Quarterly Newsletter
Volume 4, Number 4

Southern California Earthquake Center

SCEC

From the Center Directors . . .

A Possible New Beginning for CERC

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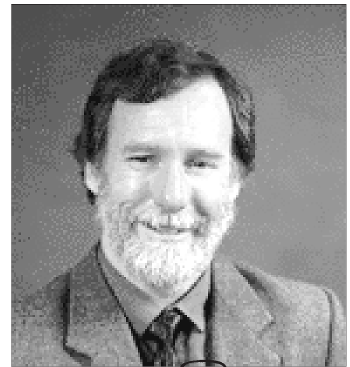
Center Director



Science Director

As PI on the CERC proposal submitted to NSF last year, I have decided that it is in our best interest to abandon efforts to renew the earthquake center through the Science and Technology Centers program.

As most of you probably know by now, we ranked very high in the review process yet were denied a site visit, even though one was recommended by the panel. After my written requests for clarification, including a phone conversation with Nat Pitts, head of the Office of Integrative Activities, brought no concrete explanations that would guide me in a more fruitful direction, I have come to the conclusion that to pursue things through the STC program at this stage would not be in our best interest.

I have also talked at length with Neil Sullivan, our vice-provost for research at USC, who just returned from a five-year stint as assistant director for polar programs at NSF. He has been privy to most of the high-level conversations regarding the STC program at the foundation, and his message was similar to Nat Pitts'.

I come to this decision after much soul searching and considerable distaste for failure! It is apparently just not in the cards for an existing center to continue in the STC program, no matter how hard we try to look different. The bottom line seems to be that the National Science Board has made it clear to NSF-STC management that it expects all STCs to sunset after 11 years.

So even if we passed the site visit, we almost certainly would not make it past the board. On one hand, it's unfortunate that it took so long for us to get that message, particularly since our pre-proposal was accepted and we made the cut to the final 44, and then the final 19 with our full proposal. However, that process forced us to give some very important thought to where we want to go from here, and that kind of introspection can never hurt an organization such as ours.

> Those who wish to participate *must* be committed to a center mode of operation.

Although we might have a chance by protesting on the grounds of a flawed process, I believe the chance of success is significantly less than 50 percent. A second failure would only involve further loss of momentum and interest on the part of center participants. Rather, I think we need to pursue a new strategy. In this regard, the STC process was not a failure for three fundamentally important reasons. First, the proposal process pulled together a large segment of the earthquake research community interested in maintaining a center. Second, we developed a "white paper"—i.e., the proposal—that reflects both a consensus and a plan (and it almost certainly can be made even better). And third, we received high marks in the NSF-STC review process, indicating there is considerable support for such a center both inside and outside the foundation.

So where do we go from here? First, I believe that taking a conciliatory approach with NSF regarding our proposal will benefit us. Such an approach coupled with the knowledge that the proposal was highly ranked can put us in a good position to propose a new center to NSF outside the STC program. One message from Nat Pitts effectively was that SCEC has a good reputation throughout NSF and we should play that card. Second, we are well positioned with respect to the new director and new initiatives being discussed at NSF.

Establishing a new center will require considerable interaction and up-front work with NSF (and perhaps the USGS, IRIS, and state of California) and may take a couple of years. For that reason, if we are to pursue this path, we need to begin right away. I want to emphasize that those who wish to participate *must* be committed to a center mode of operation. We will argue strongly that future research in earthquake physics, understanding the earthquake process, and applying the knowledge to earthquake hazard reduction, lends itself to, and can benefit immeasurably from, a center mode of activity. I view a new center in the same light as SCEC—funding cutting-edge interactive/integrative science, developing and supporting regional facilities and infrastructure, promoting and nurturing new opportunities, leveraging additional resources, developing active partnerships (e.g., with USGS, PEER, CUREe, IRIS, national labs, state geological surveys, etc.), and maintaining a robust education and outreach program.

—Tom Henyey

SCEC research and outreach play lead roles

California Science Center Launches "Track the Quake" Program

by Sara Tekula

Over the past year, the outreach staff at SCEC has become increasingly involved in activities and projects with the California Science Center, located in Exposition Park, across the street from SCEC's offices at USC. The most exciting of these projects has recently been installed, prominently featuring SCEC research results.

This new project, called "Track the Quake," is a part of the Science Center's "Think Science" program, which hosts school groups, workshops for kids, and informal learning experiences for the general public. The Science Center wanted to create a hands-on exhibit where the participants learn about the "tools" that geoscientists use when doing research. The main idea was to put the participants in the scientists' shoes.

As a result of brainstorming with several members of the SCEC staff, the Science Center decided to build a simulated fault trench to allow visitors to walk into a post-earthquake scenario and immediately begin collecting data and making observations. Other parts of the exhibit room will be designated for out-of-trench observations of building damage, roadcuts, broadcasts of data, and more, as the program develops further.

When participating in the program, students are arranged into groups, each of which has a focus: paleoseismology of the fault zone, geographical distribution of earthquakes, or the size of the earthquake. After their initial research, the groups reconvene and compile and compare their data, mimicking how real science is done in an interdisciplinary community such as SCEC.

The development team at the California Science Center consisted of Robert deGroot, Catherine Stauffer, Darryl Ramos-Young, and other members of the exhibit programs staff. SCEC Director Tom Henyey played a lead role in conceptualizing the exhibit. Representatives of the SCEC Outreach Program acted as liaison between the two centers and assembled a working group of SCEC scientists and earth science students to consult on the scientific accuracy of the project. According to deGroot, "We would be nowhere if SCEC had not assembled the working group for us."

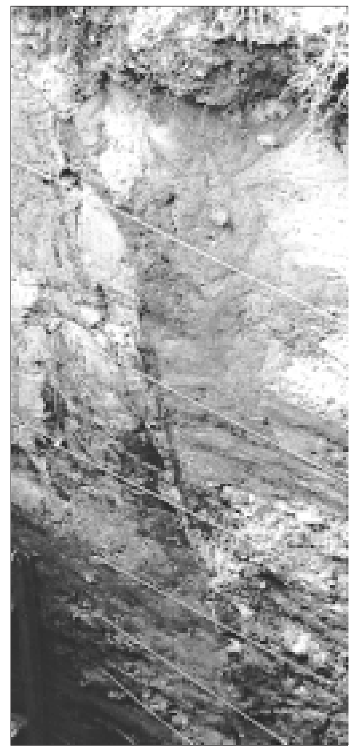
Kristin Weaver, a master's degree candidate in active tectonics at USC, used her own stratigraphic work of the Raymond fault to design the cross-section that will be used in the program. USC biology student and Science Center employee Danielle Rodin hand-painted the stratigraphic layers on a wooden panel at life size.

The SCEC Outreach Program will continue to contribute advice and consultation to the Science Center as the "Track the Quake" program continues. The SCEC publication *Putting Down Roots in Earthquake Country* will be provided in each teacher's packet.

For more information about the program, contact the California Science Center at 213-744-2019.

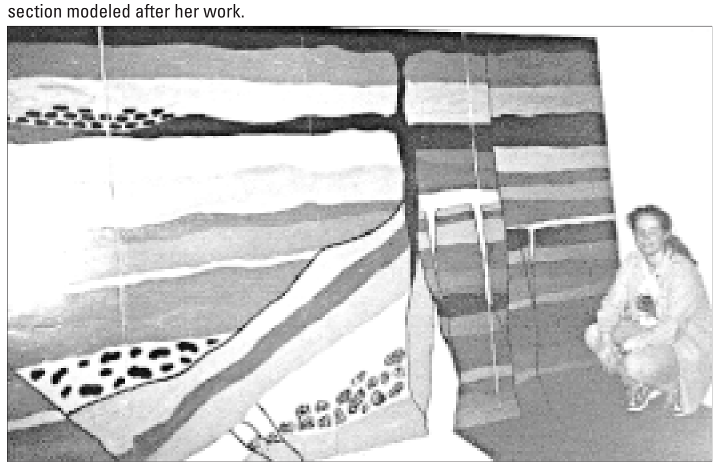
We would be nowhere if SCEC had not assembled the working group for us.

Kristen Weaver, USC, explains the trench log, which graphically represents the stratigraphy of her cross-section.



A portion of the trench wall at Weaver's Raymond fault trench, which was translated into the Science Center exhibit cross-section.

Weaver at the California Science Center alongside the Science Center's wooden cross-section modeled after her work.



Interview with SCEC scientist . . .

Thomas Heaton

Photo courtesy Caltech

Interviewed by Karen Brown for the SCEC Quarterly Newsletter.

> I think most people would consider that I'm a seismologist. I'm not sure you'd want to actually enter a building I designed.

SQN: You attended Bates College and then Indiana University where you majored in physics and mathematics. How did your interest in physics and math arise?

TH: I knew I was interested in science. I have always been interested in how things work, and I was at various times a chemistry major, a physics major, and a math major. It was sort of a process of elimination. The premeds drove me out of chemistry, and mathematics didn't seem to have enough applications, so I ended up in physics.

SQN: You went on to do a Ph.D. at Caltech in both geophysics and applied mechanical engineering. Were these two subjects unusual and unlikely partners?

TH: No, actually they're very closely related. To me, applied mechanics is more about the mechanics of continuous media. I took several classes in elasticity, and they were very useful in geophysics.

SQN: The combination of subjects also is reflected here in your position at Caltech. You have joint positions in the divisions of Engineering and Applied Sciences and Earth and Planetary Sciences. Is that a first?

TH: Probably not. I think Professor Bruce Bolt at the University of California, Berkeley has had a joint position in engineering and geophysics.

SQN: How do your colleagues and others view your joint position?

TH: It means that you have twice as many contacts. It means there are twice as many colleagues to learn the names of and what they do. There's often twice as much jargon to learn. Procedures in the different divisions are different—how people are tested and what's expected of them. There are different journals and meetings and committees…

SQN: How do you keep up with all of those?

TH: I guess the answer is that I don't. It's almost impossible to keep up with all those different things, and yet you have to keep up with at least some fair percentage of them. So it definitely makes life more complicated, and it makes it harder to focus on some individual problem.

SQN: Are there positive aspects?

TH: Oh, sure. One of the great joys in life is seeing the connections between recurring themes. Many of the problems and themes of engineering show up in some different way in seismology. And vice versa. Overall, though, I would say it's a challenge. One of the secrets to life is learning how to find satisfaction in the things around you. Although having these two things going on is confusing, I'm willing to find satisfaction in confusion.

SQN: Is there ever any misunderstanding between seismologists and engineers about the size, nature, and dynamics of earthquakes?

TH: Certainly; we come from two entirely different perspectives and universes when it comes to how we view the earthquake problem. Seismologists look at the overall process of the earth in the long term: how did it get the way it is?

In that viewpoint often the biggest events are the ones that matter the most. We have a range of sizes of things, and in the earth sciences it often turns out that the very biggest examples of something dominate how the final form looks. So we cannot ignore the big events in seismology. And, in fact, in some ways they're the ones we have to really understand because they dominate processes like plate tectonics.

In the engineering world the perspective is usually "What have we learned from our recent past about buildings similar to the ones we're putting up now, and how can we improve our current buildings?"

The very largest events usually have not happened in our recent memory, and from an engineering point of view, they're viewed as the extreme and rare occurrences. Often they're viewed as something that should not dominate our thought in terms of how to respond to them. However, for an earth scientist, those large events are the key actor.

SQN: Have you found it at all difficult to reconcile these different motivations?

TH: I find that there is a tremendous inconsistency between the earth science field and the earthquake engineering field in terms of how we view large earthquakes. It's my own view that large earthquakes are infrequent but inevitable. When they do occur, which they inevitably will, we may look very foolish if we have not diligently studied what those large earthquakes will be like.

That is, if we get another 1906 earthquake and we say we're completely surprised by what happens, then we will look very foolish, because people will say, "You knew such an earthquake was going to happen; you've been telling us it's going to happen." So the engineering field needs to understand what such an earthquake will look like.

SQN: Are you really saying that both fields need each other?

TH: Oh, clearly, both fields need each other. Sometimes the earthquake seismologists make many statements about the sizes of earthquakes or the occurrence of earthquakes that leave the public with an impression that earthquakes are so violent that there's no way to deal with them.

And then you see from the earthquake engineering profession statements like, "Well, our current codes are adequate and we're doing the correct things." At some point, there's a complete disconnect between statements from seismologists and those from engineers. The truth is usually somewhere in between.

SQN: Do you look at yourself as being more in either camp?

TH: I think most people would consider that I'm a seismologist. I'm not sure you'd want to actually enter a building I designed.

SQN: Where did you go to work following the completion of your Ph.D. at Caltech in 1979?

TH: For one year I worked as an employee at Dames and Moore. They're a geotechnical/engineering consulting firm. At the time (1978-79), a large part of their business was working on nuclear power plants or other types of energy facility.

I had an unusual position. I worked half time in the Westwood office and for the other half I was stationed at Caltech to continue my research. Then I decided it was hard to do research on a half-time basis, and when the USGS offered me a position to do research full time in the Pasadena office, I took it.

SQN: How did you enjoy the private-sector work?

TH: It was a very high-pressure world of geotechnical consulting. Lots of immediate deadlines and reports that had to be done right away. It didn't really allow a tremendous amount of time for in-depth study of an issue. But at the same time it was very challenging and rewarding. I only have good things to say about the people I worked with and the things that they do. I just really wanted to get back to research.

SQN: Did the private sector experience, although relatively brief, affect your subsequent career, views, or approach?

TH: It certainly gave me a lot of connections with groups of people that I might not normally have had without going into the consulting world. And I think that probably ultimately led to my getting a joint appointment in civil engineering.

SQN: What was it about research that attracted you back?

TH: I think the greatest joy is in seeing how things work and how they connect together. I can really say that I have lived for those eureka moments, where you can see how

> I've seen three generations of seismologists go to their graves saying, "It's coming, it's coming." You get a little skeptical after a while.

Professional Highlights
THOMAS H. HEATON

Education
Bates College, Maine

B.S., physics—Indiana University

Ph.D., geophysics; minor in applied mechanics—Caltech

Professional
Professor of Engineering Seismology, Caltech

Project chief, Southern California Seismographic Network Project

Member, ad hoc committee to plan a Southern California Earthquake Center

Project chief, Southern California Earthquake Project

Scientist in charge, USGS Pasadena Field Office

Project chief, Northwest U.S. Seismic Risk Assessment Project

Research geophysicist, USGS Pasadena

Senior seismologist, Dames & Moore, 1978–1979

Honors
Faculty Associate, California Institute of Technology

Meritorious Service Award, U.S. Department of the Interior

Memberships
American Geophysical Union

Seismological Society of America (president, 1993-1995)

Earthquake Engineering Research Institute

California Universities for Research in Earthquake Engineering

Research Committee of PEER

Global Seismographic Network Committee of IRIS

Recent Research Subjects
- Inversion of geophysical data to determine the rupture characteristics of earthquakes
- Simulation of strong ground motions for large earthquakes
- Investigations of the physics of fault rupture and the state of stress in the crust
- Investigation of the radiation damping of buildings
- Development of techniques for real-time seismology

Recent Publications
Heaton, T. H., J. Hall, D. Wald, and M. Halling. "Response of high-rise and base-isolated buildings to a hypothetical M 7.0 blind thrust earthquake." *Science* 267:206–211.

