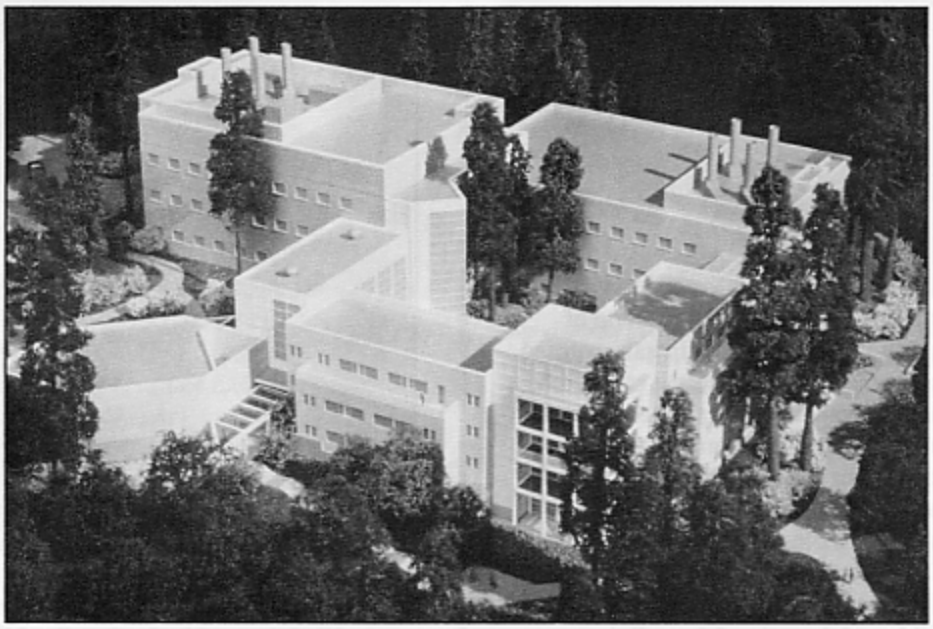
NEWS FROM THE SALINIAN BLOCK

Earth Sciences at Santa Cruz

Fall 1989



Scale model of the Earth and Marine Sciences Building. In the foreground are the office and classroom wings, in the background are the wings for teaching and research laboratories.

Change and Continuity: The Earth Sciences Board After 21 Years

This Autumn marks the 21st anniversary of the founding of the Earth Sciences Board at UCSC. Starting with one professor in 1967, we have grown to a faculty of 16, and, over the past 21 years, 773 students have received undergraduate and graduate degrees in the Earth Sciences from UCSC. Continuity has been a major characteristic of the Earth Sciences program; during our history, only two faculty have left Santa Cruz, one due to retirement, the other to accept another post (while retaining a linkage to us as an Adjunct Professor). We are especially proud of the fact that most of our faculty originally came to Santa Cruz as young Assistant Professors and have stayed to achieve international scientific prominence while teaching and conducting research here.

We are equally proud of our current and former students and their accomplishments; a sampling of the latter is presented in the following pages. Our Co-Alumni of the Year, for example, were the recipients last year of two of the most prestigious awards in the earth sciences, and a large number of other alumni have made significant contributions to science and society as teachers, researchers, exploration managers, consultants, naturalists, entrepreneurs, volunteers, executives, environmentalists, adventurers, and good citizens.

Yet while we take satisfaction in the past, we look forward to future, and the changes and opportunities it presents. The UCSC campus as a whole is in a period of unprecedented change and growth, a metamorphosis shared also by the Earth Sciences Board. Within the past three years we have added four new faculty, and we anticipate two additional appointments during the current academic year. This is the most rapid period of growth in our history, and along with new faculty have come exciting new programs and laboratory facilities in mineral physics, isotope geochemistry, earthquake seismology, and surficial geology. The successes of our past efforts and the promise of our future enterprises were instrumental in convincing university authorites to support construction of the new Earth and Marine Sciences Building (pictured above), which, when completed in 1991, will be the largest science facility on the UCSC campus.

Co-Alumni of the Year

During the past, two of the major awards for young researchers in the earth sciences went to Fred Phillips (B.A. '76) and Rich Gordon (B.A.'75). Because both are products of a UCSC undergraduate education in earth sciences, and because both had somewhat non-conventional educational experiences here (e.g. earth sciences was an almost accidental econd choice as a major for both), we are especially pleased to designate them as Co-Alumni of the Year.

Fred M. Phillips

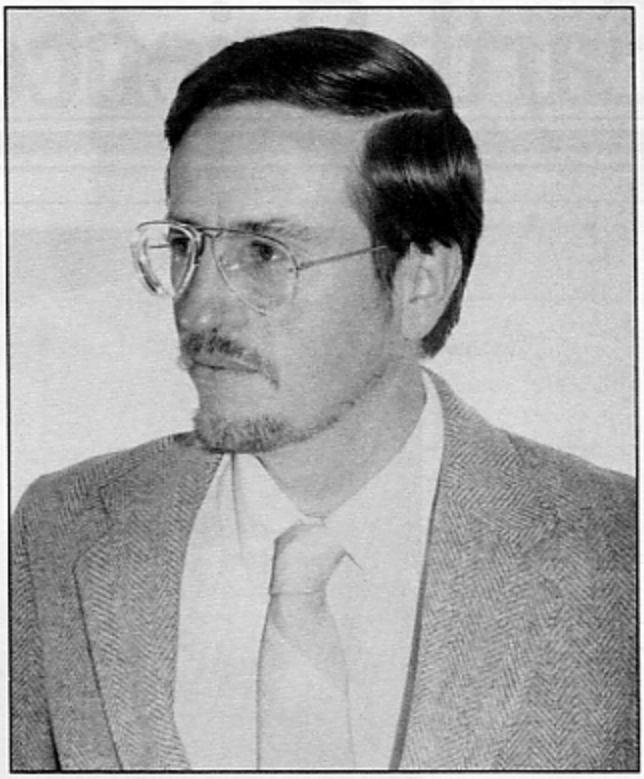
An Associate Professor of Hydrology in the Geoscience Department at New Mexico Tech in Socorro, Fred is the 1988 recipient of the F. W. Clarke Award, given by the Geochemical Society "to a young scientist for a single outstanding contribution to geochemistry or cosmochemistry." This honor is in recognition of his research on chlorine-36 and the application of this isotope to the geological dating of rocks and groundwater. Chlorine-36 is normally the product of the reaction of secondary cosmic rays with elements in minerals exposed at the earth's surface, but in some instances it can also be the byproduct of nuclear weapons testing. The technique which Fred has pioneered allows determination of the length of time that objects have been exposed on the earth's surface; it thus has a wide range of applications to important problems in archaeology, volcanology, paleoclimatology, glaciology, geomorphology and soil science.

