39th Annual Graduate Student Colloquium

Zion National Park, Utah submitted by Aaron Diefendorf

Sponsored by the
Department of Geosciences
April 16-20, 2007

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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 helps both the Department of Geosciences and Penn State to maintain and strengthen their reputations at national meetings for giving high quality talks and posters with visual appeal.

Schedule of Events:

Opening Reception	10:00 April 16th	EMS Museum, Ground Floor Deike
Poster Viewing	10:00 April 16th through 5:00 April 20th	EMS Museum, Ground Floor Deike
Talk Session 1	1:00-3:00 April 16th	541 Deike
Francios Chabaux, Department Colloquium Speaker	4:00 April 17th	22 Deike
Talk Session 2	9:00-12:00 April 18th	541 Deike
Talk Session 3	12:30-3:15 April 18th	541 Deike
Talk Session 4	9:00-12:00 April 19th	541 Deike
Poster Judging	11:00-1:00 April 19th	EMS Museum, Ground Floor Deike
Entropy and Grad Colloquium Prizes	6:00-??? April 20th	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, Chevron, and the Department of Geosciences for their donations of prize money and their generous financial support.

Committee Members 2007: Derek Sawyer (chair), Jennifer Nemitz (retiring chair), Doug Edmonds, Angela "Mouse" Larson, Wendy Nelson, Matt O'Donnell, Andy Rathbun, Julia Schneider, and Andy Wall

POSTER PRESENTATIONS

Posters will be on display in the Mineral Museum from 4/16 through 4/20

Presenter	Advisor	Title
Aubreya Adams	Andrew Nyblade	EARTHQUAKE FOCAL DEPTHS AND SOURCE PARAMETERS IN THE ZAGROS MOUNTAINS
Patrick Applegate	Richard Alley	REFINING MORAINE AGE ESTIMATES FROM COSMOGENIC EXPOSURE DATES USING THE MAXIMUM LIKELIHOOD METHOD
Brett Carpenter	Chris Marone	EARLY INSIGHTS INTO THE MECHANICAL BEHAVIOR OF MATERIALS IN THE 3D SAFOD VOLUME
Sean Culkin	Kamini Singha	EFFECTS OF RATE-LIMITED MASS TRANSFER ON EVOLUTION OF AQUIFER STORAGE AND RECOVERY EFFICIENCY
Mulugeta Dugda	Andrew Nyblade	THIN LITHOSPHERE BENEATH THE ETHIOPIAN PLATEAU REVEALED BY A JOINT INVERSION OF RAYLEIGH WAVE GROUP VELOCITIES AND RECEIVER FUNCTIONS
Timothy Fischer	Peter Heaney	BIOREDUCTION AND BIOMINERALIZATION KINETICS USING TIME-RESOLVED X-RAY DIFFRACTION
Patrick Fulton	Demian Saffer	THE EFFECT OF THERMAL REFRACTION ON HEAT FLOW SCATTER NEAR THE SAN ANDREAS FAULT, PARKFIELD, CA
Gavin Hayes	Kevin Furlong	QUANTIFYING REGIONAL VELOCITY RATIO IN CALIFORNIA: USING SEISMIC DATA TO MAP SHALLOW STRUCTURE
Daniel Hummer	Peter Heaney	NUCLEATION, GROWTH, AND PHASE TRANSFORMATION OF TITANIUM OXIDE NANOPARTICLES IN HYDROTHERMAL SOLUTION
Daniel Jones	Jennifer Macalady	BIOGEOCHEMISTRY AND GENOMICS OF EXTREMELY ACIDIC CAVE WALL BIOFILMS
Andrea Mullen	Eric Kirby	TRANSIENT BEDROCK CHANNEL EROSION RATES IN THE FINGER LAKES REGION
Jennifer Nemitz	Richard Parizek	CHEMISTRY RESPONSE OF AN ENHANCED WETLAND TO SECONDARY SEWAGE EFFLUENT LOADING
Leah Schneider	Timothy Bralower	CRETACEOUS-PALEOCENE CALCITE COMPENSATION DEPTH FLUCTUATIONS IN THE ATLANTIC AND PACIFIC OCEANS
Lucas Zoet	Sridhar Anandakrishnan	SEISMICITY ASSOCIATED WITH FLOW OF ANTARCTIC GLACIERS

EARTHQUAKE FOCAL DEPTHS AND SOURCE PARAMETERS IN THE ZAGROS MOUNTAINS

Aubreya Adams
Advisor: Andrew Nyblade

This study uses a two-step process to determine source parameters for six earthquakes originating within the Zagros Mountains of southern Iran, Turkey, and Iraq. Many public earthquake catalogs, which are compiled based on generalized global velocity models, list earthquakes in this region at depths greater than 35 km. Recent studies conducted within the region based on teleseismic records, however, have found no evidence of earthquakes at these depths. This has led to debates on the possibility of continuing subduction at the Eurasian-Arabian plate boundary, as well as about the distribution of strength within continental lithosphere.

We use a combination of moment tensor inversion and depth phase modeling to constrain earthquake focal depth and source parameters. We use a regional velocity model and local seismic records from both proprietary and public stations to invert for each earthquake's moment tensor, which represents motions at the earthquake source. We then model depth phases, which are waves reflected off of Earth's surface near the earthquake source, to confirm and refine the depths calculated via moment tensor inversion. All six earthquakes are limited to the upper 15 km, thus we do not find evidence in our study for deep (>35 km) seismicity within the Zagros Mountains. Depths calculated from this two-step process are shallower than those listed in public catalogs. This may indicate a bias in these catalogs for earthquake depths in the Zagros Mountains, which can be attributed to the use of a global velocity model in the compilation of these catalogs.

REFINING MORAINE AGE ESTIMATES FROM COSMOGENIC EXPOSURE DATES USING THE MAXIMUM LIKELIHOOD METHOD

Patrick Applegate
Advisor: Richard Alley

We suggest a procedure, based on the maximum likelihood method, for estimating the ages of moraines from cosmogenic exposure dates. The procedure described here was originally applied to radiocarbon ages in stratigraphic context by Sharon (2001, Radiocarbon, v. 43, p. 345-354; eqn. 4).

The maximum likelihood method uses stratigraphic information to refine estimates of moraine ages. In the case of two nested moraines, exposure dates from the inner, younger moraine provide information on the age of the outer, older moraine. To apply the maximum likelihood method, a likelihood function is evaluated at each possible value of the age of the outer moraine. The maximum likelihood estimate of the age of the outer moraine corresponds to the apex of this function.

Under some circumstances, the maximum likelihood method may provide a better estimate of a moraine's age than the mean of the dates from that moraine. To examine this hypothesis, Monte Carlo methods were used to generate synthetic data sets from two nested moraines. The variables in the Monte Carlo simulation were the difference in age between the two moraines and the number of dates available from each moraine. The age of the outer moraine was held constant at 20 ka. All of the dispersion of the dates on each moraine was assumed to be due to measurement error, which was taken to be 5% of the true age of each moraine. For each data set, the age of the outer moraine was estimated using the maximum likelihood method and the mean of the dates from that moraine. The two estimates were then compared to the true age of the outer moraine.

In general, the maximum likelihood method is a better predictor of the age of the outer moraine than the mean of the dates from that moraine in cases where the moraines are close in age (~1 ka or less for pairs of moraines about 20 ka old, assuming a measurement error of 5%) and more dates are available from the inner moraine than the outer. However, the maximum likelihood estimate of the age of the outer moraine depends partly on the difference in age between the moraines. Since the difference in age between moraines is usually not known, rigorous application of the maximum likelihood method is difficult. It can still be applied, on an ad hoc basis, where there is substantial overlap between the probability distribution functions of the dates from the inner and outer moraines.

EARLY INSIGHTS INTO THE MECHANICAL BEHAVIOR OF MATERIALS IN THE 3D SAFOD VOLUME

Brett Carpenter
Advisor: Chris Marone

A central problem in evaluating the relationship between fault zone properties and earthquake physics is a lack of detailed laboratory data for materials recovered from hypocentral depths. Gaining a better understanding of the strength and stability of the San Andreas Fault is important for assessment of earthquake hazards and linking observations of fault behaviors to physical processes. We report on experiments designed to explore the mechanical behavior of rocks in the 3D SAFOD volume. Experiments were conducted on fault zone materials recovered from SAFOD Phases I and II drilling and surface samples of rock formations present in the drill hole. Samples from San Andreas Drilling range in depth from 1.4 km to 4.0 km and surface samples include country rock, wall rock, and fault rock.

Experiments were conducted in a servo-controlled, double-direct shear apparatus at room temperature and humidity. Layers of pulverized fault and surface rock were sheared at constant normal stress between rough rigid forcing blocks. Normal stress and shear velocity ranged from 5 to 100 MPa and 1-300 micron/s, respectively.

We determine the Coulomb failure envelope and friction constitutive properties at a range of normal stresses. The coefficient of sliding friction is consistent over the entire normal stress range for each sample (we assume zero cohesion for the granulated layers) ranging from 0.20 to 0.63.

Velocity stepping friction experiments indicate that the samples 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. Measurements of steady-state friction as a function of slip velocity show velocity-weakening frictional behavior for some SAFOD materials at low normal stress.

These early experiments aim to begin populating a database used to constrain fault mechanical models as well as to explore the controls of strength and stability of SAF rocks. Future work will be aimed at determining the effects of temperature and pore/confining fluids on the strength and second-order frictional characteristics of fault zone materials.

EFFECTS OF RATE-LIMITED MASS TRANSFER ON EVOLUTION OF AQUIFER STORAGE AND RECOVERY EFFICIENCY

Sean Culkin
Advisor: Kamini Singha

Pressure to decrease reliance on surface water storage has led to increased interest in aquifer storage and recovery (ASR) systems, where boreholes are used to inject potable water into aquifers and to subsequently recover the stored water during times of peak demand or extended drought. The viability of an ASR scheme is usually measured by recovery efficiency, which is defined as the ratio of recovered water that meets a predefined water quality standard. At ASR sites, dual-domain rate-limited mass-transfer (RLMT), which describes the exchange of solutes between mobile and immobile porosity domains, may control transport behavior that cannot be explained strictly by advection and dispersion processes. Despite a lack of documentation in field experiments, RLMT may be a nearly ubiquitous phenomenon in heterogeneous geologic media. We use data from a pilot-scale ASR study in Charleston, South Carolina to develop a three-dimensional finite-difference model to evaluate the impact of flow and transport processes, including different mechanisms of mass transfer, on recovery efficiency. Varying connectivity between the ASR and observation wells suggest preferential flow through fracture networks in the aquifer zone. These geologic conditions, as well as single-cycle geophysical data, support our hypothesis that RLMT is affecting solute transport at this site. RLMT processes cause a rebound in salinity during storage in the fractured zones, which is successfully reproduced with a dual-domain porosity model. Single ASR-cycle model results demonstrate efficiencies on the order of 20%, notably less than the efficiencies of 100% reported by previous ASR simulations. We believe this discrepancy is due to mixing of pore fluids in the well-connected fracture network and stagnant connate water in dead-end and otherwise poorly-connected conduits during storage. Multi-cycle results show an increase in efficiency over time to 35%, consistent with pilot-study findings in the case of a dual-domain RLMT model. This contrasts with single-domain model results, which yield static efficiencies of over 60% for multiple cycles. For an idealized ASR model where RLMT is active, our simulations show an inverse relationship between mobile/immobile porosity ratios and efficiency, as well as a transfer coefficient range of 0.1 and 0.1d^{-1} where multi-cycle efficiencies are below 25%.

