simulated fault gouges: talc (particles < 125μm), kaolinite (1-4μm), illite shale (< 106μm), and feldspar (andesine) (<106μm). Layers of simulated gouge were sheared at load point velocities of 1, 10, and 100 μm s^{-1} under constant normal stress (20 MPa) between rough rigid forcing blocks to a shear strain of ~25, and then subjected to slide-hold-slide tests with holds ranging from 1 to 1000 seconds, with 0.5 mm of slip between each hold.

Talc shows little to no healing ($\Delta\mu < 0.001$) over all hold times and all loading rates, whereas kaolinite ($\Delta\mu = 0.0025 - 0.025$), andesine ($\Delta\mu = 0.002 - 0.021$) and illite shale ($\Delta\mu = 0 - 0.011$) all exhibit healing. Illite shale shows increasing healing in tests that were run at increasing load point velocity during shear before and after the holds. All gouges exhibit log-linear healing rates over all velocities and hold times, with the exception of feldspar, which deviates from this relationship at hold times > 100s. Layer compaction during holds increases with hold time and with the load point velocity. Compaction ranges from < 1 μm at 1 μm/s to 3.5 μm at 100 μm/s. Talc compacts the least and feldspar compacts the most. High compaction at high velocities is attributable to gouge dilation during shear. Low compaction is associated with the weak mineral talc, suggesting that most of the porosity reduction in weak minerals occurs under initial loading and that large porosity changes are unlikely.

The low strength of talc likely facilitates saturation of contact area even at low effective stress, as evidenced by extremely low rates of healing and compaction. Because velocity-weakening frictional behavior (a necessary condition for unstable slip) is predicated on the disruption of time-dependent strengthening processes, the presence of talc or similarly weak minerals would promote stable sliding in a fault zone.

Ages of Sevier Thrusting From Dating of Metamorphic Garnet Using the Lu-Hf

Alicia M. Cruz-Uribe
Advisor: Maureen Feineman
Pre-comps

Combined thermodynamic modeling of garnet growth zoning and Lu-Hf dating of garnet yield well-constrained pressure-temperature-time (PTt) paths. Here we present PTt paths from amphibolite-facies pelitic garnet from the Raft River-Albion-Grouse Creek metamorphic core complex that constrain the timing of thrusting in the hinterland of the Sevier thrust belt. Three general times of thrust burial are indicated: 150, 138, and 85 Ma. Lu-Hf garnet dating of burial-related garnet growth in the Raft River Mountains yielded a Late Jurassic age of 149.9 ± 1.2 Ma (2σ, MSWD = 1.1) based on three garnet fractions and a whole rock. A PT path from the schist of Mahogany Peaks in the Albion Range, Idaho, records an isothermal pressure increase indicating growth during thrusting. Lu-Hf dating of garnet from the same rock yielded an Early Cretaceous age of 138.7 ± 0.7 Ma (2σ, MSWD = 1.6) based on seven garnet fractions. An additional PT path from a nearby outcrop also records an isothermal pressure increase and a similar Lu-Hf garnet age of 132.1 ± 5.1 Ma (2σ, MSWD = 9.5) based on three garnet fractions and a whole rock. PT paths of multiple garnet grains from the schist of Stevens Spring in the Grouse Creek Mountains, Utah, exhibit isothermal pressure increases and yielded a Lu-Hf garnet age of 85.5 ± 1.9 Ma (2σ, MSWD = 3.9) based on five garnet fractions and a whole rock. The Late Jurassic burial event recorded in the Raft River Mountains is older than the ages of inception of thrusting of the western thrusts of the Sevier fold-thrust belt including the Canyon Range and Paris - Willard thrusts, but consistent with an eastward progression in initial shortening in the orogenic wedge and development of an inferred thrust load responsible for the retroarc Morrison Formation basin. Early Cretaceous hinterland burial recorded in the Albion Range is permissively coeval with activity on the Willard and Canyon Range thrusts. Finally, renewed hinterland thrust burial during the Late Cretaceous, as documented in the Grouse Creek Mountains, is consistent in timing with previous interpretations of major thrusting in frontal thrust systems of the Sevier belt, such as the development of the Absaroka thrust.

Anaerobic Biodegradation of Isoprenoid Biomarkers by a Denitrifying Microcosm

Kat Dawson
Jenn Macalady and Kate Freeman
Post-comps/Petroleum theme

Isoprenoid hydrocarbons contribute up to 30% by mass of crude oil deposits and include nearly all of the biomarker compounds used in paleoenvironmental and paleoecological reconstructions of earth history. The branched isoprenoid pristane was degraded by a denitrifying microcosm and a methanogenic, sulphate reducing enrichment, but no information about the phylogeny or biochemistry of this process has been reported. Here we describe pristane biodegradation and accompanying loss of nitrate in an activated sludge enrichment. Nitrate consumption accounts for loss of ~ 5% of the initial pristane added in 181 days.

We followed the evolution of the enrichment community using 16S rDNA clone libraries and fluorescence in situ hybridization (FISH). Later generation cultures had lower diversity and a greater percentage of clones related to denitrifying β-proteobacteria. Consistent with changes observed in clone libraries, FISH experiments showed an increase in cells hybridizing with a probe specific for Betaproteobacteria (BET42a) in later generation cultures. The enrichment degrades pristane and archaeal diether lipids, but not tetraethers. Experiments in progress are designed to establish reaction stoichiometries and to monitor intermediates that may yield insight into the degradation pathway. These data will have implications for the fate of biomarkers in modern anoxic environments and in geologic reservoirs.

Using Bubble Number-Densities of WAIS Glacier Ice as Both a Paleoclimatic and Accumulation Rate Reconstruction Tool: Methods and Current Findings

John M. Fegyveresi
Richard B. Alley
M.S. Student

It is known that density increase and grain growth in polar firn are both controlled by temperature and accumulation rate, and that the integrated effects are recorded in the number-density of bubbles as the firn changes to ice. Number-density is conserved in bubbly ice following pore close-off, allowing reconstruction of either paleotemperature or paleo-accumulation rate if the other is known. Using samples taken from the WDC06A ice core drilled during the '06-'07 West Antarctic Ice Sheet (WAIS) Divide field season, bubble sections were prepared and digitally imaged during a visit to the National Ice Core Lab in Lakewood, Colorado. These images were later manipulated, error-checked, and reduced into workable bubble number-density data. For dating purposes, I am utilizing the preliminary age scale for the WDC06A core based on DEP, and including the high resolution ICPMS chemistry data from the WDC05Q core. I'm estimating accumulation rate from the layer thickness after correcting for ice-flow strain (using a Nye model) and for densification. (The results are thus subject to revision pending finalization of the depth-age scale for WDC06A). For my thesis, I will use these accumulation rates and the bubble number-density data to estimate paleotemperatures and look for warming (or cooling) trends in the late-Holocene.

