37th Annual Graduate Student Colloquium

Lake Besaka, Metehara, Ethiopa submitted by Tyrone Rooney

Sponsored by the
Department of Geosciences
April 25-29, 2005

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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 25th**	**EMS Museum, 1st Floor Deike**
Poster Session	**1:00-3:00 April 25th**	**EMS Museum, 1st Floor Deike**
Poster Viewing	**3:00 April 25th – 5:00 April 29th**	**Blue Boards, 3rd Floor Deike**
Talk Session 1	**9:00-12:00 April 26th**	**541 Deike**
Talk Session 2	**1:00-3:00 April 26th**	**541 Deike**
Talk Session 3	**1:00-3:30 April 27th**	**541 Deike**
Entropy	**6:00-??? April 29th**	**VFW Hall**

POSTER PRESENTATIONS

Presenter	Advisor	Poster Title
David Bevacqua	Hiroshi Ohmoto	WORLD'S OLDEST HEMATITE (3.46GA) FROM MARBLE BAR, WESTERN AUSTRALIA
Catherine Brennan	Klaus Keller	DETECTING ANTHROPOGENIC CHANGE IN THE NORTH ATLANTIC MERIDIONAL OVERTURNING CIRCULATION USING OXYGEN OBSERVATIONS
Mulugeta Dugda	Andrew Nyblade	CRUSTAL STRUCTURE IN EASTERN AFAR (DJIBOUTI)
Lauren Fuqua	Timothy Bralower	EVOLUTIONARY EVENTS AND PHYTOPLANKTON RECOVERY AFTER THE K/T MASS EXTINCTION
Shawn Goldman	James Kasting	INTERPRETATIONS OF URANIUM MOBILITY AT 3.7 GA
Elizabeth Hausrath	Susan Brantley	BASALT DISSOLUTION IN THE PRESENCE OF ORGANIC ACIDS: A POTENTIAL BIOMARKER?
Gavin Hayes	Kevin Furlong	THE CRUSTAL STRUCTURE OF THE NORTHERN CALIFORNIA COAST RANGES FROM RECEIVER FUNCTIONS
Daniel Hummer	Peter Heaney	HOW DO MINERALS GROW? A TIME-RESOLVED X-RAY DIFFRACTION STUDY OF MINERAL CRYSTALLIZATION
Chris Junium	Michael Arthur	SEDIMENTARY SIGNALS OF ENHANCED NUTRIENT CYCLING IN ANOXIC OCEAN BASINS
Bryn Kimball	Susan Brantley	INVESTIGATING THE COPPER ISOTOPE COMPOSITION OF COPPER-BEARING RESERVOIRS IN ACID MIND DRAINAGE ENVIRONMENTS
Minoo Kosarian	Charles Ammon	VARIATION OF CRUSTAL THICKNESS AND POISSON'S RATION IN CONTINENTAL LITHOSPHERE
Kideok Kwon	James Kubicki	SURFACE COMPLEXATION STRUCTURES OF BACTERIAL EXTRACELLULAR NUCLEIC ACID TO IRON HYDROXIDES: IR SPECTROSCOPY AND ELECTRON STRUCTURE STUDIES
Christina Lopano	Peter Heaney	DETERMINATION OF CATION EXCHANGE RATE IN SYNTHETIC BIRNESSITE USING TIME-RESOLVED SYNCHROTRON X-RAY DIFFRACTION

Presenter	Advisor	Poster Title
Katja Meyer	Katherine Freeman and Lee Kump	RELATIONSHIP BETWEEN LIPID BIOMARKER AND PLANKTONIC MICROBIAL DIVERSITY IN SEDIMENTS OF MEROMICTIC FAYETTEVILLE GREEN LAKE, NY
Joel Moore	Susan Brantley	EFFECTS OF GIANT SEQUOIA ON SOIL CHEMISTRY
Geoff Moret	Richard Parizek	MAPPING PYRITIC ZONES ALONG THE I-99 USING INDUCED POLARIZATION
Tsubasa Otake	Hiroshi Ohmoto	“DETRITAL PYRITE” IN ARCHEAN CONGLOMERATES IS NOT EVIDENCE FOR AN ANOXIC ATMOSPHERE
Youngcheol Park	Andrew Nyblade	THE UPPER MANTLE SEISMIC P WAVE STRUCTURE BENEATH KENYA: EVIDENCE FOR A WESTERN DIPPING UPPER MANTLE THERMAL ANOMALY
Tyrone Rooney	Tanya Furman	SILICATE VEINING ABOVE AN ASCENDING MANTLE PLUME-EVIDENCE FROM NEW ETHIOPIAN XENOLITH
Winchelle Sevilla	Charles Ammon	TRENCH-PARALLEL GRAVITY ANOMALY CHANGES AND LARGE EARTHQUAKES
Burt Thomas	Michael Arthur	WINTERTIME STABLE ISOTOPIC AND GEOCHEMICAL PROFILES FROM PORE WATER PEEPERS AT THE MARGIN OF AN ACIDIC WETLAND, BEAR MEADOWS, CENTRE COUNTY, PA

WORLD'S OLDEST HEMATITE (3.46GA) FROM MARBLE BAR, WESTERN AUSTRALIA

David Cicero Bevacqua
Advisor: Hiroshi Ohmoto
Co-author: Yumiko Watanabe

The Towers Formation (3.46Ga), Warrawoona Group, Western Australia hosts the oldest major jasper/chert sequence in the world: a100m thick unit, dipping nearly vertically, continuous for over 20km and inter-bedded with pillow lavas and tuffs. Hematite, the ferric iron mineral responsible for jasper's distinctive red color, could have formed by either 1) the modern oxidation of ferrous iron minerals (e.g. siderite) or 2) primary (and/or early diagenetic) Fe^{2+} oxidation in 3.46Ga oceans. Red jasper in drill core recovered from ~100-150m underground correlates stratigraphically with jasper found at the surface, indicating the hematite formed from primary mineralization, not modern oxidation.

Primary hematite could have formed through three Fe^{2+} oxidation mechanisms: 1) photochemical reaction in surface water, 2) iron oxidizing bacteria in the photic zone, or 3) mixing with O_2-rich surface or bottom water. Discerning between these possibilities is integral to understanding the chemical evolution of the early earth and earth like planets. To that end, the first ABDP hole retrieved a continuous drill core of fresh rocks (modern weathering free) from the Towers Formation in the summer of 2003.

Approximately 110 drill core samples, including pillow lava, tuff and chert, have been investigated by employing microscopic (SEM, TEM, X-ray chemical, and petrographic thin section), chemical (GC, ICP-MS) and isotopic analyses. Special effort was made to identify: (a) the systematic morphology and grain-size distribution of hematite crystals (<1 – 50 μm) and (b) hydrothermal signatures (e.g., REE anomalies; heavy metal ratios and distribution) in the jasper/chert and associated igneous rocks. Our results suggest that most of the fine-grained hematite crystals in the Towers Formation formed by rapid mixing of Fe^{2+}-rich hydrothermal solutions with O_2-rich bottom waters. Furthermore, the presence of an oxygenated deep sea implies a fully oxygenated atmosphere at 3.46Ga.

DETECTING ANTHROPOGENIC CHANGE IN THE NORTH ATLANTIC MERIDIONAL OVERTURNING CIRCULATION USING OXYGEN OBSERVATIONS

Catherine Brennan
Advisor: Klaus Keller

Anthropogenic climate change may force ocean circulation into a new pattern, different from what previous civilizations have learned to expect. In the Atlantic Ocean, surface currents transport heat towards high latitudes, and in so doing, act to warm the North Atlantic region. These surface currents are part of the North Atlantic meridional overturning circulation (MOC) in which warm, salty water is transported from the tropics to the high northern latitudes. There, surface water becomes cold and dense, and as results, sinks. Sinking in the northern Atlantic is balanced by a southward deepwater return flow, which eventually reaches the Southern Ocean, and enters the Indian and Pacific Oceans. The loop is completed by shallow return flow from the Indian and Pacific Oceans into the Atlantic. This circulation pattern, likened to a conveyor belt, has been stable for millennia, but the geological record as well as model results indicate that the MOC has abruptly shifted in the past, and may do so in the future due to anthropogenic greenhouse gas emissions.

Here we ask, 'when would one be able to detect a change in the MOC intensity based on feasible hydrographic observations?' In particular, how fast would detection occur based on the recently installed MOC observation system at 26°N, and could detection be achieved sooner by additionally observing oxygen?' To this end, we sample simulated observations (MOC strength and oxygen concentrations at 26°N in the Atlantic) from an ocean general circulation model forced with increasing atmospheric carbon dioxide. The natural variability is approximated by the signal prior to the onset of major anthropogenic climate change (*i.e*. 1880-1940). Detection is defined when the optimal fingerprint detector lies outside the empirical 99% confidence interval of the control. This study improves on previous work by (i) explicitly accounting for observation error, and (ii) analyzing a logistically feasible observation system.

CRUSTAL STRUCTURE IN EASTERN AFAR (DJIBOUTI)

Mulugeta Dugda
Advisor: Andrew Nyblade

Afar is an excellent place to study the nature of transitional crustal structure between continental and oceanic rifting. A seismic experiment conducted in Afar in the 1970's showed that the crust in Afar is transitional between continental and oceanic rifting, with crustal thickness between14 and 26 km thick, and an average Poisson's ratio of 0.33. However, a recent study using receiver functions reported much thinner crust (8 km thick) beneath Djibouti, Afar, suggesting an oceanic origin for the crust. In this study we show that the crust under Djibouti, Afar, is an attenuated crust, transitional between oceanic and continental, as is the rest of the Afar. We applied Hk stacking of receiver functions to determine crustal thickness and Vp-to-Vs ratio for the GEOSCOPE station ATD in Djibouti. Simple stacks of receiver functions were also used to make direct comparisons with previous studies. Our estimate for the crustal thickness and Poisson's ratio for the crust under ATD station is 23±1.5 km and 0.3±0.02, respectively, consistent with average crustal structure under most of Afar.

EVOLUTIONARY EVENTS AND PHYTOPLANKTON RECOVERY AFTER THE K/T MASS EXTINCTION

Lauren Fuqua
Advisor: Timothy Bralower

The recovery of the open ocean ecosystem after the Cretaceous-Tertiary boundary mass extinction (65 Ma) was extremely slow. The surface to deep carbon isotopic gradient remained below latest Cretaceous levels for more than three million years after the boundary event, suggesting suppressed rates of carbon cycling and low phytoplankton productivity. There is a rapid change in the carbon isotopic gradient between 62 and 61 Ma, indicating the final recovery of surface water production levels (D'Hondt et al., 1998). We are investigating nannoplankton communities in the interval from 61.5 to 62.5 Ma to determine the relationship between the recovery and changes in productivity and carbon cycling. Samples were collected at high resolution from Ocean Drilling Program Sites 1209 (western Pacific) and 761 (Indian Ocean), and Deep Sea Drilling Project Sites 384 (North Atlantic) and 528 (South Atlantic).