Kanamori, H., E. Hauksson, and T. Heaton. "Real-time seismology and earthquake hazard mitigation." *Nature* 390:461–464.

Kanamori, H., D. L. Anderson, and T. Heaton. "Frictional melting during the rupture of the 1994 Bolivian earthquake." *Science* 279:839–842.

things connect. That to me is the most rewarding part of professional life.

SQN: What were some eureka moments that you will never forget?

TH: I think that the realization of how important pulses are in the propagation of rupture on faults was probably the most exciting time for me. That was about 1988.

More recently it's been quite exciting to understand better what the brittle nature of the crust is and how dynamic rupture plays into the brittleness of the crust. I haven't written that up yet.

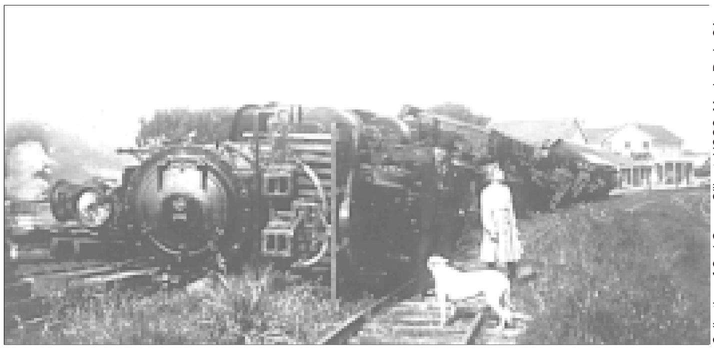
Also, I think the time, in about 1993, when Professor John Hall and I were looking down from the top of an 80-story building in Los Angeles and discussing the physics of how the building stays up in the air. There was a moment of realization that there were many assumptions made in designing the building that might not be consistent with things that I knew about ground motion.

In addition, there have been a series of exciting developments about the Cascadia subduction zone problem. The first discussions with Hiroo Kanamori about Cascadia and how it relates to other subduction zones were very exciting.

And then the correspondence between me and Brian Atwater, who was a geologist actually finding evidence for these large earthquakes in the Cascadia zone, has been very exciting, to actually see someone discover these events that Hiroo and I speculated on.

SQN: Regarding the first of these eureka moments, which your colleagues have termed the Heaton Pulse, would you please explain your idea in simple terms and how this influences damage of buildings?

TH: Once I saw it, it seemed so simple in my mind, but certainly it wasn't always so simple to explain. Judging from the puzzled looks of colleagues and from some of the reviews I got, evidently it's not so simple to explain. But it's one of those things, once you see it, it seems like, "Well of course, it can't be any other way. It works."



Collection of Carl Grove Gilbert, USGS, Menlo Park, CA

The result of the pulse-like motion that occurs close to a large earthquake can be seen in this photo taken soon after the 1906 earthquake. Thomas Heaton points out that although the pulse motion didn't greatly damage the railroad station in the background, such a motion might have serious consequences for some modern flexible buildings.

The idea is that the fault moves caterpillar-like. That is, when there is slippage between the two sides of a fault, only a small part of a fault is moving at any given time. And the question then is Why does it propagate as a pulse? The simple answer is that the friction is temporarily low on the fault for dynamic reasons.

In effect, part of the eureka is that we've been searching for some explanation of why faults are so weak, and this slip pulse mechanism seems to require a weak fault for its existence.

The next kind of question is Why is there dynamic weakening in the fault? Various people have come up with several plausible explanations. I'm currently quite attracted to the explanation that Joe Andrews and Yehuda Ben Zion have come up with about material unconformities being responsible.

SQN: You were scientist in charge at the USGS Pasadena office from 1985 until 1992, a time when the office was a key unit in responding to numerous important earthquakes. What was your contribution at that time?

TH: I pushed very hard to change the focus of the seismographic network from a network that was primarily looking at patterns of occurrence of earthquakes—locations and times—to try to come up with a system that was more multifunctional.

I tried to modify the goals of the network so that it would actually record the three components of ground shaking and could be used for a variety of purposes. One, for understanding how waves propagate around California. Two, I was very interested in seeing that we would better be able to predict motions in future earthquakes for building purposes. And three, I was quite intrigued with the possibility of actually coming up with warnings of shaking on its way.

So I pushed very hard to try to get our network turned into a practical tool for engineering and emergency management, whereas before the primary purpose of the network was for scientific research into patterns of earthquakes.

It's very satisfying now to see that the network has evolved into the TriNet Project, which is really a tremendously historic step ahead for seismology in southern California.

SQN: Please elaborate on real-time seismology and your contribution.

TH: When I was scientist in charge of the Pasadena office, I certainly pushed in the direction of improving the real-time response of the network in an earthquake. We were probably the first network in the United States to put out strong-motion instruments that telemetered data in real time. I was the lead author on a study called the National Seismic System Science Plan, which fleshed out the vision for what a new generation seismographic network could look

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like if it were implemented in the U.S.

As it turns out, we never could excite management in Washington DC enough to follow up around to attempting that very ambitious part of the project.

My vision of the center has always been that it's a political necessity. That is, we've got a

> Without a center like SCEC, we'll clearly have a tremendous vacuum in how we communicate as scientists with the rest of our society.

on that vision, but we were able to follow the vision closely in southern California with the TriNet Project. If you go back to the original circular that was written about 1989, it's pretty much a blueprint for TriNet.

Another contribution was helping the Pasadena office to become a more independent operational unit. At one point the earthquake program in southern California was almost entirely managed by the USGS's Menlo Park office. In the 1980s we pushed to have southern California become more locally managed, both by the USGS Pasadena office and then ultimately by the formation of SCEC.

I would hardly claim credit for the formation of the center, but certainly I was in the mix when the center came to be.

SQN: You also served on the board of directors and have headed several committees. Has SCEC fulfilled the vision you had for it?

TH: I think SCEC has largely fulfilled the vision. Some of the aspects are probably a little slower coming than we originally envisioned. In particular, we originally envisioned having some master stress model of the crust in southern California, and I think we are just now getting number of institutions in southern California that absolutely require coordination when we communicate with the rest of society in terms of policy decisions.

It's like night and day between having the center and the time that we didn't have it, in terms of being able to speak with a coherent single voice. In some ways I think it's probably been the most important aspect of the center. The ability to speak with a consensus has given great support to our scientific studies.

SQN: What's the future for SCEC?

TH: Well, I've got to admit I am somewhat concerned about the future. The current talk about broadening SCEC's regional focus into the entire state of California and to including far more research groups concerns me. We may lose some of that ability to focus on issues that are of importance to southern California policymakers.

There will still be a strong need for southern California institutions to communicate to governments in southern California, and I am somewhat worried about whether the future SCEC will be able to fulfill that role, if in fact there is any center at all. If we have no

OFF-SCALE

AUTHORS WHO ARE NOT EARTH SCIENTISTS BUT WISH THEY WERE

"Most people don't even know they have it until an earthquake comes and shakes it out of them . . ."

[An excerpt from an essay about some of the lesser-known effects of the series of earthquakes in northern Italy in 1997, best known for destroying the church at Assisi.]

St. Francis of Assisi was by all accounts a rich man's son who squandered his father's money on wine, women, and fancy armor for the Crusades. He had a vision one day—you could call it a spiritual earthquake vision—and in the vision Christ said to him, "Francis, dost thou not see my house in ruins? Rebuild it for me." It all depends, as Bill Clinton would say, on what you mean by the word "rebuild," and, of course, what you mean by "house." The politics of restoration, which are a large part of the cultural politics in Italy, are not only about the grandmother and the bell tower, or about greater and lesser art; they are also about class, and about memories of poverty and contempt that no prosperity ever really dulls. They are about who owns the future—the Italians who made the past a misery for so many other Italians or those other Italians, finally inheriting the earth—and they can evoke a rancor so deep that most people don't even know they have it until an earthquake comes and shakes it out of them, shakes the past to the surface.

—Jane Kramer
"The Shock of the Old"
The New Yorker, 2/8/99

Heaton on Music and Motorcycles

There's no doubt that Thomas Heaton enjoys the work he does in geophysics and engineering, but it's not the only thing he's passionate about.

Music is his other main interest, he says, adding that he has been writing songs and playing the guitar "in various forms" for 30 years.

He says that recently he added several more guitars to his collection, which includes both electric and classical instruments. He also has a small recording studio in his living room.

"My mother is a professional musician, and it's always been just around the family," he explains. "But even more than that, I've always found music a way to travel someplace else. It's a way to close your eyes and just be someplace else."

But it's more than just another way to relax. "Music is a way to let something out that you didn't even know was there. While you're playing music, emotions and things pop out that you don't even know were there."

Heaton says music is like science in that it can provide for him "those discovery moments. Music provides the same kinds of surprises, in terms of things that you didn't really expect to find."

Whereas for many years Heaton played music by himself, he is now in a band at his church. "In many ways it's been an awakening to be able to play with a group of people. That's another new experience."

Following hard on the heels of his love of music is the thrill of the road in the form of motorcycle riding and a special car—a red Corvette in his case.

Both the Corvette and a silver Honda Sport-Tour 1100 motorbike feature in framed photos on his office wall at Caltech. Heaton says he has traveled 100,000 miles on motorcycles over the past 30 years.

"The thing about motorcycling is it's either very bad or very good, but whatever, it's memorable."

Living as he does in the Los Angeles area, Heaton is no stranger to freeway riding and finds it bearable. "It's somewhat frightening, but to be honest I think it's really important to live with a certain amount of fear. I think it's a rather pointless goal to constantly be searching for safety, because in the end it evades you anyway."

If anything terrifies him, it could be old age. Why? "Because it'll kill you," he smiles.

center then we'll clearly have a tremendous vacuum in terms of how we communicate as a group of scientists with the rest of our society.

Clearly that communication is often strained. Policymakers and the public in general have a very difficult time talking to individual scientists and coming up with some sort of reasonable view of what's going on. We really need something like SCEC to help us to communicate.

SQN: Do you believe that building codes in southern California, and Los Angeles in particular, are adequate to deal with the expected large violent earthquakes?

TH: It's rather interesting that if an earthquake ruptures as a pulse, then it turns out that almost all of the energy radiated in the earthquake is contained in shear-wave pulses. Rather amazingly, you can show that those pulses are also very important for flexible buildings.

Understanding those pulses has important implications for some large buildings. Since we haven't observed the performance of large buildings together with very large earthquakes, I feel that there is great uncertainty about their performance. However, simulations of the response of tall buildings to large earthquakes show that there is reason for concern.

We know that the energy in very large earthquakes grows a factor of 30 for every unit of magnitude—so we can anticipate that large earthquakes have much greater energy. This energy can be used to damage ductile buildings. Our current building code relies heavily on ductility. Unfortunately, a large earthquake may severely challenge the ductile capacity of some types of buildings, in particular flexible buildings.

John Hall, Dave Wald, Marv Halling, and I published a couple of papers in which we said that if you have a large earthquake beneath a city, you would expect to have many of the flexible-frame buildings damaged beyond repair, and in many cases you might even expect collapses of some of these buildings.

That's been quite controversial because prior to our work, people routinely said these are the safest buildings to be in during an earthquake. We questioned whether or not their performance would be good in all situations.

SQN: What has that led to? Have you said there shouldn't be buildings beyond a certain height constructed in southern California, or made recommendations about building codes?

TH: I'm glad you asked that question. There have been some reports that we have called for a moratorium on buildings taller than ten stories. I know that John Hall has not called for such a moratorium, and I don't believe that I have, either.

I actually wrote a letter to the Seismological Society of America a couple of years ago where I said, "We don't understand what happens to large buildings in large earthquakes, and perhaps we should talk about a moratorium until we do understand." I wanted to emphasize to people that we're not quite sure what we're doing here.

I think Ken Reich of the *L.A. Times* picked up on that letter, and somehow it ended up in the *L.A. Times* that I was actively a proponent of putting a limitation on the height of buildings. However, I don't think that a height limit is the appropriate answer. It's a simplistic answer to a complicated problem. And it certainly irritated some people.

If you have a large earthquake beneath a city, you would expect to have many of the flexible-frame buildings damaged beyond repair. However, I don't think that a height limit is the appropriate answer. It's a simplistic answer to a complicated problem.

Our findings on the importance of near-source pulses were pushed along by the Northridge and Kobe earthquakes, both of which had these large pulses in cities, and the pulses did quite a bit of damage to modern, flexible buildings.

Neither of those was a very big earthquake, though, so we still point out that there could be quite a bit bigger earthquakes and bigger pulses.

I think the engineering community, though, has at least accepted that these are real issues.

SQN: Are you satisfied that enough is being done to try to resolve this matter?

TH: No; no way. We're not even close. We're building these monstrous cities directly atop earthquake regions, spending literally trillions of dollars building our cities, and our effort to understand what we're doing is pitiful.

SQN: Are you talking about in the U.S. or around the world?

TH: Around the world. It's really a rather amazing thing to think that we would invest so much in erecting structures whose performance in earthquakes is so uncertain.

SQN: How do earthquake codes vary around the world?

TH: Codes are a very complicated issue. There are currently three codes in use in the United States. There's a different code in Japan. The codes have typically been written to fix past problems. That is, after an earthquake, engineers study the performance of buildings. When a particular type of design performed poorly, they say not to do it again (by code modifications).

Some areas of the world don't use much of any code at all, and any help that we can give them is good. However, sometimes it's hard to transfer our standard of living to other parts of the world.

There is a lot of misunderstanding, I think, of how the different codes relate to each other. I have often heard people say that the Japanese code and the U.S. codes are comparable; however, after looking at some of the work of my colleague John Hall, it doesn't really seem that they're all that similar.

They're written in such different ways that it's even hard to compare them, but when you design a building under the Japanese code and design a building under the U.S. code, it turns out that the Japanese code, at least for tall buildings, is quite a bit stricter than the U.S. code.

SQN: How come so many people died in the Kobe earthquake, in a country that is wealthy by most standards?

TH: I think the short answer is that it was quite intense shaking in a very heavily populated area. In contrast, we were quite fortunate that the Northridge earthquake occurred early in the morning when our population was largely in wooden homes. Furthermore, the most severely shaken regions in Northridge were in the suburbs, where almost all the structures were residential homes.

U.S. residential houses are remarkably resilient in earthquakes; our houses are probably much better than Japanese traditional houses. Many Japanese people died in their homes because Japanese homes were not as resilient as U.S. homes.