Fred tested the chlorine-36 dating method by comparing the predicted buildup of the ratio of the radioisotope to stable chloride to the actual buildup ratios obtained from previously dated samples of volcanic rocks. His results demonstrated that the chlorine-36 buildup in rocks is a predictable function of time and could be used for geodating in the time interval between a few thousand and about 1.2 million years ago. This work thus constitutes a major advance in our ability to reconstruct the history of the Quaternary, the crucial time in which humans evolved and present climates and landscapes developed.

Fred's unusual career at UCSC is described in an accompanying article by him. A student at Cowell College (along with his wife, Lois) and one of our early undergraduates in Earth Sciences, he pursued his eclectic interests as a double major in Earth Sciences and History. After graduating in 1976, he went on to complete a Ph.D. in the prestigious Dept. of Hydrology at the Univ. of Arizona and then took up his present post in New Mexico. Born and raised in Bishop, he has thus returned to his roots within the past decade in the ruggedly beautiful and arid southwestern U.S., and it is particularly fitting that his pioneering research with chlorine-36 has the potential to increase substantially our understanding of this region, which he loves.

Reflections on a Santa Cruz Education

by Fred Phillips



"Bob Garrison has asked me to spill the beans about how I got through UCSC. I can't imagine that he wants me to actually give dollars and cents; after all, what with inflation and everything, I am sure that faculty members are a lot more expensive these days. But I can tell how I was fingered by fate and Casey Moore to be a geologist and how hunger constrained me to that choice.

When I arrived at UCSC as a freshman I signed up as a Computer Science major, not so much because I was really interested in computers as because I figured I could use what I learned about computers in whatever field I later decided to enter. At that time, of course, all computing was done by means of card readers. I very quickly became thoroughly bored with the interminable procedure of punching out programs, submitting the card decks to the Computer Center, waiting for the resulting printout telling me the program wouldn't run because of errors, correcting the errors, having the compiler find new ones, ad nauseum, and all to solve problems like alphabetizing lists of science long enough to get to the interesting problems.

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Richard G. Gordon

Rich Gordon is a 1989 recipient of the James B. Macelwane Award of the American Geophysical Union. This medal is awarded "for significant contributions to the geophysical sciences by a young scientist of outstanding ability", and his receipt of this honor is in recognition of his contributions to paleomagnetism and tectonic in three areas: (1) the interface between paleomagnetism and plate tectonics, (2) the tectonic and knematic evolution of the Pacific basin and its implications for circum-Pacific tectonics, and (3) intraplate deformation, principally through analysis of plate motion data. Much of Rich's research focuses on what paleomagnetism can tell us about plate motions in the distant past, an approach critical to understanding earth history because there are too few plates today to tell us which characteristics of current plate motion are intrinsic to plate tectonics.

An Associate Professor in the Dept. of Geological Sciences at Northwestern University in Evanston, Illinois, Rich, who grew up in San Jose and was a member of Stevenson College, entered the earth sciences program at UCSC in the early 1970's as a refugee (and rebel) from physics during his junior year, after he became attracted to geophysics by taking one of Rob Coe's courses and after extended discussions with Rob and Eli Silver. Though, when he graduated in 1975 he perhaps lacked the breadth of coursework in earth sciences of his cohorts, he applied to and was accepted into the highly rated graduate program in geophysics at Stanford on the basis of his substantial quantitative background, strong recommendations from Rob and Eli, and his obvious creativity and independence. Of his time at UCSC, Rich writes:

"I found in graduate school that my preparation at Santa Cruz was very solid, especially in geophysics. I have found that advice I received years ago from both Rob Coe and Eli Silver has served me well throughout my career. I think both saw that I liked the mathematical and theorectical side of geophysics and tried to steer me towards a better rounded approach. I recall that Rob emphasized that studying and sifting through the data was important, even if I was going to be a theorectician or modeler. Eli emphasized the importance of tackling problems that had not just mathematical or physical interest, but were of significance to the earth. These are lessons I now try to teach my students."

As a graduate student at Stanford, he developed an elegant method for determining the *minimum* velocity of a plate or continent consistent with paleomagnetic data. Using this method, he was able to demonstrate that major continents have moved more rapidly in the past than they do today (the slow motion of present-day plates is apparently an accident of present-day geometry).

Published in 1979, the work described above was one of the first of a series of key papers which have helped to change our views on how plate tectonics works. Among
important contributions in these papers have been his work on paleomagnetic Euler poles, his study of plate motion reference frames external to the plates themselves, and his collaborative research on the tectonic and kinematic evolution of the Pacific region. This partial list of his research contributions is illustrative of the breadth of his interests as well as of the originality he applies to the solution of problems.

Following completion of M.S. (1977) and Ph.D. (1979) degrees and a year as a postdoctoral fellow at Stanford, Rich went to Northwestern University in 1980 as an Assistant Professor and was promoted to Associate Professor in 1986. Among his other honors was selection as a Sloan Research Fellow in 1984 and election as a Fellow in both the American Geophysical Union and the Geological Society of America. Although he now resides in the tectonically stable midwest, it is appropriate that much of his research is aimed at understanding the tectonically unstable Pacific margin where he was raised and educated.