Results show major diversification of two dominant Cenozoic nannoliths (non-coocolith bearing, calcite-secreting nannoplankton), Fasciculithus and Sphenolithus, occurred shortly after carbon gradients were restored. The first occurrences of these two genera are associated with significant changes in calcareous nannoplankton communities, indicative of abrupt changes in surface water circulation. A rapid evolutionary sequence of early forms of Fasciculithus has been identified at Sites 1209 and 384. Two unidentified taxa were found before the first occurrence of the earliest documented species, F. pileatus SEM work currently underway is designed to elucidate the evolution of this genus. At the Pacific site, the diversification is associated with an interval of dissolution, presumably resulting from a change in deep water circulation. The significance of this relationship is currently not understood.

D'Hondt, S. et al., Organic carbon fluxes and ecological recovery from the Cretaceous-Tertiary mass extinction, Science, 282, 276-279, 1998.

INTERPRETATIONS OF URANIUM MOBILITY AT 3.7 GA

Shawn Goldman
Advisor: James Kasting

The timings of the development of oxygenated environments and of the evolution of photosynthesis are crucial to the development of biomarkers for anoxic planets. Recently, evidence for the early (prior to 3.7 Ga) evolution of oxygenic photosynthesis was reported based on lead isotope measurements in ancient sediments (Rosing and Frei, 2004). The lead isotope ratios have been interpreted as a signal of uranium enrichment in organic-rich shales and the enrichment is claimed to be the result of uranium mobility.

Since uranium is mobile under oxidized conditions, it has been argued that the presence of uranium mobility implies high levels of oxygen production prior to 3.7 Ga. Thus, it has been concluded that oxygenic photosynthesis must have been in place by this time. Here, we use simple thermodynamic to determine whether other conditions could have allowed for the observed uranium mobility. Our results show that uranium could have been mobilized by oxidation of the water column through H_2 drawdown by anaerobic bacteria (as opposed to O_2 production), particularly if the early Earth was above 70°C. Drawdown of H_2 increases the oxidation state of the water column through the following equilibrium reaction:

$$H_2 + ½\ O_2 \rightarrow H_2O.$$

Our conclusion is that the presence of this uranium enrichment is consistent with the presence of either oxygenic photosynthesis or of H_2-consumption in a hot, CO_2-rich surface environment.

M.T. Rosing and R. Frei, U-rich Archaean sea-floor sediments from Greenland--indications of >3700 Ma oxygenic photosynthesis, Earth Planet. Sci. Lett. 6907, 1-8, 2003.

BASALT DISSOLUTION IN THE PRESENCE OF ORGANIC ACIDS: A POTENTIAL BIOMARKER?

Elizabeth Hausrath
Advisor: Susan Brantley
Co-author: A. Neaman

Vascular plants, fungi, lichen, and bacteria all produce organic acids, which can strongly affect weathering by increasing the solubilibity and mobility of elements such as iron and aluminum. The effect of these organic acids on rocks, minerals and soils may produce a long-lasting and stable biomarker of life on early earth or on Mars in the form of a leached layer and zone of elemental accumulation such as that observed in spodosols.

To determine the effect of an organic acid on basalt dissolution, powdered Columba River basalt was dissolved in the presence of 0.01 M citrate, and deionized water, in long-term column dissolution experiments. Citrate was chosen based on previous experiments which indicate that it significantly enhances element mobilization from basalt. The pH of the input solutions was adjusted to 6 for both cases, sodium azide and lithium azide were added to prevent microbial growth, and two empty columns were eluted with identical inlet solutions as controls.

Preliminary results indicate that the elements Sr, Y, Zr, La, Ce, W, Th, Mg, Al, P, Ca, Sc, Ti, V, Cr, Mn, Co, Ni, Zn, Fe and Si may be leached from the basalt rocks to a greater extent in the presence of the citrate as compared to the deionized water. Further work is needed to quantify and better understand this effect, but these results indicate that elemental patterns in paleosols and weathered rock may be useful as a biomarker of life, both on Mars and on early earth.

THE CRUSTAL STRUCTURE OF THE NORTHERN CALIFORNIA COAST RANGES FROM RECEIVER FUNCTIONS

Gavin Hayes
Advisor: Kevin Furlong

The crust of Northern California has undergone a process of ephemeral thickening and thinning as a direct result of the northward migration of the Mendocino triple junction along the coast of California over the past 15Ma. The deformation is driven not by compression, but instead by a viscous coupling between the base of the North American plate and the south edge of the Gorda plate, based on the Mendocino Crustal Conveyor model.

We can use the seismologic tool of receiver functions at stations distributed through the Coast Ranges to produce snapshots of this deformation process, allowing us to image the response of the crust to the triple junctions' passage. Detailed analyses, focusing on the local crustal structure from receiver functions and also inferring the change in structure between these stations can help us identify where the major deformation takes place and how it is manifested in the crust. We find that rather than occurring gradually over a broad zone, the deformation is localized, potentially to a narrow area around station FREY (in Redwood Valley). Furthermore, rather than the thickening and thinning being evenly distributed throughout the crustal column, it seems restricted to the lower parts of the crust closer to where the coupling takes place.

Here we present a detailed receiver function analysis at three stations in the Coast Ranges, demonstrating how we can constrain major crustal characteristics through these studies. We find Moho depths varying from ~35km at station CVLO (Covelo/Round Valley) in the north to only 20km less than 100km further south; dips on the Moho on the order of 10°, predominantly in a northeasterly direction around station FREY; high Poisson's Ratio's and low velocity zones that infer melt in the lower crust. These observations can in turn help us to address our questions, key to understanding the evolution of the crust and the formation of a major plate boundary through Northern California.

HOW DO MINERALS GROW? A TIME-RESOLVED X-RAY DIFFRACTION STUDY OF MINERAL CRYSTALLIZATION

Daniel Hummer
Advisor: Peter Heaney
Co-authors: Jeffrey Post and Christina Lopano

The growth of secondary minerals during soil alteration can control a variety of environmentally important processes, such as heavy metal sequestration, microbial metabolism (e.g., Fe and Mn reducing bacteria), and equilibration of local fluid chemistry. Thus, fully understanding the mechanisms that govern mineral crystallization is vital to the study of environmental chemistry. At present, relatively little is known about the rates and mechanisms by which nanoscale clusters transform into macroscopic minerals.

Recently, the harnessing of highly intense X-ray radiation from synchrotron sources has made possible the collection of high resolution diffraction data that feature very high signal to noise ratios. By taking advantage of synchrotron sources, powder XRD patterns of crystallizing minerals can be collected in situ at regular time intervals. From these data, we can extract detailed measurements of changes in the mineral structure throughout the crystallization process with temporal resolution on the order of minutes or better.

In this study, a ~1.0 M aqueous solution of $TiCl_4$ was heated at 125 °C for 8 hrs, and then at 200 °C for an additional 8 hrs, while XRD patterns were collected every 2 min at the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratories. The data indicate that precipitation is rapid (on the order of 3-6 minutes), and occurs within the first 20 min of heating. Initial crystallization yields the transient phase anatase (TiO_2), which within the first 30 min of crystallization begins a slow phase transition to the thermodynamically stable polymorph rutile. The phase transition was still in progress at the end of the second 8 hr run. Rietveld refinements of individual patterns will be assembled to extract kinetic information about the anatase to rutile phase transition, as well as the first high-resolution determination of changes in structural parameters in both anatase and rutile as a function of particle size. Future time resolved XRD work on the effects of temperature, pH, titanium concentration, and other chemical constituents on the crystallization process in rutile and other minerals will provide a vastly improved picture of mineral precipitation in natural settings, and how these processes affect the aqueous chemistry, mineral constituents, and physical properties of environmentally important materials.

SEDIMENTARY SIGNALS OF ENHANCED NUTRIENT CYCLING IN ANOXIC OCEAN BASINS

Chris Junium
Advisor: Michael Arthur

Organic carbon rich sediments of some modern and many ancient “black-shale” forming marine basins are characterized by high orgC/Ptot and orgC/Ntot ratios, in many cases much higher than Redfield stoichiometry. This suggests preferential release of phosphate and nitrogen from particles in the water column or during early diagenesis as a result of anaerobic degradation of organic matter and reduction of metal oxide particles. For example, recent research suggests that a substantial proportion of what has typically been considered “organic P” is sorbed to metal oxide coatings on cell walls and, therefore, is easily liberated in dysaerobic to anaerobic conditions. Such rapid recycling of P, in particular, could be a strong positive feedback to productivity in surface waters of anoxic basins. However, availability of N is limited because of N consumption during denitrification or annamox reactions in the shallow chemocline of such basins. Thus, without further addition of N, productivity is limited. However, N isotope and limited biomarker data from some black shales indicate that N fixation becomes a dominant mode of organic matter production because of the enhanced P availability and N limitation. We present a globally extensive Cretaceous geochemical data set that illustrates these principles.

INVESTIGATING THE COPPER ISOTOPE COMPOSITION OF COPPER-BEARING RESERVOIRS IN ACID MIND DRAINAGE ENVIRONMENTS

Bryn Kimball
Advisor: Susan Brantley
Co-authors: Ryan Mathur, Richard Wanty, and Ian Ridley

Understanding the sources of metals and the processes that affect their transport in watersheds affected by acid mine drainage (AMD) is central to improving stream water quality. The $^{65}Cu/^{63}Cu$ ratios in streamwater from Red Mountain Creek near Silverton, Colorado, were measured using a Nu Plasma multi-collector ICP-MS. Employing the NIST 976 Cu standard and the Johnson-Mattey Zn solution to correct for instrumental mass fractionation, our preliminary results show that $\delta^{65}Cu$ values [where $\delta^{65}Cu = ((^{65}Cu/^{63}Cu_{sample}/^{65}Cu/^{63}Cu_{standard}) - 1) * 10^3$] differ both between dissolved and colloidal/suspended Cu and among sample locations. Measured $\delta^{65}Cu$ values for dissolved Cu span about 2‰; this range suggests that biotic (e.g., microbial metabolism) and/or abiotic processes (e.g., metal sorption and mineral dissolution/precipitation) may induce isotope effects during Cu partitioning. We propose to include additional measurements of Cu isotope ratios in Cu-sulfide ore minerals and streambed precipitates to assess fractionation among all Cu-bearing reservoirs in an AMD environment. If fractionation among these reservoirs is measured, we can then attempt to track mobile Cu through an AMD system using mass balance, and thereby gain insights into the mechanisms that control the mobility of Cu in these environments. Measurement of Cu isotope ratios offers the potential to become an important tool in understanding the biogeochemical cycling of metals through watersheds impacted by AMD.