If the Northridge earthquake had occurred in the middle of the day, we would have had more deaths, because people would have been out in buildings. In Japan they had a lot of building collapses, too; the very heavy shaking was right under their buildings.

We're building these monstrous cities directly atop earthquake regions, spending literally trillions of dollars building our cities, and our effort to understand what we're doing is pitiful.

That's not what happened in Northridge.

But we probably shouldn't be too smug. We do have parts of the United States, parts of Los Angeles, where we have high densities of people in buildings that we know can collapse in earthquakes. Certainly, to stand around and say, "Well, that was Japan; that couldn't happen here," that would probably be a mistake.

SQN: You've been a member since 1993 of the Mayor's Blue Ribbon Panel on Seismic Hazard Reduction for the City of Los Angeles. How has that work been?

TH: It's clear that one of the greatest concerns for the Los Angeles area is a class of buildings called nonductile concrete buildings. We had collapses in the San Fernando earthquake and in the Northridge earthquake. We had some near collapses in the Whittier Narrows earthquake. These are buildings that we know can fail even in moderate earthquakes.

Typically they're concrete buildings with frames—beams and columns—that were built prior to the mid-1970s. There are many people working in these buildings; there are hundreds of these buildings in Los Angeles, and they could be a severe source of life loss in a large earthquake in Los Angeles.

Currently there's no law that requires that they be inspected, strengthened, or retrofitted.

There are procedures developed by the engineering community to recognize and strengthen these buildings, but there are no laws that require anybody to do anything about them. I think they're probably the most obvious problem area that requires some policy and legislative attention from the City of Los Angeles.

SQN: A lot of work has been done on L.A. freeways since Northridge. Are they reasonably safe now?

TH: Clearly the freeway bridges as they were built in the 1950s and 1960s were inadequate to withstand typical shaking in strong earthquakes. The most obvious problem seemed to be undersized columns with inadequate shear strength and ductility.

Starting in the late 1980s, Caltrans put together an incredibly ambitious effort to reinforce virtually every column in every bridge in the state. I must say I'm tremendously impressed with the diligence that Caltrans has put into this problem. Whether or not there will be any failures of bridges in the future, it's hard to say. I just don't know the details. But clearly those bridges are far better than they were ten years ago. I am no longer as concerned stopping my car under a bridge as I was ten years ago.

There are still some very problematic structures for Caltrans. With standard bridges, you can reinforce the columns, but for some of the really large bridges, like the Oakland Bay Bridge or San Pedro's Vincent Thomas Bridge or Coronado Bridge in San Diego, those are different kinds of structures. I'm not sure people have a good grasp of what would happen to those bridges in a very large magnitude earthquake.

SQN: You read about the potential here in Los Angeles for a large violent earthquake. It seems like an accident waiting to happen.

TH: Certainly there are indications from the research that we've done that say that there may be some serious problems. But I'm not in a position to be able to tell you exactly what kind of earthquakes we're going to have underneath Los Angeles or exactly what's going to happen to the buildings. To do a test of those buildings full-scale is very difficult. There's a tremendous amount of work to be done if we are to understand the best strategies for building structures to withstand earthquakes.

There are people working on these problems, and they're good people. But considering what's at stake, I think we're spending a very small amount on research compared with what we've got at risk. We're not very high on the trade-off curve between our research costs and the cost of failures in the system.

SQN: Are we overdue for a big quake in southern California, or do we just not know that?

TH: In the pulse-type model "overdue" is not a very useful word. There was a fellow here that I learned a lot from—Ralph Gilman, who worked at Caltech from 1930 to about 1980. He told me: "Tom, I've seen three generations of seismologists go to their graves saying, 'It's coming, it's coming.' You get a little skeptical after a while."

The big earthquakes are inevitable. There's no question about it, but compared with our lifetime it could be any time.

SQN: What's your view on new data about slow earthquakes and the implication for seismic hazard assessment?

> It's like night and day between having SCEC and the time that we didn't have it in terms of being able to speak with a coherent single voice. In some ways I think it's probably been the most important aspect of the center. The ability to speak with a consensus has given great support to our scientific studies.

TH: It's clear that a lot of the earth's movement occurs so slowly that we don't see it on seismometers or at least in the normal range of seismometers. We've long wondered whether these slow processes happen steady state or whether they also happen in events that are much slower than our normal earthquakes.

It's become clear that, at least in some cases, they happen in events. There have been several of these events that have been recorded over periods of days. People were kind of hoping, back when we were promising to predict earthquakes, that we would see such events prior to the occurrence of large earthquakes and that those slow events would be diagnostic of a coming large earthquake.

In the past several decades, observers have documented convincing evidence that there are slow events, at least on some faults. Those slow events were not followed by anything large. Furthermore, our larger, well-observed earthquakes were not preceded by recognizable slow events.

It may be that some of these slow events actually are followed by larger earthquakes. In fact, that's what probably happened in the Chilean earthquake in 1960. It's a fascinating physical phenomenon that may teach us a lot about the mechanics of the crust, but I am not particularly hopeful that it will allow us to predict earthquakes.

SQN: What direction is your own research taking lately?

TH: I think what I find most interesting at the moment is understanding brittle failure in the earth—the size-scaling aspects of the strength of the crust. There are lots of different things being worked on, but these days I work more vicariously through students.

Before, when I was with the USGS, it was easier to do my own work. Now I try to convince someone else to follow up on ideas that have been rattling around for a while.

SQN: Do you like teaching?

TH: I like to teach provided I have time to prepare for the class. I like to teach; I'm not sure that the students like me to teach them! I enjoy doing it. Probably it would be better if I was better organized.

SQN: You don't feel frustrated sometimes as a teacher that you can't get on with your research?

TH: No, I like people. Classes are full of people.

TALES FROM THE FRONT

by Susan E. Hough

Goldilocks and the Three Bears

Southern California might be our natural earthquake laboratory as well as our own backyard. But as the T-shirt says, shift happens. It happens everywhere, including places that we as SCEC scientists might be inclined to view as tectonically boring.

For this column I will beg your indulgence to allow me to travel to one of those places for the purpose of telling you one of my personal favorite fieldwork fairy tales: Goldilocks and the Three Bears.

Well, not three bears, exactly. But bears are involved. Goldilocks, too.

This particular tale is set in the Adirondack Mountains in New York, in fall of 1988. As a newly minted post-doc at Lamont, I was part of a field crew that drove north for a piggyback seismic experiment, recording blasts from the large-scale refraction experiment being conducted across New York and New England.

I would refer to this experiment by the acronym we all used at the time (NYNEX), except that we learned later that this name belonged to a large New York telephone company that would not look kindly on sharing it. Another official acronym was therefore devised, although I can't for the life of me recall what it was.

Anyway. Deploying seismometers in the Adirondacks in the middle of autumn is every bit as much of a hardship as you might imagine. The days are cool and crisp. The nights are pleasantly brisk. The trees are alive with color.

Our entire field crew made a willing personal investment in the neon orange vests designed to designate large mammals in the forest as human beings rather than potential targets.

There is just one minor problem: autumn is bear season in parts of New York. You don't have to spend much time in the Adirondacks to learn what that means, either. Even the locals, not generally known for their opposition to hunting, seem to view the bear hunters as rowdy yahoos, interested in trophies rather than the sportsmanship of the hunt.

As proper outdoorsy types, our field crew did not worry too much about running into the bears. Bear hunters, however, were a different story. I have never to my knowledge seen bear droppings, but I have seen bear hunter droppings: beer cans and shotgun shells, often together.

Our entire field crew made a willing personal investment in the neon orange vests designed to designate large mammals in the forest as human beings rather than potential targets. Every morning, they were the last item of clothing that we put on before going out.

And this is what brings me to Goldilocks, who will provide the punch line to this tale. Goldilocks is real—she is my daughter, Sarah, then four years old and, yes, with locks of gold. She had been brought up to the field site (along with my infant son) by my husband for the weekend that our deployment encompassed.

Being the observant type, Goldilocks watched me get dressed and inquired about the one piece of clothing she had never seen me wear before—that gaudy orange vest with its jet-black trim. "Why are you wearing that?" she asked me in her best Goldilocks voice.

"So people will know I'm not a bear," I told her.

And, being a modern lass every bit as bright as she was (is) lovely, my Goldilocks replied, "But people will think you're a tiger."

I am delighted to report that our entire field crew returned from this outing with a nice little data set, unscathed by the black bears, the bear hunters, and all of those pesky tiger hunters known to hang out in the Adirondack Mountains.

Interested in sharing a fieldwork story of your own?
HOUGH@GPS.CALTECH.EDU
WWW-SOCAL.WR.USGS.GOV/HOUGH/

BENEATH THE SCIENCE

by Mark Benthien

Survey Says: What You Think about SCEC

Recently, I distributed a two-question survey to the SCEC-all email list (which every member of the SCEC community should be on). I was interested in allowing people to express what it is about SCEC, beyond the funding opportunity, that has kept them involved. We were amazed with the response to the survey.

I sent the email on a Friday afternoon, and by Monday morning I had already received 55 responses. Many were well considered and eloquent. For those of you who responded, thank you very much.

Here is the survey:

1. If you don't receive SCEC funding, will you (or do you) still participate in SCEC research, workshops, and other activities?
2. Besides funding opportunities, what are the main reasons or benefits that you are involved in SCEC?

The questions were intentionally similar. Almost everyone answered "Yes" to the first question, and some elaborated. The answers to the second question were more elaborate, as expected. The following is a sample of the responses (edited to fit here in some cases). As a whole, they show that most people in the SCEC community highly value the opportunity that SCEC provides for cooperation and exposure to cutting-edge earthquake research.

Perhaps more important than the funding is the chance to interact with other researchers in the field. Many of the best earthquake scientists are concerned with southern California earthquakes, and SCEC offers the chance to meet them and discuss ideas. SCEC is also the connection between researchers and institutions away from the annual meeting. In a

sense, SCEC has its "finger on the pulse" of our concerns for earthquake research in southern California. Through SCEC's newsletter and Web site, it is easy to keep up with the goings-on. —**James Spotila**, Virginia Technology

I find the SCEC annual meeting and some of the monthly seminars very useful to help me stay up to date on current research. This is important both for my teaching and for my research that is funded by other agencies. The summary talks given by group leaders at the annual meeting are especially helpful. The Web pages maintained by SCEC (and those of the USGS Pasadena office) have also been very useful to me in my teaching. —**Sally McGill**, CSU, San Bernardino

SCEC provides an easy medium in which researchers who approach earthquake problems from different directions can share each other's findings and collaborate. I especially like working within an organization that has so many strong ties to the public, to private engineers, and to private geologists because those are the people who are impacted the most by new findings in earthquake research. —**Kris Weaver**, USC

The interaction with other SCEC seismologists has been crucial in my professional and scientific development. My graduate career has been immeasurably improved by my attendance at talks, meetings, and informal discussions. I think I've learned more this way than through any classes I've taken. —**David Oglesby**, UCSB

Exciting areas of research from basic to very applicable, public policy implications, interaction with others working on southern California. SCEC is and should be a national demonstration project in natural hazards. Without SCEC, individual universities could neither mount nor fund more than a piecemeal attack on problems of earthquake generation, hazards, risk, etc. —**Lynn Sykes**, Columbia

I enjoy benefits of communication and collaboration with the southern California community of earthquake researchers; of SCEC-funded and SCEC-coordinated events; of keeping abreast of developments in southern California and general earthquake science; and of SCEC's example in attempts to forge new directions in earthquake science, multi-institutional collaboration, and earthquake forecasting. —**Mike Blanpied**, USGS

A great synergy. There aren't too many places outside of SCEC meetings where I get totally fired up about my work and want to rush back to my office and finish up everything I've ever promised to do. —**Ruth Harris**, USGS

In the early years of SCEC, I was able to support much of my research as a post-doc with SCEC funding. As a result of that early involvement, SCEC and its community of researchers remains very important to me. SCEC also serves a crucial role in advancing the USGS earthquake hazards program in southern California by helping to coordinate efforts between the many university departments and the USGS. SCEC meetings and email correspondences with my SCEC colleagues provide a high degree of scientific interaction that I feel would not likely exist otherwise. —**Ken Hudnut**, USGS

I still do SCEC-related research, in one case with a SCEC-funded person, and communicate with other SCEC people. But I no longer go to the annual meeting, and I very rarely go to workshops. I would go to the meeting and to more workshops if funded. Besides time and expense, I do not think it right to present work at SCEC that has been specifically turned down by SCEC. However,

Most people in the SCEC community highly value the opportunity that SCEC provides for cooperation and exposure to cutting-edge earthquake research.

some of my work is presented by others in the SCEC reports and at the annual meeting.

Some of the detailed geological and geodetic work is helpful in my understanding of the region. However, concerning structure-tectonics, I have mixed feelings on whether SCEC should be renewed for an additional ten years as an NSF Science and Technology Center. Twenty years is an awfully long time for the same group of people to be running such an influential center. In my personal case, it becomes very difficult to run contrary to SCEC paradigms. And I would not be running contrary to these paradigms if I thought they were correct on basic explanations for why there are deep, narrow basins and giant anticlines. —**Christopher Sorlien**, Columbia

✉

I participate because I'm on the advisory committee and I'm committed to establishing closer communication between the engineering and earth-science communities, and SCEC seems like a great way to do this. —**Susan Tubbessing**, Earthquake Engineering Research Institute

✉

The funding has never been the main reason for being involved with SCEC. The opportunity to collaborate with multiple institutions and researchers on a pressing societal problem is the main reason for my involvement. —**Stephen Park**, UC Riverside

✉

SCEC is much more than a funding source. SCEC sets scientific community goals for research—a group decides which are important topics for earthquake research and encourages scientists to investigate those topics. Interaction with other scientists (I am a grad student). SCEC spreads the knowledge to kids and the public—a very important function. —**Julie Nazareth**, Caltech

✉

I use the Web page and links therein all the time for my earthquakes class. It is a great source of info. I also recommend it to members of my class as a starting point for research and info. —**Andrew Meigs**, Oregon State

✉

Representing an organization in the engineering field, I look at SCEC not as a source of funding but as a source of knowledge that earthquake engineers need if they are to adequately do their job. Beyond mere adequacy, a center like SCEC, or preferably a statewide scope to such activities, is essential to advancing the earthquake engineering state-of-the-art to meet the demand for an improved predictive capability ("predictive" in the engineering sense, not seismological sense). Engineers are being asked to deliver or predict specific levels of performance for buildings and to do that with a high reliability, not just to produce, on average, buildings that only rarely collapse in earthquakes.

