NEWS FROM THE SALINIAN BLOCK

Earth Sciences at Santa Cruz

Fall 1990

"Consider This Your Wake-Up Call"

As would be expected, UCSC faculty, staff, and students in the C.F. Richter Seismological Laboratory and Institute of Tectonics played an extremely active role after the October 17, 1989, magnitude 7.1 Loma Prieta earthquake. Perhaps less known, however, is the hypothesis of preshocks by Professor Karen McNally which served to prepare our researchers for obtaining data from the October 17 quake.

An earthquake of magnitude 5.3 on June 27, 1988, was the first earthquake of magnitude greater than 4.0 on or near the Santa Cruz Mountains portion of the San Andreas fault in more than twenty years. On August 8, 1989, a second moderate earthquake, magnitude 5.4, occurred in the nearby region of Lexington Reservoir. Why should a seismic region quiet for so long suddenly display two substantial quakes timed so closely together?

Previous work, by a variety of seismologists, had shown that the portion of the San Andreas fault from San Juan Bautista to Palo Alto had not slipped as much as the region near San Francisco during the 1906 earthquake. This slip deficiency was the basis for a long-term forecast by an earthquake forecasting group organized by the U.S. Geological Survey of a 30 percent chance of a magnitude 6.5-7.0 earthquake in this region over the next 30 years.

The occurrence of the two M≥5 events led Professor McNally and others to suspect that strain was building on the Santa Cruz Mountains portion of the San Adreas fault and that this fault segment could experience an earthquake around magnitude 7 in the near future. In meeting with the press following the August 8 event, Karen cautioned, "Consider this your wake-up call."

With this hypothesis in mind and the desire for more aftershock data resulting from the August earthquake, Karen began to select sites where strong motion seismic recorders could be installed. McNally and Specialist Walter Schillinger installed equipment in the Lake Elsman region and upper Branciforte regions in late September.

> "Loma Prieta is an outstanding example of a mountain moving. It has a wedge-shaped bottom, like the prow of a ship, pointing north. Pressure against it from the Pacific Ocean forces it toward the northeast and also raises it up in the air. It is not, however, moving at a rate that should disturb real estate values."
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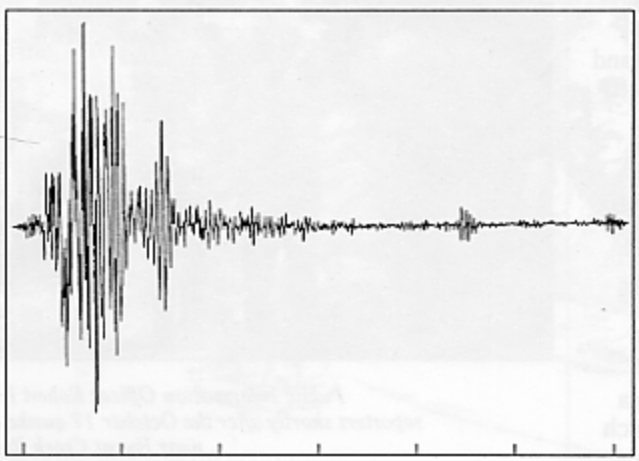
> —Dr. Bailey Willis, geologist, Stanford University, 1930
> *(Ghost Towns of the Santa Cruz Mountains,* J.Young, 1979, p.67)



This graph shows the magnitude 6.9, Oct. 17, 1989, Loma Prieta mainshock. An aftershock of magnitude 5.3, shown approximately 15 seconds later, demonstrates the difference in amplitude on the Richter scale of 16 times.

Strong motion recorders were also activated in the Richter Laboratory at UC Santa Cruz and at the home of Schillinger, near the Santa Cruz Yacht Harbor. Assistant Specialist Judy Brown and ES Graduate Students Marino Protti-Quesada and Aaron Velasco helped record physical evidence from the August quake by mapping cracks, deploying strong ground motion instruments, and checking rock falls.

On October 17, 1989, the wake-up call arrived. At 5:04 p.m. a M_S 7.1 earthquake occurred in the Santa Cruz Mountains. The hypocenter was located beneath the forest of Nisene Marks State Park. Fault rupture extended from the Lexington Reservoir to San Juan Bautista. Its depth originated at 18 kilometers. The San Andreas Fault, which marks the boundary between the North American plate and the Pacific plate, was believed to have moved approximately one to two meters, both vertically and horizontally. Unlike the simple horizontal strike-slip motion along these two plates, the vertical movement in this mainshock caused an unexpected uplift in the western portion of the Santa Cruz Mountains and a drop in the eastern portion.

The phones in the lab began ringing the next day but due to questions about the safety of the building, entrance to the Applied Sciences Building was barred. Researchers Quentin Williams and John Vidale, by climbing through a window, managed to get into the building long enough to grab maps and drag a phone outside so that inquiries could be handled.

The Richter Lab reactivated immediately after the building was reopened.

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Acting Natural Sciences Dean Clifton Poodry quickly obtained a fax machine for the lab. This allowed Administrative Assistant Susie Barber to gather preliminary reports of the earthquake's magnitude from worldwide sources.

UCSC Chancellor Robert Stevens designated the Richter Lab as a regional science coordinating center for the earthquake and approved special public parking. This and the reportage by Public Information Officer Rob Irion, enabled the rapid spread of accurate and up-to-date information. Irion and Barber quickly organized press conferences and fielded calls. A great many other students, researchers, staff and faculty also assisted with public information requests from around the world.

"We may expect light earthquake shocks for a day or two, and then thirty or forty years of monotony. Don't be afraid or get excited. Earthquakes are common the world over. They frighten many but physically injure few. As long as you live you will not die... The wise people take earthquakes as they take strawberries, as a part of life's eventful experience."

(*Santa Cruz Evening Sentinel*, April 19, 1906, p.2)

Two days after the mainshock, five additional strong motion recorders and analog recorders were deployed by Visiting Researcher Gerry Simila and McNally. Many graduate students and researchers helped with daily monitoring of the instrument deployment: John Colosi, Charles Bracher, Zhi Zhang, Yi Zhou, Aaron Velasco, Marino Protti-Quesada, Glenn Nelson (1990), Weiping Zhang, Ornella Bonamassa, Eduardo Malavassi, and Tim Duda. After the information was gathered and returned to the lab, Bonamassa, Protti-Quesada and Nelson assisted with loading the data onto computers for visual display.

One week after the October event, McNally, Lay, Visiting Researcher Gianluca Valensise, Professor Robert Anderson and ES Graduate Students Dan Orange and Protti-Quesada compiled an article on the event for rapid publication in *EOS*, the AGU newspaper. McNally and Lay wrote a proposal to the Incorporated Research Institute of Seismology (IRIS) requesting loan of Program for Array Seismographic Studies of the Continental Lithosphere (PASSCAL) instruments. Fourteen stations were placed near the northern end of the mainshock rupture, field activities were led by Susan Schwartz. The stations collected valuable aftershock data for 18 days.