THIN LITHOSPHERE BENEATH THE ETHIOPIAN PLATEAU REVEALED BY A JOINT INVERSION OF RAYLEIGH WAVE GROUP VELOCITIES AND RECEIVER FUNCTIONS

Mulugeta Dugda
Advisor: Andrew Nyblade

The seismic velocity structure of the crust and upper mantle beneath Ethiopia and Djibouti has been investigated by jointly inverting receiver functions and Rayleigh wave group velocities to obtain new constraints on the thermal structure of the lithosphere. Most of the data for this study come from the Ethiopia broadband seismic experiment, conducted between 2000 and 2002. Shear velocity models obtained from the joint inversion show crustal structure that is similar to previously published models, with crustal thicknesses of 35 to 44 km beneath the Ethiopian Plateau, and 25 to 35 km beneath the Main Ethiopian Rift (MER) and the Afar. The lithospheric mantle beneath the Ethiopian Plateau has a maximum shear wave velocity of about 4.3 km/s and extends to a depth of ~70-80 km. Beneath the MER and Afar, the lithospheric mantle has a maximum shear wave velocity of 4.1-4.2 km/s and extends to a depth of at most 50 km. In comparison to the lithosphere away from the East African Rift System in Tanzania, where the lid extends to depths of ~100-125 km and has a maximum shear velocity of 4.6 km/s, the mantle lithosphere under the Ethiopian Plateau appears to have been thinned by ~30-50 km and the maximum shear wave velocity reduced by ~0.3 km/s. Results from a 1D conductive thermal model suggest that the shear velocity structure of the Ethiopian Plateau lithosphere can be explained by a plume model, if a plume rapidly thinned the lithosphere by ~30–50 km at the time of the flood basalt volcanism (c. 30 Ma), and if warm plume material has remained beneath the lithosphere since then. About 45-65% of the 1-1.5 km of plateau uplift in Ethiopia can be attributed to the thermally perturbed lithospheric structure.

BIOREDUCTION AND BIOMINERALIZATION KINETICS USING TIME-RESOLVED X-RAY DIFFRACTION

Timothy Fischer
Advisor: Peter Heaney

The facultative anaerobic bacteria *Shewanella* is known to reduce metals in solid metal oxides. Recent research by Shane Ruebush at Penn State has shown that total membrane (TM) fractions of *Shewanella oneidensis* MR-1 are also able to carry out the reduction using formate as an electron donor. The cell membrane effectively acts as a electron transport mechanism from the donor to the metal in the solid phase. We are looking at this process using time-resolved X-ray diffraction in an attempt to understand how microorganisms break down mineral phases and precipitate others. In time-resolved X-ray diffraction experiments, birnessite (Mn-oxide) is placed in a silica-glass capillary with TM and an electron donor in solution. As the TM reduces the Mn(IV) to Mn(II), the birnessite structure is broken down and the Mn(II) is released into solution. Once in solution, it combines with carbon from the organic electron donor to form rhodochrosite ($MnCO_3$). Using Rietveld refinements of the diffraction patterns, we can determine changes over time of phase percentages, unit cell parameters, and unit cell volumes to constrain the kinetics of biologically-mediated crystal breakdown and growth. This is powerful technique in determining phase changes in any mineral system. Here we show time-resolved X-ray diffraction patterns to illustrate that the kinetics of bioreduction and biomineralization in this system are controlled by TM concentration in the solution. Furthermore, after a month of reaction, all the the birnessite is transformed to rhodochrosite.

THE EFFECT OF THERMAL REFRACTION ON HEAT FLOW SCATTER NEAR THE SAN ANDREAS FAULT, PARKFIELD, CA

Patrick Fulton
Advisor: Demian Saffer

Heat flow data from the California Coast Ranges are noteworthy in that they 1) do not show evidence of a near-fault thermal anomaly as expected from frictional heating on the San Andreas Fault (SAF), and 2) they exhibit considerable spatial scatter – as a much as 15 mW/m^2 variation over distances of 5-10 km. Previous work has shown that in the area around the San Andreas Fault Observatory at Depth (SAFOD) site near Parkfield, CA, some of the scatter can be explained by 3-D terrain effects, but the remaining unexplained patterns are unlikely a result of frictional heating on the SAF and/or substantial redistribution of heat by topographically-driven groundwater flow.

Here, we evaluate the potential role of thermal refraction caused by differences in thermal conductivity (λ) of rock units in the subsurface. We use numerical simulations of heat transport along a transect perpendicular to the SAF near Parkfield to assess the heat flow patterns resulting from geologic structure and reasonable values of thermal conductivity. Thermal conductivity is partially constrained by measurements on core samples and chips, and is assigned for general geologic units: sediment cover, Salinian granite, Franciscan mélange, and serpentinite. Regional scale geologic structure is constrained by published geophysical interpretations of cross sections coincident with our model transect. Models are prescribed atmospheric conditions at the surface and a basal heat flux of 78 mW/m^2 representing the regional average heat flow.

Results show that with only the gross-scale heterogeneity in our models, considerable spatial scatter in heat flow is generated at 100-200 m depth, with magnitudes and wavenumbers similar to observations. In addition, simulated heat flow along our transect exhibits long wavelength trends that are remarkably similar to the corresponding data. Sensitivity analysis reveals that resulting heat flow patterns are most sensitive to the ratio in λ between sediments and underlying units, and to the geometry of the geologic contact and its proximity to the depth of the heat flow measurement. The observed heat flow patterns are consistent for a range of ratios of $\lambda_{bedrock}$ / $\lambda_{sediments}$, and are robust even with fine-scale adjustments to the geologic model. Our results suggest that thermal refraction may be a significant source of heat flow scatter in this region. However, our results suggest that it is unlikely that subsurface refraction conceals a frictional heating anomaly.

QUANTIFYING REGIONAL VELOCITY RATIO IN CALIFORNIA: USING SEISMIC DATA TO MAP SHALLOW STRUCTURE

Gavin Hayes
Advisor: Kevin Furlong

For several decades, seismologists have used a variety of different methods to model the P-wave velocity structure of the Earth, and in particular, the Earth's crust. Modeling of the S-wave velocity field has been (and remains) more difficult, and as a result S-wave velocity structure is often directly related to P-wave models through empirical measurements of the velocity ratio in rocks. These velocity models are subsequently used in many different types of analyses, such as the calculation of strong ground motions in regional hazard maps, earthquake locations, and the inference of subsurface geology. In all cases, better estimates of S-wave velocity models lead to more accurate models of the parameters they are used to describe. This is of particular importance for estimates of shallow S-wave velocity structure, where we need improved models to aid in any predictive hazard analysis.

Here, we develop a straightforward technique for computing apparent velocity ratio of both the bulk seismogenic crust and shallow crust throughout California based on P- and S-wave travel-times from earthquakes to the dense network of broadband and short-period stations across the state, significantly improved since the implementation of the Earthscope project. Using this approach, we produce regional maps of velocity ratio for all California, where station coverage is dense enough and rates of seismicity high enough to allow this type of analysis. We can also isolate the very shallow (generally aseismic) crustal section to construct a velocity ratio map of the near surface. This analysis produces data that can be interpreted as a regional hazard map, covering both areas previously included in localized studies and those other areas that up until now have only been poorly characterized.

This method, which we call the Local Velocity Ratio Calculation (LVRC), yields a simple yet powerful way to analyze the velocity ratio of the crust on a regional basis. The model compares favorably to the SCEC three-dimensional velocity model, providing confidence in the robustness of the approach. Results can be used to derive S-wave velocity models of the crust that can help quantify the earthquake ground shaking susceptibility in California and other similar areas worldwide, providing useful information to aid in the science of future hazard mitigation.

NUCLEATION, GROWTH, AND PHASE TRANSFORMATION OF TITANIUM OXIDE NANOPARTICLES IN HYDROTHERMAL SOLUTION

Daniel Hummer
Advisor: Peter Heaney

Fine grained titanium oxide minerals are environmentally important in soils, where they take part in a variety of geochemical processes. They are also industrially important as catalysts, pigments, food additives, and dielectrics. It is therefore of great importance to understand the aqueous nucleation and growth processes that produce these minerals, and how they influence the resulting nanoparticle assemblages. Recent research efforts have focused on an apparent reversal of thermodynamic stability between TiO_2 phases at the nanoscale that may be caused by the increased contribution of a surface energy term to the total free energy. This reversal often causes the anatase polymorph, which is less stable in the bulk, to crystallize in hydrothermal solutions rather than the more stable rutile structure.

Time-resolved X-ray diffraction experiments have been performed at the National Synchrotron Light Source (NSLS) at Brookhaven National Labs (BNL) in which titanium oxides are crystallized from aqueous $TiCl_4$ solutions between 100 and 200 ^{o}C, while diffraction patterns are collected at an interval of ~ 4 minutes. These experiments confirm that anatase is the first phase to nucleate from solution within the first ~ 20 minutes of heating, and then slowly begins converting to rutile. This phenomenon is general across the range of temperature and Ti^{4+} concentrations that have so far been explored. Preliminary kinetic models fit to time-resolved phase abundance data suggest that the rutile may form from anatase by a dissolution-reprecipitation process rather than direct solid state transformation. In addition, whole pattern refinement of diffraction data reveals the first observation of systematically changing lattice constants during particle growth, which occurs for both phases throughout the crystallization process. The unit cell dimensions eventually converge to values close to that for bulk crystals. This suggests a significant contribution of surface strain to the bulk structure of individual nanoparticles, and may represent an important new factor controlling the properties of hydrothermally crystallized materials.

BIOGEOCHEMISTRY AND GENOMICS OF EXTREMELY ACIDIC CAVE WALL BIOFILMS

Daniel Jones
Advisor: Jennifer Macalady

Extremely acidic (pH 0-1) microbial biofilms called snottites form on the walls of sulfidic caves, where gypsum replacement crusts isolate sulfur-oxidizing microorganisms from the buffering action of limestone host rock. We investigated the phylogeny and population structure of snottites from sulfidic caves in central Italy using full cycle rRNA methods, culturing, and metagenomics. A small subunit rRNA bacterial clone library from a Frasassi cave complex snottite sample contained a single sequence group (70 clones) similar to Acidithiobacillus thiooxidans. Bacterial and universal rRNA clone libraries from other Frasassi snottites were only slightly more diverse, containing 6 bacterial species and 2 archaeal species. Fluorescence in situ hybridization (FISH) of snottites from Frasassi and from the much warmer Rio Garrafo cave complex revealed that all of the communities are simple (low-diversity) and dominated by Acidithiobacillus and/or Ferroplasma species, with smaller populations of an Acidimicrobium species, filamentous fungi, and protists. Our results suggest that sulfidic cave snottites will be excellent model microbial ecosystems suited for ecological and metagenomic studies aimed at elucidating geochemical and ecological controls on microbial diversity, and at mapping the spatial history of microbial evolutionary events such as adaptations, recombinations and gene transfers. Metagenomic data from the Frasassi snottites confirm the population structure suggested by earlier work and offer new glimpses of the physiology and biogeochemistry of the snottite community.

TRANSIENT BEDROCK CHANNEL EROSION RATES IN THE FINGER LAKES REGION

Andrea Mullen
Advisor: Eric Kirby

Bedrock channels exert fundamental controls on landscape evolution, sediment flux, and the coupling of tectonics and climate. Although significant progress has been made in understanding fluvial bedrock erosion processes (e.g. plucking, cavitation and abrasion by suspended sediment or bedload), uncertainty remains regarding the applicability of various forms of incision rules to predict channel profiles and incision rates. Generic stream power or bed shear stress models contain parameters to which it is difficult to assign physical meaning. Process-based models improve upon the generic models by including measurable parameters, but their utility is limited by uncertainties in scaling up these parameters to geologic timescales and reach-averaged length scales. Attempts to calibrate or test these incision models in field sites have met with somewhat limited success, as many are confirmations that a certain model reproduces an observed profile form; few have attempted to exploit the transient response of channel profiles to known climatic or tectonic changes in boundary conditions, despite the expectation from theory that the transient response of different models can be diagnostic of model form and parameterization.

In order to quantify the transient response of bedrock streams, we exploited a natural experiment in the Finger Lakes Region of New York in which young streams have eroded deep gorges in the valley walls of the depressions containing Seneca and Cayuga Lake. These streams have eroded through a thin deltaic deposit into relatively uniform friable Devonian shale over the past 13,350 years after a drop in base level caused by the catastrophic drainage of Glacial Lake Iroquois. The amount of bedrock removed during this time through fluvial erosion can be estimated by fitting a smooth surface to relict terrain along the U-shaped valley to yield a reach scale erosion rate for each stream. We developed a dataset of incision rates, channel gradient, initial surface slope and drainage area for each stream. We employed this data to test a series of competing incision models to see which are best capable of predicting both the present-day profiles and time-averaged incision rates.