Aside from the earth science research produced by SCEC, I use SCEC-provided information on a variety of earthquake topics almost weekly (email announcements; the newsletter; information from workshops that includes topics such as insurance or codes as well as seismology, etc.). —**Robert Reitherman**, California Universities for Research in Earthquake Engineering

✉

The SCEC community and meetings are a great source of knowledge to me. This is much more valuable to me than even the funding. —**Eldon Gath**, Earth Consultants International

✉

I work for SCEC for free (and will continue to do so). Don't consider any of it as work, but play and pleasure. I rub shoulders with greatness, get lots of good geoquake ideas, see interesting things, have lots of fun, adventure, and even the occasional mystical experience looking at faults out in the desert. —**Michael Forrest**, Rio Hondo Community College

✉

My main support has come from NEHRP. I write proposals to SCEC to take advantage of the interaction among geologists, seismologists, geodesists, etc., and to work on small-scale projects targeted on the LA metropolitan area. I wrote a proposal this time to the outreach group; this would not have been an option under NEHRP. The workshops and the interactions at annual meetings are great. But keep the field trip; I was disappointed to see it dropped last year. —**Bob Yeats**, Oregon State

✉

I think the most interesting (probably only interesting) work going on in the field of earthquake seismology is going on at SCEC. I find the meetings and seminars very interesting, and they provide a window into what is most important in this field today. —**John Orcutt**, Scripps Institute of Oceanography

✉

A core group of scientists interested in earthquake sciences. Nowhere else does one find this interaction between scientists, across all disciplines. —**Charlie Rubin**, Central Washington University

✉

We at CDMG view SCEC as a unifying forum for earthquake issues in the southern California region. As a state government agency, we impose statutory requirements on local government, which are sometimes not viewed in a positive way. We have found that SCEC facilitates community understanding and acceptance of state policies through education and a second independent expert opinion on earthquake hazard issues. Because earthquake hazard research is not a primary activity of state government, we value highly the coordinated research sponsored by SCEC. Significant new findings can improve our products for public policy. —**Chuck Real**, California Division of Mines & Geology

✉

I began participating in SCEC activities before I received funding because I thought participation was valuable for its own sake. SCEC is the best way I know of to get a "snapshot" of the current state of knowledge about the earthquake problem in southern California. The interactions with other scientists are an invaluable resource, and the knowledge transfer activities help to place earthquake science in the context of seismic hazard as a broader societal problem that requires a multidisciplinary solution. —**Lisa Grant**, UC Irvine

✉

SCEC is a very important "player" in the earth sciences. It represents the first successful attempt to integrate regionally based earth science research across discipline (and institutional) boundaries. As such, it is the starting point for anyone interested in understanding or working on the seismo-tectonics of southern California and transform fault plate boundaries.

I have never applied to SCEC for funds. I'm involved in it because I want to see it work, and grow, and be the template for other regional earth science centers. I truly believe that SCEC is much more than the sum of its parts, and I would like to see a northern/central California and other regional centers like it. —**Kaye Shedlock**, USGS

SCEC represents the first successful attempt to integrate regionally based earth science research across discipline (and institutional) boundaries.

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SCEC Presence Strong Throughout

AGU Annual Meeting

For over 75 years, the American Geophysical Union has provided a focal point for those who are expanding the frontiers of the geophysical sciences. For six days in December, geoscientists from across the globe gathered in San Francisco to share geoscience research and ideas about where the geosciences are headed.

The meeting's design allowed for different perspectives to be heard and for an interdisciplinary attendance at each session. Approximately 90 percent of SCEC's scientists and graduate students attended. Many presented their latest findings. Most SCEC scientists were listed as authors of research papers.

David Jackson, SCEC science director, led a half-day session called "Seismic Hazards and Earthquake Prediction," in which he presented his findings along with SCEC researchers Ned Field, James Dolan (both of USC) and scientists from Greece, Hawaii, and Japan.

Ralph Archuleta (UC Santa Barbara), **Thomas Heaton** (Caltech), and **John Anderson** (University of Nevada, Reno) presented posters in a session addressing strong ground motions.

Special sessions included the Bowie Lecture Series, one of which was a presentation on the geophysical implications of precarious rocks given by SCEC researcher **Jim Brune**. Brune (University of Nevada, Reno) spoke on "Constraints on Dynamic Stress-Drop and Energy Radiation from Great Earthquakes Provided by Precarious Rocks in the Mojave Desert." (See issue 4.1 of this newsletter for more on that topic.)

Other events included two educational workshops attended by SCEC Outreach Specialist **Sara Tekula**. The first, co-sponsored by the National Science Foundation and the National Association of Geoscience Teachers, focused on identifying innovative and effective techniques for teaching geosciences at the undergraduate level.

The second was a two-day workshop put on by the Geophysical Information for Teachers (GIFT) program and hosted by AGU Education Director Frank Ireton. For these two days, K-12 teachers from the San Francisco Bay Area were invited to hear presentations from scientists conducting relevant research in the earth sciences.

Katrin Hafner (SCEC Data Center) and Tekula represented SCEC at the workshop and demonstrated the resources available to teachers through the SCEC Data Center and the SCEC DESC Online program.

On December 6, a special one-time seminar for scientists and science writers was held as a part of the AGU meeting. "Publish and Perish?" gave an opportunity for scientists and the people who write about their research to "clear the air" about relations between them. Science writers from the *Wall Street Journal*, *San Francisco Chronicle*, *U.S. News & World Report*, and *Business Week* served on a panel to foster communication between the often opposing disciplines.

The spring AGU meeting will be held May 31–June 4 in Boston. More information is on the AGU web site—WWW.AGU.ORG.

SCEC Board News

Changes in Working Group Leaders

Leon Knopoff has decided to retire as leader of the Earthquake Physics Group after eight years and many solid accomplishments.

Other changes in the leadership of the working groups:

- With Knopoff's retirement as the group leader of Earthquake Physics, the board appointed **Steve Day** as the new group leader.
- With Day's move to Earthquake Physics, the board appointed **Ralph Archuleta** as the leader of the Strong Motion Prediction working group.
- Ken Hudnut has retired as leader of the Crustal Deformation working group and the board appointed **Duncan Agnew** as the new group leader.
- **Ken Hudnut** is the new chair of the SCIGN Coordinating Board.

The working group leaders are:

A: Master Model .... Dave Jackson

B: Strong Motion Prediction .... Ralph Archuleta

C: Earthquake Geology .... Kerry Sieh

D: Imaging and Tectonics/Seismicity .... Rob Clayton

E: Crustal Deformation .... Duncan Agnew

G: Earthquake Source Physics: .... Steve Day

The board also approved a return to the Riviera Hotel in Palm Springs for the 1999 annual meeting, September 27–29.

A Sonogram of the L.A. Region

Active LARSE Set to Explode in October

SCEC is continuing its preparations for the second phase of a major earthquake study of southern California, referred to as the Los Angeles Region Seismic Experiment (LARSE II). The purpose of the study is to increase understanding of the potential for earthquakes in southern California by mapping hidden earth-quake faults like the one that caused the 1994 Northridge earth-

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quake and by gathering data to estimate how severely the ground will shake in different places in future earthquakes.

The best way to achieve the goals of this study is to conduct a seismic imaging survey across the region. This survey is akin to obtaining a sonogram in the medical industry. Instead of using a sound generator to create the waves that produce an image, seismic waves are generated by both earthquakes and small detonations in shallow boreholes to create an image of the interior of the Earth.

In part one of the survey (October 1998 through spring 1999), SCEC is recording naturally occurring earthquakes on approximately 100 seismographs deployed along a line from Malibu to the Mojave Desert, passing through the epicenter of the Northridge earthquake. During part two (October 1999), SCEC will record seismic waves generated by small detonations in approximately 100 shallow boreholes on 1,000 seismographs deployed along the same line, from Santa Monica to the Mojave.

Receiving permission from landowners to conduct the experiment is progressing yet is a tedious process (what would *you* say if someone asked to detonate an explosion beneath your property?). Drilling the boreholes will begin in June, starting in the Malibu area and heading north at a rate of one hole each day.

Each hole will be lined with a 50-foot metal pipe that will be capped and locked for security. The holes will be loaded with the explosive material in mid-October, just before detonation, which will occur over three or four nights in late October. The explosive is detonated at night so that the resulting waves are not masked by common synthetic vibrations such as traffic and construction work. Each hole will then be filled as needed and the site returned to its original condition.

84-Station Array Will Continue Through April

LARSE II Passive Phase in Full Operation

The 100-km long, linear LARSE II passive array spans the Santa Monica Mountains, San Fernando Valley, Western Transverse Ranges, San Andreas fault, and western Mojave Desert. The goals of the experiment are to examine crustal and upper mantle seismic velocity structure, seismic hazard associated with anomalous site amplification, and tectonic evolution of the westernmost Transverse Ranges.

The data collection and station maintenance are being performed by two field assistants who see to it that the stations operate continuously without equipment problems or power failure, including remote, buried sites running on battery power only.

Each station consists of a short-period (L22 or L4C, all 3-component) or broadband (Guralp CMG-40T, CMG-3ESP, or CMG-3T) sensor; Reftek 24-bit data recorder (continuous recording at 25 sps, triggered at 50 sps); GPS receiver; and power supplies.

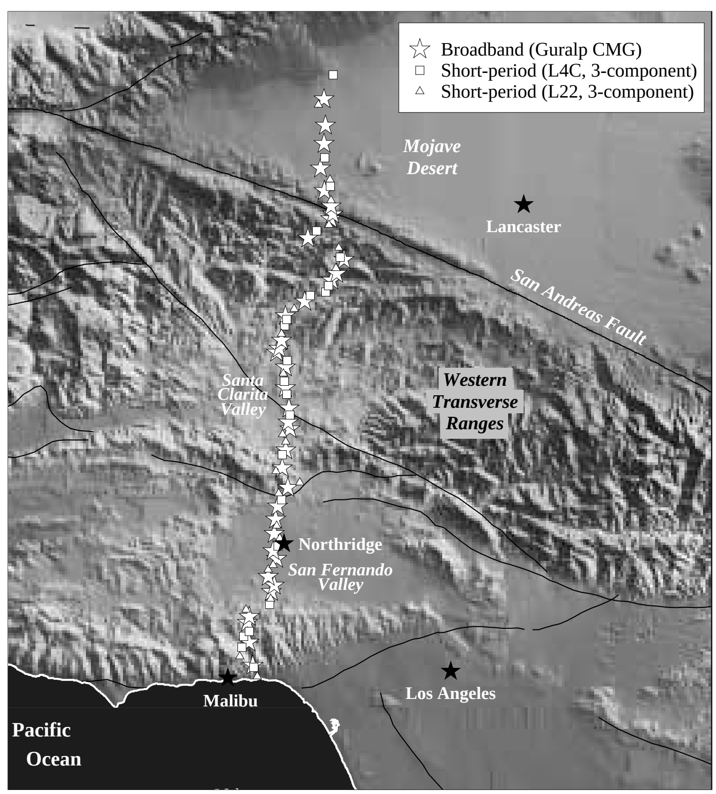
Activities already accomplished in the LARSE II passive phase:

- Selecting and permitting seismometer sites
- Organizing the collection and testing of SCEC PBIC and IRIS PASSCAL equipment
- Arranging the deployment by teams from several institutions (UCLA, Caltech, USGS Pasadena and Menlo Park, UCSB)
- Arranging for two field assistants to do station maintenance, preliminary data processing, and long-term data archiving at the IRIS data management center

The successfully operating 84-station LARSE II passive array will continue to be in place through April 1999. The team at UCLA will also be involved in the deployment and data collection efforts of the LARSE II active-source and high-resolution phases, scheduled to take place in late 1999 (see separate news brief in this issue).

The following activities will complete the LARSE II passive phase:

- Station pull-out by multi-institutional teams, similar to the deployment
- Conversion of data to mseed format, corrections for timing errors, and sensor calibrations in preparation for long-term archiving
- Creation of teleseismic and local event waveform files containing seismic phases for analysis



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April Is Earthquake Preparedness Month in California

SCEC encourages you to join us in participating with your community to raise awareness about the shaky ground we all live on and to prepare for the inevitable earthquakes.

The following Web sites contain ideas and information:

Emergency Preparedness Information Exchange
http://hoshi.cic.sfu.ca/~anderson/internet_sites.html

California Office of Emergency Services
http://www.oes.ca.gov
http://www.best.com/~trbu/oes

U.S. Geological Survey
http://quake.usgs.gov/hazprep/index.html

American Red Cross
http://www.redcross.org

Federal Emergency Management Agency
http://www.fema.gov/mit/how2.htm

Association of Bay Area Governments
http://www.abag.ca.gov/bayarea/eqmaps/fixit/fixit.html

California State Seismic Safety Commission
http://www.seismic.ca.gov

Southern Calif. Emergency Services Association
http://scesa.com

KFWB Radio: Jack Popejoy's Quake Page
http://www.kfwb.com/equakes

Los Angeles City Fire Department
http://www.lafd.org/eqindex.htm

***Putting Down Roots in Earthquake Country* Online**
http://www.scecdc.scec.org/eqcountry.html

FEMA News

Seismic Rehabilitation Guidelines and Maps Available Online

The Federal Emergency Management Agency's publication FEMA 273—*National Earthquake Hazard Reduction Program (NEHRP) Guidelines for the Seismic Rehabilitation of Buildings*, and the related FEMA 274—*NEHRP Commentary*, are now available at www.degenkolb.com/fema273/.

Both documents can be viewed and downloaded in their entirety. The seismic maps that accompany FEMA 273 are available at http://geohazards.cr.usgs.gov/eq/. This Web site also offers users a form for sending comments and recommendations to FEMA for improving the document.

FEMA and the American Society of Civil Engineers are converting FEMA 273 into a prestandard—the first step in turning FEMA 273 and 274 into an ASCE/American National Standards Institute national consensus standard that can be referenced by building codes and contracts. The prestandard will be completed by June 2000. The principal investigator for the project is Chris Poland, president and senior principal, Degenkolb Engineers, San Francisco. For more information, contact Jim Rossberg, ASCE, at (703) 295-6196 or jrossberg@asce.org.

Ancient Volcanic Cataclysms Found in Indian Ocean

The results from a recent expedition to one of the most remote places on Earth will shed new light on how and when continents formed and broke apart millions of years ago.

Scientists from the Ocean Drilling Program (ODP) recently completed an expedition to the Kerguelen Plateau. The plateau, located in the southern Indian Ocean and one-third the size of the United States, is a large igneous province (LIP). LIPs are areas where magma wells up from deep beneath Earth's surface and forms molten rock.

The international team of 45 scientists conducted its research aboard the world's largest scientific drilling vessel, the JOIDES Resolution. The major objectives of the ODP expedition, largely funded by the NSF, were to determine when volcanism was active, how much of the plateau formed above sea level, and whether continental fragments form part of the plateau.

Using evidence from fossils as well as terrestrial plant remains, the team constrained the period during which the Kerguelen LIP formed. They found that the southern Kerguelen Plateau, only hundreds of kilometers from Antarctica, formed approximately 110 million years ago. To the north, the central Kerguelen Plateau

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and the once-contiguous Broken Ridge formed between 85 and 95 million years ago. In contrast, the northern Kerguelen Plateau is much younger, having formed less than 35 million years ago. The results indicate that several episodes of volcanism formed this large plateau, rather than a single massive event.

