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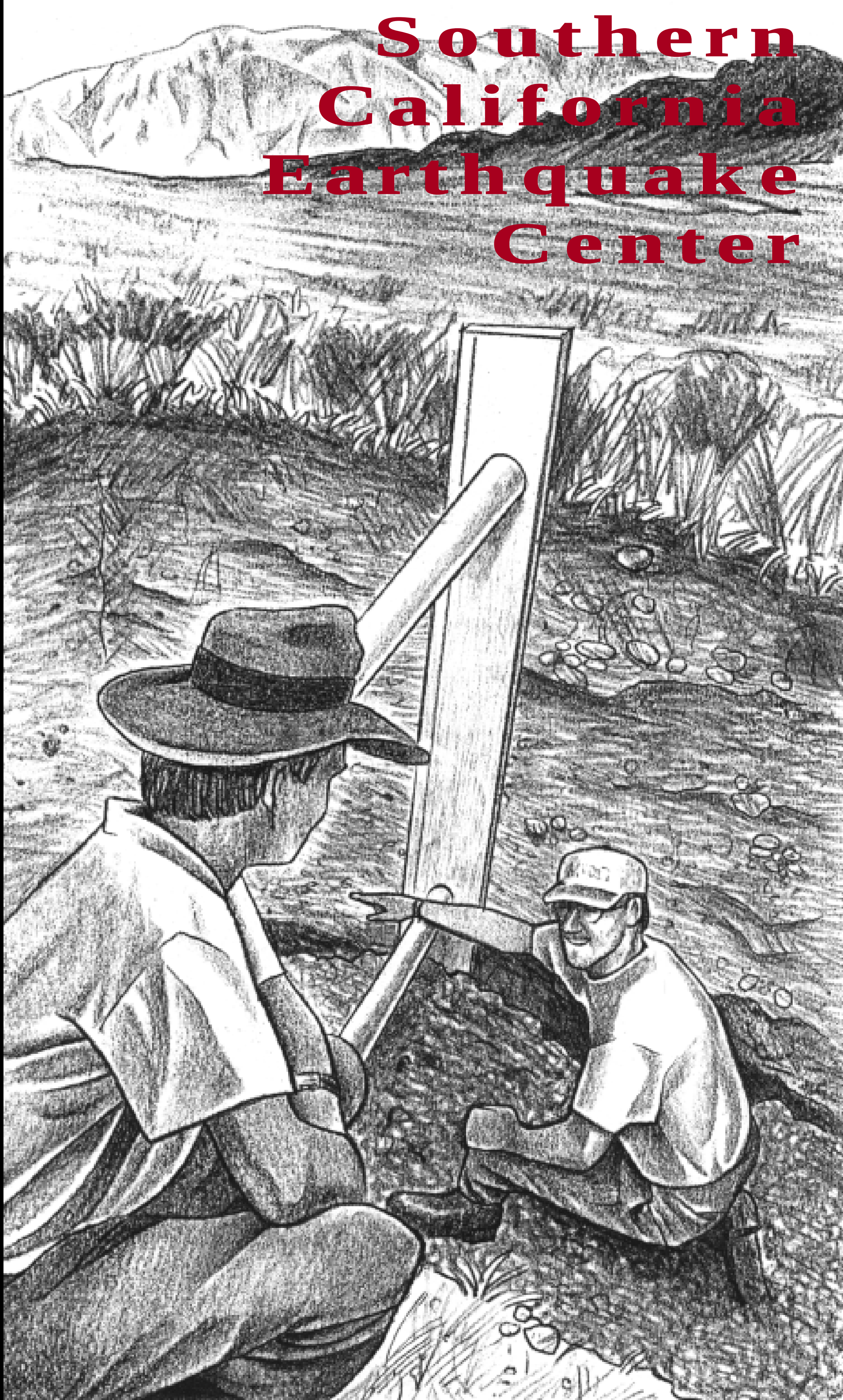
Southern California Earthquake Center

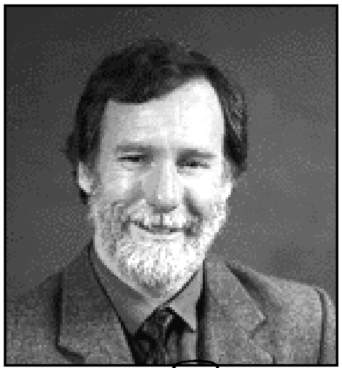


SCEC

From the Center Directors . . .

Stepping into the 21st Century

Center Director



Science Director

[Following is the letter of intent to NSF, expressing SCEC's plan to apply for another full round of funding as a Science and Technology Center, expanding its scope beyond southern California.]

Researchers from the following academic institutions—the University of Southern California (lead institution), California Institute of Technology, Columbia University, the Universities of California at San Diego, Los Angeles, Santa Barbara, Santa Cruz, Berkeley, and Davis, Stanford University, San Diego State University, the University of Nevada at Reno, the University of Utah, and the University of Colorado—in partnership with Caltech's Jet Propulsion Laboratory, the Lawrence Livermore National Laboratory, the U.S. Geological Survey, and the California Division of Mines and Geology plan to submit a proposal to the STC program on the physics of earthquakes with the principal motivation to develop advanced models of seismic hazard analysis.

The proposed STC will build upon, and greatly expand, the goals of the current Southern California Earthquake Center by: (1) extending the current center's natural laboratory to include the entire San Andreas transform plate margin, (2) focusing on the physics of the earthquake process including stress evolution, plate boundary deformation and tectonics, fault zone structure and fault interactions, earthquake nucleation, rupture dynamics, and wave propagation through complex media, (3) adding a high-performance computing component with the ultimate objective of simulating the earthquake generating system represented by the San Andreas, (4) enlarging the membership of the current center, (5) extending the knowledge transfer effort to include end users throughout western U.S., (6) adding an international component of scientific exchange and investigation of foreign earthquakes, and (7) developing a formal research, education and knowledge transfer interface with the new Pacific Earthquake Engineering Research Center.

A fundamental physical understanding of the earthquake process will enable us to develop an approach to seismic hazard analysis that: (1) is based upon greatly improved estimates of the locations, times of occurrence, and sizes of future earthquakes, and (2) incorporates realistic simulations of dynamic rupture and wave propagation for synthesizing time histories of strong ground shaking needed in performance-based seismic engineering design. Resultant computer models, together with the core database, will constitute the physical "master model" into which the diverse, multidisciplinary research activities of the center will be integrated.

We believe that the San Andreas fault system in the western U.S. offers the best opportunity for developing a physical model of the earthquake process since it is currently the best understood and most accessible such system in the world. Furthermore, the high population density of California provides the rationale for the development of advanced seismic hazard models in this region.

The proposed center's strategic plan will consist of goals and objectives that will be developed into research tasks to be tackled by multidisciplinary teams of investigators. Graduate and post-graduate education will play a prominent role in the research. Undergraduate internships, and partnerships with high-achieving primary and secondary school districts will be important parts of the educational program. Knowledge transfer activities will emphasize outreach to other scientists, practicing geotechnical and structural engineers, emergency preparedness officials, public utilities, local and state government, and the general public.

The high population density of California provides the rationale for the development of advanced seismic hazard models in this region

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SCEC Holds Sixth Annual Meeting

• Reports of Working Groups • Overview of Research • Planning the Next Incarnation •

by Jill Andrews

The Southern California Earthquake Center held its sixth annual meeting in Costa Mesa, California, in October. The purpose of the meeting was to convene Center-funded scientists and others interested in participating in Center research to discuss new and ongoing projects for the next fiscal year. This year, over 250 scientists attended.

The meeting had both administrative and science-related purposes: meeting with SCEC's advisory council to detail plans and listen to advice; a poster session in which more than 100 projects supported by SCEC were displayed and discussed; update sessions for each of SCEC's working groups; a featured speaker on the detective work that has gone into understanding the New Madrid fault; and a large panel discussion, including invited participants from several key northern California agencies, on whether and how to expand the work of SCEC to the entire state.

The program began with Center Director Tom Henyey's overview of SCEC's science program. He reiterated the Center's scientific mission: to develop and improve the scientific basis of earthquake hazard estimation through research in southern California. And the four primary objectives of the Center:

1. **Estimating earthquake potential**, or the probability of earthquake occurrence as a function of location, magnitude, and time. Earthquake potential research includes geological studies to identify active faults and to estimate their maximum magnitudes and slip rates; geodetic studies to measure regional and local strain rates; seismicity observations, and focal mechanism studies.
2. **Understanding earthquake rupture dynamics** / source physics. Earthquake rupture dynamics / source physics research includes theoretical and numerical studies of rupture initiation, propagation, and arrest.
3. **Understanding the nature of wave propagation** through a 3-D heterogeneous crust. Wave propagation research includes the development of 3-D velocity models, basin effects, focusing and defocusing of seismic waves, imaging of subsurface structures, and the estimation of path effects using theoretical and empirical Green's functions.

4. **Predicting ground motions**, or complete theoretical seismograms for any earthquakes observed at any site. Ground motion research has the objective of predicting the full theoretical seismograms ("time histories") for any combination of earthquake and site. The ultimate objective is to explain the seismic records for past earthquakes and develop the capability to predict ground motions from hypothetical future earthquakes.

Fiscal year 1998 funding will go toward Center infrastructure, education and outreach, workshops, and a special Caltrans project. Caltrans has requested SCEC assistance in gathering data and estimating seismic hazards relevant to Caltrans facilities in southern California, including development of time histories for scenario earthquakes, long-period basin response, and sources of potentially damaging earthquakes in the' metropolitan region.

Primary tasks leading to meeting the Center's scientific mission and objectives for 1998 are:

Seismic Hazard Estimation—The Phase III report will describe a suite of seismic source models for southern California, examine models for local site effects, describe the effect of 3-D wave propagation in sedimentary basins, show representative seismograms for scenario earthquakes, and discuss uncertainties and sensitivity to assumptions in seismic hazard estimation. In addition, the report will present several databases, including an earthquake catalog, fault slip rate table, soil map, and theoretical seismograms.

3-D Seismic Velocity Model—Calculation of complete seismograms requires a model to evaluate P and S wave velocities at any arbitrary point in the medium through which seismic waves propagate. SCEC will organize an interdisciplinary project to construct a standard seismic velocity model, satisfying a range of geophysical and geological observations, including strong motion seismograms, earthquake travel times, and borehole geologic data.

Stress Evolution—Earthquakes result from stress release on faults, and one desired feature of the Center's Master Model is a facility for calculating the stress accumulation from past earthquakes, tectonics, and viscoelastic stress relaxation. Research will include calculation of time-dependent stresses, and comparison of earthquake occurrence (including aftershocks) with the local stress field.

Full statements of the disciplinary working groups' goals and objectives can be found on the SCEC web site (www.scec.org). In summary, they are:

Group A: Master Model Construction and Seismic Hazard Analysis, led by David Jackson (UCLA)

The goals of Group A are to: (1) communicate the results of the "Phase III" report on seismic hazards in southern California; (2) develop the "online Phase III report," i.e., the capability to revise input data and models used in the report and to allow selected users interactive capability to apply the methodology for their own cases; and (3) develop and test realistic models of stress interactions from past earthquakes on active faults.

Many topics that will be covered in the "Phase III" report overlap those covered by other working groups. The distinction between Group A's efforts and the efforts of other groups is that Group A's activities carry a higher commitment to integration with related studies and to producing data in standard format with strict deadlines. For example, geologic studies to determine the geometry and slip history of certain sites is covered by Group C; identifying coordinates and slip rates of all fault segments to be used in seismic hazard calculations, providing these data in standard tables, obtaining consensus from the larger community on the values to be used, and assuring valid use of the data is a task for Group A.

To meet task requirements set forth in the Master Model, scientists in Group A will address seismic hazard estimation by preparing standard databases of fault geometry for use in the Phase III and subsequent reports. They will integrate geologic, geodetic, and seismological information on fault geometry and adjust slip rates to agree with estimates of total slip rate or moment rate determined from plate tectonic or other methods. They will also develop explicit models for estimating earthquake probabilities in a form required for the Phase III and subsequent reports and test these models against available earthquake catalogs and other data.

To address stress evolution, the group will develop and test models for the stress effects of past earthquakes on faults, allowing for the accumulation of aseismic tectonic stress and inelastic stress relaxation, model the effect of these stress changes on earthquake probabilities, and test these models using available earthquake data. They plan to hold workshops on this topic, establish a standard database of fault geometries and earthquake source properties, cross-check computations, and compile results in a major publication.

Group B: Ground Motion Modeling, led by Steve Day (USD)

The focus of Group B is on the prediction of ground motion time histories from earthquakes and all aspects of how source, path, and site characteristics influence seismic ground motion. Here ground motion refers to all aspects of a seismogram including ground displacements, velocities, accelerations, duration of motion, and frequency content.

One area of emphasis will be broadband synthetic time history computations for scenario earthquakes. Research will include improvement and validation of source / propagation models, improvement of the physical basis for the models, and quantification of uncertainties in ground motion predictions. Researchers collaborate in the assembly of a reviewed suite of scenario earthquake time histories for release by SCEC to the engineering community.

Another area of emphasis will be 3-D modeling of basin effects on ground motion, with particular reference to the Los Angeles basin. This process includes: (1) contributions to the development of the seismic velocity model for southern California as required to improve 3-D ground motion computations; (2) studies directed toward model validation; (3) computational studies in which source characteristics are varied to identify systematic patterns in basin excitation; and (4) computational studies to establish the sensitivity of ground motion predictions to uncertainties in the geologic model.

The third area of emphasis is site effects. Research will be funded that contributes to development and validation of empirical or theoretical methods to correct ground motion predictions for local site effects. These contributions include assembly of existing data, collection of new data where needed, statistical analysis of site response data, and data analysis and modeling directed toward an improved understanding of site response. Also important are studies of nonlinearity of site response, including research to identify nonlinear effects in recorded ground motion and the validation of computational models for nonlinearity.

Group C: Earthquake Geology, led by Kerry Sieh (Caltech)

Group C will focus in three areas in 1998. The first is paleoseismic research along the San Andreas fault. This activity is aimed at dramatically improving our knowledge of the history of large earthquakes along the southern half of California's master fault. During the September 1997 field workshop, several scientists visited and discussed existing and potential paleoseismic sites. In 1998 they

plan to continue development of two or three sites with demonstrated potential and to explore the feasibility of several other sites. (See this issue's article on the San Andreas Paleoseismology Project for details of the field workshop's activities.)

The second area of focus will be paleoseismic research within the Los Angeles Metropolitan Region. This activity will lead to determining whether large-magnitude (M7+) events have been produced by metropolitan faults in the past few tens of thousands of years. The primary method will be to excavate surface traces of nonblind faults to determine which have failed in moderate events and which have ruptured in large events. Eventually, Group C will determine the dates of these prehistoric events; the dating will not be a major focus of Group C's efforts until subsequent years, but proposals for the work will be considered in 1998.