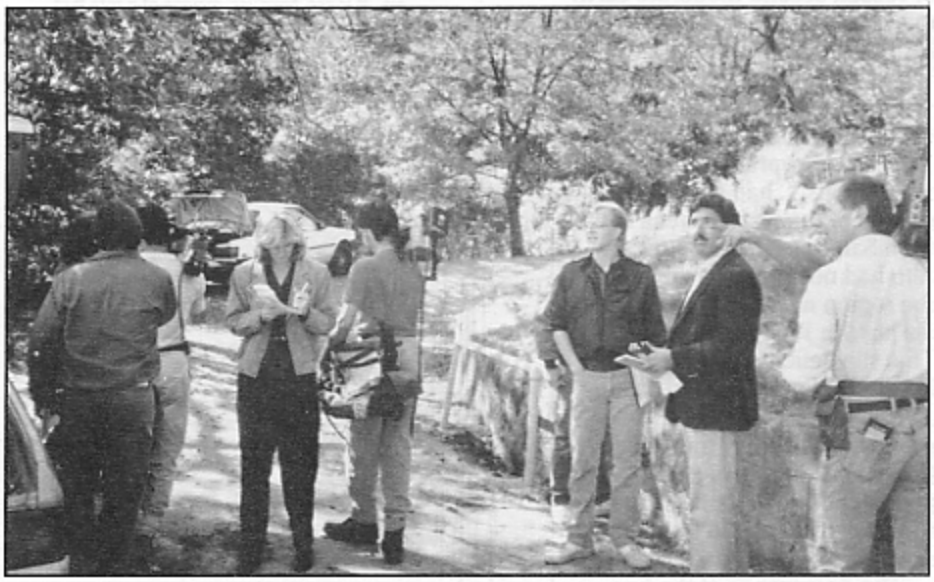
Research from this data is looking at the variability of ground shaking, nature of the fault zone, and source processes, under the supervision of Vidale, Schwartz and McNally. Ornella Bonamassa working with Vidale, Schwartz and Researcher Heidi Houston, found the surprising result that seismometers 30 yards apart detected very different levels and directions of shaking, which may explain why dwellings in the same neighborhoods suffered different levels of damage. The upper 30 feet of soil seems to determine how quake waves are propagated locally. Schwartz and Glenn Nelson are using the data to determine precisely the location of aftershocks thus defining the fault structure in the region of the earthquake. Houston has written a paper analyzing the body waves from the event and determined that the Loma Prieta earthquake was more energetic than average for its magnitude.

Valensise quickly calculated the vertical deformation expected from the event by using theoretical models and the fault mechanism of the event. He and Research Geophysicist Steven Ward have submitted a paper to *Nature* on the relationship between vertical uplift along the Santa Cruz coastal region and earthquakes along the San Andreas fault.

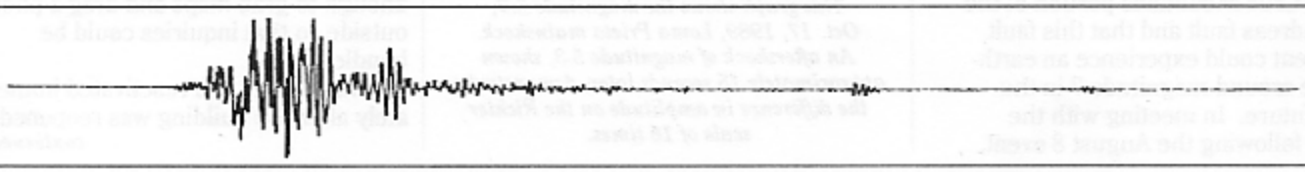
Drs. Karen McNally, Joel Yellin, Gerry Simila, R. Terdiman, Specialist Walter Schillinger and Graduate Students Marino Protti-Quesada, Eduardo Malavassi, and Zhi Zhang coauthored a paper on the local [Richter] magnitude of the earthquake using data collected from permanent and temporary seismograph stations. The magnitude found is 6.9 *not* 7.0-7.1 as widely reported.

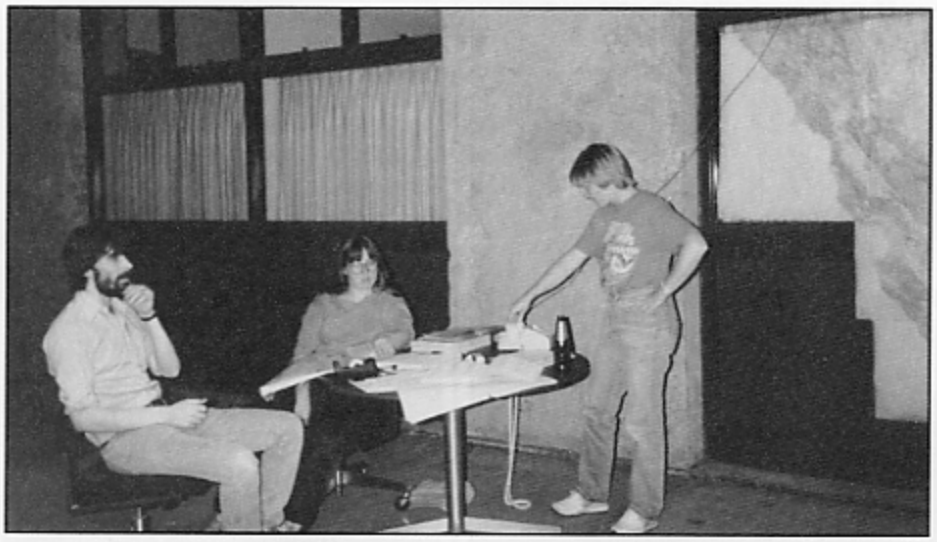
Simila and Visiting Researcher Emilio Nava have written papers with McNally and other coauthors on the locations of the earliest aftershocks (first 20 minutes), as well as the relationship between the preshocks, mainshock and aftershocks using data collected in the UCSC field studies together with data from permanent seismograph stations in the region.

Lay and Researcher Jiajun Zhang have written a paper on analysis of very long period surface waves from the event, which were used to constrain the faulting mechanism. Lay is also



Public Information Officer Robert Irion working with reporters shortly after the October 17 quake at a seismic array station near Burnt Creek Road.





(l to r) Researcher Quentin Williams, Professor Elise Knittle, and ES Graduate Student Katie Scott answering calls the day after the earthquake. Note the phone cord coming out of the window and the maps posted on the external wall of the Applied Sciences Building. Because access to the building was barred, Williams and Researcher John Vidale liberated maps and a phone by climbing through a window.

preparing a paper with Professor Terry Wallace of the University of Arizona on the body waves from the event.

Many of these projects were presented at the Fall American Geophysical Union (AGU) meeting held December, 1989, and at the Seismological Society of America (SSA) meeting held in Santa Cruz in May, 1990. The SSA meeting also featured field trips to the source region and to damaged areas.

Members of the Institute of Tectonics and the Richter Lab worked such long, hard hours that some did not leave the lab for days and virtually survived on pizza.

