Research Experience for Graduates and Post-Doctoral Researchers

Thirty-seven graduate students are involved in research administered through ICS. These students are involved in field research both locally and internationally. Many have presented their research with talks or posters at professional meetings: e.g., American Geophysical Union, Geological Society of America, Seismological Society of America, annual meeting for the Southern California Earthquake Center. In addition to the abstracts presented, ICS graduate students are also involved as authors and co-authors on articles in referred journals.

Highlight of Post-Doctoral Research

Gregor Hillers

Postdoctoral Program, Ralph Archuleta, advisor

The Role of Memory and Feedback Mechanisms on Seismicity Distributions

One of my postdoctoral projects, in collaboration with Prof. R. J. Archuleta (UCSB Crustal Studies) and Prof. J. M. Carlson (UCSB Physics), investigates the effects of memory and feedbacks on earthquake patterns. It is a major goal in seismology to understand the spatial and temporal occurrence of earthquakes, particularly of large, devastating events. However, other than gross estimates averaged over large spatial and temporal domains cannot be made at present. These assessments are primarily based on an extrapolation of past seismicity patterns, under the assumption that the overall properties of the system under consideration, e.g., the fault network in Southern California, do not change over time scales comparable to the extrapolation horizon.

In the past, computer simulations of simple mechanical models have been evaluated and served as a guide to the interpretation of real data. Although the available instrumentation allows a satisfactory monitoring of regional seismicity since the 1960's, this 50-year period covers only a fraction of the `seismic cycle,' i.e., the average occurrence of large(st) earthquakes, which is of the order of hundreds of years. Computer models, on the other hand, allow the generation of synthetic seismicity covering thousands of (model) years. By comparing patterns found in computer generated earthquake distributions to statistics of real earthquake catalogs, scientists can at least estimate which parameters control which aspect of a specific occurrence pattern.

Usually, these `control variables' are held constant during one numerical experiment, and researchers spend a good deal of their time in tweaking these parameters and comparing the corresponding results, thus exploring possible response characteristics of the model. The parameters are kept constant to isolate effects associated with each of these `tuning knobs,' and the time independence is often viewed as a satisfactory approximation to processes that occur in nature over the time intervals considered.

There is, however, a large body of evidence from a variety of field observations, laboratory and numerical experiments, which implies that the properties of a system, that affect its stability substantially, are constantly subject to change, on time scales ranging from sub-seconds to ten thousands of years associated with the passage of a rupture tip and the evolution of tectonic plate margins, respectively. Over these time scales, multiple strength degradation and healing mechanisms in the Earth's crust take place, with the competing tendencies of weakening and strengthening rock and/or fault zone properties. The constant-parameter approach assumes that these effects cancel each other out statistically.

We use a simple mechanical model of an earthquake fault and investigate the effects of relative amplitudes of weakening and healing mechanisms on generated seismicity distributions. The evolution laws, according to which the tuning parameter weaken or heal, have been adopted from results obtained in laboratory experiments focusing on rock surface abrasion and healing as a function of external control variables like slip, time, and temperature. During the numerical experiments, we measure the internal stress or energy of the system, and interpret its temporal evolution as a proxy for the evolution of the system's overall state. All parameters being constant, these functions fluctuate around their long-term average value, which is controlled by the current value of the tuning parameters. Including competing weakening and strengthening effects, however, results in a broad range of non-stationary response statistics (Figure 1). The fluctuations, which are persistent over a wide range of non-extreme parameter choices, imply that extrapolations based on past properties have to be applied cautiously. While these stress or energy fluctuations cannot be observed for real faults, the corresponding statistics of the frequency of occurrence do also show deviations from long-term static behavior.

This study looks at first-order effects in a simplified mechanical representation of an earthquake fault, and the results suggest that the relative effects of memory and feedback mechanisms on rock and fault zone properties probably control seismicity patterns to a significant degree. It implies that subtle changes in recovery processes after earthquakes are relevant for future earthquake nucleation, and that anticipated earthquake occurrences probably should account for these interseismic processes.

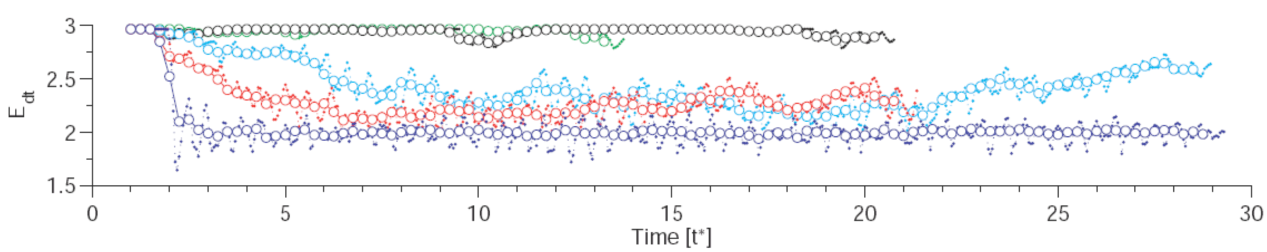


Figure 1 *Typical temporally averaged (dt=[0.1, 0.5]t*-bins) stress or internal energy levels (E) of five systems with variable healing amplitudes and constant weakening effects. Relatively high E-levels correspond to dominating restrengthening effects (black, green), while a relatively low level is characteristic for conditions in which weakening processes prevail (dark blue). While all examples show deviations from the long-term average, the red and light blue curves suggest that a statistically stable state does not exist for the values of competing mechanisms chosen. One time unit t* roughly corresponds to one earthquake cycle.*

Scaling Laws of Earthquakes

Despite the apparent complexity in the earthquake process, it is of basic interest to understand observed scaling relations between fundamental earthquake source parameters, such as fault length *L* and width *W*, average slip *u* during an earthquake of size *M*, and the stress drop *SD*, i.e., the difference in stress on a fault prior to and after the earthquake happened. Knowledge of these interdependencies helps to evaluate the seismic potential of a fault and thus to estimate the potential damages associated with earthquakes on that fault. Recent compilations of empirical *u-L* data, however, manifested a paradox between some of the hitherto assumed interrelations between *L*, *W*, *u* and *SD*. Namely, the width *W* of large earthquakes has been assumed to saturate with the width of the seismogenic zone *WZ*, usually interpreted to coincide with the depth extent of background seismicity. This would imply an increase in stress drop *SD* with earthquake size *M*, which is, despite of considerable scatter, assumed to be magnitude independent.

