Awards Administered 2004-2005

Archuleta
University of Southern California
069203
ITR/AP: The SCEC Community Modeling Environment: An Information Infrastructure
10/01/01-09/30/06
$228,051
The first year's efforts focus on simulating ground motion for scenario earthquakes in order to improve probabilistic seismic hazard analysis (PSHA)-Pathway 2 in the ITR proposal. We will complete the validation of a three-dimensional viscoelastic finite difference (FD) code that can be used to simulate low-frequency ground motion for a wide range of scenario earthquakes. This FD code will be wrapped and made available for execution on the web as a SCEC wave propagation community model. The implementation will allow coupling to user-supplied rupture models as part of Pathway 3 in the ITR proposal. Because the PSHA relies on high-frequency as well as low-frequency ground motion, we will explore hybrid methods that can extend the frequency range of the computed ground motion to produce synthetic broadband time histories. For two scenario earthquakes we will compute multiple realizations of broadband ground motion time histories from which statistical parameters can be computed. These statistical parameters will be compared to estimates based on empirical methods used in PSHA.

Archuleta
National Science Foundation
CMS-0201264
COSMOS Virtual Data Center
09/01/02-08/31/07
$397,395
Agency: COSMOS
2003-02
COSMOS Virtual Data Center
09/01//02-08/31/07
$75,000
California Dept. of Conservation-California Geological Survey
1005-807
07/01/05-12/31/05
$30,000
The proposal requests support to continue development of the COSMOS Virtual Strong-motion Data Center — COSMOS VDC — an unrestricted, Web-based, interactive strong ground motion data resource for the practicing earthquake engineering, emergency response, research, and other earthquake professional communities. The major goal of the VDC is to expand and significantly improve the accessibility and the use of all strong-motion records collected by the ever-growing number of US and international organizations (e.g. CDMG, USGS, ACOE, USBR, USC, SCEC, Japan KNET, Taiwan CWB, and others, including small networks operated by universities). The VDC operates under the direction of The Consortium of Organizations for Strong-Motion Observation Systems (http://www.cosmos-eq.org/). The COSMOS structure enables the VDC to respond to both the

organizations that collect the data and the users (academic and professional) of the data; and ensures that the VDC evolves so that it remains responsive to the community of engineers, scientists and other users of strong-motion data. This proposal is focused on advancing the science of interactive, Web-based analysis, dissemination, and use of strong-motion data for the direct benefit of the engineering and scientific communities who use the data to mitigate and understand the nature of earthquake hazards. The proposed research will advance the capability of the COSMOS VDC by further developing the proven concept of a virtual data center and its important role in coordinating the access and dissemination of strong-motion data.

The VDC provides a very cost-effective way to leverage the data processing and management resources of all of the participating agencies and organizations. The VDC continually develops, updates, and maintains a sophisticated parameter metadata environment in a state-of-the-art relational database. This permits the user to interactively query, search, retrieve and analyze strong-motion information using the latest developments in Web technology. At the same time, the accelerogram data and other data products are stored and maintained either by the collecting organization, or by the VDC, if the collecting organization so chooses, but in such a way as to be transparent to the user, thus the 'virtual' nature of the portal to the data provided by the VDC. The direct responsibility for data collection, processing, basic quality control, and storage remains primarily in the hands of the collecting agencies and organizations. The user can thus have confidence that the data are the most current available. This approach provides a major step forward in improving accessibility of the data to the research, practicing, and emergency response communities for purposes of earthquake hazard mitigation.

The funding sought by this proposal will be used together with funds provided by COSMOS to: 1) advance Web-based interfaces with the Advanced National Seismic System (ANSS) data management system; 2) advance methods for augmenting the existing VDC metadata database; 3) advance Web-based methods to facilitate efficient query and retrieval of a variety of event, station, and processed time history information; 4) develop Web-based methods for dissemination of information according to user selectable format, processing and visualization; 5) facilitate development of COSMOS standards for data formats and processing; 6) advance Web-based interfaces with other databases to enhance the metadata on earthquakes, recording site characteristics, and other relevant information for the VDC; 7) enhance Web-based interfaces and links for replication sites; and 8) advance Web-based interfaces with geotechnical databases.

Archuleta
Steidl
Nuclear Regulatory Commission
NRC-04-00-038
Garner Valley Downhole Seismographic Array
04/01/00-03/31/05
$820,059
The Garner Valley downhole seismographic array (GVDSA) is located in the Southern California between the San Jacinto and San Andreas faults. The GVDSA test site is located in a narrow valley within the Peninsular Ranges Batholith. GVDSA is located in a seismically active region 7 km from the main trace of the San Jacinto fault system and 35 km from the San Andreas fault. The San Jacinto fault system has been historically the most active strike-slip fault system in Southern California.

The San Jacinto fault has a slip rate of 10 mm/y (*Sharp*, 1967; *Rockwell et al.*, 1990; *WGCEP*, 1995). Based on historical seismicity and paleoseismological evidence *Rockwell et al*. (1990) argue that the Anza segment of the San Jacinto could produce an earthquake M 6.5-7.0. Based on historical seismicity and paleoseismological data the 1995 Working Group on California Earthquake Probabilities (*WGCEP*, 1995) assigned a mean probability of 17% for a M 7.0-7.5 within the 30-year period 1994-2024 for the Anza segment.

The Anza segment is 90 km long containing the Clark fault, Coyote Creek fault, and the Buck Ridge fault. The next segment north of the Anza segment is the San Jacinto Valley segment. WGCEP (1995) gave a 43% probability of a M 7.0 in the period 1994-2024. The last known earthquake on this segment was a M 6.8 in 1918. The Coachella Valley segment of the San Andreas has not had a major earthquake since about 1680 with an average recurrence interval of 220 plus or minus 13 yr. The WGCEP (1995) assigned a probability of 22% of a M 7.5 in the period 1994-2024. All of these studies reinforce the basic premise that GVDSA is located in an area where one should expect large amplitude ground motion from nearby major earthquakes.

Archuleta
University of Southern California
PO 094119 and PO 105819
SCEC Deputy Director
10/01/2003-01/31/2007
$68,870
Serve as Deputy Director of Southern California Earthquake Center and Chair of the Planning Committee.

Archuleta
Liu
DOI- U.S. Geological Survey
04HQGR0059
Improved Prediction Method for Time Histories of Near-Field Ground Motions with application to Southern California
01/01/04-12/31/04
$131,303
Prediction of realistic time history of ground motion from future earthquakes is essential to completely describe earthquake hazard, and as such it is a key component of the USGS Earthquake Hazards Reduction Program. While we cannot know the exact time of the next damaging earthquake, geologists, seismologists and geodesists have delineated faults that are capable of producing large magnitude earthquakes in urban areas. Recent work by Shaw and others (2002) has spotlighted the Puente Hills thrust fault system that underlies the Los Angeles metropolitan area. This system is capable of producing earthquakes from M_W 6.5 to 7.1. If there were such an earthquake, what would the ground shaking be in the greater Los Angeles area? Which areas would experience the maximum shaking? How would the local geological conditions, or the depth of the Los Angeles basin its edges affect the ground motion. We propose predicting a range of broadband time histories of strong ground motion that capture the effects of *i*)a rupture on a finite fault, *ii*)the complexity of the three dimensional Earth model and *iii*) local site conditions.

To predict the ground motion for the greater Los Angeles area we will simulate a suite of possible earthquakes on the Los Angeles segment of the Puente Hills thrust fault by combining a kinematic model of the extended seismic source with broadband Green's functions. We will develop a new technique for kinematic modeling of an extended earthquake source that is based on distribution functions for the slip amplitude, duration of slip (rise time) and rupture time. The complexity of the source process is represented by spatial distributions of randomized source parameters, but the integrated characteristics of these parameters will be constrained by the total moment (magnitude), radiated energy and the high-frequency decay of the spectral amplitudes in the source spectrum. We propose a technique to generate Green's functions that combines both the Earth model and data obtained from small earthquakes recorded on the California Integrated Seismic Network (CISN). We use a three-dimensional Earth model to calculate theoretical Green's functions for frequencies up to one to two Hertz. The 3D model incorporates the geometry of the geology in the area, including the deep basin structures. We use recordings of earthquakes with M 3~4 and one-dimensional approximations to the velocity structure to derive high-frequency (greater than 1 Hz) Green's functions that include site-specific local site conditions. The high-frequency and low-frequency Green's functions are stitched together to form a broadband Green's function that is convolved with suites kinematic source models to generate time histories of ground motion. This method will be validated using the M_W 6.7 Northridge earthquake which is a proxy for an earthquake on the buried thrust faults that underlie downtown Los Angeles.
With this approach we will simulate hundreds of earthquake scenarios on the Los Angeles segment of the Puente Hills thrust fault. These scenarios will provide a range of ground shaking that can be expected in Los Angeles from a M_W 6.5 earthquake directly beneath the city. From these ground motion time histories we can compute a range of engineering parameters such as peak acceleration, peak velocity or response spectra that can be used to estimate the likely damage from earthquakes on this fault. We want to emphasize that we are predicting a range of ground motion that will be quantified statistically so that one has a probability of a given level of ground shaking to be expected. By taking into account the geological complexity of the area as well as the full extent of the fault, the shaking intensity is unlikely to be uniform over the greater Los Angeles area. These results can be used by the appropriate agencies, who must respond to future earthquakes in Los Angeles, to implement mitigation plans such as alternative transportation routes, reinforcement of structures, temporary relocation of businesses, etc.

Archuleta
Department of Interior - USBR
04PG810719
Dam Safety office Research Project Plan
4/8/04-9/30/04
$50,120

Archuleta
Department of Interior
05HQGR0059
Predicting the Spatial Variability of Site Response
01/01/05-12/31/05
$52,013
Seismic microzonation is "the process of determining absolute or relative seismic hazard at many sites accounting for the effects of geologic and topographic amplification of motion and of soil stability and liquifaction, for the purpose of delineating seismic micro zones..in order to reduce damage to human life

and property resulting from earthquakes." (EERI, 1984). The intensity of the ground motion depends on the seismic source-earthquake magnitude distance from the seismic source, style of faulting-together with local soil conditions, topography and geological conditions. The spatial variability of the ground motion, even over relatively short distances of hundreds of meters, is difficult to predict. Peak amplitudes of acceleration or velocity can vary by a factor of five or more over distances of several hundred meters or less. Quantifying how factors such as soft soils, topography or geological conditions can affect the ground motion over small distances requires a large capital investment for instrumentation and an active seismic area that can provide a variety of different sources. The Yokohama 150 element high-density seismic array offers a unique opportunity to study the spatial variation of ground motion. In 1997 Yokohama established a dense accelerometer array to be used for mitigation of earthquake losses and real-time damage assessment. The array is within a 434 km area with an average station spacing of approximately 2 km, with many stations more closely spaced. In addition to the surface sites there are nine borehole sites, three of which are at depths around 62 m. We propose to analyze data from 41 earthquakes currently recorded on this array. Because of the density of stations we cna correlate ground motion parameters such as spectral amplification, Arias intensity, duration, cumulative absolute velocity, peak ground acceleration and peak ground velocity with geological and geographical features such as basin depth, distance to basin edges and local shear wave velocity. Rarely are there sufficient data to analyze the statistical variation in ground motion parameters over such a confined area. The results of the analysis should provide insights into how different geological or geographical features affect ground motion. Because of density of stations provided by the Yokohama array we can quantify the coherence of each parameter for different distances and correlate the same parameters with different geological conditions. With the variety of different earthquake sources we will compare ground motion from seismic sources that are crustal (less than 20 km deep) and those that are in the subducting slab (50-100 km deep). In order to predict realistic ground motion that can be used at the spatial dimensions of urban areas one must have a quantitative assessment of the natural variability due to the site response, even for sites that have similar local geology. Using the data from the Yokohama dense array we plan to quantify the variabily that site response has on predicted ground motion.

Archuleta
University of California –UC IGPP
04-08-16L-1532
Heterogeneity of Stress in the Crust and Its Effect on Earthquake Rapture
10/01/04-09/30/05
$32,900

Atwater
National Science Foundation
DUE-0205928
NSF Dirctor’s Awards for Distinguished Teaching Scholars
Animation for Visualization of Earth Processes and History
07/01/02-06/30/06
$305,000
My works on the plate tectonic evolution of western North America are especially highly cited, used, and respected. They earned me election into the National Academy of Sciences in 1997. I continue to do research on many aspects of this subject. My teaching goals are always two-fold, both to instill as much understanding as possible of the way the earth works, and also to convey my own love of the beauty, excitement and rigor of the scientific endeavor.

In recent years I have experimented with the creation of multi-media visualization products for the understanding and teaching of earth subjects. My initial animations and movies have met with great response, and are used in numerous classrooms at U. C. S. B., across the nation and around the world. I believe a major portion of the human population learns best from imagery, especially moving images, and I am very excited about the new multi-media tools that make this form of communication so much more possible. Moving imagery is especially useful and helpful for the teaching of geology, since the subject is so visual and is often far outside ordinary human scales of time and space.

I am presently refining regional geological animations and materials for southern California. If this award is granted, I plan to expand the geographic reach of this work by creating an Educational Multimedia Visualization Center for visiting teacher-scholars. Many colleagues who have seen my animations at meetings and lectures have immediately asked how to create their own. The center will allow experts in the geology of their own regions/disciplines to bring their traditional images and knowledge and to transform them into animations and presentation packages. They will return home with these products and also with a new array of skills to share around their own institutions. Their imagery products will join my works that are already out in film, videotape, as freeware on the web and as materials in the NSF-funded digital libraries of ADEPT and DLESE. Indeed, the ADEPT group is based at U.C.S.B. and is interested in developing a streamlined process for transferring content generated at the Educational Multimedia Visualization Center into their online holdings.

The award will honor and facilitate my efforts and those of many visiting colleagues. Equally important, it will recognize and honor the exceptional support this campus gives to undergraduate teaching through the U.C.S.B. Instructional Development Office. This world-class group supplies consultation and support for all aspects of teaching. The proposed Multimedia Visualization Center will build upon the long experience and excellent infra-structure of this organization, extending its services to off-campus visitors. Thus, visitors will return home with their own projects and also with new ideas about instructional support possibilities. Likewise they will share with us the innovations of their home institutions that we may learn from them and pass them along.

Becker
National Aeronautics & Space Administration
NAG5-13413
A Re-Examination of Nitrogen Heterocyclic Compounds in Extraterrestrial Samples
09/15/03-09/14/05
$80,000
The biological role of purines and pyrimidines as coding elements of ribonucleic acids (RNA) and deoxyribonucleic acids (DNA) have led to broad interest in the isolation, characterization and formation of these compounds and their related derivatives in meteorites (*Folsome et al*., 1971, 1973; *Hayatsu* (1964), *Hayatsu et al.*, 1975; *Van der Velden and Schwartz*, 1977; *Stoks and Schwartz*, 1981 a,b, 1982; *Pizzarello et al*. 2001). Geochemical studies of meteorites, especially Murchison, have provided some valuable clues about the mechanism of formation of other important organic compounds such as amino acids, via the Strecker-synthesis (*Peltzer and Bada*, 1978); however, attempts to establish a mechanism of formation for N-heterocycles remains problematic.

The problems encountered in some of the earlier work are, in part, due to very different approaches in isolating and analyzing these N-heterocycles in carbonaceous chondrites. For example, *Folsome* (1971, 1973) examined charcoal absorbates of hot-water and hot formic acid extracts using GCMS and found

mainly 4-hydroxypyrimidine, two isomeric methyl-4-hydroxypyrimidines and some non-biological compounds (e.g. pyrimidines, quinolizine). Curiously, none of the biologically occurring purines or pyrimidines was detected. This was followed up by *Hayatsu et al*. (1975) using both the *Folsome et al*. extraction method (1971, 1973) and much harsher extraction procedures (acid hydrolysis using 3-6 M HCL or trifluoroacetic acid) coupled to detection by direct probe MS without any further derivatization. They detected aliphatic amines and C_2-C_6 alkyl pyridines but no 4-hydroxypyrimidines via the *Folsome et al*. (1973) method. Using the stronger acids, two of the biological purines adenine and guanine were detected as well as the triazines melamine, cyanuric acid, urea and guanylurea, which have no known biological function.

Becker
Johns Hopkins University
862462
Organic Synthesis in Hypervelocity Impacts
11/15/02-06/30/06
$36,000
We propose to undertake a new study of the possible synthesis of pre-biotically relevant organic compounds in hypervelocity impacts. The organic matter on planetary bodies originally derived from a combination of endogenous and exogenous processes, with impact shock and post-impact recombination playing a potentially significant role (e.g., Chyba and Sagan 1992, Nature 355, 125). The inventory of organic species that may have resulted from recombining hypervelocity impact plasma remains somewhat speculative, especially for impacts above 20 km s-1 where current gun experiments cannot reach. For airless small bodies and moons, such studies are important for comparison to, and in conjunction with, the important chemical processing of ices by UV radiation. For planets with atmospheres, particularly Earth, such knowledge is needed to compare with the potentially complementary set of species synthesized in impact shock. Pulsed laser ablation (LA) is a highly-promising experimental probe of this high velocity regime (e.g., Pirri 1977, Phys. Fluids 20, 221; Mukhin et al. 1989, Nature 340, 46). A unique experimental design permits the study of LA products with both post-analysis of deposited films and high-sensitivity in situ time-of-flight mass spectrometry. Initial results have shown that exobiologically-pertinent hydrocarbon oligomers with a wide range of energies and ionization states are produced even from a completely atomized plasma. With this setup, and with an enhanced derivative design with improved control of laser coupling, energy, and spot-size, we will obtain a comprehensive analysis of the plasma recombination problem with standard carbon-matrix, meteorite, and carefully tailored ice analog materials. Dr Becker will evaluate samples in her laboratory using LDMS and high performance liquid chormatography could to a photo-diode array detector to further evaluate the organ compounds formed in the hypervelocity impact experiments.

Becker
National Aeronautics & Space Administration
NAG5-11385
Fullerenes: A New Carrier-Phase for Noble Gases in Meteorites
10/01/01-10/31/04
$86,139
The proposed project will address the hypothesis that fullerenes (pure carbon compounds with the simplest being C_{60}) are a major carrier phase for noble gases in meteorites. The focus of this research will be to isolate and detect fullerenes and endohedral fullerenes (e.g. those with encapsulated noble gas

atoms) in a suite of Antarctic meteorites including CM, CV, C2, CO3 L3.1, H3.3, CK4, CK5 and ureilites. In addition, carbonaceous chondrites including the Allende, Murchison and Orgueil meteorites will also be examined. The proposal for the Antarctic meteorites has been approved as part of a separate request to the Antarctic Working Group and will be analyzed as outlined in this study. The objectives are: (i) to ascertain how noble gases are retained in various carbon carriers (e.g. adsorption onto elemental and amorphous carbon vs. caged molecule trapping) (ii) to understand the processes that led to the formation of these molecules in the Cosmos; (iii) to measure the isotopic ratios of the trapped noble gases in this fullerene carrier phase to further assess the evolution of the early Solar system; (iv) and to re-evaluate the theories for 'Planetary' vs. 'Nucleosynthesis' to determine the origin of noble gases in planetary atmospheres. Samples will be processed using established procedures outlined in previous investigations as well as some new techniques outlined in this proposal.

Becker
National Aeronautics & Space Administration
NAG5-11560
Interstellar Organic Molecules and the Origin of Life: The Role of Exogenous
12/01/01-11/30/05
$180,249
Extraterrestrial bodies such as asteroids, comets and their associated dust, played a significant role in the early history of life on Earth and perhaps other planets. The study of life under such extreme conditions requires knowledge of such fundamental issues as the nature of the organic material and the chemical processes that led to their formation in space, the chemistry of asteroids and comets, and the preservation of organics in the early terrestrial environment. In this proposal we outline a program to examine the role of exogenous delivery of organic compounds to the early Earth by studying organic-rich meteorites (e.g. Muchison meteorite), sediments associated with giant impact events (Cretaceous/Tertiary 'K/T' boundary) and the inter-planetary dust (IDPs) found in deep-sea sediments (DSDP drilling cores). We have developed several new techniques to search for specific organic tracers that will allow us to examine the contributions of exogenous delivery in providing complex organic compounds to the early Earth and to investigate the effects of such events on the biostratigraphic record over the past several million years. Specifically, we will isolate fullerenes with trapped noble gases (*Becker et al*., 1996) and abiotic amino acids (a-AIB and isovaline; *Zhao and Bada,* 1989) in our samples and will compare the relative concentrations of these compounds to evaluate the preservation and accumulation of organics being delivered to the Earth. In addition, we will carryout laboratory experiments to probe the level of chemical complexity that can be reached as a result of exogenous delivery and will examine the complexation of organic compounds to specific mineral phases. Confirmation of the flux of extraterrestrial material in sediments throughout geologic time and its association with changes in the biostratigraphic record could have broad implications for the origin and evolution of life on the early Earth and perhaps other planets.

Becker
National Science Foundation
OPP-0229917
Collaborative Research: Permian-Triassic Mass Extinction in Antarctica
06/01/03-05/31/06
$148,985
This proposal is to continue multidisciplinary studies of the fluvial sediments in Antarctica for evidence of what caused the greatest of all mass extinctions in the history of life at the Permian-Triassic boundary.