They found that much of the Kerguelen LIP formed above sea level. They also found uniquely continental rocks in a conglomerate that was probably deposited in a river near the central and southern plateau. Studying the nature and number of pieces of an ancient continent that were incorporated into the oceanic environment will help in understanding the approximately 130-million-year-old breakup of Australia, India, and Antarctica.

More information about the program is available from Bruce Malfait, NSF, BMALFAIT@NSF.GOV.

CUREe/Caltech Collaboration

Woodframe Project Solicits Comments for Planning and Publication

As a first step in its planning process, the CUREe/Caltech Woodframe Project seeks to collect a wide variety of comments dealing with important aspects of earthquakes and wood buildings. Individuals, companies, and organizations can use this opportunity to express their viewpoints. Of particular interest are experiences about deficiencies in the status quo. The CUREe-Caltech Woodframe Project Committee will utilize the information in the planning process and will publish a compilation of the comments in original form during the first half of 1999.

Contributions that promote particular proprietary products or services will be circulated for review by the project committee but will not be published. Detailed descriptions of earthquake damage of actual buildings should not be submitted at this time; these will be the subject of a future solicitation.

Potential topics include but are not limited to:

Testing and Analysis

- Testing protocols and methods (standardization, appropriate loading protocols for different purposes, test set-ups, instrumentation)
- Types of tests needed (by component or type of data)
- What current analytical methods are best and what is needed?
- Other ongoing research programs (facilities, goals, accomplishments)

Field Investigations

- Conversion of observed damage into loss measures (repair cost, casualties, disruption) or performance levels (distinction between safety and other goals)
- Construction quality and its importance relative to adequacy of design and code provisions
- Sources of statistical information or ways to obtain it
- Differences among small residential (houses, duplexes), large residential (apartments, condominiums), and other woodframe construction (schools or commercial)

Building Codes and Standards

- Needed code changes
- Role of inspection
- Appropriateness of conventional vs. engineered construction
- California vs. other states
- Design philosophy underlying codes: can a rational basis be developed for wood in terms of an intended sequence of damage/inelasticity and consideration of dynamic properties?
- Practical issues in improving and adopting codes
- Integrating materials standards and building code engineering provisions

Economic Aspects

- Insurance: pre-earthquake ratings, post-earthquake repair
- Housing impacts
- Real estate issues (e.g., disclosure)
- Cost implications of exceeding code requirements to enhance earthquake performance

Education and Outreach

- Needs of specific audiences (engineers, architects, building officials, builders, general public)
- Methods and media that are most effective
- Topics that should be covered (new design vs. retrofit vs. repair; conventional vs. engineered; residential vs. nonresidential)

Please send by May 3, 1999, to the project manager of the CUREe/Caltech Woodframe Project:

Prof. John F. Hall
Mail Code 104-44
Caltech
Pasadena CA 91125

Or email: JOHNHALL@ITS.CALTECH.EDU.

Diskette, email, or paper submittals are acceptable. Contributions exceeding eight pages should receive prior consent. Illustrations and photographs may also be included.

The CUREe/Caltech Woodframe Project is funded by the Federal Emergency Management Agency through the California Governor's Office of Emergency Services to develop reliable and economical ways to improve the earthquake performance of woodframe construction.

A TEACHABLE MOMENT...

by Sara Tekula

Dogpaddling in the Ocean of Geophysics

Imagine being an infant at your first swimming lesson. Your parent—your security—finally lets you go into a pool of water that seems larger than life itself.

At first, you breathe some water, cough a little, and your parents reach out to help you. Moments later, they let you go again. This time, something kicks in, and you find yourself floating. The skill was innate after all—it just needed to be awakened with a jolt.

As plate tectonics pervade the geosciences, in the world of biological and social science, a basic concept—the tectonics of memory—pervades: when you immerse yourself in a new environment, your synapses work overtime, your survival juices flow. You need to get familiarized—and fast. Such are the ingredients that support long-term memory storage—in other words, the basis of learning.

There is no doubt in my mind that I learned something long-term at this fall's American Geophysical Union annual meeting in San Francisco. How all this new information can be organized in the compartments of my memory is yet to be determined, but that doesn't mean that I can't share it with you. I hope that you will come away from this column knowing or thinking or wanting to know one new thing. If so, it will have been a "teachable moment" for both of us.

my head. However, there was an undeniably intense dynamic among them, and I could have heard a pin drop during each presentation. I walked away from AGU with a notebook full of notes and ideas, and an understanding of just how much earth scientists respect each other's research.

I would like to share with you some of the most interesting things I learned, in bite-sized pieces for your rumination.

> I walked away from AGU with a notebook full of notes and ideas, and an understanding of just how much earth scientists respect each other's research.

The sessions at the AGU meeting that I found most relevant to my role in outreach and education, as well as my future role in the world of journalism, were not the sessions that focused on hard scientific research and data. Instead, they focused on a "bigger picture" approach to the geosciences, allowing a more process-oriented rather than results-oriented discussion.

The science sessions I attended, where geoscientists got the unique chance to brainstorm with other people prominent in their field, made me feel as though I was in over

Here's what you'd see if you opened my notebook:

- **The man identified with the theory of sea floor spreading**, Harry Hesse, looked at crystals growing to understand the patterns of growth of an oceanic ridge. Harry must have had a zoom lens in his brain to learn about something that huge from something that minute.
- **Hesse**, whom I've heard some Los Angeles teachers call "Crazy Harry," was so frustrated with his research on plate tectonics and sea floor spreading that he almost went back to believing in continental drift.
- **Lamont Doherty Earth Observatory** was the best place for an earth scientist to be when plate tectonics came about. By the end of the 1960s, LDEO research provided a new framework for understanding the evolution of the planet and life on it, the causes of earthquakes and volcanoes, the formation of mineral and hydrocarbon resources, and past and future global climate change. All of this at New York's Columbia University, around the time and place I was born. Birth of a theory, birth of an outreach specialist: the two should always go hand in hand.
- **In 1966,** there were two papers on sea floor spreading at AGU. In 1967, there were 60. Talk about the significance of data.
- **To limit your imagination,** use the deductive style of doing science: it's hypothesis driven. Much like going to see a movie after having read 20 reviews of the movie ahead of time.
- **To learn something beyond your imagination,** use the inductive style of doing science. Looking at new things, observing, and taking notes on a clean slate requires humility. I've got plenty of that these days—this is the type of investigation I'm engaged in here at AGU.
- **Overheard at AGU:** "Science is the organization of observations, which are the only truths in science."
- **The faults are alive with the sound of music?** It's not just a Julie Andrews (or Jill Andrews?) tune anymore. Earthquakes are "loud" and "quiet," just like music. This led me to pondering: in theory, earthquakes *are* music, aren't they? I'd love to hear your thoughts on this.
- **The "brat" vs. the "angel":** Earthquakes can be likened to "hyperactive children" vs. "calm children," but you can't always tell which one is going to scream next. If the hyperactive one pestered the calm one just enough…

Education Web Sites for Science Teachers and Students

Compiled by Sara Tekula

SCEC-Sponsored Modules (DESC Online)

SCEC Education Pages
http://www.scec.org/outreach/education.html

"The Use of Space Technology in Earthquake Studies"
http://scign.jpl.nasa.gov/learn

"Investigating Earthquakes Through Regional Seismicity"
http://www.scecdc.scec.org/Module

Science Education Standards

U.S. National
http://www.nap.edu/readingroom/books/nses/html

State of California
http://www.ca.gov/goldstandards

Scientific and Engineering Organizations

Southern California Earthquake Center
http://www.scec.org/outreach

IRIS
http://www.iris.washington.edu/EandO/

Geological Society of America
http://www.geosociety.org/educate/index.htm

Pacific Earthquake Engineering Research
http://peer.berkeley.edu/html/education.html

Mid-America Earthquake Center
http://mae.ce.uiuc.edu/ResearchPrograms/OEIP/BodyEducation.html

Earthquake Engineering Research Institute
http://www.eeri.org/Chapters/Chapters.html

American Society of Civil Engineers
http://www.asce.org/peta/programs.html

American Geological Institute
http://www.agiweb.org/ehr.html

American Geophysical Union
http://www.soest.hawaii.edu/karsten/malia/cher.html

Seismological Society of America
http://www.seismosoc.org/education/education.html

American Association for the Advancement of Science
http://www.aaas.org

Colorado School of Mines
http://www.mines.edu/Outreach

University Corporation for Atmospheric Research Education
http://www.ucar.edu/ucargen/education/eduhome.html

California Science Center
http://www.casciencectr.org/

NASA's Earth Science Enterprise
http://www.earth.nasa.gov

Center for Science Education (UC Berkeley Space Science Lab)
http://cse.ssl.berkeley.edu

Government Organizations

USGS
http://www.usgs.gov/education

Los Alamos National Laboratory
http://www.lanl.gov/external/education/

Los Angeles Public Library
http://www.lapl.org/

Los Angeles Zoo
http://www.lazoo.org/learn.htm

Los Angeles County Office of Education
http://www.lacoe.edu

California Division of Mines and Geology
http://www.consrv.ca.gov/kids/index.htm

Association of Bay Area Governments
http://www.abag.ca.gov/bayarea/eqmaps/kids.html

Science Education and Teachers' Organizations

International Geoscience Education Association
http://www.cosm.sc.edu/~csemgr/carpenter/newsltr.html

Lawrence Hall of Science
http://www.lhs.berkeley.edu/SEPUP

Los Angeles Educational Partnership: Target Science
http://www.lalc.k12.ca.us

National Association of Geoscience Teachers
http://oldsci.eiu.edu/geology/NAGT/NAGT.html

National Science Teacher's Association
http://www.nsta.org

Science Education Association
http://science.coe.uwf.edu

Teach for America Math and Science Initiative
http://teachforamerica.org/apply/math.htm

Virtual Libraries

Websurfer's Bi-Weekly Earth Science Review
http://shell.rmi.net/~michaelg/weeksreviews.html

Virtual Earth Science Library
http://www.geo.ucalgary.ca/VL-EarthSciences.html

Virtual Geophysics Library
http://www-crewes.geo.ucalgary.ca/VL-Geophysics.html

Virtual Geotechnical Engineering Library
http://geotech.civen.okstate.edu/wwwVL/index.html

Other Online Educational Products

"Plate Tectonics" CD-ROM from TASA
http://www.swcp.com/~tasa

"This Dynamic Earth—The Story of Plate Tectonics"
http://pubs.usgs.gov/publications/text/dynamic.html

Think Quest Library
http://library.advanced.org

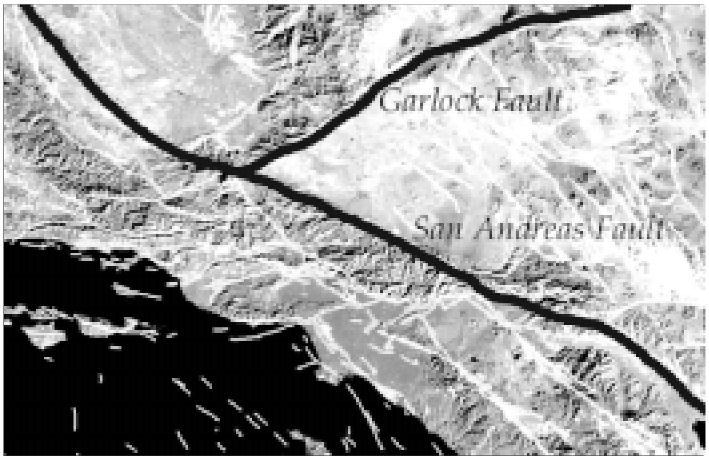
Explore Zone: Earth Science
http://explorezone.com/earth

Quake Trackers: Cyber-Seismology
http://www.geo.vuw.ac.nz./seismology/Quake_Trackers/

Featured Fault . . .

The Garlock Fault • The Garlock Fault

A Series of Articles and Interviews by Michael Forrest



The western end of the 250-km-long Garlock fault zone originates at the San Andreas fault, just south of the Great Central Valley, extends northeastward along the northern edge of the Mojave Desert, and terminates against the Death Valley fault zone. The fault separates the Sierra Nevada batholith and the Basin and Range province on the north and east from the Mojave's mosaic of crustal blocks on the south.

Fault at a Glance

The data below do not necessarily agree with those given in the accompanying articles. The discrepancies are partly caused by varying interpretations of data.

Type: left-lateral strike-slip

Length: 250 km

Nearest communities: Frazier Park, Tehachapi, Mojave, Johannesburg

Last major rupture: AD 1050 (?) near Tehachapi; AD 1500 (?) near Johannesburg (Searles Valley)

Slip rate: 2–11 mm/yr; probably averages about 7 mm/yr

Interval between major ruptures: 200–3,000 years, depending on the fault segment

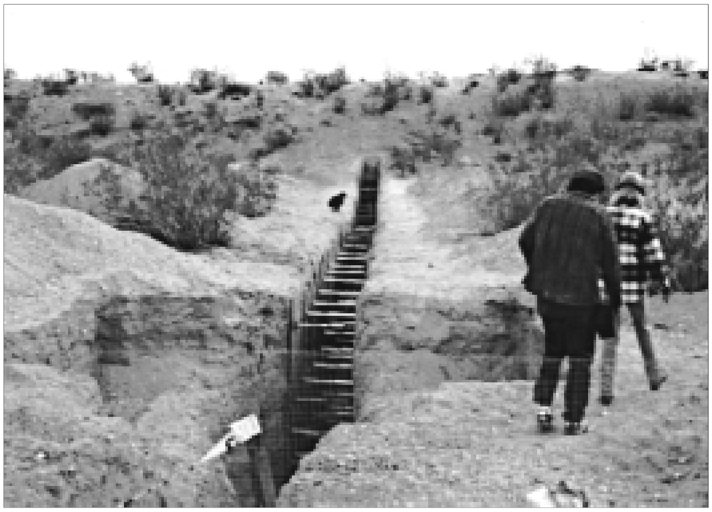
Probable magnitudes: M 6.8–7.6

Source: SCEC Data Center—WWW.SCECDC.SCEC.ORG/GARLOCK.HTML

The Trench Party

The January 1999 Garlock "trench party," hosted by Sally McGill and Tom Rockwell, proved to be an unexpectedly crowded event. A small deserted dust diamond at the end of a treacherous wash tucked away in the vast Mojave became busy with cars. Throughout the festive day, the number of people visiting the site rarely dropped below 20.

Distinguished guests included Eric Lindvall and Tanya Atwater. Lindvall formed an earthquake consulting company with Charles Richter after Richter retired from Caltech in the 1970s. Atwater was the first person to explain the origin and evolution of the San Andreas transform fault system.