VARIATION OF CRUSTAL THICKNESS AND POISSON'S RATION IN CONTINENTAL LITHOSPHERE

Minoo Kosarian
Advisor: Charles Ammon

Although much progress has been made over the last decades towards understanding Earth's structure, many questions regarding the details of lithopsheric structure remain unanswered. There is agreement on the general structure of the lithosphere, but interesting and important discrepancies are common in many areas. The purpose of our study is to gain a better understanding of patterns in lithospheric structure. A key component of the study is a survey of diverse crustal structures and tectonic environments. Such a survey provides an opportunity to confirm and revise seismic models of the crust and upper mantle. We investigate lithospheric structure throughout the Middle East, Europe, and North Africa using a simultaneous inversion of receiver functions and surface-wave dispersion. We collected seismic data from available permanent and temporary three-component broadband seismic stations throughout the region. We have gathered observations from one 166 stations recording a total of about 6,000 teleseismic earthquakes and processed more than 90,000 seismograms. The distribution includes 72 stations in the Middle East, 57 stations in Europe, 37 stations in central and north Africa. We have examined receiver functions for 120 of stations in the period of 1990-2004, and have combined them with dispersion measurements from global and regional tomographic models (Pasyanos and Walter, 2002; Ekstrom et al., 1997) to extract important constraints on the subsurface. We also applied the receiver function stacking procedure of Zhu and Kanamori [2000] to estimate Vp/Vs and crustal thickness. This initial analysis provides reasonable constraints on thickness and Poisson's ratio for each station and helps identify stations situated in complex structures, where simple plate-layered interpretations fail. For most stations crustal thickness and Poisson's ratio vary as a function of back azimuth, indicating non-isotropic plane-layered structure. The mean differences between our estimates and those of Crust 2.0 is about 1 km with a standard deviation of different about 4 km. The diversity of the targets also makes these data ideal for innovations in the seismic imaging methods.

SURFACE COMPLEXATION STRUCTURES OF BACTERIAL EXTRACELLULAR NUCLEIC ACID TO IRON HYDROXIDES: IR SPECTROSCOPY AND ELECTRON STRUCTURE STUDIES

Kideok Kwon
Advisor: James Kubicki

Deoxyribose phospho-diester and its complexes with iron dimers were modeled to simulate a double-stranded nucleic acids binding to Fe-hydroxide surface. IR vibrational frequencies of the models were calculated and compared to experimental IR frequencies of extracellular polymeric substances (EPS) adsorbed to goethite (α-FeOOH) surface, which were extracted from B. subtilis and P. aeruginosa. In addition, we calculated reaction energies approximate to adsorption energy from solution to surface for the model structures.

This study implies phosphate groups of nucleic acids may play an important role in initial bacterial adhesion by forming inner-sphere complexes with Fe-hydroxides. The frequency and energy calculations suggest nucleic acids of EPS binds to Fe-hydroxides as a monodentate complex.

DETERMINATION OF CATION EXCHANGE RATE IN SYNTHETIC BIRNESSITE USING TIME-RESOLVED SYNCHROTRON X-RAY DIFFRACTION

Christina Lopano
Advisor: Peter Heaney
Co-authors: Jeffrey Post, Sridhar Komarneni, and Susan Brantley

Birnessite is the most abundant and chemically important layer-structure Mn-oxide phase found in soils, desert varnishes, and ocean nodules. For this work, we measured changes in unit cell parameters over time to quantify the degree of cation exchange as a function of solution concentration. Aqueous K^+, Cs^+, and Ba^{2+} cations at varying concentrations at pH 7 were exchanged for interlayer Na^+ in synthetic birnessite using a simple flow-through cell, and the exchange products were monitored via time-resolved X-ray powder diffraction at the National Synchrotron Light Source. Powder X-ray diffraction patterns were collected every 2-3 minutes.

Rietveld analyses (using the GSAS program) of X-ray diffraction patterns for K- and Ba-exchanged birnessite revealed a decrease in unit cell volume over time; in contrast, Cs substitution increased cell volume. For all three cations, the exchange occurred in two stages. A rapid and dramatic change in unit cell volume was followed by a modest adjustment over longer timescales. Fourier electron difference syntheses revealed that the rapid, initial stage of exchange was marked by major re-configurations of the interlayer species, whereas the second, protracted phase of substitution represented ordering into the newly established interlayer positions. We calculated normalized volume contraction (or expansion) coefficients for the period of rapid initial exchange for each cation solution concentration. Specifically K-exchange at 0.05M, 0.01M, and 0.001M resulted in volume contraction coefficients of $1.51E^{-3}$ min^{-1}, $4.68E^{-4}$ min^{-1}, and $1.69E^{-4}$ min^{-1} respectively. These values yield the following rate equation that corresponds to the rate of cation exchange:

$$\log [\text{Rate Volume Contraction}] = 0.5524 \log [KCl] - 2.1469$$

Further refinements of the Ba^{2+} and Cs^+ exchange results will result in a comparison of the rate of exchange for different cations.

RELATIONSHIP BETWEEN LIPID BIOMARKER AND PLANKTONIC MICROBIAL DIVERSITY IN SEDIMENTS OF MEROMICTIC FAYETTEVILLE GREEN LAKE, NY

Katja Meyer
Advisors: Katherine Freeman and Lee Kump

Lipid distributions were determined in surface sediments from a range of depths in meromictic Fayetteville Green Lake, NY. Lake biota (cyanobacteria, green and purple sulfur bacteria, methanotrophs, etc.) are vertically stratified across the chemocline, making this site ideal for examining the depth distribution of microbial communities in the lake and underlying sediments. Total lipid extracts of freeze-dried sediment samples were treated with periodic acid and sodium borohydride to cleave side chains and then acetylated to produce products that are analyzed with GC-MS. Shallow mixolimnion sediments are dominated by tetrafunctionalized biohopanoids (bishomohopanol). We found both tetrafunctionalized biohopanoids and a tentatively identified hexafunctionalized biohopanoid (moretanol) in the deep euxinic basin and in sediments that intersect the chemocline. Although the distribution of hopanoid structures shifts across the chemocline, the carbon-isotope compositions of all hopanoids do not change through the transect. This isotopic uniformity is unexpected. The distribution of hopanoid structures suggests bishomohopanol is produced by aerobic autotrophs, likely cyanobacteria. Moretanol is only found in sediments at and below the chemocline and may reflect inputs from anoxygenic phototrophs, such as the purple sulfur bacteria.

MAPPING PYRITIC ZONES ALONG THE I-99 USING INDUCED POLARIZATION

Geoff Moret
Advisor: Richard Parizek

Acid rock drainage from pyritic rock unearthed during the construction of Interstate 99 near Skytop has become a multi-million dollar environmental problem. One of the factors hampering remediation efforts at the site is that the distribution of pyritic rock in the subsurface is not well known. Induced polarization (IP) is a geophysical method developed by the mining industry to detect disseminated sulfide ores. In several engineering studies, IP profiling has proved successful in delineating zones of potential acid-producing rock. This study presents four IP profiles collected along the I-99. Two of the profiles were "proof-of-concept" tests where road cuts provided information about the geometry of the pyritic zones. The remaining two profiles were collected to test the effect of deep construction fill and to determine the extent of the largest known acid-producing zone. Future work will focus on both continued mapping and demonstrating the ability of IP profiling to detect pyritic rock before construction begins.

EFFECTS OF GIANT SEQUOIA ON SOIL CHEMISTRY

Joel Moore
Advisor: Susan Brantley
Co-author: A. F. White

The role of plants in governing rates of soil mineral weathering remains unknown. Studies of soil mineral weathering rates conducted in aggrading (young, developing) ecosystems have shown increased weathering in the presence of plants. Here we report preliminary observations from a developmentally steady state ecosystem dominated by giant sequoia (Sequoiadendron giganteum). Significant differences were found in the variation and distribution of bulk oxide composition in soils from giant sequoia root zones compared to soil from a control site outside a sequoia root zone. Sequoia root zone soils exhibited CaO and P_2O_5 depletion, which may be the result of the loss of apatite and plagioclase feldspar in the soil.

“DETRITAL PYRITE” IN ARCHEAN CONGLOMERATES IS NOT EVIDENCE FOR AN ANOXIC ATMOSPHERE

Tsubasa Otake
Advisor: Hiroshi Ohmoto
Co-authors: Wladyslaw Altermann and Yumiko Watanabe

Rounded grains and pebbles of pyrite (FeS2) in gold- and uranium-rich conglomerates of Archean ages have been interpreted, mostly from their external morphology, by many researchers as detrital fragments of pyrite crystals, which were rounded during transportation in fluvial systems. They were cited as important evidence for an anoxic Archean atmosphere, because pyrite is an unstable mineral under an oxygenated atmosphere (e.g., Holland, 1994). We have investigated the morphology and composition of rounded pyrite in quartz-rich conglomerate samples from several ore horizons (~2.8Ga) in the Witwatersrand Basin using a SEM and an X-ray chemical microscope (Horiba XGT-5000).

Our investigation has revealed that: (1) both large pebbles (~10 mm) and small (0.1 – 1 mm) grains of rounded pyrite in the samples are comprised of aggregates of micro (<10 μm) pyrite crystals; (2) the rounded pyrite grains/pebbles contain appreciable amounts of Si (~0.1 - ~10 wt%), Al (~0.1 – ~5 wt%) and other rock-forming elements with highly variable ratios (e.g., Fe/S, Fe/Si); and (3) remnants of Si-rich micro layers, similar to the silica-rich laminae in banded iron formations and in jaspers, are recognizable in many large grains/pebbles of rounded pyrite. These characteristics indicate that the so-called “detrital pyrite” in Archean conglomerates was created by reactions between H2S-rich hydrothermal fluids and detrital grains of Fe-rich rock fragments such as banded iron formations or ferruginous cherts after the deposition of host rock sediments. Therefore, this rounded pyrite cannot be used as evidence for an anoxic atmosphere.

THE UPPER MANTLE SEISMIC P WAVE STRUCTURE BENEATH KENYA: EVIDENCE FOR A WESTERN DIPPING UPPER MANTLE THERMAL ANOMALY

Youngcheol Park

Advisor: Andrew A. Nyblade

We re-examined upper mantle structure beneath the eastern branch of the Tanzania rift system using P wave tomography computed with the combined data set of the 1985 and 1989 KRISP project and the 2001-2002 Kenya Broadband Seismic Experiment. Relative P wave residuals have been computed by a multi-channel cross correlation algorithm, and upper mantle P wave velocity structure has been imaged using the travel time inversion method of VanDecar. We image a strong low velocity region beneath the Kenya rift that shifts to the west with depth. Resolution tests indicate that out tomography model has limited vertical but reasonable lateral resolution. In spite of the limited resolution, it is apparent that the thermally perturbed upper mantle structure extends to depths in excess of 300 km, and dips to the west beneath the Tanzania Craton. Our model is consistent with similar tomographic image to the south in Tanzania that has been attributed to a mantle plum head under the eastern side of the Tanzania Craton.