This boundary was until recently difficult to locate and thought to be disconformable in Antarctica. New studies, particularly of carbon isotopic chemostratigraphy and of paleosols and root traces as paleoecosystem indicators, together with improved fossil plant, reptile and pollen biostratigraphy, now indicate the precise location of the boundary and have led to local discovery of iridium anomalies, shocked quartz, and fullerenes with extraterrestrial noble gases. These anomalies are associated with a distinctive claystone breccia bed, also known in South Africa and Australia, and taken as evidence of deforestation. There is already much evidence from Antarctica and elsewhere that the mass extinction on land was abrupt and synchronous with extinction in the ocean.

The problem now is what led to such death and destruction. Carbon isotopic values are so low in these and other Permian-Triassic boundary sections that there was likely to have been some role for catastrophic destabilization of methane clathrates. Getting the modeled amount of methane out of likely reservoirs would require such catastrophic events as bolide impact, flood-basalt eruption or continental-shelf collapse, which have all independently been implicated in the mass extinction and for which there is independent evidence. Teasing apart these various hypotheses will require careful re-examination of previously discovered boundary beds, and search for more informative sequences, as was the case for the Cretaceous-Tertiary boundary.

This is collaborative research on geochemistry and petrography of boundary beds and paleosols (by Retallack), on carbon isotopic variation through the boundary interval (by Jahren) and on fullerenes, iridium and helium (by Becker). Our primary field site for the first season is likely to be Coalsack Bluff in the central Transantarctic Mountains, with short visits also to Graphite Peak, Mt. Wild, Fremouw Peak and Mt. Boyd. For the second season we plan to focus on Portal Mountain in southern Victoria Land, with short visits also to Mt. Crean, Mt. Fleming and Shapeless Mountain.

Becker
National Aeronautics and Space Administration
NNG04GC17G
Atmospheric Pressure Matrix Assisted Laser Desorption/Ionization Trap Mass Spect
01/15/04-01/04/06
$328,773

Becker
National Aeronautics and Space Administration
NNG04GJ36G
Traces of Catastrophe at the End Permian
05/01/04-04/30/07
$212,523

Becker
National Science Founation
OCE-0296087
Collaborative Research: Fullerenes and the Extraterrestrial Flux of Helium
10/01/01-01/31/04
$82,306

Becker
National Science Founation
EAR-0341972
Bedout: An End-Permian Impact Site Off-Shore Northwestern Australia
08/15/03-10/31/05
$30,000

Becker
Space Telescope Science Institute
42032
Research and Education and Public Outreach Program
10/22/03-09/30/04
$5,000

Boles
Department of Energy
DE-FG02-96ER14620
Fluid Flow in Faults: Process and Effects from Modern and Paleo Systems in a Transpressional Tectonic Setting, Southern California
02/01/03-01/31/06
$365,530
We propose to expand our study of heat and mass transfer related to faulting. Future studies will include estimating spatial distribution of fault permeability as indicated by diagenetic effects and determining mechanisms and evolution of fluid movement. Our work will continue to focus on transpressional sedimentary basins of southern California, which have been actively deforming since Miocene time

Specific questions to be addressed include:

- How does permeability of the fault system and associated fluid movement evolve over time?
- What techniques are most effective at detecting thermal pulses in the fault environment?
- What diagenetic evidence is there to support the hypothesis that fluid movement is episodic and rapid?
- What are the geochemical and thermal implications of episodic fluid flow?
- What evidence is there that solid earth tides affect fluid (gas) movement in fault systems and submarine seepage at continental margins?

The study of natural seepage along continental margins has become a frontier area for geofluids research (Parnell, 2002), yet we know of few groups like ours linking methods from hydrogeologic modeling and geochemistry/sedimentary petrology to problems of flow in faulted systems. This is a true collaborative study combining field and analytical observations and data generated by the UC Santa Barbara team under the direction of James Boles with hydrogeologic and poroelasticity modeling generated by the Johns Hopkins University team under the direction of Grant Garven.

Boles
Israelachvili
American Chemical Society - PRF
PRF# 39823-AC2
Dissimilar Mineral Interfaces: Understanding Mica/Quartez Surface Interactions
07/01/2003-08/31/2006
$79,325
We propose a new interdisciplinary project of fundamental experiments on the interactions between quartz and mica separated by thin aqueous films. We seek to understand the cause of 'pressure solution', the extraordinary dissolution of quartz in contact with mica which – as inferred from more than 50 years of petrographic observations – is orders of magnitude higher than for quartz-quartz and mica-mica contacts, or for quartz-solution interfaces. Our goal is to simulate mechanical strain and physical-chemical conditions on mica-quartz contacts to establish the effects of crystallography orientation, pressure, temperature, ionic solution, and pH around natural sand formations. The results will be fundamental for understanding various processes such as quartz cementation in hydrocarbon reservoirs, the role of pressure in "pressure solution", the post-rupture healing of faults, and how dissimilar minerals interact in aqueous solutions. These results will also directly impact other disciplines and phenomena such as mixed colloidal systems and clay-swelling. The experiments will be conducted by an experienced postdoc, using a Surface Forces Apparatus (SFA), whose pioneer is my collaborator, Jacob Israelachvili (an expert on intermolecular force measurements). Experimentally modified surfaces will also be studied with the AFM. Recently, we have been able to acquire synthetically grown, micron-thick flat quartz sheets, in addition to the traditional muscovite used in the SFA-experiments. Our preliminary experiments, never before attempted, indicate that when these *dissimilar* surfaces are pressed together in aqueous solution, the quartz dissolves at a remarkable rate, leaving us confident of our ability to quantitatively investigate the important variables in the quartz-mica system.

Boles
Israelachvili
National Science Foundation
EAR-0342796
Understanding the Role of Clay Mineral Surface Interactions in Pressure Solution07/01/2000-06/30/2004
07/01/04-06-30/07
$152,345
Seismic microzonation is "the process of determining absolute or relative seismic hazard at many sites accounting for the effects of geologic and topographic amplification of motion and of soil stability and liquifaction, for the purpose of delineating seismic micro zones..in order to reduce damage to human life and property resulting from earthquakes." (EERI, 1984). The intensity of the ground motion depends on the seismic source-earthquake magnitude distance from the seismic source, style of faulting-together with local soil conditions, topography and geological conditions. The spatial variability of the ground motion, even over relatively short distances of hundreds of meters, is difficult to predict. Peak amplitudes of acceleration or velocity can vary by a factor of five or more over distances of several hundred meters or less. Quantifying how factors such as soft soils, topography or geological conditions can affect the ground motion over small distances requires a large capital investment for instrumentation and an active seismic area that can provide a variety of different sources. The Yokohama 150 element high-density seismic array offers a unique opportunity to study the spatial variation of ground motion. In 1997 Yokohama established a dense accelerometer array to be used for mitigation of earthquake losses and

real-time damage assessment. The array is within a 434 km area with an average station spacing of approximately 2 km, with many stations more closely spaced. In addition to the surface sites there are nine borehole sites, three of which are at depths around 62 m. We propose to analyze data from 41 earthquakes currently recorded on this array. Because of the density of stations we cna correlate ground motion parameters such as spectral amplification, Arias intensity, duration, cumulative absolute velocity, peak ground acceleration and peak ground velocity with geological and geographical features such as basin depth, distance to basin edges and local shear wave velocity. Rarely are there sufficient data to analyze the statistical variation in ground motion parameters over such a confined area. The results of the analysis should provide insights into how different geological or geographical features affect ground motion. Because of density of stations provided by the Yokohama array we can quantify the coherence of each parameter for different distances and correlate the same parameters with different geological conditions. With the variety of different earthquake sources we will compare ground motion from seismic sources that are crustal (less than 20 km deep) and those that are in the subducting slab (50-100 km deep). In order to predict realistic ground motion that can be used at the spatial dimensions of urban areas one must have a quantitative assessment of the natural variability due to the site response, even for sites that have similar local geology. Using the data from the Yokohama dense array we plan to quantify the variabily that site response has on predicted ground motion.

Burbank
National Science Foundation
EAR-0230403
Geologic Versus Geodetic Rates of Convergence in the Southeastern Tien Shan, China
03/01/03-02/28/06
$272,212
As geodetic studies yield increasingly precise representations of decadal patterns of crustal deformation, they pose intriguing problems that, in most sites, are unresolved at present. Geodetically defined strain demands explanation: Given a regional strain gradient, how is strain partitioned across the intervening terrain? Do multiple structures accommodate the deformation, and, if so, how do they interact to produce the regional stain pattern? Do geodetic strain rates at decadal scales provide a good representation of long-term strain rates, and, if so, at what spatial scales? How far back in time can geodetic strain rates be extrapolated, and are they consistent with geologic data on the age of initial deformation and geologic deformation rates through time? Are regional rotational gradients defined by geodetic data consistent with rotations recorded by syntectonic strata?"

Several geodetic and geologic studies along strike-slip fault zones, such as the San Andreas, suggest that a reasonable match commonly exists between the geologic and geodetic data, such that the geodetic strain rates (*Wdowinski et al*, 2001; *Hudnut et al*, 2002) match the sum of documented geologic slip rates on known faults (*Sieh and Williams*, 1990; Weldon, 1996; *Reheis and Dixon*, 1996). In contractional mountain belts, however, the correlations of short- and long-term strain rates (geodetic versus geologic) are more ambiguous. Similar geodetic strain gradients can be accommodated by very different structural patterns. For example, across both the Kyrgyz Tien Shan (*Abdrakhmatov et al*, 1995; *Reigber et al.*, 2001) and the Nepalese Himalaya (*Larson et al*, 1999; *Wang et al*, 2001), geodetic data define regional strain gradients of ~20 mm/yr of shortening. Despite similarities in overall geodetic rates, the geologic data define striking contrasts in how this strain is accommodated.

Burbank

National Science Foundation
EAR-0229911
Collaborative Research: Extrusion and Rotation During Intracontinental
02/15/03-01/31/06
$52,985
Despite recent advances in our understanding of the mechanical and thermal response of continental lithosphere to collisional orogenesis, important controversies remain. One of these centers on the role of large strike-slip faults during intracontinental deformation, and whether these structures 1) control the lateral 'escape' of quasi-rigid blocks in response to continental convergence (e.g., *Tapponnier et al*., 1982), or 2) reflect the passive localization of strain in a pervasively deforming and shearing crust (e.g., *England and Molnar,* 1990). The models make very different predictions regarding the variation of displacement along strike-slip faults, the relationship of fault displacement to deformation of the surrounding crustal blocks, and the nature of accommodation of slip at the terminations of the faults. In eastern Tibet, continuing debate over the nature of active deformation reflects, to a large degree, the limited number of rigorous geologic tests of these predictions.

The Kunlun fault is a first-order structural feature in the central and eastern Tibetan Plateau, where it presents a key opportunity to test among competing hypotheses for the role of strike-slip faults in the active deformation of eastern Tibet. Although Holocene slip rates appear to be uniform at ~11mm/yr along the central portion of the fault (*Van der Woerd et al*., 2000), several observations suggest that significant left-lateral shear along the eastern Kunlun fault does not reach the margin of the Tibetan Plateau: 1) the active trace of the fault on remote sensing (e.g., *Tapponnier and Molnar*, 1977) cannot be distinguished east of ~102°E; 2) field observations (Kirby) confirm that scarps associated with the Kunlun fault are not present east of this region; and 3) geodetic surveys indicate that, at present, little resolvable left-lateral shear passes through the eastern margin of the plateau (*Chen et al*., 2000). Determining what happens to left-lateral shear along the easternmost portion of the Kunlun fault is critical if we are to understand its kinematic and dynamic role in deformation of eastern Tibet and more generally the role of strike-slip faults during intracontinental deformation.

We propose to test several hypotheses regarding the mechanisms of transfer and/or accommodation of displacement at the apparent termination of an intracontinental strike-slip fault:
• *Hypothesis 1:* Displacement is transferred to kinematically linked, strike-slip faults that:
    a. transmit displacement across and beyond the plateau margin, or
    b. transmit displacement to shortening structures at the plateau margin.
• *Hypothesis 2:* Displacement is absorbed by distributed shortening within the plateau resulting in crustal thickening.
• *Hypothesis 3:* Displacement represents passive rotation of faults in response to a diffuse, clockwise regional shear.

Testing these hypotheses will focus on the following tasks:
• Determining Late Pleistocene-Holocene slip rates along the easternmost segment of the Kunlun fault, with special attention to potential variations along strike.
• Establishing the geometry, kinematics, and rates of displacement on candidate accommodation structures (both within the plateau and at its margin).

• Assessing the magnitude and distribution of differential rock uplift and river incision in the Anyemaqen Shan (the prime candidate for shortening within the plateau)
This study promises to bring a detailed chronologic perspective to bear on the nature of accommodation of strain at the terminations of large, intracontinental strike-slip faults. We will document the presence or absence of displacement gradients present near the ends of such structures. The study will define the relationship of fault displacement to regional deformation patterns and will determine some of the mechanisms by which displacement is transferred to other structures. Finally, it will determine to what degree fault displacements are linked to deformation of the bounding blocks. The combined results will yield critical new insights into the problem of extrusion versus rotation during continental deformation.

Burbank
National Science Foundation
EAR-0196414
Collaborative Research: Geomorphic-Geodynamic Coupling at the Orogen Scale: Himilayan Transec in Central Nepal
03/15/01-12/30/05
$1,330,878 and REU supplement $14,194
One of the most provocative-yet largely untested-recent hypotheses concerning orogenic evolution is that regional variations in climate strongly influence spatial variations in the style and magnitude of deformation across an actively deforming orogen. Recent progress in quantifying rates of both tectonic and geomorphic processes and in modeling surface and lithospheric processes sets the stage for an integrated, quantitative, field- and model-based investigation of the interactions and feedbacks between geomorphic, climatic, and tectonic processes. We propose to examine these interactions where they are likely to be most clearly expressed: the Nepalese Himalaya. Not only in this the quintessential collisional orogenic belt, but its topographic growth and erosional history have been suggested as key controls on global climatic changes. Our integrated study focuses on a major transverse catchment, stretching from the edge of the Tibetan Plateau to the foreland and traversing some of the highest topography in the world. This transect spans the major structural elements of the Himalaya, as well as monsoon-to-rainshadow climatic conditions. We bring together expertise in process-based geomorphology, glaciology, climatology, structural geology, thermochronology, cosmogenic radionuclide dating, modeling, and documentary film making for a multi-pronged approach intended to evaluate one overarching, but largely untested hypothesis:

- Rates of erosion vary spatially as a function of climate and this spatial variability in erosion controls the partitioning of deformation within an orogen.

Furthermore, we will collect data to assess the following related, but subsidiary hypotheses:

- The erosional response to rapid lateral advection of crust across a basement ramp-crustal scale fault-bend folding, for example-creates erosion rates that are nearly equal across the entire topographic escarpment of the Himalaya, ranging from 8 km to 1 km in elevation.
- Above a certain threshold erosion rate, the topography attains a dynamic ‘equilibrium’ or steady state that is independent of erosion rate.
- Topographic characteristics (relief, slope angles, normalized river gradients) correlate more strongly with erosion rates than they do with variations in climate or lithology.

Despite the broad scope of these hypotheses and the impossibility of resolving all details, we have developed a research strategy that, over a four-year span, will enable us to define the primary characteristics of denudation, rock uplift, climate, and topography across the Himalaya and to calibrate some process-based 'rules' for major erosional agents, such as glaciers, rivers, and landslides. A key to success will be the integration of data from diverse subdisciplines (climate, geomorphology, tectonics) at the scale both of intensively monitored subcatchments and of the entire trans-Himalayan catchment. Spanning seven subdisciplines in earth and atmospheric sciences, this project brings together researchers from seven US institutions and three governmental agencies in Nepal.

Burbank
National Aeronautics and Space Administration
NAG5-13758
Tectonic-Climate Interactions in Active Orogenic Belts: Quantification of the approach to steady-statetopography with SRTM data
10/01/2003-09/30/2006
$244,988
Active orogenic mountain belts around the world have been imaged during the SRTM. We propose to utilize the newly acquired topographic data in conjunction with data on the development of drainage networks, magnitude of erosion, patterns of deformation, and the extent of glaciation to address key questions about the topographic evolution of collisional mountain belts. An emerging consensus indicates that topographic steady state is commonly achieved in collisional orogens if rates of deformation are rapid and sustained. In this proposal we will investigate the geomorphic and topographic changes that occur during the transitional phase of a range approaching steady state. We will focus much of this research on drainage networks, because these control the dissection of pre-steady-state topography and modulate hillslope responses to base-level changes. In the central Tien Shan, we have found an outstanding site where fluvial channel growth can be traced from its incipient stages to full development and where network growth through time, interactions with active folds and thrust faults, and the impact of contrasting initial slopes can all be quantified in pre-steady-state conditions.

As dissection increases, changes in hillslope characteristics provide key indices of the evolution of pre-steady-state topography. In the Kyrgyz Range (north Tien Shan), geologic mapping and thermochronology show that denudation increases from <1 km in the east to >4-5 km in the west. This denudation gradient corresponds to a range-scale transition from pre- to nearly complete topographic steady state. We will exploit this spatial gradient to quantify topographic indices of the approach to steady state in both glaciated and non-glaciated terrains.

By combining these two study areas in the Tien Shan, we can quantify both hillslope and fluvial evolution toward steady state. Our research will revolve around the following questions:

- How do drainage networks evolve toward steady state as they interact with active folds and faults?
- What progressive topographic changes occur within a rapidly deforming, but pre-steady-state landscape and at what stage do slopes pass thresholds for widespread bedrock landsliding.
- To what extent can topographic characteristics be used to differentiate between pre-steady-state and steady-state orogenic belts?

• Are there fundamental differences in the topography of active mountain belts between glaciated and non-glaciated terrains? If so, how are these differences manifested in pre-steady-state and steady-state mountains?

To answer these questions, we will combine SRTM topography with cosmogenic nuclide dating, multispectral ASTER imaging, Ikonos DEMs and imagery for select areas, differential GPS, and extensive field work in the Tien Shan. Our previous studies of the topographic growth of even small folds provide insight on progressive dissection of pre-steady-state topography. This proposed research will permit us to extend these studies to the scale of ranges and to illuminate details of both channel networks and hillslopes as they evolve toward steady state in both non-glacial and glacial topography. Although not specifically focused on natural hazards, progressive topographic change defines the template on which surface processes generate hazards. Moreover, quantification of the spatial and temporal evolution of fluvial networks, hillslopes, and topography will permit development of new models for the growing collisional mountain belts and will provide insights on the tectonic, climatic, and erosional controls on their topographic evolution.

Burbank
National Science Foundation
EAR-0117242
Collaborative Proposal: Scaling and Displacement Relationships for Thrust Faults
04/01/2001-03/31/2005
$214,464 and $6,850 REU supplement
We have undertaken research on scaling (displacement-length) relationships in thrust faults and on the ways in which thrust faults link, anastomose, and evolve through time. The bulk of the field work is focused on the Ostler Fault system in the South Island of New Zealand and was begun in mid-January, 2002. The initial field work involved the integration of detailed topographic surveying of scarp morphologies, measurement of offset and deformed geomorphic features, subsurface surveys of displaced structural markers, and geochronologic studies of offset markers. The topographic surveys were conducted with differential GPS augmented by analysis of a high-resolution TOPSAR DEM. These topographic data were integrated with co-registered subsurface data, primarily derived from ground-penetrating radar surveys and electrical resistivity studies.

The next field season will involve a focus on structural and geomorphic mapping, rather than on scaling parameters of faulting. We have discovered unusual (and unusually well displayed) structural geometries with elongate rotated backlimbs and strongly folded forelimbs on thrust anticlines. Our goal this year is to map the large scale geometry of the fault zone along its 50-km-long expression, document the structural style and its potential dependence on the rock which is being deformed, and analyze the geomorphic response to these growing, linking, and interacting folds and faults.

Burbank
UC Del Amo
SB040075
Colca and Cotahuasi Valleys Geomorphology Hazard Project: Study of the geomorpho
07/01/2003-10/01/2004
$10,620

English: Colca and Cotahuasi Valleys in southern Peru have become a popular tourist destination near the city of Arequipa. The influx of visitors has launched an economic, social and cultural recovery after many centuries of isolation. This new wave of activity could be severely curtailed or even halted because of the threat that natural disasters caused by seismic and volcanic activity and catastrophic erosion pose to the area.

This project is an initial approach to understanding the interaction of volcanic activity, seismic effects caused by constant tectonic uplift, fluvial erosion in deep gorges, slope processes and climate change in order to determine how they influence natural disasters. These variables will be measured and Geographic Information System-based mathematical models will be designed as tools to locate the hazardous areas and to determine their typology and magnitude.

The project is a joint effort of the University of California at Santa Barbara and at Santa Cruz and the Universidad Complutense of Madrid, in collaboration with the Instituto Geofísico of Peru.

Spanish: Los valles de Colca y Cotahuasi, situados al sur del Perú, cerca de la ciudad de Arequipa, está siendo objeto de una creciente actividad turística. La visita de múltiples turistas es el motivo del reciente despegue económico, social y cultural de la región, después de siglos de aislamiento. Este desarrollo puede ser drásticamente abortado debido a los importantes riesgos naturales que amenazan la región, a causa de la actividad de los procesos sísmicos y volcánicos y a la importancia de los procesos erosivos de tipo catastrófico.