According to McNally, "Disasters such as this earthquake are what teaches the experts—in this case the seismologists—the difference between looking at an accident [earthquake] and being in one."

For a list of papers produced by the Institute of Tectonics, contact Susie Barber, Tectonics ORU, UCSC, Applied Sciences Building, Santa Cruz, CA 95064. Ω

NOT MERELY ACADEMIC!

For those of us who spend our lives in the university, teaching and doing research, it is depressing to read or hear that some issue being discussed is "merely academic"—that is, so abstract and irrelevant to real-world concerns that one need hardly bother with the conclusions. On October 17, 1989, the "real world" came to realize that the work we in the Earth Sciences Board do is very useful, informative and necessary. Everyone, inside and outside the academy, was made graphically aware that we all live on the edge, the edge in this case being an active plate boundary.

This issue of the Earth Science Newsletter is dedicated to telling how our faculty, students, and alumni involved themselves after the earthquake in all sorts of earthquake-related activities. This involvement continues today, although at a less frantic pace than in those early, very uncertain hours just after the earthquake, when suddenly we were all physically and emotionally shaken. We hope you are not only informed by this account, but also encouraged by it to know that the Earth Sciences Board is, indeed, concerned about the "real world." Ω

GRIGGS WORKING WITH COUNTY

Although the October 17 earthquake was a devastating event for the entire central coast of California (present estimates of $6 billion in damage, with $350,000,000 in Santa Cruz County), it has also been an incredible research opportunity. Most geologists only get one large geologic disaster in their lifetimes. For a geologist who works on geologic hazards, Santa Cruz County has been the place to be for nearly a decade. The 100-year storm and floods and mudflows (Love Creek) of 1982, the severe coastal storm damage in 1983, and another severe winter in 1986 with widespread slope failure through out the county, prepared us in some ways for the October 17 earthquake.

Because of his 15 years of involvement with Santa Cruz County as a geologic consultant and advisor, ES Professor Gary Griggs was called the morning after the earthquake and asked to assist in assessing earthquake damage and problems. The initial days were spent with County Public Works assisting them with highway and road problems, and field checking those areas which were hardest hit. An emergency office was set up in the County Government

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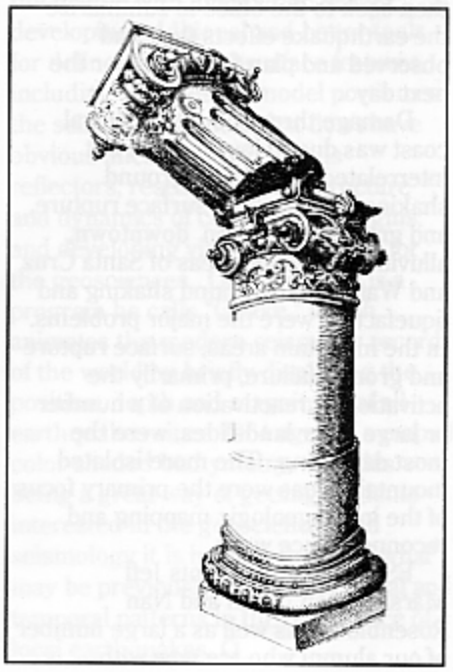

This photo, taken approximately 1 km east of Highway 17 on Summit Road, shows a left lateral offset whereas the San Andreas fault moves right laterally. The left lateral movement has been attributed to reactivation of an old landslide rather than the fault rupture reaching the surface.

Center and for the next week Griggs and other county geologists were in the field from 7 a.m until 5 p.m., and then back to the office to summarize the earthquake effects they had observed and plan field work for the next day.

Damage throughout the central coast was due to four distinct but interrelated processes: ground shaking, liquefaction, surface rupture, and ground failure. In downtown, alluvium-underlain areas of Santa Cruz and Watsonville, ground shaking and liquefaction were the major problems. In the mountain areas, surface rupture and ground failure, primarily the activation or reactivation of a number or large older landslides, were the most damaging. The more isolated mountain areas were the primary focus of the initial geologic mapping and reconnaissance work.

ES Graduate Students Jeff Marshall, Jeff Nolan and Nan Rosenbloom, as well as a large number of our alumni who are now with government agencies such as Santa Cruz County and the USGS or with local consulting firms all worked directly under the coordination of County Geologists Piai Levine and Mary Anne Mckittrick, both former Earth Sciences students. Alumni included Gerry Weber (class of 1980), Joe Hayes (1985), Scott Miller (1989), Remelle Burton (1988), Mark Foxx (1984), and Hans Nielsen (1984)

The work evolved from an emergency response at the reconnaissance level to one of more detailed mapping of the areas of major ground breakage and slope failure. Subsequently, the posting of unsafe-to-occupy homes and the initiation of site specific geological hazards assessment began under county supervision. Due to the scale and extent of the effects of the earthquake, the county received funding through the Federal Emergency Management Agency (FEMA), managed by the Army Corps of Engineers, to carrying out a detailed geological and geotechnical investigation of the Summit area where ground failure was the most extensive. A Technical Advisory Group including Griggs and Gerry Weber was established. The group has been meeting regularly to coordinate the research efforts in the Summit.

"This promises to be the greatest season Santa Cruz ever enjoyed. Tens of thousands of people will be here from San Francisco, and they will be here soon. Their homes are in ruins, and everything is favorable to them coming to this town and climate."

(*Santa Cruz Evening Sentinel*, April 21, 1906, p.4)

Griggs, with Marshall and Rosenbloom, was contracted monitor large slide masses in the Summit area to determine possible movement associated with the expected onset of winter rains. The program consisted of fifty quadralateral arrays installed across the head and lateral scarps of the landslides initiated by the earthquake, and eight recording strain gages. Because drought conditions continued through the winter, no significant movement was recorded between December 1989 and May 1990. Thus the issue of long-term stability of these slide masses, which are home sites for hundreds of people in the Summit area, remains an unresolved question. The post-earthquake work continues in the Summit area and may extend into winter 1991.

Another research effort undertaken by Griggs and Nathaniel Plant (1990) was to fly the coast from Bolinas to Monterey recording failure of coastal bluffs initiated by the October 17 earthquake on 35 mm camera and videotape. Bluffs failed from San Francisco to Monterey. Nine cliff top dwellings have been demolished and more are threatened because of loss of foundation support. The results of this work were reported in the cover story of the April issue of *California Geology*.

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LETTER FROM THE CHAIR

Dear Alumni and Friends:

The 1989-90 Academic year went by incredibly quickly. Many changes have taken place. Thorne Lay and Justin Revenaugh joined our academic ranks (see accompanying profile). Staff members Chris Flanagan and Dan Sampson both left to work in private industry. We hired a new board assistant who is also our development coordinator, Roxanne Kunnanz-Petersen, and her part-time assistant Barbara Lee. Also, Jim Gill has agreed to serve as acting dean for the Division of Graduate Studies and Research.