SILICATE VEINING ABOVE AN ASCENDING MANTLE PLUME-EVIDENCE FROM NEW ETHIOPIAN XENOLITH

Tyrone Rooney
Advisor: Tanya Furman
Co-authors: Dereje Ayalew and Gezahegn Yirgu

The central Main Ethiopian Rift lies in a transitional zone between the continental rifting of East Africa and the sea floor spreading associated with the Red Sea. Lithospheric and sub-lithospheric processes that occur during the transition from continental to oceanic magmatism may be investigated using xenolith-bearing basalts. Explosive Quaternary basaltic eruptions in the Debre Zeyit (Bishoftu) and Butajira regions of the Main Ethiopian Rift, located 20 km to the west of the main rift axis, host Al-augite, norite and rare lherzolite xenoliths, xenocrysts and megacrysts. The host basalt, which is mildly nepehline-normative, was generated as a small degree partial melt of fertile peridotite between 15 and 25 kb. Al-augite (Type II) xenoliths are the most abundant xenolith in these two regions and are derived from crystallised or partially crystallised dyke/veins at depths of up to 35km. Neither carbonatitic nor hydrous (amphibole + phlogopite) metasomatism is evident in either the xenoliths or host basalts, suggesting that infiltration of silicate melts that produced Al-augite veining/dyking dominates the regional lower crust and lithospheric mantle. The metasomatic influence of Al-augite dykes/veins is evident in the elevated Ti and Fe contents of primitive xenoliths interpreted as fragments of the sub-continental lithospheric mantle. Recent geophysical tomography indicates that this veining/dyking is pervasive and segmented, supporting the association of these Al-augite veins/dykes with the formation of a proto-ridge axis. Al-augite xenoliths and megacrysts have been observed in other continental rift settings such as Durango (Luhr, 2001) and Lake Baikal (Litasov, 2000), indicating Al-augite silicate melt metasomatism is a fundamental process associated with continental rift development.

TRENCH-PARALLEL GRAVITY ANOMALY CHANGES AND LARGE EARTHQUAKES

Winchelle Ian Sevilla
Advisor: Charles Ammon

Subduction zones release approximately 90% of global seismic budget and are the loci of the largest earthquakes. Recent studies have demonstrated a correlation between large earthquake occurrences (Mw ≥ 7.5) and trench-parallel gravity anomaly (TPGA), which is the residual gravity after subtracting the average trench-normal gravity profile from the free-air gravity data. A statistical analysis showed that large earthquakes commonly occur in regions with strong negative TPGA, while regions with strong positive TPGA are generally aseismic.

The main goal of this work is to determine whether an increase in TPGA will be observed in the post-seismic gravity data after a large earthquake. This study takes advantage of the newly acquired gravity data from Gravity Recovery Climate Experiment (GRACE) mission launched in 2002 and the Geosat and ERS1 data (1994 to 1995). The initial part of this study is the constructions of TPGA maps of subduction zones with large earthquake occurrences between the years 1995 and 2002 using the data from both missions to evaluate the change in TPGA. A positive correlation between the temporal changes in gravity anomaly and earthquake occurrences may provide important constraints for seismic hazard analysis, specifically regions with very low TPGA may be closer to failure than regions with high TPGA values.

WINTERTIME STABLE ISOTOPIC AND GEOCHEMICAL PROFILES FROM PORE WATER PEEPERS AT THE MARGIN OF AN ACIDIC WETLAND, BEAR MEADOWS, CENTRE COUNTY, PA

Burt Thomas
Advisor: Michael Arthur

Wetland margins lie in a transition zone between methane consuming uplands and methane producing lowlands. Steep hydrologic, pedologic, biologic and chemical gradients across wetland margins result in significant uncertainty about how these margins affect wetland methane budgets. Here we introduce methodology and report winter measurements from a transect of pore water peepers that extend from the forested edge of an acidic fen to the sphagnum dominated lawn.

The wetland is bounded on 3 sides by hills of quartz-cemented sandstones and shales. The data presented here are from liquid samples collected in mid December 2004 from four pore water peepers positioned in a transect perpendicular to the wetland margin. These peepers are deployed within permanently installed outer casings so that a time-series of pore water data can be collected over several seasons. The peeper cells are designed to be used with common laboratory filters (45 mm, .2 µm polypropylene) and provide spatial resolution of 5 cm in the vertical dimension. The cells are sampled for gas analyses using gas-tight syringe additions to flushed headspace vials. The remaining cell contents are analyzed with a field-portable pH/Eh meter and frozen immediately for aqueous chemical analyses. Headspace above pore water samples are measured for dissolved methane concentrations using gas chromatography with a flame ionization detector. Dissolved concentrations are calculated from Henry's Law relationships. The $\delta^{13}C$ of methane was determined on headspace samples with >10 ppm CH_4 with a continuous flow isotope ratio mass spectrometer. Stable carbon isotopic compositions of methane are reported relative to VPDB via an internal standard.

Eh and pH profiles show an inverse relationship with depth. Constant values are observed from 0-25 cm (Eh, 650 mV and pH, 4) with the highest gradients in Eh and pH in an interval approximately 25-45cm below the water surface. Eh and pH profiles reestablish constant values below this zone (Eh, 350 mV and pH, 5.0). The trends in Eh and pH with distance from the wetland margin are primarily expressed in peeper cells below 45 cm where values of Eh and pH trend lower toward the center of the wetland. Dissolved methane concentrations range from low µM - 2mM with distinct concentration gradients that correlate with gradients in Eh. One notable observation is that none of the samples within 20 cm of the surface show significant dissolved methane concentrations. In the absence of a concentration gradient the flux of methane to the surface via diffusion is likely minimal. Carbon stable isotopic ratios of methane range between -54 to -74 ‰ with the majority of those values between -65 and -72 ‰. In profiles, these values trend heavier toward the surface. Significant methanotrophy in upper horizons would be consistent with the observed trends in δ^{13} CH_4 profiles.

ORAL PRESENTATION SCHEDULE - TUESDAY MORNING

Time	Presenter	Advisor	Title
9:00	Andrew Rathbun	Chris Marone	LABORATORY STUDY OF THE FRICTIONAL PROPERTIES OF TILL
9:15	Courtney Johnson	Kevin Furlong	POTENTIAL EARTHQUAKE HAZARDS BENEATH MT. TAMALPAIS: MODELING FAULT INTERACTIONS
9:30	Joseph Razzano	Peter Flemings	TAHOE FIELD CASE STUDY – UNDERSTANDING RESERVOIR COMPARTMENTALIZATION IN A CHANNEL-LEVEE SYSTEM
9:45	Nathan Harkins	Eric Kirby	ARE THE MOUNTAINS GOING UP OR ARE THE RIVERS GOING DOWN IN NE TIBET? QUANTIFYING UPLIFT AND TOPOGRAPHIC DEVELOPMENT IN THE ANYEMAQUEN SHAN
10:00	**Break**		
10:15	Xiaoli Liu	Peter Flemings	FEEDING AND PASSING GAS THROUGH THE HYDRATE STABILITY ZONE AT SOUTHERN HYDRATE RIDGE, OFFSHORE OREGON
10:30	Leo Peters	Sridhar Anandakrishnan	EVIDENCE OF SUBGLACIAL SEDIMENT DEFORMATION IN THE ONSET REGION OF TRIBUTARY C1B, WEST ANTARCTICA
10:45	Angela Larson		
11:00	Scott Miller	Rudy Slingerland	CONVEXO-CONCAVE LONGITUDINAL PROFILES OF TRANSHIMALYAN RIVERS, WITH IMPLICATION FOR THE HISTORY OF THE SOUTH TIBETAN FAULT SYSTEM

LABORATORY STUDY OF THE FRICTIONAL PROPERTIES OF TILL

Andrew Rathbun
Advisor: Chris Marone
Co-authors: Sridhar Anandakrishnan and Richard Alley
MS Student

Recent studies show that small-amplitude stress changes can trigger ice sheet motion and subglacial seismicity. Deformation in the subglacial region plays a key role in determining slip behavior, including creep, transient slip, and stick-slip (seismic) motion. 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 frictional constitutive properties of till from the Matanuska Glacier, Alaska and Caesar Till from the Scioto Lobe of central Ohio.

Experiments were conducted in a servo-controlled, double direct shear apparatus with dried till samples sheared at displacement rates of 1 to 300 μm/s and normal stresses of 50 kPa to 5.0 MPa. Till was sheared in a three-block arrangement in which two layers are sandwiched between a central forcing block and two stationary blocks. The nominal frictional contact area is constant during shear with an initial layer thickness of 1 cm. We studied the effect of saturation, sliding history, normal stress, and slip velocity. In these experiments, the frictional contact area was 100 cm^2 and the forcing blocks were grooved perpendicular to the shear direction with a depth of 0.8 mm and wavelength of 1 mm. The Matanuska till had grains ranging from 6.3 mm to finer than .063 mm with a mean of 2.67 mm whereas the Caesar till has a smaller mean grain size of 0.60 mm, but lacks silt and clay sized particles. In all cases the grain size used in experiments is less that 1/10 the layer thickness to minimize boundary effects.

Results at all normal stress of 0.5 MPa show stable sliding for both dry and saturated experiments. Samples from the Matanuska till show an increase of friction with velocity. This trend indicates velocity-strengthening behavior. The velocity-strengthening exponentially decays with increased normal stress. Caesar till dominantly shows velocity-strengthening behavior, however, the degree of strengthening is much less than with Matanuska samples. When the Caesar experiments were repeated under saturated conditions a transition from velocity-weakening to strengthening was seen. The lowest normal stress conditions, 50 and 100 kPa weakened, but larger normal stresses showed strengthening increasing with normal stress. Coulomb-Mohr failure envelopes give an internal friction angle of 31.5 degrees and cohesion of 9.5 kPa. While Caesar till has a friction angle of 29.4 and 28.0 with a cohesion of 29.6 and -8.5 for dry and saturated experiments respectively. Our results indicate velocity-strengthening and thus imply that shear of the glacial till will be dominantly stable under the conditions studied.

POTENTIAL EARTHQUAKE HAZARDS BENEATH MT. TAMALPAIS: MODELING FAULT INTERACTIONS

Courtney Johnson
Advisor: Kevin P. Furlong
Additional Collaboration: Eric Kirby
MS Student

The major earthquake hazards in the San Francisco Bay area are the strike-slip faults that litter the region. However, the complex geometries and slip budgets of these faults imply that there is the potential for linkages between them that may have been previously unrecognized. Specifically, blind thrust structures may connect segments of strike-slip faults, completing regional slip budgets. These faults not only help explain the variable topography observed but also may serve as additional earthquake sources within the region.