CHEMISTRY RESPONSE OF AN ENHANCED WETLAND TO SECONDARY SEWAGE EFFLUENT LOADING

Jennifer Nemitz
Advisor: Richard Parizek

As the Pennsylvania State University and other such communities grow in the near future, an increasing concern will be how to deal with the nutrient loading in wastewater. One possible solution to remediate the wastewater is to use natural, enhanced, and man-made wetlands to remove the nutrients. The enhanced natural wetland on the border of the Toftrees Golf Course and Penn State's Gamelands sprayfield was chosen as a test site. For this research project, we wanted to analyze the ability of the pond/wetland to remediate secondary sewage effluent. On November 21, 2005, secondary sewage effluent was added via a pipe to the Toftrees Pond/Wetland at a rate of approximately 100 gpm. Secondary effluent was continuously added through the research period until the cessation of the project on September 29, 2006.

Water samples were collected weekly from the both the inlet pipe and from a weir pool at the outlet of the pond. Samples were sent to Fairway Laboratories, Inc. and were analyzed for biological oxygen demand, total suspended solids, total phosphorus, ammonia, nitrate, nitrite, specific conductance, pH, alkalinity, chloride, and hardness. The chloride concentration was used as a conservative tracer. Average chloride concentrations dropped from 191 mg/l in the effluent to 161mg/l in the pond discharge, indicating a dilution effect from precipitation. The drop in nitrate concentration from an average of 11.5 mg/l in the effluent to an average of <1 mg/l at the outlet is too large to be from dilution, so denitrification must be occurring. Average total phosphorus concentrations dropped from 3.9 mg/l to 1.4 mg/l.

The Toftrees Pond/Wetland proved to be an effective system for removing nitrate and phosphorus from Penn State's secondary sewage effluent. The remediative capacity of Toftrees Pond was not stressed during the research period and could probably accommodate a much higher nutrient loading. However, problems such as increased pH (to pHs above 10) and increased sediment load must be dealt with before increased loadings can occur.

CRETACEOUS-PALEOCENE CALCITE COMPENSATION DEPTH FLUCTUATIONS IN THE ATLANTIC AND PACIFIC OCEANS

Leah Schneider
Advisor: Timothy Bralower

The calcite compensation depth (CCD) is the controlling factor for the deposition of deep sea carbonates. Because it is dependent on factors such as water chemistry, sea level, climate, primary productivity, and tectonics, fluctuations in the CCD are indicative of regional-global oceanographic changes. The most comprehensive research on changes in the CCD was completed in the 1970s and 1980s. Since that time there have been major advances in age control, significant revisions of the geologic time scale, as well as the completion of several more ocean drilling legs, all of which increase the resolution at which the CCD can be reconstructed. To determine the response of the Cretaceous and Paleocene oceans to climatic, oceanic, and tectonic events we have constructed CCD curves for the Atlantic and Pacific Ocean basins. Results show at least two instances of marked shoaling in the Atlantic during the middle to late Cretaceous while the Pacific Ocean levels remained constant until major perturbations in the latest Cretaceous. Data confirm previous studies and provide added constraints on the timing and magnitude of shifts in the CCD and their relation to major changes in climate and oceanography.

SEISMICITY ASSOCIATED WITH FLOW OF ANTARCTIC GLACIERS

Lucas Zoet
Advisor: Sridhar Anandakrishnan

We report on local and regional seismicity in the Transantarctic Mountains. The TAMSEIS (Transantarctic Mountains Seismic Experiment, 2000-2003) data were analyzed for source locations using P-wave arrivals. TAMSEIS consisted of 43 portable broadband seismographs deployed across the Trans-Antarctic Mountains and East Antarctica during 2001-2003. Large numbers of events, approximately 50 per day, were detected. The events cluster in the areas of the David Glacier and Drygalski Ice Tongue to the North and Darwin Glacier and Byrd Glacier to the South, with little activity in between. In addition to the greater seismicity of these two regions relative to the rest of the mountain chain, there also appears to be regularity in the timing of the more northerly seismic events at David Glacier. The events are neither uniformly distributed nor Poisson-distributed in time, but occur in isolated, concentrated bursts. The spacing between bursts is approximately one half day; we investigate hypotheses of daily periodicity vs. tidal periodicities. We hypothesize that the events are related to the motion of these outlet glaciers. These glaciers drain a significant portion of the interior East Antarctic Ice Sheet and are particularly important because of the relatively low flux of ice through the mountains in between (where the Dry Valleys are situated).

TALK SESSION - MONDAY AFTERNOON

Talks will be held Monday 4/16 from 1:00 - 3:00 in room 541.

Time	Presenter	Advisor	Title
1:00	**Brett Carpenter**	Chris Marone	THE EFFECTS OF NORMAL STRESS AND FORCE CHAINS ON THE TRANSITION FROM ROLLING TO JAMMING IN SHEARED GRANULAR MEDIA
1:15	**Patrick Fulton**	Demian Saffer and Barbara Bekins	DEHYDRATION OF THE FRANCISCAN ASSEMBLAGE AND FLUID OVERPRESSURE DEVELOPMENT ON THE SAN ANDREAS FAULT: A HYPOTHESIS TEST
1:30	**Evan Goldstein**	Eric Kirby	TESTING FLUVIAL INCISION MODELS IN LANDSCAPES UNDERGOING DIFFERENTIAL ROCK UPLIFT
1:45	**Jennifer Nemitz**	Richard Parizek	OCCURRENCE, FATE, AND TRANSPORT OF PHARMACEUTICALS AND PERSONAL CARE PRODUCTS IN AN ARTIFICIAL RECHARGE SYSTEM AT PENN STATE'S LIVING FILTER
2:00	**BREAK**		
2:15	**Yongcheol Park**	Andrew Nyblade	BODY AND SURFACE WAVE TOMOGRAPHY FOR THE ARABIAN PENINSULA AND RED SEA
2:30	**Derek Sawyer**	Peter Flemings	SHEAR-INDUCED STRESS, PORE PRESSURE, AND CONSOLIDATION IN FINE-GRAINED SUBMARINE LANDSLIDES
2:45	**Julia Schneider**	Peter Flemings	CONSOLIDATION, PORE PRESSURE, AND FLUID FLOW IN MUDSTONES OF BRAZOS-TRINITY BASIN IV, NORTHERN GULF OF MEXICO

THE EFFECTS OF NORMAL STRESS AND FORCE CHAINS ON THE TRANSITION FROM ROLLING TO JAMMING IN SHEARED GRANULAR MEDIA

Brett Carpenter
Advisor: Chris Marone
Masters

I report on laboratory experiments designed to investigate the transition from rolling to jamming in a granular medium under shear at constant velocity. The behavior of sheared granular materials is important in many industrial applications, mechanical lubrication, and geophysics as related to fault mechanics. In my experiments, layers of 550 μm diameter, soda-lime glass beads were sheared in a double-direct shear testing apparatus. Layers ranged in thickness from 1 bead diameter (a monolayer) to 3 bead diameters and normal stress was varied from 100 kPa to 750 kPa.

The steady-state coefficient of friction for a monolayer is 0.02, and increases to values over 0.10 for thicker layers. At a shear displacement rate of 10 μm/s, the friction of granular layers thicker than a monolayer is on the order of 0.12. A clear distinction between a rolling layer and a jamming layer is evident. Using jamming as a proxy for force chain formation, I determine that force chains are present within the layer as soon as the layer deviates from a perfect monolayer.

Jamming and the formation of force chains occur whenever the layer is thicker than a monolayer causing the differences in behavior between a rolling and jamming layer. Although present in layers ranging from 1.25 bead diameters to 3.00 bead diameters, force chains appear not to strengthen the layer as expected. Longer force chains should carry more stress and thus result in a frictionally stronger layer leading to the expectation that a 3.00 bead diameter layer would be frictionally stronger than a 1.25 bead diameter layer. I conclude that force chain length in these thin layers does not exhibit control on the frictional strength of the layer, but only the state of the layer, rolling or jamming.

DEHYDRATION OF THE FRANCISCAN ASSEMBLAGE AND FLUID OVERPRESSURE DEVELOPMENT ON THE SAN ANDREAS FAULT: A HYPOTHESIS TEST

Patrick Fulton
Advisors: Demian Saffer and Barbara Bekins
Post Comprehensive

Many plate boundary faults, including the San Andreas Fault (SAF), appear to slip at anomalously low shear stress. One long-standing explanation for a “weak” SAF is that fluid release by dehydration reactions during regional metamorphism generate near-lithostatic fluid pressures, which are localized on the fault and reduce the effective normal stress. We evaluate this hypothesis by calculating realistic fluid production rates for the SAF system, and incorporating them into 2-D fluid flow models. Our results show that fluid sources are too small and short-lived to generate, sustain, or localize fluid pressures on the fault sufficient to explain its apparent weakness, for a wide range of permeability distributions. Our results imply that alternative mechanisms, possibly acting locally within the fault zone, are necessary to explain fault weakness.

TESTING FLUVIAL INCISION MODELS IN LANDSCAPES UNDERGOING DIFFERENTIAL ROCK UPLIFT

Evan Goldstein
Advisor: Eric Kirby
Pre-Comprehensive

Fluvial incision into bedrock sets the local base level in mountain ranges and strongly modulates both the topographic character of the range and the geodynamic evolution of active orogens. Despite intensive investigation over the past decade, significant uncertainty remains regarding the applicability of various fluvial incision models in natural landscapes. In particular, the dependence of channel incision on the flux and caliber of sediment and the adjustment of channel width present challenges to modeling bedrock incision. Although theoretical considerations suggest that channel profiles adjusted to spatially invariant rock uplift may not be diagnostic of model form (Whipple and Tucker, 2002), channels adjusted to strong spatial gradients in rock uplift posses several characteristics, including variation in the direction of tectonic forcing relative to channel flow, which may help discriminate between competing models. Here we examine a suite of channels developed across and along a growing fold in the Himalayan foreland (using high-resolution satellite derived DEMs and aerial photography) in an effort to test the form and parameterization of several fluvial incision models. We utilize known channel incision rates (inferred to match the rock uplift field, e.g. Lavé and Avouac, 2000) to derive estimates of sediment flux. We measure channel gradients from DEMs and estimate channel width from high- resolution aerial photography to calibrate and test several models of fluvial incision at reach-averaged length scales and over geologic timescales. Our results suggest that channel gradients increase linearly with rock uplift/incision rate, and that channel width is invariant with incision rate across a range from 5-14 mm/yr. Although detachment-limited models (such as stream power) adequately capture increases in gradient observed on channels flowing against uplift-rate gradients (low to high), these models fail to capture profile form on the falling limb. Our results suggest that hybrid models explicitly accounting for the role of sediment in the channel may be better at predicting channel gradients in this landscape.

OCCURRENCE, FATE, AND TRANSPORT OF PHARMACEUTICALS AND PERSONAL CARE PRODUCTS IN AN ARTIFICIAL RECHARGE SYSTEM AT PENN STATE'S LIVING FILTER

Jennifer Nemitz
Advisor: Richard Parizek
Post-Comprehensive

Municipal wastewater treatment, remediation and reuse remain critical topics in the present eco-friendly age of dwindling water resources. The occurrence of pharmaceutical and personal care products (PPCPs) in aquatic environments is the newest potential water pollution concern. This study looks at the occurrence, fate and transport of PPCPs at Penn State's Living Filter Project, an integrated wastewater recycling system consisting of secondary effluent, overland flow, flow through natural wetlands, infiltration/percolation through the deep soil column, and groundwater recharge. Penn State University has been applying up to 4 mgpd of secondary sewage effluent at a 2-inch per week rate year-round at the Living Filter Site since 1983. A unique opportunity exists to assess the fate and transport of PPCPs through an entire water system consisting of secondary treatment, land application, infiltration and groundwater recharge.

Water samples are extracted via solid phase extraction on 3M Empore High Performance Extraction Disks. Analyses are preformed on a HP 6890 Gas Chromatograph coupled with an HP 5973 Mass Selective Detector using a customized temperature program. Initial scoping studies and preliminary results are presented for secondary effluent, overland flow, overland flow before and after wetland treatment, soil water, and groundwater. A variety of PPCPs including atrazine, DEET, cholesterol, acetaminophen, 2, 6-di-tert-butyl phenol, trimethoprim, and 5-methyl-1H-benzotriazole have been found within the Living Filter system. Future work will include the development of a fate and transport model for PPCPs within the unsaturated zone using chlorine as a conservative tracer.