The third area is investigations of various neotectonic and paleoseismic problems in southern California. This activity includes projects that would not be part of the two activities described above. Research will address fundamental problems or practical issues of seismic hazard evaluation and fault behavior. Subjects may include the evaluation of the geometry, styles and rates of important southern California structures, and the dates and magnitude of their latest earthquakes; evaluation of the magnitude of aseismic permanent deformation; and fundamental observation-based studies of fault segmentation and the repetition of earthquake ruptures.

Group D: Subsurface Imaging and Tectonics/ Source Processes and Seismicity, led by Rob Clayton (Caltech)

At the 1996 annual meeting it was decided to combine groups D and F under the single title Subsurface Imaging, Seismicity, and Tectonics. The objectives and specific areas of interest are now combined from both groups and contribute to all questions raised in the SCEC plan. Group D will continue its 5-year plan of investigations in the following areas:

- Integrated velocity models and seismicity parameters
- Subsurface structure of the L.A. basin
- Relationship of seismicity patterns to structure
- Dynamic and kinematic tectonic studies
- Measurements of fault-zone properties
- Stress measurements
- High-resolution studies of shallow fault zones

The LARSE II proposal to conduct an active source survey from Santa Monica through the Northridge epicenter and across the Santa Susana Mountains was submitted to SCEC, NSF, and USGS in the first part of 1997. If fully funded, the experiment will be done in the fall of 1998.

At the 1997 annual meeting, the following specific areas of research were identified:

- Integration of basin velocity models with regional models
- Relocation of seismicity catalogue in the new model and the integration of source parameters (mechanisms) in the catalogue
- Use of trapped waves and high-resolution techniques to measure fault-zone properties such as asperities or segmentation
- Development of dynamic tectonic models that relate plate loading forces to geologic and geodetic strain rates and to seismicity
- Acquisition and archiving of industry seismic and borehole data
- Rapid determination of source parameters from near-real-time ground motion measurements
- Use of waveform methods to determine seismic structure and velocities

Group E: Crustal Deformation, led by Ken Hudnut (USGS Pasadena)

Group E will continue to improve the SCEC velocity map, and apply it and other high-precision geodetic measurements to the tasks in new projects for the coming year. Research is encouraged that addresses these tasks and applies promising approaches to problems such as stress evolution, fault interaction, and post-seismic behavior.

Group E's efforts are divided into "infrastructure" and "science." Infrastructure is defined more broadly than it is by other groups and is meant to include the acquisition of data for crustal deformation, hazards, and other modeling. The "science" goals are focused on the interpretation of such data.

In the infrastructure category, preference will be given to projects that best complement anticipated products of the SCIGN (e.g., studies or activities that provide spatial or temporal information that will not be attainable with the SCIGN array). In the science category, projects that make innovative use of data or products from the SCIGN project are encouraged. Infrastructure work will include continued contribution toward operation of SCIGN to provide a regional framework for other GPS studies and to begin to elucidate more details of deformation in the Los Angeles region.

Plans also include continuing work toward production of the third release of the SCEC velocity map. This includes continuing data processing and analysis (and some software support) by three or four institutions working together. In addition, the group plans operation of an archiving facility to get field GPS data onto the SCEC-DC archive, in support of continuing work on the velocity map. Additional GPS fieldwork, especially in support of the velocity map project, will be another targeted research area.

This year, the group is conducting economical projects to support occupations of the many campaign mode GPS stations that have not been occupied in several years and that would improve the SCEC velocity map. Other modest research projects, e.g., studies of Landers or Northridge post-seismic deformation, will also be

conducted. Continued operation of Piñion Flats Observatory will provide a detailed time history of strain.

In the science category, plans include interpretation of velocity maps: how to convert from velocity to strain to hazardous strain? The group needs to construct physical models that explain the velocity map and model stress interaction and stress evolution. Other questions include: What geodetic signals are expected from geophysical or geological models, especially in the Los Angeles region? How can we infer stress change, especially at seismogenic depths, from surface displacements? In the area of post-seismic phenomena, are there regional, long-period signals? If so, how may they be explained? Are there changes in aseismic slip rate on neighboring faults following moderate-to-large earthquakes in the region (e.g., Landers and Northridge)? What can be learned about coseismic slip heterogeneity? What is an accurate error model for continuous GPS data?

Group G: Physics of Earthquake Sources, led by Leon Knopoff (UCLA)

Group G will focus in three areas in 1998. The first is the evolution of seismicity and stress. The group intends to model the evolution of seismic histories and the space-time evolution of the stress field on a two-dimensional network of faults, with reference to the network of faults in southern California. In particular, they wish to understand space-time clustering and self-organization on systems with inhomogeneous, nonuniform properties and geometries to simulate the occurrence of large- and intermediate-magnitude earthquakes, and their comparison with contemporary earthquake catalogs.

Particular issues that bear on the above problem include: (1) fracture dynamics; (2) interactions with a viscous substrate; (3) healing and self-healing; (4) the influence of geometry on the growth of fractures; (5) segmentation and characteristic earthquakes; (6) the relaxation of stresses at geometrical barriers to rupture and other dissipative processes; (7) the influence of dissipation on the regional nucleation and clustering of seismicity prior to large earthquakes on the time scales of available earthquake catalogs; (8) stationarity, or otherwise, in the time series of large and intermediate magnitude earthquakes in southern California and appropriate statistical descriptions of the seismicity in southern California; (9) fault growth and evolution; (10) correlations in the stress field; and (11) networks of tiles or of branching faults.

The second area of focus will be source-time slip functions. Group G scientists will calculate source-time functions for dynamic models of faulting under conditions of inhomogeneity of geometry and stress on faults. Of special interest is the relationship between dynamic fault motions and the level of friction during sliding, inhomogeneity in the fracture thresholds, and arrest conditions.

The third area will be friction during individual earthquakes. Group G scientists will also study the relationships between the microphysics of rapid sliding and macroscopic parameterizations of faulting. This research will focus on: (1) the problems of nucleation and breakout; (2) the problem of the final state of stress on a fault and how motion is arrested; (3) the relationship between fault geometry and friction; (4) fluid-rock interactions; (5) frictional heating during rapid slip; (6) the relationship between the irregularity of slip and aftershock distributions; (7) the dynamics of granular media (gouge) and the development of slip in a fault zone; (8) the problems of weakening of friction in the dynamic regime of faulting; (9) the transition between static and dynamic friction; (10) fault-zone dynamics under constraints of heterogeneous physical properties and geometry.

NOTE: At this writing, all proposals in response to the RFP for 1998 projects had been submitted to the SCEC administration. The proposals will be reviewed during the first two weeks of January 1998, and decisions for funding will be made at a two-day meeting of the board of directors on January 22-23, 1998.

What Is the Southern California Earthquake Center?

The Southern California Earthquake Center (SCEC) actively coordinates research on southern California earthquake hazards and focuses on applying earth sciences to earthquake hazard reduction. Founded in 1991, SCEC is a National Science Foundation (NSF) Science and Technology Center with administrative and program offices located at the University of Southern California. It is co-funded by the United States Geological Survey (USGS). The center also receives funds from the Federal Emergency Management Agency (FEMA) for its Education and Knowledge Transfer programs. The Center's primary objective is to develop a state of the art probabilitistic seismic hazard model for southern California by integrating earth science data. SCEC promotes earthquake hazard reduction by:

- Defining, through research, when and where future damaging earthquakes will occur in southern California
- Calculating the expected ground motions
- Communicating this information to the public

To date, SCEC scientists have focused on the region's earthquake potential. Representing several disciplines in the earth sciences, these scientists are conducting separate but related research projects with results that can be pieced together to provide some answers to questions such as *where* the active faults are, *how often* they slip, and *what size* earthquakes they can be expected to produce. Current work focuses on seismic wave path effects and local site conditions for developing a complete seismic hazard assessment of southern California.

Information: Call 213/740-1560 or e-mail *ScecInfo@usc.edu*

Uncertainty in Earthquake Source Characterization for the Los Angeles Basin

by Bill Foxall

A major source of uncertainty in seismic hazard estimates for the Los Angeles basin is uncertainty in the geometry—and in some cases the existence—of significant active faults. This epistemic uncertainty stems largely from the fundamentally different tectonic deformation models—specifically, “thin-skinned” and “thick-skinned” models—that have been proposed for the region.

Thin-skinned models, besides containing major active blind thrust ramps, imply significantly different sub-surface geometries for some major surface faults from those in the thick-skinned model. These uncertainties are not systematically incorporated in the CDMG / USGS earthquake source model, which is the model used in SCEC Phase III.

The objective of my 1997 SCEC project, in collaboration with Norm Abrahamson and Allin Cornell, was to develop a set of internally consistent earthquake source characterizations for the L.A. basin and the surrounding region that captures the range of viable alternative tectonic interpretations.

This set of alternative characterizations will enable the source uncertainties to be propagated through probabilistic seismic hazard analyses to obtain rigorous estimates of uncertainties in the hazard using a “logic tree” approach (see, for example, Senior Seismic Hazards Analysis Committee [SSHAC], 1997). One of the most important steps in constructing the logic tree is assigning appropriate relative weights to the alternative source descriptions, based on careful consideration of the weight of evidence for each of the alternatives.

Development of the alternative source characterizations was centered on a workshop held at USC on September 18-19, 1997, which 54 SCEC scientists attended. The workshop was structured, following a simple form of the procedures recommended by SSHAC (1997), to: (1) ensure that development of the source characterizations is based on the latest state of knowledge; (2) through the exchange of current information and directed debate of the evidence for and against each of the tectonic interpretations, to lay the foundation for determining relative weights for the source characterizations; and (3) ensure that the source characterizations and associated weights represent the consensus view of the SCEC community.

The workshop included 18 invited talks given by proponents of the alternative tectonic models and by other researchers having recent results that have direct bearing on the models. Three knowledgeable “evaluators,” Kathryn Hanson (Geomatrix), Lee Silver (Caltech), and Bob Smith (Univ. Utah), had the role of evaluating the tectonic models and source characterizations, and, in conjunction with the “technical integrator” team (Abrahamson, Cornell, and Foxall), of weighting the alternatives.

A set of “strawmen” source characterizations developed before the workshop, based on a thorough review of current data and interpretations, served to focus the discussion. Hazard estimates resulting from the strawmen were compared to examine the sensitivity of the hazard to differences among the source characterizations.

The workshop went a long way toward achieving its objectives. However, we did not reach our goal of completing the logic tree and assigning a preliminary set of weights on which the workshop participants could give their feedback. This was because, in the time available, we were unable to incorporate all the new information that was presented, particularly that relating to new regional detachment and crustal shortening models.

A significant outcome with respect to the central thin- versus thick-skinned issue was widespread (although not unanimous) agreement that evidence presented by Karl Mueller strongly suggests that the Compton-Los Alamitos thrust of Shaw and Suppe (1996) has been inactive since at least 15ka. The existence and activity of the Compton thrust also has a direct bearing on the geometry and rupture characteristics of the Palos Verdes fault.

This is the most complex source characterization issue in the southwestern basin, since in the most plausible of the alternative models proposed by Shaw and Suppe, the thrust offsets the Palos Verdes (and Newport-Inglewood) fault, allowing the possibility of vertical segmentation of the fault. There was similar agreement that, based on evidence summarized by Jim Dolan, the Santa Monica Mountains thrust is also either inactive or slips at a much lower rate (<0.5 mm / yr) than originally proposed by Davies et al. (1989).

The workshop also focused on the mechanics of crustal shortening in and surrounding the north and NE basin, including assimilation to the NW of right-lateral displacement on the Elsinore-Whittier system. Data on Holocene deformation rates of fold and fault structures in this area are still sparse. Given geodetic results showing a concentration of deformation in the north basin and the apparently low slip rate on the central Sierra Madre fault, our poor understanding of this area is an important source of uncertainty in source characterization. The “extrusion” model of Walls et al. (1997) accounts for the geodetically observed rates by postulating slip rates in the range 0.5–3 mm / yr on prominent but poorly studied faults, including the Chino, San Jose, and Verdugo, but these rates have yet to be validated.

Researchers studying deformation along the Elysian Park anticlinorium (Yeats, Oskin, Shaw) agreed that sources of active folding NW and south of the Whittier fault are most likely short (10-20 km), en echelon, steeply dipping reverse fault segments. These faults, the sources of moderate events like the 1987 Whittier Narrows earthquake, are probably best modeled as a zone of distributed faulting. Other major uncertainty issues related to shortening in the north basin that are being incorporated into the source characterization include:

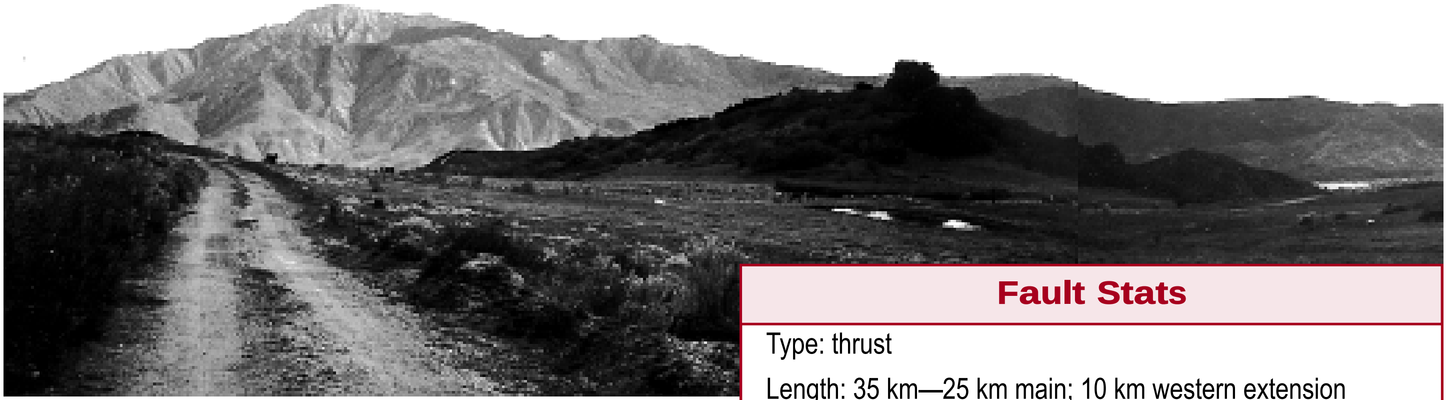
- Implications for the activity and existence of the Elysian Park thrust ramp (and central basin decollement) of Shaw and Suppe (1996) of the

See “Uncertainty” on Page 15

New Surgery on California's Main Fault

The San Andreas Paleoseismic Project

A Field Trip to San Gorgonio Pass



Fault Stats

Type: thrust

Length: 35 km—25 km main; 10 km western extension

Slip Rate: uncertain

Most Recent Rupture: Holocene; Late Quaternary (western)

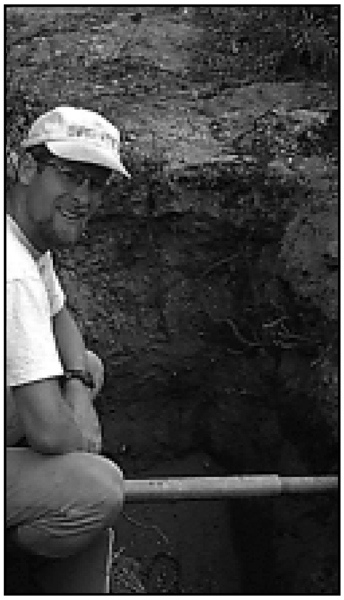
Maximum Magnitude: 6.0–7.0 (?)