Este proyecto supone una primera aproximación al estudio de la interacción entre las actividades volcánica y sísmica, derivadas de un constante levantamiento tectónico regional, la incisión fluvial en profundos cañones, los procesos de ladera y los efectos del cambio climático, de cara a comprender como influye dicha interacción en la génesis de las catástrofes naturales. Todas estas variables serán medidas y analizadas a través de la aplicación de Sistemas de Información Geográfica, que permitirán obtener modelos matemáticos, los cuales servirán para extrapolar los resultados y definir las áreas amenazadas por riesgos y especificar su tipología y magnitud.

El proyecto se deriva de la colaboración entre las universidades de California en Santa Bárbara y Santa Cruz y la Universidad Complutense de Madrid, en colaboración con el Instituto Geofísico del Perú.

Burbank
American Chemical Society
41960-AC8
Illuminating the evolution of thrust-fault systems using deformed geomorphic markers
01/01/05-08/31/07
$79,600

Burbank
National Science Foundation
EAR-0408675
Collaborative Research: econciling geologic and geodetic rates of deformation: The role of distributed strain in the upper crust
07/01/04-06/30/07
$47,980
Displacement rates on faults, both past and present, are the observational foundation for understanding the geodynamics of rapidly deforming lithosphere. In principle, knowledge of the spatial and temporal distribution of surface deformation rates can yield insights into rupture behavior, lithospheric rheology,

and slip transfer along networks of faults. At present, two primary data sets define these rates: geodetic data (primarily GPS) and geologic estimates of fault displacement. Interpretation of geodetic data is typically accomplished by specifying fault geometries in block models which relate secular velocity gradients to slip on major faults (e.g., McClusky et al., 2001). Such models rely on two primary assumptions: 1) deformation in block interiors is attributed entirely to elastic strain accumulation on bounding fault zones, and 2) strain accumulation on faults can be modeled as creep on the projection of fault planes beneath an elastic halfspace. Over geologic timescales, of course, the Earth's interior deforms by ductile flow. Models which consider lithospheric deformation as an elastic layer overlying a viscoelastic lower crust and mantle yield an important result: if the Maxwell time is significantly shorter than the recurrence time of characteristic seismic events, then velocities measured in the wake of a recent earthquake are significantly faster than for a corresponding elastic model (REF). Thus, 'discrepancies' between geodetic and geologic data may yield insight into lithospheric rheology (e.g., Dixon et al., 2003), provided, of course, that the rates and distribution of geologic slip are well known.

A striking aspect of the presently available geodetic and geologic data sets in southern and eastern California is the pronounced mismatch that exists along several regional fault systems within the Eastern California Shear Zone (ECSZ), a network of transtensional structures in the western Basin and Range (e.g., Reheis and Sawyer, 1997) and strike-slip faults in the Mojave Desert (Dokka and Travis, 1990). Geodetic studies indicate that ~12-14 mm/yr of right-lateral shear passes through eastern California and must be accommodated, at least in part, by displacement on these faults (Sauber et al., 1994; Savage and Lisowski, 1995; Dixon et al., 1995; Dixon et al., 2000; Miller et al., 2001; McClusky et al., 2001). However, geologic investigations consistently yield slip rates which total just about 50% of the geodetic velocities (e.g., Beanland and Clark, 1995; Reheis and Sawyer, 1997; Lee et al., 2001). The reasons for this discrepancy are currently unknown: 1) are the fault representations in the geodetic models too simplified to capture the actual displacement patterns; 2) are earthquakes clustered in time, thereby causing highly irregular short-term rates (e.g., Rockwell et al., 2000); 3) does viscoelastic deformation from recent earthquakes 'contaminate' the geodetic data (e.g., Dixon et al., 2003); or 4) are geologic studies missing a significant component of deformation, perhaps distributed on networks of small faults? A satisfactory understanding of strain fields, predicted slip distributions from geodetic data, and interacting fault systems will probably only be achieved once these questions have been addressed.

The scope of the shear zone in eastern California and the numerous structures involved pose a challenge to adequately . Instead, we suggest that critical insights may be gained by examining a relatively restricted region where there is pronounced disagreement between presently understood geodetic and geologic measures of displacement rate, where the fault geometry is relatively simple (but more complex than existing models), and where the opportunity exists to obtain geologic strain rates across an entire fault system.

For these reasons, we propose to conduct a focused study in the northern Owens Valley (Fig. 1). This region contains several major faults (including the Owens Valley fault, White Mountain fault zone, and Sierra Nevada frontal fault system) and numerous smaller faults distributed throughout the valley. Modeling of geodetic campaign measurements suggests that ~6mm/yr of dextral shear passes through the region. Slip rates derived from trenches in the southern Owens Valley (Lee et al., 2001; Bacon et al., 2003) and piercing points in the northern Owens and White Mountain fault systems (Kirby et al., 2002), however, are typically <2 mm/yr or even <1 mm/yr. Dixon and others (2003) recently argued that the geodetic data could be interpreted as a viscoelastic response to the 1872 earthquake on the Owens Valley

fault (Beanland and Clark, 1994). However, this result implicitly assumes that geologic slip rates on the Owens Valley fault zone adequately represent the distribution of geologic slip across the entire Owens Valley. The presence of numerous fault scarps, many of which displace Quaternary alluvium, distributed across the valley and into the surrounding mountain ranges suggests to us that a significant component of regional transtension may be accommodated on 'diffuse' fault arrays.

We propose to test this hypothesis by developing budgets for Late Quaternary deformation across the central and northern Owens Valley. Through a combination of tectonic geomorphology, structural geology, and chronology of Quaternary deposits, we seek to understand the distribution of deformation across the valley, as well as the manner in which displacement is passed among structures in this geometrically complicated region. Our goals are i) to provide a more complete description of geologic slip rates and off-fault deformation in the Owens Valley; ii) to test and improve current fault models for the distribution of slip across this zone; iii) to ultimately assess the degree to which discrepancies between geodetic and geologic slip rates reflect the dynamics of temporal variations deformation.

Geologic Setting and Description of Key Questions

Since the pioneering geodetic surveys of Savage and others in the Owens Valley (Savage et al., 1975; Savage and Lisowski, 1980), it has been recognized that a significant component of plate boundary deformation occurs within a ~100 – 150km wide shear zone which trends from the Gulf of California, extends through the Mojave Desert, and passes along the western margin of the Basin and Range province (Savage et al., 1990; Dokka and Travis, 1990; Sauber et al., 1994). Recent geodetic surveys coupled with elastic block models indicate that, at present, ~11-14 mm/yr of right-lateral shear is accommodated within the ECSZ (McClusky et al., 2001; Miller et al., 2001).

South of the Garlock fault, this shear is accommodated on a series of right-lateral strike slip faults in the western Mojave (Dokka and Travis, 1990) and by block rotation in the eastern Mojave (Schermer et al., 1996). North of the Garlock fault, shear is accommodated primarily on 3 regional fault zones: the Owens Lake/Little Lake/Airport Lake systems, the Panamint Valley/Searles Valley/Ash Hill system, and the Death Valley fault zone (Fig. 1). In total, geologic slip rates across these structures appears to be between 5 and 8 mm/yr, or ~50% of the geodetically measured deformation across the ECSZ. This observation seems to be a robust feature of the ECSZ both north and south of the Garlock fault. Recent studies have advanced the hypothesis that this discrepancy reflects dynamic, transient behavior of the fault systems, either as 1) oscillatory strain between conjugate fault systems (Peltzer et al., 2001), 2) a consequence of viscoelastic relaxation following the 1872 Owens Valley earthquake (Dixon et al., 2003), or 3) temporal clustering of seismic strain release (Rockwell et al., 2001). Each of these interpretations carries profound implications for our understanding of the dynamical behavior of fault systems. At present, however, geologic slip rates on some of the key structures in Owens Valley are insufficiently known to fully address the significance of transient phenomena such as these. In particular, we have only a limited understanding of the degree to which strain accommodated on arrays and networks of small, distributed faults within Owens Valley contributes to the total displacement field. In this section, we outline the current state of understanding regarding the geometry and slip rates of major structures in the northern Owens Valley and highlight inadequacies that, in our view, make it difficult to discern, with any degree of confidence, the magnitude of the 'discrepancy' between geologic and geodetic rates.

National Science Foundation
EAR-0507431
Collaborative Research: Upward and Outward: Tibetan Plateau Growth and Climatic Consequences
09/01/05-08/31/06
$100,384

Intellectual merit: The Tibetan Plateau not only serves as the worldís best laboratory for studying intracontinental deformation, but also acts as the continentsí largest perturbation to atmospheric circulation. Accordingly, changes in the height or lateral extent of the plateau both should reflect deep-seated processes in the lithosphere and should affect climate. The proposed research will examine physical mechanisms that link geodynamic processes operating beneath the Tibetan Plateau since Late Miocene time to concurrent local and regional environmental changes. Geodynamic phenomena include folding of oceanic lithosphere south of the Indian subcontinent, the onset of accelerated deformation north of Tibet, and an outward growth of the plateau on its eastern and southeastern margins. Environmental changes include a strengthening of the Indian Monsoon, the aridification of regions both south and northeast of Tibet, and an increase in eolian deposition northeast of Tibet, and even to the North Pacific Ocean. Mechanisms that can link the geodynamic and environmental changes include an increase in the mean elevation of the plateau and an outward growth of it by flow of lower crust that rapidly expands the area of high topography.

Much of the plateau has been examined through multi-disciplinary studies supported by the NSFís Continental Dynamics Program, but a key area for understanding the links between these processes, Tibetís northeast margin, remains only cursorily studied. The proposed research will include focused studies (1) to determine when deformation occurred along the northeastern margin of Tibet and how much crustal shortening has occurred, (2) to date the initiation of erosion and river incision into high terrain and (3) to decipher when particular regions of high terrain began shedding debris to both nearby and distant basins, both of which will address when relief was created, (4) to map spatial and temporal patterns of environmental change, (5) to exploit geophysical data to discriminate among possible processes occurring within the crust and mantle, and (6) to understand how high topography affects regional atmospheric circulation, dust transport, and heat transport within the atmosphere. These studies will create an image of how northeastern Tibet has grown outward and how that growth has affected regional climate.
Broader Impacts: The interaction between tectonics (large-scale deformation of Earthís crust and upper mantle) and environmental change (especially climate) is emerging at the forefront of the earth sciences. Because of Tibetís role in both large-scale tectonics and as a perturbation to atmospheric circulation and climate, a knowledge of its history of growth and its impact on climate change contributes not only to the understanding of how crust and mantle interact in large-scale continental geodynamics, but also to modern atmospheric sciences through the forcing of climate by topography.

This work will bring together young scientists, who constitute the majority of the principal investigators, in a multidisciplinary study that includes sedimentary and structural geology, geochronology and geochemistry, paleoenvironmental study, solid-earth geophysics, and

atmospheric sciences. The forefront of modern science lies at the intersections of different disciplines, and graduate and undergraduate students will participate in this interaction first-hand. To demonstrate how such interactions occur and how multiple hypotheses can be addressed and discussed, a short (~15 minute) video aimed at high school students will be created. Finally, by close collaboration with Chinese geologists, this project will foster international collaboration, and with its graduate students and a majority of young principal investigators, this project will encourage the growth of interdisciplinary science.

Burbank
UC Lawrence Livermore National Laboratory
SB050041
Calibrating Erosion Rates in Rapidly Eroding Landscapes Using Cosmogenic Nuclides and Numerical Models
08/01/04-07/31/06
$35,704
This proposal aims to develop a collaboration among the Center for Accelerator Mass Spectrometry (CAMS) at LLNL and three departments and one research institute at UCSB. The collaboration will meld existing expertise and facilities at CAMS with numerical modeling, field expertise, and laboratory development at UCSB and will explore ways in which accelerator mass spectrometry can be applied to landscape development and in which landscape models can be applied to problems of interest to LLNL geochemists and climate modelers. The overall goals are two-fold: (i) to develop numerical models and test them with new field data in order to calibrate erosion rates in rapidly eroding terrain using cosmogenic radionuclides (CRNs); and (ii) to initiate the development of a CRN processing/preparation laboratory at UCSB. This lab and the involved faculty are expected to form the basis of a long-term collaboration between UCSB and LLNL in scientific projects related to landscape evolution and global change. LLNL scientist R. Finkel will act as a skilled advisor in planning and setting up the laboratory. Burbank, Dunne, Chadwick, and Niemi each are conducting research focused on erosion rates in mountainous terrains, where they utilize concentrations of cosmogenic radionuclides (CRNs) in sediments to measure erosion rates. In rapidly eroding mountains where landslides dominate erosional flux, traditional methods of assessing erosion rates with CRNs fail to compensate for stochastic variability in the sediment-delivery process due to landsliding. To investigate the impact of landslides and create an appropriate interpretive model and methodology, UCSB research scientist N. Niemi, along with Burbank, Dunne, and Chadwick, is developing a numerical model that uses a calibrated landslide “rule” to predict the temporal and spatial variability in landslide-induced sediment fluxes and CRNs. The support requested here will help further development of this model and enable model testing and calibration using measured CRN concentrations in key field samples. The result will be an exportable, calibrated model that will have widespread applicability to rapidly eroding ranges around the world. This collaboration will allow UCSB researchers to visit LLNL to learn about sample preparation and analytical techniques employed at LLNL, to assist in AMS runs, and to introduce new interpretive methods to members of CAMS and the Geochemistry Group at LLNL. In addition it will allow Finkel to make several trips to UCSB to learn more about erosion modeling, to aid in setting up a CRN preparation laboratory, and to interact with students interested in applying AMS techniques in their research.

Busby
Department of Interior

05HQAG0010
Geologic Mapping of the Central Sierran Frontal Fault System with Implications for the Tahoe Basin and the Carson-City Bridgeport Population Corridor
04/21/05-03/31/06
$29,246
This research will unravel the Neogene to Recent evolution of the Sierra Nevada—Basin and Range transition in the central Sierra Nevada. This segment of the Sierran range front lies within the Walker Lane, a complex system of dominantly right-lateral strike slip faults that accommodates ~20-25% of Pacific-North America plate motion. The range-front fault system in the central Sierra consists of a series of left stepping, *en echelon* escarpments, with focal plane mechanisms that suggest a major strike slip component on active normal faults. Field data from these active faults are notably lacking, however, and very little is known of the long-term history of slip on them. I propose a synergistic project involving a team of three Ph.D. students that will map Sierran range front faults between Carson Pass and Sonora Pass. In these projects, the students will map Sierran basement rocks, including plutonic and metamorphic rocks, to find kinematic indicators and distinctive features that can be used as piercing points across faults. They will divide previously undifferentiated Tertiary volcanic rocks by applying modern volcanic facies analysis and by mapping unconformity surfaces. Together with $^{40}Ar/^{39}Ar$ dating, this will allow the students to reconstruct the paleogeography and fault movement histories for Neogene time. They will map Quaternary deposits and, where appropriate, use GPS surveys to accurately measure active fault scarps and offset Quaternary features, such as streams, moraine crests and river terraces. They will become trained in digital mapping techniques using Hewlett Packard IPAQ unit with integrated GPS receivers and touch-sensitive screens for mapping geologic features onto geo-referenced base maps, including topographic maps, DOQQs and satellite images, using ARC GIS. The synergism of having three graduate students mapping and interpreting similar rocks and faults at the same time will be an enormous educational advantage.

Busby
National Science Foundation
EAR-1025779
Collaborative Research: Miocene Volcanism in the Sierra Nevada, California
03/01/2002-08/31/2005
$300,000
Volcanic and volcaniclastic rocks of the northern and central Sierra Nevada (California) represent a piece of the mid-Miocene volcanotectonic puzzle about which very little is known, relative to the rest of the western United States. This gap in our knowledge is crucial because the mid-Miocene was a time of fundamental tectonic change in the western United States (Atwater, 1970; Dickinson, 1997). This areally extensive "missing piece" of the mid-Miocene volcano tectonic puzzle is an important piece, because it lies in a tectonic setting that is transitional between subduction, Basin and Range, and hotspot settings. Recent work has suggested that a strong degree of coupling exists between the Pacific and North American plates, and that this regime was established in mid-Miocene time. However, none of the dozens of recent regional tectonic papers consider the role of Sierran mid-Miocene volcanism in tectonic reconstructions, probably because too little is known of the volcanology, geochronology and structure of these rocks. The Sierran volcanic rocks are also of great interest in a process volcanological sense, because they are dominated by voluminous, widespread breccias, at least some of which appear to have been fragmented in the vents prior to eruption (Curtis, 1954). No one has attempted to determine the volcanological origin of these rocks for the past half century. Furthermore, new geochronologic and

stratigraphic data from the Sierran breccias show that at least some of them are interstratified with a flood basalt that is the same age as the Columbia River Basalt group, referred to as the Lovejoy basalt (Wagner et al., 2000). Recent studies have documented similar enigmatic, voluminous breccias in flood basalts provinces of Greenland, Siberia, Africa and Antarctica. Can the volcanological origin of voluminous breccias be directly linked to flood basalt provinces, or do they represent a style of volcanism that can more generally be linked to extensional provinces, including extensional arcs?

We propose to establish a regional stratigraphic structural and geochronological framework for Miocene volcanic rocks of the northern to central Sierra Nevada, and at the same time reconstruct structural settings and volcanological processes. We will make detailed volcanic and sedimentary lithofacies maps, and use these to determine the nature and timing of synvolcanic faulting. We will use petrography, image analysis and Scanning Electron Microscope (SEM) imaging of the Sierran breccias to study and quantify clast and matrix types, morphologies, dimensions and fragmentation styles (brittle, ductile, transitional), and compare the results with published examples of volcanic breccias of all plausible origins. We will carry out preliminary geochemical analysis of representative suites by XRF (including all samples to be dated), and also compare compositions of clasts with matrices in the breccias. We will sample for $^{40}Ar/^{39}Ar$ age dating from stratigraphic successions containing at least three or four different datable units, to test for geological consistency in our age data, and analyze single mineral grains (total fusions) as well as performing incremental step heating experiments.

This work is divided into two areas. North of Lake Tahoe, we will target six recently-mapped quadrangles containing Lovejoy basalt, with the goal of making a tectonic reconstruction for Mid-Miocene time. South of Lake Tahoe, we propose to carry out a modern process volcanological study of voluminous breccias that were erupted from at least a dozen vents on the present-day Sierran crest, and flowed westward into the present-day foothills. Busby will coordinate the project, collaborating/supervising field studies in both areas with all other workers. Skilling will supervise a master's student's detailed study of vent-related breccias south of Lake Tahoe, co-supervise a postdoctoral fellow of Busby's, who will study proximal-to-distal variation in the breccias south of Lake Tahoe, and consult with Busby north of Tahoe. Gans will co-supervise a PhD student of Busby's who will work north of Lake Tahoe, and Gans will perform the $^{40}Ar/^{39}Ar$ analyses for the entire project.

Carlson
Archuleta
Pine
Israelachvili
Langer
W.M. Keck Foundation
19990997
The Interdisciplinary Program in Seismology and Materials Physics
09/01/1999-09/01/2004
$1,115,170
With a grant of $1,000,000 from the W.M. Keck Foundation the University of California, Santa Barbara will create the Interdisciplinary Program in Seismology and Materials Physics. The Program will blend UCSB's strengths in science and engineering by assembling a team of physicists, engineers, materials scientists, and geoscientists to address some of the most outstanding and overlapping problems that arise in seismology and materials physics today. Our unique approach connects fundamental progress in

understanding complex processes in materials - friction, fracture, deformation - with seismological applications. This field is poised for major advances due to recent breakthroughs in the theoretical and experimental understanding of materials, many stemming from UCSB in the areas of friction, fracture, and deformation, and the extraordinarily rapid, worldwide growth in computational capabilities. In addition to studying real geological materials, a major theme for this Program will be the study of analog processes in simpler, more controlled environments, and incorporation of the results of those investigations into numerical simulations of seismic phenomena. The Interdisciplinary Program in Seismology and Materials Physics will provide the foundation to develop physically based models for seismological applications centered on fundamental results from materials science and physics. Our goal is to develop new methodologies and through our visitors programs and the young people we train, extend these methodologies to the various regimes where simulations play a role in seismology.

Clark
University of Alaska, Fairbanks
UAF-05-0140
Survival of Methane in Rising Marine Bubble Plumes: Testing a Critical Assumption of the Clathrate Gun Hypothesis
03/01/05-02/28/06
$85,977
Marine sediments contain some of the world's largest reservoirs of methane, one of the most important greenhouse gases. These reservoirs include shallow gas hydrates that have both biogenic and thermogenic sources (Kvenvolden, 1993; 1995; Sassen et al., 1999; Buffett, 2000) and deeper hydrocarbon accumulations. Understanding the geological occurrence, geographical distribution, stability, and importance within the global carbon budget of gas hydrates has become the focus of many research initiatives and is a target objective of NURP. Because the global carbon cycle is an integral part of the global climate system, massive dissolution of gas hydrate deposits has been invoked to explain rapid climatic transitions that appear in the geologic record (Dickens et al., 1995; Katz et al., 1999; Kennett et al., 2000, 2003). This idea is commonly referred to as the Clathrate Gun Hypothesis.