BODY AND SURFACE WAVE TOMOGRAPHY FOR THE ARABIAN PENINSULA AND RED SEA

Yongcheol Park
Advisor: Andrew Nyblade
Post-Comprehensive

I have imaged tomographically the three-dimensional velocity structure of the upper mantle beneath the Arabian Peninsula using teleseismic P- and S-waves and Rayleigh wave phase velocities. The data for this study come from the Saudi Arabian National Digital Seismic Network (SANDSN) operated by King Abdulaziz City for Science and Technology (KACST: 21 broadband stations and 4 short-period stations). I augmented the SANDSN data with delay times measured from permanent Incorporated Research Institutions for Seismology (IRIS) stations in the region (RAYN, EIL and MRNI) and the 1996 Saudi Arabian PASSCAL Experiment (9 broadband stations). For the P-wave model 3416 ray paths from P- and PKP-waves and 1602 ray paths from S- and SKS-waves for the S-wave model were used. For the Rayleigh wave phase velocity tomography, I included data from the Ethiopian Broadband Seismic Experiment and obtained the maximum 1606 rays with the best coverage between periods of 44 and 140 s. The body and surface wave models yield consistent results, although the surface wave tomography shows poor horizontal resolution. The models show strong low velocity regions beneath the southeastern Arabian Shield and the northeastern edge of Arabian Shield. The low velocity anomaly in the southeastern part of the Arabian Shield is separated structure from the low velocity zone beneath the northeastern edge of the Arabian Shield and dips to the south in the body wave models. It likely represents the northeastern edge of the Afar hotspot. The origin of the low velocity anomaly beneath the northeastern part of the Shield is uncertain.

SHEAR-INDUCED STRESS, PORE PRESSURE, AND CONSOLIDATION IN FINE-GRAINED SUBMARINE LANDSLIDES

Derek Sawyer
Advisor: Peter Flemings
Pre-Comprehensive, Petroleum Theme

Submarine landslides are ubiquitous features on continental margins worldwide and one of the most common observations of their deposits is a characteristic low-porosity signature. This dense nature has been shown to cost the petroleum industry millions of dollars by dramatically slowing the penetration rate of jet pipes, and suction anchor piles, which form the critical foundation to offshore wells. The low-porosity signature is a clue to the underlying processes that operate during landsliding. I present a quantitative soil model that links stress, pore pressure, and strain during shearing of clays having and elastic-plastic rheology. Normally deposited fine-grained sediment compacts during drained shearing. However, during undrained shearing, compaction is prohibited, which elevates pore pressure and decreases effective stress. I hypothesize that this undrained shear feedback process contributes to landslide failure and movement, and a low-porosity profile develops during subsequent deposition and drainage. I apply a back-of-the-envelope test of this model on a shallowly buried submarine landslide deposit from the Gulf of Mexico to show that this is a viable model.

CONSOLIDATION, PORE PRESSURE, AND FLUID FLOW IN MUDSTONES OF BRAZOS-TRINITY BASIN IV, NORTHERN GULF OF MEXICO

Julia Schneider
Advisor: Peter Flemings
Pre-Comprehensive, Petroleum Theme

We hypothesize that due to rapid basin fill sedimentation pore fluids in mudstones underlying the Brazos-Trinity Basin IV in the deepwater Gulf of Mexico have overpressures reaching approximately 50% of the hydrostatic effective stress. The only big difference in the approximately 130 m thick mudstones, which are laterally continuous and comparable in thickness and composition, is the thickness of the overlying sediment fill. These overlying turbidite deposits and hemipelagic sediments cause overpressure in the mudstones in the basin center compared to normally pressured mudstones at the margin, as documented from IODP Expedition 308 Sites U1319 and U1320. The hypothesis is based on a preliminary in-situ pore pressure prediction from a comparison of porosity profiles at both sites and will be tested with three approaches. First of all, we will perform deformation experiments on whole core to estimate overpressure by correlating preconsolidation stress with hydrostatic effective vertical stress. Secondly, we will conduct a pore pressure modeling study with a finite difference approach to predict whether overpressure is likely to occur in the basin. It will incorporate known rock properties from core samples, logging data, consolidation tests, and sediment loading rates. Thirdly, we will compare the predicted pore pressures, lab experiments and modeling results with in situ pore pressure measurements (penetrometer data from IODP Expedition 308) to provide evidence based on direct measurements.

TALK SESSION - WEDNESDAY MORNING

Talks will be held Wednesday 4/18 from 9:00-12:00 in room 541.

Time	Presenter	Advisor	Title
9:00	**Heidi Albrecht**	Katherine Freeman and Jennifer Macalady	ECOLOGICAL, ENVIRONMENTAL, AND PHYSIOLOGICAL CONTROLS ON HOPANE DISTRIBUTIONS IN CYANOBACTERIA, SULFUR OXIDIZING, AND SULFUR REDUCING BACTERIA
9:15	**Aaron Diefendorf**	Katherine Freeman	ISOTOPIC AND MOLECULAR SIGNATURES IN ANCIENT SOIL ORGANIC MATTER: PRELIMINARY STUDIES FROM THE LATE PALEOCENE AND EARLY EOCENE OF THE BIGHORN BASIN, WY
9:30	**Bryn Kimball**	Susan Brantley and Jennifer Macalady	USING COPPER ISOTOPES TO DISTINGUISH BIOTIC AND ABIOTIC EFFECTS ON ACID MINE DRAINAGE
9:45	**Kristin Morell**	Donald Fisher	UPPER PLATE RESPONSE TO CHANGING SUBDUTION PARAMETERS, PACIFIC CENTRAL AMERICA
10:00	**Tsubasa Otake**	Hiroshi Ohmoto	EXPERIMENTAL EVIDENCE FOR NON-REDOX TRANSFORMATIONS BETWEEN MAGNETITE AND HEMATITE UNDER H_2-RICH HYDROTHERMAL CONDITIONS
10:15	**BREAK**		
10:30	**Andrew Rathbun**	Chris Marone	LABORATORY STUDY OF NONLINEARITY AND FABRIC-DEPENDENCE OF TILL
10:45	**Aaron Regberg**	Susan Brantley and Kamini Singha	ELECTRICAL SIGNATURES ASSOCIATED WITH ABIOTIC AND IN VITRO DISSIMILATORY IRON REDUCTION
11:00	**Jocelyn Sessa**	Timothy Bralower and Mark Patzkowsky	ENVIRONMENTAL AND ECOLOGICAL CONTROLS ON FAUNAL DYNAMICS IN THE PALEOGENE GULF COASTAL PLAIN
11:15	**Joe Valenti**	Peter Flemings	SEISMIC IMAGING OF THE AUGER FIELD, GULF OF MEXICO
11:30	**Andrew Wall**	Peter Heaney	COPPER ISOTOPE FRACTIONATION DURING THE OXIDATIVE PHASE TRANSITION OF SULFIDE MINERALS, CHALCOCITE TO COVELLITE, USING TIME-RESOLVED SYNCHROTRON X-RAY DIFFRACTION

ECOLOGICAL, ENVIRONMENTAL, AND PHYSIOLOGICAL CONTROLS ON HOPANE DISTRIBUTIONS IN CYANOBACTERIA, SULFUR OXIDIZING, AND SULFUR REDUCING BACTERIA

Heidi Albrecht
Advisors: Katherine Freeman and Jennifer Macalady
Pre-Comprehensive

Biohopanoids are a class of lipids made by bacteria that are often used as biomarkers. They are used even though remarkably little is known about their function and synthesis. To expand and fortify the use of lipid biomarkers in paleoenvironmental and ecological studies, we need to better understand which microorganisms synthesize specific lipids, and how lipid synthesis is influenced by environmental conditions. Hopanoids are thought to be analogous to eukaryotic sterols, functioning as membrane rigidity factors. They have been found in 30% of bacterial species screened for their presence, a tiny portion of bacterial species. It is unknown if hopanoids hold the same function in all species, or if the structures and abundances of hopanoids change in response to environmental stimuli. We hypothesize that hopanoids lower membrane permeability to H^+ and O_2. Therefore, hopanoid production is stimulated by environmental conditions that necessitate lower membrane permeability, such as, 1) low nitrogen availability (stimulating N fixation), 2) low pH, and 3) the exposure of oxygen to anaerobic or microaerophilic organisms. We will grow bacteria that are known to produce hopanoids (*Anabaena variabilis, Acidthiobacillus thiooxidans,* and *Desulfovibrio gigas*) under each of the above conditions. Their lipids will then be analyzed for both the abundance and structures of biohopanoids. Abundance will be measured using gas chromatrography – mass spectrometry (GC-MS) while structures will be identified with liquid chromatography – mass spectrometry (LC-MS). Hopanes from culture studies will be compared to those in environmental samples to evaluate if lab results can be used to interpret environmental conditions. Samples from the sulfidic Frasassi cave system, Italy, will be analyzed with the same procedures. The cave system offers simplified diversity that is genetically isolated compared to most environments and offers an analogy to early earth environments, when only prokaryotes were present. Preliminary results indicate that the cave system hosts bacteria that produce hopanoids but their structure and abundance is unknown.

ISOTOPIC AND MOLECULAR SIGNATURES IN ANCIENT SOIL ORGANIC MATTER: PRELIMINARY STUDIES FROM THE LATE PALEOCENE AND EARLY EOCENE OF THE BIGHORN BASIN, WY

Aaron Diefendorf
Advisor: Katherine Freeman
Pre-Comprehensive

Terrestrial climate studies often employ carbon isotopes of organic matter preserved in ancient soils. Yet, interpretations of these records are limited by our understanding of the mechanisms underlying long-term preservation of soil organic matter. The biogeochemical cycling of carbon in the soil environment is complex and bulk soil organic carbon represents a mixture of carbon derived from surface and sub-surface biomass. Processes that preserve organic matter in soils are subject to variations in temperature, water, chemical composition, oxygen content, and mineral interactions. However, it is unclear how different temperature and hydrologic conditions might bias the chemical and isotopic properties of organic matter preserved in ancient soils. Alteration of carbon isotope values of soil organic matter are observed in modern soil studies.

Preliminary investigations focus on 5 laterally extensive (~15 km) carbonaceous shale and mudstone sequences within the late Paleocene and early Eocene of the Bighorn Basin (WY, USA). Stratigraphic variations in carbon isotope values of organic matter are consistent with long-term regional changes. However, time slice transects, with similar lithologies, are consistent with respect to carbon isotope values from organic matter, despite differences in total organic carbon.

Future studies will focus on characterizing and quantifying plant-derived biomarkers and novel microbial lipid indices as well as fossil, sedimentary and geochemical characteristics preserved in terrestrial lithologies representing wet-to-dry transects for time slices of the late Paleocene and early Eocene in the Bighorn Basin. It is our goal to reveal source and preservation biases by exploring the influences of biomass, moisture/precipitation and temperature on terrestrial carbon isotope signatures over geologic timescales.