Recurrence Interval: uncertain

Description: Dips to the north. The San Gorgonio Pass area is complex geologically. Here the San Andreas interacts other faults (notably the San Jacinto fault zone and the Pinto Mountain fault) and becomes fractured from just north of San Bernardino to just north of Indio, about 110 km. Because this deformation has been going on for over a million years, ancient and inactive strands of the San Andreas fault can be found here.

by Jill Andrews

In late November, Professor Kerry Sieh (Caltech) invited me to join him and some of his students for a day of mapping a potential study site on the Morongo Indian Reservation near Banning. Although I've promoted the work of earthquake scientists for many years, I'd never spent a whole day just observing geologists at work in the field. I jumped at the opportunity. I came away with a new perspective on geology-as-vocation, secretly wishing I had been exposed to it when I was making career choices 20 years ago.



My goal was to do a short newsletter article about SCEC's Group C (Earthquake Geology) plans to propose a "new attack" on the San Andreas fault (the "San Andreas Paleoseismic Project"). I did my own "trenching" to dig deeper into the history of paleoseismology at the San Andreas fault.

The ability to evaluate earthquake hazards is based on understanding the past behavior of earthquake-producing faults. The greatest source of information about prehistoric is the geologic record. Paleoseismology is the study of the occurrence, size, timing, and frequency of ancient earthquakes. It extends over a much longer time period than our historic records, and so is important to us because the recurrence intervals for large, damaging earthquakes in active regions are usually a few hundred to a few thousand years for longer than the period of historic or instrumental record.

In 1986, the National Academy of Sciences recognized that paleoseismology contributed fundamentally to understanding earthquakes. After spending a day with Sieh and his students, I can add that paleoseismology is a great way to combine science with enjoying the outdoors. Or as Sieh says, a "wonderful combination of outdoor physical activity and intellectual activity that applies physics, chemistry, structural geology, and sedimentology to real world problems." That combination attracted him to geology as his undergraduate major at UC Riverside in the early 1970s.

At that time, paleoseismology was a concept that had not yet been born. Sieh did his graduate work at Stanford, proposing as his thesis a study of Pallett Creek, now considered the first successful paleoseismic site. Located astride the San Andreas fault 55 km northeast of Los Angeles, the site is on the locked segment between Tejon and Cajon Pass. Twelve large prehistoric and historic earthquakes were deduced from detailed descriptions of offset beds, fractures, sand blow deposits, and filled crevices, all dated by radiocarbon methods and displayed in the walls of the trenches (Figure 1). In the 20 years since the first Pallett Creek excavations, dozens of trench sites on major faults all over the world have revealed ancient records of repeating large earthquakes.

San Andreas Project

The newly-proposed "San Andreas Paleoseismic Project" is based on the concept that

scientists aren't collecting data rapidly enough to make significant progress toward understanding how the San Andreas fault behaves. A more complete dataset is needed. Since 1978, data from three or four paleoseismic sites have shown that the San Andreas fault breaks about every 105-160 years on average, depending on location along the fault. But the recurrence rate at each site is irregular. SCEC's Earthquake Geology group has recognized that there aren't enough existing study sites to put together a clear history of the fault's behavior in space and in time. Significant questions remain: Where have the great ruptures been? What have been their ends? How similar have repeated ruptures been?

The San Andreas Paleoseismic Project will entail a study of about 600 km of the San Andreas fault, stretching from Parkfield to the Salton Sea. Project participants (see sidebar) want to add eight more sites to the existing four over the next three years. The goal is to collect data that will help improve the Center's earthquake physicists' models of fault behavior as well as a more complete story of what has happened on the San Andreas fault. The data would also include tight enough dates using the best dating constraints, and information on what the slip amounts have been from event to event. This would help the physicists place constraints on their physical models, to better determine what can happen in the future. Sieh hopes that within 20 years to have realistic forecasts of where and how big the next earthquakes will be on the San Andreas fault. (He also hopes the next great earthquake will not happen in that time.)

Choosing the Sites

Site selection has typically been based on individual investigators' peer reviewed proposals. Sites for trenching are carefully chosen after geologic observation and mapping. To evaluate both horizontal and vertical components of displacement

The Value of Burro Flats

I went bushwhacking to look at two pit trench sites with Doug Yule (Caltech) and Andrew Meigs (Oregon State University). We saw fault scarps visible across the terrain, which is being buried by alluvium. These are young deposits coming down out of the uphill stream. The sand and gravel spreads across the swamp, unbroken.

This is the first place they would dig a full-size trench. There are some organic-rich layers in this pit trench. At the bottom of one of the pits is a black organic-rich peat layer. There's mostly sand and gravel above it, then some thick, dark organic-rich layers. This is ideal stratigraphy for paleoseismology—a high sedimentation rate with organic-rich layers. It's in-situ carbon, so the scientists avoid the issue of reworking charcoal.

The purpose of this pit is to determine whether the area has the stratigraphy needed to get good samples, and it turned out to be just what they wanted to see: sand and gravel inter-layered with organic material layers.

There's a chance they could find the displacements caused by up to 15 seismic events. More data equals better models: by placing that large number of events in time and space, they could gain a great deal of insight into the mechanisms of the fault and frequency of occurrences in that area. If they can compare the records they get with Wrightwood and the others, the information they derive could fill in the gap of missing information along this portion of the fault.

on strike-slip faults, two or more trenches are usually needed. Commonly, trenches dug perpendicular to the fault allow measurement of vertical displacement, and those dug parallel to the strike of the fault plane allow evaluation of the horizontal component of displacement. The objective is to find a “piercing point,” a distinctive feature that is offset along the fault (like a buried channel) so it can be identified again where it exits the fault on the opposite side. When datable material is recovered from these offset features, slip rates are calculated as the ratio of displacement to the time of event occurrence.

Because SCEC has a group dedicated to earthquake studies from a geological point of view, site selection for this project is a team effort. Sieh and his colleagues organized a September 1997 workshop dedicated to finding the best sites for consideration. The three-day field survey entailed a drive along about 500 km of the fault. They looked at sites that had either been fully developed (such as Pallett Creek and Wrightwood) or sites with potential, such as Burro Flats or Frazier Park. There were 15 people on the workshop trip. The plan is to deploy two principal investigators plus their graduate students per site, working either on feasibility studies for new sites or sites in progress.

Group C anticipates that new sites will evolve each year as older sites are completed and results published. The decision-making process will be democratic, and accountability will be emphasized. Sieh believes this will motivate scientists to get the work done in a timely fashion.

The Dating Process

Radiocarbon dating coupled with the best stratigraphy allows scientists to date offsets with uncertainties of ± 20 years. Although better dating methods have been possible in other geologic environments (for example, corals can be dated with precisions of just a few years), paleoseismologists are eager to use more precise dating methods for the San Andreas fault.

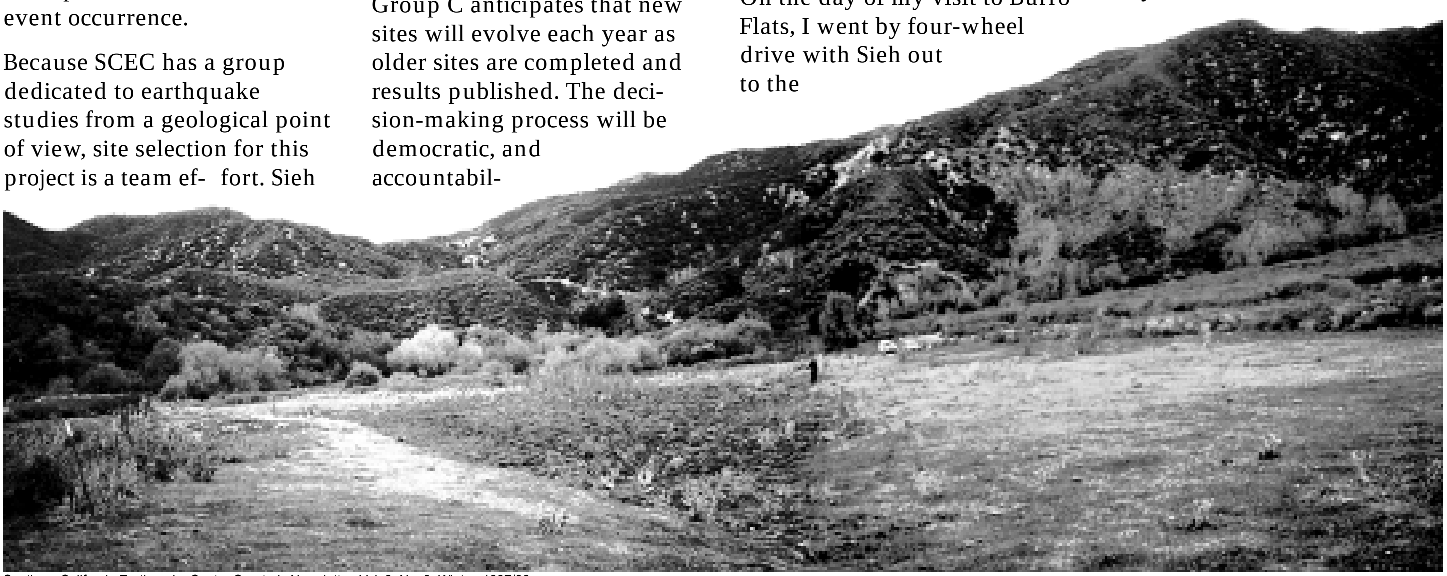
The best sites for the San Andreas fault are those that are depositing sediments faster than the earthquakes are happening. The sediments have to be thick enough so that earthquake “event horizons” can be distinguished from each other. This was the case at the Pallett Creek, Indio, Wrightwood, and Carrizo Plain sites. More high-quality sites may exist, although some creative civil engineering may have to be employed to drain them. Good examples are the Burro Flats and Frazier Park sites, both still swamps.

Burro Flats Feasibility Study

On the day of my visit to Burro Flats, I went by four-wheel drive with Sieh out to the Morongo Indian Reservation. According to Sieh, part of the site has obvious geomorphologic evidence of youthful faulting; another part has no obvious geomorphic expression of faulting but may contain an excellent stratigraphic record in the subsurface. He pointed out that those two are mutually exclusive. A surface that has experienced several earthquakes is not really very useful in a paleoseismic sense, because one can’t differentiate the individual earthquakes. At Burro Flats, the surface sat there for a thousand years and built up some structure—little anticlines, little synclines—but the event horizons aren’t distinguishable because they’re

Workshop Participants

Ramon Arrowsmith, Arizona St. Univ.
James Dolan, USC
Thomas Fumal, USGS, Menlo Park
Lisa Grant, Chapman Univ.
Scott Lindvall, Harza Engineering
Karl Mueller, Univ. of Colo., Boulder
Thomas Rockwell, San Diego St. Univ.
Charles Rubin, Central Wash. Univ.
Mike Rymer, USGS, Menlo Park
Gordon Seitz, Univ. of Oregon
Gianluca Valensise, Istituto Nazionale di Geofisica, Rome
Steven Ward, UC Santa Cruz
Ray Weldon, Univ. of Oregon

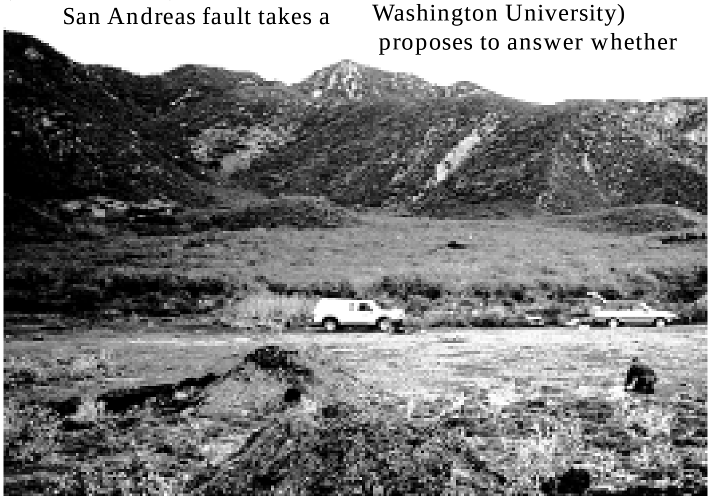


all on the same surface. If sediment buries a site more rapidly than the earthquakes are happening, then the landforms are also buried.

A promising feature of Burro Flats is that part of the site is very clear geomorphically because it is probably a thousand year-old surface that shows where the faults are going—right into the part that is buried. In that sense, says Sieh, the site is better than the Pallett Creek site and about the same quality as the Wrightwood site. Burro Flats also looks very good in terms of peat stratigraphy, event horizons, and young Holocene stratigraphy.

On the day of my visit, the students were mapping the fault zone on their computer-generated maps of the area The five students are adding geology to a digitized topographic map. Some trenches dug the week before revealed the stratigraphy beneath the surface. One of the trenches had thin peats and very young gravel, indicating this may be a worthy site for further study.

From Burro Flats, one can look back toward Mt. San Jacinto and see right down the fault. There are several visible scarps and a small sag pond. Burro Flats, according to mapping long ago by Clarence Allen (1953 GSA Bull.), is where the San Andreas fault takes a 15-km step—the biggest step in the entire fault and in fact, the biggest step in this part of the plate boundary. Scientists wonder whether this step impedes rupture from the south or rupture from the north. It's possible the December 1812 (Wrightwood) earthquake rupture ended near here. They think the ~1680 earthquake (seen at Wrightwood and Lake Cahuilla) might have been produced by a rupture that continued all the way through this large stepover. They also think that the ~1480 earthquake rupture (seen at Wrightwood, Pallett Creek, and Indio) might also have ripped right on through.



The San Gorgonio pass area is probably one of the most important structures for geologists to study because it is in the middle of the only part of the southern San Andreas that hasn't broken in the last 140 years. Other sites with promise will be considered for funding for 1998. Two examples are Frazier Park and the Carrizo Plain. Tom Rockwell (San Diego State University) and Scott Lindvall intend to address the question of timing of past San Andreas fault earthquakes at Frazier Park to determine how repeatable the 1812- and 1857-type earthquakes may be. Charlie Rubin (Central Washington University) proposes to answer whether scientists can correlate prehistoric earthquakes between the Carrizo and Mojave segments by recovering slip per event in the Carrizo Plain.