Cesium Sequestration With Birnessite at a High pH

Claire R. Fleeger
Peter J. Heaney
Pre-Comps

Storage tanks at the DOE Hanford site in Richland, Washington are leaking solutions that are extremely basic (pH > 12) and concentrated in radioactive Cs-137 and Sr-89. The underlying Ringold Formation consists of poorly consolidated clays, silts, and sands rich in Fe and Mn oxides that include birnessite composed of layered MnO octahedral sheets, which is an extremely efficient ion exchanger. For the first time, the interactions of birnessite with alkaline Cs-rich fluids are explored to determine the capacity of birnessite to sequester Cs-137. Specifically, cation exchange products of batch reactions involving dissolved Cs- and Na-birnessite at pH values ranging from 7 to 14 are characterized by using X-ray diffraction (XRD) and scanning electron microscopy (SEM). Changes in the birnessite structure as a function of pH and exchange time are determined with Rietveld refinements. Based on previously published reports, the exchange rate increases with decreasing pH; therefore, we expect to see the rate decrease as the pH increases. In future studies, time resolved XRD (TR-XRD) will monitor the exchange process *in situ*.

Quantifying the Processes Controlling Turbulent Flow During Pumping Tests

Brad Kuntz
Kamini Singha
M.S. Student

Both field observations and theoretical work have found that the relationship between pumping rate (Q) and drawdown (s) is not always a linear relationship; these differences, or losses, occur because of both laminar and turbulent flow conditions (e.g., Jacob, 1947; Mackie, 1982; Kruseman and deRidder, 1990). Field observations often deviate from theoretical solutions resulting in proportionally more drawdown with increased pumping rate. One factor contributing to this behavior is turbulent flow in the aquifer. Pumping tests are performed on water supply wells to determine the continuous flux of water that can be removed from the aquifer without dewatering the well. This flux is known as well yield. Drawdown is the measured distance between the original or static water level and the water level in the well during a pumping test. Accurately determining drawdown and understanding its corresponding controlling factors is critical to determine an accurate well yield.

We simulate multiple pumping tests on an aquifer using MODFLOW 2005 and vary the physical and hydraulic parameters to determine what parameters promote turbulence. Turbulent flow during pumping tests is promoted by hydraulically conductive features such as high porosity, conduits, or extensive fracture networks in the aquifer. Homogenous aquifers lacking discrete hydraulically conductive features are less likely to encounter turbulent flow. Turbulent flow in the aquifer is not probable for pumping rates less than approximately ~ 189 L/min (50gpm). Therefore at low pumping rates Turbulence can does not account for nonlinear drawdown as observed in the field. At sufficiently high pumping rates turbulent flow can account for greater than 20% increase in theoretical drawdown solutions.

The Impact of Splay Faults on the Fluid Budgets of Subduction Zones: a Modeling Approach

Rachel M Lauer
Demian M Saffer
Pre-Comps

In subduction zones, fluid flow pathways represent the primary control on our understanding of forearc dewatering mechanisms, devolatilization, and chemical transport. In addition, flow pathways govern the distribution of fluid pressure driven by sediment consolidation and dehydration, and thus the slip behavior and mechanical strength of faults. In particular, faults are ubiquitous features at convergent margins, although little is known about their role in distributing fluid pressures, transporting volatiles, and their overall effects on the fluid budget. Geochemical anomalies in seafloor seeps (Cl, B) suggest that faults provide a hydraulic connection from deep within the subduction zone to the seafloor, and therefore play an important role in the flux of volatiles in the forearc. It is expected that these faults would relieve fluid pressures along the décollement as they transport fluids and volatiles toward the seafloor, although their overall impact on the fluid budget is not clear. Here, we report the results of a two-dimensional numerical model of coupled fluid-flow and transport designed to quantify the role of splay faults on fluid budgets, the distribution of fluid egress at the seafloor, the migration of chemically discrete fluids, and pore pressures within the forearc of an erosional subduction zone, using the well studied Costa Rica margin as an example.

Rapid Outer Forearc Uplift Inboard of the Panama Triple Junction: Burica Peninsula, Central America

Kristin Morell
Don Fisher
Post-comps

New geomorphic and structural mapping on the Burica Peninsula, an outer forearc peninsula located only 15 km inboard of the Panama Triple Junction, reveals temporal and spatial patterns of rapid Plio-Quaternary uplift that characterize the effect of Panama Fracture Zone subduction on the upper plate. There are two potential impacts: 1) oblique subduction of a bathymetric step due to the juxtaposition of thick Cocos plate west of the Panama Fracture Zone against thinner Nazca plate to the east and 2) changes in basal traction due to the major change in convergence rate and direction at the triple junction. Our analysis of structure and late Quaternary deformation indicates that tilting and thrust faulting associated with the bathymetric step is the more important of the two impacts.

Uplift is recorded by a flight of up to five marine terraces that surround the peninsula and reach elevations as high as 100 m above modern sea level. Radiocarbon dating of a suite of shell samples within the lowest terraces located ~ 1.5 – 4 m above modern sea level yields Holocene ages that range between 510 +/- 40 and 10,650 +/- 50 YBP. More recent data indicates that the highest terrace within the southern portion of the peninsula is associated with Oxygen Isotope (OIS) stage 3. These ages combined with known terrace inner edge elevations and facies constraints suggest that the peninsula has experienced uplift at a rate as high as ~3 mm/yr throughout the Holocene.

The uplift and possible east-directed tilting of marine terraces results from slip along a deeply rooted NE-dipping thrust fault located offshore of the western coast of the peninsula. This fault roots within the Cretaceous basement of the Nicoya Fm, and contains a NW-striking thrust splay that bisects the peninsula down the center. This thrust splay is marked by sheared basalts of the Nicoya Fm in the hanging wall (with a deformation fabric that dips to the northeast), juxtaposed against an overturned syncline of mudstones within the Charco Azul Fm in the footwall. This newly defined structural architecture runs counter to prior interpretations that emphasize the importance of right lateral strike slip faulting as an upward continuation of the Panama Fracture Zone.

The 1994-1995 Earthquake Swarms in Northern Tanzania and the Role of Diking Versus Faulting During Early Stages of Rift Development

Gabriel Mulibo
Andrew Nyblade
Pre-comps

The role of border faulting versus dikes in accommodating extensional strain in continental rift systems is not well understood. Extension during the earliest stage of rifting is thought to occur primarily along border faults while dikes likely accommodate much of the strain during late synrift stages. However, a recent diking event and associated seismicity in an area of nascent rifting in northern Tanzania suggests that magmatic process could play a more important role during the initial stage of rifting than previously thought. In this study, the origin of two earthquake swarms in northern Tanzania, the Manyara and KwaMtoro swarms, has been evaluated through event relocation, modeling of regional depth phases and examination of focal mechanisms. The data used in this study are from the 1994-95 broadband seismic experiment in Tanzania.

For the Manyara swarm, seismicity is distributed over a region 20 km wide and extends to >30 km depth. Hypocenters correlate well with the Manyara rift, and focal mechanisms of many events show normal faulting with nodal planes having the same NNE orientation as the Manyara rift border fault. This result indicates that the events are most probably caused by slip along the border fault and related other faults beneath the Manyara rift. The depth extent of seismicity shows that the faults extend into the lower crust. Seismicity in the KwaMtoro swarm is distributed over a region ~10 km wide but extends only to ~12 km depth. There are no mapped faults within the swarm, but a strong correlation between the N-S orientation of the swarm, the N-S orientation of nodal planes in focal mechanisms, and N-S striking extensional structures nearby, suggest that events in this swarm are also caused by slip on a system of rift faults. Results from a crack opening model are consistent with this interpretation. Our results thus support the view that extensional strain during the earliest stages of rifting is mainly accommodated by slip along rift faults.

