## Session Q – Geological and Planetary Sciences
(Alphabetical)

**Stable Isotope and Trace Element Geochemistry and Paleomagnetism of the Paleocene-Eocene Thermal Maximum as Recorded by the Sierra Blanca Limestone, California**
Melissa J Bernardino
*Mentors: Joseph Kirschvink and Timothy Raub*

The Paleocene-Eocene Thermal Maximum (PETM) records a ~55 million year old severe global warming spike resulting from an injection of isotopically light carbon into the atmosphere. Despite the unknown mechanism(s) for the PETM, the ramifications of this increase in carbon include a 5-9 °C temperature increase and perturbation of the global carbon cycle that lasted 100-200 thousand years, the mass extinction of benthic foraminifera, and proliferation of single-celled magnetotactic bacteria. The PETM is only recognized on the west coast of North America in the Santa Susana limestone of the eastern Santa Monica Mountains, but it may also be recorded by better preserved outcrops of the Sierra Blanca limestone, located in the San Rafael Mountains. I hope to evaluate how subtropical reefs respond to this episode of ancient global warming by analyzing inorganic $\delta^{13}C$ and $\delta^{18}O$ stable isotopes and trace elements, the extent of the negative carbon isotope excursion, the periodicity of the global warming and the rhythm of the peak temperature in the Sierra Blanca limestone. Analyses of ferromagnetic resonance and paleomagnetism were also conducted in search of magnetite chains suggesting enhanced suboxia via the production and preservation of magnetofossils.

**Constructing three-dimensional map of the early Tertiary unconformity in the South Mountains (SBM), California**
Laainam Chaipornkaew
*Mentor: Joann Stock and Janet Harvey*

The SBM fault zone, at the eastern edge of the eastern California shear zone, runs through the range as a complex series of fault splays. Although recent alluvium is not displaced by the fault, there is evidence of displacement in older alluvium. Mapping out the extent of the early Tertiary unconformity could refine a geologic map of the area. This may provide some insight into the potential of the SBM fault for renewed activity. A geologic map of the area is made using personal observations and the interpretation of the aerial photos, satellite images and previous geologic maps of the area. Additional data needed for the 3D map reconstruction are also being obtained during summer fieldwork. Non-volcanic sandstone (Tnvs) and volcanic sandstone (Tvs) are both observed directly above the early Tertiary unconformity. Clast compositions of Tnvs are basement. Though not locally derived, they suggest low topography relief and a relatively flat unconformity surface. Moreover, Tvs is better sorted and has sand-sized grains of possibly locally derived Mesozoic basement. Observation of Tvs implies a low energy environment during the early Tertiary. The final 3D surface of the unconformity is defined from the interpretation—positions and elevations—of the contact between Mesozoic basement and Tertiary non-volcanic/volcanic units using ArcGIS software. This generated 3D unconformity will be used to confirm the outcrop pattern of the early Tertiary unconformity, and how it has been displaced by younger faults.

**Measuring Iron Isotopes in Marine Particulates to Determine the Source of Bioavailable Iron in the Pacific Ocean**
Perrin Considine
*Mentor: Jess Adkins*

Most of the world's photosynthesis takes place in the oceans, where about one third of it is rate-limited by the minute amounts of iron present in the seawater. This project tried to conclusively determine the source of this bioavailable iron by harvesting iron from marine particulate samples in the Pacific Ocean and looking for isotopic signatures associated with either continental dust or redox processes in underwater sediments of the continental slope. Processing filter samples with leaches of various temperatures, durations, and acid strengths seemed to access either different pools of iron within the samples, or demonstrate a weakness in a previously established leach of hydroxylamine hydrochloride acetic acid. The bioavailable leachate was purified through anion exchange column chromatography. This leachate was then measured for concentrations of various metals and the ratio of 56Fe to 54Fe isotopes in various profiles throughout the Pacific Ocean. Preliminary data seems to imply that a standard metal leach containing a reducing agent either accesses only the outer, superficial layer of iron in particulates (when compared to a stronger leach with an oxidizing agent), or it sets up an isotope-biasing redox equilibrium between the isotopes. Filter samples from more profiles are being processed for further analysis.