Whether or not massive eruptions of gas hydrates can inject enough methane into the atmosphere to significantly warm the planet is controversial for a number of reasons including uncertainties associated with the transport process through the ocean. The Clathrate Gun Hypothesis assumes that the ocean is a passive system unable to take up, store, and oxidize the methane released at the seafloor. During the eruptions, the released methane must travel from the sediments to the ocean surface in large bubble plumes. Because the ocean contains very little methane, there is the potential for a significant fraction of the released methane to dissolve into the water column during its transit.

We propose to examine the dynamics of large bubble plumes in the marine environment to determine the fundamental controls governing the dissolution of rising methane bubbles. We will conduct our research with the Coal Oil Point hydrocarbon seep field, a natural laboratory for studying large bubble plumes in the shallow ocean. The total gas flux to the atmosphere from this field is about 150,000 m3 day-1 (Hornafius et al., 1999) and individual seeps emit as much as 7000 m3 day-1. Measurements collected at the sea surface and throughout the water column at one seep have demonstrated that large bubble plumes modify ocean chemistry and circulation (Leifer et al., 2000; Clark et al., 2003). These plumes create distinct columns of rising seawater and bubbles within the ambient ocean. Our hypothesis is that bubble plume processes enhance the amount of methane that survives the transit through the water column and,

thus, the Clathrate Gun Hypothesis assumption that the ocean is unable to take up and oxidize methane released at the seafloor during catastrophic events is valid. This research will examine the potential exchange of seawater between the rising bubble plume and the ambient ocean, a fundamental process that may increase the amount of methane that dissolves into the ocean during its transit through the water column. Earlier research on large marine bubble plumes has neglected to examine this process. Results from this research will compliment fields in addition to hydrate research such as the identification of seafloor vents of oil slicks from either anthropogenic (pipe line leaks) or natural origins.

Clark
Water District of Southern California
SB020079
San Gabriel Spreading Area Tracer Study and Rio Hondo-South Montebello Well#5 Tracer Study
01/01/02-12/31/05
$103,004

Clark
UC Riverside
W-962
Nature of Flow and Gas Dynamics Below Spreading Ponds
07/01/02-09/30/04
$56,000

I will be working collaboratively with Dr. Thomas Meixner (Dept. of Environmental Sciences, UC Riverside) on a project that will quantify the sources, fate, and transport of arsenic and selenium in the San Diego Creek Watershed, Orange County, CA. My role will be to collect and interpret chlorofluorocarbon (CFC) and tritium/He-3 data from the shallow groundwater. The CFC samples will be analyzed in my laboratory at UCSB and the tritium/He-3 samples will be sent to a non-UC laboratory for analysis. After determining apparent groundwater ages with these tracers, I will work with Dr. Meixner to integrate the CFC and tritium/He-3 data set with his arsenic and selenium data set.

Clark
Big Bear Area Regional Waste Water Agecy
01640
Big Bear Tracer Study
12/01/03-12/31/04
$23,821
The Big Bear Tracer Study is intended to directly determine groundwater transit times from the pilot spreading ponds to selected monitoring and production wells. It will be conducted in conjunction with Geoscience Support Services, Inc. and the Big Bear Area Regional Waste Water Agency as part of the Big Bear ground water replenishment study.

The specific goals of this study are:
I) Inject sulfur hexafluoride (SF_6) tracer and quantify its concentration in the pilot spreading ponds over a period of two weeks. SF_6, a non-toxic and non-reactive gas, is an ideal tracer of groundwater flow. It has been shown in laboratory experiments and in one field experiment conducted in Orange County, CA, that, in the absence of non-aqueous phases, its movement is not retarded in porous

media (Wilson and Mackay, 1993, 1996; Gamlin et al., 2001). It has been used as a tracer for mixing and gas exchange for decades in a number of setting including lakes, rivers, and the open ocean (Wanninkhof, 1985, 1987; Ledwell et al., 1986; Clark et al., 1994, 1996). More recently, SF_6 has been used successfully in four groundwater studies in California (Orange County, LA County, Ventura County and Lancaster) that traced the movement of artificially recharged water through ground water systems (Gamlin et al., 2001; Fram et al., 2003; Clark et al., 2004, Clark unpublished data). In all cases, permission was requested and granted by the Department of Health services to use SF_6 as a tracer in these potable supply aquifers.

There are a number of advantages of using SF_6 as a tracer of artificial recharge. First, SF_6 is more economical than most other tracers and, hence, more water can be tagged decreasing the probability of that the tracers will pass wells undetected. Second, it does not change the density of the tagged water, thus buoyancy effects do not complicate the interpretation of the experimental results (e.g. Istok and Humphrey, 1995). Third, SF_6 does not degrade the quality of the water; it causes no known adverse health effects (Lester and Greenberg, 1950). Forth, because it is a gas, SF_6 can be removed from water easily by aeration.

The disadvantage of using SF_6 is it is a gas and is lost from solution via gas exchange at the air-water interface. Hence, the concentration in the spreading area will be variable and difficult to predict. Furthermore, during the proposed experiment, the recharged water will flow for more than 60 ft through a Vadose zone prior to reaching the water table. It is possible that the majority of tracer could be lost from solution in this zone. However, results from the Orange County and Ventura County gas tracer experiments conducted at spreading ponds indicate that gas lost in the Vadose zone (beneath the pond) is small (Gamlin et al., 2001; Clark et al., 2004; Clark et al., unpublished data). Apparently in these settings, the majority of the recharged water passed through saturated parts of the Vadose zone to the water table.

The gas tracer will be carefully injected into each pilot spreading pond by bubbling near the water inlet pipe using an existing flow controller. The flow controller will be supplied to this project at no cost. The target concentration is 50 ng/l (~300 pmol/l; 1 pmol = 10^{-12} mol), approximately 100,000 times greater than the detection limit (0.007 ng/l or 0.05 pmol/l). Because of gas exchange at the air-water interface, we will collect and analyze surface water samples every few days during the course of the approximately two week injection period. Hence, we will empirically determine the initial concentration of SF_6 in the infiltrating water. Assuming a percolation rate of 0.5 ac-ft/day, SF_6 will be injected into approximately 7 ac-ft of recharge water at each site during the proposed experiments. We will complete the injection at the first spreading pond before starting at the second.

Groundwater samples will be collected in pre-weighed Vacutainer™ in triplicate by personnel from Geosiences and sent to UCSB for analysis. At the nearby monitoring wells, samples will be collected every 2 to 3 days for the first month of the experiment. Thereafter, samples will be collected weekly until tracer is no longer observed. At the production wells, groundwater samples will be collected monthly. Although the sampling frequency at the production wells is long compared to the injection period, we believe we will be able to resolve the tracer patch because of dispersion within the aquifer.

The first arrival of SF_6 represents transport along the "quickest" flow path. It does not represent the bulk groundwater flow or the mean travel time of the groundwater entering the well. The arrival of peak SF_6 concentrations at narrow screened monitoring wells is representative of the bulk groundwater flow assuming a homogenous aquifer. This is not the case for production wells that often draw (and mix) groundwater from a number of flowlines that have different travel times.

Clark
UC Davis
K011552-04
Stockton Deep Water Channel Tracer Experiment
06/01/05-06/30/06
$50,714

Clark
UC-IGPP
05-GS-024
The Importance of Groundwater Weathering in the Upper South Fork Kern River Catchment
10/01/04-09/30/05
$23,500
Chemical weathering of silicates consumes atmospheric CO_2, an important greenhouse gas, and releases ecologically important nutrients and trace elements. Most field studies have estimated chemical weathering rates using mass balance calculations of solute fluxes into and out of small watersheds. This method for calculating chemical weathering rates determines the total amount of weathering occurring within a basin without identifying the relative strengths of the different reservoirs such as the soil and shallow groundwater that contribute to the solute flux.

We are interested in understanding the relative contributions from the groundwater zone to the overall weathe order to determine this we need to know the rates of chemical weathering within groundwater and the "age" groundwater that feeds streams during baseflow. We developed a new approach for quantifying chemical weath the shallow groundwater in Sagehen Basin (Nevada County CA) using prior IGPP-LLNL support. Fundam mehod was the merging of solute mass balance calculations with geochemical groundwater dating tech determined that concentrations of the major cations increased with groundwater age (Rademacher et al. 2001). F calcium concentrations increased by more than a factor of three during the first 40 yrs of groundwater flow. Thi indicative of a chemically evolving groundwater system; water with longer residence times has more time to i the surrounding material and weather primary minerals. Additionally, we determined that baseflow in Sagehe composed of relatively old groundwater by comparing the geochemical fingerprint of the creek with the finge spring water which changed with groundwater age (Rademacher et al., 2004). Compositionally, the creek duri was most similar to springs that had geochemical ages of about 25 yrs. This surprising result indicates that a rel groundwater system exists in Sagehen Basin and that chemical weathering within the shallow ground significantly to the solute flux. Furthermore, it implies that stream solute chemistry should be partially determ size of the groundwater system. Streams emanating from larger basins with deeper sediments should c groundwater and therefore, these streams should have higher cation concentrations than streams from sm Additionally, the result indicates that there should be a significant lag between changes in stream chemistry a changes.

Using our geochemical field approach, we propose to determine chemical weathering rates in the groundwater zone of the Upper South Fork Kern River watershed (Inyo and Tulare Counties, CA). Our primary goals are 1) to determine if groundwater chemically evolves at similar rates throughout the Sierras and 2) to determine if relatively old groundwater supplies late summer baseflow elsewhere in the Sierras as it does in Sagehen basin. These results will add a perspective to the surprising Sagehen Basin results and should lead to a better model for the hydrochemistry of watersheds in the Sierra Nevada.

Gans
National Science Foundation
EAR-0230439
Neogene Evolution of the Sonoral Margin: The Transition from Backarc Extension
01/01/03-12/31/05
$360,347

Many of the fundamental processes that govern continental rifting and lead to rupturing of continental lithosphere and birth of an ocean remain poorly understood. The transtensional Gulf of California - Salton Trough represents a superb natural laboratory to explore these issues. It provides along-strike and across-strike views of the rifting process and records the transition from distributed continental extension in a backarc setting to final rupturing of the North American lithosphere and capture of Baja California by the Pacific Plate along the modern transform margin. Though much progress has been made in understanding the plate tectonic framework and modern strain field of this region, how this continental rift system evolved in space and time is still poorly understood. Our limited knowledge of how extensional and transcurrent strains are spatially and temporally distributed on the adjacent continental margins - particularly the Sonoran Margin, has made it difficult to adequately evaluate and test models for the kinematic and dynamic evolution of this rift.

This proposal requests funds to quantify the distribution, magnitude, timing, and style of Neogene deformation and magmatism across a portion of the Sonoran rifted margin in order to evaluate the kinematics of the transition from earlier (pre-12 Ma) distributed backarc extension to post-12 Ma transtensional deformation associated with the cessation of subduction and transfer of Baja California to the Pacific Plate. This is an ambitious multi-disciplinary study that will bring together scientists and students from the U.S. and Mexico in an attempt to unravel the history of extension and strike-slip faulting within a particularly well exposed but poorly understood rifted continental margin adjacent to the Gulf of California.

The principal tool to be employed is geologic mapping, as this is the only way to identify the important fault systems and to work out the details of local structural, volcanic, and sedimentary histories. Six investigators (3 senior personnel and 3 Ph.D. students) will devote up to two months/year in the field over a three year period with the goal of deciphering in detail the structural evolution of a 80 by 100 km area in southwestern Sonora, from the coast near Guaymas to the Sierra Mazatan metamorphic core east of Hermosillo. In addition, structural and stratigraphic studies will be carried out on two representative Neogene basins in eastern Sonora to assess whether significant late Miocene deformation affected areas further inboard. Approximately 60 new high-precision $^{40}Ar/^{39}Ar$ age determinations on key pre-, syn-, and post-tectonic volcanic units will be obtained to document local volcanic and sedimentation histories and to bracket the timing of structural events. K-feldspar $^{40}Ar/^{39}Ar$ multi-domain diffusion, apatite (U-Th)/He, and fission track analyses will be employed to determine low temperature cooling histories in the footwalls of large normal fault systems to assess extensional slip histories and to gain insight into erosion rates and thermal structure of the upper crust in the past. This evolving structural, stratigraphic, and geochronologic database will be

compiled and continuously updated in a GIS format and made available to the geologic community via the web. Some of the important questions to be addressed by our study include:

•How is strain distributed across the Sonora rifted margin? What are the magnitudes of extension and transform motions across this margin (a) prior to the cessation of subduction at this latitude (pre 12 Ma), (b) during early (12-6 Ma) transtensional deformation, and (c) after final rupturing of the lithosphere and opening of the Gulf of California (post 6 Ma).

•Do the observed strains magnitudes and strain histories on the Sonoran margin support the kinematic model of *Stock and Hodges* (1989), wherein Pacific-North America plate motions were initially partitioned between orthogonal extension inboard of Baja and strike slip deformation outboard of Baja California during "Proto-Gulf" transtensional deformation? Or do the observed strain histories on the Sonora margin suggest an earlier or more gradual transfer of Baja California to the Pacific Plate?

•Was the earlier backarc and intra-arc extension(e.g. *Gans*, 1997) continuous in space and time with younger (post 12 Ma) deformation associated with the change to a transform margin? What influence did the older extensional deformation have on the geometry and kinematics of the younger extensional and/or strike-slip deformation and are their fundamental differences in structural style and strain rate between the deformations that occurred in these two fundamentally different tectonic settings?

•Where was the locus of volcanism during the Neogene evolution of the Sonoran margin and how did its character change as the plate margin evolved from convergent to transform? What is the spatial and temporal relationship between Neogene magmatic activity and deformation?

•What was the character and timing of Neogene sedimentation on the Sonoran rifted margin (as recorded by widespread lacustrine and alluvial fan deposits) and how does this sedimentation relate to the structural evolution?

•Fundamentally, how does the deformational history of the Sonoran rifted margin relate to the geometry and kinematics of the evolving North America-Pacific plate boundary and what does this imply about the relative importance of plate boundary versus body forces as a driving mechanism for distributed continental deformation?

The greatly improved understanding of the Neogene pre-rupturing history of the Gulf of California region that will emerge as a direct consequence of our investigation of the Sonoran margin will place critical new constraints on models for the evolution of this continental rift.

Gans
Rio Tinto America Industrial Minerals
SB030073
Structural and Stratigraphic Setting of Borate Mineralization in the Eastern Rio Tinto
01/01/03-2/28/05
$40,919
Funds are requested to support an integrated field and geochronologic investigation of the eastern Calico Mountains with the aim of understanding the structural and stratigraphic setting of borate mineralization in the Old Borax deposit. This study will constitute the Masters Thesis research project for John Singleton, under the direction of Dr. Phil Gans at UCSB. The study will include:

(a) Detailed geologic mapping at a scale of ~ 1:10,000 of a ~7 square mile area in the eastern Calico Mountains, including the Old Borate deposit.
(b) Construction of restorable cross sections across the eastern Calico Mountains, illustrating the map scale structure and stratigraphy of this area.
(c) Construction of detailed stratigraphic columns of the Miocene sedimentary and volcanic section for different parts of the eastern Calico Mountains, illustrating variations in the character and thickness of different lithologic units.
(d) Detailed structural analysis of map and outcrop scale faults and folds in the eastern Calico Mountains, with a description of the geometry of various structures and an assessment of the sequence and kinematics of structural events. Specifically, structural data will be collected to document the deformational history of this region and to evaluate how much of this deformation is a consequence of extension and normal faulting vs. gravity sliding, vs. transpression or regional contraction.
(e) $^{40}Ar/^{39}Ar$ geochronology on any dateable units within the sedimentary and volcanic section that will better constrain the timing of sedimentation, volcanism, mineralization, and structural events in the range.

This evolving data base will be made continuously available to US Borax personnel as the study proceeds, and copies of the final masters thesis and any supplementary data will be provided to interested parties upon completion of the study by June of 2004.

Gans
Rio Tinto Exploration
SB060013
Miocene stratigraphy of the Gravel Hills-Mud Hills-northern Calicvo Mts., central Mojave Desert, CA
09/01/05-12/31/06
$40,825
Funds are requested to partially support an integrated field and geochronologic investigation of the sedimentation and tectonic history of the central Mojave aimed at reconstructing the stratigraphic architecture and structural deformation of the Miocene sedimentary basins north of the latitude of Barstow. This study will constitute the Ph.D. thesis for **Error! Contact not defined.**, under the direction of Dr. Phil Gans at UCSB. The study will include:

1) Detailed geologic mapping at a scale of 1:12,000 of critical regions in the central Mojave comprising a 70 km along-strike and 60 km across-strike transect of exposed Miocene sedimentary rocks.
2) Compilation of accurate stratigraphic sections from isolated ranges and reconstruction of the 3-dimensional stratigraphic architecture of the Miocene basin illustrating variations in the character and thickness of different lithologic units.
3) Stratigraphic analysis of paleocurrent and provenance data, and reconstruction of the paleogeography of the central Mojave.
4) Compilation of an extensive $^{40}Ar/^{39}Ar$ geochronologic database of sedimentary rocks across the region and construction of a temporal framework in which to place the stratigraphic architecture of the basin and evaluate the timing and distribution of lithofacies in time.
5) Final synthesis including a series of “time slices” maps illustrating relations between the tectonic history and the sedimentation of the region in time.

This evolving database will be made continuously available to Rio Tinto personnel for the duration of the research and copies of the final dissertation and any supplementary data will be provided to interested parties upon completion of the study in June of 2007.

Goetz
Navy
N6921803 IPA0001
Bioremediation and Microbiology Technical Support
10/01/02-10/30/05
$303,000
Biodegradation of petroleum contaminated soil and water. As follow-on to work previously conducted by the Navy, the contractor shall produce technical reports, presentations, and articles related to the remediation of petroleum-contaminated soils, water, and sludges. In addition, the contractor shall conduct studies on the fate and transport of hydrocarbons and hydrocarbon degradation products.

Solid Waste Management: Navy and Marine Corps solid waste reduction and recycling programs are ongoing efforts to divert solid waste. In coordination with facility personnel, NFESC is tasked with designing and implementing solid waste management programs and providing technical support during regulatory negotiations and oversight. The contractor shall support continuing efforts to reduce and treat solid waste through evaluation of operations and review of permit requirements.

As part of this effort, the contractor shall produce a chapter on composting for a Navy sponsored solid waste management practices (SWMP) guide. The guide will aid installations in reducing waste and waste management costs. The guide will discuss installation generated waste streams and discuss how to compost organic waste. The chapter will describe the science of composting, the benefits of composting, composting techniques composting equipment, test procedures, composting feed materials, composting standards, disposal of the finished product, vector and pathogen reduction, manpower requirements, composting references and web site information. The feasibility of composting on-site vs. other locations such as a local private or municipal composting facility should be compared. Pictures and diagrams shall be used to illustrate the chapter.

Long-term Monitoring and Maintenance Plan (LTMMP), Former Naval Air Station Barbers Point, Hawaii. The remedial investigation (RI) conducted in conjunction with the BRAC ordered closure of NAS Barbers Point included ~ 35 acres of land that the Navy has retained. The results of this investigation are summarized below. These results are relevant to the Long-Term Monitoring and Maintenance Plan (LTMMP) because contaminated soil from other areas of the base were excavated and used to cap the area known as the monofill. As a result, the Navy is required to monitor and maintain the landfill cap for thirty years.

The Navy used the monofill for the disposal of biosolids that were air-dried on-site. The biosolids contained diesel range hydrocarbons and there is some evidence that asbestos may have been disposed at this site. However, the bulk of the asbestos was probably disposed in the adjacent solid waste landfill. Even though sludge was been disposed at this site for more than 20 years, the RI did not detect hydrocarbons or elevated metals in the subsurface unconfined aquifer. Furthermore, the ground water is aerobic which suggests that little or no migration of organic matter has occurred over the intervening years. Small quantities of methane were detected in some soil gas samples. Since microbial degradation

of the methane occurs in the near surface aerobic soils, the concentration of vented methane is probably less than that detected in the soil gas samples.

As required by 40 CFR 503, sewage sludge disposed of at the monofill was analyzed quarterly. A review of the years 1993-1996 shows a few samples with low levels of toluene, ethylbenzene, and/or xylenes and none with benzene, PCBs or common chlorinated hydrocarbons including PCE, TCE, and chloroform. chlordane, dieldrin, DDE, and DDT were reported in 2-3 samples at ppb concentrations and PAHs (primarily; naphthalene, phenanthrene, fluorene, anthracene, pyrene) were often present either alone or in various combinations along with phthalate esters. These results are consistent with the soil gas analyses that detected only methane. Metals (primarily; Al, Zn, Hg, Cd, Cr, Cu, Pb, Ni, Ag) were present in most samples.

Since the RI indicates little or no migration of contaminants from any of four potentially problematic areas, the question becomes what are the appropriate monitoring requirements. The contractor shall work with NFESC and PWC Pearl Harbor to review applicable documents, identify appropriate analytical methods and design a realistic monitoring plan. Meetings with the PACDIV Remedial Action Contractor and Hawaii Department of Health (DOH) might be required to support the contractor's technical review and recommendations.