Moving at a rate of ~35 mm / year, the southern San Andreas is really where the action is in terms of our social, economic, and political concerns. Both the Frazier Park and Carrizo Plain site results could help scientists determine whether they should use a segmentation model or one that has unpredictable end points. It's also possible that an event only rarely occurs that involves the central complex part of the San Gorgonio pass, but when it does occur, it will be large.

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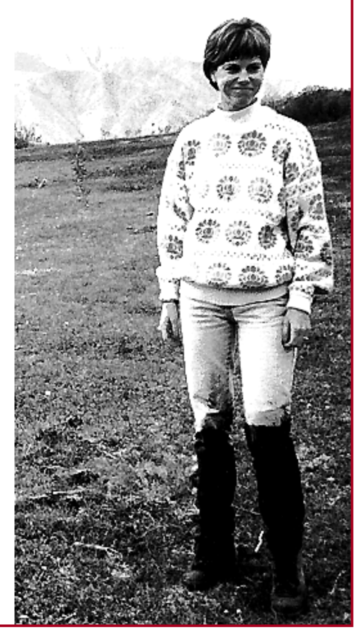
Hanging Out with the Students

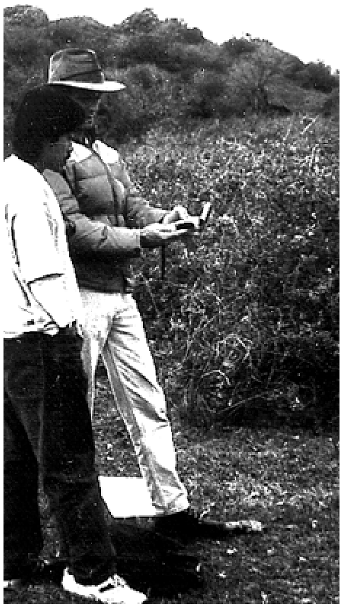
Clyde and Arnie (Doug Yule's dogs) were eager to join us for lunch. I sat on the grass with the Caltech geology students who are fulfilling their field course requirement. Margaret Belska is going to be a planetary geologist; Rowena Lohman is interested in geomorphology as it relates to glaciers and climate.

After finding out what the surface of the earth looks like, they say it's interesting to learn how to interpret what they see in terms of earthquakes. The students all found their work in paleoseismology interesting and expected to use it as a research tool in their future careers. They haven't done this kind of field work before—each student is working on a complete map of the fault for the course requirement.

Graduate student Greg Gerbi and undergraduate Matt Dawson have both declared majors in geology. They will lay down the base map to be used in the trenching proposal. The map they started with is a digitized topo map from the USGS. They are also surveying the area using plotted data points.

The students are mapping fault scarps and landslide scarps and any discontinuities in the topography—including the little cliff ("probably a fault scarp") I leaped from while trying to cross the stream. As you can see from the photo, I gained an intimate knowledge of the organic-rich streambed when I landed in it.





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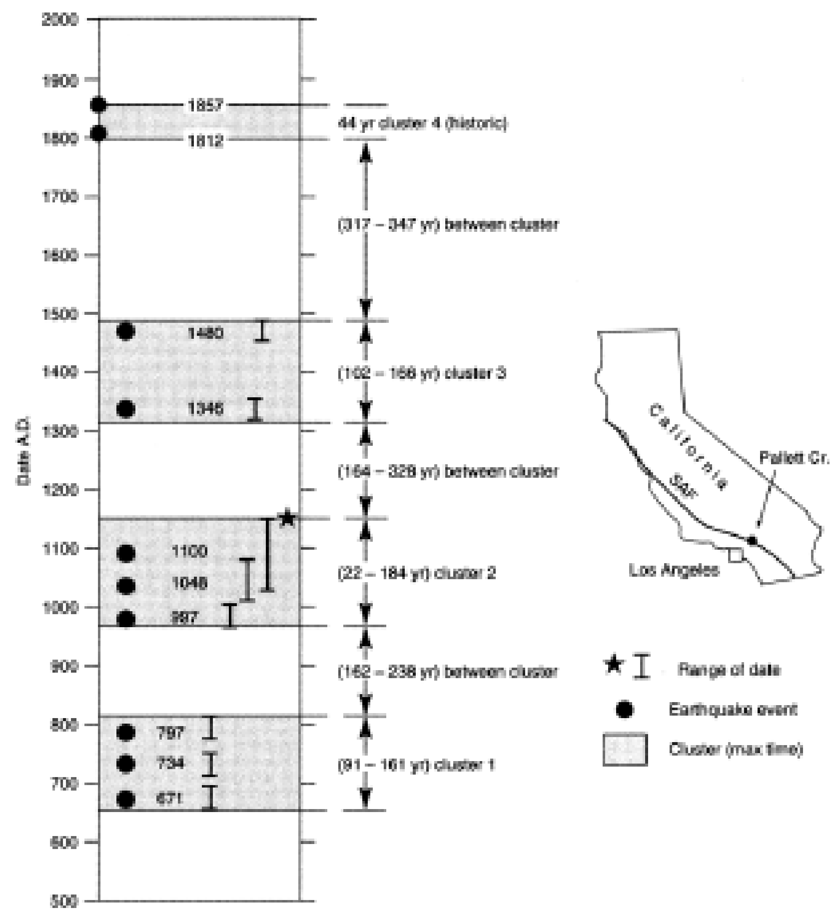

Graph showing chronology of two historical and eight prehistoric earthquakes on the Andreas fault at Pallett Creek.
(Data from Sieh et al., 1989 [22])

Captions for San Andreas Paleoseismology Project Article

Page 10, Top:
View looking east from Burro Flats, Mt. San Jacinto in the distance; at right, visible fault scarps of the San Andreas fault.

Page 10, Bottom:
Doug Yule crouches over a pit trench, one of several dug for the Burro Flats feasibility study.

Page 11, Top:
The area around the San Gorgonio Pass Fault Zone, including Burro Flats. This map is from the SCEC Data Center web site: HTTP://WWW.SCECDC.SCEC.ORG/SANGPASS.HTML.

Page 11, Bottom:
Andrew Meigs ponders the organic-rich layers in a Burro Flats pit trench. The trench’s layers make it ideal for a paleoseismic study.

Page 12, Top:
Doug Yule points to the sedimentary layers in this Burro Flats pit trench. Horizontal bars are shoring devices to protect researchers from cave-ins.

Page 12, Bottom:
View to the west. Foreground is the Burro Flats feasibility study site. Several pit trenches were dug in this area. Many trenches had to be drained because of the high water table.

Page 13, Bottom Left:
View from Burro Flats feasibility study site looking north. The little hill in the foreground is a pit trench; note the gentle sloping of the alluvial fan.

Page 14:
Kerry Sieh (in hat) explains to a Caltech geology student how to use a GPS unit to establish coordinates for mapping the Burro Flats site.

INTERNATIONAL DECADE FOR NATURAL DISASTER REDUCTION

CONFERENCE
Modern Preparation and Response Systems for Earthquake, Tsunami, and Volcanic Hazards

Santiago, Chile, April 27–30, 1998

At the XXI General Assembly of the International Union of Geodesy and Geophysics (IUGG) in Boulder, Colorado, in June of 1995, Chile was proposed as host of a major IDNDR conference to highlight the ability of modern technology to lessen the risk in large urban and industrial areas from earthquakes, volcanoes, and tsunamis. The cosponsors are the International Association of Seismology and Physics of the Earth's Interior (IASPEI) and the International Association of Volcanology and Chemistry of the EarthÕs Interior (IAVCEI). The 1998 conference is planned to respond to the United Nations call for all governments, universities, and private organizations to strengthen their IDNDR activities to reduce risks related to natural disasters.

Recent advances in practical technologies can now be implemented relatively inexpensively. Particularly, modems connected to telephone, radio, and satellite links with digital monitoring instruments in and around critical structures in densely populated areas allow easy access to fast low-cost personal computers. These can be networked to demography and infrastructure databases. Preliminary experience with such smart systems in Los Angeles, Mexico City, and Japan, for example, will be discussed at the conference.

The conference will be organized to ensure working interaction between scientific, engineering, government, business and emergency service professionals. The emphasis will be on information, dissemination, and risk reduction.

For more information: IDNDR conference c/o IUGG Chile National Committee—tel: 56-2-26962188; fax: 56-2-698-8278; email: igm@reuna.cl

Quake Course on Educational Television

"Earthquakes of the Pacific Northwest" is a general-interest course that will be offered on Oregon educational television during winter-spring term of 1998. The three-hour course will review the earthquake hazard from the Cascadia Subduction Zone, crustal faults, and from the Juan de Fuca Plate.

This is followed by discussions of earthquake forecasting, earthquake insurance, stability of buildings including the effects of recent upgrading of the building code for seismic protection, and role of government agencies. Included is a section on retrofitting a typical Northwest residence and on preparing for the next earthquake. Speakers will include local experts from government and private industry.

The course satisfies a baccalaureate core curriculum requirement for a course relating science, technology, and society. Credit is through Oregon State University. The text will be the manuscript of a forthcoming book, Earthquakes of the Pacific Northwest by the instructor, Dr. Bob Yeats. Additional information can be obtained from Dr. Yeats at 541-737-1226.

Uncertainty—from Page 9

apparent inactivity of the Compton-Los Alamitos thrust.

- Viability and implications of the regional decollement and associated low-angle splay faults under the San Gabriel Mountains and Valley interpreted by Ryberg and Fuis (1997) from LARSE seismic reflection Line 1. This interpretation proposes thin-skinned deformation under the San Gabriel Valley, and presumably it can also be viewed as new evidence for thin-skinned deformation under the NE basin. However, the splays, as interpreted by Ryberg and Fuis, would intersect a steeply dipping Sierra Madre fault at shallow depths, making it difficult to reconcile this interpretation with surface geological evidence for the continuing activity of the fault. The single 2-D reflection profile does not allow estimates of the dips or lateral extent of the proposed structures.
- Viability and implications of the new seismotectonic model for the Los Angeles region proposed by Seeber and Geiser (manuscript in preparation, 1997). This model postulates that a mid-crustal ramp is forming under the L.A. basin, which the authors associate with the reflection interpretation of Ryberg and Fuis, but also supports the deep, high-angle faults of current thick-skinned models.

I am presently completing development of the alternative source characterizations and the logic tree, based on the workshop results and further discussions with the evaluator panel and with SCEC scientists. This work includes developing "limbs" on the tree to deal with the new issues uncovered at the workshop. The complete source characterization model will be sent to the evaluator panel, accompanied by summaries of the main issues and interpretations. The evaluators will individually assign their weights to the alternatives. The evaluator panel and TI team will then meet to discuss the model and weights in preparation for a "mini" workshop involving 10 or 12 key SCEC researchers. At this workshop we will elicit feedback on the source model and weights that will enable us to finalize the source characterization.

William (Bill) Foxall, 510-424-3767, email foxall1@llnl.gov

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Positions Available

RESEARCH ASSISTANT
Seismology

The Southern California Seismographic Network, which records, archives, and reports on earthquake activity in southern California, has an opening for a data analyst. We are looking for a new member of our team to analyze data from the Southern California Seismic Network. Duties: operating analysis software, interactive computer analysis of digital seismic data, and quality control and archiving of seismic data. BS degree and one year of related experience, or equivalent, desirable. Must have exposure to computers and college level classes in physical sciences, preferably geology and geophysics. Must be detail oriented and have the ability to work with a team. Full time; hours flexible. If interested, contact Caltech (Caltech employment office (626) 395-4661; http://www.cco.caltech.edu~empoly/posting.html) or send resume to kate@bombay.gps.caltec.edu. Job posting #4191.

ASSISTANT PROFESSOR
Geophysics

The Department of Geology at Arizona State University invites applications for a tenure-track Assistant Professor faculty position in Geophysics. Individuals with research interests in solid earth geophysics, seismology, geodynamics, or crustal dynamics are encouraged to apply. Expected to develop a vigorous research program and to be committed to quality teaching at the undergraduate and graduate levels. A Ph.D. in geophysics or related science and evidence of research and teaching achievement or potential are required. Starting August 16, 1998. Information: Prof. James A. Tyburczy, Geophysics Search Committee Chair, Department of Geology, Box 871404, Arizona State University, Tempe, AZ 85287-1404, (602) 965-2637, fax (602) 965-8102, E-mail: jim.tyburczy@asu.edu. Web site: http://www-glg.la.asu.edu

POSTDOCTORAL SCHOLAR
Geophysics

The California Institute of Technology is seeking applicants for a Postdoctoral Scholar in Geophysics. Candidates in any area of geophysics are encouraged to apply. Completion of the Ph.D. by the beginning of the appointment is required. Independent research interests complementary to existing research programs encouraged. Appointment made as soon as possible. Duration is normally two years.

Applications via web: http://www.gps.caltech.edu or by writing: Geophysics Postdoctoral Search Committee Seismological Laboratory, Division of Geological & Planetary Sciences 170-25 Caltech, Pasadena, CA 91125. Information: Marcia Hudson, GPS Division Office, 170-25 Caltech, Pasadena, CA 91125 (tel: 626/395-6111, e-mail: marcia@gps.caltech.edu)

POST-DOCTORAL RESEARCH ASSOCIATE
Computational Rock Physics

The University of Edinburgh is accepting applications for a Post-Doctoral Research Associate to work on the development and application of an existing computer code for modeling the scale dependence of groundwater flow and contaminant transport in fractured rock. The ideal candidate will have completed a Ph.D. in a relevant subject, a basic knowledge of brittle-field deformation or fluid-rock interactions, and strong computational skills, preferably parallel programming. Contract runs for three years, with a starting salary depending on experience.

Inquire: Dr. Ian Main, Tel: +44 (0)131 650 4911; Email: ian.main@ed.ac.uk

Application: Personnel Department,University of Edinburgh, Edinburgh EH8 9TB; Tel: 0131 650 2511; http://www.admin.ed.ac.uk/persnnel/recruit.htm

LABORATORY INTERN
Geoscience

The Woods Hole Field Center of the USGS invites intern applications for a laboratory position with the gas hydrates research team. The USGS gas hydrates project is a multidisciplinary study involving offshore seismic surveys, downhole geophysics, geochemistry and laboratory experiments. This position involves participation in all facets of the laboratory experiments in which methane hydrates are formed and decomposed in sediments under simulated deep-sea conditions. The length of this project is two years.

A bachelors degree in earth sciences with strong computer skills (Mac and Windows), success in laboratory course work (in any physical or natural science discipline), previous experience in a laboratory, course work in sediments (or soils) and sedimentary processes, and familiarity with instrument control/data acquisition software preferred.