Evolution of a Ridge-Transform Intersection, Northern Iceland

Caroline O'Hara
Peter LaFemina
M.S. Student

The intersection of the dextral Husavik-Flatey fault (HFF) system with the Theistareykir Fissure Swarm (TFS) in northern Iceland provides an analog site for detailed study of the geometries, kinematics, and localization processes at a ridge-transform intersection. In this region, the Eurasia and North America plates are extending at approximately 2 cm/yr at the latitude of the TFS. The HFF accommodates approximately 1 cm/yr of this motion. Fault-rift interactions are recorded in post-glacial lava flows that form a continuous surface across the area.

In August 2008, we collected high resolution terrestrial LiDAR data in an approximately 0.25 square kilometer region of the fault-rift intersection, along with geologic measurements of fault strike, trend of opening, and vertical and horizontal offset of meter-scale faults in the same region. Analyses of aerial photographs allows mapping of kilometer-scale faults and fissures. In addition to these data, a GPS derived velocity field provides local and regional plate motion vectors. A high-resolution Digital Elevation Model (DEM) of the intersection will be created from the LiDAR data, and will be used to quantify fault slip across the intersection.

The ability to observe 10,000 years of deformation in this post-glacial surface identifies the intersection of the Husavik-Flatey Fault and the Theistareykir Fissure Swarm as an ideal location to study the processes at work in similar slow-spreading ridge-transform intersections along the mid-oceanic ridge system, that are otherwise nearly impossible to see. With our new data collected in August, we will quantitatively constrain the 3-D nature of the interactions using the LiDAR and field observations and, using the regional GPS measurements, place this system into the larger-scale kinematic framework of Iceland.

Topographically-Driven Fluid Flow Through a Heterogeneous Permeability Subsurface: Implications for Surface Heat Flow Near Parkfield, CA

Margaret Popek
Demian Saffer
M.S. Student

Surface heat flow near Parkfield, CA exhibits substantial scatter that is not observed in other portions of the California data set, with differences as large 15 mW/m^2 over lateral distances of 5-10 km. This scatter has been an important limitation on interpretations of regional heat flow in terms of geodynamic processes, but to date has not been explained. In the California Coast Ranges, distinct lithologic units with widely varying permeabilities have been juxtaposed by Mesozoic subduction and displacement along the fault, suggesting that complex groundwater flow paths are likely. Here, we test the hypothesis that heat advection through an upper crust characterized by heterogeneous permeability can generate the magnitude and spatial characteristics of the scatter in the heat flow data set. We created a 2D coupled groundwater flow-heat transport model along a cross-section perpendicular to the SAF, constrained by data from geologic maps, wells, and geophysical surveys, in order to explore and quantify the relationships between topography, permeability, and simulated near-surface heat flow. We assign a constant temperature and atmospheric pressure at the topographic surface; the lateral model boundaries correspond to regional groundwater divides and are designated as no-flow for both heat and fluid flow, and we prescribe a constant heat flux of 78 mW/m^2 and a no-flow hydrologic boundary at the model base 10 km beneath sea level. We evaluate the role of the 1-3 km thick package of Tertiary sediments overlying basement by assigning an impermeable basement and considering sediment permeabilities from 10^{-15} - 10^{-20} m^2. Surface heat flow in these models generates the characteristics of the surface heat flow – elevation and variability relationships observed in the Parkfield dataset. Based on our results, we suggest that heat advection by groundwater flow mediated by heterogeneous permeability in the upper crust is one plausible mechanism for generating the observed scatter in heat flow.

Experimental Constraints on Frictional Heat Generation and the Earthquake Energy Budget

Andrew Rathbun
Chris Marone
Post-comps

Grain size reduction and frictional heat production play a key role in the earthquake energy budget. Earthquake theory and seismic observations suggest that most energy in an earthquake should be manifested as frictional heat; however, field studies and drilling have failed to find the predicted heat flow or temperature anomalies across large active faults. Recent studies are divided on whether much of the energy during seismic slip may instead contribute to grain size reduction. This study tests current earthquake energy budget hypotheses in a series of laboratory experiments under controlled conditions where frictional heat production and grain size reduction can be directly observed.

Experiments were conducted on two materials with similar initial grain size distributions, soda lime glass beads which exhibit seismic motion and stable sliding f110 quartz. Particle size analysis was conducted on post-shear material and surface area was calculated from both particle size and nitrogen BET analysis. The change in surface area compared to pre-shear material allows for the calculation of the energy consumed by grain size reduction and comparison of these values to the total work of each experiment.

The rate of frictional heat production is constrained by comparing our temperature measurements to results of 3D transient models of conductive heat transport. The model domain consists of our 3 steel blocks and two 1 mm thick actively shearing sample layers. Separate simulations are run for heating efficiency factors ranging from 50% to 100%. Model simulations were produced for each experiment with the total work (W) calculated based on the experimental data. The average heat generation rate is computed from the data and renewed every one second, with total simulation times generally ~140 seconds.

Grain size and nitrogen BET analysis show that for both our aseismic experiments and seismic experiments show that grain size reduction is consistent with previous studies that suggest the energy consumed is small. This number is further constrained by comparison of our temperature measurements with heat flow modeling that suggest at least 80% of the total energy goes towards frictional heat production. Our results imply that the energy contributing to grain size reduction in an earthquake may be considerable; however, in our experiments most of the energy release is still accounted for by frictional heat production.

Regularly Spaced (in Time) Seismic Events Originating From Beneath David Glacier in the Transantarctic Mountain Range of Antarctica

Lucas Zoet
Sridhar Anandakrishnan
M.S. Student

Highly regular seismicity associated with the flow of David Glacier in the Transantarctic Mountains of Antarctica has been detected and analyzed. We used data from the Transantarctic Mountain Seismic Experiment (TAMSEIS) network, which consisted of 42 broadband seismometers deployed from November 2000 through December 2003. The seismic events recur regularly (approximately 20 min). Travel time measurements determined that the events originated from the base of David Glacier (approximately 2.3 km deep in this area). Low angle faulting determined from P-wave first motions indicate a fault strike of 185 degrees, which is normal to the flow of David Glacier. The events are likely caused by an asperity beneath David Glacier that regularly releases stress, which is accumulated as David glacier flows over the asperity. The regularity of the events is steady due to the constant and homogenous driving stress of the overlying ice as well as the weakness of the bed. Models of earthquake source regions that include a few asperities within a weak active fault are thought to display this behavior. The regularly recurring ruptures beneath David Glacier provide a field based study of stick slip faulting, on a time scale in which large numbers of events can be recorded within relatively short monitoring period.