Together with Prof. S. G. Wesnousky (U Reno), we explored the implications of a relaxed lower-seismicity boundary on fundamental scaling relations. We use a quasi-dynamic 3D model of a 2D strike slip fault, developed during my doctorate studies, and compare results from numerical simulations with and without the possibility of slip propagating below *WZ*. Synthetic seismicity from the relaxed case produces statistics compatible with observations, including a constant *SD-M* (no increase of stress drop with size) and *u-L* scaling, respectively. On the other hand, the model prohibiting deep slip produces an increasing *SD* with earthquake size, which is in apparent conflict with data. Our study, along with a variety of other indirect observations, suggests that a large earthquake continues to grow in the downward direction, but with decreasing growth rates. It is difficult to observe seismic slip unequivocally at these depths (15-20 km) with seismological and geodetic measurements, and it possibly generates frequencies that are longer compared to the seismic frequency band. However, our observations might encourage increased sensitivity to coseismic processes at depth.

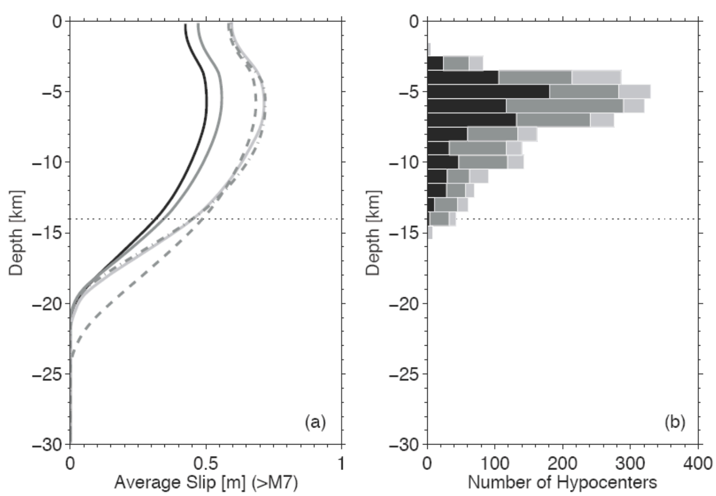


Figure 2 *(a) Averaged slip-depth profiles from models that allows slip to propagate below WZ, indicated by the dotted horizontal line. The amount of slip below -15 km depends on the parameters chosen, but is substantial. (b) Depth distribution of background seismicity in the model, which terminates at WZ. Usually, this type of data is used to estimate the largest vertical extend of earthquakes that occur in a particular region. The juxtaposition to the slip profiles suggests that this assumption is not necessarily justified.*

Efficient Generation of Multiple Rupture Scenarios

One of seismologist's contributions to appropriate building codes is to provide estimates of the ground motions that are expected in the vicinity of an active fault. This usually requires a `tool-chain,' consisting of a (dynamic) source model, the wave propagation effect and the site response, providing the possibility to compute a multitude of different rupture scenarios and subsequent ground motions. It is inherently difficult, however, to automatically produce a large number of rupture models that display observed variability in earthquake source properties. While different approaches seem fruitful and are pursued by a number of research groups, I participate in an effort lead by Dr. P. M. Mai (ETH Zurich), in collaboration with the URS Corp. office in Pasadena, which aims to take a shortcut by using synthetic final slip distributions and to efficiently extract input parameters for dynamic rupture models from them.

A suite of synthetic slip maps, resembling spatial complexity comparable to that of natural earthquakes, are generated by the same 3D quasi-dynamic multi-cycle approach discussed above, in response to variable boundary conditions with different degrees of heterogeneity. Empirical scaling relations are then applied to estimate input parameters for dynamic rupture codes. Preliminary results of this approach suggest that this is a highly efficient method to produce the desired number of event realizations, showing realistic variability. However, the mapping or scaling relations turn out to give satisfactory results---and hence realistic rupture propagation pattern---only during mature parts of the rupture. The scaling breaks down in the nucleation region and in areas where the event stops. This behavior can be understood considering the assumptions that underlie the theoretical scaling estimates. Current and future theoretical and numerical work is directed at a more refined estimate of the mapping functions covering all aspects of rupture, and to extract the governing input parameters to dynamic rupture codes in a more rigorous way.

Michael Vendrasco

Postdoctoral Program, Susannah Porter, advisor

Michael Vendrasco is nearing completion of a comprehensive study of shell microstructures in Cambrian molluscs, focused on two main tasks: (1) identifying new cases of shell microstructure in Cambrian molluscs via the Scanning Electron Microscope (SEM); and (2) critically evaluating published records of all such structures and entering the information into a database. The creation of the database has involved an intensive reassessment of each published report because of the equivocal nature of many cases of apparent shell microstructures. This data has been combined with information on Cambrian mollusc shell microstructures from over 1,100 SEM photos taken by Vendrasco.

To look for new cases of shell microstructure, Vendrasco processed many kilograms of rocks collected from Yunnan, China with Susannah Porter (PI of NASA Astrobiology grant that supplied funding) and Guoxiang Li (Collaborator in NASA grant). Vendrasco picked out thousands of molluscs and mollusc-like Problematica from acid etched residues of Cambrian limestones from the Chinese localities as well as previously processed acid macerates from Siberia and Australia. He did this at facilities located at the University of California, Santa Barbara (UCSB), the Nanjing Institute of Geology and Paleontology (NIGP) in China, and the Naturhistoriska Riksmuseet (NRM) in Stockholm, Sweden. Sorting at NIGP and NRM was accomplished with the help of Guoxiang Li and Artem Kouchinsky (Collaborator in NASA grant) respectively. Both Li and Kouchinsky etched limestone rocks from various Early and Middle Cambrian Formations from China and Siberia and arranged access to museum collections and SEM facilities at their institutions. In addition, Kouchinsky has donated thousands of photos of molluscs and Problematica that he has taken in the recent past, most of which are unpublished and many of which show exquisite detail of shell microstructures.