Letter from the Chair

Dear Alumni and Friends:

As of June of this year, I took over the role of chair from Jim Gill. Jim's performance as Chair was outstanding, and the entire Board benefited immensely from his energy and foresight. In the three years Jim was Chair, the Board experienced more growth - four new faculty positions - than it had in the previous decade. Moreover, plans for the new Earth and Marine Sciences Building were initiated and completed during his tenure. (Gary Griggs deserves special recognition for spearheading the building committee.) Jim's principal Board responsibility now is fund raising associated with the new building, thus you should expect to hear from him soon. So Jim, a hardy thanks from all of us!

Most likely our growth will continue. We will recruit a reflection seismologist during the 1989-90 academic year, and we expect to add two more positions in the next two or three years. Our growth reflects changes that are taking place on the entire campus. The present enrollment of UCSC is about 9,500, and for better or worse, is expected to reach 15,000 by 2005. Construction is nearing completion of the dorms and other facilities for College Eight, and College Nine, which will emphasize Pacific Rim studies, is in the planning stage.

One of our principal rewards as teachers is hearing from our ex-students. So, please take a minute and fill out the form on the back of this newsletter, or just jot us a note. We would love to hear from you!

- Ken Cameron

Following our Students

Paul Bogseth (B.S. '76) is President and Principal Engineering Geologist of Bogseth-Hetherington, Inc. in Mission Viejo, Calif.; his firm is engaged engineering geology, including soil and foundation studies, and hydrogeology. Applying the knowledge he gained from his doctoral dissertation on coral skeleton growth, **Brent Constantz** (M.S. '84, Ph.D. '86) is chairman and chief scientist of Norian, a newly formed medical device corporation based in Mountain View and engaged in biomineralization research aimed at developing novel biomaterials for use in orthopaedic surgery and dentistry, (e.g., synthetic apatite). Based in San Francisco, **Julia Diridoni** (B.S. '87) works for ICF Technology, Inc. carrying out initial investigations of potential hazardous waste sites in the western U.S. Serving as a Docent at the California Academy of Sciences in San Francisco (and also as mother to Sarah, age 3, and Katherine, age 1) is **Carol Farrar Orrich** (B.S. '83). **Vince Matthews** (Ph.D., '73) has recently accepted a position in Philadelphia as Vice President of Exploration and Production with the Penn Virginia Corporation; this firm, founded in 1882, explores for and produces coal, limestone, and oil & gas.

Carol (Hirozawa) Reiss (B.S. '77) works for the U.S. Geological Survey in Menlo Park, and **Scott Hamlin** (B.A. '75) is in Sacramento as a ground-water hydrologist with the USGS's Water Resources Divison, where one of his projects is a study of ground-water resources in the western part of San Francisco. Likewise living in Sacramento, **Scott Walker** (B.S. '79) is an Associate Engineering Geologist with the Central Valley Regional Water Quality Board working on problems of ground water contamination; Scott received an M.S. degree from the Univ. of Arizona in 1982 and, prior to his present post, was a consulting mining and engineering geologist. Also working in hydrogeology is **Barbara Walsh** (M.S. '79), who last year joined Bechtel Civil Engineering, Inc in San Francisco as a Supervising Hydrogeologist; for eight years prior to her job with Bechtel, Barbara worked for the Environmental Protection Agency on a variety of projects involving hydrogeology and evaluation of waste disposal sites. **Greg Eiche** (B.S. '82) lives in Healdsburg, Calif. where he is a Project Manager for Hydrogeology for Brunsing Associates; in 1985, Greg received an M.Sc. in geology from McGill University in Montreal.

Yet another success story in hydrogeology is **Martin Feeney** (B.S. '76), who did graduate work in Water Science at UC Davis and is now Senior Hydrogeologist and a founding member of Staal, Gardner & Dunne, Inc., a Ventura-based firm of consulting engineers and geologists who provide consulting services for government and private businesse in geotechnical engineering, ground water resources and environmental engineering. Among the firm's 50 employees are **Ron Gordon** (B.S. '79), who is a Senior Engineering Geologist and was the first employee hired; and **Edward Tschupp** (B.A. '75), who serves as Head of the Solid Waste Division and is in charge of the hydrogeology and regulatory compliance for 12 landfills within the Central California Coastal area (after graduating from UCSC, Edward received an M.S. in Geologic Engineering from the Colorado School of Mines). Martin writes: "We continue to grow and would appreciate you encouraging other talented graduates to consider our firm as part of their job search."

Clem Shearer (Ph.D. '78) recently left the USGS to assume the position of Dean for Budget and Planning at Carleton College in Northfield, Minnesota. After more than 12 years in petroleum exploration with Texaco and Conoco, **Nancy Benson Brewster** (B.S. '73) writes that she and her family have recently moved to Edmund, Oklahoma from Colorado and that she has temporarily forsaken geology for "dishes, halloween costumes, books, & mowing one acre"! Closer to home, **Genevieve Fire-Halvorsen** (B.S. '79) lives in Los Altos and works as a Construction Engineer with the City of Mountain View Public Works Department, overseeing city construction

projects and off-site private development construction; Genevieve made the transition into civil engineering (she is a Registered Associate Civil Engineer) by way of an MSCE degree from UC Davis and reports that her training in Earth Sciences at UCSC provided valuable background for her present engineering career. From Calgary, Alberta comes news that **Jack Wendt** (Ph.D. '74) recently switched positions from a post as a research carbonate sedimentologist with ESSO Canada to exploration work with Canadian Hunter Petroleum Co.