Thursday Morning Talks

TIME	PRESENTER	ADVISOR	TITLE
10:00	Heidi Albrecht	Kate Freeman & Jenn Macalady	Hopanoid Distributions in Field and Culture Studies of Sulfur Oxidizing Bacteria
10:15	Jamey Fulton	Mike Arthur & Kate Freeman	Holocene Black Sea Cyanobacterial Ecology Elucidated by Pigments and Nitrogen Isotopes
10:30	William Craddock	Eric Kirby	Timing and Magnitude of Upper Crustal Shortening in the Gonghe Basin Region of the Northeastern Tibetan Plateau
10:45	Brad Kuntz	Kamini Singha	Solute Transport in Clay Rich Materials: Controls of Physical and Chemical Processes
11:00	BREAK		
11:15	Matthew O'Donnell	Mark Patzkowsky	Differential Preservation of Marine Environments and Biased Diversity Trends: Modeling Effects and Empirical Validation
11:30	Andrew Wall	Peter Heaney	Copper Isotope Fractionation During Leach Layer Development on Cu-sulfide Minerals
11:45	Heather Graham	Kate Freeman	Biochemical and Morphological Indicators of Light Regime in Extant and Fossil Leaves: Identifying Canopy Closure in Ancient Forests

Hopanoid Distributions in Field and Culture Studies of Sulfur Oxidizing Bacteria

Heidi L. Albrecht
Katherine H. Freeman and Jenn L. Macalady
Pre-comps

Hopanoid biomarkers play an important role in reconstructions of the Earth's past biogeochemistry and evolution. Despite their excellent preservation potential and utility for microbial paleontology, relatively little of the Earth's modern microbial biosphere has been explored with respect to hopanoid production. It is hypothesized that hopanoids are used by bacteria to tune the physical properties of membranes. Therefore, geochemical gradients in nature may be associated with systematic changes in hopanoid diversity and abundances. Bacteriohopanpolyols (BHPs) are produced by oxidizing-oxidizing and reducing-reducing bacteria and sulfur cycling environments, anoxic and euxinic, have been theorized to occur at critical periods in geologic history.

We hypothesize that BHPs are important for microbial adaptation to pH and sulfide concentrations in oxidizing-oxidizing microbial communities. We investigated this hypothesis using both pure laboratory cultures and with samples of natural biofilms collected across oxygen and sulfide concentration gradients in the field. Field samples were collected from the sulfidic Frasassi cave system, Italy, where the geomicrobiology of abundant sulfur cycling biofilms have previously been studied in detail. Samples were collected, freeze-dried and analyzed by atmospheric pressure chemical ionization liquid chromatography/mass spectrometry (APCI-LC/MS). To quantify on the LC/MS system we developed four standards and a protocol to characterize response factors for representative bacteriohopanpolyols (BHPs): Bacteriohopane-32,33,34,35-tetrol (BHT), bacteriohopanetetrol cyclitol ether, bacteriohopanepentol cyclitol ether and pregnandiol. The hopanoid standards were grown in cultures, extracted, and purified with a two dimensional HPLC separation technique. We accounted for drift in our quantitation protocol.

Our preliminary samples show a wide diversity in structures (eight) and abundance throughout the cave system. We are investigating correlations in structures, abundances, geochemistry and microbiology. We will apply a multivariate statistical approach. We observed six different BHPs in cultured *Acidithiobacillus sp.* including one new structure, tentatively identified as an unsaturated bacteriohopanepentol. A cave sample of *Acidithiobacillus sp.* dominated biofilm only produced three structures. Future work will quantify the cultures grown in varying media. The ultimate goal of this work is to link ecological, physiological and environmental changes to biomarkers in a rich-rich system that is an analogue to early earth systems.

Holocene Black Sea Cyanobacterial Ecology Elucidated by Pigments and Nitrogen Isotopes

Jamey Fulton
Mike Arthur and Kate Freeman
Post comps and Petroleum theme

Stratified oceans of the Phanerozoic Oceanic Anoxic Events apparently were dominated by bacterial nitrogen fixation. Decreased marine N:P nutrient ratios resulting from increased denitrification and decreased phosphate burial efficiency under anoxic waters drove this nutrient regime. This model is upheld by the presence of cyanobacterial hopanoid biomarkers in sedimentary records and $\delta^{15}N$ values indicative of nitrogen fixation. However, in the largest modern redox-stratified marine basin, the Black Sea, bacterial nitrogen fixation seems to be only a minor contributor to the nitrogen cycle. In this study, we use geochemical proxies to evaluate the role of bacterial nitrogen fixation during the deposition of the Holocene Black Sea sapropel, starting 7.8 ka. We report bulk and compound-specific nitrogen stable isotope values of pyropheophytin *a* as well as the surprising finding of scytonemin, a pigment produced only by cyanobacteria exposed to ultraviolet radiation, in certain intervals in these sediments.

In the Holocene, nitrogen fixation in the Black Sea was most prominent during times when the chemocline was deeper than in the modern water column. Apparently a decrease in density contrast between surface and deep waters allowed deeper seasonal mixing and the upwelling of phosphorus-rich deep waters and subsequent decreased N:P nutrient ratios favoring bacterial nitrogen fixation. Nitrogen fixation is recorded in the sediments as bulk and compound-specific pyropheophytin *a* $\delta^{15}N$ values near 0 ‰ and -5 ‰, respectively. We have also detected scytonemin in two intervals characterized by especially low $\delta^{15}N$ values. This compound suggests abundant filamentous or colonial cyanobacteria were living at the sea surface, a marked ecological shift from modern phytoplankton distributions. These data support the hypothesis that cyanobacterial nitrogen fixation, at times, contributed significantly to the Black Sea nitrogen cycle. Interestingly, nitrogen fixation did not dominate the entire time period of sapropel sedimentation and stable stratification. This finding suggests that high influx of fluvial nitrate into the Black Sea limits its utility as a modern analog for studying nitrogen cycling during oceanic anoxic events.

Timing and Magnitude of Upper Crustal Shortening in the Gonghe Basin Region of the Northeastern Tibetan Plateau

William H. Craddock
Eric Kirby
Post-comps

Characterizing the space-time patterns of the growth of high topography in Asia is an important step toward a deeper understanding of the mechanics of intracontinental deformation and its influence on global climate. In northeastern Tibet, there is emerging evidence that a number of ranges around the margins of the plateau experienced a pulse of deformation in the Late Miocene (ca. 12-8 Ma). It remains uncertain, however, whether this event was confined to the margins of the plateau, or whether interior regions deformed synchronously. Here we present a preliminary assessment of the timing and magnitude of upper crustal shortening along the margins of the Gonghe-Tongde basin complex. The Gonghe basin is located at the boundary between the high plateau of central Tibet and the southern flank of the Qilian Shan, and as such it is well-suited as a site to begin reconstructing patterns of plateau growth. The basin is overthrust by two regionally-extensive fault systems, the Qinghai Nan Shan (QNS) fault system on the north side and the Gonghe Nan Shan (GNS) fault system on the south side. Both fault systems are associated with deformation of Tertiary strata; variations in dip, sedimentary facies, and provenance are used to interpret the onset of growth along the margins of the Gonghe basin. A combination of the architecture of pre- and syntectonic basin strata, field measurements of fault dip, fault plane solutions, and topographic analysis of fold backlimbs for the GNS and QNS leads us to infer that the fault systems are a) trishear fault propagation style thrust faults and b) south vergent, with ~30° degree fault ramps soleing into a gently dipping decollement. Reconstructions of fold evolution suggest that the area has experienced > 5 km of upper crustal shortening in the late Cenozoic. A combination of magnetostratigraphy, biostratigraphy and cosmogenic burial ages provides preliminary age control. South of the GNS, a 250 m thick package of growth related strata are found to be 3.4 – 0.5 Ma. A 500 m thick exposure of growth strata on the north side of the range is also interpreted to be Plio-Quaternary in age. At present, however, we can only place a minimum bound on the onset of deformation of ca. 4-5 Ma. In light of a companion study interpreting the onset of deformation along the QNS at ≥ 5-7 Ma, deformation of the Gonghe region appears to be slightly more recent than at the plateau margins. Historic seismicity and deformation of late-Quaternary alluvial surfaces on both fault systems indicate that these structures have remained active into the Pleistocene.