Additionally, Vendrasco examined over 70 type specimens of molluscs and mollusc-like taxa housed at the NIGP and NRM, which has allowed for a more precise identification of the species of molluscs and Problematica that preserve shell microstructure.

Much new data on shell microstructures in Cambrian molluscs have been found via the SEM work, including microstructures in species that previously lacked such data, some species with new types of microstructure, and many species with microstructures found in new areas of the shell. This work has also provided significant information about the commonality and variation in appearance of shell microstructures in the earliest molluscs. The completed database forms a large part of the projects described below. Moreover, the fossils have provided useful information on some problematic taxa like *Ocruranus*-*Eohalobia* and *Mellopegma*.

Information from the database of microstructures described above was used in concert with new cladistic analyses of these molluscs to help infer phylogenetic relationships. Vendrasco coded the morphology of the fossils by choosing and defining physical characters and delineating homologous character states. He then recorded the states of each character for each well-preserved mollusc with clear details of shell microstructure and ran the computer-based cladistic analyses. The resulting most parsimonious cladograms derived from diverse combinations of character sets (e.g. using only shell characters, using only non-microstructure characters) were compared.

The cladograms derived from each analysis are remarkably similar, sharing most major branches, meaning that shell microstructure characters possess a strong phylogenetic signal for molluscs. Therefore these characters will be useful in helping to ascertain relationships within molluscs, and between molluscs and similar-looking Problematica. Understanding the latter will aid in determining the magnitude of the Cambrian explosion by making clearer which problematic taxa are most likely molluscs and which are not. This will allow a more precise count of the total number of higher taxa that originated during the Cambrian explosion. In addition, the cladistic analysis suggests that pores may have been primitive in the molluscan shell, a surprising conclusion that may lead to a better understanding of what the earliest molluscan shell was like, and how it originated.

The database described above also contains detailed stratigraphic information for each case of shell microstructure. Vendrasco has used this database to plot the distribution of shell microstructures through time on a global stratigraphic column for the purpose of identifying temporal trends in molluscan shell microstructure. In addition, he has counted frequencies of shell damage and repair within the species *Mellopegma georginensis* in successive beds from the Middle Cambrian of Australia to document changes in predation intensity over a shorter time scale. Cases of shell damage that seem most likely to be due to predation have been photographed via the SEM. These are significant finds as clear-cut cases of shell damage through predation are quite rare in the Cambrian. To provide good analogs from modern molluscan shells with predatory damage, Vendrasco has made latex and epoxy molds of these specimens for the purpose of comparing with the signs of damage on fossil internal molds.

The data indicate that there is an increasing trend towards shells with stronger microstructures such as nacre and crossed-lamellar through the Cambrian. In addition, shells became thicker and more molluscs developed the ability to burrow into the sediment during that interval. Therefore, the arms race between predators and molluscan prey had already begun in earnest during, or just before, the Early Cambrian, providing further evidence that predation was a primary cause of the Cambrian explosion. The analysis of shell damage frequency in *Mellopegma* in the Middle Cambrian shows that there may have been an increase in predation through that interval, but more work needs to be done to verify the suspected pattern.

Publications arising from this research:

1. Vendrasco, M.J., S.M. Porter, G. Li, and A. Kouchinsky (2006). More shell microstructures in Cambrian molluscs. GSA Abstracts with Programs.
2. Vendrasco, M.J., S.M. Porter, G. Li, and C. Fernandez (2008). A reassessment of the enigmatic *Ocruranus-Eohalobia* group of small skeletal fossils from the Early Cambrian of eastern Yunnan, China. CalPaleo Abstracts.
3. Vendrasco, M.J., S.M. Porter, G. Li, and A. Kouchinsky (Accepted for publication in *Palaeontology*, 2008). New data on molluscs and their shell microstructures from the Middle Cambrian Gowers Formation, Australia.
4. Vendrasco, M.J., S.M. Porter, G. Li, and C. Fernandez (To be submitted to *Lethaia* by July 2008). A reassessment of the enigmatic *Ocruranus-Eohalobia* group of small skeletal fossils from the Early Cambrian of eastern Yunnan, China.
5. Vendrasco, M.J., A. Kouchinsky, S.M. Porter, and C. Fernandez (To be submitted to *Palaeontology* later in late summer, 2008). Biology and evolutionary role of *Mellopegma* Runnegar and Jell, 1976, a Cambrian mollusc from Australia, Russia, and North America.
6. Vendrasco, M.J., S.M. Porter, A. Kouchinsky, and G. Li (To be submitted in late 2008). Early evolution of shell microstructure in molluscs: patterns and causes.

Presentations given by Michael Vendrasco on this research:

1. "More shell microstructures in Cambrian molluscs", presentation given at the Geological Society of America National Meeting, October 2006.
2. "Shell microstructures in early molluscs", departmental seminar given at California State University, Fullerton, September 2007.
3. "Early evolution of shell microstructure in molluscs", keynote talk given at the Paleontological Society of Washington, January 2008.
4. "A reassessment of the enigmatic *Ocruranus-Eohalobia* group of small skeletal fossils from the Early Cambrian of eastern Yunnan, China", presentation given at the California Paleontology Conference, April 2008.

Highlight of Graduate Student Research

Brian Clarke
Ph.D Program, Douglas Burbank, advisor

Climatic and lithologic influences on erosional efficiency in Fiordland, New Zealand