**Quantifying Fault Offset Across Owens Valley: Paleointensity of the Golden Bear and Coso Dikes**
Matthew J. Feldman
*Mentors: Joseph Kirschvink, Timothy Raub*

Remarkable dikes on either side of Owens Valley, California suggest 65 km of dextral slip occurred at ages much older than previously thought. Kylander-Clark (2005) investigated striking chemical similarities between the Golden Bear dike of the Sierra Nevada and the Coso dikes in the Coso Ranges, and Pluhar et al. are investigating paleomagnetic directions from those same dikes. However chemistry is nonunique, and recent rotations complicate paleomagnetic directional correlation. I used paleointensity techniques to test whether the Golden Bear dike correlates to a specific Coso Range dike, 60-65 km away. A Thellier-Thellier and other new novel paleointensity experiments are attempted to determine whether the dikes were contemporary and the strength of the Geomagnetic field at the end of the Creaceous long normal chron. These paleointensity experiments are supported by magneto-mineralogical study of the various lithologies of dike and country rock.

**Exploring the Role of Non-Gaussian Assumptions in Estimating Subsurface Fault Slip**
Thomas Harris
*Mentor: Mark Simons*

Inferring the spatial distribution of slip on subsurface faults using geodetic data is necessarily ill-posed. Observations are limited to the surface of the earth's crust. Noise and the mitigating effect of the elastic crust on subsurface fault movements further exacerbate the difficulties of correctly estimating subsurface fault movements. We extract useful data from these observations by producing a simple, quick estimation technique for generating limiting bounds on models of subsurface fault slip. The simplicity of the model allows us to explore the effects of assuming different distributions of information. Researchers commonly use Gaussian statistics to reflect the distributions of measurement noise and model-anticipated slip. However, such suppositions sometimes produce less than ideal results for a particular problem—suggesting that perhaps the world is not always Gaussian in behavior. In this project, we use MATLAB to investigate the consequences of assuming that other distributions are applicable. This process will hopefully provide scientists with an effective tool for approximating subsurface movements quickly and with a reasonable degree of accuracy. Such a tool can potentially contribute to the construction of a worldwide earthquake/tsunami early-warning system.

**(Uranium-Thorium)/Helium Dating of Martian Rocks**
Joy Lin
*Mentor:* ***Kenneth A. Farley***

(Uranium-thorium)/helium dating, if feasible on Mars, might allow us to establish ages of rock units directly on the Martian surface. To use this technique, it is necessary for helium to be quantitatively retained in Martian rocks at low, Martian temperatures. Thus, a verification of the viability of this technique is required. We study terrestrial analogs to Martian hematite concretions, jarosite and basalts. From the first two, we can learn at what absolute age and location water had been present on Mars. From basalts, we can determine the past time periods of volcanism and the geomorphologic evolution on Mars. The latter can also be used to put precise constraints on the Martian geologic timescale based on impact crater densities. We heat the samples to different temperatures and measure the amount of 4He that diffuses out using a mass spectrometer and associated vacuum lines. Then we calculate the diffusion coefficient from the Arrhenius equation with the parameters of time and amount of helium output. Once the plot of log(D/a2) as a function of 1/T is adjusted for the effect of different properties such as different trace compositions and grain sizes, we extrapolate linearly to determine the diffusivity constant at Martian temperatures.

**From the First Radiation of Planktonic Animals to the Hirnantian Glaciation and Mass Extinction: Tracking Ordovician Global Change With Magnetic Reversal Stratigraphy and Magnetofossils**
Priya Nayak
*Mentors: Joe Kirschvink, Tim Raub, and Woodward Fischer*

The Cambrian-Ordovician boundary, ~490 Ma, saw the first radiation of plankton into the pelagic realm, bringing chemical changes to ocean water. The Hirnantian stage, ending the Ordovician period, ~444 Ma, saw a severe but unusually short glaciation and mass extinction. My project attempts to place location, duration, and oxidation constraints on these times of global change. By constructing a "bar-code" of reversed and normal polarities of the Earth's magnetic field, as recorded in the rocks of Green Point, Newfoundland for the Cambrian-Ordovician boundary and Anticosti Island, Quebec for the Hirnantian stage, a global comparison of the different lithologies and fossils in rocks of contemporary time periods can be effected. Furthermore, creating "bar-codes" may give an idea of sedimentation rate and time-scale of isotope excursions, since the time period over which the pole reverses is known (at longest, about

10,000 years). To uncover the magnetic component of the Earth's field at the time of sedimentation, demagnetization of weaker, more recent components is achieved via low-temperature steps, high-temperature steps, and alternating-field demagnetization. This project also looks for magnetofossils using electron paramagnetic resonance spectroscopy in samples from both boundaries since magnetotactic bacteria are proxies for oxygenation and carbon flux in bottom waters.