Inquire to either or both:
Oak Ridge Associated Universities
Mr. Wayne Stevenson
130 Badger Avenue
Oak Ridge, Tennessee 37831-0117
423-576-3283
The Environmental Careers Org.
Mr. Martin Mitchell
179 South Street
Boston, MA 02111
617-426-4783 x121

PH.D. RESEARCHER
Tectonics

The research team of Structural Geology and Tectonics of the Department of Geology and Physical Geography at Aristotle University of Thessaloniki, Greece, wishes to host a Greek-speaking Ph.D. researcher in Tectonics (Analogue Modeling). The position requires working in Greece for 2 or 3 years and having at least two years post-doctoral research experience abroad. He or she will carry out research as well as teaching. For further information: Ass. Professor S. Pavlides (Tel +30-31-998494; fax 998482; 998552; E-mails: Pavlides@geo.auth.gr or Dimitra@geo.auth.gr)

FACULTY POSITIONS
Geophysics/Geodynamics & Petrology/Volcanology or Hydrogeology

The Central Washington University Geology Department invites applications for two full-time, tenure-track appointments to begin in September, 1998. The first position is in solid earth geophysics, in particular, geodynamics or seismology. The second position is in either field petrology/volcanology, or hydrogeology, with a demonstrated interest in incorporating geologic principles into the study of hydrologic processes. We seek candidates who demonstrate potential for excellence in and commitment to undergraduate education, including introductory level instruction or education of future teachers. The successful candidate will be expected to carry out an active research program. A Ph.D. in Geology or allied field is required on employment. Contact: Search Committee Chair (specify Geophysics or Petrology/Hydrogeology), Department of Geology, Central Washington University, Ellensburg, WA 98926-7418. Potential candidates can contact Charles M. Rubin at [509])963-2827, or E-mail charlier@picante.geology.cwu.edu

RESEARCH GEOLOGIST
Quaternary Geology

Nevada Bureau of Mines and Geology, a research and public service unit of the University of Nevada, Reno, and the state geological survey, seeks a tenure-track geologist to work in one or more of the following aspects of Quaternary geology and hydrogeology applied to issues in Nevada: geomorphology, neotectonics, environmental geology, sedimentology of alluvial fans and basins, ground-water hydrology, and earthquake, flood, subsidence, and other urban hazards. Applicants must have a Ph.D. in geology, hydrogeology, or related fields or equivalent. Must also have a record of research. Good communication skills, commitment to public service, ability to complete projects in a timely way, and ability to attract funding are essential.

The position will be an academic, tenure-track, beginning on or soon after August 17, 1998. Applicants are encouraged to have information on file by January 31, 1998. Contact Search Committee Chair, Nevada Bureau of Mines and Geology, Mail Stop 178, University of Nevada, Reno, NV 89557-0088 for more information, or consult web—http://www.nbmg.unr.edu

SCEC Research Publications

The SCEC Quarterly Newsletter will now publish the references only for published articles, no longer listing ones that are submitted, in review, or in press. Authors should email their updates to Mark Benthien (benthien@terra.usc.edu) to have their publication listed in the newsletter.

289. Kagan, Y. Y., Earthquake size distribution and earthquake insurance, *Communications in Statistics: Stochastic Models*, 13, no. 4, pp. 775–797, 1997.

290. Grant, L. B., J. T. Waggoner, C. von Stein, and T. R. Rockwell, Paleoseismicity of the north branch of the Newport-Inglewood Fault Zone from cone penetrometer test data, *Bulletin of the Seismological Society of America*, 87, no 2, pp. 277–293, 1997.

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364. Deng, J., and L. R. Sykes, Stress evolution in southern California and triggering of moderate, small, and micro earthquakes, *Journal of Geophysical Research*, 102, pp. 24411–24435, 1997.

365. Ben-Zion, Y., and J. R. Rice, Dynamic simulations of slip on a smooth fault in an elastic solid, *Journal of Geophysical Research*, 102, pp. 17771–17784, 1997.

371. Eneva, M., and Y. Ben-Zion, Techniques and parameters to analyze seismicity patterns associated with large earthquakes, *Journal of Geophysical Research*, 102, pp. 17785–17795, 1997.

386. Zhao, D., Y. Xu, D. Wiens, L. Dorman, J. Hildebrand, and S. Webb, Depth extent of the Lau back-arc spreading center and its relationship to subduction processes, *Science*, 278, pp. 254–257, 1997.

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Abstracts of Recent Publications

Below are the abstracts that have been submitted for recently published SCEC publications. The numbers are the SCEC publication number. See the full publication list above.

350. Andrews, D. J., and Y. Ben-Zion, Wrinkle-like slip pulse on a fault between different materials, *Journal of Geophysical Research*, 102, pp. 553–571, 1997.

Pulses of slip velocity can propagate on a planar interface governed by a constant coefficient of friction, when the interface separates different elastic materials. Such pulses have been found in two-dimensional plane strain finite difference calculations of slip on a fault between elastic media with wave speeds differing by 20%. The self-sustaining propagation of the slip pulse arises from interaction between normal and tangential deformation that exists only with a material contrast. These calculations confirm the prediction of Weertman [1980] that a dislocation propagating steadily along a material interface has a tensile change of normal traction with the same pulse shape as slip velocity. The self-sustaining pulse is associated with a rapid transition from a head wave traveling along the interface with the S-wave speed of the faster material, to an opposite polarity body wave traveling with the slower S speed. Slip occurs during the reversal of normal particle velocity. The pulse can propagate in a region with constant coefficient of friction and an initial stress state below the frictional criterion. Propagation occurs in only one direction, the direction of slip in the more compliant medium, with rupture velocity near the slower S-wave speed. Displacement is larger in the softer medium, which is displaced away from the fault during the passage of the slip pulse. Motion is analogous to a propagating wrinkle in a carpet. The amplitude of slip remains approximately constant during propagation, but the pulse width decreases and the amplitudes of slip velocity and stress change increase. The tensile change of normal traction increases until absolute normal traction reaches zero. The pulse can be generated as a secondary effect of a drop of shear stress in an asperity. The pulse shape is unstable, and the initial slip pulse can change during propagation into a collection of sharper pulses. Such a pulse enables slip to occur with little loss of energy to friction, while at the same time increasing irregularity of stress and slip at the source.

Abstracts continued

351. Gao, S., H. Liu, P. M. Davis, L. Knopoff, and G. S. Fuis, A 98-station seismic array to record aftershocks of the 1994 Northridge earthquake, USGS Open-File Report 96–690, p. 28, 1996.

This report is intended to document the NEAR (Northridge Earthquake Aftershock Recording) experiment and data set so that it can be used by others in the seismological community. During March 26 to April 16, 1994 an array of 98 digital (Reftek) seismic stations recorded over 1,000 Northridge aftershocks. Fifty-three aftershocks were recorded by 40 or more stations. The stations were located in two clusters in Sherman Oaks and Santa Monica, respectively, and along two profiles traversing the San Fernando Valley and the NW part of the Los Angeles Basin. A triggering mode with 125 samples per second, 20~s pre-triggering length, and 60~s post- triggering length was used. The data set has been sorted into event files and submitted to both the SCEC (Southern California Earthquake Center) and IRIS (Incorporated Research Institutions for Seismology) data centers. Seventy-five stations were equipped with L28 4.5 Hz sensors, eight with L22 2.0 Hz sensors and fifteen with L4C 1 Hz sensors. All stations were equipped with three-component seismometers. Among the over 200,000 files recorded by the network, 37,107 files were sorted into 1550 events. The total size of the sorted waveform data is 1.3 Gigabytes. The data is in SEGY format, which can be easily converted into SAC, AH, SEED, and SIERRA format using codes provided by the IRIS data center

355. Li, Y. G., F. L. Vernon, and K. Aki, San Jacinto fault zone guied waves: a discrimination for recently active fault strands near Anza, California, *Journal of Geophysical Research*, B6, no. 11, pp. 689–691, 701, 1997.

We deployed three 350-meter-long eight-element linear seismic arrays at the San Jacinto Fault Zone (SJFZ) near Anza, California, to record microearthquakes during August to December of 1995. Two arrays were deployed 18 km northwest of Anza, across the Casa Loma fault (CLF) and the Hot Springs fault (HSF) strands of the SJFZ. The third array was deployed across the San Jacinto fault (SJF) in the Anza slip gap. We observed fault-zone guided waves characterized by low frequency, large amplitudes following S-waves only at the CLF array and the SJF array for earthquakes occurring within the fault zone, but not at the HSF array for any events. The amplitude spectra of these guided waves showed a peak at 4 Hz at the CLF, and 6 Hz at the SJF, which decreased sharply with the distance from the fault trace. In contrast, no spectral peaks at the frequency lower than 6 Hz were registered at the HSF array. We used the finite-difference method to simulate these guided modes as S waves trapped in a low-velocity waveguide sandwiched between high-velocity wall rocks. While the results are nonunique, the guided mode data are adequately fit by a waveguide 120 m wide on the CLF where the S-velocity is 2.7 km/s, and 50 m wide on the SJF in the Anza slip gap where the S-velocity is 2.9 km/s; the S-velocity within the waveguide is reduced about 20 to 25 percent from that of the surrounding rock. But, there is no low-velocity waveguide on the HSF at depth. We tentatively interpret that the distinct low-velocity waveguide on the CLF was a result of the rupture of the 1899 M7.0 earthquake occurring near the towns of San Jacinto and Hemet while the HSF was not ruptured in this event. Locations of the events with guided modes further infer that the fault-plane waveguide along the CLF, to a depth of at least 18 km, dips northeastward at 75-800. The waveguide becomes nearly vertical along the SJF in the gap.

365. Ben-Zion, Y., and J. R. Rice, Dynamic simulations of slip on a smooth fault in an elastic solid, *Journal of Geophysical Research*, 102, pp. 17771–17784, 1997.

We report on numerical simulations of slip evolution along a two dimensional (slip varies only with depth) vertical strike-slip fault in an elastic half-space, using a framework incorporating fully inertial elastodynamics. The model is a follow up on earlier quasistatic and quasidynamic simulations of deformations along smooth fault systems inelastic continua. The fault is driven below a crustal depth of 24 km by a constant plate velocity of 35 mm/yr. Deformation at each fault location in the crustal zone is the sum of power-law creep and rate- and state-dependent friction, where both processes have temperature-dependent (and hence depth varying) coefficients and both take place locally under the same stress. The simulations employ two versions of rate- and state-dependent friction: a “slip” law which requires nonzero velocity for state evolution, and an “aging/slowness” law that incorporates state evolution and restrengthening in stationary contact. The assumed constitutive laws and distribution of frictional parameters are compatible with laboratory experiments. The elastodynamic calculations are based on spectral representations of variables, and a new algorithm providing a unified computational framework for calculations of long deformational histories containing short periods of rapid dynamic instabilities. The simulations show dynamic rupture propagation and wave phenomena not accounted for in the previous quasistatic and quasidynamic works. However, the results are qualitatively similar to those obtained by corresponding quasistatic and quasidynamic calculations. Slip histories along a smooth fault, simulated here with full dynamic calculations for various constitative laws and model parameters, consist mostly of quasi-periodic large events. This indicates that inertial dynamics does not provide a generic mechanism for generating spatio-temporal complexities of slip. On the other hand, calculations done for cases representing, approximately, strongly disordered systems do show rich histories with a range of event sizes. This is compatible with our previous conclusions that the origin of observed broad distributions of earthquake sizes is strong fault zone heterogeneities. The fully dynamic calculations illustrate the evolution of nucleation phases of instabilities associated with accelerating and expanding creep. Final slip values of model earthquakes in full elastodynamic calculations are larger than those of corresponding quasistatic and quasidynamic events.

371. Eneva, M., and Y. Ben-Zion, Techniques and parameters to analyze seismicity patterns associated with large earthquakes, *Journal of Geophysical Research*, 102, pp. 17785–17795, 1997.

A pattern recognition algorithm is developed to provide potential parameters employed in the analysis include degree of spatial nonrandomness in two distance ranges, spatial correlation dimension, spatial repetitiveness of earthquakes with a similar size, average depth of events, time interval for the occurrence of a constant number of events, and ratio of the numbers of events in two magnitude intervals. The parameter temporal variations are compared quantitatively with the time series of large events using a technique of association in time. The significance of the association frequencies is evaluated by comparison with chance associations estimated from corresponding simulated random time series. The developed techniques differ from existing approaches in the following aspects. The parameters here emphasize the spatial distribution of earthquakes. Possible correlations among the parameters are evaluated to determine the final set of parameters to be monitored. Threshold values for the assumed anomalies are chosen with consideration of properties of the available earthquake catalogs, such as the number of large events to be retrospectively predicted. Equal weight is given to both locally high and locally low parameter values. Care is taken to distinguish between anomalies preceding large events and those following previous events. It is shown that the relationship between precursory local extrema and precursory trends is nonunique, with precursory local extrema of the same type frequently associated with opposite observable precursory trends. The application of the seismicity parameters and pattern recognition techniques is demonstrated using synthetic earthquake catalogs generated by models of segmented fault systems in a three-dimensional elastic solid [Ben-Zion, 1996].

386. Zhao, D., Y. Xu, D. Wiens, L. Dorman, J. Hildebrand, and S. Webb, Depth extent of the Lau back-arc spreading center and its relationship to subduction processes, *Science*, 278, pp. 254–257, 1997.

Seismic tomography and waveform inversion reveal that very slow velocity anomalies (5-7%) beneath the active Lau spreading center extend to 100 km depth, and are connected to slow anomalies (2-4%) in the mantle wedge to 400 km depth. This indicates that geodynamic systems associated with back-arc spreading are related to deep processes, such as the convective circulation in the mantle wedge and deep dehydration reactions in the subducting slab. The slowest anomalies exist just west of the Lau spreading center, consistent with the observation that current ridge propagation processes are moving the spreading center away from the Tonga arc.

SCEC-Sponsored Science Seminar & Workshop on Sediment Nonlinearity

When:
Seminar: Jan. 29, 1998 (afternoon)
Workshop: Jan. 30, 1998

Where: USC

Organized by: Ned Field (field@usc.edu)

Description:
It has been understood for more than 100 years that sediments can increase the level of earthquake ground motion relative to bedrock. However, there has been a long-standing and often contentious debate between seismologists and engineers on whether the response of sediments to strong ground motion is similar to that of relatively well-studied weak motion. The prevailing view in the engineering community, based almost exclusively on laboratory studies, is that sediments respond nonlinearly. That is, amplification factors are generally reduced for stronger ground motion because the finite strength of sediments causes a breakdown of Hooke's law. This perspective has been applied in engineering practice. Seismologists, on the other hand, have traditionally been skeptical because of a lack of evidence and a skepticism that laboratory studies represent in situ behavior. They've generally concluded that either sediment nonlinearity is insignificant or that it is buried among the myriad of other complicating factors (i.e., uncertainties) in the data. Recent progress in several disciplines makes the time ripe for a seminar and workshop on this problem.