Landscape evolution in collisional orogens is predominantly driven by spatial and temporal patterns of climatically induced differential erosion in concert with tectonic forcing. Here we investigate the influence of climate, lithology, topography and the primary erosive processes on the landscape morphology of Fiordland, South Island, New Zealand. Spatial patterns of differential erosion, derived from detrital cosmogenic radionuclides (CRNs), across the width of Fiordland reveal an inverse relationship with rainfall gradients. Erosion rates appear highest in the east and decrease towards the rain-soaked west coast. This decoupling of basin averaged erosion rates and modern rainfall gradients suggest that Fiordland morphology is not controlled by stream-power styled river incision. We suggest instead, that glacial and peri-glacial processes are the primary erosive agents governing landscape morphology of the region. Correlation of topographic swath profiles and paleo-ELA gradients, determined from cirque outlets, indicate that the elevation of the mean and maximum topography may be controlled by long-term average gradients in the paleo-ELA. Hypsometric analysis of the range indicates that the amount of landmass diminishes significantly above the paleo-ELA. Slope-altitude distributions reveal that hillslopes steepen with elevation to reach and maintain threshold slopes above the paleo-ELA. The correlation of topographic profiles, hypsometry, and slope distributions with paleo-ELA gradients suggests that topographic limits and the spatial distribution of threshold hillslopes may be controlled by a glacial- or peri-glacial buzzsaw process. The lithologic influence on morphology and erosional efficiency is dominated by the degree of fracturing within underlying bedrock. Initial measurements of bedrock fracture densities in the shallow subsurface appear to follow broad patterns of catchment averaged erosion rates across the range. Additionally, bedrock fracture densities show an altitudinal dependence, with increased fracturing above modern snowline. The eastward verging topographic asymmetry of the range and the similarity in spatial patterns of erosion derived from detrital CRNs and long-term denudation patterns from thermochronologic data suggest that spatial patterns of erosion and the resulting orogenic geometry are controlled by differential patterns of surface uplift raising high peaks into an altitude dependant zone of enhanced erosional efficiency.

Looking south from the Southern Alps into Fiordland, New Zealand (photo credit Brian Clarke)

Mt. Tasman looming over the Fox glacier, Southern Alps, New Zealand (photo credit Brian Clarke)

Jeanette Hagen,
Ph.D Program, Cathy Busby, Advisor

The Sierra Nevada is the longest and tallest mountain chain in the U.S. and has long been considered among the youngest. The age, uplift history, and fault history of the Sierra are currently the subject of geologic debate by workers using a variety of data sources and analytical tools. In my research, I integrate volcanology, sedimentology, stratigraphy, structural geology, and geochronology to examine the fault history in the central region of this young range. My study addresses the following question: When did range-front faulting begin in the central Sierra Nevada? My results show that faulting started by 10 million years ago (Ma), much earlier than previously reported. It is important to understand the history of these faults as they are the reason that the Sierra Nevada is such a dramatic topographical feature, and they control the elevation and nature of the Sierra on both the steep eastern escarpment and the gently sloping western side.

The Sierra Nevada frontal faults are the western edge of the Walker Lane belt, an important zone of strike-slip motion that accommodates up to 25% of Pacific – North American plate motion. By studying faults that moved at 10 Ma, I can help other geologists understand how the faults are moving today and what impact that will have on human populations at Lake Tahoe and Reno, Nevada.

My new mapping along the range front at Sonora Pass (Figure 1) suggests that range-front faulting began immediately before the eruption of the high-potassium Stanislaus Group at 10 Ma, and in fact that the eruptions may have resulted from this initiation of tectonism. The commencement of faulting at 10 Ma is much earlier than the 3 Ma date that is hypothesized to the north in Lake Tahoe by other researchers.

I have studied and mapped faults at Carson Pass (Highway 88) and Sonora Pass (Highway 108), and at Ebbetts Pass (Highway 4) (Figure 1). While lab work is important to my research and justifies many of the conclusions that I have drawn, the field component is the center of my project, and provides the backbone for all of my work. I have been accompanied in the field by my advisor, Professor Cathy Busby, as well as Dr. Dave Wagner from the California Geological Survey, Prof. Keith Putirka from Fresno State, Dr. Chris Pluhar from UC Santa Cruz, and Prof. Ian Skilling from the University of Pittsburgh. I am completing lab work in geochemistry at Fresno State with Prof. Keith Putirka and geochronology with Prof. Paul Renne at the Berkeley Geochronology Center. The ages for many of my samples should be available by the end of this year, and I will then be able to constrain the timing of faulting at Carson Pass.

One of my goals in my research is to construct a continuous geologic map from Sonora Pass through to Carson Pass. I believe that with another field season next summer, I will be able to accomplish this task.