Several recent graduate students have accepted teaching posts. **Scott Patterson** (Ph.D. '86) will teach structural geology at the University of Southern California. **Mitchell Colgan** (Ph.D. '89) will travel to South Carolina where he will be an Assistant Professor of Geology at the College of Charleston; he will also be in charge of a research project investigating the effects of climate change on the southeastern U.S. **Cathy Rigsby** (Ph.D. '89) will develop a program in sedimentology-stratigraphy at California State University at Long Beach; Cathy recently participated as a shipboard sedimentologist on Leg 125 of the Ocean Drilling Program in the western Pacific. This past year, **Rob McCaffrey** (Ph.D. '81) joined the faculty at Rensselaer Polytechnic Institute in Troy, New York, where he continues his geophysical studies of convergent margins, including Papua New Guinea and Indonesia. **Chris Metzlar** (B.S. '79), after completing a Ph.D. at UCSD's Scrippps Institution of Oceanography, is teaching at MiraCosta College near San Diego and developing new courses in the Earth Sciences. **Allan Krill** (B.S. '76) reports that he has been appointed Professor of Geology at the Norwegian Institute of Technology/ The University of Trondheim, with main teaching responsibilies in structural geology; Allan, who received a Ph.D. from Yale after graduating from Santa Cruz, emigrated to Norway to work as a State Geologist with the Norwegian Geological Survey, and, although he remains an American citizen, he writes that he, his wife and 2-year old child "are fully commited to careers and life in Norway."

Second-hand reports indicate that **Conrad van Bruggen** (B.A. '81) works for Tandem Computers in Santa Clara, and **Barry Cernoch** (B.S. '84) is completing an M.S. in Geological Engineering at the Univ. of Nevada-Reno (and working for Summit Geotechnical in Reno). Working also in Reno, with Hydro-Search, are **Jennifer Thornburg** (B.S. '86) and **Jeanne Ruefer Ridder** (B.S. '84); Jeanne, who is a Staff Hydrogeologist, recently completed requirements for the M.S. degree in Hydrogeology at UN-Reno. **Gail Bakker** (B.S. '85) lives in Boulder Creek and is starting at Stanford in the M.S. program in Water Resources Engineering. In Vancouver, Washington, **Graham Mortyn** (B.S. '87) works for Sweet-Edwards/ EMCON Associates, conducting hydrogeological and geotechnical studies of groundwater and soils; he was recently promoted from the technical to the professional staff of his firm. Another UCSC grad in Vancouver, Washington is **Bill Connelly** (Ph.D. '76), who is Exploration Manager for Nerco Oil & Gas Co. Soon to be traveling to Nepal and other parts of SE Asia, **Lisa Dierauf** (B.A. '87), works with The Trust for Public Land in San Francisco. Continuing her stint as a Research Associate at Lamont-Doherty Geological Observatory of Columbia University, **Nancy Breen** (Ph.D. '87) is investigating significant departures from 2-dimensionality at convergent margins, employing various marine geophysical mapping techniques along with geodetic measurements of earth strain. **Brian Globerman** (Ph.D. '85) is a Postdoctoral Teaching Fellow at Temple University in Philadelphia and has recently published a series of papers on paleomagnetism, tectonics, and the use of computers in the geosciences. **Jim Tait** (B.S. '86, M.S. '88) is enrolled in a Ph.D. program in the College of Oceanography at Oregon State University and will do research on sedimentary mechanics. Though based in Los Angeles, **Douglas Goodwin** (B.S. '78) is conducting regional exploration and assessment studies for gold in Western Australia for the Australian Mine Management. At the University of Colorado, **Jeff Deen** (B.S. '86) is finishing his Ph.D. research involving a stable isotope study in the Julcani Mining District of Peru; in recent years he been employed in research with the USGS and the Odon Construction Co.

The Houston area continues to house a strong contingent of UCSC graduates. **Mark Levorsen** (B.S. '79) works as a hydrogeologist/ground water geologist with ERM-Southwest, Inc. in Houston; after graduating with an M.S. from the Colorado School of Mines, he married Laura BeVier in May 1988. Working out of Houston, **Lee Lyons** (B.A. '84) is engaged in petroleum exploration and production work in the mid-continent region for Global Natural Resources. At NASA's Johnson Space Center, **Kathy Sullivan** (B.A. '73) continues duties as an astronaut-mission specialist and has recently been involved in planning for the deployment of the Hubble space telescope during an upcoming mission of the space shuttle. **Nancy (Brewster) Budden** (B.S. '74) is Manager of the Office of Science Integration for Lunar and Mars Exploration; her duties include long-term planning for possible manned missions to these two planetary bodies. Earlier this year, after several years working with the National Science Foundation in Washington D.C., Nancy married Terry Budden and joined him in Houston where he is a geologist with Unocal. A similar concentration of ex-Santa Cruzers works with Exxon in Houston. **Kevin Biddle** (B.S. '73) is Exploration Advisor for Exxon activities in Latin America and the Far East; **Parke Snavely** (Ph.D. '84),

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New Earth and Marine Sciences Building Moves Forward

In the spring of 1986 the Earth Sciences and Marine Sciences faculty began the process of planning for a new building. After being occupants of three different buildings since the program in Earth Sciences at Santa Cruz began in 1967, it has been a time-consuming but rewarding effort to plan a building for our research and teaching needs from the ground up. **Gary Griggs** has been chair of the planning committee and **Rob Coe, Ken Collerson, Bob Garrison,** and **Karen McNally** served as committee members. Due to the efforts of the faculty and staff of the University, as well as the architects and laboratory planners working on the building, the planning and design efforts have remained on schedule. The project has been through project planning, design development, and schematic drawing phases, and final construction drawings are now being prepared. This new building will contain 83,000 square feet of assignable square feet (making it the largest science building on the UCSC campus), of which 36,440 sq ft will be assigned to Earth Sciences and 3,500 sq ft will be assigned to the Tectonics Organized Research Unit. Also to be housed in this building will be facilities for the Marine Sciences program, the Institute of Marine Sciences, and some elements of biology. The building (see photo on page 1) will consist of two poured-in-place concrete laboratory blocks, a steel and glass office block, and a connecting link housing a large lecture hall and two classrooms. All of these elements will surround a landscaped central courtyard, and the building will be located on the slope to the southeast of the present Natural Sciences II building. Groundbreaking is scheduled to take place in early 1990 and completion in the fall of 1991.