At the seminar (afternoon of Jan. 29, 1998), representatives from each discipline will give overview talks on the following topics:

- Lab-based studies of sediment response conducted by the engineering community
- How engineers use these results to theoretically model sediment response
- Seismological evidence for and against sediment nonlinearity
- The view from the rock-mechanics / physics community
- What's applied in the building codes

The purpose of this seminar is to educate the general SCEC community and to bring the members from the various disciplines up to speed about the other disciplines.

With this introduction, the workshop on the next day will focus on specific technical issues that remain unresolved. Participants will be invited to present and discuss results that pertain to these issues. Given the unprecedented diversity of disciplines that will be in attendance, it is hoped that this workshop will establish points of agreement and disagreement, stimulate crossbreeding, and identify priorities for future research.

For more information about the workshop, please contact Ned Field (213-740-7088; field@usc.edu).

Five SCEC Press Briefings

On November 14, 1997, SCEC scientists Thomas L. Henyey, James Dolan, David Jackson, and Edward (Ned) Field held a press conference to present information on five new findings on southern California earthquakes. Readers of SQN who would like more information should contact the scientists mentioned at the conclusion of each brief.

1 SCEC to Catalog the History of the San Andreas Fault

The Southern California Earthquake Center will conduct a new series of paleoseismic studies of the San Andreas fault over the next few years. *Paleoseismology* is the investigation of earthquakes well after their occurrence. The San Andreas was the focus of the first paleoseismic studies in southern California by Kerry Sieh and others in the 1970s and 1980s. But with the inception of the Southern California Earthquake Center in 1991, the emphasis shifted to the Los Angeles metropolitan area and its many faults, which pose a hazard to the urban environment. The new efforts, using new technologies and previous data and experience should produce a huge increase in our understanding of this fault system and how frequently we can expect earthquakes.

Although much remains to be done to characterize the earthquake history in the Los Angeles basin, important new questions regarding the San Andreas and its potential impact on the adjacent metropolitan areas have emerged. The new paleoseismic studies will help give us enough data to begin to answer:

- What are the maximum magnitudes of events on the San Andreas?
- Does the fault largely rupture segment by segment or by cascading through multiple segments?
- What is the most likely direction of rupture propagation?
- How do these questions bear on the issues of the so-called “earthquake deficit” and the potential for generating very large, long-period, long-duration ground shaking in the heart of the L.A. basin—shaking that may adversely affect some of our largest structures, including bridges and high-rise buildings?

Contacts

James Dolan, USC (213) 740-8599; Kerry Sieh, Caltech (626) 395-6115; Tom Heaton, Caltech (626) 395-4232; Kim Olsen, UCSB (805) 893-7394; David Jackson, UCLA (310) 825-0421.

References:

Robert S. Yeats, Kerry Sieh, and Clarence R. Allen, *The Geology of Earthquakes*, Oxford University Press, 1997.

The Paleoseismology Web Site: HTTP://GLDAGE.CR.USGS.GOV/PALEOSEI/PPMAIN.HTM

2 Great Earthquakes on the San Andreas Leave Long Stress Shadows

The great 1857 Fort Tejon earthquake (M 7.8), which ruptured the San Andreas fault from central California to Cajon Pass, was the largest earthquake to hit southern California during the historic period. This great earthquake was followed by approximately 50 years of seismic quiet in the region west of Cajon Pass, including the Los Angeles basin.

Calculations of stress changes produced by this earthquake indicate a reason for that quiet: many nearby faults were relaxed by the action of the earthquake. That is, they had some of their accumulated strain (the pressure that can lead to earthquakes) released in the nearby motion of the great earthquake. This relaxation resulted in a "shadow"—a region in which future earthquakes were delayed. On the other hand, earthquakes continued in other regions, especially on faults southeast of Cajon Pass, including the San Jacinto fault, where stresses were not changed or were perhaps even increased.

Scientists hope for a better understanding of this correlation between earthquakes and changes in the stresses in surrounding areas in order to better estimate the long-term probabilities of earthquakes in those areas.

Contacts

Ruth Harris, USGS (650) 329-4842; Jishu Deng, Caltech, (626) 395-6948.

3 Structural Design May Have to Include Depth of Sedimentary Basin

New computer simulations of the expected ground motion caused by probable earthquakes on major southern California faults suggest that we might have to change how we build some of our structures if we want them to survive. They show that the depth of a sedimentary basin (the Los Angeles basin is an example of a large one) has more effect on the surface motion than previously thought. Specifically, a deeper basin can amplify both the strength and duration of long-period ground shaking (the "rolling motion" from earthquakes).

These new results are made possible by the use of high-performance computers that are able to do the calculations necessary to manage a more realistic 3-D model that includes the behavior of the sub-surface features. The computational requirements increase dramatically for 3-D calculations and as the ground motion frequencies are increased. Currently, only frequencies less than 1 cycle per second are being considered for structural design purposes, but as computational power increases and, in particular, our knowledge of the subsurface geology improves, simulations with frequencies greater than 1 cycle per second will become possible.

The simulations included nine "scenario" earthquakes on faults that are capable of generating moderate-to-large earthquakes in the near future. The scenarios included historical earthquakes as well, such as the 1993 Long Beach, 1987 Whittier Narrows, and 1994 Northridge events.

Results indicate that the 3-D simulations show amplification factors several times greater than those based on earlier models, as well as significantly longer durations. The degree of ground motion amplification generally increases with depth. Furthermore, seismic waves that propagate into a basin from earthquakes occurring outside that basin tend to be amplified more than waves from earthquakes on faults within the basin.

Contacts

Kim Olsen, UCSB (805) 893-7394 (email kbolsen@crustal.ucsb.edu); Ralph Archuleta, UCSB (805) 893-8441; Geoff Martin, USC (213) 740-9124; Steven Day, SDSU (619) 594-2663.

References

Olsen, K. B., R. J. Archuleta, J. R. Matarese (1995). "Three-dimensional simulation of a magnitude 7.75 earthquake on the San Andreas fault," *Science*, **270**:1628.

Olsen, K. B., and R. J. Archuleta (1996). "Three-dimensional simulation of earthquakes on the Los Angeles fault system," *Bull. Seism. Soc. Am.*, **86**:575-596.

Olsen, K. B. (1997). "Site classification and site-specific amplification for basin effects," *Probabilistic seismic hazard in southern California: uncertainties due to assumptions and models*, in review.

Kim Olsen's web site: HTTP://WWW.CRUSTAL.UCSB.EDU/~KBOLSEN

Interview with Ralph Archuleta, *SCEC Quarterly Newsletter*, Vol. 3, No. 2, pp. 10-14.

4 A New Crustal Deformation Map of Southern California Offers Surprises

SCEC is collecting and interpreting geodetic data (exact measurements of positions on the earth's surface) for southern California to monitor the motions of faults and their potential for earthquakes. A major product of this work is a set of deformation velocity estimates (the rate at which the Earth's crust moves, or deforms, from point to point) for 287 sites in southern California. These new measurements, the result of non-earthquake (aseismic) motions, reveal how much strain is building in each of these locations—i.e., more strain may mean more chance of the need for earthquakes to relieve that strain.

The resulting map of deformation velocities is so accurate that strain rates (i.e., relative movements between points) can be determined directly from the map. Geodetically determined strain rates on individual faults seem to be in reasonable agreement with geologically estimated fault slip rates. If true, this would imply that deformation of the earth's crust between earthquakes is relatively steady, not deviating much from its long-term average ("long-term" refers to thousands of years).

This agreement is important for modern seismic hazard estimates, which usually assume that immediate (years to decades) earthquake potential is proportional to the long-term slip rate on faults. In spite of the apparent agreement between long-term and short-term slip rates, the spatial distribution of the present strain rate is still surprising. The regions of highest strain rate do not appear to be on the major faults as expected, but rather (with one exception), in the regions *surrounding* previous earthquakes.

These post-earthquake effects could complicate efforts to determine long-term slip rates on faults using geodetic data since relating the strain field (which is being determined from the new southern California permanent GPS network) to future earthquakes will require an understanding of the effects of past ones.

Contacts

David Jackson, UCLA (310) 825-0421; Zheng-kang Shen, UCLA (310) 825-9084; Ken Hudnut, USGS (818) 583-7232.

References:

D. D. Jackson, Z.-k. Shen, D. Potter, X.-B. Ge, L.-y. Sung (1997). "Southern California deformation," *Science*, **277**:1621.

SCEC Crustal Deformation Study Group web site: HTTP://WWW.SCEC.ORG/RESEARCH/GROUPE/INDEX.HTML

5 New Study Blends Science, Engineering into Hazard Analysis

A SCEC report, currently under review and scheduled for release in spring, merges scientific and engineering issues related to the analysis of earthquake hazards. The report focuses on incorporating "site response" (the reaction of Earth's surface to earthquakes) into hazard maps.

Producing hazard maps with site response requires integration of scientific information from geologists, seismologists, and geotechnical engineers. Seismic hazard analysis, a study focus by SCEC researchers, provides a framework for bringing together these different disciplines to produce self-consistent models.

Previously, earth scientists and engineers used inconsistent definitions of site response. The subject was often treated separately from hazard analysis. Hazard maps were developed for "rock" conditions, and then a site-specific response was separately computed to account for the different soil types at study sites.

In this new report, site response is brought *inside* the hazard calculation. Doing so provides a useful framework for evaluating ground motion issues, such as the best way to characterize site response. The traditional approach to characterizing earthquake ground motion has been probabilistic, leading to forecast statements such as: there is a 20-percent probability that this site will experience ground shaking greater than a certain amount in the next 40 years. The wave of the future will be to provide detailed predictions (called synthetic seismograms) of how the ground will actually shake during various hypothesized earthquakes.

Another key issue in site response is the extent of so-called "nonlinear" behavior during strong shaking. Nonlinearity refers to nonelastic behavior of the soils, which, if and when it occurs, can profoundly affect engineering design. An important product of the report will be a suite of hazard maps depicting the sensitivity of the hazard to various alternative models of the seismic source, attenuation (wave energy dissipation), and site response. A major goal is to identify the major sources of scientific uncertainty in seismic hazard assessments to guide future research and reduce the uncertainty.

Contacts

Ned Field, USC (213) 740-7088; Norm Abrahamson, Pacific Gas & Electric (510) 428-9823; Geoff Martin, USC (213) 740-9124; David Jackson, UCLA (310) 825-0421; John Anderson, University of Nevada at Reno (702) 784-4265; Steven Park, UC Riverside (909) 787-4501.

References

"Probabilistic Seismic Hazard in Southern California: Uncertainties due to Assumptions and Models," Southern California Earthquake Center Draft Report, October 30, 1997. In review.

OFF-SCALE

READINGS FROM AUTHORS WHO ARE NOT EARTH SCIENTISTS BUT WISH THEY WERE

"The earth is not a mere fragment of dead history to be studied only; it is living poetry"

Spring convinces me that Earth is still in its swaddling clothes and stretches out baby fingers in every direction. Nothing is inorganic. These leafy heaps lie along the bank like the slag of a furnace, showing that Nature is "in full blast" within. The earth is not a mere fragment of dead history, stratum upon stratum like the leaves of a book, to be studied by geologists and antiquaries only, but it is living poetry like the leaves of a tree, preceding flowers and fruit— it is not a fossil earth, but a living earth. Compared with Earth's great central life, all animal and vegetable life is merely parasitic. Its throes will heave us from our graves. You may melt your metals and cast them into the most beautiful molds you can; they will never excite me like the forms which this molten earth flows itself into—and not only the earth but the institutions upon it are plastic like clay in the hands of the potter.

Henry David Thoreau
Walden

The Global View . . .

Two Large Earthquakes Hit Central

Macerata

CAMERINO / ACCUSATO DI DIFFUSIONE DI NOTIZIE FALSE

Il terremoto non avvenne ed ora chi lo predisse va sotto processo

The People

Two Earthquakes Hit Central Italy

Two earthquakes hit central Italy on September 26, 1997, killing 12 people and leaving tens of thousands homeless. The first earthquake, M 5.5, centered in Marches, east of Umbria, struck at 2:33 AM. The second, M 5.9, hit nine hours later and was reported to have been two separate shocks in rapid succession.

Tremors were felt in Rome, 80 miles south, and Venice, 150 miles north. Two Franciscan friars and two surveyors were killed in the second quake while examining damage that had already been done to the Basilica of St. Francis of Assisi in the first quake. The earthquake caused the collapse of two 360-square-feet sections of the ceiling, with frescoes attributed to 14th-century masters Giotto and Cimabue.

In most communities in the region of Umbria—the area hit hardest by the earthquakes—the majority of houses were left standing. Some had gaping cracks down the walls, or partially collapsed tile roofs; others were untouched. A sample of 3,500 houses in the region were inspected; 41 percent were uninhabitable. The exception was Nocera Umbra and surrounding villages where the rate was 72 percent. A 29-year-old metal worker, Marcello Chiocca, described the aftershocks as almost supernatural. “I think of it as a long worm, writhing down the valley,” he said. “It felt as though the ground was dancing below us.” The two quakes were the most serious to hit Italy since 1980. That devastating earthquake registered 6.8 on the Richter scale and killed 2,570 people in the region east of Naples.

Reference

HTTP://WWW.NYTIMES.COM

The Ground

Surface Breaks in Umbria-Marche

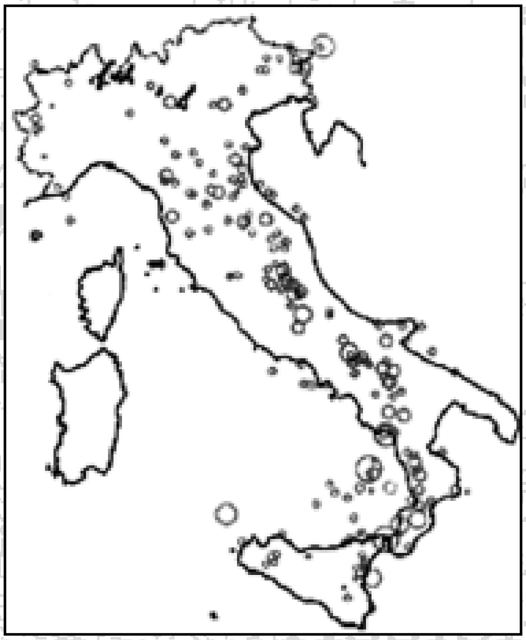
Starting from September 26, 1997, field investigations were conducted in the epicentral area of Colfiorito which endured severe damage from the earthquakes of September and October 1997. A group of geologists and seismologists provided first accounts and results of detailed investigations and studies in the epicentral area.