Analysis of uplift patterns in the Marin County – Mt. Tamalpais region and best estimates of slip on major strike-slip faults in the area precludes that fault-normal shortening as the primary mechanism generating the observed elevations. We propose that the Marin County – Mt. Tamalpais region is instead underlain by one or more blind thrust structures. These faults would connect the northern Hayward Fault to the San Andreas near Point Reyes. We test our hypothesis against a number of different fault geometries that have the potential to produce the present-day elevations in the region, taking into account realistic estimates of erosion. In evaluating the earthquake potential on the proposed blind thrusts, we have modeled an array of fault geometries, spatial extent, slip distribution, and linkages between strike-slip faults in the region. Additional keys to constraining the earthquake potential of such structures are improved estimates of slip rates and histories of major faults in the San Francisco Bay area, as well as a more complete record of current displacements and erosion rates in the region.

TAHOE FIELD CASE STUDY – UNDERSTANDING RESERVOIR COMPARTMENTALIZATION IN A CHANNEL-LEVEE SYSTEM

Joseph Razzano
Advisor: Peter Flemings
Co-authors: Chekwube Enunwa, Asha Ramgulam, Turgay Ertekin and Zuleima Karpyn
MS Student, Petroleum Theme

Normal faults and stratigraphic complexity within a channel-levee system form compartments in the Tahoe Field. Tahoe lies 140 miles east-southeast of New Orleans in Viosca Knoll (VK) Blocks 783, 784 & 827 in water depths ranging from 1,200ft to 1,600ft. The main reservoir, termed the M4.1, is a Late Miocene sand located approximately 10,000ft below sea-level. It was formed by turbidite flows that entered an unconfined slope setting and deposited a NW-SE trending channel-levee system. This channel-levee system is draped over an anticlinal dome and cut by normal faults. Faulting forms the updip trap in the M4.1 and plays an important role in the compartmentalization of the reservoir. Pressure analysis indicates multiple pressure profiles within the M4.1 which could be an indication of compartmentalization. High amplitudes parallel structural contours in the southeastern portion of the field and are interpreted to record a hydrocarbon-water contact. Amplitudes decrease as the levees thin laterally to the southwest and northeast and this is interpreted to record stratigraphic pinchouts. Two of the reservoir compartments are separated by the levee channel. Channel-levee architecture along with faulting plays a key role in the compartmentalization and trapping of hydrocarbons in the M4.1.

ARE THE MOUNTAINS GOING UP OR ARE THE RIVERS GOING DOWN IN NE TIBET? QUANTIFYING UPLIFT AND TOPOGRAPHIC DEVELOPMENT IN THE ANYEMAQUEN SHAN

Nathan Harkins
Advisor: Eric Kirby

One of the great questions in modern geology resides in the unknown bulk kinematic properties of the Tibetan plateau. An accurate picture of plateau kinematics helps to constrain both the rheologic properties of the Tibetan crust and upper mantle, and the mechanisms and chronology of past plateau growth. The Kunlun fault, in NE Tibet, is a major continental strike-slip fault that appears to terminate near the plateau margin. Offset landforms that indicate a slip rate gradient from >1cm/yr to <0.2 cm/yr along the eastern Kunlun fault corroborate this fault termination. Patterns of tectonically driven surface uplift and subsidence within the Anyemaquen Shan, an elongate area of high elevations and relief developed around the around the fault termination, would give insight into the kinematics of the northeastern plateau. These uplift patterns, however, are confused by a potential series of non-tectonically generated transient incision events along the Yellow River (from climate change or drainage integration events). We use the morphologies of rivers to identify patterns of incision that are consistent with both a transient event along the Yellow River and spatially broad steady-state uplift within the Anyemaquen Shan. Basin-wide sediment cosmogenic nuclide content samples yield erosion rates that are consistent with an uplifting landscape (0.3-0.4 mm/yr) but do not exhibit a spatial pattern consistent with this uplift. As this project is ongoing, we hope to use more cosmogenic sampling and determinations of incision rates along the Yellow River in order to: 1. Explain the anomalous pattern of cosmogenic erosion rate determinations. 2. Better segregate patterns of transient river incision and steady-state uplift in the Anyemaquen Shan. 3. Quantify the pattern and rates of steady-state uplift in the Anyemquen Shan.

FEEDING AND PASSING GAS THROUGH THE HYDRATE STABILITY ZONE AT SOUTHERN HYDRATE RIDGE, OFFSHORE OREGON

Xiaoli Liu
Advisor: Peter Flemings
PhD Student, Post-Comps

We present an equilibrium model of methane venting through the hydrate stability zone at southern Hydrate Ridge, offshore Oregon. Free gas supplied from below forms hydrate, depletes water, and elevates salinity until pore water is too saline for further hydrate formation. This system self-generates local three-phase equilibrium and allows free gas migration to the seafloor. Log and core data from Ocean Drilling Program (ODP) Site 1249 show that from the seafloor to 50 meters below seafloor (mbsf), pore water salinity is elevated to the point where liquid water, hydrate and free gas coexist. The elevated pore water salinity provides a mechanism for vertical migration of free gas through the regional hydrate stability zone (RHSZ). This process may drive gas venting through hydrate stability zones around the world. Significant amount of gaseous methane can bypass the RHSZ without forming gas hydrate. Furthermore, we show that the hydrate accumulation via gas phase transport exists at a metastable equilibrium. This offers not only the benefit of ease-of-recovery, but also the jeopardy that only small changes in seafloor pressure and temperature may trigger widespread dissociation.

EVIDENCE OF SUBGLACIAL SEDIMENT DEFORMATION IN THE ONSET REGION OF TRIBUTARY C1B, WEST ANTARCTICA

Leo Peters
Advisor: Sridhar Anandakrishnan
MS Student

A soft, deformable sediment bed is vital in initiating streaming ice flow along the Siple Coast of West Antarctica, based on new seismic data and previous work. New geophysical results from a seismic reflection experiment in the onset region of tributary C1B image a subglacial sedimentary basin, with drumlin features present at the base of the ice sheet, indicative of the deformation of soft sediments as the ice slides over the underlying sedimentary basin. This sedimentary basin lies just upstream of a speed-up in ice velocity, a decrease in basal shear stress, and continuous sediment cover, all of which indicate the development of streaming ice flow. The sediment deformation observed here suggests that streaming ice flow may not be able to develop along the Siple Coast of West Antarctica until basal drag is sufficiently reduced and lubricated basal sliding can be continuously maintained.

IMAGING THE 410 AND THE 660 KM DISCONTINUITIES BENEATH THE TRANSANTARCTIC MOUNTAIN AND THE EAST ANTARCTIC CRATON USING RECEIVER FUNCTIONS

Angela Marie Larson
Advisor: Andrew Nyblade
PhD Student, Pre-Comps

Deployed from 2000-2003, the Transantarctic Mountain Seismic Experiment (TAMSEIS) consisted of 41 portable broadband seismometers spread across three main tectonic regions of Antarctic: East Antarctic, the West Antarctic Rift System and the Transantarctic Mountains (see figure, from Lythe et al 2001). One array followed the Antarctic coast near the Ross Sea, and the other two arrays are normal to each other and cross the Transantarctic Mountains. In this study, the TAMSEIS data are being used to gain insight into the thermal structure of the mantle by stacking receiver functions to image the 410 and 660 km discontinuities.

This research has significant impact on the current debate concerning the mechanism that formed the Transantarctic Mountains. This mountain range was formed in the Cenozoic and closely parallels the West Antarctic Rift System. It is considered by many to be a classic example of rift flank uplift, but there are several competing theories for the driving force behind its uplift. One hypothesis suggests a mantle plume rising beneath the region but a second proposal limits any thermal anomaly to the region closer to the surface and not extending deep into the mantle. Higher than normal temperatures affect the transformation depths for phases of olivine, making the normal 410 km transition deeper and the 610 km transition shallower. Mapping relief on the 410 and 660 km discontinuities can therefore be used to place constraints on the depth extent of thermal anomalies in the upper mantle Preliminary results for this study using a 1-D velocity model show clear arrival suggesting some topography on both discontinuities.

CONVEXO-CONCAVE LONGITUDINAL PROFILES OF TRANSHIMALYAN RIVERS, WITH IMPLICATION FOR THE HISTORY OF THE SOUTH TIBETAN FAULT SYSTEM

Scott Miller
Advisor: Rudy Slingerland
PhD Student, Post-Comps

Recent geological and geochronological studies, supported by thermo-mechanical geodynamic models, show that rock comprising the Higher Himalaya has been extruded from beneath the Tibetan Plateau along the South Tibetan fault system (SFTS) and above the Main Himalayan Thrust (MHT). Whether this is an active phenomenon, however, is currently debated. If extrusion is active, longitudinal profiles of Transhimalayan rivers should reflect its velocity field. Longitudinal profiles of these rivers are, in fact, convexo-concave as they pass from the Tibetan Plateau through the Higher Himalaya to the Lesser Himalaya and Sub-Himalaya. Convex reaches are as long as 50 km. Does this convexo-concavity develop as a steady-state consequence of extrusion? Explanations for the convex reaches put forward to date suggest these are transient knickzones, migrating headward in response to relatively recent rock uplift, or palimpsests reflecting the down-valley limits of Quaternary glacial erosion.

ORAL PRESENTATION SCHEDULE - TUESDAY AFTERNOON

Time	Presenter	Advisor	Title
1:00	Matthew Bachmann	Lee Kump	A NEW METHOD FOR QUANTIFYING RATES OF GROUNDWATER POLLUTION REMEDIATION BY SUBSURFACE MICROBES
1:15	Louanne Christoper	Peter Flemings	COMPARISON OF NUMERICAL AND ANALYTICAL SOLUTIONS OF THE 1-D DIFFUSION EQUATION FOR FLOW IN POROUS MEDIA
1:30	Courtney Turich	Katherine Freeman	A RELATIONSHIP BETWEEN THE ARCHAEAL LIPIDS AND SALINITY
1:45	Phil Morath	Tim White	HYDROCARBON GENERATIVE POTENTIAL OF MID-CRETACEOUS STRATA IN SOUTHEASTERN SOUTH DAKOTA AND NORTHWESTERN IOWA
2:00	**Break**		
2:15	Doug Edmonds	Rudy Slingerland	GEOMETRIC PROPERTIES OF BIFURCATING DELTA DISTRIBUTARY CHANNELS
2:30	Jon Samuelson	Chris Marone and Barry Voight	LABORATORY INVESTIGATION OF THE FRICTIONAL BEHAVIOR OF GRANULAR VOLCANIC MATERIAL
2:45	Chris Junium	Michael Arthur	SEDIMENTARY, PETROGRAPHIC, AND GEOCHEMICAL EVIDENCE FOR BENTHIC MICROBIAL MATS AND A REFINED MUDSTONE STRATIGRAPHY FOR THE NEOPROTEROZOIC KWAGUNT FORMATION, CHUAR GROUP, GRAND CANYON

A NEW METHOD FOR QUANTIFYING RATES OF GROUNDWATER POLLUTION REMEDIATION BY SUBSURFACE MICROBES

Matthew Bachmann
Advisor: Lee Kump
Co-author: Jay Regan
PhD Student, Post-Comp

Subsurface microbial respiration rates are difficult or impossible to measure by traditional methods in largely inaccessible groundwater aquifers. This study examines the utility of Q-RT-PCR (Quantitative Reverse Transcriptase Polymerase Chain Reaction) for making rate measurements of geochemically significant microbial processes at a field site in the Florida Keys with a nitrate contamination problem. This technique measures the abundance of expressed functional denitrifying genes as a proxy for denitrification rate, and can measure a respiration rate on a single sample at a single point in time.