Honors and Awards

For the first time in the history of the Board, two under graduates have graduated with Highest Honors in Earth Sciences, an honor which recognizes great distinction in all of their coursework at UCSC. Congratulations are due to **Thomas Montoux** and **Thomas (Ken) Fowler,** who were also designated as Undergraduates of the Year for 1989 by a vote of the Earth Sciences faculty. Thesis honors for 1989 were awarded to **Laura Horgan** and **Greg Grimsich** who submitted outstanding senior theses.

Among current graduate students, **Elisabeth Widom** has received an award to support her thesis research from the Achievement Rewards for College Scientists Foundation, Inc., (ARCS) a San Francisco-base group whose aim is to promote science education in the U.S. Elisabeth's Ph.D. thesis, conducted under Jim Gill's supervision,

Elisabeth Widom

Eileen Hemphill-Haley

Elise Knittle

focuses on the chronology and geochemistry of recent eruptive rocks in the Azores and Canary Islands, utilizing U-Th disequilibria measurements.

This year's winner of the Waters Award, recognition of an outstanding Ph.D. thesis proposal, is **Eileen Hemphill-Haley,** whose dissertation research involves the usage of benthic marsh foraminifera and diatoms to estimate the magnitude of relative sea-level changes along the coast of Washington, as related to coseismic subsidence created by subduction zone earthquakes during the Holocene. This work will be carried out under Leo Laporte's supervision. Eileen received a B.S. in geology from Humboldt State Univ. in 1982 and worked for several years with the USGS before enrolling in the Ph.D. program at UCSC in 1987.

Also during this past year, faculty member **Elise Knittle** is the recipient of a prestigious Alfred P. Sloan Foundation Research Fellowship, an award given to outstanding and promising young scientists in the U.S. and Canada. One of twelve women to receive Sloan Fellowships this year, Elise plans to use her $25, 000 fellowship partly to purchase new laboratory equipment but mostly to provide support for graduate students who will assist her experimental work aimed at deciphering the composition of the earth's deep interior.

In Memoriam

With great sadness we report the death of **Dr. Jaime Gonzalez-Ruiz** (Ph.D. '86) on July 21, 1989 in Ensenada, Mexico. Jaime first became seriously ill in December 1988 and, after a period of apparent improvement, died suddenly of cancer.

Born in Iguala, Guerrero, Mexico on May 23, 1956, Jaime received his bachelor's degree from National University of Mexico in 1979. He received an MS degree in geophysics from the California Institute of Technology in 1981 and came to UCSC for Ph.D. work under Karen McNally when she moved here from Caltech. Jaime's Ph.D. thesis research was on Earthquake Source Mechanics and Tectonophysics of the Middle American Subduction Zone in Mexico. After receiving his Ph.D. degree in 1986, Jaime accepted a position as Professor at the Centro de Investigacion Cientifica y Educacion Superior de Ensenada (CICESE) and continued his studies of earthquake seismology. In the past few years he made frequent trips back to Santa Cruz to continue research activities at the Richter Seismological Laboratory.

Many of us remember Jaime as a gentle and friendly scholar who was always deeply concerned, not only about science, but also about the welfare of his fellow human beings. His premature death at such a young age is a tragedy, and we will miss him badly.

A scholarship fund in Jaime's name has been established to help promising young Mexican students at CICESE (some of these students may subsequently come to UCSC for further graduate study). This is particularly appropriate since Jaime himself was able to study in the U.S. because of his prior scholarship at UNAM, despite his family's modest income, and since Jaime was very devoted to teaching young Mexicans for the future. If you are able to contribute to this scholarship fund, please send your donation to Karen McNally (checks made out to her) at the Earth Sciences Board. Note that even small contributions in U.S. dollars can be very helpful in Mexico.

New Seismologist makes Waves

The latest addition to the Earth Sciences Board faculty is **Thorne Lay**, a 33 year old seismologist who is coming to UCSC from the University of Michigan where he has taught since 1983. Thorne has been both a Sloan Fellow and Presidential Young Investigator, and has published over 60 papers in the last nine years. He will succeed Karen McNally as Director of the Tectonics Institute.

Thorne has taught seismology at all levels from general education to graduate lecture courses, and enjoys teaching. He is an observational seismologist with broad interests including the structure of the core and core-mantle boundary, the nature of the lower-upper mantle boundary, and upper mantle heterogeneity especially at subduction zones. His early work helped formulate the asperity model of earthquake source physics. He and a postdoctoral researcher who will accompany him to UCSC, Dr. J. Zhang, are continuing work in this latter area by extracting details of the earthquake rupture process from the full frequency band of seismograms. Thorne also has worked in the area of explosion seismology which is relevant both to high resolution seismic imaging of crustal and upper mantle heterogeneities that can be related to geological events, and to the monitoring of nuclear tests. Readers of EOS may recognize his name because he has been editor of its Seismology section. He also serves on national seismology-related committees such as for IRIS and the technical advisory structure for monitoring nuclear test ban treaties.

Born in Texas, Thorne studied both geology and engineering at the University of Rochester before taking his Ph.D. from Cal Tech. At UCSC he expects to interact with the mineral physicists and geochemists interested in deep earth phenomena and with the tectonicists interested in the geodynamic history of collisions and subduction zones, as well as with the seismologists of the Richter Lab. The Board is being rejuvenated by new young people, and is glad that Thorne is one of them.

Lee Face on the arm of a star dune in the Northern Panamint Valley (photograph by Bob Anderson)

What a Difference . . .