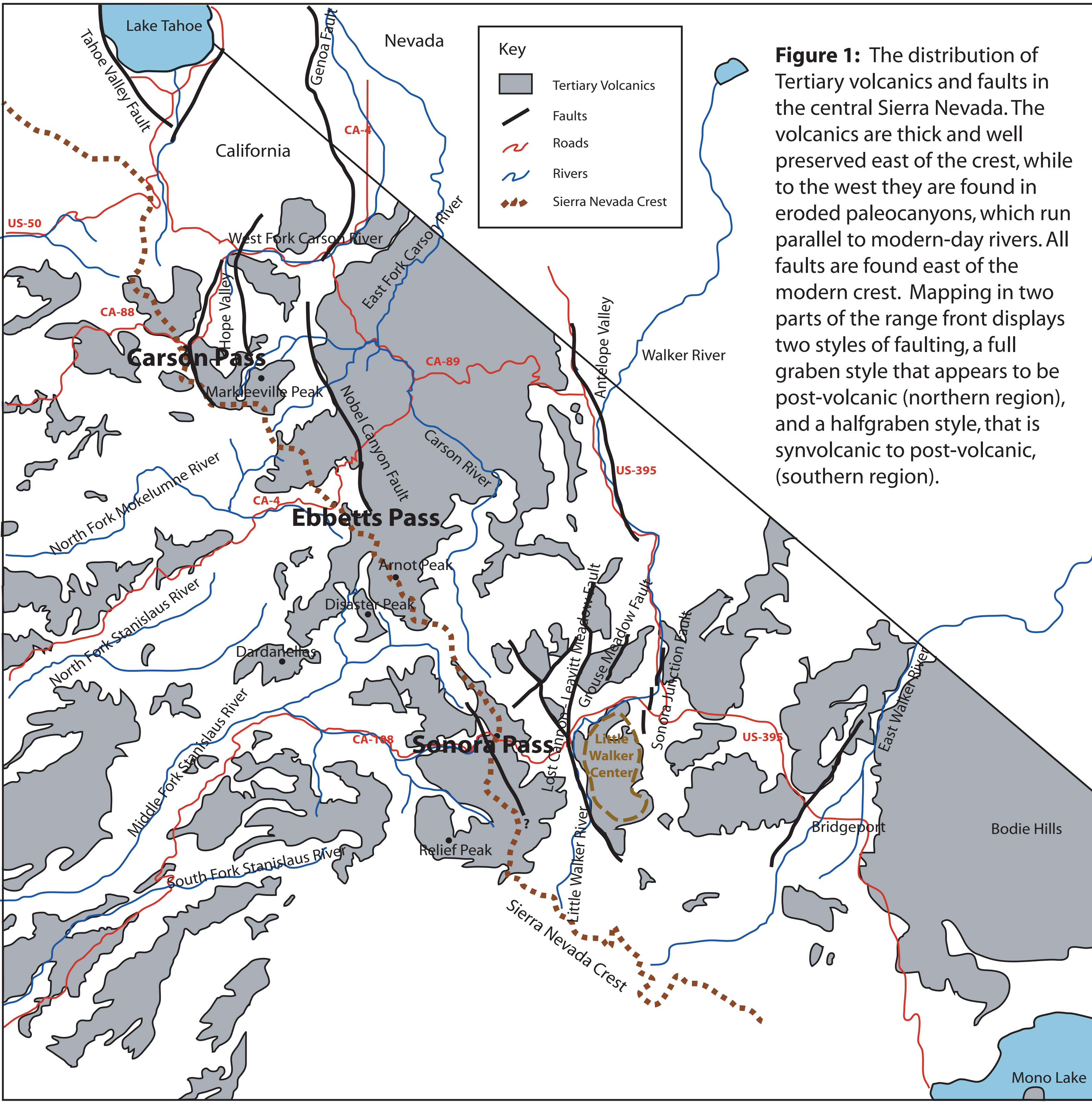


Figure 1: The distribution of Tertiary volcanics and faults in the central Sierra Nevada. The volcanics are thick and well preserved east of the crest, while to the west they are found in eroded paleocanyons, which run parallel to modern-day rivers. All faults are found east of the modern crest. Mapping in two parts of the range front displays two styles of faulting, a full graben style that appears to be post-volcanic (northern region), and a halfgraben style, that is synvolcanic to post-volcanic, (southern region).

Andrew Kylander-Clarke
Ph.D Program, Brad Hacker, advisor

The main goal of my PhD research at UCSB has been to understand the spatial and temporal history of high- and ultrahigh-pressure (UHP) rocks, (i.e., continental rocks that are subducted to depths in excess of 100 km) from the Western Gneiss Region in western Norway, using geochronology, petrology, and thermal modeling. In particular, I have been interested in the timescales and lengthscales of continental subduction and exhumation and the constraints these place on tectonic processes. I have primarily focused on comparing the ages of two different chronometers, Lu-Hf and Sm-Nd, to measure rates of processes. My research was the first widespread application of Lu-Hf dating to UHP rocks and, as a result, has shown the vast potential for the implementation of this method to solve geologic problems. It has also led to a new paradigm in UHP tectonics: continental subduction is slow.

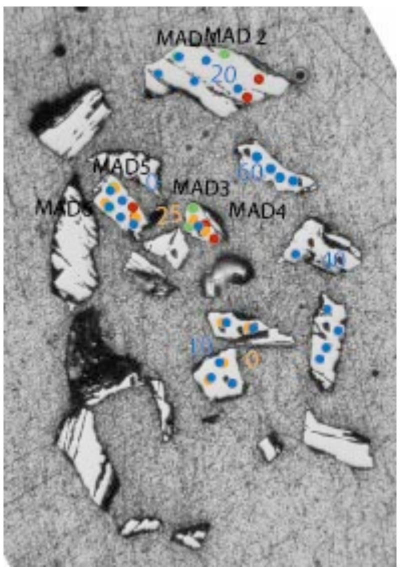
Both Lu-Hf and Sm-Nd geochronologic methods can be implemented on the same grains and commonly yield distinct ages because of the different affinities of garnet for each of the parent elements (i.e, Lu and Sm). Lutetium is incorporated into garnet early, resulting in high concentrations in the core, whereas Sm is incorporated more evenly. Because of this difference, garnets typically yield older Lu-Hf ages than Sm-Nd ages; these ages place limits on garnet growth rates. I analyzed over a dozen samples, the combination of which indicate 20 Myr of metamorphism, from initial HP crystal growth to peak depths. This is a surprising result that contradicts the reigning paradigm that continental subduction is short lived. Protracted continental subduction was previously thought impossible because it would yield temperatures that exceeded those observed from UHP terranes worldwide. I created thermal models to test this and found that slow subduction yields reasonable temperatures in the subducted slab, provided that it is thick. These models also yield temperatures that are consistent with those observed in western Norway upon exhumation, giving credence to their predictions about subduction. In the future, I hope to develop more sophisticated models to better understand the effects of melting and buoyancy on collisional processes as well as employ the Lu-Hf dating method in other applications.