USING COPPER ISOTOPES TO DISTINGUISH BIOTIC AND ABIOTIC EFFECTS ON ACID MINE DRAINAGE

Bryn Kimball
Advisors: Susan Brantley and Jennifer Macalady
Pre-Comprehensive

Recent experiments have shown that abiotic leaching of the copper (Cu) sulfide chalcopyrite causes greater Cu isotope fractionation between original mineral (Cu_{min}) and leachate Cu (Cu_{aq}) ($\Delta_{aq\text{-}min} = \delta^{65}Cu_{aq} - \delta^{65}Cu_{min}$ = 0.92-1.63 ± 0.23‰) than in the presence of *Acidithiobacillus ferrooxidans* ($\Delta_{aq\text{-}min}$ = 0.10-0.53 ± 0.23‰), a known Fe- and S-oxidizing Proteobacterium. With these distinct abiotic and biotic Cu isotope signatures in mind, we surveyed the Cu isotopic composition of primary minerals and stream water affected by acid mine drainage in an enargite- and chalcopyrite-containing drainage located in southwestern Colorado, USA. The δ^{65}Cu values measured for local enargite (δ^{65}Cu = -0.01 ± 0.12‰) and chalcopyrite (δ^{65}Cu = 0.16 ± 0.12‰) are within the general range of previously reported values for terrestrial primary Cu sulfides (-1 < δ^{65}Cu < 1). These mineral samples show lower δ^{65}Cu values than stream waters (δ^{65}Cu = 1.36 - 1.74 ± 0.12‰). Acidic leaching of enargite-rich rocks in batch experiments releases Cu_{aq} that is isotopically identical to the enargite, so this process does not explain the environmental fractionation. Fractionation between chalcopyrite and stream samples ($\Delta_{aq\text{-}min}$ = 1.4 ± 0.17‰), however, is similar to the previous abiotic chalcopyrite leach experiment. Interestingly, the observed biotic Cu isotope signature is not detected in the field. Mass balance supports the likelihood that the fraction of leached Cu that associates with microorganisms is less significant in the open field system compared to the closed batch experiments. Our study reveals that Cu isotope measurements are a useful tool for better understanding Cu sources and mobility in the environment, and will aid in both ore prospecting and toxic metal remediation.

UPPER PLATE RESPONSE TO CHANGING SUBDUTION PARAMETERS, PACIFIC CENTRAL AMERICA

Kristin Morell
Advisor: Donald Fisher
Pre-Comprehensive

Southeast migration of the CO-NZ-CA Triple Junction results in the lateral migration and growth of the Fila Costeña Thrust Belt at a current rate of ~55 mm/yr. The Fila Costeña Thrust Belt, located in the inner forearc of Costa Rica and western Panama, is created due mainly to the shallow and rapid subduction of the CO plate under the CA plate along the Middle America Trench. The on-land projection of the Panama Fracture Zone, which represents the current boundary between the down-going CO and NZ Plates, marks the eastern termination of the Fila Costeña, as well as the eastern extent of CO subduction. Four out of five thrust faults terminate laterally or are buried by lahars inboard of the Panama Fracture Zone. Balanced cross-sections confirm that relative shortening rates progressively decrease from the center of the thrust belt to its southeast termination. The incipient and on-going migration of the thrust belt with the CO-NZ-CA triple junction is also observed in the landscape and topography near the thrust belt's termination. Wind gaps, beheaded streams and channel morphology point to reorganization of channel networks due to a growing topographic divide. Moreover, suites of fluvial terraces and volcanic flows from nearby Barú Volcano record recent uplift and incision within an active thrust belt.

EXPERIMENTAL EVIDENCE FOR NON-REDOX TRANSFORMATIONS BETWEEN MAGNETITE AND HEMATITE UNDER H_2-RICH HYDROTHERMAL CONDITIONS

Tsubasa Otake
Advisor: Hiroshi Ohmoto
Post-Comprehensive

Transformations of magnetite ($Fe^{II}Fe^{III}{}_2O_4$) to hematite ($Fe^{III}{}_2O_3$) (and vice versa) have been thought by many scientists and engineers to require molecular O_2 and/or H_2. Thus, the presence of magnetite and/or hematite in rocks has been linked to a specific oxidation environment. However, the availability of reductants or oxidants in many geologic and industrial environments appears to have been too low to account for the transformations of iron oxides through redox reactions. Here, we report the results of hydrothermal experiments in mildly-acidic and H_2-rich aqueous solutions at 150°C, which demonstrate that transformations of magnetite to hematite, and hematite to magnetite, occur rapidly without involving molecular O_2 or H_2:

$$Fe_3O_4(Mt) + 2H^+_{(aq)} \leftrightarrow Fe_2O_3(Hm) + Fe^{2+}_{(aq)} + H_2O$$

The transformation products are chemically and structurally homogeneous, and typically occur as euhedral single crystals much larger than the precursor minerals. This suggests that, in addition to the expected release of aqueous ferrous species to solution, the transformations involve release of aqueous ferric species from the precursor oxides to the solution, which reprecipitate without being reduced by H_2. These redox-independent transformations may have been responsible for the formation of some iron oxides in natural systems, such as high-grade hematite ores that developed from Banded Iron Formations (BIFs), hematite-rich deposits formed on Mars, corrosion products in power plants and other industrial systems.

LABORATORY STUDY OF NONLINEARITY AND FABRIC-DEPENDENCE OF TILL

Andrew Rathbun
Advisor: Chris Marone
Pre-Comprehensive

The nonlinearity of till deformation can be strong or slight, depending on initial fabric and on deformation conditions, as shown by our new experiments. Deformation in the subglacial region plays a key role in determining slip behavior, including creep, transient slip, stick-slip motion, and seismicity. However, progress in understanding these phenomena is limited by uncertainty in the rheology and frictional properties of glacial till. We report on detailed laboratory experiments to measure the creep and frictional constitutive properties of Caesar till sampled from the Scioto Lobe of the Laurentide Ice Sheet, collected in central Ohio.

Experiments were conducted in a servo-controlled, double direct shear apparatus with dried samples at normal stresses ranging from 50 kPa to 5 MPa. Till was sheared in a three-block arrangement in which two till layers are sandwiched between a central forcing block and two stationary blocks. We studied the effect of saturation, initial deformation fabric, stress history, and the boundary conditions of loading. The nominal frictional contact area is 100 cm^2 and remains constant during shear. The layer thickness is 1 cm prior to shear. Caesar till has a mean grain size of 0.60 mm, but lacks large amounts of silt and clay sized particles.

Constant shear stress experiments were employed to study frictional creep. Creep was induced after an initial strain ranging from 0 to 1 to investigate the role of shear fabric on deformation. Experiments were started at 68% of the shear strength with stress increased in steps until tertiary creep occurred. At 40 minutes after a stress step, we calculated strain rate (slope of strain versus time over a two minute period). The stress exponent, n, was determined from the equation $dgdt = At^n$. Where g is shear strain, t shear stress, and A is a constant.

We find that fabric has a significant effect on the rheology of till. With no initial strain, strain rates were 10^{-6} to 10^{-5} s^{-1} with a corresponding stress exponent of n=6.8. At strains of 1, strain rates were slightly less ($5x10^{-7}$ s^{-1}) and increased rapidly as the stress approached the shear strength. Intermediate initial strains of 0.15, 0.25, 0.55, and 0.68 showed progressively decreasing strain rate with initial strain. In experiments with no fabric development corresponding to initial strain of less than 0.2, the stress exponent ranged from n~3 to n~7 until the onset of tertiary creep, which occurred immediately when stress reached 90% of the shear strength. For experiments with initial strain of greater than 0.2 the stress exponent is greater than 10 indicating plastic deformation. In cases of strong fabric development, strains larger than 0.6, the stress exponent was larger than 40 near the shear strength.

ELECTRICAL SIGNATURES ASSOCIATED WITH ABIOTIC AND IN VITRO DISSIMILATORY IRON REDUCTION

Aaron Regberg
Advisors: Susan Brantley and Kamini Singha
Pre-Comprehensive

Several researchers have described anomalous electrical signatures associated with bacterial activity in anoxic zones in aquifers containing organic contaminants. It is thought that these signals can be attributed to (bio)geochemical changes caused by the oxidation of organic contaminants and the reduction of associated species like iron oxides. We report laboratory observations of changes in electrical conductivity (EC) that can be attributed to specific (bio)geochemical reactions involving reductive dissolution of iron oxides enzymatically and nonenzymatically. Abiotic reduction of ferrihydrite by ascorbic acid in batch experiments causes a cumulative 20-40% increase in measured conductivity, (EC increases by ~300 μS/cm). This change can be attributed to a decrease in conductivity (ΔEC) from increasing proton activity (ΔpH = 3.25 --> 5.07, EC = -200 μS/cm) and an increase in dissolved Fe(II) (Δ [Fe] = 2.2 - 3.3 mM, ΔEC = 400 -700 μS/cm). Conductivity is presumably unaffected by Fe(II) sorbed to the ferrihydrite. Rates calculated from this method are comparable to literature rates for similar experiments. In a similar *in vitro* system, total membrane fractions from *Shewanella oneidensis* MR-1 were used to reduce ferrihydrite in the presence of formate and HEPES buffer. A 10 – 15% increase in conductivity was observed in the batch experiment (ΔEC = ~280 μS/cm). This ΔEC is attributed to an increase in the concentration of de-protonated HEPES as well as carbonate ion as formate is oxidized. Fe(II) released in this system is quickly sorbed onto the ferrihydrite surface and is not thought to change conductivity. Despite the sorption of iron in these *in vitro* experiments, conductivity changes measurably and documents the rate of the reaction. Accessory changes like buffer de-protonation play an important role in interpreting the electrical signals caused by dissimilatory iron reduction. In order to accurately interpret field data it is necessary to anticipate these changes and attempt to monitor them chemically. Through this work we hope to link chemical changes caused by bacterial activity in the lab to electrical anomalies measured in the field. By quantifying the changes in conductivity, we will investigate rates and distributions of bacterial activity at the field scale.

ENVIRONMENTAL AND ECOLOGICAL CONTROLS ON FAUNAL DYNAMICS IN THE PALEOGENE GULF COASTAL PLAIN

Jocelyn Sessa
Advisors: Timothy Bralower and Mark Patzkowsky
Post-Comprehensive

Climate change has long been considered a major driver of origination, extinction, and population restructuring in macroinvertebrates, however relatively few studies have tested these relationships quantitatively. The Paleogene represents an ideal system in which to study the effects of climate change on organisms because it contains gradual and rapid increases and decreases in temperature, including a sudden (~ 200 Ky) rise of about 5 degrees Celsius worldwide, the Paleocene Eocene Thermal Maximum (PETM). Superimposed on the response of communities to temperature change is recovery from the Cretaceous-Paleocene (K-P) extinction. This project aims to categorize and separate the ecological effects of these perturbations on shallow shelf molluscan communities preserved in the eastern portion of the Paleogene Gulf Coastal Plain (Mississippi and Alabama). In particular, the relationship between assemblage level properties, such as diversity, evenness, and species dominance, and temperature is explored in comparison to the time it takes communities to recover from the K-P extinction. The rapidity and magnitude of the PETM exceeds all other known climatic changes during this time period. Thus, initial analyses focused on quantifying faunal turnover and population structure changes resulting from the PETM and comparing these effects to 'background' times of less severe environmental change and to the interval immediately following the K-P.

The data used in this study include both field and literature based abundance collections ranging from the earliest Paleocene through late Eocene. Approximately 26,000 individuals of about 600 species from twelve formations were identified to species level when possible. While the PETM appears to have caused substantial species level turnover when compared to background times, higher taxonomic levels were unaffected. Similarly, the diversity, abundance structure, and ecological composition of communities remained unchanged before and after the PETM. Analyses indicate that the diversity of early Paleocene communities was fairly similar to that of the rest of the Paleogene, implying that the recovery from the Cretaceous-Paleocene extinction was rapid. Overall, climate change seems to influence when faunal turnovers occur, but does not appear to control the diversity of localized communities.

SEISMIC IMAGING OF THE AUGER FIELD, GULF OF MEXICO

Joe Valenti
Advisor: Peter Flemings
Masters Talk, Petroleum Theme

The Auger field in the Gulf of Mexico, developed by Shell, has been a prolific producer for over ten years. Several seismic surveys have been performed throughout the course of its production history. An overview of the surveys, with particular emphasis on the pre-platform shoot, will be given. Basic lithological and fluid imaging theory will be discussed, along with application to interpretation. To that end, theory has been used to create synthetic seismograms that tie well wireline logs to the seismic surveys.

COPPER ISOTOPE FRACTIONATION DURING THE OXIDATIVE PHASE TRANSITION OF SULFIDE MINERALS, CHALCOCITE TO COVELLITE, USING TIME-RESOLVED SYNCHROTRON X-RAY DIFFRACTION

Andrew Wall
Advisor: Peter Heaney
Pre-Comprehensive

The focus of this research is to understand Cu isotope fractionation associated with the weathering of secondary copper minerals. As shown by previous work, chalcocite (Cu_2S) transforms to covellite (CuS) by the oxidation of Cu^{1+} to Cu^{2+} and the loss of Cu from the mineral structure. Mathur *et al*. (2005) have demonstrated that the Cu isotope composition of the solids becomes lighter during this reaction. In the current study, we have explored time-resolved X-ray diffraction as a means of monitoring the many intermediate phases that are part of the reaction sequence.