Biocorrosion. In collaboration with the Oceans Engineering Group at NFESC, the contractor shall investigate the role of microbial biofilms in the corrosion of metals. These studies shall be designed to determine if bacterial growth on metal surfaces in seawater enhances or retards corrosion and to what extent. The contractor shall produce a report documenting the findings of this investigation.

Environmental Forensics. The contractor shall work with the Technical Transfer Group in the Environmental Restoration Division at NFESC to develop methods for better determining the source and fate of environmental contaminants. The results shall be presented in a series of lectures in conjunction with the International Society for Environmental Forensics.

Hazardous Waste Treatment; Bioreactors. In collaboration with PWC Pearl Harbor (Code 300) NFESC is working to implement a biological treatment system for fuel tank residuals. Laboratory and pilot scale tests have shown that diluted oily wastes mixed with inorganic and organic nutrients stimulate rapid hydrocarbon degradation by bacteria already present in the waste. At PWC Pearl Harbor, an existing 10,000-gallon storage tank was converted to use as a sequencing bioreactor using off the shelf equipment and monitors to create a full-scale treatment system. The system is designed to operate as a zero-discharge system with clean effluent going to the sewage system or recycled through the bioreactor. Biomass that accumulates in the reactor is periodically harvested and composted at the PWC operated composting facility. Initially, the Navy will concentrate on treating fuel tank residuals. Once field tests are complete, additional waste streams could be added to include oily sludge from sewage lift stations, ship oily waste, used oil waste tank bottoms, and fuel tank bottoms.

Hacker
National Science Foundation
EAR-0215641
Collaborative Research: Thermal, Petrological, and Seismological Study of Subduction Zones
09/01/02-08/31/06

$130,126
We propose to continue our thermal–petrological–seismological study of subduction zones to attack some significant new issues:
1) The geometry and vigor of mantle-wedge convection represent a major source of uncertainty in modeling the thermal structure of subduction zones. To better understand the extent of hydration and the relationship between forearc mantle hydration and the depth of slab–wedge viscous coupling, we propose to ...
2) Expanding our phase diagrams—and hence automated rock properties calculations to metasomatized MORB will address how the variability of oceanic crust affects physical properties, dehydration, and, potentially, seismicity. We will incorporate the effects of fluid or melt-filled cracks or other porosity into our calculations, and deliver this improved mineral and rock properties spreadsheet to the community.
3) Further tests of the dehydration–seismicity hypothesis will be made by examining the petrological structure–seismicity patterns in more subduction zones—especially those with PT paths intermediate between the "hot" and "cold" endmembers—and by evaluating whether along-trench changes in seismicity along individual subduction zones vary in ways consistent with the dehydration–seismicity hypothesis. We will also determine whether peaks in seismicity and moment rate correlate better with areas of predicted dehydration or to changes in slab shape.
4) Testing the hypothesis that lower seismic zones are permitted by mantle dehydration...
5) Using full-waveform modeling coupled with the petrologic modeling, we will test a suite of realistic slab models against the observed dispersion curves.
6) Earthquake hypocenters provide key tests of the double seismic zone hypothesis, the hypothesis that the main zone is associated with hydrated mafic rock, and the notion that the forearc mantle wedge is aseismic. Specifically, it would be valuable to place constraints on the maximum/minimum possible width of a double seismic zone, on locations of dip changes, and to quantify the likelihood of any possible events lying within the mantle wedge.

Hacker
National Science Foundation
EAR-0003568
Collaborative Research: United States-China Scientific Cooperative Project
08/01/01-07/31/06
$276,114
The Sulu ultrahigh-pressure (UHP) metamorphic terrane in east-central China is part of the Sulu-Dabie-Hong'an-Qinling suture between the Sino-Korean and Yangtze cratons. Together the Sulu, Dabie and Hong'an terranes constitute the world's most extensive exposures of UHP rocks and have been identified as the primary Chinese research target for the next five years. We propose a multidisciplinary investigation of the Sulu UHP terrane in conjunction with the Chinese Continental Scientific Drilling Program (CCSD). Our objective is to understand the mechanisms and processes by which buoyant continental crust is subducted to depths exceeding 100 km and then exhumed, and to quantify the relationships of this process to continental collision. Reflection seismic profiling, structural geology, rare-earth-element geochemistry, geochronology, stable- and radiogenic isotope geochemistry, petrology and mineralogy—of surface rocks and core samples from the CCSD project—will be employed to test existing geodynamic hypotheses. We plan to build on our 10-year geochronological-petrological-structural study of the Dabie-Hong'an area by completing a parallel study in the Sulu region. Validated models of UHP tectonics and continental collision will be built upon the foundations provided by this and previous work.

It is an accepted tenet of geology that very low T at high P constitutes a "forbidden zone" never realized in the Earth— all exposed rocks appear to have experienced geothermal gradients hotter than 5–10°C/km. In the Sulu-Dabie terrane, however, we have recently discovered ultramafic rocks from the forbidden zone. These rocks must have formed in a cold subduction zone and constitute important recyclers of H2O into the mantle. Recent UHP experiments reveal that numerous hydrous phases are stable in the forbidden zone; some occur in the Chinese UHP rocks. Garnet peridotites with an upper mantle signature are rather abundant in the Sulu region and are a major target of the CCSD project. They provide not only a wealth of information on the physical and chemical characteristics of the lithospheric mantle, but also provide valuable insight into the dynamics of crust/mantle interaction during continental subduction, during collisional orogenesis, and within the forbidden zone.

The key questions we expect to answer are:
(1) What crust-mantle interaction processes take place when continental material is subducted to great depths, and how do such processes affect crustal growth and global geochemical recycling? Can state-of-the-art analytical tools determine the age of fluid/rock interactions?
(2) What new constraints on petrotectonic processes do UHP garnet peridotites of the mantle wedge provide? How were such peridotites emplaced into the crust during subduction, and how did they evolve during exhumation?
(3) What are the implications of UHP metamorphism at forbidden-zone P-T conditions and what roles do hydrous phases in the cold subducting slab play in the recycling of volatiles into the Earth's mantle?
(4) How do we differentiate the subduction/collisional architecture of orogens from the effects of younger events using present-day deep-seismic profiles?
(5) What exhumation mechanisms and rates of ascent prevent UHP mineral assemblages from being completely obliterated by metamorphic overprinting and/or partial melting?
(6) In what tectonic settings are the generation and exhumation of UHP rocks possible? Is continental collision required?

Our proposed U.S.-China–Japan–France–Germany–UK cooperative project will establish fruitful scientific exchange among international researchers. We will obtain essential seismic, structural, petrochemical, mineralogical, and geochronological data that address the questions enumerated above. It is important that this project begin soon to take advantage of the ICDP Donghai drilling project started in 2000. We have already begun exchanges with our CAGS colleagues, and limited research on core samples recovered from the pre-pilot holes has commenced.

Hacker
Woods Hole Oceanographic Institution
A100169
Contraints on the Genesis of Continental Crust via Arc Magmatism: Geology
08/01/00-01/31/06
$298,325
This proposal is for a multi-year, interdisciplinary study of the exposed crustal section of the Talkeetna island arc to address the rate and mechanism of continental growth at convergent margins. The Talkeetna arc section, particularly in the Nelchina-Tonsina region, is a crustal section through an accreted, Jurassic subduction-related magmatic arc, from volcanic, volcaniclastic and sedimentary rocks at the top to residual mantle peridotites at the base. Detailed studies of exposed, island arc sections can provide a

crucial link between geophysical observations and geochemical studies of volcanic rocks in active arcs. In the same way that ophiolite studies have provided an ideal counterpoint to both marine geophysics and analysis of mid-ocean ridge basalts in developing a complete picture of crustal accretion at oceanic spreading ridges, studies of arc sections will be essential to progress in understanding arc magmatism and crustal genesis over the coming decade.

Our study addresses a key question regarding arc processes: What is the rate and mechanism of continental growth at convergent margins? Arc crust is basaltic. Continental crust is formed mainly in arcs. Continental crust is andesitic. How can these three ideas be reconciled? Clearly, although each of these points is open to question, research funded by this grant will mainly address the first one. However, in our proposed study we will also determine compositional layering of the arc crust, and constrain proposed scenarios for lower crustal delamination during and after arc magmatism. Most importantly, work on the Talkeetna section can provide crucial constraints on the composition and timing of accretion of the middle and lower arc crust, which are generally not exposed in active arcs. Evidence from rare plutonic exposures in the Aleutian and Izu Bonin arcs indicates that different processes or different primary magmas may produce intrusive and extrusive rocks, so that inversion of volcanic rock compositions is not sufficient to determine the bulk crustal composition, nor the nature of primary melts passing from the mantle into the lower crust.

In our proposed study, we will address various aspects of crustal genesis in a practical way, applying a variety of analytical techniques. Our research goals are to (1) make an improved geological map and use a fully two -dimensional approach to better constrain the relative proportions of the different rock types in the Talkeetna arc crustal section; (2) determine the deformation history of lower crustal rocks, identify and date faults along which section may be missing or repeated, , make thermobarometric estimates from mineral compositions, and thereby better constrain how much of the section is missing and how to interpolate the data for the rocks that are exposed; (3) make extensive measurements of physical properties of rock samples for comparison with the growing database on seismic refraction and reflection in arcs; (4) conduct detailed investigations of residual mantle harzburgites and igneous ultramafic rocks just below the base of the gabbroic crust in order to determine the mode of melt transport from the mantle into the crust, and determine the relative importance of ultramafic “cumulates”; (5) conduct major trace and isotopic analysis on a comprehensive suite of samples from all the igneous rocks in the section, together with extensive new geochronology studies, to delineate how many liquid lines of descent are represented in the arc crustal section, and which are most volumetrically important; (6) use petrological and trace element modeling techniques to quantify the possible proportions of different rock types, for comparison with the proportions of rock compositions determined by geologic mapping, providing a further constraint on the bulk composition of the arc crust; and (7) to look at the P-T-t history of the lower crust, in order to constrain Moho temperatures in active arcs, and to provide constraints on the density and viscosity of arc lower crust during and after magmatism.

Hacker
National Science Foundation
EAR-0309995
Collaborative Research: Direct Observation of Depth Variation in Fault Zone ...
01/15/04-12/31/06
$116,316

Intellectual Merit of the Proposed Activity: The relationship between earthquake mechanics and fault-zone structure is one of the most fundamental unresolved issues in earthquake science. It remains unclear whether seismic ruptures always occur on a well defined planar structure or whether the complexity observed

in exhumed fault zones plays an important role in the nucleation and propagation of earthquakes. Stated another way, is earthquake mechanics fundamentally a problem in granular mechanics, or should it be viewed primarily in terms of frictional sliding along a single slip surface? These issues are critical for the question of scaling laboratory experiments to the natural faulting environment. A related issue is the role of fault-zone structure in the long- and short-term transport of fault-zone fluids, and their role in the faulting process. Although much has been learned about these issues from structural studies of exhumed examples, seismic studies of active fault zones, and laboratory studies of the mechanics of earthquake nucleation, this overall set of issues has proven to be extremely difficult to address in a systematic fashion on a single fault. This proposal seeks to exploit a unique example of a major strike-slip fault that has been tilted during exhumation, such that a continuum of exhumation levels—from the near-surface down into the lower crust—are now exposed along strike. Moreover, this fault (the Miocene Salzach-Ennstal-Mariazell-Puchberg [SEMP] fault zone in Austria) has participated in its own exhumation to a limited extent, reducing potential structural overprints related to younger faulting.

Objectives and methods: The proposed research will characterize the geometry and internal structural architecture of the SEMP fault zone throughout the entire depth range of the seismogenic crust, with a focus on the recognition of depth-dependent changes in fault-zone structure. Field studies will focus on structural transects across the SEMP fault zone at exhumation levels ranging from the near-surface at the eastern end of the fault (Vienna pull-apart basin), within the seismogenic crust (central Austria), and down into the ductile lower crust exposed in the Tauern window of western Austria. In addition to detailed field mapping of structural fabrics, fluid-rock interactions, relative timingrelationships, and variations in fault geometry, the proposed research will include detailed analysis of fault-zone rocks designed to explore deformation at a wide range of scales using petrographic microscopy, cathodoluminescence microscopy, fluid-inclusion studies, scanning electron microscopy, and transmission/analytical electron microscopy.

Broader Impacts: At least one graduate student and one undergraduate will be actively engaged in the proposed research, which should give them many of the tools they need to be productive researchers. The teaching abilities of the graduate student should improve as a result of interaction with the undergraduate, and through teaching assistantships they will have during the 1-2 years of their PhD studies for which they are not supported by this project. The project will enhance the infrastructure for research at USC and UCSB through the continued use of existing facilities, which always leads to improvement. Research at allied institutions will benefit from the networks and partnerships constructed among the senior researchers and the students (e. g., our active collaboration with Professor Lothar Ratschbacher and his students at the University of Freiberg in Germany). The results of the project will be disseminated through peer-reviewed earthscience journals and formal presentations at the GSA and AGU national conventions and joint AGU-EGS-EUG meetings in Europe.

Kneller
British Gas PLC
SB030076
Three Dimensional Heterogeneity of Submarine Channel-Levee Systems: Lithofacies
01/01/03-12/31/04
$44,000
BHP-Billiton Petroleum
SB020105
Three Dimensional Heterogeneity of Submarine Channel-Levee Systems: Lithofacies
01/01/02-12/31/04
$66,000

CONOCO
SB020122
Three Dimensional Heterogeneity of Submarine Channel-Levee Systems: Lithofacies
06/01/01-07/31/04
$66,000
Interpretation of channel systems and mass transport complexes in seismic data from the Gulf of Mexico.

The principal objective of the contract is to develop a long-term mutually beneficial relationship with the PI. In the process, we may be creating a center of excellence in sediment gravity flow process understanding at Santa Barbara. An additional objective is to enable individuals from BHPBilliton to join the PI at Santa Barbara, or in the field. This should be of benefit to both BHPBilliton and the research program.

The PI will share the results from the first year of two consortium studies starting 2001 at Santa Barbara as described separately. BHPBilliton will provide access to at least one of the 3D seismic surveys in the Western Atwater Fold Belt of the Gulf of Mexico, and the PI will provide a full description of the Plio-Pleistocene depositional system architectural elements (geometry, scale and internal structure) and post-depositional modification by gravity failure (geometry, scale). The above should be integrated into a geological model. To facilitate this work, the PI will spend six weeks in BHPBilliton's offices in Houston during the calendar year 2002. In addition, he will join BHPBilliton on a 10 day field workshop to the Karoo, South Africa.

Kneller
BHP-Billiton Petroleum
SB020104
The Impact of Mass Transport Complexes on Turbidite Hydrocarbon reservoirs
01/01/02-12/31/04
$66,000
The three-year study will use a combination of outcrop studies (in a context of existing outcrop work, and published sea-floor studies on modern systems), seismic and well data to assess links between the geometry, volume and emplacement style of the mass flow deposits themselves, and to assess their potential produceability as well as barrier risk; and also to assess and quantify the effects of such mass-flow-generated submarine relief on the geometry of overlying or interstratified sands. The relationship between sand body geometry and MTC's will be resolved using outcrop studies and, where available, high-resolution seismic.
The principal outcrop areas will be the Carboniferous Jejenes Formation in San Juan province, Argentina, The Eocene La Jolla Group of Southern California, the Eocene Hecho Group of northern Spain, and the late Cretaceous Rosario Group of Baja California, Mexico. Fieldwork will be carried out using a four-wheel-drive vehicle. Where sponsors are able to release 3D shallow seismic data, these will be studied on the workstation at UCSB to provide constraints on large scale 3D geometries. The work will be carried out by the senior PI, with field assistants and/or postgraduate or post-doctoral researchers as circumstances permit.

The project will be administered from UCSB. Project management will be by liaison committee, formed of at least one member from each of the sponsor companies, and the PI; it will meet at Santa Barbara or a field locality at least once a year

Output would be in the form of: dimensional data for component lithofacies of MTC's from outcrop and core (where available); models relating fluid flow characteristics to lithofacies properties; dimensional data for the mass flows; dimensional data for associated ponded sands; outcrop and subsurface system case studies; general process and architecture models for reservoir facies associated with MTC's.

Kneller
University of Leeds
SB020081
Turbidites Research-Continuation
08/01/02-07/31/04
$112,473
In collaboration with Dr. W. D. McCaffrey at Leeds University on Phase 3 of the Turbidites Research Industrial Consortium I will conduct investigations into the properties and deposits of turbidity currents, and the applications of these studies to hydrocarbon reservoir prediction in the subsurface.

Keller
Clark
UC Energy Institute
SB040034
Hydrocarbon Emissions from Natural Seeps: Ventura County, California with implications for air pollution
07/01/03-06/30/05
$37,356
Hydrocarbons, including oil, tar, and methane, are emitted naturally at the surface at numerous locations (seeps) around the world, often near known oil fields. Recently, workers studying the emissions of methane from near shore sediments below the Santa Barbara Channel have determined that methane emissions from these seeps are greater than the hydrocarbons emitted from all vehicles in Santa Barbara County. Worldwide, hydrocarbons are of significant concern because they contribute to air pollution and photochemical smog, and methane is a greenhouse gas that contributes to global warming. Although estimates have been made of the volume of methane emitted from underwater seeps, few have been made from seeps on land, and little is know about the possible reduction of natural hydrocarbon emissions due to pumping of oil from wells. This research seeks to fill this gap in knowledge.

Luyendyk
National Science Foundation
OPP-0088143
Collaborative Research: Antarctic Cretaceous-Cenozoic Climate, Glaciation
09/15/01-08/31/05
$470,720 and $7,500 REU supplement and Workshop $5,675
The Ross Embayment, including the Ross Sea rift, separates East and West Antarctica today. The Ross Sea rift and western Marie Byrd Land (wMBL) are part of the West Antarctic rift system. It is widely accepted that this region is undergoing active deformation, but the rates and causes of deformation are essentially unknown. Crustal motions may be occurring across the Ross Sea rift today. Crustal uplift could be occurring in wMBL due to isostatic rebound following the last glacial age. If tectonic motion is occurring in the Embayment this could greatly influence global plate circuit calculations. Post glacial rebound in wMBL would depend on the configuration of the ice sheet during the Last Glacial Maximum

and when this occurred. The main question is whether or not the ice sheet collapsed in mid-Holocene time.

In December 1998 we installed three continuous and autonomous GPS stations on outcrops in wMBL, in the Rockefeller, Phillips, and Clark Mountains. Results from three years of data collection indicate essentially no extension between McMurdo station (MBL4) and the network. The results show an overall length rate of –0.7±3.5 mm/yr between MCM4 and the wMBL network. With additional years of measurements we should be able to discriminate whether this rate is near zero or not to about 1 mm/yr. We also expect to detect strain gradients within wMBL. The network also suggests a dome of uplift centered near the Rockefeller Mountains, with the maximum rate being in the Rockefeller Mountains of 12±8 mm/yr. This is consistent with proposed post-glacial rebound for the region. With over seven years of data we expect to determine crustal strain rates to an accuracy of one mm/yr horizontal and 2 mm/yr vertical. The strain data from wMBL and the Transantarctic Mountains will enable us to construct models for tectonic extension and glacial rebound in the West Antarctic rift.

We propose to continue operation of the three stations in wMBL for another four year period. These stations will be upgraded with modern receivers and satellite data downloading when such downloading becomes feasible. We will add an additional continuous station during the 2002/2003 season in the Transantarctic Mountains near the South Pole on Mount Howe. We will install a second new continuous station at Mount Coates in the Transantarctic Mountains 2003/2004 season at the location of the previously operational continuous station. This will create a network that is geometrically ideal for understanding the orientation of maximum extension across the Ross Embayment and will clarify the pattern of postglacial rebound. Should Mount Coates be re-established by Carol Raymond we will install that station at another location in the Transantarctic Mountains.

This project is collaborative with other geodetic investigations in Antarctica and we will freely share our data. This includes networks led by Carol Raymond of JPL-Caltech in the Transantarctic Mountains, the WAGN (Marie Byrd Land) project led by Ian Dalziel, at University of Texas at Austin, and the Transantarctic GPS project led by Larry Hothem of the USGS. We will also collaborate with Erik Ivins at JPL, who is an expert on postglacial rebound. Our team brings together experts in wMBL geology and tectonics, tectonic geodesy, and lithospheric deformation.