Surface breaks were examined in detail using before-and-after aerial photographs, revealing freshly exposed earthquake-induced dislocations. Main surface fissures and cracks appear in three different areas:

- East of Costa village, where an 80-m dislocation, striking N 120–N130, is visible on a steep slope (30° to 40°) at the interface between a bedrock fault (limestones) and slope deposits (mainly vegetal soil of a pinewood grove). The apparent vertical movement ranging from 4 to 25 cm is marked by a dark brown band that corresponds to the trace of the soil. No recent striations are visible on the plane, but using the band trace, both left lateral and right lateral components of movement can be measured along the plane. No ruptures appear along the same fault plane in the nearby contact between limestones-limestones, limestones-slope breccias or limestones-Quaternary deposits. No rupture is visible in the section exposed along the nearby road-cut (about 20 m to the SE).
- East and NE of Monte Birbo, along the western side of Monte Tolagna. The opened cracks and fissures, which are unevenly distributed along 170 m, are confined at the base of a bedrock fault plane, striking N160–N140, and showing a dark brown band suggesting 3 to 5 cm of vertical movement. As in the previous observations, movements are either sinistral or dextral, the steep slope is 35° to 45°, and slope deposits are made of limestones breccias and layered gravels in a sandy matrix on which has developed the present soil and related vegetation. No ruptures appear when along the fault plane and in a flat area (to the NW), the contact is limestones-limestones. No ruptures are visible along strike to the SE when the fault plane is covered by slope deposits or is visible in thalwegs.
- Along the NW side of Monte Miglioni (east of Taverne and Borgo), two ruptures are orthogonal to a newly made road going to Selvapiana village. Although located on two different sides of a sharp turn, the two

Italy, Including St. Francis' Assissi

ruptures are aligned along the same trend N135–N145. The ruptures, which consist of 2- to 4-cm opened cracks with a left lateral en echelon geometry, coincide with a normal fault showing a 10-cm thick gouge zone that limits a Mesozoic formation from late Quaternary deposits. No vertical displacement is visible in this area, the total length between the two ruptures being about 100 m. To the NW at the Monte Le Scalette, a dark brown band of about 100 m with 4 to 5 cm of vertical movement is also visible at the interface between a soil and a fault plane which cuts a stream incision, showing a right lateral movement on the left-hand side and left lateral movement on the right-hand side.



After the detailed examination of surface breaks, taking into account the moderate earthquake magnitudes and 8- to 15-km depth of the two main seismic events, it is believed that the deep-seated normal fault did not rupture to the surface. No coseismic faulting and related displacement can be inferred from the produced surface dislocations. Although some minor differences in the fault characteristics can be noted, focal mechanisms provided by CMT of ERI Tokyo, EMCS Potsdam, and Harvard are, however, in good agreement with the local active tectonics.

Historical catalogues also mention the occurrence of similar damaging earthquakes in this region in 1279 (I=IX) and in 1799 (I=IX-X), but no surface ruptures were reported. Finally, the occurrence of multiple strong shocks (see also the M 5.1 of October 3, 1997) reveals the complex tectonic pattern of this area.

Researchers involved in the field data collection: R. Basili, F. Galadini, M. Meghraoui, P. Messina (GNDT/CNR-CS Geologia Tecnica, Rome); A. Amato, C. Chiarabba, G. B. Cimini, G. Selvaggi (Istituto Nazionale di Geofisica, Rome) V. Bosi, P. Galli, (Italian Seismic Survey, Rome).

The Overview

Seismicity of the Italian Peninsula

The Italian National Seismic Network records more than 2,000 earthquakes per year. Crustal seismicity represents the majority of the activity recorded. Crustal seismicity is mainly concentrated in the Alps, along the Apennines and in Quaternary and active volcanoes. A few seismic sequences also occur in the Gargano promontory, while Apulia and Sardinia seem to be relatively aseismic.

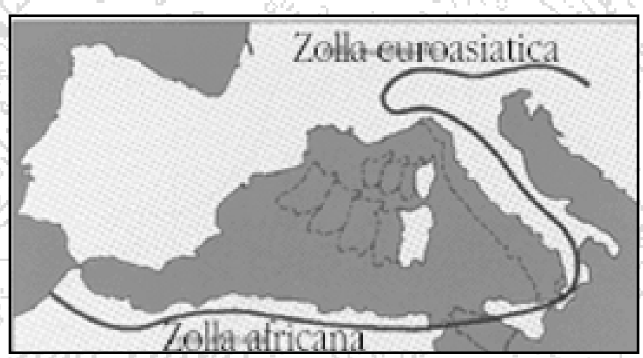
Intermediate depth and deep earthquakes also occur beneath the Italian peninsula . Although their number is relatively small, they are of great importance for understanding the geodynamics of deep processes. Earthquakes as deep as 500 km are recorded in the southern Tyrrenian zone, deepening from SE towards NW, beneath the Calrian Arc.

The largest activity is recorded approximately at 300 km depth, where earthquakes may reach M 7. Intermediate depth earthquakes can also be found in the Northern Apennines. Only a few intermediate depth earthquakes are recorded there, and their magnitudes rarely exceed 4.0. The maximum depth observed for these earthquakes reaches about 100 km. These earthquakes, although not yet well studied, suggest an active subduction process also for the northern Apennines.

Instituto Nazionale di Geofisica web sites:

HTTP://WWW.INGRM.IT

HTTP://WWW.GEOFISICO.WNT.IT/SISMOHP.HTML



New Chair of State Seismic Safety Commission

An Interview with Pat Snyder

Pat Snyder, a member of the California Seismic Safety Commission since 1989, was recently elected to lead the 17-member policy body. This past year Ms. Snyder headed the committee responsible for developing the recently released California Earthquake Loss Reduction Plan (see sidebar). As we mentioned in our last issue, SCEC participated in the focus group on education and information dissemination for the publication.

Ms. Snyder has had 39 years' experience as disaster nurse, administrator, and director for the American Red Cross. In addition to her work during the San Fernando, Coalinga, Whittier, and Northridge earthquakes, she has put her extensive experience to use in more than 35 disasters throughout the country. As an International League of Red Cross Societies Delegate, she went to Mexico in 1985 to help formulate recommendations for recovery programs after the Mexico City earthquake. Ms. Snyder was also a consultant to Japan following the Kobe earthquake in 1995 and conducted seminars on management of volunteers. She developed a Red Cross training program still used in several western states. She was awarded the National Red Cross Harriman Award (the highest honor given by the American Red Cross), the Alfred E. Alquist Award (California Earthquake Safety Foundation for Outstanding Achievement in Earthquake Safety), and many other awards throughout her career.

Ms. Snyder, a native southern Californian, was enthusiastic about talking with us about her new role with the commission and its relationship to scientific research within the SCEC community.

SCEC: How will your tenure as chair differ from that of previous chairs in that you are from a social background and not science or engineering or government?

PS: My background has been helpful in bringing the various interests of our commissioners together to head in one direction. In the past, the commission has had many agendas, depending on the leadership or the personality of the Commissioners. We're all looking at earthquakes as a common issue. The analogy I draw is that in working with my disaster background with the Red Cross we had to bring the people from mass care or the sheltering function together with the damage assessment and the financial folks. Everyone had separate interests, but we had to bring them together for the common good. And I think that's what I've been able to build on: bringing diverse interests together toward meeting a common goal. That's what I'm able to transfer toward the leadership of the Commission, without hammering away on the social service issues.

SCEC: What about the times when you feel that a social issue needs to be hammered? Do you step out of the chair role and be the advocate for the social services?

PS: Absolutely—you can never take that out of a person. I still feel strongly that people in the most vulnerable housing are probably the least prepared to deal with an earthquake. They're the ones who have the most difficulty recovering. We don't face it because we haven't been forced to face it. We haven't been hit with an earthquake in downtown Los Angeles, for example, a major earthquake that displaces thousands of people.

SCEC: What is your opinion of the value of SCEC-type research to predict where earthquakes are going to hit and how hard they're going to hit?

PS: By telling us where they expect earthquakes to occur, we can examine the demographics of the populations in those areas, and that's a tool for emergency planners to force the issue and look at some of these very difficult problems.

SCEC: What do you see as the value of coordination between researchers and emergency planners?

PS: It's always been an issue at every conference I've ever attended—the geologists speak with the geologists; architects, with the architects—we're not talking to each other. We need a mechanism to more easily transfer the research that is done to those who plan for and respond to earthquake emergencies. That's probably something that SCEC is going to be able to accomplish because that's the purpose of someone like Jill Andrews, as Director of Knowledge Transfer.

SCEC: What big challenges does the commission face?

PS: Most people don't wake up in the morning planning for earthquakes. A tough task facing the commission is getting the attention of the legislators and other decision-makers about earthquake issues because they are listening to issues like education. That's one of the problems we're having right now—getting seismic safety initiatives off the ground.

SCEC: What are your goals for your term as chair?

PS: It's not just my goal. I've spoken with each commissioner individually. To a member, they all feel that our role is to assist in implementing the *California Earthquake Loss Reduction Plan*. They feel that that is our primary mission. We're going to various locations throughout the state to introduce the plan and ask local people to tell us about their communities. It doesn't happen at the state level; implementation happens throughout the state at every level.

We're scheduled for a policy presentation in Washington DC at the end of February. It will be a high-level policy meeting that will focus on California's plan. Governor Wilson has been asked to speak. L.A. City Council Member (and Commissioner) Hal Bernson will be a presenter. FEMA is interested in using California's plan as a model for all states and all natural disasters.

SCEC: What is the Seismic Safety Commission's role in supporting research efforts?

PS: I want to make sure that researchers like those who participate in SCEC know about the commission's research plan. It dovetails with the loss reduction plan. In fact, FEMA tells us they will not fund research within the California following a disaster unless it is supported by those plans.

SCEC: Since you're a southern Californian, do you think you are prejudiced in the direction of southern California issues?

PS: Not at all. I'm as interested in the Bay Bridge and Oakland and Hayward, and maybe it's because I've worked in these areas at various times during earthquakes that I've become bonded to them. So I feel as strong about the northern California community as I do to my own, particularly when it comes to earthquakes. I can't say politically or geographically that I have the same feeling, but as far as preparedness, I think I can extend that to say I have the same feeling for the whole country or the whole world.

SCEC: From the point at which you became chair and right now, has there been anything that was a big surprise?

PS: The biggest surprise was having to work within the state bureaucracy. I was very well acquainted with the Red Cross bureaucracy, and nothing surprised me. Learning how to maneuver within the state system was a big learning curve. From my Red Cross background, I have always been neutral—that's one of the principles of the Red Cross. And to move from that to a state system which functions with a political system has been another big transition for me.

SCEC: You've had a lot of immediate post-earthquake experience.

PS: Yes. I remember the 1971 earthquake very vividly. And I was in Coalinga the day after the earthquake and we had numerous aftershocks that were nearly as strong. I was in Mexico City after the earthquake and experienced all those aftershocks. And of course, I was home for the Whittier quake. I have experienced a lot of earthquakes.

SCEC: Is it possible not to have had those experiences and keep your level of concern about seismic safety?

PS: That's a good question. I have trouble identifying with the current ice storm in New England. It's not part of my experience—I've never been that cold; I've never been without electricity and heat for a week and a half. While I read about it, I can't internalize it. And the earthquakes I can very readily internalize, and I know the fear that comes with it. We had a little "boomer" the other night. It was a 3.5, but it felt much stronger than that. I was sitting next to the sliding glass door in a chair and I was out of that chair immediately heading away from that glass door. Without the experience, you don't have that same reaction. I've seen what it's done to people, primarily in Mexico City and Northridge and San Fernando—those are the three that really were the strongest in my memory.

SCEC: How do we get people to care and prepare if they haven't had your experience?

PS: We have to develop incentives. Again, there is other research that can be done—the cost effectiveness of retrofitting. I'm convinced that for insurance people, builders, developers, and others, it's money-wise to prepare. We are all wrapped up in our own personal lives, and to take time out of our lives and money out of our paychecks to do something about earthquakes preparedness is a hard sell. There should be an incentive such as reduced insurance rates for those who've retrofitted or taken other preparedness measures in their homes. It should be like other areas of insurance—if you have air bags, you get lower rates; if you put on a fire retardant roof, you pay less for fire insurance.

SCEC: Do you have a particular message for SCEC participants and constituents?

PS: I would encourage them to read the *California Earthquake Loss Reduction Plan* and look at the initiatives within their fields of expertise. It's important that those are all findings from the past three earthquakes in California. The initiatives in the plan come out of the experiences and recommendations of their professional community. The plan is a living document. It needs the active participation of SCEC and the scientific community it represents to stay alive and to be effective.

Seismic Safety Commission Releases State Earthquake Mitigation Plan

The California Seismic Safety Commission released the state's comprehensive plan for reducing the risks from earthquakes. The *California Earthquake Loss Reduction Plan* is the third update of the commission's recommended policies for managing long-term earthquake risk. The commission is an independent state agency made up of 17 volunteer members who recommend earthquake safety policies at the state level.

The document serves as the strategic plan for the state's executive and legislative branches in implementing seismic safety. The plan also fulfills the Federal Emergency Management Agency's requirement for a state hazard mitigation plan. Without the plan, FEMA would not be able to distribute post-earthquake relief and mitigation funds.

The Seismic Safety Commission produced this plan under the mandate of the California Earthquake Hazards Reduction Act of 1986. The long-awaited report, endorsed by Governor Wilson, is the product of months of meetings and deliberations with representatives of private and public agencies, including state, federal, and local government as well as representatives of SCEC.

The plan incorporates lessons learned from the Northridge (1994) and the Kobe (1995) earthquakes and focuses on 11 elements: geosciences, research and technology, education and information, economics, land use, existing buildings, new construction, utilities and transportation, preparedness, emergency response, and recovery.

"Forming partnerships, using new technologies, and emphasizing transfer of knowledge are key components of the plan," commented SCEC's Jill Andrews, who participated in shaping the knowledge transfer and other SCEC-related portions of the plan. "We have to keep finding new ways of proving that mitigation is necessary and that it works. SCEC's work can form the foundation for the plan's goal of loss reduction."

The *California Earthquake Loss Reduction Plan* sells for $15. Order it from the California Seismic Safety Commission, 1900 K St., Suite 100, Sacramento, CA 95814. Call (916) 322-4917 or email sscbase@aol.com for information. The commission's web site is www.seismic.ca.gov.

Calendar

January 1998

27-28—Workshop with Los Alamos National Lab, "Earthquakes and Urban Infrastructure"; Los Angeles. Contact: Grant Heiken (LANL), Jill Andrews

29-30—SCEC Science Seminar & Workshop on Sediment Nonlinearity. L.A. Ned Field: field@usc.edu

February

4-7—Earthquake Engineering Research Institute annual meeting, Fairmont Hotel, SF. 50th anniversary of EERI. Theme: "Past, Present and Future Issues in Earthquake Engineering." SCEC's Jill Andrews, chair of EERI's Innovative Technolgy Transfer Forum, will host 2-hour workshop to review the forums's mission and goals and start identifying useful products. eeri@eeri.org

March

8-15—Fourth International Conference on Case Histories in Geotechnical Engineering. St. Louis, MO. Abstracts due 12/15/97. buddyp@shuttle.cc.umr.edu.