**Characterizing Mantle Plumes Using Numerical Models of Mantle Convection and Seismic Wave Propagation**
Ayon Sen
Mentors: Michael Gurnis and Eh Tan

The theory of thermal plumes that arise out of mantle convection was developed to explain hotspot phenomena. However, many fundamental properties of these plumes are unknown, such as their geometry, function, and even whether they exist or not. Using computational methods, we take a first step towards characterizing these plumes by trying to quantify their widths. We first construct a high-resolution model of a plume in CitcomS, an easily modifiable mantle convection model which can output seismic velocities. We then use this output in SPECFEM3D, which simulates the propagation of seismic waves through the plume model, producing synthetic seismograms that allow us to study any possible relationship between multipathing in the seismic waves and the width and geometry of the plume. Essentially, this would allow us to make assumptions about plume structure indirectly from seismic data, and understanding plume structure would in turn have implications for understanding plume function in the mantle.

**Examination of Cassini Images to Investigate Possible Presence of Low Altitude Cloud and Fog Banks on the South Polar Surface of Titan and Corresponding Implications of Surface Liquid**
Alexandra L Smith
*Mentor: Michael Brown*

We use data from the VIMS instrument aboard the Cassini spacecraft from 2004-2007 to search for and map low altitude fog banks near the south polar surface of Saturn's moon Titan, examining in particular the area south of 50 degrees S latitude. By comparing each surface image - taken at low methane opacity (2.03 microns), penetrating the dense hydrocarbon atmosphere all the way – with the corresponding tropospheric image – taken at moderate methane opacity (2.12 microns), penetrating down to the 40km high tropospheric cloud level-, we label bright wispy patches seen on the surface image but not on the cloud image as fog. Furthermore, we examine the spectral information of the best image sets to better understand the heights of observed features. We find that south polar fog occurs frequently, in various locations, and with varying degrees of transience. Since the southpole has a ~16 day rotational period, little interesting topography, and too low an average humidity for fog to be intrinsically present, we conclude that the observed fog must be due to active evaporation of liquid methane from the surface, which we propose arises from frequent rainfall, corresponding with the fog's transient quality and location.

**Implications of Exceptional Southeast California Exposure on Earth's Magnetic History**
Will Steinhardt
*Mentor: Joseph Kirschvink*

In the Little Chuckwalla Mountains of Southern California, there is a one-of-a-kind outcrop where, due to exceptional tectonics, there exists what may be the best snapshot of magmatic intrusions on the planet. At this exceptional exposure, there exists a dike over two kilometers long that merges into the surficial flow it feeds. It has always been assumed that paleodirections and intensities were equivalent regardless of whether they came from flow materials that cool in a matter of hours or days as opposed to samples from dikes that cooled over hundreds of years. Thus, at this unique locality, we can determine a possible paleomagnetic correction factor for the conditions of cooling. A longer cooling time facilitates the growth of a greater number of large crystals that will have multiple domains, leading to potentially drastically different field preservation from samples with much smaller, more stable, single domain crystals. Finding a fundamental difference in the intensities of the dikes and flows could lead to a revision of our current understanding of the Earth's magnetic field.

**Understanding the North American Permian-Triassic Mass Extinction Record: Isotopic Study of Quinn River Formation, Nevada**
Vivian Z. Sun
*Mentors: Joseph Kirschvink and Timothy D. Raub*

The Permian-Triassic mass extinction event, which occurred 251 million years ago and marked the greatest loss of biodiversity in Earth's history, is isotopically characterized by a -9% excursion of inorganic carbon-13. This excursion is used to locate the precise boundary in strata that span the boundary interval. We collected samples from the Quinn River Formation in northwestern Nevada and analyzed the isotopic composition of carbonates in this section to locate this event. Other objectives consist of microdrilling powders and cutting sub-samples of unweathered rock for purposes of nitrogen-15, sulfur-34, trace element, and biomarker analyses to obtain a full picture of the Permian-Triassic extinction. The significance of a verified North American P-Tr boundary is that it would strengthen the case that the Permian-Triassic event as global in nature, occurring in both the eastern (i.e. Eurasian, "Paleo-Tethyan") and western (i.e. North American, "Panthalassan") extremities of the supercontinent Pangaea.