Interview with SCEC scientist . . .

Thomas Heaton

Photo courtesy Caltech

Interviewed by Karen Brown for the SCEC Quarterly Newsletter.

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.

> 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.

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.

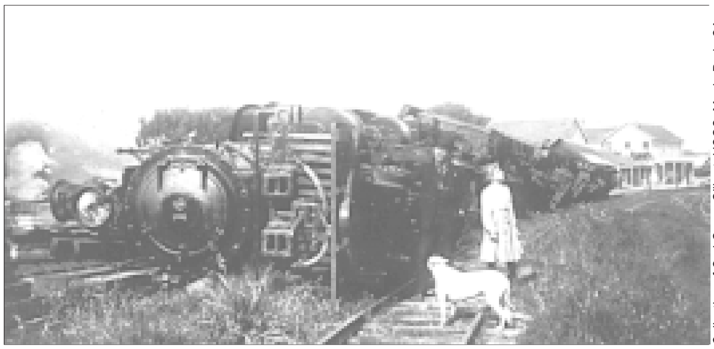
Also, I think the time, in about 1993, when Professor John Hall and I were looking down from the top of an 80-story building in Los Angeles and discussing the physics of how the building stays up in the air. There was a moment of realization that there were many assumptions made in designing the building 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



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.

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."

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 number of institutions in southern California that absolutely require coordination when we communicate with the rest of society in terms of policy decisions.

> 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

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?

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.

> 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.