Niemi
National Science Foundation
EAR-0310252
Paleotopography of an Evolving Extensional Orogen, the Central Basin and Range
10/01/03-09/30/06
$126,490
This project is designed to look at the topographic evolution of a portion of the central Basin and Range in the western United States during a period of late Cenozoic extensional tectonism. A variety of paleoaltimeters, geologic studies, and geophysical models have alternately predicted that the western United States has experienced either significant late Cenozoic uplift or substantial late Cenozoic lowering due to, or at least synchronous with, large magnitude intracontinental tectonism. In part these disparate results may be due to the geologic complexity of the western United States, and the fact that many of the study areas may have undergone differing tectonic histories in late Cenozoic time. The central Basin and Range province, between

Las Vegas and the Sierra Nevada is an ideal locality to study the paleotopographic evolution of the western United States because of 1) the wide spread and detailed geologic mapping that has been completed, resulting in a fairly complete palinspastic reconstruction of Tertiary extension; 2) recent passive and active seismic and other geophysical experiments in the region which delinieate the crustal structure and 3) studies that have examined the evolution of the sub-Basin and Range lithosphere through this same time period using xenoliths and the geochemistry of volcanic rocks. A newly developed paleoaltimeter based on basalt flow vesicles is well suited for approaching this problem due to the extensive coverage of basalts in this study area, the broad age range of the flows, and the desert environment which keeps them relatively fresh. We propose to sample approximately 40 sites for paleoaltimetry across a 300 km transect from the Sierra Nevada to the Spring Mountains, Nevada and determine the paleoelevations of these sites from late Miocene to Pliocene or Recent time.

This study has broad impacts for several reasons; first it bears strongly on the hypothesis that late Cenozoic epierogeny has affected climate, both in the United States and globally. The work also ties together years of work in developing map view palinspastic reconstructions of Basin and Range extension by adding a third dimension to the deformation, and finally, this study will be the first broad tectonic study using the newly developed altimeter. Collaborations with both the developers of the altimeter and the analytical facilities which process the samples should result in a stream lined process for future use of this altimeter, as well as testing and demonstrating its use in tectonic studies.

Olsen
University of California Los Alamos National Laboratory
SBB-014A
Fully Non-Linear Inversion of Dynamic Earthquake Rupture Propagation
11/01/02-10/31/05
$94,093

Numerical simulation codes (*Olsen et al.*, 2002) are now sufficiently sophisticated to estimate ground motions in large urban areas by including large-scale, state-of-the-art three-dimensional models of sedimentary basins (*Olsen et al.*, 1995) using high-performance computing. However, a limiting factor in the accuracy of the predicted ground motions, even for the low frequencies, is accurate knowledge about the complexity of earthquake rupture. *Olsen et al.* (1997) showed that inclusion of the heterogeneity in rupture propagation is critical for accurate prediction of the resulting ground motion around the fault which is an important part of seismic hazard assessments. Another critical research area where accurate knowledge of rupture parameters is essential, earthquake prediction, is maybe the most important of them all. If we can further our understanding of the conditions under which earthquakes initiate, propagate, and arrest, as well as their variations in stress and friction, we may be able to predict the occurrence of future damaging events and thereby mitigate the loss of lives and property.

The conventional procedure to infer information about the rupture history of large earthquakes is a linear inversion for the slip history on the fault by matching recorded and synthetic accelerograms (*Wald and Heaton*, 1994). Such inversion has traditionally been carried out kinematically, which has some important limitations, in particular unphysical constraints on the rupture velocity and omitting dynamic rupture effects from the normal-stress interaction with the free surface. For example, the latter effects can play a significant role for earthquakes on shallow faults or ruptures breaking the surface (*Oglesby et al.*,

1998; *Gottschammer and Olsen*, 2001), including earlier arrival times caused by super-shear rupture velocities and an increase of peak horizontal motions by up to about a factor of three. Therefore, when ignoring the dynamics, slip inversion may produce biased information about the rupture.

A more physically correct inversion would therefore take into account the dynamics of the rupture, i.e., the stress, strength, and friction parameters. However, such inversion is highly complicated due to the strong nonlinearity of the dynamic problem, as demonstrated by *Peyrat et al.* (2001) who inverted for the dynamic rupture history of the 1992 M7.3 Landers, California, earthquake using a trial-and-error method. The results by *Peyrat et al.* (2001) showed that the radiated waves are highly sensitive to the distribution of stress and friction parameters on the fault, an essential requirement for the inversion to work. Here, we attempt to carry results by *Peyrat et al.* (2001) to a new level using a fully systematic, nonlinear inversion method.

Olsen
National Science Foundation
EAR-0113377
ITR/IM/AP: Websim 3D - A Web-Based System for Generation, Storage, and dissemination of earthquake ground motion simulations
04/15/02-03/31/06
$142,055
We plan to continue the work on improving 'websims'. We are in the process of extending the php software to allow for cross plot of synthetics from different scenarios at the same site. This will allow for comparisons of results from different codes and rupture scenarios, and thereby the possibility of checking for errors, accuracy, and assessing scenario-specific differences. This extension will be used for both ground motion waveforms and fault time histories, such as sliprate/slip/stress histories on the fault. The latter will be particularly useful for two projects within SCEC: 1) the dynamic code validation exercise and 2) the SCEC Reference Earthquake project. Both projects will benefit from user-friendly (cross-)plot and comparison of time histories, generated by different rupture models or different modeling groups. Moreover, the extension will be able to contour scalar fields such as rupture times on the fault and peak motions on the ground, via MATLAB's web services toolbox. We also plan to add an interactive upload form for users to deposit simulation results, and generate plot and printouts of the comparisons.

Polet
Department of Interior
05HQGR0003
Installation and Further Development of a Fully Automated Global Centroid Moment Tensor Code at the National Earthquake Information Center
12/01/04-09/30/06
$98,292
We propose to install the autoCMT software, which computes fully automated global Centroid Moment Tensors and has been operating successfully at Caltech but will cease to be supported there in May 2004, at the National Earthquake Information Center in consultation with Dr. Paul Earle. For the past decade, this system has provided a valuable service as one of the few, if not only, providers of completely automatic reliable CMT solutions for worldwide events greater than a magnitude 5.5. We propose further improvements that will result in a more efficient, more reliable and faster system to deliver completely automatic CMT solutions for worldwide large earthquakes.

The existing systems at the NEIC either do not run fully automatically, do not determine a centroid time or location and/or are less suited for great earthquakes, because of their reliance on short period body waves, in contrast to the very long period surface waves used by the autoCMT. Thus the autoCMT system fulfills an important need at the NEIC and should be considered complimentary in nature to existing methods. The long period nature of the seismic waveform data the process uses as its input has the additional advantage that the method is relatively insensitive to the effects of timing errors, mislocation, and lateral heterogeneity. Through numerical and visual comparisons with existing methods, we show that the autoCMT determines reliable moment magnitude estimates and mechanisms, and performs particularly well for events greater than 7.0. It is especially notable that this fully automatic method performs equally well as its human reviewed counterparts for most large events, even with its input minimum of only 12 waveforms.

In consultation with Dr. Paul Earle and other personnel at the NEIC, we propose to further develop and implement our existing software and integrate it with routine NEIC operations. The proposed improvements to the system include: faster triggering, data access and processing; enhancing the readability and documentation of the code to facilitate its use and possible future modifications; adding a clear quality assessment of the solution and the addition to the code of improved data quality control of the waveform data, both prior to the CMT inversion as well through an iterative set of subsequent inversions.

This system represents an important improvement of rapid global large earthquake source and location characterization at the NEIC. It will deliver near real-time and accurate post-earthquake information on the likely impact of the earthquake, due to its size and location, the likelihood of surface rupture, its possible directivity (from the relative location of hypocenter and centroid location) and tsunamigenic potential (from the centroid time). The autoCMT solutions also have a valuable use as a near real-time starting point for full finite fault rupture inversions and strong ground motion predictions of great earthquakes and currently performs this function for Chen Ji's software at the NEIC.

Porter
Massachusetts Institute of Technology
5710001790
Dynamical change in global biogeochemical cycles accompanying early animal evolution
09/01/04-08/31/05
$56,484
Susannah Porter will be responsible for providing paleontological data and access to rock and fossil specimens from the mid-Neoproterozoic Chuar Group, western North America. Specifically, she will provide 1) rock samples for biomarker analyses; 2) ten to twenty algal microfossils from each of ~30 samples for microchemical investigations; and 3) paleontological data, including estimates of abundance and diversity along a paleoeonvironmental gradient, and SEM and TEM studies of microfossil structure. Rock samples will be obtained both from collections of Chuar rocks currently housed at UCSB, and from a collecting trip conducted during Year 1. Shale samples will be processed by a palynological preparatory laboratory and in Porter's lab, and algal microfossils picked using a dissecting microscope. Paleontological data will be obtained using light microscopy, SEM, and TEM. Porter's lab has state-of-

the-art light and dissecting microscopes; UCSB houses both SEM and TEM facilities. (Note: Porter has a proposal pending that in part supports paleontological analyses of Chuar Group microfossils. If that proposal is funded, the budget for this work will be revi

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Prothero
National Science Foundation
DUE-0231414
Collaborative Research: Moving Data Based Inquiry Learning to the Internet
01/01/03-12/31/05
$438,848
The over-arching goal of this project is to increase science literacy of general education learners who may not become scientists. The specific goal of this project is to create a well-researched oceanography course, live and online, widely disseminated, with a modern inquiry based pedagogy. The design focuses on science literacy using real earth data, collaboration between learners, and a strong connection to societal issues.

The project is based on a successful NSF CCLI pilot project that supported the creation of software and course materials that enables online auto-graded homework assignments, scientific writing activities, on demand grade calculation, and peer interaction, with powerful instructor assessment capability. It has been tested, refined, and evaluated in 2 live oceanography classes at UCSB. New capability will be created to support the fully online course with collaborative projects with strong peer to peer interactions. It will be first implemented in Spring 2003.

An instructor team has been assembled. The team consists of faculty representing 4 California community colleges, 2 California state colleges, 2 large state universities (not including UCSB), and a small private college. Yearly workshops are planned to support team collaboration and dissemination of technology and pedagogy.

Major themes are integration of technology in education and faculty development. We also expect to have an indirect impact on teacher education and diversity through the composition of the project team, some of whom have been active in teacher preparation and/or teach at campuses with a diverse student population.

Sorlien
National Science Foundation
OCE-0327273
Collaborative Research: Basin Evolution Along Continental Transforms: Nested Hi-resolution Multichannel Survey in the Marmara Sea
03/01/04-02/28/07
$69,972
Basins form along continental transform faults. Strike-slip faults are carefully balanced with fault direction and fault slip parallel. Thus they are susceptible to changes in kinematics and fault orientation and can easily develop zones of compression or extension. Strike-slip faults are characterized by motion parallel to their strikes, so that changes in kinematics and fault orientation result in zones of compression or extension. Extensional basins along transforms form at different scales and levels of complexity. The largest systems can be made up of multiple basins. Under finite strain, these basins the stress field

changes and these basin must evolve. Do continental transform basins evolve from a broad, diffuse zone towards a single-throughgoing fault? Do they become more complex, or is complexity a stable characteristic? On what time scale does this occur, and what is driving this evolution?. For example, are space problems at fault bends solved by changes in slip on a single fault, or, does slip partition so that pure strike-slip motion occurs through bends with space problems solved by subparallel normal or reverse faults?

We propose to study basin formation in Marmara Sea along the North Anatolia fault system. There are a number of reasons why the 75 x 200 km basin Marmara Sea is the best place to study transform basin formation and the evolution of a continental transform fault. These reasons include the fact that most of the system is covered by water allowing high quality MCS data to be rapidly acquired, yet is surrounded by outcrop and it also contains islands. The deformation rates along the North Anatolian fault in Marmara Sea are high, and, the system may have initiated in late Miocene or later, so evolution of the system is rapid. There has been a lot of international interest in the area since the devastating and deadly 1999 earthquakes, resulting in a lot of abundant available data, complementary to what we propose.
We propose to acquire of a nested grid of high-resolution MCS and gravity data, and integrate these data with existing and planned data. This work will be undertaken in collaboration with scientists from MTA, Istanbul Technical University and the Marmara Research Center in Turkey, the Istituto di Geologia Marina in Bologna, Italy, as well as a scientist from Greece. The ongoing research on the Marmara Sea has included collection of collected swath bathymetry, coring and a range of shallow seismics that image the near-surface deformation from the present-day kinematics. Recent deep-penetration reflection and OBS refraction seismic are imaging the crustal structure and Moho. What is missing from the Marmara Sea is a stratigraphic framework that can enable the tectonic evolution of the Marmara Sea to be unraveled. Existing moderate resolution MTA and older industry MCS data provide a groundwork, but have insufficient coverage and resolution to answer questions about the basin evolution.

We will collect high-resolution MCS data during a 35-day leg on the *R/V Maurice Ewing* using a pair of GI guns and a 96-channel 1200-m streamer to obtain images of the strata in the upper 2-3 km with 3-5 m resolution. During the first part of the cruise we will collect a 5x7.5 km grid of high resolution MCS data over the entire Marmara. Our aim is to develop a stratigraphic framework that will allow us to correlate sequences between basin and develop a relative temporal framework. During the second part of the cruise, we will collect several closely-spaced (1x2 km) grids of critical regions in order to elucidate the tectonic history of the Marmara Sea and its implications for the evolution of strike-slip basin systems. These grids will detail the stratigraphic record of deformation and fault motion at crucial bends and junctures in the fault system. Onboard processing will enable us to adjust our track based on survey results. The results of this cruise will be integrated with the other ongoing efforts at different spatial scales to help develop a coherent model the of the formation and evolution of the Marmara Sea.
Intellectual Merit. This project will result in a better understanding of the evolution of strike-slip basins. We will investigate how basins and uplifts are related to different classes of master-fault structures, such as jogs or bends. Our strategy is to study the Marmara Sea basins through their evolution and thus reveal how they have responded to known external factors. Systematic differences between short and log-term structure may reflect changes in the effects of tectonic stress, gravity, and sediment load during the growth of the basin, providing insight in the into the mechanisms that control .strike-slip basin development.
Broader Impacts. The city of Istanbul, with more than 12m people and a majority of buildings constructed without complience to building codes is more likely than not to experience strong shaking

from a large earthquake in the Marmara Sea during the next 30 years. Thus hazard, exposure, and vulnerability are all unusually high and the resulting risk is huge and a major challenge. An interdisciplinary group at Columbia University's Hazard and Risk Research Institute is working with similar organizations in Turkey and elsewhere to evaluate this risk and to design realistic programs to decrease it. One of the PIs has pursued basic earthquake science in the Marmara Sea area since the first destructive earthquake in 1999 and is also taking a major role in the risk evaluation and reduction effort. Risk-reduction measures in a major population center in advance of an earthquake would mark a major achievement that could guide future efforts worldwide. This project would provide a better understanding of current fault segmentation and temporal history of the fault system that will directly apply to the risk-reduction effort.

Spera
National Science Foundation
EAR-0073932
Collaborative Research: Energy-Constrained Geochemical Models for Open System Magma bodies with anatexis, replenishment, magma mixing and fractional crystallization
02/01/01-12/31/04
$89,259
Existing tools that model the geochemical evolution of open-system magma bodies suffer from several limitations, the most critical of which are lack of accounting of energy-conservation and lack of inclusion of the consequences of wallrock partial melting. A new tool has been developed that models the geochemical evolution of a magma body-wallrock system in which energy, mass and species are conserved as wallrock and magma approach thermal equilibrium. At web site **http://magma.geol.ucsb.edu/research/recharge.html** there are 3 documents relevant to this model. The first 2 are manuscripts in review at the *J. of Petrology*. Paper I, entitled *Energy-Constrained Open-System Magmatic Processes I: General Model and **E**nergy-**C**onstrained **A**ssimilation and **F**ractional **C**rystallization (EC-AFC) Formulation,* provides background, theory, limitations, mathematical form and implementation of a set of self-consistent ordinary differential equations that describe the geochemical evolution of magma in an open system undergoing concurrent assimilation and fractional crystallization (AFC). Paper II, entitled *Energy-Constrained Open-System Magmatic Processes II: Application of EC-AFC Model to Magmatic Systems*, discusses the influence of thermochemical and thermophysical parameters on magma geochemical evolution. The model is also applied to several natural systems to derive new geological insight. The third item is user-friendly down-loadable code to perform EC-AFC calculations on a PC or Mac. Our EC-AFC model is fully explained, working, available, and has already led to significant discovery about AFC processes (see manuscripts referred to above). We propose to build upon this EC-AFC framework by accomplishing five new tasks. (1) Implementation of a self-consistent treatment of magma **R**eplenishment to the existing model to develop a user-friendly EC-RAFC model. (2) More tightly couple phase equilibria and thermochemical constraints to EC-RAFC. This is accomplished using information from the MELTS code (e.g., Ghiorso, 1997) to implement a procedure whereby melt productivity functions $f_a(T_a)$ and $f_m(T_m)$, which are essential in EC-RAFC, are determined for user-defined compositions of initial magma, wallrock and replenishment magma. In addition, phase equilibria data will enable better approximations of bulk partition coefficients for magma and wallrock as a system undergoes RAFC. (3) Allow for the development and maintenance of compositionally distinct melt reservoirs within an EC-RAFC magma body. This will enable us to apply EC-RAFC to zoned ignimbrites. The prevalence of such deposits in the geological record (e.g., in continental hydrothermal-magmatic regions) and their associations with zoned magma bodies make this an essential step for

developing an EC-RAFC model that is broadly applicable. (4) Allow for a melt extraction efficiency less than unity (i.e., where 100% of wallrock anatectic melt is not added to the standing magma body); this modification accommodates a scenario where mass and energy addition can be decoupled and addresses the physics of melt extraction in a quantitative manner. (5) Apply the enhanced version of the EC-RAFC simulator to six to a dozen carefully documented magmatic systems spanning a range of geologic environments in order to explore potential systematics in the relative roles of fractional crystallization, recharge and assimilation in magma bodies associated with particular tectono-magmatic settings (e.g., MOR, continental arcs). This research has the potential to impact the work of the large number of geoscientists who generate and interpret geochemical, geochronological, petrographic and petrologic data from extant and ancient magmatic systems and will parallel the dramatic improvement in the amount and quality of geochemical data describing magmatic systems.

Spera
Department of Energy
DE-FG03-01ER15210
Mesoscale Molecular Dynamics of Geomaterials: the Class Transition, Long-Range Structure of Amorphous Silicates and Relation between Structure, Dynamics and Properties of geomaterials at elevated Temperature and Pressure
09/01/01-10/31/05
$270,000
Mesoscopic Molecular Dynamics (MMD) simulation reveals the nanoscale dynamics of collections (~10^6-10^8) of atoms on the microsecond (10^{-6} s) timescale. MMD simulation enables one to address fundamental problems in the geo- and environmental sciences utilizing large-scale computational methods while simultaneously addressing basic scientific issues. MMD represents an ideal tool for investigation of nanostructured materials and nano-scale dynamics where clusters of particles (oft-times involving cooperative motions) are important (Smirnov, 2000; Binder, 1995). MMD informs us regarding both the structure and dynamics of materials and may be used to study phenomena as diverse as memory glass (Kruger and Jeanloz, 1990), polyamorphism (Grimsditch, 1984; Mishima, 1994; Poole et al, 1993; Saika-Voivod et al, 2001), fracture and superplasticity in polycrystalline materials at high temperature (Holian and Ravelo, 1995; Ogawa, 1998; Bachlechner et al, 1999) and the transition between metastable (supercooled) liquid and its corresponding nonequilibrium glass, the glass transition problem (Debenedetti, 1996;Angell, 1988, 1991; Angell et al, 1997). Nano-phenomena commonly govern the macroscopic behavior of materials; if we are to understand macroscopic behavior more profoundly we must better understand processes and material structures at the atomic level. Solution of a number of practical problems in the environmental and geosciences requires better knowledge of nano-phenomena especially if one wishes to make predictions regarding structure, properties and function of materials at conditions of temperature, pressure, oxygen fugacity and activity of H_2O not amenable to experimental study such as those deep within the Earth's crust, lithosphere or deep interior.

In this proposal, we set out a program of research using the Molecular Dynamics method applied to silicate geomaterials in order to address several important geoscience problems. The workhorse tools we plan to employ are two MD codes developed at UCSB in the past decade. The first is a standard MD code that scales as N^2, where N is the number of particles used in the simulation. We have used this code extensively in the past decade (Rustad et al, 1989, 1990, 1991a,b,c, 1992, Stein and Spera, 1995, 1996, Nevins and Spera, 1998, Bryce et al, 1997, 1999, Morgan and Spera, 2001a,b). In the past year, we have developed at UCSB a new MD code based on the Fast Multipole Algorithm (FMA) of Greengard and

Rokhlin (1987, 1989; Greengard and Gropp, 1990; see also Cheng et al, 1999 for an updated version). The FMA enables one to practically implement Mesoscopic Molecular Dynamics (MMD) since it provides the ability to study systems containing up to 10^8 particles over times scale of tens to hundreds of nanoseconds (e.g., see Campbell et al, 1999). We are now in the process of restructuring the code to run efficiently on parallel machines at NERSC and on a network of workstations (NoW). This level of resolution in space and time will enable a deep look into nanoscale geomaterial problems with direct application to current geoscience issues.