All Photos: Michael Forrest

With coarse, dry gravels and sediments, sheets of plywood are unnecessary to hold back the trench walls.

Atwater, like many of the other visitors, was impressed by the depth of the trench—the deepest she's climbed into. "You couldn't be claustrophobic and do this job," she commented.

The Garlock trench party was stimulating. The science sparked debate. The cider was hot. Baja the dog impressed everyone with his trench digging when he caught the scent of a lizard. And the ride home across the twilight expanses of the Mojave was enchanting.

Baja digs his own trench.

The Garlock Fault • The Garlock Fault

Interview with Roy K. Dokka

The Tectonics

Any student of the tectonic framework and evolution of the Mojave Desert—including the function and significance of the Garlock fault—will have read papers by Roy Dokka. Few tectonicists have studied the Mojave as thoroughly as he has.

Dokka is the Adolphe G. Gueymard Professor of Geology and Geophysics at Louisiana State University. This "mini-interview" with him was conducted recently via email.

Q What is the nature of the Garlock fault? Is it a response to the Big Bend in the San Andreas fault? Does it release regional stress created by the bend? Does it facilitate crustal rotation in the Mojave block?

A The Garlock has a history that is longer than most people realize. The western half was active 24-21 Ma and facilitated crustal extension in the central Mojave Desert. My reconstructions indicated that 20-30 km of *right* slip should have occurred along the western Garlock.

Mapping of pre-Cenozoic bedrock yields matches that imply only ~40 km of total left slip for the Garlock. The classic net slip determined along the central Garlock is ~65 km of *left* slip. Add it up! Back then the Garlock was oriented ~N10E. Between 21 and ~16 Ma, it rotated clockwise ~45 degrees along with much of the central Mojave and southern Sierra with a huge right shear zone called the Trans-Mojave-Sierran shear zone.

I have recent papers in *Geology* and the *Geological Society of London Special Volume* that explain this. (See the websites below for the text of the papers.) The San Andreas may have cut the westernmost part of the old western Garlock and displaced 300 km of it up to the Pinnacles area in central California.

The modern Garlock became active in late Miocene time as an accommodation structure related to the onset of Basin-Range normal faulting and extension according to Greg Davis and Clark Burchfiel (1973). The eastern part of the Garlock has the misfortune of occurring within the eastern California shear zone, the little brother of the San Andreas fault system. The eastern quarter of the Garlock has been severed by one of the more active strands of the ECSZ. It is aseismic east of the break and these relationships (i.e., a shorter Garlock) may suggest that the Garlock is less of a seismic hazard.

The Garlock is older than the Big Bend. It is *not* correlative with the Big Pine fault. As Davis showed, the Garlock is a passive structure in the tectonics of the region. It formed as a result of the behavior of other structures.

Q Is there any place you could recommend that the casual geologist go for a look at the fault?

A I would go to the top of the Rand Mountains and look WNW; go in the early morning for the best view. Koehne Lake is a pull-apart basin formed along the Garlock and is associated with one of the largest negative gravity anomalies in North America.

Q Any personal observations regarding the fault—any adventures in the desert?

A Strange things happen when I am near it. An F-16 buzzed a helicopter I was using to examine the Garlock and then dropped bombs so powerful, the explosions shook the copter.

Q Is there anything written about the Garlock that you would take issue with?

A The Garlock is not a conjugate fault to the San Andreas as proposed by Mason Hill and Tom Dibblee in 1953. They are different ages. The world at this scale does not work mechanically in the same way as in rock deformation laboratory experiments.

The Garlock has served as a strain marker, recording the regional effects of right shear of the eastern California shear zone since late Miocene time. The curvature of the eastern half of the Garlock is the main result.

To read more about Dokka's ideas on the tectonic evolution of the southwestern Cordillera and the Garlock fault look at these sites:

www.geol.lsu.edu/rkd_dir/collapse.html

www.geol.lsu.edu/rkd_dir/1997gsl_dir/1997_gsl.html

Paleoseismology is not for the claustrophobic. Dry sediments are easier to shore and offer greater peace of mind than wet ones. The Garlock trench provided a good workout for those who climbed, ducked, and crawled from one end to the other.

The Garlock Fault • The Garlock Fault

Interview with Sally McGill

The Paleoseismology

Q What is the observed displacement on the fault at this trench site?

A The smallest gully offset we see is 7 m. In 1991, I interpreted that as the amount of slip in a single earthquake. But from the trench we're seeing the two most recent earthquakes are fairly closely spaced in time. So that 7 m of displacement may have actually happened in two separate earthquakes.

Q Does that make you think the maximum magnitude earthquake for this fault is small?

A Yes. With a 3-m slip event vs. a 7-m slip event, there might be more frequent but smaller earthquakes.

Q In general, what is the current thinking regarding the maximum magnitude earthquake possible on the Garlock?

A Kerry Sieh and I have a paper from 1991 in which we looked at different scenarios and different segments that could rupture. I think if the eastern or western segment ruptured separately, that could be M 7.5. If they ruptured together, it could be M 7.8.

Q When were the last events?

A From our work at this site, Event Y occurred in approximately AD 1800 and Event W in AD 1600.

Q When you look at the trench walls, isn't it surprising how little the sedimentary layers are deformed during a big earthquake at the slip surface of the fault?

A Yes, they come right up to the fault without any significant deformation.

Q For every M 7 event, does the rupture take a slightly different path?

A Sometimes they happen to go on the same path, but often they go on different paths. If they always went on the same path, we wouldn't be able to recognize one earthquake from another. And 3 m or 7 m of offset is spread out on all these different faults. This one we're looking at may have had only 20 cm on it. In some places, the Landers rupture was just one single fault, but in other places, it was a broad zone of parallel faults—and that's what seems to have occurred here: a broad zone of parallel faults.

It's often surprising how little deformation can be found directly across a fault strand. Sally McGill investigating the Garlock fault.

Eric Lindvall, Tom Rockwell, and Scott Lindvall, discussing the Garlock's fault structure.

Interview with Tom Rockwell

The Digging

Q This is one of the largest paleoseismic trenches I've seen. What are its dimensions?

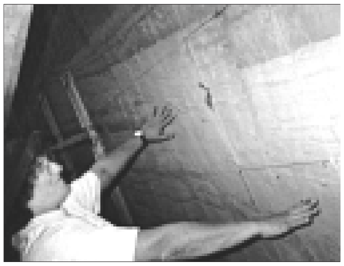
A The trench is 38 m long and about 6 m deep. The trench was dug with a large backhoe at the end of November.

Q What's next for this trenching site?

A We're going to bring an excavator out, back fill it, and then we're going to bench it and go down another 3 m. We can't shore it any deeper. We'll cut benches at 5-ft intervals so the overall slope is about 1 to 1.

Q What's the ultimate goal?

A To date the entire Holocene.



Tanya Atwater examining the Garlock fault.

The Garlock Fault • The Garlock Fault

The Science

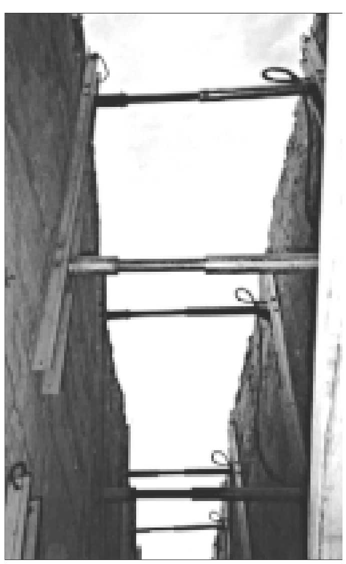
The sinistral 250-km-long Garlock fault zone originates at the San Andreas fault, just south of the Great Central Valley, extends northeastward along the northern edge of the Mojave Desert, and terminates against the Death Valley fault zone. The fault separates the Sierra Nevada batholith and the Basin and Range province on the north and east from the Mojave's mosaic of crustal blocks on the south.

The best documented slip rate estimate for the fault zone has been made on its eastern half at Searles Lake (Jackson et al., 1995) by McGill and Sieh (1991, 1993) based on offset geomorphic features. Dated displacements range between 4–7 m near the El Paso Mountains, 2–3 m near Searles Valley, and 2–4 m near Pilot Knob, yielding a horizontal slip rate of 4–9 mm/yr.

The 1994 Working Group on the Probabilities of Future Large Earthquakes in Southern California prefers to assign the entire fault a slip-rate of 4–11 mm/yr. (Eberhart-Phillips et al., 1990) with a preferred horizontal rate of 7.5 mm/yr. (Jackson et al., 1995). The total cumulative offset on the fault is estimated to be 64 km (Davis and Burchfiel, 1973).

The western half of the fault, which has a more complex surface trace, is more seismically active than the eastern half. On average, there have been between 20 and 30 M 2+ events per year on the Garlock since 1981, including all the earthquakes occurring within 10 km of the fault. Seismicity rose to 40+ events in 1988, 1990, and 1992. The fault has produced 7 or fewer M 3+ events per year since 1947 except in 1952, 1933, 1988, and 1992.

Historically, there have been no surface ruptures on the fault (Peterson and Wesnousky, 1994). The depth of seismicity along the Garlock fault is generally 15 km or less, reaching a maximum of 17 km. Also the seismogenic depth along the Garlock fault appears to increase to the west with increasing distance from the thinner Basin and Range crust. Two seismicity depth horizons seem to occur along the length of the fault: one between 3 and 4 km and another between 7 and 8 km.



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Davis G. A., and B. C. Burchfiel, 1973. Garlock fault: an intracontinental transform structure, southern California. *Geol. Soc. Am. Bull.*, 84:1407-1422.

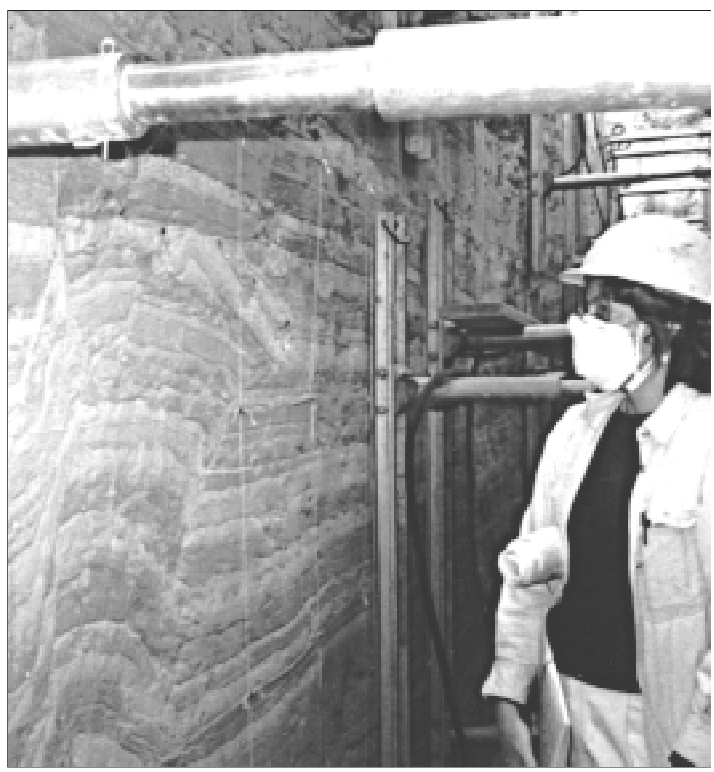
Eberhart-Phillips, D., M. Lisowski, and M. D. Zoback, 1990. Crustal strain near the Big Bend of the San Andreas fault: analysis of the Los Padres-Tehachapi trilateration networks, California, *J. Geophys. Res.*, 95:1139-1153.

Jackson D. D. et al., 1995. Seismic hazards in southern California: Probable earthquakes, 1994-2024: *Bull. Seis. Soc. Am.*, 85, 379-439.

McGill, S. F. and K. E. Sieh, 1991. Surfical offsets on the central and eastern Garlock fault associated with prehistoric earthquakes. *J. Geophys. Res.*, 96:21597-21621.

McGill, S. F., and K. E. Sieh, 1993. Holocene slip rate of the central Garlock fault in southeastern Searles Valley, California. *J. Geophys. Res.*, 98:14217-14231.

Peterson, M. D., and S. G. Wesnousky, 1994. Fault slip rates and earthquake histories for active faults in southern California, *Bull. Seis. Soc. Am.*, 84:1608-1649.



Sally McGill stands beside one of the main strands of the fault zone. In a large quake, she would have been nudged to the left by the wall of rock behind her.

SCEC-Funded Projects for 1999

The SCEC board has completed its review of proposals submitted in response to the 1999 RFP. A list of research projects supported by SCEC in 1999 is shown at the end of this article.

SCEC received 129 proposals (including several collaborative proposals) requesting more than $7.1 million. Most proposals were from scientists long involved in the SCEC effort. SCEC has $5.2 million in funding for 1999: $3.85 million from NSF, $1.1 million from the USGS, and $250,000 from Caltrans.

The SCEC Scientific Mission

The center's research objectives are to develop and improve the scientific basis of earthquake hazard estimation. The primary emphases are (1) earthquake potential, or the probability of earthquake occurrence as a function of location, magnitude, and time; (2) rupture dynamics; and (3) ground motion, or complete theoretical seismograms for any earthquake observed at any site.

Earthquake potential studies include geological studies to identify active faults and estimate the magnitudes and slip rates of the earthquakes they generate; geodetic studies to measure regional and local strain rates; seismicity observations and focal mechanism studies; theoretical studies that relate earthquake potential to tectonic setting; and hypothesis testing.

Rupture dynamics research includes theoretical and numerical studies of rupture initiation, propagation, and arrest; studies of energy flux, stress interactions, and the stress changes resulting from rupture; observation and interpretation of rupture propagation using seismic, geologic, and geodetic data.

Ground motion studies have the objective of predicting the full theoretical seismograms ("time histories") for any combination of earthquake and site. Our objective is to explain the relevant seismic records for past earthquakes, and develop a capability for predicting ground motions from hypothetical future earthquakes. Ground motion calculations should account for complexities in rupture dynamics, wave propagation, and nonlinear site effects.

General Themes for 1999

Three special emphases from last year will continue to receive attention this year: stress evolution and its effect on earthquake potential, site and path effects on strong ground shaking ("Phase III"), and construction of a three-dimensional seismic velocity model for use in strong motion modeling.

During 1999, SCEC is encouraging "legacy" projects that serve to integrate scientific results from SCEC's research activities and present them in a lasting, accessible format. Examples that are already complete or in progress include the Phase I (Landers Earthquake), Phase II (probable earthquakes 1994-2024), and Phase III (site and path effects) reports, the Strong Motion Database, the Three Dimensional Seismic Velocity Model, and the Crustal Deformation Map. A new start this year will be a major report on earthquake potential.