Pure, naturally occurring chalcocite powders were placed in a flow-through capillary reaction cell and exposed to an aqueous solution of 0.01 M ferric sulfate for ~ 4 hrs. Real-time diffraction data were collected at intervals of 2 min at beam line X7B, National Synchrotron Light Source, using a MAR345 imaging plate. The $\delta^{65}Cu$ values of the starting and final powders as well as the leachate were measured using a Finnigan Neptune multi-collector inductively coupled plasma mass spectrometer.

The powder diffraction data clearly revealed that chalcocite passes through a complex series of partially oxidized intermediate phases during its transformation to covellite. Reaction kinetics for the 0.01 M ferric sulfate experiments were sufficiently rapid that no chalcocite was present by 8 minutes and covellite appeared within 14 min. at room temperature. The time resolution allowed observations of the following intermediate phases throughout the reaction: djurleite ($Cu_{1.94}S$), digenite ($Cu_{1.80}S$), anilite ($Cu_{1.75}S$), geerite ($Cu_{1.6}S$), and yarrowite ($Cu_{1.13}S$). These intermediate reaction steps were characterized by the presence of 2 or more phases. Isotope results indicated that the original chalcocite powders had $\delta^{65}Cu$ values of 0.46 +/- 0.12‰ and the residual covellite powders had $\delta^{65}Cu$ values of 0.13 +/- 0.12‰. The $\delta^{65}Cu$ values of the leachate progressively decreased during the reaction with starting δ65Cu values of 2.41+/- 0.12‰ and ending values of -2.55 +/- 0.12‰. Coupling isotopic analyses obtained during the entire reaction sequence with our time-resolved XRD results will make it possible to associate Cu fractionation behavior with specific mineral phases.

TALK SESSION - WEDNESDAY AFTERNOON

Talks will be held Wednesday 4/18 from 12:30 - 3:00 in room 541.

Time	Presenter	Advisor	Title
12:30	**Charles Bohn**	Peter Flemings	CHARACTERIZATION OF THE YELLOW SAND IN AUGER FIELD, GULF OF MEXICO, USA
12:45	**James Fulton**	Michael Arthur	NITROGEN CYCLING DURING SAPROPEL DEPOSITION IN THE BLACK SEA
1:00	**Gavin Hayes**	Kevin Furlong and Charles Ammon	RELOCATION AND RUPTURE PROCESSES OF LARGE PLATE BOUNDARY EARTHQUAKES NEAR SOUTH ISLAND, NEW ZEALAND
1:15	**Chris Junium**	Michael Arthur	DOWNSLOPE TRENDS IN NITROGEN ISOTOPES FROM SURFACE SEDIMENTS FROM THE PERU MARGIN UPWELLING ZONE
1:30	**Alexis Navarre-Sitchler**	Susan Brantley	WEATHERING, POROSITY AND EFFECTIVE DIFFUSION COEFFICIENTS: IS ARCHIE'S LAW THE BEST MODEL?
1:45	**BREAK**		
2:00	**Matthew Reilly**	Peter Flemings	CHARACTERIZATION AND COMPARTMENTALIZATION OF THE BLUE SAND, AUGER BASIN, GULF OF MEXICO
2:15	**Jon Samuelson**	Chris Marone	THE EFFECT OF DILATANCY AND COMPACTION ON THE STABILITY OF A FLUID INFILTRATED FAULT
2:30	**Doruk Seren**	Turgay Ertekin and Peter Flemings	ENGINEERING DISCUSSION OF THE GEOSYSTEMS TEAM 4 PROJECT: DRAINAGE AND PRESSURE BEHAVIOR OF THE AUGER YELLOW AND BLUE SANDS
2:45	**Burt Thomas**	Michael Arthur and Chris House	DECIPHERING THE ACETATE CYCLE IN POREWATERS WITH INTRAMOLECULAR ISOTPIC MEASUREMENTS
3:00	**Jennifer Williams**	Susan Brantley	WEATHERING REACTIONS IN SOILS ON PEORIA LOESS DOCUMENT MINERAL WEATHERING KINETICS AS A FUNCTION OF CLIMATE

CHARACTERIZATION OF THE YELLOW SAND IN AUGER FIELD, GULF OF MEXICO, USA

Charles Bohn IV
Advisor: Peter Flemings
Masters, Petroleum Theme

Localized variation in accommodation space caused by syndepositional faulting exhibits the dominant control on the distribution and quality of the Yellow Sand in Auger Field. The Yellow Sand is laterally continuous across Auger Basin, a 243 $mile^2$ salt withdraw mini-basin located on the continental slope in water depths of 3000 ft in the Gulf of Mexico. Regional mapping of the Yellow Sand seismic event indicates an average dip of 10 - 15 degrees to the southwest across Auger Field. The Yellow Sand is bisected by a down-to-the-east fault and a series of down-to-the-north faults. Well log data in the field show thickening and increased quality across the down-to-the-north faults. This research will provide a foundation to relate accommodation space to depositional processes acting in deep water systems.

NITROGEN CYCLING DURING SAPROPEL DEPOSITION IN THE BLACK SEA

James Fulton
Advisor: Michael Arthur
Pre-Comprehensive

Organic-matter-rich marine sedimentary rocks, termed “black shales,” have stimulated active debate regarding the water column conditions required for their formation. The Holocene Black Sea is the largest modern marine basin depositing OM-rich sediments and thus is a natural laboratory for studying black shale deposition. In this study I examine the events surrounding the accumulation of OM-rich sapropel sediments in the Black Sea with specific focus on (1) “preservation vs. production” during the transition from unit III to unit II sedimentation at ca. 7800 years BP when sapropel accumulation began, and (2) nutrient cycling and the role of nitrogen fixation in the basin during deposition of unit II, deposited from 7800 to 2000 years BP. Both production and preservation of marine organic matter appear to play a role in Holocene Black Sea sapropel accumulation, with preservation preceding increased production. As well, decreases in nutrient nitrogen availability in the surface waters stimulated nitrogen fixation during intervals of unit II deposition.

Marine-derived organic matter is a much greater component of unit II sediments than unit III, as evidenced by increases in percent organic carbon, $\delta^{13}C_{organic}$, and hydrogen index across the III/II boundary. In deep basin sediments from under ~2200m of water, organic carbon concentrations gradually increase toward the top of unit III as abundant dark laminae are dispersed in gray marl. Shallower water cores from the Black Sea margins do not preserve laminations in unit III but do record a minor increase in percent organic carbon toward the top of unit III. These data suggest that anoxia developed first in the deep basin where bioturbation was inhibited starting ca. 9000 years BP. Nutrient release, notably phosphorus, from the fully anoxic deep sediments stimulated increased surface water productivity and nitrogen fixation, as shown by decreasing $\delta^{15}N_{organic}$ values across the unit III/II boundary.

Over the past 7800 years nutrient cycling in the Black Sea has been dynamic, responding primarily to changes in river discharge and chemocline depth in the sea. The most OM-rich samples from unit IIb were deposited during a period characterized by high river discharge, a shallow chemocline, and ^{15}N-enriched sedimentary organic matter. Sediments from unit IIa, on the other hand, were deposited under dryer conditions with less nutrient input from rivers and a less stable pycnocline with deeper mixing of oxygenated surface waters. These conditions tend to stimulate nitrification/denitrification which lowers the nitrogen/phosphorus ratio in the surface waters selecting for nitrogen fixing organisms. Low $\delta^{15}N$ values in unit IIa attest to nitrogen fixation during this interval.

RELOCATION AND RUPTURE PROCESSES OF LARGE PLATE BOUNDARY EARTHQUAKES NEAR SOUTH ISLAND, NEW ZEALAND

Gavin Hayes
Advisors: Kevin Furlong and Charles Ammon
Post-Comprehensive

New Zealand sits astride a complex section of the Pacific:Australia plate boundary in the South-west Pacific, exhibiting two oppositely verging subduction zones. Adjacent to the North Island of New Zealand, the Pacific Plate subducts westward beneath the Australian Plate, while to the south the Australian Plate sinks eastward beneath the Pacific Plate and New Zealand's South Island at the Fiordland subduction zone. These two subduction zones are joined by the Alpine Fault, a large continental transform that bisects the South Island. Further south again, the Australian and Pacific Plates translate past each other along the Macquarie Ridge transform system that has hosted some of the Worlds' largest strike-slip earthquakes in recorded history.

The geometry, development and kinematics of the Macquarie and Alpine fault systems depend to a large extent on the structure and behavior of the Australian Plate as it translates past and subducts beneath the Pacific Plate in southern New Zealand. Understanding the interactions between the Australian and Pacific Plates at and near the Fiordland subduction zone is a key component of understanding the evolution of this plate boundary system, and in particular the Alpine fault, as much a hazard to New Zealand as the San Andreas Fault poses to the Western US.

Over the past ~15 years, over 80 moderate-to-large earthquakes have been well recorded along this system. These events include two M7+ earthquakes on or near the Fiordland subduction zone, and two M8+ earthquakes on or near the Macquarie Ridge system further south. Here we combine surface wave relocations, finite fault modeling and source time function estimation to more accurately determine the locations and sense of rupture of these events and thus to help constrain the characteristics and evolution of the plate boundary.

DOWNSLOPE TRENDS IN NITROGEN ISOTOPES FROM SURFACE SEDIMENTS FROM THE PERU MARGIN UPWELLING ZONE

Christopher Junium
Advisor: Michael Arthur
Pre-Comprehensive

Trends in the nitrogen isotope values of bulk sediments deposited under the oxygen minimum zone on the Peru Margin were studied in samples from deck-deployed box cores and push cores acquired by submersible on two transects at 12^{o} and 13.5^{o} from 75 to 1000m water depth. Previous work of Arthur et al., (1998) has shown that organic matter is more poorly preserved than would be expected despite the low-oxygen conditions (<5 μmol/kg). This is attributed to constant advection of low concentrations of dissolved oxygen, activity of organisms, and resuspension and downslope transport of organic matter by strong bottom currents up to 30 cm/s. These processes extend exposure time to oxidant (dissolved oxygen or nitrate) which progressively degrades surface and suspended organic matter. Bulk nitrogen isotope values average 7.5 permil and range from 4.0 to 10.9 permil. The average of 7.5 permil is typical for modern upwelling zones where denitrification is the dominant suboxic autotrophic metabolism within the oxygen minimum zone. The variability in nitrogen isotope values reflects the influence of resuspension and downslope movement of sediment. Nitrogen isotope and pyrolysis hydrogen index values decrease down-slope are positively correlated while atomic C/N ratios increase. This suggests that increasing exposure times to oxidant and removal of labile nitrogen results in decreasing nitrogen isotope values. This trend is contrary to normal isotope degradation kinetics which typically drive nitrogen isotope values higher but could be achieved through selective degradation of ^{15}N-enriched proteins and amino acids which has been observed where denitrification is occurring (van Mooy et al., 2002).

WEATHERING, POROSITY AND EFFECTIVE DIFFUSION COEFFICIENTS: IS ARCHIE'S LAW THE BEST MODEL?

Alexis Navarre-Sitchler
Advisor: Susan Brantley
Post-Comprehensive

Weathering rinds can be defined as small-scale saprolites that develop on un-weathered clasts. Developed in a controlled environment and protected from physical weathering by surrounding material, these clasts provide a unique setting to examine chemical weathering processes without complications due to the removal of weathered material by physical erosion. Weathered basalt clasts have been collected from a chronosequence of alluvial terraces along the Pacific coast of Costa Rica to investigate the processes that control weathering rind advance. The parent basalt has very low porosity (1-3%) therefore, transport is diffusion controlled as are weathering reactions in the reaction front (~1 mm wide). The dissolution of basalt at the interface results in the creation of secondary porosity (35-50% in the rind) thereby changing the effective diffusion coefficient. According to Archie's Law the effective diffusion coefficient (D_e) is related to porosity (φ) by $D_e = D_o\varphi^2$, where D_o is the diffusion coefficient in pure water. Values of the exponent on porosity can range from 0.33 to 5 for diffusive gas in soils to aqueous diffusion in clays. Reactive transport models of this system using Archie's Law are unable to predict the thin (~1 mm) reaction front.