Anthropogenic nitrate is the most common groundwater contaminant in the United States. In the Florida Keys, excess nitrate from wastewater injection facilities creates high nutrient groundwater plumes that adversely impact local water quality in restricted canals, and may be responsible for observed eutrophication of the offshore reef environment. Three dimensional finite element groundwater models of this aquifer system are limited by poor constraint on the rate of microbial denitrification between the point of injection and the point of release. Traditional methods of measuring denitrification are unfit for such a task, due to the aquifer's low permeability and the high sampling requirements required for model constraint.

The technique developed here measures the ratio of expressed RNA copies to DNA copies of the nitrite reductase gene *nirS*. To build a correlation between denitrification rate and expressed gene abundance, the model organism *Paracoccus denitrificans* was grown in batch culture under controlled conditions. Denitrification rate was measured by mass balance, total DNA and RNA were extracted throughout the growth sequence, and *nirS* gene abundance was measured by Q-RT-PCR. Future work will include mixed cultures from the aquifer under study, and will examine the effect of temperature and nutrient conditions on the correlation between respiration rate and expressed gene abundance.

COMPARISON OF NUMERICAL AND ANALYTICAL SOLUTIONS OF THE 1-D DIFFUSION EQUATION FOR FLOW IN POROUS MEDIA

Louanne Christopher
Advisor: Peter Flemings
MS Student, Petroleum Theme

This study compares finite difference solutions with analytical solutions of the 1-D diffusion equation for fluid flow to constrain errors and determine the accuracy and application of numerical modeling simulations. Accuracy of the numerical solution is increased when more elements (smaller size) and smaller time steps are used, at the expense of computation time. Applicability of analytical solutions for comparison depends on the boundary conditions and initial conditions used in the derivation and should be matched to the model. The error function method derived for the infinite half-space model shows good agreement in early times with the Fourier series solution for a finite space. The Gibson solution is used for comparison with models incorporating consolidation source terms.

A RELATIONSHIP BETWEEN THE ARCHAEAL LIPIDS AND SALINITY

Courtney H. Turich
Advisor: Katherine H. Freeman
Co-author: A. Daniel Jones
PhD Student, Post-Comps

Archaea, a distinct prokaryotic domain of life, synthesize unique ether-linked membrane lipids which can be particularly well-preserved as molecular fossils. The recalcitrance of these biomarkers, coupled with the broad distribution of Archaea, has sparked interest in finding relationships between Archaeal lipids and environmental parameters with the goal of developing paleoproxies applicable in a range of geological settings. Other workers have proposed two promising proxies based on suites of tetraether lipids, the TEX86 proxy for paleowater temperature and the BIT proxy for past terriginous input. Our study examines trends in Archaeal lipid distribution as a function of salinity. We have found a strong correlation between salinity and the ratio of archaeol (a C40 diether) and caldarchaeol (a C80 tetraether). Liquid chromatography-atmospheric pressure chemical ionization-mass spectrometry (LC-APCI-MS) analysis of intact core ether lipids extracted from particulate organic matter and sediments show that the archaeol : caldarchaeol ratio increases linearly from freshwater to hypersaline environments. Thus far, these trends appear to be insensitive to temperature (19-31ºC) or pH (4.1-7.9). The origin of this relationship may be a shift in community structure, specifically from uncultured Euryarchaeota groups which produce both archaeol and caldarchaeol, to a distinct halophile clade which produce only diethers. We will continue to confirm this correlation and its possible origins in modern samples, and test the utility of this relationship as a possible proxy for paleosalinity in ancient sediments.

HYDROCARBON GENERATIVE POTENTIAL OF MID-CRETACEOUS STRATA IN SOUTHEASTERN SOUTH DAKOTA AND NORTHWESTERN IOWA

Philip Morath
Advisor: Tim White
MS Student, Petroleum Theme

Historically, shallow accumulations of methane associated with glacial drift have provided local energy resources in the midwestern U.S. One hypothesis suggests that the origin of the gas is contemporary methanogenesis, that is, modern communities of microorganisms feeding on organic rich bedrock.

Throughout much of southeastern South Dakota and northwestern Iowa, Cretaceous rocks lie beneath glacial drift. The Cretaceous was a time of enhanced organic carbon burial, an observation that explains the globally vast fossil fuel resources of this age. Therefore, Cretaceous rocks in the Midwest present a possible source rock for natural gas generation.

My focus is the Middle Cretaceous Dakota Formation, Graneros Shale, and Greenhorn Formation from the Davison core, southeast South Dakota, and the Hawarden core, northwest Iowa. Total organic carbon contents (%TOC) range from ~0 to 53% in the Dakota Formation, although values are <1% in much of the formation. Thin carbonaceous shales and coals were observed in both cores. Hydrogen Index (HI) values ranging from ~0 to 200 in the Dakota Formation are indicative of dominantly terrestrially derived, gas-prone organic matter, an observation verified by visual and petrographic observations.

%TOC values range from ~0 to 8% in the Graneros Shale while HI values of ~50 to 600 indicate that the organic matter represents a mix of terrestrial and marine derived organic carbon. In the Greenhorn Formation, %TOC ranges from ~0 to 10% with HI values from ~100 to 700; these values indicate a greater proportion of marine organic components with terrestrial organic matter. These observations are consistent with the overall transgressive nature of the sequence of strata.

T_{max} values for organic matter in all of the study formations in the Hawarden core range from ~415 to 430, and maximum vitrinite reflectance values range from 0.421 to 0.501 in the Dakota Formation of the Davison core, values indicative of thermal immaturity relative to oil and gas generation. The quantity, quality and maturity of Middle Cretaceous organic matter are consistent with contemporary methanogenesis, although trapped Cretaceous biogenic gas cannot be ruled out. Further study of the organic matter and regional stratigraphic relationships will help to understand the formations as potential gas sources for unconventional reservoirs associated with glacial drift.

GEOMETRIC PROPERTIES OF BIFURCATING DELTA DISTRIBUTARY CHANNELS

Doug Edmonds
Rudy Slingerland
MS Student

The process of channel bifurcation lies at the heart of delta function and form, yet the geometries and stabilities of distributary diffluences, and the hydrodynamic conditions that give rise to them, cannot be predicted. To better understand this process we have collected the distributary network topologies of 26 deltas representing a broad range of climates, sediment and vegetation types, and river discharges. Channel widths, channel lengths from diffluence to diffluence, diffluence angle (a) and the length-width ratio of diffluence pairs were measured from Landsat 5 images with 30 meter per pixel resolution using GIS tools. This resolution precluded channels narrower than 100 m; we also eliminated distributary channels that rejoined downstream. Diffluence order is here defined as the number of diffluences upstream of the current diffluence. Channel width was non-dimensionalized by width of 0^{th} order channel and channel length was non-dimensionalized by the width of that channel.

Results show that the distributary channel diffluence angles in our dataset are normally distributed with $a = 78^{o}$ and $s = 26^{o}$ *(N = 540).* Channel widths and lengths are log normally distributed with $x = 0.40$ *(N = 340)* and *21.50 (N = 195),* respectively. The channel width and length ratios of the bifurcate arms are square root-log normally distributed with $x = 0.60{:}1$ *(N = 170)* and *0.57:1 (N = 68),* respectively. A statistically significant positive correlation $R^2 = 0.57$ *(N = 195)* exists between dimensional channel length (L) and width (W) of bifurcates such that $L = 13.33W^{1.09}$ consistent with scaling theory. Partitioning of these properties within a delta was examined by binning the data according to diffluence order. When binned and averaged by diffluence order, diffluence angles show no trend, however there is a well-defined decrease in channel width, channel length with increasing order. Channel width and length ratios show the same trend, but are more scattered. When dimensional channel width and length are binned by order and fitted to a power law, length becomes a progressively higher order function of width with increasing diffluence order.

A rational theory explaining these values remains to be proven. The diffluence angle is not easily predicted by the dynamics of turbulent plane jets, and the average width and length ratios of the bifurcate arms are opposite the ratios predicted by the theory of Bolla Pittaluga et al. (2003) for braid-bar diffluences.

LABORATORY INVESTIGATION OF THE FRICTIONAL BEHAVIOR OF GRANULAR VOLCANIC MATERIAL

Jon Samuelson
Advisors: Chris Marone and Barry Voight
MS Student

We report on detailed laboratory experiments designed to elucidate the frictional behavior of volcanic materials, including pyroclastic flow debris from Soufriere hills volcano, Montserrat, and lahar deposits from Mt. St. Helens. Experiments were conducted in a servo-controlled, double-direct shear apparatus by shearing two 5-mm thick layers of loosely packed pyroclastic material between three roughened forcing blocks under conditions of monitored temperature and humidity. The central block is driven between the stationary side blocks at a precisely controlled displacement rate (typically 10 μm/s). We studied the effects of loading velocity, normal stress, grain size distribution, and water content. Normal stress was maintained constant during shear. A range of grain sizes and grain size distributions were examined, using material up to 1.0 mm in diameter. Median diameter (Mdϕ) and the phi deviation measure (σϕ) were varied, as well as several other distribution parameters. Experiments were conducted on pyroclastic material of fine (0.063-0.125 mm) and coarse (0.5-1.0 mm) grain sizes, as well as two broader grain size distributions (0.125-1.0 mm, and 0-1 mm). Using a normal stress range of 0.75 to 8 MPa we created a Coulomb-Mohr envelope and found that the coefficient of internal friction varies from 0.62 to 0.64 over this grain size range. The residual coefficient of sliding friction increases slightly, from 0.63 to 0.64, with increasing grain size and stays constant at 0.62 with a widening of the grain size distribution. For experiments on the natural grain size distribution (0-1 mm), we varied the shear velocity in the range 10 to 900 μm/s. These data indicate that the value of residual sliding friction increases with slip velocity, and thus exhibits velocity strengthening frictional behavior. A series of variable normal stress experiments were run at 100 μm/s so as to create a Coulomb-Mohr envelope that indicates the coefficient of internal friction increases from 0.62 at a shear velocity of 10 μm/s to 0.64 at 100 μm/s. Ongoing experiments include slide-hold-slide tests to identify time-dependent frictional healing effects and saturated tests to investigate the effects of water. Our results indicate that the frictional properties of granular, volcanic sediment are sensitive to shear velocity, normal stress, and are relatively insensitive to variations in grain size distribution.