Solute Transport in Clay Rich Materials: Controls of Physical and Chemical Processes

Brad Kuntz
Kamini Singha
M.S. Student

Solute transport in shale and clay-rich materials is particularly difficult to ascribe to one process because these low permeability materials restrict flow, increasing the residence time and therefore permitting extended interaction between solute and matrix. Interpreting solute transport processes such as advection, sorption, and diffusion in clays and shales is challenging because of chemical heterogeneity, physical and hydraulic variations within the shale-soil system. As a result, characterization of solute transport processes in shallow systems that includes both shale and shale-derived soil can be easily attributed to either a physical or chemically driven process with little verification. I will conduct laboratory experiments on shales and shale-derived soils to differentiate the important physical and chemical processes of solute transport by quantifying solute transport parameters as a function of material.

This research will document how solute transport behavior changes as a function of material and the operation of physical and chemical parameters controlling transport in low permeability settings. Conceptual models of chemical and physical processes have been used to explain transport that does not fit classical advective-dispersive behavior, as seen at countless sites. Two common models are (1) the nonequilibrium sorption model and (2) the dual-domain mass transfer model. For example, diffusion of solutes between stagnant water zones and a mobile domain has been used explain longer-than-anticipated solute transport times. Similarly, adsorption and desorption processes can also be invoked to explain longer-than-anticipated solute transport times. I hypothesize that delayed solute transport in soils will be controlled primarily by adsorption, whereas similar behavior in shale will be controlled by diffusion between mobile and immobile domains. The soil materials are likely to have more surface sites permitting ion exchange processes. Transport in shale, on the other hand, is generally accommodated by secondary porosity structures such as fractures and bedding planes, therefore ion exchange processes may be limited to these surfaces such that nonequilibrium behavior is largely a function of dead-end pore space.

By developing controlled experiments, I will focus on the how the parameters controlling physical and chemical mass transport mechanisms operate. This research is unique in that it will capture solute transport as a function of chemical and physical parameters in shales and the soils derived from such, while also enabling us to predict solute transport on geologic time scales.

Differential Preservation of Marine Environments and Biased Diversity Trends: Modeling Effects and Empirical Validation

Matthew J. O'Donnell
Mark E. Patzkowsky
M.S. Student

How well do observed patterns in fossil diversity reflect the original trends? This question has troubled paleobiologists for decades and has inspired a flurry of recent research. Clearly the amount of rock preserved at any given time will determine the number of fossil taxa recovered, but the picture is much more complicated. During changes in sea level, certain environments are preserved better than others. Since actual diversity varies among environments as well, any differential preservation of environments will bias preserved diversity trends. We offer a model to explore the possibility of a preservation bias in observed diversity trends. Within a framework of an onshore-offshore gradient with multiple environments, gradients of diversity, extinction, and preservation are applied to produce a degraded diversity record. The interactions of these three gradients can produce diversity, origination, and extinction trends which mimic those seen in the fossil record. While preservation cannot fully explain all variations in the fossil record, the model suggests that preservation may be partly responsible, and in some cases play a significant role. We use some empirical data for each of the three gradients to validate the model and compare synthetic data to actual data.

Copper Isotope Fractionation During Leach Layer Development on Cu-sulfide Minerals

Andrew Wall
Peter Heaney
Post comps

Previous studies have shown that upon oxidation and release of Cu from chalcocite (Cu_2S), covellite (CuS) will form after proceeding through a complex series of intermediate phases. Here we investigate the influence of mineral leach layers on Cu isotope fractionation by combining time-resolved X-ray diffraction, electron dispersive spectroscopy (EDS), and isotope analysis.

Flow-through capillary reaction cells were packed with pure, naturally occurring chalcocite powders and exposed to various concentrations of aqueous ferric sulfate for up to 6 hrs. Real-time diffraction data were collected at intervals of 2 min at beam line X7B, National Synchrotron Light Source. The $\delta^{65}Cu$ values of the leached Cu as well as the starting and final powders were measured using a Finnigan Neptune multi-collector inductively coupled plasma mass spectrometer. Cross sections of leached powders were analyzed using an Oxford Inca 200 EDS to obtain Cu:S ratios.

Isotope analysis and diffraction data revealed that during the initial stages of the reaction when chalcocite was present the average $\Delta_{(aq\text{-}min)}$ value was 3.19+/-0.14‰. At the endpoint of the reaction where only covellite appeared the $\Delta_{(aq\text{-}min)}$ value averaged -1.15+/-0.14‰. These values decreased throughout the reaction as intermediate phases formed and disappeared. Preliminary EDS results confirm that Cu:S ratios decrease from the core to the edge of the mineral grains. This evidence supports diffraction data to suggest that oxidation proceeds stepwise from the exterior to the interior of Cu sulfide grains, generating a sequence of intermediate phases that concentrically rim the grains. The formation of these phases and the concomitant changes in $\Delta_{(aq\text{-}min)}$ values indicate that a combination of redox isotope effects and the growth of mineral leach layers control Cu isotopic fractionation during dissolution.

Biochemical and Morphological Indicators of Light Regime in Extant and Fossil Leaves: Identifying Canopy Closure in Ancient Forests

Heather V. Graham
Kate Freeman
Pre-comps

Forests with closed canopies are of enormous climatic and ecological significance, affecting albedo, hydrologic cycles, atmospheric circulation, and the carbon cycle. Closed canopy forests provide a great variety of microhabitats into which much of the diversity of life has specialized. The geologic history of closed canopy forests is poorly known, however, because fossils seldom preserve information on tree spacing, size, or branching. The purpose of this study is to determine which leaf features in living forests indicate the existence of a dense canopy and the sensitivity of these features to environmental conditions within stratified forests. In this study I will sample along a vertical light gradient in an extant forest measuring morphological and biochemical leaf traits known to vary within canopies and concentrating on those leaf traits that are preserved in the fossil record. By considering irradiance a driver of physiological responses, which are in turn expressed as changes in measurable anatomical features and biochemical properties, a closed canopy forest could be identified in fossil assemblages as co-existing leaves expressing morphological and chemical features appropriate to different irradiance regimes. This study will develop new tools that can be used to infer the existence of closed canopy forests in the past, dramatically improving our understanding of when and where closed canopy forests appeared, and how they may have affected climate and the evolution of the lineages that specialize in this habitat. This study offers a comprehensive collection of biochemical, anatomical and physiological features, increasing our understanding of ecophysiological response to light.