In the work plan set down below we explain how Mesoscopic Molecular Dynamics simulations will be used to explore the following problems: (1) The intermediate and long-range structure of M_2O-MO-Al_2O_3-SiO_2 silicate glasses and supercooled liquids. (2) The origin of dynamical heterogeneity in supercooled liquids around the glass transition temperature and its relationship to theories of viscosity such as the thermodynamic Adam-Gibbs-DiMarzio theory and the dynamical (nonequilibrium) mode-coupling theory. (3) Computing thermodynamic and transport properties of geomaterials under conditions of high pressure with special focus on the relationship between nanoscale structure and pressure in equilibrium geoliquids in the range 50-135 GPa. Properties of interest include the phonon thermal conductivity, ionic conductivity, shear viscosity, heat capacity and tracer diffusivity. These quantities for perovskitic liquids at ~5000 K are largely unknown and have important ramifications for the evolution of a putative Hadean terrestrial magma ocean, the stability and heat-transfer capabilities of possible a Ultra-Low Velocity Zone (ULVZ) of silicate melt at the core-mantle boundary as well as the convective history of the Earth's mantle. (4) Study of the nanoscale basis for superplasticity and associated grain boundary diffusion in crystalline silicates

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Spera
National Science Foundation
ATM-0425059
ITR(ASE)-(sim): Collaborative Project: Virtual Laboratory for Earth and Planetary Materials Studies
10/01/04-09/30/08
$89,555
This project aims to enhance the development of a novel branch of computational materials science: the theory of earth and planetary materials. Its flourishing in the last decade was enabled by the maturing of computational condensed matter physics, the development of reliable and portable 'first principles' software for materials simulations, and powerful computer systems. Today it is possible to investigate realistically the physical and chemical properties of complex materials at conditions typical of planetary interiors that were unthinkable ten years ago. Only independent determination of these properties in these materials at the relevant conditions can provide a basis for 1) an interpretation of observational data in the context of likely planetary processes, 3) a basis for a discussion of their internal chemical and physical states, and 2) critical input for more sophisticated and reliable modeling of their interiors. This task is still exceedingly challenging to experiments but fundamental to advance our understanding of planets to new levels.

This project will reach across and assemble efforts from different disciplines in this inherently interdisciplinary research field. Most importantly, it will explore emerging computational technologies, such as computational stirring, grid computing, and visualization to bring state-of-the-art techniques from computational materials physics to new levels of performance. This is most needed to improve reliability and the level of complexity required in simulation of planetary materials. At UCSB PI FJ Spera will use

large scale Molecular Dynamics codes in his possession to study the role H_2O plays in molten silicates at elevated temperature and pressure. This work will be done in the Magma Rheology Lab at UCSB and at NERSC.

Spera
National Science Foundation
EAR-0440057
Collaborative Research: Internally-Consistent Model for Trace and Major Element Evolution in Open System Magma Bodies: Merging EC-RAFC and MELTS
01/01/05-12/31/07
$197,133
The objective of this research is to develop a computational geochemical tool, the Magma Chamber Simulator (MCS), to describe the major and trace element, isotopic, mass, and thermal evolution of open system magma bodies undergoing simultaneous recharge, assimilation, and fractional crystallization. The MCS provides a self-consistent thermodynamic description of a composite magma-host rock-recharge system, subject to energy and mass exchange during the approach to thermal equilibrium. The MCS couples multicomponent phase equilibria to trace element and isotope evolution by appropriately linking the energetics of partial melting and assimilation, recharge, and fractional crystallization to major and trace element species conservation and Gibbs energy minimization or entropy maximization via a set of coupled non-linear differential equations. The MCS is constructed by reformulation and integration of two extant modeling tools, MELTS and EC-RAFC. The MCS will track the geochemical and petrological evolution of solids and liquids in an open-system magma chamber. The MCS, applicable to a wide variety of lithospheric magmatic systems, is poised to address questions relevant to modern igneous petrology/geochemistry. An overview of several of these questions, in the context of studies in classical settings such as ocean island magmatism (Hawaii), subduction zone magmatism (Arenal), continental flood basalt magmatism (Parana), and layered mafic intrusions (Bushveld Complex) is provided. The MCS software will be made available via the Web as a Microsoft Excel spreadsheet. Within this spreadsheet, the user will also be able to run a stand-alone version of MELTS. MCS will serve a user base as diverse as professional researchers and undergraduate petrology students. Several undergraduate geochemical-petrology modeling exercises, including case studies utilizing published data, will be developed using the MCS software tool and made available on the Web.

The **intellectual merit** of the proposed activity centers on the well-documented idea that magma chambers are inherently open systems subject to simultaneous contamination, recharge and fractional crystallization. At present, there is no single, self-consistent, rigorous model for simulating the phase equilibria, major and trace element, and isotopic evolution of liquids and solids in open systems. Development of such a model would allow field, geochemical, petrological, and geochronological studies of magmatic systems to be placed in a quantitative framework that would enable predictions about the behaviors of magmatic systems. Through application of the MCS to the diverse array of magmatic systems represented on Earth, progress can be made on the fundamental question of how magma diversity is achieved. Petrogenetic studies demand a holistic approach, and the MCS, which will allow constraints from phase equilibria to be incorporated with trace element and isotopic information in a dynamic context, will provide petrologists and geochemists a reference model applicable to natural magmatic systems.

The **broader impacts** resulting from the proposed activity are that the geochemical and petrological community will be provided with a user-friendly desktop computational tool for systematically, self-consistently and quantitatively investigating the evolution of dynamic, open-system magma bodies. This tool, which will be available on a number of web sites, will be of use not only to professional researchers but also to undergraduate geology students. As part of the outreach activities, exercises for undergraduate/graduate petrology classes will be developed in collaboration with students. Students involved in research activities will be exposed to computational modeling as well as use of geologic data to answer relevant questions in igneous petrology. It is anticipated that undergraduate and graduate students will work as teams on aspects of this work. Thus, this study will not only impact the research of a large number of professional petrologists/geochemists, but it will also contribute to the training of students in research, curriculum development, and collaborative endeavors.

Steidl
Brigham Young University
02-0105
Permanently Instrumented Field Sites for Study of Soil-Foundation-Structure-Interaction
10/01/02-09/30/04
$1,255,589
Steidl
Network Earthquake Engineering Simulation Consortium
NEES Consortium Operations 2004-2014
10/01/04-09/30/05
$525,994
Steidl
National Science Foundation
NEES Permanently Instrumented Fields Sites-UCSB Equipment Site Upgrade Proposal
10/01/04-09/30/05
$33,551
This proposal will provide NEES with two field laboratories for the study of SFSI, liquefaction, and lateral spreading. The requested funds will be used to enhance existing, well-studied, and well-characterized seismic array sites: Wildlife and Garner Valley. The enhanced NEES sites will be capable of both active and passive experiments, including an SFSI test structure with shaker and structural instrumentation at Garner Valley. As well as becoming part of NEES, both sites will interact with ANSS.

Permanently instrumented field sites for the study of soil-foundation-structure-interaction (SFSI) and soil failure address one of the identified research needs for the second round of NEES equipment/sites. There is need to further study SFSI in real structures under seismic input, but there are always complexities with real structures that can mask understanding of the SFSI phenomena. Study of soil failure is also complicated in urban or geologically-complex settings. Simple, well-characterized test sites are needed to increase understanding of the physics behind SFSI and soil failure in earthquakes.

This proposal adds to the NEES program a unique pair of permanently instrumented sites that address this research need. In particular, two simple sites in the seismically active Southern California region will be enhanced and brought into the NEES equipment portfolio, linked by next-generation wireless

communications to the NEES grid. The Wildlife site will provide a test facility for active and passive measurement of soil response and soil failure under dynamic loading. The Garner Valley site will provide research opportunities for those developing tools for site characterization and for the evaluation of soil properties and how they change with time after seismic disturbance. The project will provide unique research opportunities for studying the physics of SFSI. The sites will also be an excellent test bed for new *in-situ* site characterization techniques, and new sensor technologies. The field sites will also have an impact on undergraduate and graduate teaching programs in earthquake engineering, geotechnical engineering and engineering seismology. Students will be able to participate in the active experiments through teleparticipation as well as on-site workshops. Data and research from both sites will be significant to ANSS.

Tanimoto
National Science Foundation
Ocean-Solid Earth Interaction: Seismic and Satellite Data
07/01/04-06/30/06
$171,543
During the past few decades, it has become clear that the Earth's components - atmosphere, ocean and solid Earth - interact in complex ways on various time scales. Seismograms reveal such interactions, mainly on days without large earthquakes. One example is the continuous background oscillations that was first reported in 1998, whose cause is actually still unknown.

The atmospheric excitation hypothesis was pursued by a few groups, including this PI, but it is becoming clear that the power through the direct-forcing mechanism by atmosphere is not sufficient. The correlation length in atmospheric pressure changes, which is proportional to modal amplitudes in the stochastic excitation mechanism, is not 10 km as was originally assumed (approximately the scale height of atmosphere), but is rather like a few hundred meters at frequencies of about 3 mHz. On the other hand, ocean waves seem to have sufficient energy in the form of infragravity waves in the frequency band between 3 and 15 mHz. Furthermore, the infragravity mechanism seems to be able to explain the overall characteristics of spectral shape in this frequency band, which has a broad peak at about 7-9 mHz.

This is a two-year proposal which will evaluate this ocean-wave excitation hypothesis by theoretical modeling and observational data analyses. Our efforts will focus on: (i) search for the source location of excitation, because there are some indications in data for a rather localized source for a given (short) time interval, (ii) modeling geographic variations in spectra through comparison between theory and data, and (iii) characterization and monitoring of seismic and satellite data, including six-months and annual components.

Intellectual merit: The goal of this proposed study is to understand the cause and mechanism of ubiquitous seismic oscillations and to learn the implications to mechanical coupling between the ocean and the solid earth. Thus, it represents a scientific pursuit for trying to understand a novel enigmatic phenomenon. The data occupy a unique frequency band between about 3 and 15 mHz and may add a new dimension to our understanding of mechanical couplings in the Earth system. The phenomenon may be of interest to a broad range of earth scientists. As with any other scientific pursuit of new knowledge, it may have some future benefit. For example, it may be critical for detection of slow earthquakes in the future, because the continuous

oscillations are the principal source of noise in this frequency band. There is some hint that previous slow-earthquake studies have been hampered by these oscillations. Understanding the nature of this phenomenon will give us insight on how to reduce noise and enhance other signals in the same frequency band.
The broader impacts: This study takes advantage of seismic and satellite (ocean) data whose complimetary use have not been examined before. Use of seemingly unrelated data will undoubtedly become important in geosciences in order to advance our understanding of the Earth as a dynamically connected system.
The project will hire and educate a graduate student.

Tanimoto
UC-LANL
04-1206
Cause of the continuous oscillations of the Earth
10/01/03-09/30/05
$27,961

Wyss
National Science Foundation
DEB-0206762
Dissertation Research: Phylogeny of the Rhynchosauria
08/01/02-11/30/04
$9,724
The major objective of this study is to produce a comprehensive phylogeny of all Early, Middle, and Late Triassic rhynchosaurs, including abundant new fossils of the previously fragmentary taxon from Madagascar and newly and/or incompletely described taxa from Argentina and Brazil. A second objective is to analyze patterns of dental evolution within this ubiquitous group of Triassic herbivores. Proposed activities resulting from this research include: travel to South American, German, and South African rhynchosaur collections, detailed examination and description of dental and skeletal characteristics, construction of an all-encompassing data matrix of characters scored from first-hand observations and measurements, and parsimony and multivariate analysis to assess phylogenetic relationships within the Rhynchosauria. Because rhynchosaurs have been used extensively to correlate Triassic terrestrial faunas worldwide, the projected impacts of this study go well beyond the benefits of an inclusive reassessment of rhynchosaur evolutionary histories. The results of this research will help establish a worldwide biochronologic correlation of the newly discovered Middle or Late Triassic fauna from Madagascar with roughly contemporaneous faunas (particularly those found in Argentina and Brazil), and will potentially yield insights into Triassic biogeographic linkages in the Southern Hemisphere during this important time of diversification in the fossil record.

Wyss
National Science Foundation
DEB-0317177
Collaborative Research: Andean Fossils Mammals - Phylogenetic and Geologic Implications
10/01/03-09/30/06
$150,004
The bizarre mammal fauna arising from South Americaís isolation as an island continent for

most of the Cenozoic (65-0 Ma) has captivated evolutionary biologists since Darwinís time. Over the past decade the PI's have discovered numerous highly unexpected new faunas from the Andes of central Chile. These faunas illuminate several long standing phylogenetic, evolutionary, and biochronologic problems; calibrate key intervals of the Cenozoic South American land mammal sequence; and help elucidate mammalian evolution across a broad time span (at least 40-15 Ma). The first of these assemblages to be uncovered, the ~31.5 Ma Tinguiririca Fauna, is remarkable in many ways, including a) the notable completeness of the >400 specimens collected to date; b) its diversity (>25 taxa, most new); c) that it represents the first Paleogene mammals known from west of the Andean divide and a new South American Land Mammal ìAgeî; d) the oldest known caviomorph rodents (an allochthonous immigrant group); e) the earliest hypsodont-dominated fauna known globallyóthereby supporting the early appearance of open grassland habitats in South America; and f) clarifying events around the Eocene/Oligocene boundary (~34 Ma) and its associated climatic, paleoenvironmental and biotic changes. Many of the numerous discoveries we have made subsequently (spanning at least 4° north-south of Tinguiririca) promise to be equally significant.

In addition to their paleontological importance, these Andean faunas are providing the first radioisotopic calibration of several parts of the standard SALMA sequence and have helped revolutionize understanding of the geologic history of this region. The realization that fossils occur throughout a thick sequence of volcanic sediments of the central Andean Main Range has brought to light a major new repository of information about South American mammal evolution, one that is virtually untapped and enormous in scope. These deposits thus hold the potential to generate one of the most complete and well-calibrated records of South American mammal evolution known, an objective we intend to advance through this proposed research.

The current project builds on our previous successes in three major directions. First, the project team will further extend its *field collection and exploration* program to discover additional localities and faunal horizons, and to augment sampling from several existing ones. Second, the team will *establish an integrated geochronologic framework*, emphasizing high-precision $^{40}Ar/^{39}Ar$ dating (complemented by stratigraphy, biochronology, and magnetostratigraphy) for the most important of the dozen existing faunas, and any that are newly identified during the proposed work). And third, the project team will use the exceptional new cranial and postcranial material of Eocene-Miocene taxa in these faunas to *undertake rigorous studies of the phylogeny and diversification of several major endemic South American mammal clades* (basal caviomorph rodents, argyrolagoids and other major groups of ameridelphian marsupials, and interrelationships of notoungulate ìfamiliesî). These systematic analyses will develop from continued preparation and description of these diverse, well-preserved fossils, and rigorous alpha taxonomic studies and higher-level phylogenetic analyses of constituent taxa. Collectively, these areas of inquiry will clarify biotic, environmental, and geologic events during crucial intervals of South American land mammal evolution, and will refine currently poorly-constrained parts of the geochronology of the SALMA sequence. These advances are essential for better understanding the timing and rates of mammalian diversification.

Our project, as in the prior NSF-supported research, should have significant societal impacts, ranging from field and research training of 2 excellent US women graduate students, to student training and informal educational outreach in Chile (our partners in this work), through exhibits and other educational programming reaching the Field Museum's 1.6-2.3 million annual visitors.

Wyss
American Chemical Society
40881-AC8
Using Fossil Mammals to Unravel the Geologic History of the Central Chilean Andes
04/01/04-08/31/05
$39,500
With the revised budget and timetable, we (US graduate student, field assistant, at least one Chilean professional) will be conducting one field season at Laguna del Laja, Chile, rather than three. We will collect fossils and geochronology samples from several disjunct stratigraphic sections to determine their temporal relationship. Salary for the US graduate student is provided for three months during field work and geochronology processing, and for one summer month for the graduate student and a fraction of a month for the PI. One investigator will travel to the Field Museum in Chicago for compartive study of their South American fossil mammal collections. The 15 best geochronological samples will be processed. The results of this work will be presented at the annual meetings of the Society of Vertebrate Paleontology and the Geological Society of America, and in journal publications.

The sixteen months of awarded funding will enable us to return to collecting sites discovered previously (Trapa Trapa East, Trapa Trapa West, Cerro Los Pinos, Estero Campamento), to prospect for fossils intensively in those sites, and to seek additional primary volcanic flows for radioisotopic dating. The age diagnostic fossils and $^{40}Ar/^{39}Ar$ radioisotopic ages will be used to correlate between collecting areas, contributing, ultimately, to a reconstruction the tectonic history of the Laguna del Laja area. In summary, the shortened timeframe of our proposal curtails our field efforts to a single season and limits the amount of analysitical work to be carried out, but the goals of the project remain unchanged.

SCEC AWARDS

Burbank/Archuleta
University of Southern California
075639-A ARP22
Radiated Seismic Energy from a Dynamic Faulting Model of the Northridge Earthquake
0/01/02-01/31/07
$67,000
We propose to compute the seismic radiated energy for the 1994 Northridge earthquake. First, we will determine the initial stresses from the slip distribution using the method of *Bouchon* (1997). The initial stresses will be based on the slip distribution derived by *Liu and Archuleta* (2002). Because of a reduced budget we may not be able to consider the slip distribution derived by *Wald et al*., (1996). From the stress distribution we will derive a spatially heterogeneous initial stress and yield stress. The sliding friction stress will be fixed. From this distribution of stresses and in concert with a slip weakening friction law we will dynamically rupture the fault. The static stress drop will allow the computation of the elastostatic work available. This work is partitioned into work spent during fracture (fracture energy and relaxation) and work radiated as seismic energy. We will compute the radiated seismic energy as we have done for

the 1979 Imperial Valley earthquake (*Favreau and Archuleta*, 2003). This research will be carried out by Shuo Ma, a graduate student at UCSB under supervision by the principal investigator.

Burbank/Liu
University of Southern California
075639-P LPP03
Quantifying Uncertainty in Finite Fault Inversions
02/01/02-01/31/07
$20,000
In our original proposal we included the following statements of work: 1) estimate the uncertainty in the finite fault solution using the bootstrap method, 2) examine the effect of different objective functions on the finite fault inversion, 3) apply our approach to the data from the 1994 M 6.7 Northridge earthquake, 4) use a hybrid technology in the bootstrap process of analyzing the data. The bootstrap process would use the global inversion method (*Liu and Archuleta*, 2000) and the original data set to invert for a best source model. This solution is then chosen as starting model, and a linearized iterative inversion technique (*Hartzell,* 1989) would be applied to invert bootstrap data samples.

With the modified budget we will do the proposed work with a significant modification. We will not adapt the bootstrap method to the linearized iterative inversion technique of Hartzell (1989). Instead we still use our global inversion method (*Liu and Archuleta*, 2000) in the whole bootstrap process. This adjustment will not affect the basic objectives of the proposal. It reduces the time for the researcher supported by this proposal; however, the computer time to complete the work will increase significantly which may limit the number of parameter studies that can be done.

Burbank/Olsen
University of Southern California
075639-Q OKP14
Estimation of LA Basin Seismic Wave Amplification Effects
02/01/02-01/31/07
$20,000
We propose to continue ongoing work comparing ground motion computed by prescribed and dynamic rupture propagation for dipping faults buried up to 5 km (*Gottschammer and Olsen*, 2001). We use a fourth-order finite-difference (FD) method and the mixed boundary condition with a rate- and slip-weakening friction law. The numerical grid is parallel to the fault plane with the free surface at an angle with respect to the numerical grid by introducing a vacuum layer. Preliminary results for a 45 degree dipping thrust fault suggest that inclusion of these effects increases the peak displacements and velocities above the fault significantly by including the increase in moment due to normal-stress effects at the free surface (see Fig 1. of Progress Report: How Can We Improve Ground Motion Estimates by Lessons Learned from Rupture Dynamics?). The results suggest that dynamic interaction with the free surface can significantly affect the ground motion for faults buried less than 1-3 km. We believe that the proposed research can help delineate the range of effects that may be expected in a realistic earthquake scenario.

We propose to continue the work by (*Gottschammer and Olsen*, 2001) by comparing prescribed and spontaneous dynamic rupture propagation on dipping thrust faults buried 0-5 km in half-space and realistically layered models, as well as ground motions on the free surface for frequencies less than 1 Hz. The comparisons include dynamic simulations using a 3D FD method with rate-and-state friction on a

planar fault in a realistically layered medium. In the continuation of the project proposed here we will test the effects of using more realistic heterogeneous dynamic rupture parameters, as well as variation of the stress level in the near-surface material. We will continue testing the findings that ground motions from buried faulting are consistently stronger than that from earthquakes having large surface slip (*Somerville*, 2000), for heterogeneous distributions of rupture parameters.

Burbank/Olsen
University of Southern California
075639-R OKP15
Estimation of Dynamic Rupture Parameters
02/01/02-01/31/07
$15,000
We propose to continue to develop, implement and test a systematic inversion method to estimate rupture propagation and the underlying dynamic parameters for large historical earthquakes using the Neighborhood algorithm (NA). We will test the efficiency and limitations of the method on realistic fault models. The tests include estimating the number of parameters that can be reliably determined, the dependence of the initial model, of the control parameters of NA and selection of rupture parameters (i.e., stress, friction, or rupture energy), the need for constraints on the rupture parameters, and rate of convergence. We will implement ways of speeding up the convergence of the method, including 'early detection' of 'poor' models, for example those where rupture does not initiate. We will optimize the finite-difference forward modeling method in terms of RAM and cpu-time requirements. To achieve this goal, we plan to use the efficient Perfectly Matched Layers (PML) absorbing boundary conditions (*Marcinkovich and Olsen*, 2003).