SEDIMENTARY, PETROGRAPHIC, AND GEOCHEMICAL EVIDENCE FOR BENTHIC MICROBIAL MATS AND A REFINED MUDSTONE STRATIGRAPHY FOR THE NEOPROTEROZOIC KWAGUNT FORMATION, CHUAR GROUP, GRAND CANYON

Chris Junium
Advisor: Michael Arthur
Co-author: Kevin Bohacs
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Integrated study of the sedimentology, stratigraphy, and geochemistry of the mudstones of the Chuar Group reveals many important details of the break-up of Rodinia, the rise of early macroscopic eukaryotes, and conditions leading up to the first Neoproterozoic Snowball Earth episodes.

Mudstones of the Kwagunt formation (~500 m thick) accumulated in an intracratonic, marine rift basin on the western edge of Laurentia. They display a wide range of sedimentary and geochemical characteristics that suggest that organic carbon burial in Kwagunt Formation was mediated by benthic microbial mats. Pseudo-cross laminated structures, carbonaceous lenses, crinkly, silty, anastomosing and discontinuous laminations occur in deeper-water intervals, and fenestral laminations, roll-up features and pustular surfaces, indicative of mat dessication, are more common in shallower regions. The occurrence of even-over-odd preferences in n-alkane distributions and possible monomethyl-alkane series support the interpretation of theses sedimentary structures as benthic microbial mats with associated sulfide-oxidizing bacteria and accord with previous observations of quaternary-branched-diethylalkanes and monomethyl-alkane series by other researchers.

Detailed mudstone stratigraphy displays two modes in the relation between total organic carbon (TOC) and silt content. The bulk of the stratigraphic section (~425 m) is TOC-poor (0-5 %TOC) and displays a positive relation between silt content and TOC. Two TOC-rich (> 5 %TOC) intervals within the Walcott Member, the uppermost member of the Kwagunt formation, demonstrate an inverse relation where silt content is to proportional to 1/%TOC. These two trends are attributed to variations in basin evolution, sediment distribution and dilution, along with increased primary production and more reducing conditions that enhance carbon burial. Greater %TOC associated with increased silt delivery may be the result of increased riverine nutrient delivery or chemocline rise during wetter conditions. The two TOC-rich intervals within the Walcott Member are likely a result of basin deepening and expansion that traps silt nearshore which fosters the deposition TOC-rich black shales (>5% TOC) by limiting siliclastic dilution.

ORAL PRESENTATION SCHEDULE - WEDNESDAY AFTERNOON

Time	Presenter	Advisor	Title
1:00	Alex McKiernan	Demian Saffer	IN-SITU CLAY DEHYDRATION AND LATERAL FLOW IN THE NANKAI TROUGH, JAPAN
1:15	Derek Sawyer	Peter Flemings	STRATIGRAPHY OF A LATE PLEISTOCENE TURBIDITE SYSTEM ON THE LOUISIANA SLOPE: SUBMARINE CHANNELS, A BASIN-FLOOR FAN, AND SLOPE FAILURES
1:30	Audrey Hucks	Peter Flemings	OBSERVATIONS OF TIDALLY INFLUENCED PORE PRESSURES AT ODP SITES 808 AND 1173 (NANKAI TROUGH) BEFORE AND AFTER ACORK VALVE CLOSURE
1:45	Andrew Krug	Mark Patzkowsky	GEOGRAPHIC VARIABILITY IN RECOVERY PATTERNS FROM THE LATE ORDOVICIAN MASS EXTINCTION
2:00	Anthony Riccardi	Michael Arthur and Lee Kump	PERTURBATIONS TO THE CHEMOCLINE OF THE OCEAN DURING THE END PERMIAN MASS EXTINCTION
2:15	Aubreya Adams	Andrew Nyblade	ANTARCTIC UPPER MANTLE STRUCTURE AS DETERMINED BY JOINT INVERSION OF PHASE VELOCITIES AND RECEIVER FUNCTIONS
2:30	Joel Moore	Susan Brantley	REACTIVE TRANSPORT MODELING OF REACTION FRONTS
2:45	Robert Selover	Rudy Slingerland	CLINOFORM MORPHOLOGY IN THE GULF OF PAPUA, PAPUA NEW GUINEA AS PREDICTED BY SEASONAL CIRCULATION PATTERNS USING THE NAVY COASTAL OCEAN MODEL
3:00	Timothy Watson	Andrew Nyblade	UPPER MANTLE VELOCITY STRUCTURE BENEATH THE TRANSANTARCTIC MOUNTAINS FROM BODY-WAVE TOMOGRAPHY USING TAMSEIS DATA
3:15	Shawn Goldman	James Kubicki	MODELING FE ISOTOPE FRACTIONATION BY ORGANIC LIGANDS IN SOLUTION

IN-SITU CLAY DEHYDRATION AND LATERAL FLOW IN THE NANKAI TROUGH, JAPAN

Alex McKiernan
Advisor: Demian Saffer
PhD Student, Pre-Comps

Ocean Drilling Program (ODP) Leg 190 to the Nankai Trough, southwest Japan, noted the presence of low-chlorinity pore waters at Site 1173, 11 km seaward of the deformation front. The introduction of fresh water to subducting sediments can occur through the lateral flow of dehydration-sourced fluids from depth, or in-situ via clay dehydration. The relative contribution of each mechanism has implications for pore fluid pressure within subducting sediments, and therefore the shear strength of the plate boundary fault through the manipulation of effective stress. Here we present simulations that suggest most, if not all, of the PWF observed at Site 1173 and other sites along the Muroto Transect can be explained by in situ clay compression and dehydration, where interlayer water within smectite is both squeezed out during compaction and released during thermal transformation to illite; little to no lateral flow is necessary.

STRATIGRAPHY OF A LATE PLEISTOCENE TURBIDITE SYSTEM ON THE LOUISIANA SLOPE: SUBMARINE CHANNELS, A BASIN-FLOOR FAN, AND SLOPE FAILURES

Derek Sawyer
Advisor: Peter Flemings
M.S. Student, Petroleum Focus

I integrated an extraordinary industry dataset of 3-D seismic and wireline gamma ray logs to study the geometry, lithology, and geologic evolution of a late Pleistocene deep-water turbidite system. Superb three-dimensional seismic imaging of the shallowly buried sedimentary section in deep-water oilfields provides a rare opportunity to study detailed stratigraphy and occurrence of sands not possible in deeper reservoirs. In the Mars-Ursa region on the Louisiana continental slope, is a basin-floor fan, ponded a paleo-basin with unconfined-flow turbidites. The basin-floor fan is sand-rich and interbedded with shale. Following basin-floor fan deposition, two channel-levee systems deeply incised the basin-floor fan (up to 400 m) and buried it under thick levees. Both channel cores are sand-rich and both developed thick levees that are composed of thin silt and sand beds. Slope failures occurred on the flanks of the levees and created deep escarpments (> 100 m) on the paleo-seafloor. This study serves as a useful analog for addressing geometrical and lithological questions regarding deeper, reservoir-level turbidite systems that operated in the deep-water environment.

OBSERVATIONS OF TIDALLY INFLUENCED PORE PRESSURES AT ODP SITES 808 AND 1173 (NANKAI TROUGH) BEFORE AND AFTER ACORK VALVE CLOSURE

Audrey Hucks
Advisor: Peter Flemings
MS Student, Petroleum Theme

Since 2001, fluid pressures have been monitored at the seafloor and in isolated borehole intervals in sealed Ocean Drilling Program wells in the Nankai Trough, offshore Japan. The wells penetrate low-permeability trench sediments and volcaniclastics overlying oceanic basement in and near the toe of the Nankai accretionary prism. Prior to research cruise KR02-10 (summer 2002), valves had vibrated open on the ACORK instrumentation so that hydrostatic rather than formation pressures were being recorded. During the cruise, these valves were closed, and the pressure response suggests that all gauges are now measuring formation fluid pressures. Pressure records all show an oscillating tidal signal that, following closure of the ACORK valves, is phase shifted and/or attenuated in amplitude at all gauges relative to hydrostatic pressure oscillations at the seafloor. Based on applications of equations developed by Wang and Davis (1996) to predict pressure response in layered sediments to tidal loading, estimates of loading efficiencies of the accretionary wedge sediments are in keeping with observations of cemented intervals at the ACORK locations, but permeability estimates are several orders of magnitude lower than core-derived permeability estimates in the Nankai sediments. A possible explanation for this discrepancy is that the ACORK data provides formation-scale permeability estimates, while core samples can only provide small-scale permeability estimates that do not account for heterogeneities such as fractures.

GEOGRAPHIC VARIABILITY IN RECOVERY PATTERNS FROM THE LATE ORDOVICIAN MASS EXTINCTION

Andrew Krug
Advisor: Mark Patzkowsky
PhD Student, Post-Comps

Global diversity trends are ultimately the accumulation of regional diversity patterns. The biogeographic structure of mass extinction and post-extinction recovery is therefore integral in understanding the evolutionary impact of mass extinction events. Here, we compare sampling standardized diversity dynamics between the paleocontinents of Laurentia and Baltica spanning the Late Ordovician mass extinction and Early Silurian recovery (Caradoc through Wenlock). Preliminary data for Avalonia will also be presented. Our data consist of community lists of genera of the following groups: articulate and inarticulate brachiopods, trilobites, anthozoans, and bivalves. Community lists were compiled from a survey of the literature and supplemented by the Paleobiology Database (http://www.paleodb.org/).

Sampling standardized curves show dramatic differences between Laurentia, Baltica, and Avalonia. The Baltic curve shows a large drop in diversity at the extinction boundary and a protracted recovery, with diversity beginning to increase around 15 myr after the extinction. Avalonian data, though preliminary, appear to show diversity patterns similar to Baltica, with a large drop in diversity in the Rhuddanian and a protracted rebound. Laurentian diversity, however, remains flat or increases slightly through the time interval considered, despite high extinction levels at the Ordovician-Silurian boundary. The Laurentian curve indicates a complete rebound in diversity to pre-extinction levels within 5 myr of the extinction, 10 myr before the recovery in Baltica and Avalonia. These data support the idea that the recovery in Laurentia was assisted by immigration, causing a shift to more cosmopolitan taxa and shortening considerably the amount of time necessary to replenish diversity in this region. Why Laurentia should be more receptive to immigrants than other paleocontinents requires investigation, but these processes serve to enhance the spatial complexity in the recovery process and must therefore influence the restructuring of ecosystems following this mass extinction event.