Friday Morning Talks

TIME	PRESENTER	ADVISOR	TITLE
9:00	Aubreya Adams	Andy Nyblade	Rayleigh Wave Phase Velocities in Southern Africa
9:15	Marco Finotello	Jordi Julia & Andy Nyblade	Crustal Structure Along the Transantarctic Mountain Front Using Receiver Functions
9:30	David Yoxtheimer	Andrew Nyblade	Use of the Square Array Direct-Current Resistivity Method for Characterizing Karst Aquifers
9:45	Jon Erik Samuelson	Chris Marone	Modeling the Effect of Quasi-Drained Fault Zone Dilatancy on Friction Constitutive Properties
10:00	BREAK		
10:15	Bryn Kimball	Sue Brantley & Jenn Macalady	Using TEM and μ-XRF to Characterize Bacterially- Mediated Precipitation of Dissolved Copper
10:30	Aaron Regberg	Sue Brantley & Kamini Singha	Electrical Conductivity Associated with Dissimilatory Iron Reduction: Are Microbial Biofilms Conductive?
10:45	Elizabeth Herndon	Sue Brantley	Impact of Aeolian Deposition on Mn Cycling in Soils
11:00	Christopher K. Junium	Mike Arthur	Globally Distributed Black Shale Deposition was Fueled by Nitrogen Fixation During the Cenomanian-Turonian, Oceanic Anoxic Event II

(continued on next page)

Friday Morning Talks (cont)

TIME	PRESENTER	ADVISOR	TITLE
11:15	BREAK		
11:30	Jonathon Schueth	Tim Brawlower	Multivariate Analysis of Microplankton Reovery After the Cretaceous-Paleogene (K-P) Mass Extinction
11:45	Leah Schneider	Tim Brawlower & Lee Kump	Variations in Nannoplankton Populations and Oceanic Water Column Stratification During the Late Early Eocene
12:00	Melissa Pardi	Russell Graham	Pleistocene Mammal Community Without Modern Analogs: Fossil Vertebrates From Don´s Gooseberry Pit, Black Hills, SD
12:15	Aaron Diefendorf	Kate Freeman	ΔC_{leaf} Relationships with Phylogeny, Leaf Habit, and Climate: Implications for Interpreting Paleoecology and Paleoclimate
12:30	Tim Fischer	Peter Heaney	Manganese Oxide Dissolution in Response to Biotic and Abiotic Stimuli: Insights from XAS and Synchrotron Diffraction Action
12:45-1:45	Sarah Das	PSU Alumni Award Recipient	Slip Sliding Away? Investigating Greenland Meltwater Routing and Ice Sheet Response

Rayleigh Wave Phase Velocities in Southern Africa

Aubreya Adams
Andrew Nyblade
Post-comps

Rayleigh wave phase velocities are examined in Southern Africa using data from a combination of AfricaArray stations and public stations to examine the structure of the crust and upper mantle beneath the Kaapvaal Craton and surrounding regions. This study employs a non-traditional method of measuring phase velocities by approximating the wave-field generated by each earthquake as two plane waves. Using this two plane-wave approximation, we are able to match the characteristics of the wave field as it enters the area of our study better than is possible using more traditional, single plane-wave methods. This allows us to more accurately model velocities within our study area.

Phase velocity curves as a function of period, which is analogous to depth, are presented for the study area. Velocity maps show the variations in velocity at each period throughout the study area. Future developments in this project, including inverting for anisotropic phase velocities and the inversion of phase velocities for shear-wave velocities, will be explored.

Crustal Structure Along the Transantarctic Mountain Front Using Receiver Functions

Marco Finotello
Jordi Julia and Andrew Nyblade
M.S. Student

In this work, we investigate the crustal thickness variation along the front range of the Transantarctic Mountains using teleseismic waveforms recorded by the Transantarctic Mountain Seismic Experiment (TAMSEIS). From 2000-2003 this experiment deployed 41 three-component broadband seismometers that were divided into three geographic arrays: Coastal, East-West, and North-South. Receiver functions were computed for 16 stations that are located on bedrock to avoid complications caused by reverberations in the ice layer. Estimates of crustal thickness and bulk Vp/Vs ratio were obtained using the H-κ stacking method. The P-to-S (Ps) converted phase across the crust-mantle boundary is clearly observed in all the stations, but the reverberation of the crustal multiples (PpPs, PsPs+PpSs) are difficult to identify. The lack of multiples likely indicates that the crust-mantle boundary is gradational, thus making difficult to estimate bulk Vp/Vs ratios accurately. Variations in the earth structure around the stations were also investigated, but no dependence of crustal properties with back-azimuth has been found. Finally, preliminary results indicate that the crust beneath the crest of the Transantarctic Mountains is ~39 km thick, in contrast to thicknesses ranging between 30 and 35 km along the mountain front.

Use of the Square Array Direct-Current Resistivity Method for Characterizing Karst Aquifers

David Yoxtheimer
Andrew Nyblade
Post-comps

The use of standard collinear electrical resistivity surveying methods have been demonstrated to be useful for characterizing the presence of voids, caves, and other karst features in carbonate bedrock settings by many researchers. The square array technique was originally developed as an alternative to conventional collinear arrays when dipping subsurface, bedding, or foliation was present. This research builds on the foundation of previous square array work to characterize karst bedrock aquifers to estimate preferred aquifer anisotropy orientation and ultimately to predict groundwater flow directions. In this research project the upper portion of fractured, karst bedrock aquifers are being investigated through use of the square array resistivity method to characterize karst aquifer anisotropy due to bedrock fracture systems. The initial results from the analysis of square array data collected from the karst aquifers indicate that the electrical anisotropy coefficent increases with depth and the minimum resistivity measurements are coincident with bedrock strike and/or mapped fractures. Groundwater flow in these complex fractured bedrock aquifers is generally coincident with either bedrock strike on a regional basis or fractures on a localized basis, therefore the square array should be a useful tool for predicting local and regional groundwater flow directions.

Modeling the Effect of Quasi-Drained Fault Zone Dilatancy on Friction Constitutive Properties

Jon Erik Samuelson
Chris Marone
Post comps

Dilatancy may have a significant effect on the strength and stability of fault zones through increases in effective stress resulting from decompression of pore fluids. As fault accelerates from a slow steady background value to earthquake like velocities the porosity of the gouge layer may change [e.g. $\Delta\phi = -\varepsilon \ln(v_0\theta/D_c)$]. If the rate of fluid diffusion into the gouge layer is small compared to the rate of pore volume increase, the effective stress on the fault zone will increase, which may inhibit the nucleation of unstable slip. In addition to strengthening through an increase in effective stresses, the evolution of frictional strength may also change *via* changes in the rate and state friction parameters a, b, and D_c. Such changes may result from changes in contact junction properties, as a function of normal stress or porosity, or *via* granular effects. We explore such effects using a simple, 1-D elastic model for a gouge layer of known frictional strength (μ), permeability (k), initial porosity (ϕ_0), dilatancy coefficient (ε), and rate and state friction parameters (a, b, D_c). The gouge layer is saturated with water of bulk modulus (K_w), and has initial pore pressure (P_p), and viscosity (η). We conduct velocity stepping experiments and study evolution of friction, porosity, and effective stress using rate and state friction laws. Elastic interaction between the slider and the layer is controlled by the stiffness of the spring pulling the slider (K_s) at constant effective normal stress (σ_n-P_p) *via* the equation $d\mu/dt = K_s(v_{lp}-v)/(\sigma_n-P_p) + \mu/(\sigma_n-P_p)dP_p/dt$. This complex coupling can lead to changes in the effective magnitude of all of the rate and state parameters, a, b, and D_c, but at steady-state leave the combined friction rate parameter, a-b, unchanged. We explore the unsteady regime where the parameters are evolving, representing the case where the time of drainage in the gouge layer is long compared to the time necessary for the new steady-state porosity to evolve (θ). We investigate these changes by modeling a range of drainage parameters ($k,\eta,\varepsilon,\phi_0$) paying particular attention to ε, which we determined experimentally for fine grained quartz sand (4.7e-5 at 0.8 MPa to 3.8e-4 at 30 MPa), Westerly granite gouge (2.0e-4 at 5 MPa to 1.2e-4 at 30 MPa), and clay rich ODP gouge (1.5e-4 at 5 MPa to 1.1e-4 at 30 MPa). We invert our model output results to obtain effective values of the friction parameters a, b, and D_c. Early results indicate (using ε = 5e-4, ϕ_0 = 0.15, and a 10-30 μm/s velocity step) that D_c can be effectively doubled as a result of undrained fault zone depressurization.