The October 17, 1989, Loma Prieta earthquake had such an effect on all that it was an obvious subject for this year's newsletter. The format is somewhat different than previous years. It focuses on alumni and board activities associated 43with the earthquake rather than general accomplishments during the last year. One interesting fact not mentioned elsewhere is that Ken Collerson and Researcher Ross Williams spent one full month recalibrating our new mass spectrometer.

On October 13 and 14, 1990, we held our first all-alumni reunion. The October 17 earthquake was the theme. Three talks were presented by Karen McNally, Bob Anderson and Gary Griggs. Field trips were given by Gerry Weber, Anderson, Griggs, and ES Graduate Student Jeff Marshall. On Sunday we had an openhouse at the Applied Sciences Building and a picnic much like the traditional picnic for Earth Sciences students. More than 140 people attended the events.

Special thanks goes to Applied Geomechanics, Inc., Digital Graphics, Rogers Johnson and Associates, and Weber and Associates for their cash donations to help with the reunion. Roxanne deserves much of the credit for the success of the reunion; without her energy and organizational skills the event probably would not have happened. She and Léo Laporte produced this newsletter which, because of "time out" for the reunion, is coming to you two months later than hoped; but here it is, nonetheless!

We think the reunion was a success and would appreciate hearing comments from participants. Whether or not you attended, we would like suggestions for future activities. Please take a moment and complete the form on the last page of the newsletter. We would love to hear from you.

—Ken Cameron Ω

ALUMNUS OF THE YEAR: GERALD WEBER

Gerald Weber completed his Ph.D. at UCSC Earth Sciences Board in 1980. His thesis was a study of faulting along the San Gregorio fault zone in San Mateo County. This has been the basis of his continuing interest in neotectonics and Pleistocene geology in the central California coastal area. Geologic articles for the educated layperson and the general public are Weber's current writing focus.

In retrospect, Gerry is amazed that he got to Santa Cruz when he did. More than six years of working in the oil industry in Bakersfield convinced him that it was time to get out of oil and into something he was more interested in. He decided to go back to graduate school. Why Santa Cruz? The main benefit was that the department was small. After going to the University of Texas in Austin for his M.S., Weber realized that he did not want a similar "big university" experience. The Santa Cruz area also offered a great deal of interesting geology and beautiful scenery.

Weber has always been interested in teaching. He periodically taught courses throughout the 1970's for UCSC and De Anza College. Sand and Beaches, initially developed by ES Professor Robert Garrison, was Gerry's favorite class. He considered the class a rigorous attempt to teach geology to non-majors. According to Weber, "Many students left after the first two classes when they learned that it was not beer drinking and hanging out on the beach."

In 1983, Weber began teaching field geology classes for the Earth Sciences Board at UCSC. His main reason is that he believes it is one of the most important classes that an undergraduate takes in geology. It incorporates a lengthy period of time of close field observations, sorting the observations by quality, and dealing with the uncertainly of field data. He believes that without a class of this kind, students might not develop the ability to be sufficiently critical of field data and maps. It is essential, says Gerry, that students learn that published maps are really "progress reports" and that many simply reflect the ideas in vogue at the time during which they were put together.

The summer field class gives students two, three-week exercises to work out a complex geologic problem. Students learn to sort out uncertainties associated with field work. At the beginning of the course, most students are uncertain about their abilities to observe, record, synthesize, and interpret. They develop and improve

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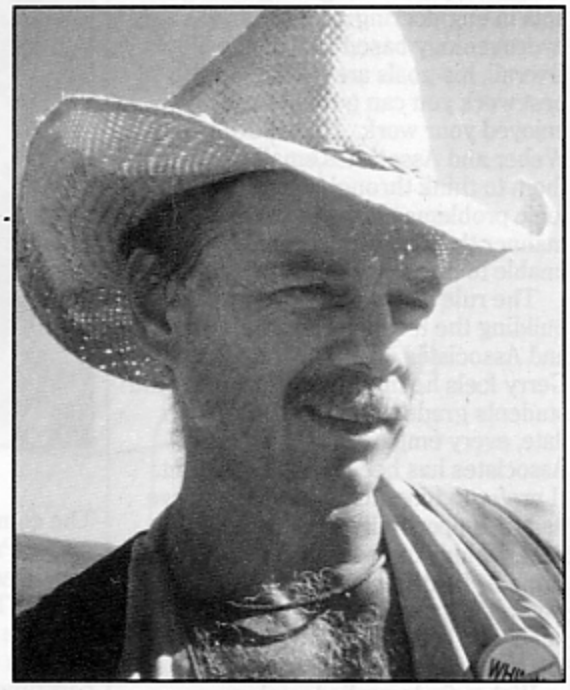

Gerald Weber

these skills over the summer, thus increasing their confidence in doing field work. Weber thinks self-confidence is essential in developing good field geologists.

"Everything seems to be so queer,
Just about this time of year.
You don't know what the
earth is about,
Everything seems to be inside out.
It also seems to be upside down,
The earth is acting just like a clown.
Shaky earth, I wish that I
could say to you
One little word or two
And that is this—
When to shaking business
you get about
Will you please be so kind as to
leave me out?"

Leslie Francis Deacon, aged 10,
Santa Cruz Mountains
(*The Santa Cruz Mountain Realty*, July 1906)

Weber has made a living in a field that relies heavily on his interests—applied geology or engineering geology. He owns and operates Weber and Associates, a firm of geologic consultants in engineering geology and hydrogeology based in Watsonville. Overall, his goals are simple; do the best work you can possibly do and enjoyed your work. He believe keeping Weber and Associates small allows them to think through complex geologic problems and analyze projects in a manner that most larger companies are unable to do.

The rule of thumb used when building the technical staff of Weber and Associates is hire only the best. Gerry feels he finds the best among the students graduating from UCSC. To date, every employee of Weber and Associates has been a UCSC student. "I prefer to hire students whom I have had the opportunity to observe in the field geology classes. Seven weeks of summer field brings out the best, or the worst, in a person. It is easy to determine who has it and who doesn't, by the end of my class," says Weber.

Weber finds applied geology a worthy challenge. On a day-to-day basis he applies the science to solving real problems. Most of the time, it is too real—at least more real that one would like it to be. Consultants work within a budget developed by competitive bidding thus making a profit can be a challenge.

The initial effect of the October 17, 1989, Loma Prieta earthquake was physical and emotional chaos, and a gridlocking of activity for Weber and Associates. "There were so many demands on our time that we ground to an almost complete standstill," says Weber. It was difficult to get work done for the first two weeks. Gerry was teaching the introductory field class at the time of the earthquake, and worked non-stop until Thanksgiving. The initial chaos was followed by over commitment and the realization that Weber and Associates couldn't get the work that had been promised done with existing staff.

Gerald Weber

The company then started to rapidly grow. Prior to the quake the company consisted of four geologists including Gerry. The company now employs seven full-time geologists, a geologist/draftsman, an office manager and one to two part-time geologists/ technicians. The workload, though it varies, has doubled over what it was prior to the earthquake.