In order to better understand how effective diffusion coefficients are changing across the weathering front we use micro-computed tomography data collected across the reaction front with 4.4 μm resolution to measure both total and effective porosity. We define effective porosity as porosity contained in through going pathways across a sample interval. To address scaling effects we use sample intervals ranging from 100 μm to 250 μm. Results show that at low total porosity (<15%), effective porosity is 0% but over a range of 18-25% total porosity, the effective porosity increases from 0 to 100% where effective porosity equals total porosity. Effective diffusion coefficients of $1.8\text{x}10^{-11}$ cm^2 sec^{-1} and $2.5\text{x}10^{-9}$ cm^2 sec^{-1} were measured in parent basalt (φ~3%) and altered basalt (φ~25%), respectively. Numerical modeling of the diffusion profiles indicates a tortuosity of $1.2\text{x}10^{-5}$ in the core. These results have been used to develop a threshold model for calculating diffusion coefficients that, when used in modeling of the basalt clasts, predicts the reaction front thickness more accurately than Archie's Law. To our knowledge, this study represents the first attempt to determine how diffusion coefficients are affected by changes in porosity due to weathering processes.

CHARACTERIZATION AND COMPARTMENTALIZATION OF THE BLUE SAND, AUGER BASIN, GULF OF MEXICO

Matthew Reilly
Advisor: Peter Flemings
Masters, Petroleum Theme

The Auger field is located 214 miles South West of New Orleans, Louisiana. The field consists of five productive layers, The Blue Sand is one of two shallow charged sand layers. The Pleistocene Blue sand is Oil and Gas productive from massive and laminate sands that were deposited in the Auger mini basin. A salt diapir and faulting are the major trapping mechanisms. The Blue sand can be divided into several compartments by extensional fault systems which may have a significant influence in hydrocarbon flow regime. Evidence also exists that shows that the Blue Sand may be further subdivided vertically into separate Massive and Laminated layers. Sand thickness changes significantly across faulting as evidenced from seismic and well log data. Production and seismic data indicate that the Blue sand extends well below the Oil Water Contact and provides significant pressure support. Changes in the depositional character and structure of the Blue Sand suggest compartmentalization. Structural geometry of the Blue Sand and the overlying Yellow Sand suggest syn-depositional faulting. Hydrocarbon flow in the reservoir has been monitored by a 4D seismic survey, production logging and cased hole resistivity logs. My Thesis aims to use this data to further analyze the Blue Sand. I aim to establish a high resolution drainage history model that will greatly assist the geological understanding of the Blue Sand. This thesis will be a useful analogue for any deep water turbidite system.

THE EFFECT OF DILATANCY AND COMPACTION ON THE STABILITY OF A FLUID INFILTRATED FAULT

Jon Samuelson
Advisor: Chris Marone
Post-Comprehensive

The role of fluids is a central issue in understanding fault slip, earthquake nucleation, and dynamic rupture propagation. We report on experiments in which simulated fault gouge was sheared under controlled pore pressure and true-triaxial stress conditions while permeability evolution was monitored via flow normal to the shear direction. Experiments were conducted in double direct shear within a pressure vessel at room temperature. Samples were jacketed and subjected to either constant pore pressure (P_p), or a differential pore pressure inducing flow across the gouge layer. Confining- and pore-pressures were maintained via high precision servo-controlled pressure intensifiers. Experiments involved slide-hold-slide tests and velocity step tests at effective normal stresses ranging from 2 to 30 MPa and P_p ranging from 1 to 4 MPa. Gouge layers were constructed using a precision leveling jig to be 4 mm thick prior to shear. Frictional contact area was 5 cm x 5 cm.

Velocity stepping experiments were conducted by instantaneously increasing the load point velocity from 1 μm/s to values ranging from 3 to 100 μm/s, and back to 1 μm/s after steady state sliding was attained. We find that the friction rate parameter (a-b) ranges from being positive (0.0003 to 0.004) to approximately velocity neutral. The critical slip distance (D_c) ranges from a few μm's to a few 10's of microns. Dilation associated with upsteps in shearing velocity is associated with water being drawn into the gouge layer. The volume of water drawn into the gouge layer is shown to increase logarithmically with the magnitude of the velocity step at a rate of 0.02 cm^3 per multiple of 10 increase in load point velocity.

Measurements of fluid flow normal to the layer during shear show that fluid is imbibed into the layer upon upsteps in shear velocity and expelled from the layer on downsteps in velocity. Respective decompression or compression of the internal pore fluid results in decreases or increases in pore fluid pressure, such changes in pore pressure have the potential to change the mechanics of the nucleation of earthquake slip. Fluctuations in pore pressure are modeled using a finite element modeling technique.

ENGINEERING DISCUSSION OF THE GEOSYSTEMS TEAM 4 PROJECT: DRAINAGE AND PRESSURE BEHAVIOR OF THE AUGER YELLOW AND BLUE SANDS

Doruk Seren
Advisors: Turgay Ertekin and Peter Flemings
Masters, Petroleum Theme

The Auger Yellow and Blue Sands demonstrate several challenges that are common to petroleum E & P operations in the Gulf of Mexico. Among the engineering challenges involved are identification of clues about structural complexity by analysis of fluid property and composition data, pressure data, and gas and water production data. Fluid 'fingerprinting', Pressure Transient Analysis, and conceptual and numerical models for water encroachment and production help constrain geological interpretations of the often inconclusive well log, core, and seismic data. This presentation will break down some of the available data and discuss its implications for understanding of and continued production from the Yellow and Blue Sands.

DECIPHERING THE ACETATE CYCLE IN POREWATERS WITH INTRAMOLECULAR ISOTPIC MEASUREMENTS

Burt Thomas
Advisors: Michael Arthur and Chris House
Post-Comprehensive, Petroleum Theme

Acetate is a rapidly cycled intermediate in most anaerobic environments because it is produced by a wide array of fermenters or autotrophic acetogens, and it is a near universal substrate for heterotrophic respirers or aceticlastic methanogens. Tight coupling between supply and demand results in low micromolar levels of acetate in most minerotrophic wetlands. However, in acidic peatlands acetate can reach mM concentrations. The near ubiquitous balance between production and consumption in minerotrophic wetlands breaks down at certain times of the year in peatlands.

Intramolecular carbon isotopic measurements of acetate represent a powerful tool to decipher the processes that produce and consume acetate. Here I report the first measurements from an online pyrolytic technique to analyze the intramolecular carbon isotopic composition of acetate in peatland porewaters. In addition I report the isotopic composition of coproduced methane and carbon dioxide. These measured values are used in isotope mass balance calculations to estimate the fraction of methane derived from two fundamental methane production pathways. Moreover, these isotopic measurements provide clues to the source and fate of acetate by distinguishing between the acetate produced by fermenters and the acetate produced by autotrophic acetogens.

WEATHERING REACTIONS IN SOILS ON PEORIA LOESS DOCUMENT MINERAL WEATHERING KINETICS AS A FUNCTION OF CLIMATE

Jennifer Williams
Advisor: Susan Brantley
Pre-Comprehensive

Through physical and chemical weathering, primary minerals are transformed to soil minerals in the Critical Zone. Using a published dataset, we investigated reaction fronts occurring in modern soils developed on Peoria Loess in the Mississippi River Valley over the last 10,000 to 13,000 years. After normalization to Zr, elemental concentrations document several different characteristic reaction fronts. Na, Ca, and Mg are depleted at the surface while Al, Fe, and Si show depletion at the surface and enrichment at depth. In contrast, the macronutrients P and K show reaction fronts that reveal the effect of biogenic uptake. Finally, the elemental profile for Mn is classified as an addition-only profile which reflects a relative increase in concentration from parent to surface. This Mn profile is attributed to contaminated dust input. Using the GENESIS v2 Global Climate Model, we performed climate simulations for three periods (modern, 6kyr BP and 10kyr BP) roughly spanning the time of soil development, and extracted model temperature, precipitation, and soil pore water flux for a north-south transect representing the Mississippi Valley. The extents of mineral reaction and reaction kinetic constants vary as functions of these climate variables along the transect. Reaction rate constants will be summarized as a function of these variables for minerals in the profiles.

TALK SESSION - THURSDAY MORNING

Talks will be held Thursday 4/19 from 9:00-12:00 in room 541.

Time	Presenter	Advisor	Title
9:15	**James Bonelli**	Mark Patzkowsky	EXAMINING THE RESPONSE OF TROPICAL MARINE ASSEMBLAGES TO LATE MISSISSIPPIAN ENVIRONMENTAL CHANGE
9:30	**Katherine Dawson**	Jennifer Macalady and Katherine Freeman	ANAEROBIC DEGRADATION OF THE ISOPRENOID 2,6,10,14-TETRAMETHYLPENTADECANE BY A DENITRIFYING MICROCOSM
9:45	**Brooke Fambrough**	Rudy Slingerland and William Heins	THE INFLUENCE OF CHANGING FLOOD HYDROGRAPHS ON FLUVIAL SANDSTONE COMPOSITION AND GRAIN SIZE DISTRIBUTION
10:00	**Nate Harkins**	Eric Kirby	CONSIDERATION OF TERRACE RISER EVOLUTION PROMOTES A RE-EVALUATION OF SLIP-RATE DETERMINATIONS ALONG THE KUNLUN FAULT, NORTHEASTERN TIBET
10:15	**Elisabeth Hausrath**	Susan Brantley	WHAT CAN WE LEARN FROM DEPTH PROFILES ON MARS?
10:30	**BREAK**		
10:45	**Lev Horodyskyj**	Lee Kump and Tim White	GEOCHEMISTRY OF A LATE CAMBRIAN PALEOSOL, ELK POINT, SOUTH DAKOTA
11:00	**Mouse Marie Larson**	Andrew Nyblade	IMAGING UPPER MANTLE STRUCTURE BENEATH THE CAMEROON VOLCANIC LINE FROM PRELIMINARY BODY-WAVE TOMOGRAPHY
11:15	**Joel Moore**	Susan Brantley	CROSS-SCALE COMPARISON OF CLAY AND SHEET SILICATE DISSOLUTION KINETICS: LABORATORY TO FIELD
11:30	**David Cannon**	Terry Engelder	A REINTERPRETATION OF FRACTURING AT TETON ANTICLINE, SAWTOOTH RANGE, MONTANA

EXAMINING THE RESPONSE OF TROPICAL MARINE ASSEMBLAGES TO LATE MISSISSIPPIAN ENVIRONMENTAL CHANGE

James Bonelli Jr.
Advisor: Mark Patzkowsky
Post-Comprehensive

A major focus of evolutionary paleoecology has been to understand how global levels of biodiversity have been affected by past environmental or biologic perturbations. Although informative, global scale analyses lack the resolution required for understanding how the geographic components of global diversity change in response to perturbation. In other words, how are shifts in global biodiversity accommodated at the smaller geographic scales of depositional basins or local communities? Herein lies the key to understanding the ecological processes that drive global scale patterns and control diversity within regional ecosystems.

Here I use the fossil record of Late Mississippian (Chesterian Series) marine invertebrates from the Illinois Basin (USA) to investigate how regional generic diversity varied across the onset of the Late Paleozoic Ice Age (LPIA), an event that coincides with a 28% decrease in global generic diversity. A total of 199 paleoecologic collections were made from eleven consecutive depositional sequences across the onset of the LPIA. Each of these depositional sequences represents one cycle of sea level change and can be thought of as a replicate natural experiment in reestablishing the regional marine ecosystem to the study area. This provides an excellent framework within which to measure quantitatively changes in regional generic diversity during an interval of global diversity loss.

Results from sample standardized diversity curves for each sequence show marked diversity change across the onset of the LPIA. However, this change runs counter to the global pattern; regional diversity is significantly higher after the start of the LPIA and lower before. These findings suggest that there must be significant regional variability in the diversity response of biotas to the LPIA to generate a global pattern of diversity loss at this time. Future work will focus on using a hierarchical approach to understand how the alpha (collection diversity) and beta (turnover diversity) components of regional diversity changed as a result of the observed diversity increase in the Illinois Basin. In addition I will also examine components of regional diversity in the Appalachian Basin (USA) in order examine variability in the diversity response among basins.