Principal Investigator	Project Title	Affiliation	Group
Duncan Agnew/Dave Jackson/Rob Reilinger/ Greg Lyzenga/Susan Owen	Improving the SCEC Crustal-Motion Map: GPS Data Collection and Archiving	UCSD/UCLA/MIT/H. Mudd/USC	E
Duncan Agnew/Dave Jackson/Tom Herring	Improving the SCEC Crustal-Motion Map: GPS Data Processing	UCSD/UCLA/MIT	E
John Anderson/Feng Su/Yuehua Zeng	High Frequency Ground Motion by Regression and Simulation	UNR	B
Jill Andrews	SCEC Education and Outreach for 1999	USC	I
Ralph Archuleta	Portable Broadband Instrumentation	UCSB	I/B
Ralph Archuleta/Alexei Tumarkin	SCEC SMDB and EGFL	UCSB	I/B
Ramon Arrowsmith/Lisa Grant	Historic and Paleoseismic Behavior of the South-Central San Andreas	Arizona State/UC Irvine	C
Yehuda Ben Zion	Dynamic Rupture in Heterogeneous Fault Zones	USC	F
Yehuda Ben Zion	High Resolution Imaging of Fault Zone Properties	USC	D
Yehuda Ben Zion	Coupled Self-Organization for Evaluating Seismic Risk and Precursors	USC	F
Yehuda Bock	SOPAC Infrastructure Support for SCIGN	UCSD	I/E
Jim Brune	Survey Precarious Rocks on Foot Wall of Major Thrust Earthquakes	UNR	B
Jim Brune/Rasool Anooshehpoor	Study Toppling Accelerations of Precarious Rocks Perpendicular to SAF	UNR	B
Jim Brune/Yuehua Zeng/John Anderson	Constraints for Great Earthquakes from Precarious Rocks	UNR	F
Rob Clayton	Reciprocal Green's Functions	Caltech	B
Rob Clayton	Enhancements to the Southern California 3D Velocity Model	Caltech	D
Rob Clayton	SCEC Data Center Operations	Caltech	I
Paul Davis	Analyze Northridge Aftershock and Santa Monica Hi-Res Experiment	UCLA	B
Paul Davis	Management of LARSE II (UCLA) Stress Modeling and Data Analysis	UCLA	D
Paul Davis	LARSE II: High Resolution Santa Monica Experiment	UCLA	D
Steve Day	Effects of Low Velocity Near-Surface Sediments on Long Period Basin Response	SDSU	B
Steve Day	Three-Dimensional Simulations of Long Period Ground Motion in LA Basin	SDSU	B
Steve Day/Ruth Harris	Dynamic Modeling of Earthquakes on Inhomogeneous Faults	SDSU	F
Jishu Deng/Egill Hauksson	Stress Evolution and Earthquake Triggering in Southern California	Caltech	A
James Dolan	Paleoseismology of the San Andreas Fault at Elizabeth Lake, California	USC	C
James Dolan	Paleoseismologic and Slip Rate Investigation of the Verdugo Fault	USC	C
Andrea Donnellan	Response of the Ventura Basin to the Northridge earthquake	JPL	E

Ned Field/James Dolan/Bill Foxall/ Dave Jackson/Steve Ward/Jishu Deng/ John Anderson/Mark Petersen	Working Group on Southern California Earthquake Potential	USC/LLNL/UCLA/UCSC/ Caltech/UNR/CDMG	A
Ned Field	Completion of the Phase III Report and Non-Technical Overview	USC	A
Stephen Gao	SKS Splitting Beneath Southern California Revisited	Arizona State	D
Stephen Gao	Search for and Modeling of Slow Tectonic Transients	Arizona State	A
Eldon Gath/Tania Gonzalez	Training Workshop: Fault Investigation Planning and Trench Logging	ECI	W/C
Lisa Grant	Holocene Paleoseismology of the San Joaquin Hills, Orange County, California	UC Irvine	C
Rob Graves/Arben Pitarka	Ground Motion Validation Studies on the SCEC 3D Seismic Velocity Model	Woodward-Clyde	B
Katrin Hafner/John Marquis/Egill Hauksson	Earthquake-Related SCEC Educational Modules for the WWW	Caltech	I
Brad Hager/Liz Hearn/Tom Herring/Bob King/ Simon McClusky/Rob Reilinger	Estimates and Models of Landers Postseismic Motions and Displacements	MIT	E
Jeanne Hardebeck/Egill Hauksson	Tectonic Stress and Earthquake Hazards	Caltech	A
Egill Hauksson/Julie Nazareth	3-D Velocity Models, Focal Mechanisms, and Maximum Depth of Seismicity	Caltech	D
Moritz Heimpel/Leon Knopoff	Model of the Southern California Fault Network	UCLA	F
Don Helmberger	Basin-Edge Structures from Waveform Modeling	Caltech	D
Tom Henyey	1999 SCEC Management Operations	USC	I
Tom Henyey	1999 SCEC Meetings and Workshops	USC	I
Tom Henyey	1999 Post-Doctoral and Visitor Program	USC	I
Tom Henyey/Rob Clayton/Paul Davis	1999 LARSE 2 Field Operations	USC/Caltech/UCLA	D
Martha House	Bedrock Uplift of the San Gabriel Mountains	USC/Caltech/UCLA	C
Gene Humphreys	Southern California Dynamics	Oregon	D
Dave Jackson	Management and Public Relations	UCLA	I
Dave Jackson/Yan Kagan	Seismic Hazard Estimation	UCLA	A
Hadley Johnson	So. Calif. Strain Field from SCEC Crustal-Motion Map: Web-Based Application	UCSD	E
Yan Kagan/Dave Jackson/Zhengkang Shen	Stress Modeling	UCLA	A
Hiroo Kanamori/Egill Hauksson	Enhancement of TERRAscope	Caltech	I/D
Monica Kohler	Management of the LARSE II Passive Array, II	UCLA	D
Daniel Lavallee/Ralph Archuleta	Nonlinear Strong Ground Motion During Northridge at Van Norman Dam	UCSB	B
Yong-Gang Li/John Vidale	Seismic measurements of fault process zones using P, S and trapped waves	USC/UCLA	D
Peng-cheng Liu/Ralph Archuleta	Source Parameter Inversion Using 3-D Green's Functions	UCSB	B
John Louie/Jim Brune/Rasool Anooshehpoor	Shallow Site Response and Fault-Reflection Recording During LARSE-2	UNR	B
Harold Magistrale	Integrating Tomographic and Basin Models for 3-D Velocity Model Version 2	SDSU	D
Harold Magistrale	Geotechnical Constraints for 3-D Velocity Model Version 2	SDSU	D
Harold Magistrale/Steve Day	Moho Configuration for 3-D Velocity Model Version 2	SDSU	D
Sally McGill	Paleoseismic Studies of the San Andreas Fault in the San Bernardino Area	CSU San Bernardino	C
Bernard Minster	Intermediate Term Earthquake Prediction Algorithms	UCSD	A
Kim Olsen	Ground Motion Modeling in Los Angeles	UCSB	B
Kim Olsen	3-D Elastic Finite-Difference Simulation of a Dynamic Rupture	UCSB	F
Jim Rice	Elastodynamic Simulations of Rupture Propagation and Earthquake Sequences	Harvard	F
Jim Rice	New Methodology in Computational Seismology for Dynamic Rupture	Harvard	F
Tom Rockwell/Scott Lindvall	Completion of Paleoseismic Studies of San Andreas Fault at Frazier Mountain	SDSU/William Lettis	C
Mousumi Roy/Rob Clayton	2D & 3D Modeling of Gravity, Topography, and Seismic Data the L.A. Region	New Mexico/Caltech	D
Charlie Rubin	Hydraulic Trench Shoring for Paleoseismic Studies in Southern California	Central Washington	C
Charlie Rubin	Variations of Fault Slip Per Event on the Carrizo Segment, San Andreas Fault	Central Washington	C
Charlie Rubin	Site Reconnaissance for Paleoseismic Studies along the Sierra Madre fault	Central Washington	C
John Rundle	Pilot Program for the GEM Project	Colorado	A
Charlie Sammis	Fault-Zone Physics	USC	F
Nano Seeber/John Armbruster	Earthquakes, Faults and Stress in Southern California	Columbia	A
John Shaw	Seismic Reflection Transect and Geologic Cross Section of L.A. Basin & S.P. Bay	Harvard	D
John Shaw	Velocity Structure of the L.A./San Fernando Basins from Sonic Logs etc.	Harvard	D
Peter Shearer	Precision Relocation of Los Angeles Region Seismicity	UCSD	D
Kerry Sieh/Egill Hauksson	Relationship of Aftershocks to Mainshock Rupture of the Landers Earthquake	Caltech	D
Kerry Sieh/Doug Yule	Neotectonic and Paleoseismic Investigation of the SAF, San Gorgonio Pass	Caltech	C
Walt Silva	Geotechnical Constraints for 3-D Velocity Model Version 2	Pacific Engr	D
Chris Sorlien	Rapid Subsidence and South Propagation of Santa Monica Mtns-Channel Is	UCSB	C
Jamie Steidl	Application of Site Characterization Studies to Ground Motion Prediction	UCSB	B
Jamie Steidl/Ralph Archuleta	Workshop - Borehole Data Utilization and Blind Prediction Test	UCSB	W
Jamie Steidl/Ralph Archuleta	Borehole Instrumentation Initiative	UCSB	I/B
Ross Stein	Training Workshop for Elastic and Viscoelastic Coulomb Stress-Change Software	USGS	W
Lynn Sykes	Development of a Physical Model of Stresses in Southern California	Columbia	A
Alexei Tumarkin/Ralph Archuleta	Integrated Approach to Time Histories Prediction	UCSB	B
Mladen Vucetic	Dynamic and Cyclic Soil Properties for Evaluation of Non-Linear Site Response	UCLA	D
Steve Ward	Research Toward the Master Model	UCSC	A
Steve Ward	Seismicity Simulations: Northern California	UCSC	A
Steve Wesnousky	Seismicity, Fault Evolution, and Growth of Fault Networks	UNR	A
Frank Wyatt/Duncan Agnew	Pinon Flat Observatory: Continuous Monitoring of Crustal Deformation	UCSD	I/E
Bob Yeats	An Undergraduate Course in Earthquake for Non-Majors	Oregon State	I
Bob Yeats	Subsurface Synthesis of Northern L.A. from the Wilshire Arch to Whittier Fault	Oregon State	C
Yuehua Zeng/John Anderson	Simulation of Ground Motion in the Los Angeles Basin	UNR	B

SCEC Research Publications and Abstracts

The following is a list of recent publications based on SCEC-funded research. SCEC authors must obtain SCEC contribution numbers for all papers to acknowledge SCEC funding. In return, their papers are added to the SCEC Publication Database. This database is reported to the NSF during each SCEC evaluation. To receive a SCEC contribution number, complete the online form at WWW.SCEC.ORG/RESEARCH/SCECNUMBER.HTML, which requires authors, title, publication name, abstract (very important), and any other bibliographic information available. The SCEC number will be returned via email along with the proper NSF/USGS/SCEC acknowledgement statement.

The SCEC Quarterly Newsletter now publishes the references only for published articles, no longer listing ones that are submitted, in review, in press, etc. The complete list (both searchable and sortable) is available at WWW.SCEC.ORG/RESEARCH PAPERS.HTML and will no longer be printed in the newsletter in its entirety each year. A hardcopy version of the list can be obtained by calling 213-740-5843 or emailing SCECINFO@USC.EDU.

439. Su, F., J. G. Anderson and Y. Zeng, Study of weak and strong ground motion including nonlinearity from the Northridge, California, earthquake sequence, *Bulletin of the Seismological Society of America*, 88, no. 6, pp. 1141-1425, 1998.

This article presents a new method to estimate S-wave site response relative to a regional layered crustal model. The method is useful for site specific strong motion prediction because the estimated site response functions are referenced to an idealized regional layered model for which we know the ground response exactly. We applied this method to the Northridge earthquake sequence. We determined the site amplifications, from aftershocks with magnitudes 2.6 to 4.3, at 21 stations, which were co-located with strong motion stations. These site response functions were then used to modify synthetic seismogram calculated for the Northridge mainshock in the same regional layered crustal model and thus obtain site-specific ground motion estimates. These site-specific synthetic seismograms have higher correlation to observations in comparison to the synthetic seismograms without weak motion site correction. They have similar amplitude and frequency content to the observations, especially at sites with recorded peak ground accelerations below 0.3g. At sites with larger ground motions, however, this approach overestimates the strong motion. The differences are made clear when we estimate site response functions from the strong motion records and compare them with those from weak motion records. We express the differences as the average ratio of the weak to strong motion site response (AWS Ratio). When the ground motion is low, the AWS Ratio is near unity, indicating that the weak and strong motion site responses agree with each other within the uncertainty. However, The AWS Ratio increases as the ground motion amplitude increases. The difference in weak and strong motion site responses becomes significant at stations where peak acceleration was above 0.3g, peak velocity was above 20 cm/sec, or peak strain was above 0.06% during the mainshock. This result demonstrates directly from the ground motion observations the relationship between nonlinear site response and peak ground motion parameters. The nonlinearity is present on soft rock sites as well as on sediment sites.

440. Roy, M., Evolution of fault systems at a strike-slip plate boundary: A viscoelastic model, *Geophysical Research Letters*, 25, 15, pp. 2881-2884, 1998.

A viscoelastic model of crustal deformation suggests that the formation and evolution of strike-slip fault systems are strongly influenced by rheologic contrasts between the upper and lower crust. When deformation is driven by a narrow zone of high shear in the mantle, the presence of a low-viscosity lower crustal layer underlying a primarily elastic upper crust widens the deformation zone with time and promotes the formation of a broadly distributed network of interacting faults within the upper crust. In contrast, the deformation zone in a primarily elastic crust is narrow, encompassing a single, plate-bounding fault. Patterns of surface strain rate and seismicity are thus significantly more complex in the presence of a low-viscosity lower crust, due to interactions between faulting in the upper crust at short time scales and viscous behavior in the lower crust at long time scales.

446. Deng, J., M. Gurnis, H. Kanamori, and E. Hauksson, Viscoelastic flow in the lower crust after the 1992 Landers, California, earthquake, *Science*, 282, pp. 1689-1692, 1998.

Space geodesy showed that broad-scale postseismic deformation occurred following the 1992 Landers earthquake. Three-dimensional modeling shows that afterslip can only explain one horizontal component of the postseismic deformation, whereas viscoelastic flow can explain the horizontal and near-vertical displacements. The viscosity of a weak, about 10-km-thick layer, in the lower crust beneath the rupture zone that controls the rebound is about 10^18 Pascal seconds. The viscoelastic behavior of the lower crust may help to explain the extensional structures observed in the Basin and Range province and it may be used for the analysis of earthquake hazard.

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Publication Descriptions

General Publications

Putting Down Roots in Earthquake Country—The U.S. Geological Survey and SCEC produced two million copies of this illustrated 32-page color publication. Its message is that earthquakes are inevitable but understandable and that damage and serious injury are preventable.