Emily Peterman
Ph.D Program, Brad Hacker, advisor

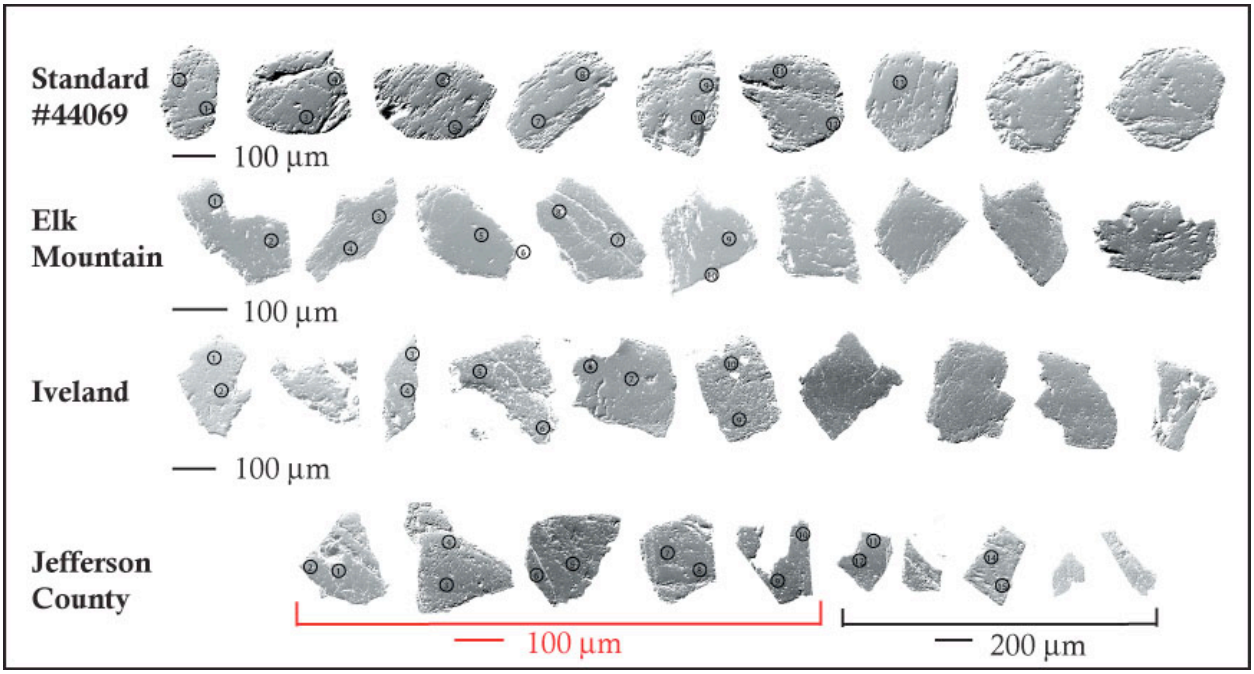
Monazite (Ce[LREE, Th]PO_4) has long been a target of geochronology for several reasons: it contains both U and Th, thereby providing three decay schemes to assess concordance; it is present in a range of rock types metamorphosed above greenschist facies conditions, primarily pelites and granitoids, and can persist through melting events; and monazite grains often preserve compositional domains that can be linked to changes in pressure, temperature and/or mineralogy. Recent extraordinary improvements in microbeam geochronology have made age determinations at the sub-grain scale much more accessible and precise. Despite these numerous advantages, four of the most commonly employed techniques for monazite geochronology—secondary ionization mass spectrometry (SIMS), thermal ionization mass spectrometry (TIMS), electron probe micro-analysis (EPMA) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS)—yield different ages for the same suite of samples. This research centers on determining the causes of the age discrepancies with the ultimate goal of establishing the best approach to yield the most accurate *and* precise ages for monazite.

One of the leading hypotheses for the age discrepancies correlates compositional variability with deviations in apparent age. To address this issue, I constructed chemical profiles for eight samples using an electron microprobe and a high precision SIMS instrument. I collected isotopic age data for these sample samples *in situ* using two LA-ICP-MS and two SIMS instruments, and benchmark single grain U-Pb ages using a TIMS instrument. The current dataset suggests that age discrepancies are not caused by a single interference, but rather the convolution of several species, some of which inhibit ionization efficiency and others that inflate the peak size of targeted masses. Continuing research focuses on deconvolving these signals to establish a protocol for handling monazite age data.

Emily Peterman
epeterman@umail.ucsb.edu



Each colored dot marks the location of individual analyses for different geochronology techniques employed in this study.



Numbered circles denote the location and size of analysis spots with the LA-ICP-MS. Grain images are back-scattered electron images demonstrating the compositional homogeneity of the samples.

Jan Schmedes
Ph.D Program, Ralph Archuleta, advisor

The Earthquake Source and Strong Ground Motion

The design of earthquake resistant buildings requires thorough understanding of data from previous events. Because data are sparse in the near source region of large magnitude events, simulation of large magnitude earthquakes is necessary to fill the gap. Most predictions of ground motion from finite faults are based on kinematic models of the rupture process. In these models one prescribes the behavior of the earthquake rupture, for example the distribution of slip on the fault and the rupture velocity. However, the parameters that represent the kinematic model are not that well known. In particular, the correlation between the parameters is often ignored. Dynamic models of faulting, which solve the constitutive equations, can yield insights into the source processes for the low frequency (generally less than 1.0-2.0 Hz) part of the spectrum. However, the goal is to predict ground motion over a broad frequency range.

To implement a kinematic rupture model generator one needs to understand the kinematic parameters. In particular, we need to infer the statistical distribution of these parameters on the fault and the correlation between these parameters. Moreover, it is important to understand how different earthquake source parameters influence the ground motion at the free surface. This requires a physical understanding of the earthquake source process.

My research focuses on two main topics:

Gain a better understanding of the earthquake rupture process itself and refine existing simulation methods. I have parallelized an existing finite element code (Ma, 2006) in order to be able to compute many dynamic rupture models on a computer cluster belonging to Prof. Chen Ji. These models are then analyzed for the distributions of the source parameter and possible correlation between different source parameters. The results we will extract from the dynamic models will be used to refine the method of Liu et al (2006).

Use the available simulation methods to attack problems posed by the observed data. One of the problems I have been focusing on is the problem of saturation of ground motion (Schmedes and Archuleta, 2007). Data suggest that the peak ground velocity and peak ground acceleration at a site close to the rupture (within a few km) do saturate with magnitude. That is, the peak values do not keep increasing with increasing magnitude. We can explain this observation by the fact that due to geometrical spreading of the elastic waves, that is the decrease of their amplitude with the distance between the source exciting the wave and the station, each stations peak values are produced by a portion of the fault close to the station. More detailed information can be found in Schmedes and Archuleta (2007).

References

Liu, P., R. J. Archuleta, and S. H. Hartzell (2006), Prediction of broadband ground-motion time histories: Hybrid low/high- frequency method with correlated random source parameters, *Bull. Seism. Soc. Am.*, *96*, 2118-2130.

Ma, S. (2006), Phd dissertation, *UCSB*.

Schmedes, J., and R. J. Archuleta (2007), Oversaturation of peak ground velocity along strike slip faults, *submitted to BSSA*.

RESEARCH EXPERIENCE FOR UNDERGRADUATES

Twenty-four undergraduate students are involved in research administered through ICS.
Four undergraduate students are involved in administrative work through ICS.