Using TEM and µ-XRF to Characterize Bacterially-Mediated Precipitation of Dissolved Copper

Bryn E. Kimball
Susan Brantley and Jennifer Macalady
Post-comps

This study focuses on interactions of dissolved Cu with both the Fe- and S-oxidizing Proteobacterium *Acidithiobacillus ferrooxidans*, a prokaryote found in acid rock drainage, and the abundant ferric minerals that form during *A. ferrooxidans* growth. We used Transmission Electron Microscopy (TEM) and Energy Dispersive X-ray Spectroscopy (EDS) to image and characterize cells grown at pH 2.0 in medium with 0, 0.1, 1, and 10 mM Cu added. We also used micro-X-ray fluorescence microscopy (µ-XRF) to characterize the chemistry of single cells and surrounding precipitates.

We analyzed precipitates with no cells (abiotic), precipitates with live cells, and precipitates with dead cells. Abiotic precipitates were globular, 0.5 – 0.75 µm in size after 2 days, contained O, P, S, Fe, and trace Cu, and were noncrystalline. Live biotic precipitates were 0.5 µm after 2 days and 1.5 µm after 7 days, chemically similar to abiotic precipitates but lacked P, and were crystalline. These precipitates were jarosite based on X-ray diffraction. Dead biotic precipitates were 20 – 50 nm in size after 6 days, were chemically similar to abiotic precipitates, and did not diffract electrons.

Cells grown in all experiments exhibited granules, with an average P/O = 0.37 ± 0.08 (atomic %) based on EDS, indicative of polyphosphate granules. Copper (and Fe) was associated with these granules. Copper was also a component of the jarosite precipitates. Copper likely coprecipitated with jarosite since the pH was too low for adsorption.

Preliminary µ-XRF results showed higher Cu concentrations within a dead cell relative to extracellular precipitates, with the highest concentration in the polyphosphate granule. We expect further µ-XRF on live cells to reveal cytoplasms free of Cu, and polyphosphate granules with only trace Cu, if any. This work reveals that live and dead *A. ferrooxidans* cells, as well as ferric precipitates, can remove dissolved Cu from solution at low pH. Future work aims to determine how significant these potential sinks are in affecting metal mobility in natural environments.

Electrical Conductivity Associated with Dissimilatory Iron Reduction: Are Microbial Biofilms Conductive?

Aaron Regberg
Susan Brantley & Kamini Singha
Post-comps

Dissimilatory iron reducing bacteria like *Shewanella* and *Geobacter* play an important role in the global iron cycle. However, the geochemical samples necessary to calculate field scale reaction rates of iron reduction are expensive to collect and difficult to obtain. Recently, geophysical signals like resistivity, induced polarization and self potential have been associated with zones of increased biogeochemical activity in the field and the laboratory. These techniques are cheaper to implement and offer the promise of continuous automated data collection. We present data from batch experiments in the laboratory that suggest a geochemical reaction rate is obtainable by measuring changes in geophysical parameters. Geophysical and geochemical reaction rates were within 25% of each other. However, in some cases, the clear link between geophysical measurements and geochemical changes may be obscured by the presence of bacteria. Laboratory data from flow through reactors reveals an anomalous geophysical signature that cannot be explained by changes in geochemistry. We model the data using percolation theory to describe the presence and growth of an electrically conductive biofilm on mineral surfaces. Microbial biofilms must be between 5 and 75 times more conductive (depending on the exact number of bacteria) than the surrounding fluid to account for the anomalous conductivity signals measured. Finally, we present preliminary data from electrochemical experiments that demonstrate a 3 order of magnitude increase in electrical conductance as biofilms form on graphite electrodes. Geophysical measurements do respond to dissimilatory iron reduction and may be able to track microbial reaction rates if the question of biofilm conductivity can be adequately resolved.

Impact of Aeolian Deposition on Mn Cycling in Soils

Elizabeth Herndon
Susan Brantley
Pre-comps

Aeolian mass transport is a potentially critical, yet largely unrecognized, component of the manganese cycle. Mn is an essential micronutrient for plants and animals; however, high Mn exposure can lead to neurological disease in humans and forest decline in sensitive ecosystems. Furthermore, reactive Mn-compounds can affect organic matter breakdown, nutrient cycles, and heavy metal mobility. High Mn levels are observed in soils at the Susquehanna Shale Hills Observatory (SSHO), a forested watershed in central Pennsylvania, USA. The SSHO is a Critical Zone Observatory established to examine regolith evolution on shale. Using the mass transfer coefficient, $\tau_{Ti,Mn}$, to evaluate Mn mobility in the regolith, we find that surface soils are enriched relative to the parent shale ($\tau_{Ti,Mn} = 5.18 \pm 4.9$). Here, we present findings that Mn addition to SSHO soils is best explained by industrial-aged aeolian inputs and propose a mass balance model to quantify atmospheric deposition. Elevated Mn concentrations in foliage (4,600 ± 1,500 ppm), leaf litter (8,500 ± 1,000 ppm) and the organic horizon (16,400 ± 13,800 ppm) indicate active cycling by vegetation; therefore, biotic mixing is incorporated into the model in order to evaluate the role of biota in creating the observed addition profile. Additionally, x-ray absorption spectroscopy is used to characterize structural and redox changes in Mn-compounds through biogeochemical cycling.

Analysis of soils data from throughout the United States and Europe suggests global patterns of Mn enrichment in surface soils coincident with industrial or population centers. The SSHO field study can provide a comprehensive analysis of biogeochemical Mn cycling and may have international relevance concerning the long-term effect of industrial Mn emissions on ecosystems.

Globally Distributed Black Shale Deposition was Fueled by Nitrogen Fixation During the Cenomanian-Turonian, Oceanic Anoxic Event II

Christopher K. Junium
Michael A. Arthur
Post-comps

Widespread expansion of suboxic water masses during the Cretaceous, Cenomanian-Turonian Oceanic Anoxic Event II (OAE II, 93.5 Ma) impacted significantly the balance of the global marine nitrogen cycle. Here I present compound specific $\delta^{15}N$ data from chlorophyll *a*-derived geoporphyrins, a global bulk $\delta^{15}N$ dataset and the results of a N-cycle isotope mass balance box model that support an extraordinary expansion of nitrogen fixation-enhanced primary productivity during OAE II. Geoporphyrin $\delta^{15}N$ data from Demerara Rise confirm that stratigraphic variability and absolute values of bulk $\delta^{15}N$ values during OAE II reflect primary changes in the nitrogen cycle. During OAE II primary producers in much of the Cenomanian Turonian ocean utilized dissolved inorganic nitrogen (DIN) that was ^{15}N-depleted and supplied by diazotrophic bacteria. Modeling results reflect a global negative shift in the $\delta^{15}N$ of DIN which is observed in the sedimentary $\delta^{15}N$ record. These results support a tight coupling between dentrification, nitrogen fixation and the phosphorus cycle on a global scale. Widespread nitrogen fixation and high carbon burial rates during OAE II require a high phosphorus flux from a larger deep-water phosphorus reservoir and decreased burial efficiency. This model is in stark contrast with those that invoke stratification and stagnation to promote anoxia. Rather, increased supply via advection of phosphorus, and micro-nutrients such as iron to the surface from deep waters stimulates biological nitrogen fixation, allowing the elevated organic matter flux that is the necessary condition for long-term anoxia.