Work following the earthquake for Weber and Associates has consisted primarily of evaluating damaged properties and attempting to mitigate the effects of the slope failure associated with the quake. They have also been doing some applied research on ground fissuring and landsliding associated with the earthquake. The USGS funded mapping of landslides and ground cracking by Weber and Associates in the epicentral area, the Forest of Nisene Marks. They will also be studying some of the large ground failures in the summit area through exploratory trenching of the main scarps of the slides with funding from FEMA. From this study they hope to develop a technique for determining the history of movement of these large landslides.

Over the past twenty years at UCSC Weber has seen many students including himself barely able to squeak by financially. He relied heavily on whatever funding was available. UCSC is a young school and wealthy alumni are few. He decided since his business is doing well, now is a good time to start contributing to the Earth Sciences Board. Gerry recently made a generous contribution and established the Earth Sciences Student Special Needs fund. This fund will provide assistance with field research, conferences, travel money, and other things for which money is not available. He thinks this fund is worthy of support.

Weber believes strongly in getting away from everything now and then. He enjoys river rafting, playing pool, and watching major league baseball. "For total relaxation, nothing compares to a 23-day trip on the Colorado River through the Grand Canyon. Drinking beer and rowing the big drops—can't beat it," Gerry adds.

Where will Weber and Associates go from here? Gerry is not sure. They are trying to get into larger, research oriented projects. He adds, "If oil stays at $30 a barrel, I may start dusting off some of those old oil and gas prospects that I've got in the office. Anyone interested in doing a little exploration in the La Honda area?"

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EARTHQUAKE STIMULATES IDEAS FOR ANDERSON

Soon after 5 p.m. on October 17, 1989, it became apparent to ES Professor Robert Anderson that the Santa Cruz Mountain earthquake was closely related to the slight restraining bend in the San Andreas fault in these mountains.

Two ideas quickly crystalized for Anderson. First, if the mountains undergo periodic uplift due to repeated earthquakes, and at the same time are slipping relative to the bend, then the resulting long-term topography on the Pacific Plate ought to be a streaked out set of mountains parallel to the fault. Inspection of the topographic maps of the Santa Cruz Mountains seemed to support this idea. The range is indeed streaked out to the northeast. Second, farther from the fault, the uplift should result in emergence of marine terraces along the Santa Cruz coastline. The pattern of marine terrace elevation should reflect the combination of the coastline and uplift pattern at the time the terrace was formed.

The preliminary uplift pattern, produced by modelling geodetic data on local mountain tops, showed a very close correspondence of the two patterns. This modelling was done by Dr. Gianluca Valensise, a visiting earth scientist from Italy.

Anderson's research in subsequent months attempted to surround these ideas with data derived both from geologic literature, the local landscape, and monitoring of motion on the cracks generated by the earthquake with ES Professor Gary Griggs and students.

The Uplift/Terraces Story

To test his ideas relating to the patterns on the local marine terraces, it was necessary for Anderson to document the elevations of the terraces.

There was also the need to document the coseismic uplift pattern. Jeanne Buckthal (class of 1990) helped compile available elevations of shoreline angles on the terraces. These had previously been collected by C.S. Alexander in the early 50's, and in the late 70's by Gary Griggs and Bill

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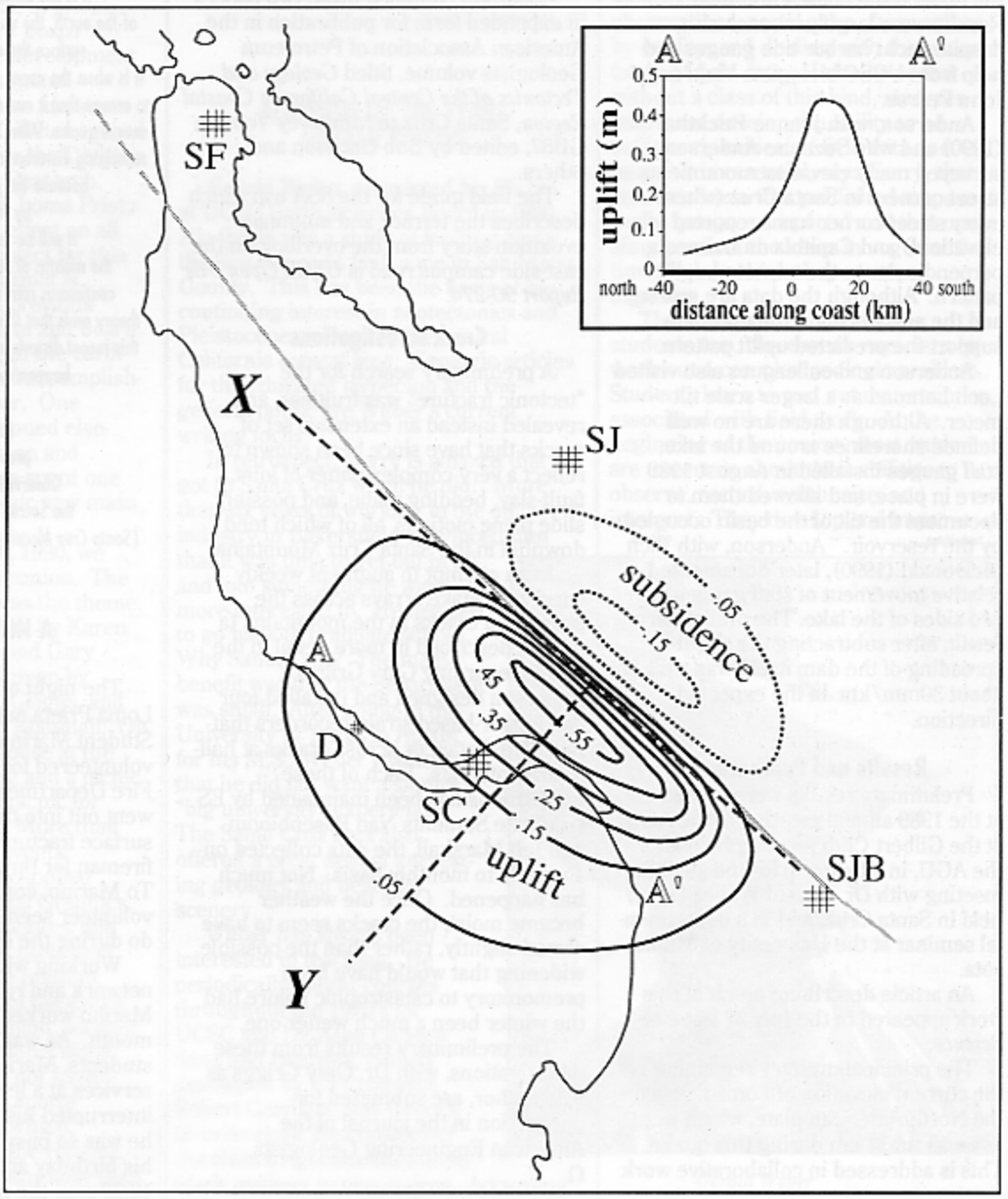


Bradley, a professor at the University of Colorado.