The all-male Earth Sciences Faculty in the Spring of 1977. Front row from right to left, Léo Laporte, Casey Moore, Bob Garrison, Aaron Waters (now retired and living in Tacoma, Washington), Othmar Tobisch. Back row from right to left, Jim Gill, Gary Griggs, Ken Cameron, Eli Silver, Rob Coe and Al Smith (now a research geophysicist at Lawrence Livermore National Lab and an Adjunct Professor of Earth Sciences at UCSC).

- A Decade Makes!

No longer an all boys club, here is the Earth Sciences faculty and research staff, posed along Westcliff Drive in March 1989. Front row, right to left, Léo Laporte, Bob Garrison, Peggy Delaney (she is a member of both the Earth Sciences and Marine Sciences faculties), Gary Griggs, Othmar Tobisch, Elise Knittle. Second row, right to left, Karen McNally, Ken Collerson, Shirley Dreiss, Rob Coe, Casey Moore, Ken Cameron, Heidi Houston (Research Associate in geophysics), Eli Silver. Back row, right to left, Stanley Flatté (Physics and Earth Sciences Boards), Jim Gill, Quentin Williams (Research Associate in mineral physics), Bob Anderson, Don Reed (Research Associate in marine geophysics), and John Vidale (Research Associate in geophysics).

Sand

This story describing some of Assistant Professor Bob Anderson's research and written by Carolyn Strange, originally appeared in Science Notes. *The drawings are by Ellen Bennet and Judy Ward. We are grateful to Carolyn, Ellen and Judy, and to the Science Communications Program for permission to reproduce this.*

No one in the area had ever seen a windstorm like the one that swept California's southern San Joaquin Valley on December 20, 1977. A major high-pressure ridge developed over Idaho, and a low-pressure trough deepened over the Pacific Ocean. In 24 hours the ensuing wind removed as much as 50 million metric tons of soil from 2000 square kilometers of agricultural and range land—equivalent to removing six centimeters of soil from the entire state of Rhode Island. Dust drifted into San Francisco and as far away as Red Bluff. Egg-sized rocks became airborne, and in places the wind scoured away up to 60 centimeters of soil. High voltage towers designed to withstand 250 kilometer per hour winds toppled. Houses were sandblasted from top to bottom, their windows heavily frosted or broken. Trees were stripped of leaves and bark, and telephone poles were abraded to their full height.

Cedar fenceposts not worn entirely away by wind-driven sand were sculpted into weird shapes. These shapes preserved profiles loaded with clues to how sand moves during an intense windstorm.

For Robert Anderson, the fencepost profiles were a puzzle, and his graduate advisor at the University of Washington challenged him to mathematically explain the shapes of these and other sand-eroded profiles. Anderson accepted.

A testament to the countless hours of Anderson's life the project occupied, a wind-sculpted San Joaquin Valley cedar fencepost still stands in his office at UCSC, as he continues his investigation into the bizarre and beautiful—and now to some extent predictable—effects of wind and sand.

Wind-blown sand can sculpt anything in its path, from fenceposts to boulders. Wind can also fashion sand into imposing dunes or seas of uniform ripples, some of the most regular patterns in nature. In fact, on any smooth, dry bed of sand, ripples will begin to form minutes after a wind springs up.

"Somehow, nature has arranged things so that a simple system of sand and air magically organizes itself into intriguing formations like ripples and dunes," says Anderson, now assistant professor of earth sciences at UCSC.

Anderson, a geomorphologist, studies the landscape, its shapes and the processes that give rise to them. In particular, he is trying to understand the nitty gritty

Bob Anderson

processes by which wind moves sand, hoping to unravel the secrets behind the "nifty patterns" it leaves.

Understanding how wind moves sand and soil contributes to the study of geology, ecology, weather and even space exploration. For example, sediments eroded from the Gobi Desert in China and blown half way across the Pacific Ocean are a major component of Hawaiian topsoils. The historic Dust Bowl of the 1930s, in Oklahoma and Kansas, is a similar instance of devastating wind-driven soil erosion. In Antarctica, the same principles apply to wind-blown snow. And on Mars, whose face is occasionally clouded by tremendous dust storms visible even from Earth, understanding how wind blows sand may be critical. Instruments and optics of any probe landing on Mars will be subject to abrasion by particles carried by the Martian winds.

On Earth, wind-tunnel and field studies over several decades have shown that sand grains travel in wind mainly by hopping, or "saltation." Most grains carried by the wind take many short-distance hops. At the end of a hop, each grain hits the sand bed, from which it may rebound, splash out other grains, or both. Any grains splashed out are themselves carried along by the wind.

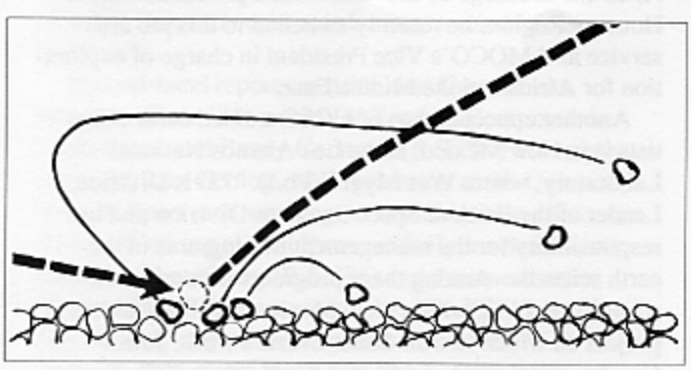
Some grains rebound from the bed at higher than average speeds. These grains are airborne longer and gain momentum as they fly along in the wind. When such long-trajectory grains hit the bed, they hit with greater force, splashing out even more grains.

Some of these grains rebound from the bed at higher than average speeds, and the process escalates—but only up to a point. The wind can carry just so many grains before the load of sand it's carrying actually slows it down. As more and more grains become airborne, the wind loses momentum to them. Eventually this feedback process causes the number of airborne grains and the wind speed to stabilize, reaching a "steady state." Because this process is largely controlled by the impacts of grains at the bed, geologists wanted a better understanding of what happens when a single grain hits a bed of sand. "You have to go back to the grains," Anderson says. "A dune is just a bunch of air and a bunch of grains."