Future Seismic Hazards in Southern California, Phase I: Implications of the 1992 Landers Earthquake Sequence—Primarily a study of the implications of the Landers earthquake, this report discusses the recent increase in the frequency of earthquakes in southern California.

Seismic Hazards in Southern California: Probable Earthquakes, 1994 to 2024 (Phase II)—This report represents a major advance in our knowledge of how often shaking from earthquakes in specific areas of southern California will be strong enough to cause moderate damage.

SCEC Quarterly Newsletter—Features include contributions by SCEC scientists and working group participants; a compilation of currently available resources, published materials, and databases; a "Fault of the Quarter," showcasing a southern California fault; and an interview with a prominent SCEC scientist in each issue.

Field Trip Guides

Palos Verdes Peninsula—Written for teachers and students as well as the general public, this guide offers a lively narrative on a number of sites at which to observe fossils, rock structures, and faults. Two foldout maps are included. ($5.00)

Palos Verdes Fault—This field trip guide is designed for engineers, geotechnical professionals, and earth scientists. Unlike the broad information provided in the Palos Verdes Peninsula field trip guide, this guide focuses on the Palos Verdes fault. Included is a discussion of the fault as a whole as well as information pertaining to the many sites along the route.

Newport-Inglewood and Whittier-Elsinore Fault Zones—Rather than offering a route to follow for a field trip, this guide discusses the two fault zones, allowing the reader to design his or her own trip. Emphasis is on the methods scientists use to learn about faults, such as trenching.

Caltrans/City of Los Angeles/County of Los Angeles Task Reports

The **Task H-1** report describes improved empirical models for scaling the amplitudes of earthquake response spectra for the southern California region. (3 volumes)

The **Task H-2** report focuses on potential destructive earthquakes along the Hollywood and Santa Monica faults.

The **Task H-3** report examines the use of weak motion amplification factors for microzonation, and the relationship between weak and strong motion amplification.

The **Task H-4** report describes the development of empirical models for scaling duration of strong ground motion by utilizing regression analyses of recorded data.

The **Task H-5** report describes the compilation of a GIS based geotechnical database of the Los Angeles Basin for use in strong ground motion site characterization. (3 Volumes)

The **Task H-6** report documents the earthquake performance and liquefaction-related damage to bridges in the magnitude 7.8 Luzon, Philippine earthquake (July 1990) and the magnitude 7.5 Costa Rican earthquakes (April 1991).

The **Task H-7** report demonstrates seismic hazard analysis methodology with respect to selected sites in the Los Angeles basin, and illustrates several methods for generating acceleration time histories.

The **Task H-8** report describes the use of geotechnical data to reassess and improve the Los Angeles geological data base used to develop liquefaction potential maps. This report complements Task H-5.

The **Task H-9** report focuses on the cataloging of available strong motion records for vertical ground acceleration time histories, together with the computed acceleration response spectra.

Calendar

April 1999

12-16 First National Congress on Seismic Engineering. Organized by: Asociacion Espanola de Ingenieria Sismica. Madrid, Spain. Contact: tel/fax: 91 523 26 85, attn: Srta.Isabel Malagon.

18-21 American Society of Civil Engineers Structures Congress. New Orleans, LA. ASCE, 1801 Alexander Bell Drive, Reston, VA 20191; 1-800-548-2723, (703) 295-6009; fax: (703) 295-6144; email: conf@asce.org; or R. Richard Avent, chairperson of the steering committee: (504) 388-8735; fax: (504) 388-8652.

19-23 European Geophysical Society 24th General Assembly. The Hague, Netherlands. Full descriptions at www.copernicus.org/EGS/EGS.html. Contact: EGS Office, Max-Planck-Str. 13, 37191 Katlenburg-Lindau, Germany; +49-5556-1440; fax: +49-5556-4709; email: egs@copernicus.org.

26-29 Basic Hazards in the U.S. (HAZUS) Training. Offered by FEMA, Emergency Management Institute (EMI). Emmitsburg, MD. Contact Lillian Virgil, EMI, 16825 South Seton Avenue, Emmitsburg, MD 21727; (301) 447-1490.

May 1999

3-5 Seismological Society of America Annual Conference. Seattle, Washington. Contact: S. Malone, Geophysics Program, Box 351650, University of Washington, Seattle, WA; 98195-1650; (206) 685-3811; fax: (206) 543-0489; email: ssa99@geophys.washington.edu; www.geophys.washington.edu/SEIS/SSA99/.

4-7 International Decade for Natural Disaster Reduction Regional Conference for the Mediterranean. Valencia, Spain. Contact: Madeleine Moulin-Acevedo: (41-22) 917-9709; email: madeleine.moulin-acevedo@dha.unicc.org.

9-13 Canadian Geophysical Union Annual Scientific Meeting. Banff, Alberta, Canada. Contact: D. Eaton: deaton@julian.uwo.ca; www.gp.uwo.ca/cgu/frame.html.

17-19 Third International Conference on Seismology and Earthquake Engineering. Sponsor: International Institute of Earthquake Engineering and Seismology. Tehran, Iran. Contact: IIEES, P.O. Box 19395/3913, Tehran, I.R. Iran; tel: (98 21) 229 5085; fax: (98 21) 229 9479; email: see3@dena.iiees.ac.ir.

25-27 Tsunami Symposium. Sponsor: Tsunami Society. Honolulu, Hawaii. Contact: Charles Mader, Tsunami Symposium Program Chairperson, 1049, Kamehame Drive, Honolulu, HI 96825-2860; (808) 396-9855. Tsunami Society, P.O. Box 25218, Honolulu, HI 96825; or call the symposium chairperson George Curtis: (808) 963- 6670.

31- June 4 American Geophysical Union 1999 Spring Meeting. Boston, MA. Contact: AGU Meetings Department, 2000 Florida Avenue, N.W., Washington, DC 20009; (800) 966-2481 or (202) 462-6900; fax: (202) 328-0566; email: meetinginfo@agu.org; www.agu.org.

June 1999

1-4 American Geophysical Union Spring Meeting, Boston, MA. See http://earth.agu.org/meetings/sm99top.html

8-11 Community and Family Preparedness Conference. Host: FEMA Community and Family Preparedness Program. Mt. Weather, VA. Contact: Ralph Swisher, FEMA, (202) 646-3561; email: ralph.swisher@fema.gov.

9-12 11th Annual IRIS Workshop, June , Tenaya Lodge @ Yosemite, CA. See www.iris.washington.edu/HQ/workshop99_info.html.

13-16 Association of Contingency Planners 1999 Symposium: "Setting the Trend for the Next Millennium." Los Angeles, CA. Contact: ACP, (414) 768-8000, ext. 134; email: acp1999@excite.com; www.ACP-International.com.

16-18 FEMA Second Annual Emergency Management Higher Education Conference. Emmitsburg, MD. Contact: Wayne Blanchard, (301) 447-1262; fax: #(301) 447-1598; email: wayne.blanchard@fema.gov.

July 1999

5-9 International Decade for Natural Disaster Reduction Programme Forum 1999. Geneva, Switzerland. Contact: Madeleine Moulin-Acevedo, IDNDR Secretariat, United Nations, Palais des Nations, CH-1211 Geneva 10, Switzerland; tel: (41-22) 917-9709; email: madeleine.moulin-acevedo@dha.unicc.org.

5-9 International workshop on Tomographic Imaging of 3-D Velocity Structures and Accurate Earthquake Location, Pafos, Cyprus. Dr. Nitzan Rabinowitz, Geophysical Institute of Israel, see WORKSHOP@IPRG.ENERY.GOV.IL

19-30 XXII General Assembly of the International Union of Geodesy and Geophysics (IUGG)/International Association of Hydrological Sciences. Birmingham, U.K.: July 19-30, 1999. See: www.wlu.ca:80/~wwwiahs; or email: 44iahs@mach1.wlu.ca.

19-30 International Union of Geodesy and Geophysics XXII General Assembly (see above), International Association of Hydrological Sciences Symposium 1: "Hydrological Extremes: Understanding, Predicting, Mitigating." Birmingham, U.K. Convenor: Lars Gottschalk, tel: +47 22855809; fax: +47 22855269; email: lars.gottschalk@geofysikk.uio.no.

22-27 1999 International Union of Geodesy and Geophysics XXII General Assembly (see above), Inter Association Symposium on "Geophysical Hazards: Risk Assessment, Mitigation and Warning Systems." Birmingham, U.K. Web site: www.bham.ac.uk/IUGG99/.

August 1999

9-12 Ninth International Conference on Soil Dynamics and Earthquake Engineering (SDEE '99). Sponsors: Institute of Solid Earth Physics, University of Bergen, Norwegian Society for Earthquake Engineering. Bergen, Norway. Contact: K. Atakan, email: sdee99@ifjf.uib.no; www.ifjf.uib.no/seismo/sdee99.html.

15-30 Field trip to western turkey: Extensional tectonics, modern and historical earthquake surface breaks and archaeoseismology. 90 (212) 285 6299; 90 (212) 285 6210, fax; ealtunel@ogu.edu.tr or barka@itu.edu.tr

31–Sept 2 Autonomous Data-Gathering Systems in Extreme Environments, Jet Propulsion Laboratory, Pasadena, CA. Abstract and Reg. Deadline: July 15. Contact: Andrea Donnellan, JPL, 818-354-4737, andrea@cobra.jpl.nasa.gov; http://geodynamics.jpl.nasa.gov/antarctica.

September 1999

6-9 Western States Seismic Policy Council 21st Annual Conference. Santa Fe, New Mexico. Contact: WSSPC, (415) 974-6435; fax: (415) 974-1747; email: wsspc@wsspc.org.

27-29 SCEC Annual Meeting, Palm Springs, CA. Contact SCEC, 213/740-5843 or see www.scec.org.

26-30 California Emergency Services Association Annual Conference and Training: "Defining 21st Century Emergency Management, Managing Reality vs. Perceptions in a Media World." Palm Springs, CA. Contact: Wendy Milligan, (805) 644-0899; fax: (850) 642-2883; email: scesamgr@aol.com.

October 1999

1-Nov 15 – LARSE II Experiment. Volunteers needed. Contact Mark Benthien, SCEC Outreach, benthien@terra.usc.edu.

27-28 Sixth Annual Congress on Natural Hazard Loss Prevention. Sponsor: Institute for Business and Home Safety. Memphis, TN. Contact: (617) 292-2003; fax: (617) 292-2022; email: info@ibhs.org; www.ibhs.org.

27-29 Second Meeting on Seismology and Seismic Engineering of Mediterranean Countries—Sismica99. Faro, Portugal. Tel/fax: +351 (0)89 803561 (ext. 6545); fax: +351 (0)89 823539; email: seismic99@ualg.pt; www.ualg.pt/est/adec/sismica99/sismica99gb/index.htm.

December 1999

13-17 Fall American Geophysical Union meeting, San Francisco, CA. See http://earth.agu.org/meetings/sm99top.html.

January 2000

30-Feb 4 12th World Conference on Earthquake Engineering. Auckland, New Zealand, P.O. Box 2009, Auckland, New Zealand; tel: 64-9-529 4414; fax: 64-9-520 0718; email: 12wcee@cmsl.co.nz; www.cmsl.co.nz/12wcee; also see www.eeri.org/Meetings/12WCEE.html.

Earthquake Information Resources Online

SCEC on the Web
www.scec.org

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.TRINET.ORG/EQREPORTS
Southern California Seismic Network weekly earthquake reports

HTTP://SCEC.GPS.CALTECH.EDU/FTP/CA.EARTHQUAKES
SCSN weekly & monthly earthquake reports (archives to Jan. 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)

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/NORTH
Summary of work of USGS after Northridge '94, including datasets

HTTP://WWW-SOCAL.WR.USGS.GOV/LISA/NETBULLS
Southern California Seismic Network (bulletins)

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

Work by two SCEC-funded researchers, John Anderson and Steve Wesnousky. Contains lists, maps, and seismogram data from recent earthquakes, including searchable earthquake catalogs and more

HTTP://ERP-WEB.ER.USGS.GOV/
Recent USGS NEHRP Research Contracts

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/
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- 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

HTTP://WWW.LIB.BERKELEY.EDU/CGI-BIN/PRINT_HIT_BOLD.PL/UCBGIS/
UCB GIS Task Force integrates GIS activities with other resources

HTTP://WWW.NWI.FWS.GOV/THINKTANK.HTML
GIS think tank on problems of digital mapping for NWI data

HTTP://FGDC.ER.USGS.GOV/LINKPUB.HTML
List of FTP directories for federal Geographic Data Committee

Continued on next page . . .

Online Resources *continued*

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, from casual user to researcher

http://www.ggrweb.com/
Information technologies, 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
Make shaded relief maps with GMT. Catalog of maps by Geoffrey Ely at ICS/UCSB. DEM for southern California. 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://www.seismic.ca.gov/ssccatr.htm
California's earthquake hazard mitigation plan

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

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

http://www.kfwb.com/epc/epcfact.html
Emergency Preparedness Commission for L.A. City & County

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-socal.wr.usgs.gov/seismolinks.html
Comperhensive list of links to seismology, geology, vulcanology

http://www.geophys.washington.edu/seismosurfing.html
Clearinghouse of research data & informmation

http://www.trinet.org/
Trinet—the seismic system for southern California

http://mceer.eng.buffalo.edu/enews
Express news, customizable service that delivers earthquake/ hazards information selected from MCEER Information Service

http://www.civeng.carleton.ca/cgi-bin/quakes
Recent quakes (with a good 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://kfwb.com/eqpage.html
KFWB Quake Page (by Jack Popejoy)

http://smdb.crustal.ucsb.edu/
A relational database strong motion recordings.

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.seismic.ca.gov/sscleg.htm
State and federal bills being tracked by Seismic Safety Commission

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

http://shell.rmi.net/~michaelg/weeksreview.html
Biweekly earth science review

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

Education

http://www.scec.org/outreach
SCEC Education Pages: semi-complete; check it out & give us feedback

http://www.usgs.gov/education
USGS Learning Web:A great site with many resources

http://mceer.buffalo.edu
MCEER Education Program

www.iris.washington.edu/EandO
IRIS Education Outreach: Try the "Seismic Monitor"

http://peer.berkeley.edu/html/education.html
Pacific Earthquake Engineering Research: terrific ed. program

http://www.aaas.org/
American Association for the Advancement of Science

http://www.agiweb.org
American Geological Institute

SCEC Quarterly Newsletter

a component of the Center's Outreach Program

For more information on
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SCEC Quarterly Newsletter

SCEC Quarterly Newsletter is published quarterly by the Southern California Earthquake Center, University of Southern California, Los Angeles, CA 90089-0742, USA, telephone 213/740-1560 or 213/740-5843, fax 213/740-0011, email: SCECinfo@usc.edu.

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Looking through the Garlock fault trench by Michael Forrest

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