Tilt Surveys

Anderson made several attempts to measure the tilt associated with the uplift pattern which is still very poorly documented.

Working with Valensise, early attempts to document the magnitude of the uplift at the coast were made. Results were largely inconclusive despite yacht harbor tide gauges and help from UCSC biologists Vicki and John Pearse.

Anderson, with Jeanne Buckthal (1990) and wife Suzanne Anderson, surveyed many elevation monuments at street corners in Santa Cruz (where every street corner has a reported elevation!) and Capitola on transects perpendicular to the expected uplift pattern. Although the data are sparse and the noise is high, they seem to support the predicted uplift pattern.

Anderson and colleagues also visited Loch Lomond as a larger scale tilt meter. Although there are no well defined shorelines around the lake, staff gauges installed in August 1989 were in place, and allowed them to document the tilt of the basin occupied by the reservoir. Anderson, with Rich McDonald (1990), later documented relative movement of staff gauges on two sides of the lake. The preliminary result, after subtracting the slight spreading of the dam itself, was a tilt of about 30mm/km in the expected direction.

Results and Publications

Preliminary results were presented at the 1989 annual meeting of the AGU, at the Gilbert Club meeting held after the AGU, in a field trip for the 1990 SSA meeting with Dr. Gerald Weber (1980) held in Santa Cruz, and in a departmental seminar at the University of Minnesota.

An article describing much of this work appeared in the July 27 issue of *Science*.

The principal mystery remaining is the current elevation of Loma Prieta on the North American plate, which went *down* about 14 cm during this quake. This is addressed in collaborative work with Dr. Susan Schwartz, assistant research seismologist, and ES Graduate Student Dan Orange, where they identify the Sargent and Berrocal fault systems as potentially active players in the raising of the southern Santa Cruz Mountains. This paper was published in the July issue of *Geophysical Research Letters*, edited by ES Professor Karen McNally and Research Geophysicist Steven Ward.

Anderson compiled these two papers in expanded form for publication in the American Association of Petroleum Geologists volume, titled *Geology and Tectonics of the Central California Coastal Region*, Santa Cruz to Monterey Volume GB67, edited by Bob Garrison and others.

The field guide for the SSA trip which describes the terrace and mountain evolution story from the overlook on the east-side campus road is *USGS Open File Report 90-274*.

Crack investigations

A preliminary search for the "tectonic fracture" was fruitless, and revealed instead an extensive set of cracks that have since been shown to reflect a very complex patter of joint, fault-slay, bedding plane, and possibly slide plane motions, all of which tend downhill in the Santa Cruz Mountains.

In an attempt to augment weekly surveys of stake arrays across the prominent cracks in the mountains (a project described in more detail in the article regarding Gary Griggs), Anderson designed and installed four datalogger-based strain recorders that measure distances across cracks at half-hourly intervals. Each of these installations has been maintained by ES Graduate Students Nan Rosenbloom and Jeff Marshall, the data collected on a weekly to monthly basis. Not much has happened. Once the weather became moist, the cracks seem to have closed slightly, rather than the possible widening that would have been premonitory to catastrophic failure had the winter been a much wetter one.

The preliminary results from these investigations, with Dr. Gary Griggs as lead author, are submitted for publication in the journal of the American Engineering Geologists. Ω

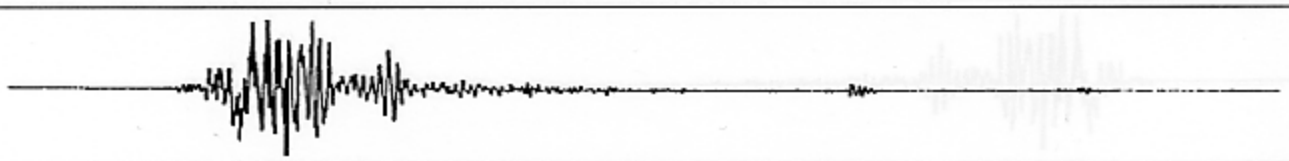
"When it rains many days in succession,
the rain, in descending to the bowels of the earth
until it finally reaches the strata of fire, is condensed
into vapor, therefore the more rain the more vapor.
After the vapor reaches its maximum of expansion
on account of the heat, it tries to escape upward as
does the vapor in a boiling pot of water.
If there were enough vapor from the pot of water
it would raise the cover and escape.
It is the same way down in the bowels
of the earth, the vapor trying to find its way to the
surface through the different layers.
It is when the vapor is on its upward journey seeking
to escape that it causes the strata to separate, giving a
severe quake. After it has once found its way out the
remaining disturbances are of less duration naturally,
because the passage is already made
by the previous one.
It will be remembered that during
the months of January and Febuary we had
continuous rainfall. The facts that I base my
theory on is that this rainfall was the direct cause of
this recent disturbance. I have seen the same thing
happen many times in Mexico."

Father Heredia,
previous head of the
Observatory of the College of
the Sacred Heart, Puebla, Mexico
(*Santa Cruz Morning Sentinel*, April 24, 1906, p.1)

A HOT VOLUNTEER

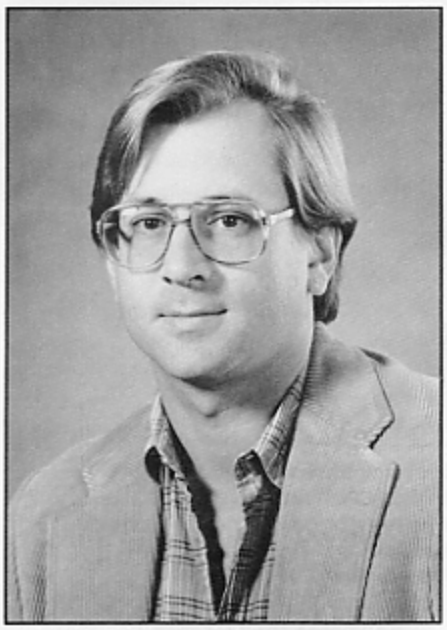
The night of the October 17, 1989, Loma Prieta earthquake, ES Graduate Student Marino Protti-Quesada volunteered for the Santa Cruz City Fire Department. He joined those who went out into the field to check for surface fractures. Marino had been a fireman for three years in Costa Rica. To Marino, coming forward to volunteer seemed an obvious thing to do during the crisis.