But understanding the impact process is difficult because a staggering number of grains are involved, and they can be arranged in an almost infinite number of ways. The micro-landscape that an impacting grain "sees" is enormously variable. "It's so blasted complicated. It's like the billiard ball problem to the nth degree," Anderson says.

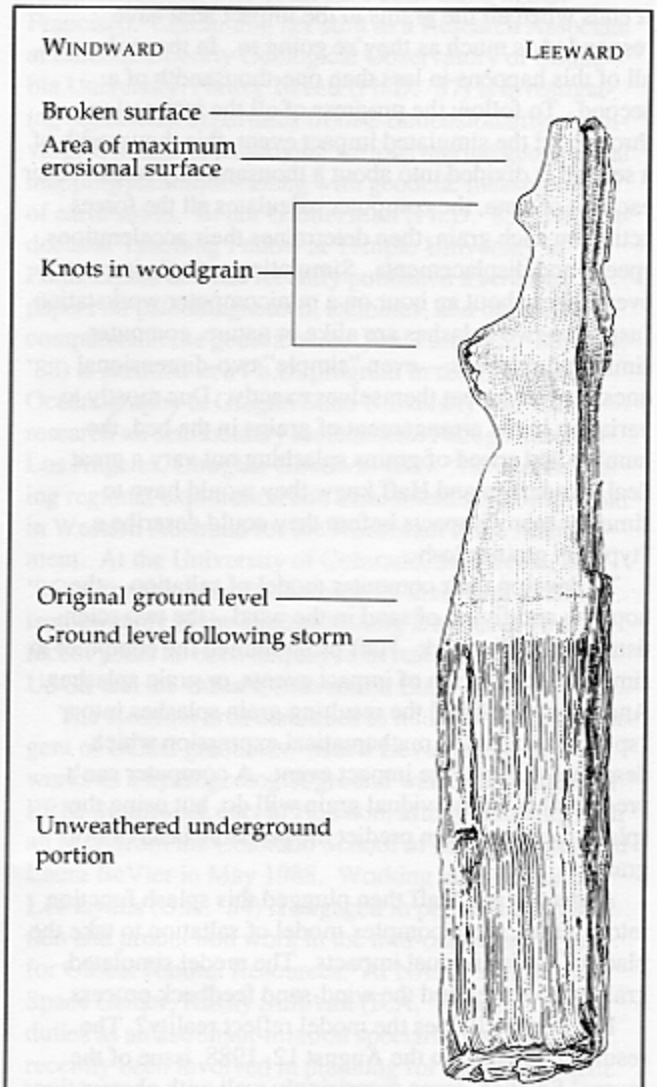
In fact, the problem is impossible to consider without the aid of computers. So Anderson and his collaborator, Peter Haff, now at Duke University, developed a computer model that simulates interactions of sand and wind. One part of the computer model simulates a tiny slice of a sand bed. On that bed, one grain impacts others, which push on others, and so on. The computer calculates the interactions and keeps track of each grain in the population. "Because of computing limitations, we can't do the problem in three dimensions yet. We're doing it in two dimensions with a few hundred grains," Anderson says.

(continued on page 12)



JUDY WARD

A sand grain (dotted line) hits a bed of sand, rebounds and simultaneously knocks other grains from the bed. Some are caught and carried along by the wind.



ELLIN BENNETT

***Cedar fencepost** sculpted by sand and dirt. The leeward side (right) and the buried lower half were protected from wind-blown grit. The windward side (upper left) was cut more or less, depending on such factors as the hardness of the wood and the force with which the particles hit.*

Sand *(continued from page 11)*

The computer simulation takes friction into account and treats the grains as hard masses of the same size, as if they had stiff springs attached wherever they contact another grain.

An "impact event" begins when one of these computer-generated grains hits the computer-generated bed. It ends when all the grains in the impact area have responded as much as they're going to. In the real world, all of this happens in less than one-thousandth of a second. To follow the progress of all the interactions throughout the simulated impact event, this thousandth of a second is divided into about a thousand tiny steps. After each bit of time, the computer calculates all the forces acting on each grain, then determines their accelerations, speeds and displacements. Simulating a single impact event takes about an hour on a minicomputer workstation. Just as no two splashes are alike in nature, computer-simulated splashes —even "simple" two-dimensional ones—never repeat themselves exactly. Due mostly to variation in the arrangement of grains in the bed, the number and speed of grains splashing out vary a great deal. Anderson and Haff knew they would have to simulate many impacts before they could describe a "typical" grain splash.

To develop their computer model of saltation—the hopping and flying of sand in the wind—the two scientists divided the work. Haff programmed the computer to simulate a collection of impact events, or grain splashes. Anderson simplified the resulting grain splashes into a "splash function," a mathematical expression which describes the average impact event. A computer can't predict what an individual grain will do, but using the splash function it can predict the probable behavior of grains.

Anderson and Haff then plugged this splash function into a larger, more complex model of saltation to take the place of the individual impacts. The model simulated grain trajectories and the wind-sand feedback process.

But how well does the model reflect reality? The results, published in the August 12, 1988, issue of the journal Science, agree surprisingly well with observations of wind-blown sand in nature, says Anderson. For instance, the scientists determined how much sand would move how far in a certain amount of time (given a particular wind speed and grain size). The values predicted by the model were well within the range of values measured in wind-tunnel studies.

But the aim of a scientific model is not just to mimic nature. Good models suggest theories that in turn lead to predictions that can be tested. "This is just the first step to understanding the whole saltation game," Anderson says.

The model has already proved its usefulness in at least one way. It predicts, for the cases studied, that the number of airborne grains and the wind speed stabilize—or achieve a steady state—in one to two seconds. Measuring this response time in wind-tunnel experiments would have been extremely difficult.