Undergraduates worked for the Portable Broadband Instrument Center (PBIC) that provide researchers with year-round access to a "pool" of high-resolution, digital seismic recording equipment. The equipment consists of data recorders, data acquisition systems and sensors. A broad dynamic range of recording is obtained by pairing both weak motion and strong motion sensors with a single recorder. Principal Investigator Jamie Steidl manages the PBIC out of ICS.

NEES@UCSB provides undergraduate students with the opportunity to work with research facilities such as the Garner Valley Field Site and SFSI Structure and the Wildlife Refuge Liquefaction Field Site. Research activities at the field sites include both active shaking at the sites as well as the use of recorded earthquakes and ambient noise to study local site response. The George E. Brown Jr. Network for Earthquake Engineering funded by the National Science Foundation (NEES). Principal Investigator Jamie Steidl manages NEES@UCSB out of ICS.
http://nees.ucsb.edu

Garner Valley Field Site and SFSI Structure

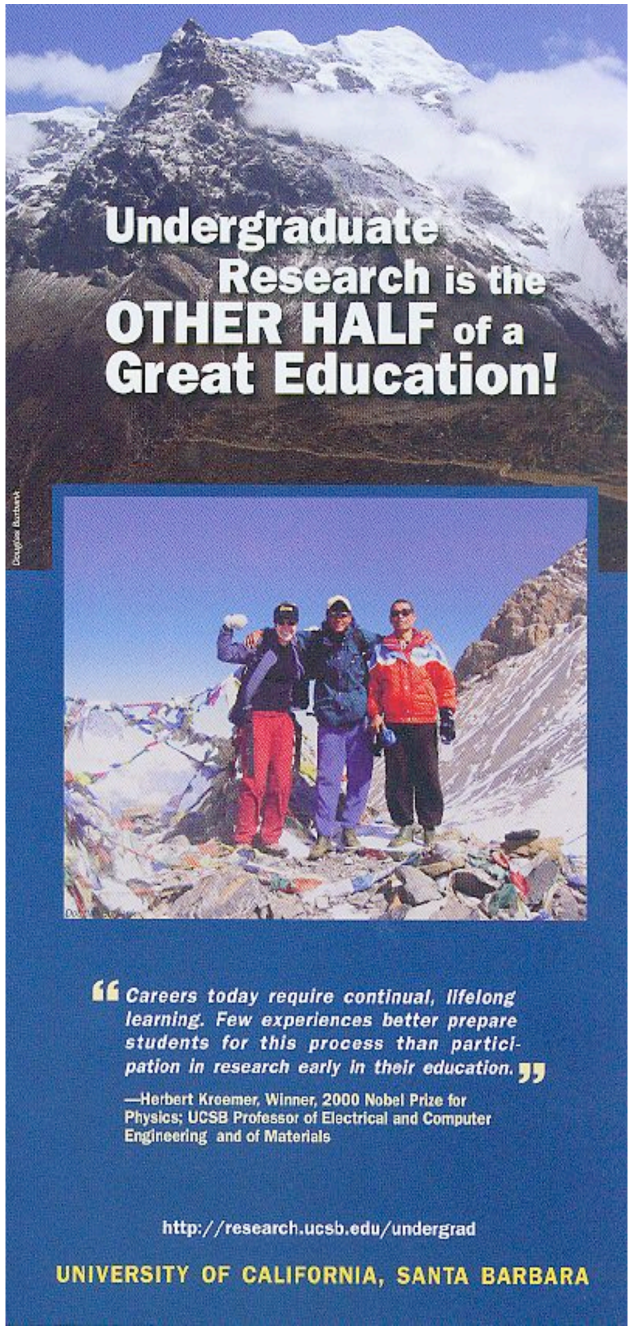
Wildlife Refuge Liquefaction Field Site

UCSB Operated Observatories two engineering seismology array facilities donated to UCSB by the Japanese are currently operated using ICS resources. These arrays are very similar in scope to the NEES observatories. One is located in Southern California near Borrego Springs and the other is located in Central California, near the towns of Salinas and Hollister. These additional arrays provide greater chances for catching a big earthquake in close at a densely instrumented site as they are also located in seismically active areas.

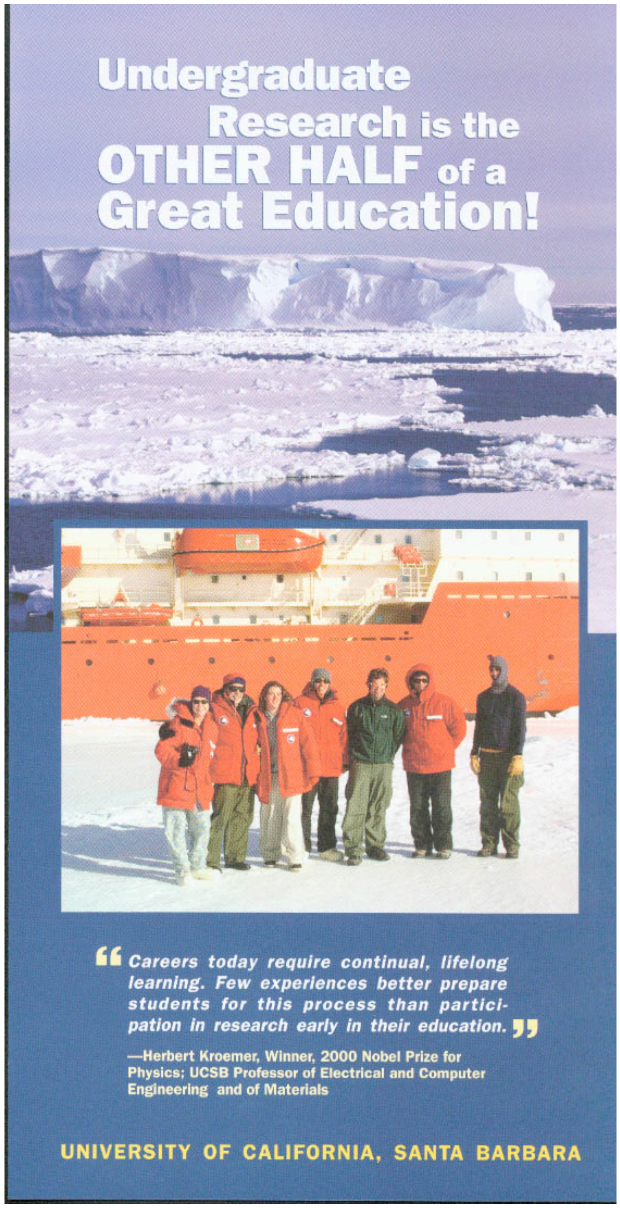
The UCSB Borrego Downhole Array Facility