Working with the field seismic network and running data processing, Marino worked 18 hours a day for one month. As was the case with several students, Marino contributed time and services at a level which greatly interrupted his regular routine. In fact, he was so busy working that he forgot his birthday and did not realize it until 12:30 a.m. the next morning. Ω



NEW FACULTY

Thorne Lay



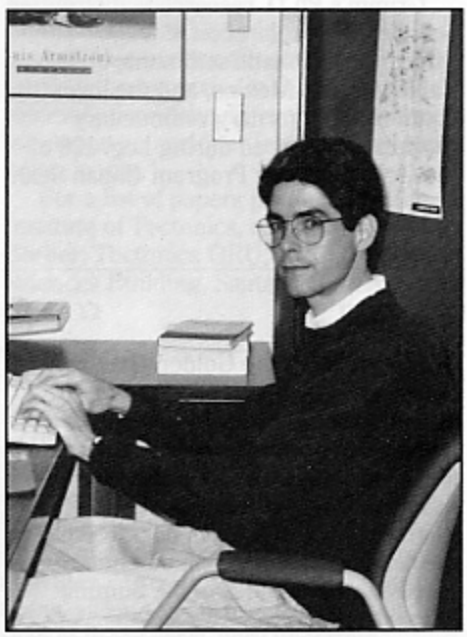
Before to coming to UCSC as professor of Earth Science and director of the Institute of Tectonics, Thorne Lay was an associate professor at the University of Michigan. He received his M.S. and Ph.D. (1983) in Geophysics from the California Institute of Technology.

While the Earth can be viewed as having a surface divided into quasi-rigid "plates," the mechanisms that drive these plates and other large-scale dynamic processes inside the Earth's interior remain unclear. Investigation of these processes requires analysis of diverse information and a multidisciplinary perspective. Lay's primary research interests involve analysis of seismic waves to define the structure of the Earth's deep interior and the mechanics of faulting systems. These applications must be integrated with other geophysical and geochemical information in order to understand the fundamental processes. This multidisciplinary effort is leading to a new paradigm for this major internal transition zone, with implications for heat transport and chemical evolution of the mantle and excitation of the Earth's magnetic field. An example is Lay's research program on the core-mantle boundary, where seismological models must be integrated with mineral physics and geodynamics to interpret processes 3,000 km deep in the Earth.

Lay's other interests in subduction zone earthquake rupture process, slab deformation, and lithospheric heterogeneity, also entail broad geophysical and geochemical contexts. In addition, he is active in research on the physics of underground nuclear explosions to enhance national capabilities for verifying nuclear text limitation treaties.

While these applications involve a wide variety of analysis procedures, the unifying theme in Dr. Lay's work is the quantitative application of physics and mathematics to understand the dynamics of the Earth.

Justin Revenaugh

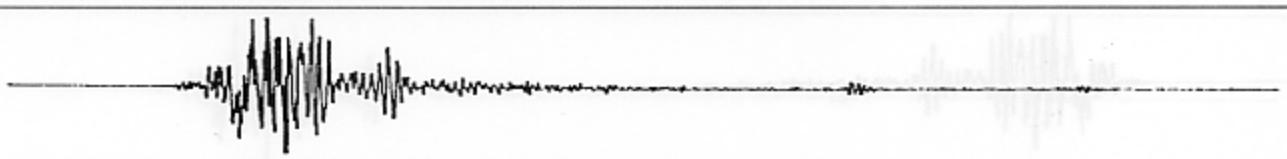


Having earned his Ph.D. at MIT, Justin Revenaugh come to the Earth Sciences Board as assistant professor from Shell Development Company of Houston, Texas, where he applied reflection and solid-Earth seismology to energy exploration and developed tools to help geologists spot subtle variations in the properties of shallow rock interfaces, some of which could be construed as indications of profitable hydrocarbon reservoirs.He describes himself as a "structural seismologist," focusing his interests in imaging Earth structure, be it in the crust, the mantle, or the core.

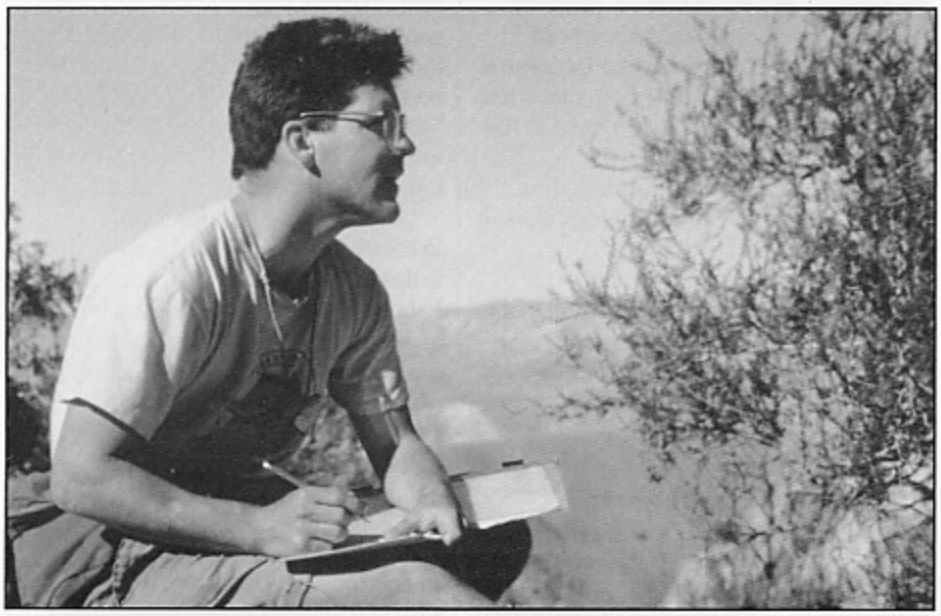
At UCSC, Revenaugh with Professors Eli Silver and Casey Moore is developing the Crustal Imaging Laboratory, an offshoot of the Institute of Tectonics, designed to centralize the hardware, software, and processing resources needed to do state-of-the-art crustal imaging. He is also taking the initiative to overhaul the current geophysics curriculum.

Revenaugh's research includes use of long period seismic waves (frequencies 100 to 1000 times lower than the lowest pitches humans can perceive) to look for extremely subtle changes in property of the Earth's mantle. In a series of six papers he details the results which have important implications for the structure, dynamics and evolution of the Earth. He also has examined the interplay between the Earth's gravity field and convection in its interior.

His current projects include studying the mantle with long-period waves; developing additional and better tools for delineation of subsurface features, including how best to model portions of the seismic wave field that don't have obvious linear and continuous reflectors; researching the structure and dynamics of continental margins; and developing visualization tools for the geosciences. One such tool is a program he calls "Quake," which animates the modern seismicity record of the world by briefly displaying the position, depth and magnitude of all earthquakes since 1964 against a map of color-shaded bathymetry. Besides being a great way of getting students interested in the geosciences and seismology it is helping to reveal what may be previously unnoticed spatial and temporal patterns in the recurrence of local earthquakes. Ω



GRIMM DELIVERS BEST PAPER



Kurt Grimm

At the 1990 annual meeting of the American Association of Petroleum Geologists, ES Graduate Student Kurt Grimm was recognized for delivering the best student talk. His address, "Doomed Pioneers: Event Deposition and Bioturbation in Anoxic Marine Environments," evolved out of research carried out with Karl Follmi, a post-doc at UC Santa Cruz from 1987-1989, in Professor Robert Garrison's lab. Grimm received a $2,000 award and the Board received $5,000.