PERTURBATIONS TO THE CHEMOCLINE OF THE OCEAN DURING THE END PERMIAN MASS EXTINCTION

Anthony Riccardi
Michael Arthur and Lee Kump
Co-author: Steven D'Hondt
PhD Student, Pre-Comps

The latest Permian is a time of major change in ocean chemistry, as well experiencing the greatest mass extinction of the Phanerozoic. The causes of these changes remains a subject of intense research and many current theories invoke changes to the oceanic sulfur cycle. Carbonate associated sulfate (CAS) has the potential to provide a high resolution record of variations in the concentration and stable isotopic composition of seawater sulfate. The majority of current data derive from evaporites or pyrites, both of which are relatively rare in the stratigraphic record. Our research focuses on the marine CAS record, and we have obtained samples from two sections that span the Permian-Triassic boundary (PTB); the Meishan and Shangsi sections located in Southern China. Isotopic analysis of the CAS provides a detailed record of several isotopic shifts in $\delta^{34}S$ approaching and across the PTB. Values for $\delta^{34}S$ range from 30‰ to -15‰ (VCDT) reversing several times across the sections. The $\delta^{13}C$ ($\delta^{13}C_{carb}$ - $\delta^{13}C_{org}$) in the samples increase to the event and sharply decrease across the event horizon, potentially indicating a buildup and decline of CO_2. We interpret the patterns of isotopic shifts to indicate an unstable chemocline overlying euxinic deep water which periodically upwells into the photic zone. The introduction of sulfide damaged the shelf ecosystem and altered the isotopic composition of the surface water sulfate. The sulfidic intrusions occurred several times during the end-Permian. A large sulfide release occurred during the major extinction interval, and subsequent releases occurred during the earliest Triassic.

ANTARCTIC UPPER MANTLE STRUCTURE AS DETERMINED BY JOINT INVERSION OF PHASE VELOCITIES AND RECEIVER FUNCTIONS

Aubreya Adams
Advisor: Andrew Nyblade
PhD Student, Pre-Comps

The lithospheric structure of Antarctica is bimodal, its eastern side having the features of a stable craton while its western side is a collection of crustal blocks and rifts called the West Antarctic Rift System. These two lithospheric regions are separated by the Transantarctic Mountains which are the largest non-compressional mountains in the world. These mountains and the surrounding lithosphere are believed to have played important roles in the breakup of Gondwanaland and in the initiation of the glaciation of West Antarctica, yet no definitive mechanism has been determined for their uplift.

Previous studies have shown evidence of a low velocity zone beneath the Ross Island area, near the intersection of the Transantarctic Mountains with the coast, indicating the possible presence of a plume structure. The lateral extent of the low velocity zone away from Ross Island, however, is uncertain. To further investigate structure beneath and away from the Ross Island, this study investigates both receiver functions and surface wave phase velocities using a joint inversion. By considering both data sets, the study takes advantage of the sensitivity of receiver functions to vertical variations in velocities as well as the horizontal sensitivity of surface wave dispersion to produce models of seismic wave velocity in the upper mantle. Preliminary results will be presented for two stations from the Transantarctic Mountains Seismic Experiment, or the TAMSEIS network, which was deployed from 2000 to 2003 to investigate the structure of the Transantarctic Mountains. One station, MINN, is located 130 km south of Ross Island, while the other station, MAGL, is located 170 km north of Ross Island.

REACTIVE TRANSPORT MODELING OF REACTION FRONTS

Joel Moore
Advisor: Susan Brantley
Co-authors: Peter Lichtner and Art White
PhD Student, Pre-Comps

Reaction fronts define the rates and mechanisms of chemical weathering for a given system with implications for nutrient cycling, long-term regulation of atmospheric CO_2, and in a steady-state system, the rate of formation of soil. The three-million-year old Merced chronosequence has been an ideal field location for successful calculations of field weathering rates. Mineralogical and chemical data from Merced indicate the development of reaction fronts defined by a loss of minerals in the upper part of the older soils. The reaction front extends over at least 3 to 4 m. The meter-scale thickness of the reaction front in this granitic alluvial material contrasts with thinner reaction fronts in other weathering systems, especially those developing on bedrock. For example, reaction fronts on weathering basalt clasts in river terraces in Costa Rica are less than a millimeter in thickness while reaction fronts on weathering granite in Rio Icacos, Puerto Rico are centimeters in thickness. The broader Merced reaction front implies that weathering is proceeding slower in the unconsolidated alluvium than in the other two systems. In part, the lower and more episodic rainfall at Merced causes pore waters to approach equilibrium more quickly, reducing dissolution rates in the alluvium relative to the tropical samples. This approach to equilibrium is modeled with the reactive transport code FLOTRAN using a single continuum formulation that ignores the presence of fast pathways in the weathering profile. As expected, model results using laboratory dissolution rates occurs more rapidly than dissolution rates in the field. Better correlation between model and field results was sought by changing chemical affinity parameters or reactive surface area parameters. Preliminary results from a simplified mineralogical system have shown that the evolution of the chemical weathering in the Merced chronosequence can be modeled with FLOTRAN, elucidating controls on the thickness and the rate of advance of the reaction front.

CLINOFORM MORPHOLOGY IN THE GULF OF PAPUA, PAPUA NEW GUINEA AS PREDICTED BY SEASONAL CIRCULATION PATTERNS USING THE NAVY COASTAL OCEAN MODEL

Robert Selover
Advisor: Rudy Slingerland
MS Student

At any given time, the facies progressions encountered traveling from the terrestrial realm (beach front/estuary/subaerial delta) along a sigmoidally shaped [Basinward: shallowly dipping surface, sharp drop (rollover point) to the steep face, shallowly dipping surface] path toward the abyssal plain characterize a chronostratigraphic surface, known as a clinoform. When these same facies progressions are observed in the sedimentary record, they too can be used to define chronostratigraphic surfaces. Hence, studying clinoforms is a good way to augment the understanding of timing within a basin, and may ultimately betray the exact chronology of events. Furthermore, clinoforms are a fundamental component of sequence stratigraphic architecture. Understanding their nature and origin helps to improve the understanding of how sequences are generated and how accommodation space in a basin fluctuates through time.

Several mechanisms have been proposed as explanations of the means by which clinoforms originate and self-propagate. One of these explanations invokes ocean circulation to redistribute riverine sediment plumes and resuspend sediment landward of the rollover point into a basinal clinoform sedimentation pattern. The Gulf of Papua is a foreland basin, containing two northward-thickening, stacked clinoforms that have been roughly correlated with sea level changes, subsidence rates, and net circulation patterns over the past 50,000 years. The purpose of this study is to describe seasonal circulation patterns in both a qualitative and quantitative manner, with the goal of testing the hypothesis that they are responsible for a net depositional pattern similar to that observed in the modern day clinoform. This test will employ several FORTRAN and Matlab computer models, allowing for reproducible quantitative analyses of the circulation data to be conducted. In particular, the Navy Coastal Ocean Model will provide several years' worth of three-dimensional velocity field for the Gulf of Papua, calculated at an hourly-to-daily scale, which can then be compared with actual data collected within the gulf.

UPPER MANTLE VELOCITY STRUCTURE BENEATH THE TRANSANTARCTIC MOUNTAINS FROM BODY-WAVE TOMOGRAPHY USING TAMSEIS DATA

Timothy Watson
Advisor: Andrew Nyblade
MS Student

The Transantarctic Mountains (TAM) consists of gently tilted fault blocks resulting from the vertical crustal movement during the Cenozoic. Paralleling much of the West Antarctic Rift System, the TAM is considered by many to be a classic example of rift flank uplift, however evidence supporting a clear uplift mechanism has yet to be provided. Additionally, the adjacent East Antarctic Craton exhibits anomalously high elevation for a cratonic block, approximately 1 km above sea level, when corrected for glacial loading. To investigate these two unique tectonic features of the Antarctic continent, body-wave tomography is being conducted with broadband seismic data collected by the 2000-2003 Transantarctic Seismic Experiment (TAMSEIS). The tomography results should enable us to make inferences about the thermal state of the upper mantle. Constraints on the thermal state of the upper mantle beneath these regions may enable us to discriminate between the competing uplift models. P-wave tomography results reveal an apparent low velocity anomaly at depths of 100-300 km beneath the TAM in the Ross Island vicinity. This anomaly appears to extend only about 70 –80 km inward from the coast, locating it under the front of the TAM. The high degree of variability exhibited under the TAM is not found inland beneath the East Antarctic Craton. The preliminary S-wave model yields to the first order, a consistent structure with the P-wave model.

MODELING FE ISOTOPE FRACTIONATION BY ORGANIC LIGANDS IN SOLUTION

Shawn Goldman
Advisor: James Kubicki
PhD Student, Post-Comps

The ability to trace the isotopic processing of Fe would be advantageous for a number of reasons, such as tracking the progress of microbes used for Fe-remediation in modern environments, determining the role Fe-utilizing bacteria played in ancient environments, and understanding the redox history of the Earth's ocean waters. Fe isotopes have been proposed as a useful biomarker (Beard and Johnson, 1999), and there is a good amount of debate on their utility in this regard. Fractionation has been shown in biological systems (Beard and Johnson, 1999), but fractionation for inorganic systems has proven to be at least as large (Bullen, et. al, 2001). Developing modeling techniques to analyze this will allow detailed understanding of fractionation processes. Due to the high binding affinity of organic ligands for Fe, previous experimental work has focused on fractionation of Fe during ligand-promoted dissolution of Fe (Brantley et. al, 2004). Here, we model equilibrium fractionation factors between Fe-ligand complexes and Fe-water complexes in solution. The Fe-water complexes were modeled for both ferrous and ferric Fe, so that fractionations associated with changes in the bonding environment of Fe could be compared to fractionations associated with changes in the redox state of Fe. These models show consistently larger fractionations associated with changes in oxidation state compared to changes in the bonding environment of Fe. This study implies that the greatest potential for fractionation in biological systems is in either biologically-mediated redox reactions or in kinetic effects. This study also lays the groundwork for future isotopic studies on fractionations in other metal-ligand complexes. Future work will also be done on removal of Fe from mineral surfaces, and on precipitation of minerals such as Fe-oxyhydroxides nb and Fe-sulfides. Fractionation during the formation of these minerals has implications for the redox history of the Earth's ocean, as shown by the geological record of Fe isotopes measured in shale hosted pyrite grains.

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