The UCSB Hollister Earthquake Observatory

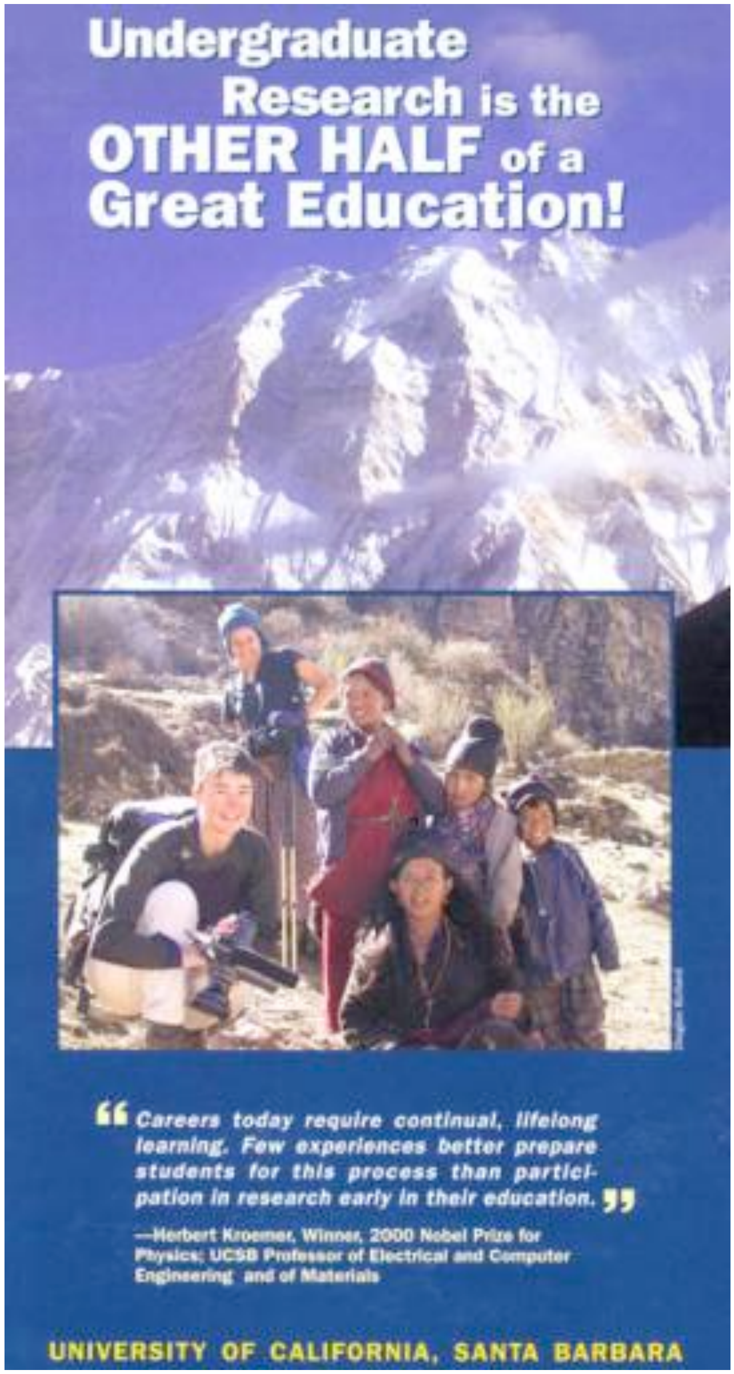
The research projects administered at the Institute have been featured by the Office of Research publication on undergraduate research opportunities brochure from 2002-2005. Covers of the brochure are featured following this page.



Cover: Awesome research Monsoon-drenched Himalayan gorges and wind-swept alpine desert on Tibet’s southern plateau were natural laboratories for undergraduate Karen Vasko in spring 2004. The senior’s research project documented effects of the previous year’s catastrophic flood, which displaced boulders more than 15 feet in diameter. Vasko also was field assistant to Beth Pratt, \a graduate student mentored by UCSB geology professor Douglas Burbank, director of the Institute for Crustal Studies. Burbank leads an eight-university team studying interactions between climate, erosion, and mountain building in the world’s highest mountains. As Vasko helped install devices to monitor river flow, sediment loads, snow melt, and air temperature, she went from tropical rivers to glaciers at 18,000 feet. (Inset: Karen Vasko and two Nepalese assistants reach an alpine pass festooned with prayer flags.)



Cover: Extreme Research Very cool by any measure, a four-week expedition to Antarctica gave five undergrads, two graduate students and their faculty mentor a chance to explore new areas of the ocean floor in the minus 15-degree Antarctic summer of January 2003. Prepping for National Science Foundation-supported research in the coldest, windiest, highest, driest continent on earth included medical exams, full dental tune-ups, and a mandatory geophysics course. Led by Bruce Luyendyk, professor of Geological sciences and principal investigator in UCSB's Institute for Crustal Studies, the research team prepared for drilling from the Ross Ice Shelf that will answer questions about the evolution of the East and West Antarctic ice sheets, Antarctic climate, global sea level, and tectonic history of the West Antarctic rift system.



Cover photo: ***7,8000-Mile Field Trip*** Nepal’s Annapurna mountain range in the Himalayas was junior Michelle Garde’s research lab for eight weeks in spring 2002. Garde (left, in back) was field assistant to Beth Pratt (left, foreground), graduate student working under the supervision of Douglas Burbank, geology professor and director of the Institute for Crustal Studies. Burbank is leading an eight-university team studying inter actions between climate, erosion, and mountain building in the world’s highest mountains. Garde also did her own research, which produced “valuable information on the history of a colossal, 5000-year-old landslide and rates of erosion in this mountainous region,” according to Burbank. (The family in this photo was herding sheep near Tibet where the researchers were camping.)