Grimm's Ph.D. research is distributed between the exploration of Oligo-Miocene phosphatic sediments in Baja California Sur, Mexico, and the investigation of Quaternary sedimentary rhythms discovered during Leg. 128 of the Ocean Drilling Program (Japan Sea). Ω

AGI EMPLOYS ALUMNI

Applied Geomechanics, Inc. (AGI), located in Live Oakes, CA, employs five UCSC Earth Sciences alumni: Gary Holzhausen (class of 1971), President; Howard Egan (1984), Systems Manager; Greg Baker (1987), Geophysicist and Programmer; Frank Horath (1989), Applications Specialist; and Daniel Sampson (1983), Production Manager.

During the October 17, 1989, Loma Prieta earthquake, AGI recorded a surprisingly small fault rotation (uplift about 30 microradians) near the Santa Cruz Yacht Harbor suggesting that the Summit Ridge area was upthrust relative to coastal Santa Cruz. Following the quake, AGI's equipment was installed on the Golden Gate Bridge to evaluate any potential effects of the quake upon the structure and to develop a long-term movement signature. AGI is now working with William Cotton Associates, the USGS, the Corps of Engineers, and FEMA to characterize the movement of ancient, potentially reactivated landslides in the Summit Ridge area. Ω

"The earthquake shakes on Wednesday will be good for Santa Cruz if the people thereof will hereafter build better buildings against earthquakes."

(*Santa Cruz Evening Sentinel*, April 19, 1906, p.2)

"A bad earthquake at once destroys our oldest associations: the earth, the very emblem of solidarity, has moved beneath our feet like a thin crust over a fluid; — one second of time has created in the mind a strange idea of insecurity, which hours of reflection would not have produced."

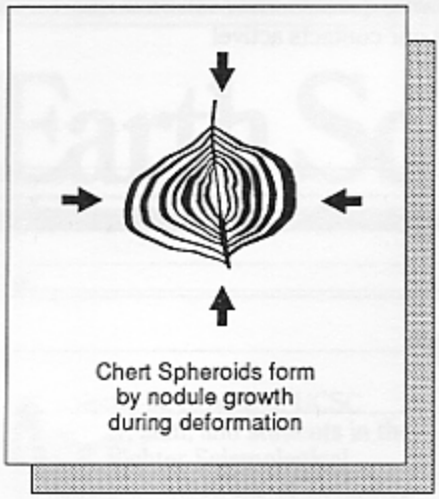
—Charles Darwin
(After experiencing the Great Chilian earthquake of 1835)

INFORMATION OUTREACH PROGRAM

Following the October 17, 1989, Loma Prieta earthquake the Earth Sciences Board received many requests Board members to give public addresses explaining the causes of the earthquake, allay fears, dispel rumors, and provide information on the potential for further aftershocks. To meet this need for accurate information both on campus and in the Santa Cruz community, a group of ES graduate and undergraduate students met to organize a program of earthquake lectures which would explain the causes of seismic events and the methods by which they may be forecast.

The response was tremendous. Requests began to pour in from campus organizations, schools, churches, and community service organizations. Lon Abbott, Al Bol, Charlie Crocker, Charlie Dunlap, Fred Hochstaedter, Maria Ledesma, Jeff Marshall, Rich McDonald, Dan Orange, Nan Rosen- bloom and Harold Tobin volunteered their time to give talks. Coordinated by Hochstaedter, the program to date has given talks and lectures to thousands (*literally!*) of community members. Ω

EXCELLENCE AWARD FOR BEHL



Chert Spheroids form by nodule growth during deformation

Selected out of 177 presentations for having the highest standards of delivery and content, ES Graduate Student Rick Behl received the Excellence of Presentation Award at the 1990 annual meeting of the Society for Sedimentary Geology (SEPM). Behl's oral presentation and paper entitled, "Chertification in the Monterey Formation of California: An Extended Process of Diagenesis and Deformation," was judged on presentation skills, visual aid use, content, and organization.

Behl's Ph.D. research focuses on the processes and timing of chert formation in two distinct suites of rocks. The petrographic and oxygen-isotope study of cherts in the Miocene Monterey Formation of California is revealing important features of chertification within a marginal marine, siliceous and organic-rich sediments that have been extensively deformed since deposition. Ω

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That "Fault" in the Mountains

And Other Happenings in High Places, Analyzed by Lizzie Beecher

(from the *Santa Cruz Sentinel*, June 5, 1906, p.2)

WRIGHTS, [Santa Cruz Mountains], June 4. —Geologists seem to agree in laying the blame for the great earthquake on the Santa Cruz Mountains. It makes us feel like a friend of mine who had suffered severely from ill health for a number of years and had been much tried by Christian Scientists and faith healers who told her that she would be well if she only thought so. She said it was bad enough to be sick without being told it was her own fault.

Dr. Branner says that slips in faults may be caused by pressure, which is produced by the shifting of weight by the action of streams carrying deposits of sand, etc. If this is the case, why may not this seismic disturbance have been produced by shifting the weight of millions of tons of water caused by changing of the course of the Colorado river and the filling of the Salton sea? Rather far-fetched? A trifle, I admit, but it is the boast of this age that it annihilates distance. If we can have telescopes, telegraphs, telephones and tele-photographs, why should not we have a tele-temblor? Not that we want one! Not in the least. But as we can not shift the fault, we would like to shift the blame.

Would some one please inform us as to the exact extent of these much abused Santa Cruz Mountains? Geologists seem to include the ridge running all the way to San Francisco under that term, but George Robertson speaks of them as ridges ranging from 300 to 500 feet elevation. That certainly does not include us as we boast an elevation of from 1,500 to 3,800 feet. Besides, the fault extends all the way to Point Arena. I insist that the northern range take their share of the blame.

There is one consolation: I am glad to know that we are rising and not falling. I approve of aspiration, but I think that when Skyland and the Summit humped themselves so hard as to split open on top, they rather overdid the matter. Also we are glad to note the great increase in friendliness between the residents of Skyland and Loma Prieta Av., but we did not look for Skyland itself to make advances towards us as it apparently did on the memorable 18th of April.

In response to M. Lienald, I would say that no one that I have heard of contemplates leaving these beautiful mountains on account of the recent slip. We don't feel as though we were living on the side of a volcano, and we do not expect to experience another such shake if we stay here. No, we have had it out, and it is another man's turn now. In a prarie fire the safest place is the one which has been burned, so we console ourselves with the thought that we have been shaken down—or up—to stay.

Dear Alumni:

The recent reunion was fabulous! Please take a moment to completed the following questions and return this form to the Earth Sciences Board. Let's keep the planning going and our contacts active!

—Gary Holzhausen, Class of 1971

Name:_____

Mail Address (circle: home or business):_____

Telephone:_____

Employer:_____

Position:_____

Recent Achievements or News:_____

Comments regarding the reunion or suggestions for future activities:_____

Board of Studies in Earth Sciences
University of California, Santa Cruz
Santa Cruz, California 95064

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