Multivariate Analysis of Microplankton Reovery After the Cretaceous-Paleogene (K-P) Mass Extinction

Jonathan Schueth
Tim Bralower
M.S. Student

The Cretaceous-Paleogene (K-P) mass extinction resulted in the near complete destruction of planktonic ecosystems in the ocean. While the extinction has been well documented, the recovery from such a catastrophic event is not well understood. Calcareous nannoplankton and planktonic foraminifera provide excellent data to investigate ecosystem recovery because they have a detailed and well-preserved record across the K-P boundary, and nannoplankton (primary producers) and foraminifera (secondary producers) are at the base of the oceanic ecosystems. This is the first study that quantifiably compares the recovery of both calcareous nannoplankton and planktonic foraminifera on a global scale. Using Non-metric Multidimensional Scaling (NMS) of samples from five locations around the world, we seek to test the following hypotheses: (1)Nannoplankton and foraminifera recovery is related because it is believed that nannoplankton were a food source for foraminifera. (2)An impact-related environmental force controlled the recovery of calcareous plankton. (3)Planktonic ecosystems recovered when diversity reached pre-extinction levels. From the analysis, it was determined that environmental stress was the primary variable influencing post-extinction recovery. The results of the analysis show a strong geographical trend with northern latitude sites being more stressed than southern latitude sites. This indicates an impact-related stress such as heavy metal loading, which would have been focused in the northern hemisphere by oceanic and atmospheric currents, was the primary factor that controlled microfossil recovery. Foraminifera are more stressed after the extinction than nannofossils in the open ocean, while nannofossils were more stressed in shelf sections. Forams may have been able to recover more quickly after the extinction on shelf sections because the nannoplankton shelf assemblages, which were dominated by small, weakly calcified taxa, provided a better food source for foraminifera than the larger, more strongly calcified nannoplankton that dominated open-ocean assemblages. A definition for ecosystem recovery was determined by comparing the NMS results with Shannon-Weaver diversity and paleoenvironmental interpretations for microfossil taxa. Recovery took place when the environmental stress lessened allowing for an increase in diversity of planktonic organisms. The removal of environmental stress also resulted in the evolution of ecologic specialists further signifying a recovery from the K-P extinction event.

Variations in Nannoplankton Populations and Oceanic Water Column Stratification During the Late Early Eocene

Leah Schneider
Tim Bralower and Lee Kump
Pre-comps

The efficiency of the global oceanic biological pump (OBP) has the potential to significantly influence atmospheric pCO_2 levels and, in turn, climate. During the Eocene, in one of the most pronounced cooling intervals of the Cenozoic, enhanced oceanic productivity has been suggested as a mechanism for the long-term draw down of pCO_2. The initiation of the Eocene-Oligocene transition is marked by a significant turnover in global nannoplankton assemblages as well as changes in the biologic pump and water column stratification as indicated by stable isotopes. The similarity in the timing of these events suggests a connection between plankton populations and water column conditions. Between 50 and 45 Ma, the genus *Reticulofenestra* dramatically increased in abundance and retained its dominance through the Eocene/Oligocene boundary. This trend is global, including low latitude settings where the evidence for the cooling of surface waters during this transition has been contested. The changes in nannoplankton populations are strongly tied to decreasing surface temperature and water column gradients, both of which are tied to enhanced nutrient supplies. By using traditional micropaleontological techniques, multivariate statistics, and stables isotopes, we are able to demonstrate a link between nannoplankton origination and oceanographic setting during a major climatic transition.

Pleistocene Mammal Community Without Modern Analogs: Fossil Vertebrates From Don's Gooseberry Pit, Black Hills, SD

Melissa I. Pardi
Russell W. Graham
M.S. Student

Late Quaternary faunas from the northern Great Plains are important for paleoecological studies due to their close proximity to the ice front during the last glaciation, and for the novel biological communities preserved in their records. Because the late Pleistocene-Holocene transition is characterized by rapid fluctuations in climate and dynamic reorganization of ecological communities, it is a time of great interest to paleoecologists, biogeographers, and conservation biologists. Don's Gooseberry Pit, a pit cave in the Black Hills of South Dakota, provides a unique opportunity to investigate mammal community reorganization because it contains the first relatively continuous Pleistocene/Holocene fossil record from the northern plains. Radiometric dating places this record between 5,000 yr B.P. (middle Holocene) and 17,000 yr B.P (full glacial); consequently, its diverse small mammal fauna documents change in community structure throughout the late Quaternary.

The late Pleistocene fauna is unlike anything seen in modern ecosystems. For example, lemmings that are currently restricted to the arctic tundra are found in association in fossil deposits with voles and other species that are restricted to habitats south of the boreal forest today. These non-analog faunas probably represent environments and habitats that do not exist today. Therefore, mammals responding to modern global warming may form new communities in the future. These issues are critical in formulating conservation plans for species and communities.

$\Delta^{13}C_{leaf}$ Relationships with Phylogeny, Leaf Habit, and Climate: Implications for Interpreting Paleoecology and Paleoclimate

Aaron F. Diefendorf and Kevin E. Mueller
Katherine H. Freeman
Post comps

Changes in plant ecology may be a significant—but often understated—factor controlling carbon isotope values of terrestrial organic carbon in the geologic past. For example, paleofloristic data in the Bighorn Basin (WY, USA) document a mixed angiosperm-conifer flora in the late Paleocene, which shifts to an angiosperm-dominated flora during the Paleocene-Eocene Thermal Maximum (PETM). This event correlates with a 2-3 ‰ increase in carbon isotope fractionation inferred from plant n-alkanes and bulk organic matter (Smith et al., 2007). An improved understanding of Δ_{leaf} has potential to provide insights to climatic and botanical factors underlying the large variability typically observed in ancient terrestrial organic carbon.

We have compiled a large data set comprised of Δ_{leaf} values for 249 species of woody plants (48 publications, 80 sites, 7 biomes, 57 Families, 151 Genera) delineated by leaf habit and phylogeny, and by climate, biome, and geography. We observe positive linear relationships between Δ_{leaf} and mean annual precipitation across all biomes, latitudinal zones and within plant functional groups.

We also observe statistically significant differences between leaf habit and phylogeny in our global dataset across biomes where 1) deciduous angiosperms have higher Δ_{leaf} than evergreen conifers and 2) deciduous conifers have higher discrimination than evergreen conifers. When comparing differences between leaf habit and phylogeny at individual sites, we observe larger Δ_{leaf} differences between plant functional types. Comparisons within a given site helps to limit variation in canopy effects, respiration, humidity, and precipitation and thus may have better specificity with regard to geologic samples. Our findings highlight a need to constrain ecological and precipitation effects prior to paleoclimate reconstruction or chemostratigraphy based on bulk carbon isotope records.