We propose to examine in detail the constraints that near-fault strong motion records can provide for the slip-weakening distance (*Mikumo et al.*, 2003). In particular, we propose to investigate the resolution of D_c. We will estimate D_c from near-fault ground motions for the 1979 Imperial Valley and 2002 Denali earthquakes. We will examine the radius of influence from the fault on near-fault strong motion records in order to address the severity of the averaging process controlling the estimate of D_c. Finally, we propose to estimate the effect of different kinds of slip-weakening behavior on the resolution of the method.

Burbank/Oskin
University of Southern California
075639-T OMP04
Implementation of the SCEC Community Vertical Motion Map
02/01/02-01/31/07
$10,000
This Geologic Vertical Motion Database (GVMD) and vertical motion map utility will be developed and maintained at the Institute for Crustal Studies at the University of California, Santa Barbara. Similar in organization to existing databases of fault geometry (CFM), fault activity (FAD), crustal motion (CMM) and seismic velocity (CVM), the GVMD and vertical motion map utility will be an on-line, maintained, and documented resource available to the scientific community.

N. Niemi and M. Oskin will each devote two months to completion and testing of the GVMD and vertical motion map utility. Niemi and Oskin are both geologists experienced with Arc/Info GIS and familiar

with object-oriented programming languages and database-driven web applications. Niemi has been programming in ArcGIS for the past year full time as academic staff at the Massachusetts Institute of Technology. Population of the GVMD with available geologic data will take advantage of the variety of experience and resources available at the Institute for Crustal Studies at the University of California, Santa Barbara. C. Sorlien will aid in planning of the database structure and entry of marine geologic subsidence and uplift data from onshore and offshore basins. Oskin will devote one additional month to entry of onshore tectonic geomorphology and thermochronology uplift data.

Burbank/Liu
University of Southern California
075639-C LPP02
Resolution and Stability Analysis of Finite Fault Inversions
02/01/02-01/31/07
$20,000

Since the original inversions of strong motion data by *Trifunac and Udwadia* (1974), there have been a vast array of inversion methods applied to near-source ground motion records. Correctly determining the kinematics parameters of the rupture process is fundamental to our understanding of earthquake physics. The kinematic parameters obtained from an inversion can be used to infer the stress drop distribution (e.g., *Mikumo and Miyatake*, 1995; *Bouchon*, 1997; *Day et al.*, 1998) that in turn can be used as the input for dynamic models (e.g., *Olsen et al*, 1997; *Nielsen and Olsen*, 2000; *Archuleta and Favreau*, 2001). The kinematic parameters have been used to infer scaling properties (e.g., *Somerville et al.*, 1999; *Mai and Beroza*, 2000) and as input to finite difference codes in an attempt to determine frictional parameters (e.g., *Ide and Takeo*, 1997). Of course, the spatial and temporal distribution of source parameters is critical in forward modeling of ground motion. As such the inversions serve as a baseline for the range of parameters that are plausible in predicting ground motions for engineering design purposes.

Methods for inverting the data usually require parameterization of the faulting process by dividing the finite fault into a grid of small cells or subfaults and approximating the ground motion at a given station by a linear sum of the synthetics originating from these subfaults. There is no criterion to decide how large a subfault should be. Several papers show that changes in the size of subfaults can have a significant effect on a finite-fault inversion (*Hartzell and Langer*, 1993; *Das and Suhadolc*, 1996). In a similar vein there is a wide range of objective functions that are to be minimized in the process of comparing synthetic time histories with the data. It is unclear how the choice of an objective function affects the inversion results. The rupture process on the fault is deduced through iteratively fitting the synthetic time histories to recordings (by use of the objective function). Obviously the solutions obtained from this inversion process will depend on the Green's functions because they are essential to the representation theorem used to compute synthetics that are compared to data. With the recent advent of efficient 3-D numerical wave propagation methods and improved knowledge about the crustal structure, it is now possible to invert for kinematic parameters of a finite fault using Green's functions computed from a 3-D structure. Do 3-D Green's functions improve the resolution of kinematic source parameters?

This proposal focuses on three elements of finite fault inversion methods: 1) influence of subfault size; 2) choice of objective function for minimizing the difference between synthetics and 3) effectiveness of 3-D Green's function in determining the kinematic parameters of faulting.

Burbank/Sorlien

University of Southern California
075639-U SCP04
Contributions to the SCEC Community Fault Model: Relating Onshore-offshore Stratigraphy and Fault-Fold Activity Beneath Santa Monica Bay
02/01/02-01/31/07
$20,000
This study proposes to utilize high resolution and industry seismic reflection data, well and seafloor geologic data, and swath bathymetric and backscatter data to investigate Quaternary deformation. We will correlate strata from ODP Site 1015 in Santa Monica bathymetric basin north to the Shelf Projection Anticline, and to sets of 800 X 2500 m grids of high-resolution reflection data that cross both the Dume segment of the Santa Monica fault and the San Pedro Basin fault and related folds. Ongoing NEHRP-supported structure-contour mapping of the top Miocene and top Repetto Formation horizons will be extended to include one or more late Quaternary horizon as they are identified by correlation to onshore stratigraphy, and by biostratigraphic interpretation of a detailed list of benthic foraminifera for an offshore well. Several approaches will be used to correlate pre-latest Quaternary stratigraphy to the south of the Shelf Projection, possibly by regional correlations to wells offshore Redondo Beach, by correlation to our existing stratigraphic interpretations west and north of the Shelf Projection, or even correlating south of Palos Verdes (the Beta Field area). Activity on high-angle faults can be determined from vertical separation of a given horizon, and activity on folds can be determined by thinning and onlap of strata onto the fold. We will also incorporate submarine geomorphology using multibeam bathymetry and backscatter data, combined with high-resolution seismic reflection data. After the active faults and folds are identified and their kinematics interpreted, we can model the interactions between folding and blind thrusting, as well as strike-slip faulting. In this way the post-4 Ma average displacements can be related to modern deformation and seismicity.

Burbank/Steidl
University of Southern California
075639-L SJP06
SCEC Borehole Instrumentation Program
02/01/02-01/31/07
$90,000
One of the major goals of the Center is to compute theoretical seismograms for scenario earthquakes in the Los Angeles and Southern California region. Existing strong-motion data are used to calibrate and improve our computational techniques. Ground motions recorded at strong motion stations throughout Southern California are a combination of the complex earthquake source process, the propagation path from the source zone to the station, and the local near-surface site conditions at the station. Separation of source, path, and site effects is limited by the current availability of data, the lack of detail in our knowledge of the crustal structure, and our understanding of the earthquake source process. Widespread and varied ground motions and damage patterns over short distances produce a large degree of uncertainty in our ability to predict ground motion from future earthquakes. In order to reduce the uncertainty in our theoretical seismograms of possible scenario earthquakes, we will observe and remove the near-surface site effect at a few select stations having “typical” southern California soil profiles by using borehole instrumentation. Observations from the SCEC borehole project allow for direct estimation of site effects, provide a test for the calibration and improvement of physical models of soil response, and give us a clearer picture of the incident ground motion that can then be used to study in more detail the earthquake source process and the regional crustal structure.

Much of the variability mentioned above is caused by the local near-surface site conditions and shallow crustal structure. The upper several meters to several tens of meters in the geologic section have major influence on amplification or deamplification of seismically generated ground motions and the initiation of ground deformation or ground failure. Evaluation of ground response and ground deformation in these upper layers, and the interaction with foundations and structures, is a critically important aspect of safe and economical engineering design. One of the primary goals of SCEC is to generate analytical and empirical models for accurate prediction of ground response and ground deformation due to earthquakes. A required element for the development of these models is well-instrumented field sites where actual ground response and deformation can be monitored during earthquake shaking to provide benchmark case histories for model development and verification. Records from a number of sites with a variety of soil types and geometric configurations are needed to provide a range of site conditions commensurate with those commonly encountered in engineering design.

Under this proposal, the SCEC borehole instrumentation program will continue ongoing efforts to increase the number of these benchmark sites in the Southern California region (currently nine) and to make the data available in real-time through the SCEC data center. We will continue to use the data to develop the numerical techniques for linear and nonlinear site response analysis, dynamic modeling of soil behavior at large strain, and analysis of source and path properties. We will seek out new targets of opportunity to provide observations from deep rock sites in close proximity to active faults. Collaborations with other agencies will continue to allow us to stretch the SCEC dollar and provide significant value for the cost. We will also contribute to the short-term goals of the implementation interface group through a newly formed collaboration with our engineering colleagues and the NSF engineering funded George E. Brown Jr. NEES program.

Burbank/Archuleta
University of Southern California
075639-B ARP23
SCEC Strong Motion Database
02/01/02-01/31/07
$29,999

By this proposal we are requesting funding to continue development of the COSMOS Strong-Motion Virtual Data Center – (COSMOS VDC) – an unrestricted, web-based, interactive strong ground-motion data resource for practicing earthquake engineers, emergency response and recovery agencies and officials, researchers, and other earthquake professionals. The urgent need for effective and efficient access to strong-motion data has been well documented. Through the foresight of the agencies that have deployed and operate strong-motion networks there now exists an abundance of data. With the increasing deployment of digital recorders with high dynamic range such as TRINET, ANSS, and KNET, we can expect a continuing increase in the rate of data recorded. However, the full impact of the strong-motion data on public safety in earthquakes depends on their accessibility to the engineers, seismologists, and other users. With the basic goal of providing practicing earthquake professionals and public officials efficient, routine access to strong motion data as part of their practices, COSMOS has developed the VDC (http://db.cosmos-eq.org/).

The natural venue for this access is through the World Wide Web, which provides the means to retrieve data from any type of computer, view and copy plots and maps to the user's computer, etc. The

universality of the Web allows equal access to all of the engineering and seismological communities, to large companies as well as university consortia. The VDC allows the user to search for and select the data most appropriate for a particular project or application, based on the individual user's needs. The VDC is the only strong-motion data center that is attempting to provide access to all strong-motion data on-line.

Burbank/Steidl
University of Southern California
075639-V SJP09
Attenuation Analysis of Borehold Data for CVM
02/01/02-01/31/07
$50,000
The method used in this project will be nonlinear waveform inversion. The model parameters to be determined in the global inversion method developed by *Liu et al.* (1995a, b) are Q_o and P, where the attenuation is defined as $Q(f) = Q_0 f^P$. We assume this standard functional form for the frequency dependence of Q and use the global inversion to determine the dependence on a site-by-site basis. The exponent P is bounded by the two end member cases where $P = -0.5$ and $P = 0.5$. It is possible to invert for other material properties using this global inversion scheme; however, we will fix the other material properties using the independent site characterization data at these sites and focus solely on attenuation.

The forward model will be calculated using a modified 1D Haskell tranfer matrix that incorporates the ability to accurately include frequency dependence of attenuation. The synthetics will be generated using the borehold data as the input. Surface observations and synthetics will then be transformed into the wavelet domain for the global inversion. We have had success in the past in modeling waveform data from borehole arrays to frequencies of up the 10 Hz (*Steidl et al.*, 1998). Initial inversions will span the frequency range of 0.1 to 10 Hz, and depending on the results, we may attempt to push the upper frequency limit higher, or alternatively, compute a high frequency inversion in the frequency domain, matching spectra instead of waveforms.

Burbank/Tanimoto
University of Southern California
075639-W TTP06
Testing and Improving the SCEC Community Velocity Model 3.0 with TriNet Broadband Data
02/01/02-01/31/07
$25,000
Broadband seismic data from TriNet provides an excellent opportunity to test the SCEC Community Velocity Model 3.0 (*SCEC CVM 3.0; Kohler et al.*, 2002). Our preliminary analysis in the first year indicated that surface waves for frequencies about 20-50 mHz are not fit by the CVM 3.0. We propose to analyze teleseismic surface waves and body waves recorded by TriNet and to construct an improved model. The ultimate purpose is to construct a model of large-scale 3D structure in Southern California which will serve as a good reference model. The resulting model will enhance the CVM 3.0 in many ways. For example, S-wave velocity structure in the crust and mantle will be better constrained because of the addition of surface wave data to the body wave data. The model will provide an extension into the oceanic region because of new TriNet stations and the accumulation of island station data. The model will also expand the mantle region covered by the CVM 3.0. The mantle in the CVM 3.0 spans a region smaller than the crustal region. The model will provide a well-constrained overview of long-wavelength features in the entire Southern California region and thus will help us understand the overall tectonic

features. Our preliminary maps contain some surprising features that will potentially lead to a new understanding of large-scale tectonics in this region.

Burbank/Olsen
University of Southern California
075639-E OKP10
Direct Measurement of the Slip-Weakening Distance from Near-Fault Strong Motion Data
02/01/02-01/31/07
$20,000
The proposed research is inspired by the request from two different Focus Groups to analyze the nature of friction, in particular using information from radiated waves emitted by the earthquake rupture (Goals 3d and 4c). Here, we propose to investigate in detail to which extent one of the most important frictional parameters controlling earthquake rupture propagation, the slip-weakening distance D_c, may be estimated directly from near-fault strong motion records for steeply-dipping shear faults. Preliminary results using numerical dynamic rupture simulations in a slip-weakening model indicate that D_c can be estimated within an error of 50% as the slip displacement at the time of the peak slip-velocity T_{pv} from the near-field fault-parallel component of ground motion. This technique may provide the only estimate of D_c independently of the fracture energy G, and therefore also an estimate of the strength drop using D_c and G. The method provides a very simple approach that could lead to significant progress in characterizing the friction of earthquake rupture.

Burbank/Olsen
University of Southern California
075639-F OKP11
3D Ground Motion Simulation in Basins
02/01/02-01/31/07
$29,500
The project will foster the integration of 3D ground motion simulation methods and results into engineering applications. We will validate 3D simulation methods and apply them to complex geological structures, with emphasis on urban sedimentary basins. We propose a coordinated, multi-institutional investigation, with funding shared between the Pacific Earthquake Engineering (PEER) Center and the Southern California Earthquake Center (SCEC). The PEER and SCEC research components will be fully integrated, and the project will be structured to address the engineering and science requirements of both Centers. A companion proposal with the same title and team of investigators was submitted to SCEC in December 2001.

Burbank/Olsen
University of Southern California
075639-G OKP12
Fully Three-Dimensional, Multi-Scale Waveform Tomography for the Los Angeles Basin
02/01/02-01/31/07
$10,000
We propose to conduct a 3D tomography study for the seismic velocities in the LA Basin and its immediate neighboring regions. The approach we take represents an improvement to the similar studies in three aspects. First, we use waveform-based measurements such that more information in seismic records can be utilized to provide better constraints (coverage) to the velocity structure. Second, we adopt

accurate finite-difference method to compute sensitivity or Frechet kernels of the measurements so that 3D reference models can be accommodated without the need for high frequency or averaging approximations. Finally, we pursue the inversions in a multi-scale fashion, starting from lower frequency and inverting for larger-scale structures, and progress to higher frequencies and smaller-scale structures. This ensures that the linearity between data and structural parameters is better preserved at each step of the inversions.

Burbank/Olsen
University of Southern California
075639-H OKP13
How Can We Improve Ground Motion Estimates by Lessons Learned from Rupture Dynamics?
02/01/02-01/31/07
$25,000
The proposed research is a priority within several SCEC focus groups. The Fault Systems Group asks for examination of the effects of fault (Goal 2f) and fault-zone (Goals 2a, g) complexities. In the Rupture Dynamics Group, goals include rupture branching (Goal 4e), normal-stress effects (Goal 4f), and rupture behavior at step-overs (Goal 4h). The Wave Propagation Group requests analysis of near-fault ground motion and the effects on strong ground motion from energy trapped between the fault plane and the free surface for thrust fault. (Goal 5-4).

Here, we propose to address these issues to improve estimates of strong ground motion using significant advances recently obtained in dynamic rupture modeling. We will compare traditional prescribed (kinematic) and spontaneous dynamic rupture propagation and will report on differences for thrust faults with various dip angles and dynamic friction. We will examine the significance of fault curvature and bends on near-fault strong ground motion. Finally, we will examine to which extent broadband strong motion synthetics may be improved by including results from dynamic rupture modeling, such as the shape of the sliprate functions and variation in rise time.

Burbank/Sorlien
University of Southern California
075639-K SCP03
Building the SCEC 3D Community Fault Model: Santa Barbara Channel and Santa Monica Bay
02/01/02-01/31/07
$30,000
We have produced digital structure-contour maps of deformed strata and of fault surfaces that cover a large area of Santa Monica Bay, Santa Barbara Channel, and offshore south-central California. SCEC funds are requested for extending and completion of existing digital maps and for construction of a web page for release of these maps. These maps and related information will be made available for use in the 3D Community Fault Model (CFM). This effort also includes improving the velocity model and depth conversion for certain maps, and improving the gridding from digitized contours for others. Mapped fault surfaces include the Red Mountain, North Channel, Pitas Point, and Dume (offshore Santa Monica). SCEC funding will allow us to construct digital surfaces on the offshore Oak Ridge fault and on the offshore Malibu Coast-Santa Cruz Island fault, and extend mapping on the offshore Red Mountain and other faults. We will have NEHRP funding during 2002 to complete mapping in northeast Santa Monica Bay, including the offshore Santa Monica-Dume fault, Palos Verdes fault (if present, *Fisher et al.*, 2001), and on strands of the broad San Pedro basin fault zone.

Burbank/Steidl
University of Southern California
075639-M SJP07
SCEC Portable Broadband Instrument Center
02/01/02-01/31/07
$160,000
The Portable Broadband Instrument Center's (PBIC) ability to respond rapidly to a major Southern California earthquake with the deployment of seismographs in the near-source region is a critical asset of SCEC. This has been highlighted by the success of the PBIC deployments from four major earthquake sequences in the past decade. The ability to conduct innovative experiments using PBIC equipment in between earthquake sequences is another important asset of SCEC. The list of PBIC publications is a testament to the importance and success of the SCEC PBIC program and how it has facilitated research over the years. This proposal is to continue support of the operations and maintenance of the existing PBIC equipment, to continue the software and web development, and to serve as seed funding for a new state-of-the-art PBIC proposal that will be submitted to the NSF Major Research Instrumentation (MRI) program in January, 2003. This new PBIC would include wireless communication technology and next generation network dataloggers for seamless integration of data into the Southern California TriNet regional network, or any other regional network that supports real-time telemetry of data.

Burbank/Tanimoto
University of Southern California
075639AB TTP07
Improving S-Wave Velocity in the SCEC Community Velocity Model through Teleseismic Broadband Data
02/01/02-01/31/07
$50,000
Taking advantage of a vast amount of broadband seismic data from TriNet, we propose to construct a model of 3D large-scale structure in Southern California. Specific data to be analyzed are teleseismic surface waves and body waves recorded by TriNet. The resulting structure will be of a lower resolution than the one developed by the Community Velocity Model but has two attractive features:

- S-wave velocity structure in the crust and mantle down to a depth about 100 km can be constrained. The model will constrain large-scale features of 3D structure in the crust and mantle and thus *may serve as a good starting model for the inversion of more detailed 3D structure*.

- The model provides a well-constrained overview of long-wavelength features in the entire Southern California. It will help us understand the overall tectonic features. Our preliminary maps contain some surprising features that may lead to new understanding of large-scale tectonics in this region.

We have collected phase velocity data from TriNet for about 3000-4000 paths for Rayleigh and Love wave data and are in the process of measuring body wave differential travel times for about 70 events we have collected so far. During the proposed period of this study, we will develop a 3D S-wave velocity model for Southern California which will satisfy both surface waves and differential body wave travel

times. We will also examine existing P-wave velocity models (e.g., *Kohler et al.*, 2001) by measuring P-wave differential travel times in TriNet data.

Burbank/Sorlien
University of Southern California
075639AC SCP06
The faults responsible for the complete Palos Verde anticlinorium: Alternate representations for the Community Fault Model
02/01/02-01/31/07
$20,000

Burbank/Sorlien
University of Southern California
075639Y SCP05
Alternate representation of the Channels Islands thrust for the Community Fault Model
02/01/02-01/31/07
$20,000

Burbank/Niemi
University of Southern California
075639AA NNP02
Seismic Hazard Assessment of Urban, fault-Related Uplifts from Quantitative Geomorphology
02/01/02-01/31/07
$16,137

Burbank/Niemi
University of Southern California
075639Z NNP01
Development and Integration of the SCEC Community Vertical Motion Map
02/01/02-01/31/07
$19,035

Burbank/Liu
University of Southern California
07563AC LPP04
Developing and Validating a Method for Prediction of Broadband Time Histories
02/01/02-01/31/07
$25,000

Burbank/Archuleta
University of Southern California
07563AC ARP28
3D Rupture Dynamics, Validation of the Numericlal Simulation Method
02/01/02-01/31/07
$41,000

Burbank/Archuleta
University of Southern California
07563X ARP29
Quantifying the Variability in Linear Site Response
02/01/02-01/31/07
$20,000

Burbank/Archuleta
University of Southern California
07563AC ARP32
Inversion of Seismic and Geodetic Data from the 2004 Parkfield Earthquake
02/01/02-01/31/07
$30,000

Burbank/Archuleta
University of Southern California
0100810 ARP33
Implementation of SCEC Research for Seismic Risk Reduction02/01/02-01/31/07
$40,000