16-18—Seismological Society of America annual meeting. Boulder, CO. snewman@seismosoc.org.

May

26-29—American Geophysical Union Spring Meeting, Boston, MA. meeting. info@kosmos.agu.org; HTTP://WWW.AGU.ORG.

31-June 4—U.S. National Conference on Earthquake Engineering, Seattle, Washington. eeri@eeri.org

June

25-27—Western U.S. Earthquake Insurance Summit, Sacramento, CA. Hosted by WSSPC & Western Council of State Governments. More info next issue.

July

12-15—Natural Hazards Workshop, Boulder Colo. For more info see WWW.COLORADO.EDU/HAZARDS/

October

17-20—SCEC annual meeting, Palm Springs, CA.

November

11-13—Fourth International Conference on Corporate Earthquake Programs, Tokyo. Conference addresses EQ safety of business and industries.

"Physics of Earthquakes" Series at USC

The "Physics of Earthquakes" is a special seminar series that will usually be held once a week at 10 AM on Tue., in Science Building, room 123. Each 2-hour seminar will include a short introduction, a lecture, and discussion.

Some of the speakers and titles are listed below. Updates are listed on the web: HTTP://WWW.USC.EDU/DEPT/EARTH/.

January 27, Prof. Hiroo Kanamori, Caltech, "Frictional Melting During Faulting"

February 10, Dr. Vladimir Lyakhovsky, HU of Jerusalem and USC, "Simultaneous evolution of earthquakes and faults in a rheologically layered half-space"

February 18, Prof. Mark Zoback, Stanford U, "Lithospheric strength and crustal deformation" (Day and time change, Wed 10:30)

February 24, Dr. Susan Hough, USGS Pasadena, "Imaging attenuation variability at the Coso Geothermal Field"

March 3, Dr. Yan Kagan, UCLA, "Scale-invariance of earthquakes"

March 10, Prof. Bill Klein, Boston U. and ITP

March 17, Dr. Karin Dahmen, Harvard, "Statistics of earthquakes in simple models of heterogenous faults"

March 24, Dr. Dave Lockner, USGS Menlo Park

March 31, Prof. Leon Knopoff, UCLA

April 7, Prof. Steve Day, SDSU

April 14, Prof. Tom Rockwell, SDSU, "Applications of paleoseismology in understanding earthquake recurrence"

April 21, Dr. Jishu Deng, SCEC/Caltech, "Stress evolution and earthquake triggering in southern California"

SCEC Notes

Dr. Forrest Did It

SCEC's Michael Forrest—who has been with us since our first issue and has written several feature articles for this newsletter—finished his Ph.D. at USC. in November, after a mere eight years as a graduate student.

He's been leaping about with the intolerably broad and irritating smile that fifteen-year-olds wear when they first fall in love (well, at least that's the way someone described him.)

SCEC Post-Doctoral 2-Year Fellowships Announced

The SCEC directors and board members are pleased to announce the names and projects of the recipients of the 1998-99 SCEC two-year post-doctoral fellowships. The names, affiliations, project titles, and mentor scientists for each are listed below. Congratulations to all three of you and don't forget to submit your status reports to SQN.

Peggy Johnson, Ph.D. at UC-Berkeley, will work with Sue Hough of the USGS on an "Investigation of Seismic Source Processes, Low-Angle Thrust Events, and TriNet Response, Using Empirical Green's Function Deconvolution of Small (M<5) Earthquakes."

Jan Vermilye, Ph.D. at Columbia's Lamont Doherty, will work with Nano Seeber at Lamont on "Magnitude and Spatial Distribution of Pressure Solution Strain Associated with the Displacement of Faults in Southern California."

Lupei Zhu, Ph.D. at Caltech, will work with Leon Teng at USC on two projects: "Empirical Green's Function Data Base and Broadband Strong-Motion Prediction" and "Basin Structure from Modeling Local Waveforms."

Earthquake Information Resources On Line

SCEC on the Web

www.scec.org

Earth Sciences

SCEC Data Center

HTTP://WWW.SCECDC.SCEC.ORG/
SCEC Data Center home page

HTTP://WWW.SCECDC.SCEC.ORG/RECENTEQS
Recent earthquake activity in northern and southern Calif. Maps and earthquake lists are interactive and updated at the time of an event

HTTP: / / WWW.SCECDC.SCEC.ORG / EARTHQUAKES / CURRENT.TXT (TEXT)
HTTP://WWW.SCECDC.SCEC.ORG/EARTHQUAKES/CURRENT.GIF (MAP)
Southern California Seismic Network weekly earthquake reports

HTTP://SCEC.GPS.CALTECH.EDU/FTP/CA.EARTHQUAKES
SCSN weekly earthquake reports archives to January 1993

HTTP://WWW.SCECDC.SCEC.ORG/SEISMOCAM/
Caltech / USGS Seismocam: waveform displays of data 30-seconds-old earthquakes in southern California: includes aftershock maps, animations of aftershock sequences and rupture models, a clickable map of historic southern California earthquakes, and *Putting Down Roots in Earthquake Country* (online book)

HTTP://WWW.SCECDC.SCEC.ORG/EQSOCAL.HTML
Main page

HTTP://WWW.SCECDC.SCEC.ORG/CLICKMAP.HTML
Southern California clickable earthquake map

HTTP://WWW.SCECDC.SCEC.ORG/LABASIN.HTML
HTTP://WWW.SCECDC.SCEC.ORG/EASOCAL.HTML
Los Angeles basin clickable earthquake map

HTTP://WWW.SCECDC.SCEC.ORG/EQSOCAL.HTML
Earthquakes in southern California

HTTP://WWW.SCECDC.SCEC.ORG/BYMONTH.HTML
Time-lapse animations of southern California seismic activity

HTTP://SCEC.GPS.CALTECH.EDU/CGI-BIN/FINGER?QUAKE
"Finger Quake" ftp (updated frequently)

HTTP://WWW.SCECDC.SCEC.ORG/FAULTMAP.HTML
Southern California fault map

HTTP://WWW.SCECDC.SCEC.ORG/LAFAULT.HTML
Faults of Los Angeles

HTTP://WWW.SCECDC.SCEC.ORG/LARSE.HTML
LARSE home page

HTTP://SCECDC.GPS.CALTECH.EDU/CATALOG-SEARCH.HTML
Interactive SCSN seismicity catalog search page

HTTP://WWW.SCECDC.SCEC.ORG/EQCOUNTRY.HTML
Putting Down Roots in Earthquake Country (online book)

Seismo-Surfing the Internet

HTTP://WWW.GEOPHYS.WASHINGTON.EDU/SEISMOSURFING.HTML
Clearinghouse of research data & informmation

USGS Web Sites

HTTP://WWW.USGS.GOV
General USGS site

HTTP://GLDSS7.CR.USGS.GOV/
National Earthquake Information Center

HTTP://GEOLOGY.USGS.GOV/QUAKE.HTML
Earthquake Information

HTTP://QUAKE.WR.USGS.GOV/
USGS Menlo Park

HTTP://WWW-SOCAL.WR.USGS.GOV
USGS Pasadena

HTTP://GEOHAZARDS.CR.USGS.GOV/NORTHRIDGE/
USGS Response to an Urban Earthquake — Northridge '94

HTTP://WWW-SOCAL.WR.USGS.GOV/LISA/NETBULLS/NETBULL_LIST.HTML
Southern California Seismic Network

HTTP://WWW.SEISMO.UNR.EDU
Nevada Seismological Laboratory

Features work by two SCEC-funded researchers, John Anderson and Steve Wesnousky. Contains lists, maps, and seismogram data from recent earthquakes. Also: background geologic and seismicity maps; searchable earthquake catalogs; contact lists, brochures, geophysics degree program information; courses in earthquake fundamentals and scientific visualization.

USGS email addresses

NEIC@USGS.GOV
National Earthquake Information Center

NGIC@USGS.GOV
National Geomagnetic Information Center

NLIC@USGS.GOV
National Landslide Information Center

Paleoseismology

HTTP://INQUA.NLH.NO/COMMPL/PALSEISM.HTML
The INQUA Subcommission on Paleoseismicity: content list and authors for the special issue of journal of geodynamics arising from the INQUA Berlin 1995 symposium on paleoseismicity.

Active Tectonics

HTTP://WWW-GEOLOGY.UCDAVIS.EDU/~GEL214/
University of California, Davis—Active Tectonics
• Lecture notes ("Contents")
• Problem sets ("Problems") for this course
• WWW links ("Links") of interest to students and researchers
• References

GIS Web Sites

HTTP://WAREHOUSE.GEOPLACE.COM/
Bibliography of GIS & environmental applications:

HTTP: / / PASTURE.ECN.PURDUE.EDU / ~ENGELB /
Bernie Engel, professor of agricultural engineering: soil and water conservation, environmental issues, systems engineeering

See "On Line Resources" on Page 30

On Line Resources continued

http://www.lib.berkeley.edu/cgi-bin/print_hit_bold.pl/UCBGIS/
UCB GIS Task Force integrates GIS activities with other resources at UCB campus, recommends GIS services for library

http://www.nwi.fws.gov/thinktank.html
GIS Think Tank on problems of digital mapping for users of NWI data

http://fgdc.er.usgs.gov/linkpub.html
List of FTP directories for federal Geographic Data Committee

http://mis.ucd.ie/staff/pkeenan/gis_as_a_dss.html
Paper on how to use a GIS as a DSS generator

http://spsosun.gsfc.nasa.gov/EOSDIS_services.html
A spectrum of services, some for casual users, some for research scientists, some inbetween

http://www.ggrweb.com/
Services of information technologies, earth sciences, GIS, GPS, & remote sensing industries

Geodetic Information

http://lox.ucsd.edu
This site is the IGPP & Scripps Orbit and Permanent Array Center (SOPAC) and features global (IGS) and regional (SCIGN) continuous GPS archive, SCIGN maps, time series, and site velocities.

GMT

http://quake.ucsb.edu
Helps make shaded relief maps with GMT. Has catalog of maps produced by Geoffrey Ely at the ICS/UCSB. Downloadable digital elevation model for southern California in GMT-readable (netCDF) format. The grid covers the region 121W 115W 32.5N 35.5N at a resolution of 3 arc sec. You can get to the web page from the ICS home page, then click on Mapping, and then Geoff's Map Catalog.

Preparedness, Disaster Management

http://www.best.com/~trbu/oes/
California Governor's Office of Emergency Services: information on Earthquake Preparedness Month campaign

http://kfwb.com/eqpage.html
KFWB Quake Page (by Jack Popejoy)

http://kfwb.com/cucamong.html
KFWB Webservice exclusive: trenching the Cucamonga fault:

http://www.highways.com/lasd-eob/
The Los Angeles Sheriff's Department Emergency Operations Bureau

http://www.johnmartin.com/eqprep.htm
John A. Martin & Associates

http://www.eerc.berkeley.edu/
Earthquake Engineering Research Center offers extensive, searchable database of abstracts, reports, and other resources. New: "Lessons from Loma Prieta,"with papers, images, and data.

Earthquake Information Sites

http://www.eqnet.org/
EQNET

http://www.civeng.carleton.ca/cgi-bin/quakes
Recent quakes (with a great map viewer)

http://www.crustal.ucsb.edu/scec/webquakes/
Up-to-the-minute southern California earthquake map—latest 500 earthquake locations. Java-enabled browsers only.

http://www.consrv.ca.gov/dmg/shezp/psha0.html
Probabilistic Seismic Hazard Map, California

http://www.abag.ca.gov/bayarea/eqmaps/liquefac/bayaliqs.gif
Bay Area hazard map

http://www.wsspc.org
Western States Seismic Safety Policy Council site, an overall earthquake safety information source.

http://www.scecdc.scec.org/glossary.html#BLIN
Glossary of terms (in progress)

http://www.geophys.washington.edu/seismosurfing.html
Seismic Info Sources

http://www.seismic.ca.gov/ssccatr.htm
Seismic Safety Commission—state earthquake hazard mitigation plan

http://www.seismic.ca.gov/sscleg.htm
Seismic Safety Commission legislation page (current state and federal bills being tracked and analyzed by the Commission)

http://www.seismic.ca.gov/sscsigeq.htm
Seismic Safety Commission—significant damaging California earthquakes

Internet Discussion Groups

wsspc-l@nisee.ce.Berkeley.edu
Western States Seismic Policy Council discussion group

eq-geo-net@gsjtmws8.gsj.go.jp
Paleoseismic ListServe

gvn@volcano.si.edu
Global Volcanism Network

quaternary@morgan.ucs.mun.ca
Research in quaternary science

seismd-l@bingvmb.bitnet
Seismological discussion list (SEISMD-L)

quake-l@listserv.nodak.edu
Earthquake discussion list

Conferences, Events

http://www.eeri.org
February 4-8, 1998—Earthquake Engineering Research Institute annual meeting, San Francisco.

Southern California Earthquake Center Administration

SCEC Board of Directors

Southern California Earthquake Center Knowledge Transfer Program

The SCEC administration actively encourages collaboration among scientists, government officials, and industry. Users of SCEC scientific products (reports, newsletters, education curricula, databases, maps, etc.) include disaster preparedness officials, practicing design professionals, policy makers, business communities and industries, local, state and federal government agencies, the media, and the general public.

Knowledge transfer activities consist of end user forums and workshops, discussions among groups of end users and center scientists, written documentation and publication of such interactions, and coordination of the development of end user-compatible products.

Planned and in-progress products and projects include:

- Insurance industry workshops; proceedings; audio tapes
- Engineering geologists' workshops; proceedings; geotechnical catalog.
- Vulnerability workshops, city and county officials
- Media workshops
- Field trips
- Quarterly newsletter
- *Putting Down Roots in Earthquake Country* handbook
- SCEC WWW pages (WWW.SCEC.ORG)
- SCEC-sponsored publications; scientific reports

For more information on the SCEC Knowledge Transfer Program, contact Jill Andrews, Director, Knowledge Transfer phone 213/740-3459 or email *jandrews@usc.edu*
or
Mark Benthien, Outreach Specialist phone 213/740-0323 or e-mail *benthien@usc.edu*.

SCEC Quarterly Newsletter

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Have questions? Call, fax, or email:

Tel: 213 / 740-1560
Fax: 213 / 740-0011
Email: *SCECinfo@usc.edu*

SCEC on the Internet

SCEC Knowledge Transfer and Education Programs are reachable via electronic mail. Ask general questions, make requests, send us information for use in our resource center or for consideration for publishing in the next newsletter.

SCECinfo@usc.edu

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SCEC Quarterly Newsletter

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