ANAEROBIC DEGRADATION OF THE ISOPRENOID 2,6,10,14-TETRAMETHYLPENTADECANE BY A DENITRIFYING MICROCOSM

Katherine Dawson
Advisors: Jennifer Macalady and Katherine Freeman
Pre-Comprehensive, Petroleum Theme

Despite enhanced preservation due to low reactivity, both aerobic and anaerobic mechanisms are active in the biodegradation of normal, branched and aromatic hydrocarbons in the marine environment. Bregnard *et al.* (1997) demonstrated the degradation of the saturated, branched chain hydrocarbon pristane (2,6,10,14-tetramethylpentadecane) by denitrifying microcosms and enrichment cultures obtained from an aquifer. Following a similar protocol, we recently demonstrated the loss of nitrate from enrichments using an activated sludge inoculum where pristane was the sole carbon source. At room temperature, the nearly complete disappearance of 53.7 µmoles nitrate was observed within 26 days. After the addition of concentrated nitrate to the cultures, an additional 492.5 µmoles of added nitrate was consumed in 155 days. This loss of nitrate accounts for a 7.147 ± 0.42 mg loss of pristane, 4.74% of the initial substrate, in 181 days. The microorganisms active in the anaerobic pristane degrading microcosms have been characterized through the creation of a 16S rDNA clone library. Experiments are in progress, to enrich cultures of sulfate reducing bacteria which utilize pristane and archaeal tetraether lipid cores as a sole carbon source. The results of these experiments will contribute new understanding of anaerobic degradation of hydrocarbons in oil reservoirs and pollutant plumes.

THE INFLUENCE OF CHANGING FLOOD HYDROGRAPHS ON FLUVIAL SANDSTONE COMPOSITION AND GRAIN SIZE DISTRIBUTION

Brooke Fambrough
Advisors: Rudy Slingerland and William Heins
Masters, Petroleum Theme

Climate change modifies the flood and sediment hydrographs of rivers, which then modifies the compositions, and grain-size distributions of sand delivered to sedimentary basins. It would be useful to predict these changes quantitatively, as for example, in reservoir studies in frontier basins. Towards this end we have conducted a series of numerical experiments using MIDAS (Model Investigating Density and Size-Sorting) in MATLAB, simulating the fluvial transport and deposition of sand-sized heterogeneous quartz and feldspar mixtures under varying flood hydrographs. The experimental design consists of a standard steady-state control run to which are compared various runs of simulated flood conditions with increased discharge (Q) and sediment discharge (Q_s) in varying ratios. Q, Q_s, and the feed stock size distribution (D_{50} = 0.33 mm, quartz D_{50} = 0.35 mm, feldspar D_{50} = 0.23 mm) and composition (quartz/feldspar ratio by weight = 4) are held constant throughout each model run. Results show that when Q and Q_s are each increased in direct proportion, the bed coarsens, the bed slope decreases, and the quartz/feldspar ratio of the degrading bed increases. When Q_s is increased at a greater rate than Q, the bed alluviates to a new steeper graded slope. The alluviated deposit fines and increases in feldspar downstream. These experiments imply that a change to a wetter climate (all other factors being equal) causes a temporary fining of sediment delivered to a basin and a decrease in the quartz/feldspar ratio of the deposited sands.

CONSIDERATION OF TERRACE RISER EVOLUTION PROMOTES A RE-EVALUATION OF SLIP-RATE DETERMINATIONS ALONG THE KUNLUN FAULT, NORTHEASTERN TIBET

Nathan Harkins
Advisor: Eric Kirby
Post-Comprehensive

An accurate description of the current tectonic deformation field across the Indo-asian collision zone is central our understanding of the behavior of continental lithosphere during orogenesis. Identifying long-term strain rates along Tibetan continental strike-slip faults is essential if geodetic constraint on modern surface deformation is to be used to constrain rheologic and mechanic properties of the crust. Previous workers along the Kunlun fault, a left lateral strike-slip fault in northeastern Tibet, used offset fluvial terrace risers to identify a spatially uniform slip-rate of 11-12 mm/yr over the late Pleistocene and Holocene. The use of fluvial terrace risers as passive markers of displacement is increasingly common, as these landforms offer the potential to determine slip rates over 1,000 – 100,000 yr and are found across a wide variety of landscapes. However, a potential disconnect exists between the 'age' of a terrace (typically inferred from dated material in terrace treads) and accumulation of displacement across the terrace riser. We use a spatially and temporally compact flight of offset terrace surfaces at an opportune location along the easternmost Kunlun fault to place tight bounds on slip rates of 4-5 mm/yr, and demonstrate scenarios that may have lead previous workers along this structure to overestimate rates. Comparison of surveyed riser profiles to a simple, slope-diffusion model of riser topographic evolution over time illustrates these scenarios and allows us to corroborate these rates at a second site along the Kunlun. Our interpretations of these slower rates are further strengthened by the magnitude of Kunlun fault offset recorded in glacial moraines at a site ~100 km to the west, which indicate rates of <7 mm/yr. Importantly, similar analysis is beginning to reveal previous overestimates of rates along other Tibetan fault zones. A reinterpretation of 'slow' rates along the Kunlun and other strike-slip faults dramatically shifts the model paradigm under which we view ongoing Tibetan tectonics.

WHAT CAN WE LEARN FROM DEPTH PROFILES ON MARS?

Elisabeth Hausrath
Advisor: Susan Brantley
Post-Comprehensive

Basalt is a common lithology on both Mars and Earth. However, despite its importance, basalt weathering rates remain poorly understood. Minerals in soils, regolith, and alteration rinds form weathering profiles as parent minerals are increasingly altered. Profiles of chemistry and mineralogy as a function of depth record information about mineral dissolution rates as well as transport, duration of weathering, erosion, and aeolian deposition.

We have studied elemental weathering profiles formed on basaltic parent material in two field weathering environments: tropical Costa Rica, and arctic Svalbard (Norway) using the reactive transport model CrunchFlow. The gradients formed at these interfaces between parent rock and weathered rind allow a comparison of basalt weathering under different climate regimes, duration of weathering, pH and physical erosion. We have also studied a putative weathering rind on Mars using CrunchFlow to interpret duration of weathering.

GEOCHEMISTRY OF A LATE CAMBRIAN PALEOSOL, ELK POINT, SOUTH DAKOTA

Lev Horodyskyj
Advisors: Lee Kump and Tim White
Post-Comprehensive

Soils form on sediments and bedrock exposed to the atmosphere and can record the effects of various processes, including changes in moisture content, temperature, and biological activity, which acted upon soil prior to burial. Although paleosols (ancient soils) can be subject to post-burial alteration, careful analysis of paleosols can yield information about the conditions in which they developed. Previously, pre-Ordovician paleosols have been studied to determine the oxidation state of the atmosphere. Few recent studies have attempted to investigate the possibility of a microscopic terrestrial biota inhabiting pre-Ordovician paleosols.

A previously unstudied late Cambrian paleosol in a drill core from Elk Point, South Dakota has been analyzed for major oxides, sulfur, organic carbon, and iodine in order to determine if a terrestrial biota was present at this time. The paleosol developed on Precambrian metagabbro basement and is overlain by the late Cambrian Mt. Simon Sandstone, placing its development chronologically before the advent of vascular plants.

Major oxide profiles in the paleosol show complete loss of sodium as well as significant losses of calcium, magnesium, and manganese. Phosphorus is absent at the top of the profile, but present at lower depths. Some quantities of iron have been lost in the paleosol. There is no sulfur present, but the paleosol does retain a small amount of organic carbon (up to 0.11%). Iodine is an element that is closely associated with organic material. Preliminary data suggest that iodine is present in this Precambrian paleosol at variable concentrations. The oxide profiles are consistent with elemental loss through weathering reactions, and the presence of organic carbon and iodine in this paleosol indicates that a terrestrial biota may have been present.

IMAGING UPPER MANTLE STRUCTURE BENEATH THE CAMEROON VOLCANIC LINE FROM PRELIMINARY BODY-WAVE TOMOGRAPHY

Mouse Marie Larson
Advisor: Andrew Nyblade
Pre-Comprehensive

The Cameroon Volcanic Line (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 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. One suggestion is that the line is the result of a localized mantle convection cell resulting from edge flow from the nearby Congo Craton to the southeast. Another possibility is that there may be a plume that is rising to the surface along of previously weakened linear zone. In this scenario, the magma may rise sporadically to the surface at different points along the line thereby explaining the apparent lack of age progression.

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 is currently being used for a body-wave tomography study to study the upper mantle structure beneath Cameroon. Preliminary results from a P wave travel time tomography will be presented and used to evaluate possible models for the origin of the Cameroon Volcanic Line.

CROSS-SCALE COMPARISON OF CLAY AND SHEET SILICATE DISSOLUTION KINETICS: LABORATORY TO FIELD

Joel Moore
Advisor: Susan Brantley
Post-Comprehensive

Understanding and predicting the dissolution of minerals in field settings is key to describing and predicting soil processes such as soil development, acid neutralization, and sustainable production of crops and lumber as well as for issues such as waste disposal and remediation. Models, whether conceptual or computational, are a key part of understanding field mineral dissolution but any model is only as good as the model inputs. One of the most crucial model inputs is the laboratory kinetic data for mineral dissolution. To achieve a robust dataset of laboratory kinetic data, experimental data have been compiled and synthesized to develop rate laws for clay and sheet silicate dissolution rates versus pH. Within a conceptual model, the laboratory results should provide information to predict relative dissolution rates in the field. For example, in the laboratory, chlorite dissolves faster than smectite, and smectite dissolves faster than illite. Preliminary calculations of clay and sheet silicate dissolution and transformation in soil from the Shale Hills experimental watershed indicate that the predicted relative rates from the laboratory are correct. The congruence between laboratory and field data give confidence that the calculations of field rates from Shale Hills, among the first known calculations of clay and sheet silicate dissolution and transformation in the field, are on the right track. Future work may use the rate laws derived from laboratory data in a computational model to more precisely predict clay and sheet silicate kinetics in the Shale Hills soils.

A REINTERPRETATION OF FRACTURING AT TETON ANTICLINE, SAWTOOTH RANGE, MONTANA

David Cannon
Advisor: Terry Engelder
Masters

Classic mapping of Teton Anticline (Sawtooth Range, Montana) documented two fracture assemblages (i.e., Stearns, 1964; Friedman and Stearns, 1971). Each assemblage is characterized by one fracture in a plane defined by principal stresses and two fractures intersecting to make a modest acute angle bisected by the direction of the maximum principal stress. These two prominent sets as mapped by Stearns include set I with cross-fold joints and set II with fold-axis parallel joints (i.e., strike joints). Advances in an understanding of linear elastic fracture mechanics over the past 35-40 years allows for an extensive reinterpretation of the Stearns model for fracturing at Teton Anticline.

Foreseen problems of the Stearns model for fracture characterization upon folding include the following. First, classic patterns assume that joints and shear fractures are cogenetic. Second, the pattern does not account for pre-folding fracture sets common to most if not all foreland fold-thrust belts. Third, it does not admit the possibility of multiple joint set propagation during folding. Fourth, the classic patterns do not admit that disjunctive cleavage can be mistaken for fracturing. Finally, the classic patterns do not admit the possibility that some fracturing is a consequence of bedding parallel styolitization.

A number of observations can be applied to the above problems with the classic patterns of fracturing about a fold given by Stearns. First, late to post-fold fracture zones reflect small-displacement wrench faulting. These late-stage fracture zones are the sites of preferential growth of conifers that, when viewed from a distance, give the impression of conjugate fractures in the cross-fold orientation. Second, jointing in the Jurassic Morrison is consistent with a prefolding regional joint set in the cross-fold orientation and the pre-folding LPS. Third, multiple joint sets are consistent with fold growth and may well have populated the cross-fold fracture assemblage of Stearns. Fourth, disjunctive cleavage appears on several scales and could have been responsible for the Stearns interpretation that there was a strike-parallel assemblage and a bedding normal assemblage. Fifth, the most common fracture type in the Mississippian Madison is a mini-fracture associated with bedding-parallel styolitization during overburden compaction. These could have easily populated both Stearns fracture assemblages.