With this new information, researchers can now consider a variety of more complex situations in future models. They can model gusty winds by varying wind speed, or snow by varying the elasticity and density of the grains. To model saltation on Mars, they can vary the characteristics of the atmosphere. The model can also be extended to sand with more than one grain size. Anderson hopes that ultimately the model will be so streamlined that it can make predictions based only on fundamental physical properties of the grains and the atmosphere.

Eventually, knowledge gained from such computer-simulated sandstorms may help answer a multitude of questions about how wind moves particles and carves objects, from fenceposts to entire landscapes. On the esthetic side, it will help unravel the natural processes that build giant dunes and paint patterns of ripples.

—Carolyn Strange

Following our Students *(continued from page 5)*

after conducting regional studies in the Middle East and western North America, is now involved in exploration in the eastern U.S.; **Ken Ehman** (B.S. '80), who earlier completed a Ph.D. at UC Davis, does research in basin analysis; and **Peter Vrolijk** (Ph.D. '87), after stints as a postdoctoral research fellow at the Univ. of Cambridge in England and at the Univ. of Michigan, has joined Exxon's research work on basin analysis and sediment diagenesis. **Rob Leslie** (B.S. '78, M.S. '80), who received a Ph.D. in marine geophysics at Colombia's Lamont-Doherty Geological Observatory in 1986, is currently the Project Leader for Production Geophysics research at the Shell Development Co. in Houston. Also based in Houston is **Dave Work** (M.S. '70) who is a Vice President of AMOCO in charge of exploration and production in the Houston Region; he recently switched to this job after service as AMOCO's Vice President in charge of exploration for Africa and the Middle East.

Another concentration of UCSC-trained earth scientists is in New Mexico, at the Los Alamos National Laboratory, where **Wes Myers** (Ph.D. '73) is Division Leader of the Earth & Space Sciences Division and has responsibility for the management of programs in the earth sciences. Among these programs is continental scientific drilling within New Mexico's Valles Caldera, a project on which two ex-Santa Cruzers work, **Jamie Gardner** (B.S. '76) and **Fraser Goff** (Ph.D. '77); Fraser also works in geothermal exploration in Central America. Involved in Los Alamos-sponsored geological studies in Nevada are **Dave Vaniman** (Ph.D. '76) and **Schon (Sue) Levy** (B.S. '70), and **Bob Raymond** (Ph.D. '75), after

completing research on the sedimentology and petrology of coal, is now engaged in a study of the formation and age-dating of desert varnish (such dating will be useful in dating erosion surfaces and in neotectonic studies). Working also on the desert varnish project is **Steven Reneau** (B.A. '80), who completed a Ph.D. in geomorphology at UC Berkeley and is now a postdoctoral fellow at the Los Alamos lab. **Don Krier** (B.X. '76) is a containment scientist at Los Alamos; his research is the desert varnish project and sedimentation in Creede Caldera.

A third nest of UCSC-trained earth scientists is at Syracuse University in Syracuse, New York. On the faculty there as Assistant Professors are **Cathy Newton** (Ph.D. '83) and **Peter Plumley** (Ph.D. '84). Current graduate students at Syracuse include **Jane Reid** (B.S. '84), **Ed Romanowiez** (B.S. '85), **Steve Roof** (B.S. 84), **Lauret Savoy** (M.S. '83), and **Peggy Vance** (B.A. '80).

Illustrating the diversity and interest of the work our graduates do, **Rosemary Sliney** (B.S. '81) is Asbestos Program Manager at Thermo Analytical, Inc. in Richmond, California, where, employing her mineralogical-petrographical training from UCSC, she supervises the optical and transmitted electron microscope laboratories; this past year, she completed the circle by returning to Santa Cruz to give a seminar for the Optical Mineralogy class on asbestos minerals and their identification by polarized light microscopy. **Will Osborn** (B.S. '85) is Geochemical Supervisor in the East Mesa Geothermal Field; Will lives in Holtville, Calif. and is completing an M.S. degree in UC Riverside's Geothermal Resources Program. **Mike Angell** (B.A. '85), after receiving an M.Sc. degree from Imperial College in London, has been working with the Ocean Drilling Program at Lamont-Doherty Geological Observatory in New York and will shortly return to graduate school for Ph.D. work. Currently using their geological training in educational/recreational roles are **Jim Toney** (B.S. '85), who is a river guide in California during the summers and works on the ski patrol in Colorado during the winters, and **Lauren Beggs** (B.A. '86) who is a bicycle tour guide in Telluride, Colorado.

In the Middle East, **Abdul Khodair** (Ph.D. '78) continues his teaching duties in geophysics at the Petroleum University in Dhahran, Saudi Arabia. **Jane Ellis-McNaboe** (B.S. '79) is also in Dhahran, where her husband is a geologist with Aramco. **Charles Lawson** (B.S. '73), who earlier received a Ph.D. from Princeton, is Science Attache at the American Embassy in Tel Aviv, Israel for the next three years; prior to this posting, he served for16 months in the Science Bureau of the State Department. **Daniel Wachs** (Ph.D. '73) has been on leave for the past year from the Geological Survey of Israel in order to teach engineering geology at North Carolina State University in Raleigh; when he returns to Jerusalem, he will begin a project in the area of the famous Masada fortress aimed at determining faulting along the Dead Sea rift during the past 2000 years. Also overseas are **Rick Le Veque** (B.S. '77), employed by Unocal in Bangkok, Thailand and engaged in petroleum exploration in southeast Asia, and **Bob Tallyn** (B.S. '70), who is based near London as Unocal's Exploration Manager for Europe, North Africa, and the Middle East.

Jim Hein (Ph.D. '73) continues research in marine geology with the U.S. Geological Survey in Menlo Park. His wide-ranging studies include service as Chief of the Seamount Evolution and Resources Program and also of the North Pacific Geochemistry Program, as well as U.S. National Chairman of an UNESCO-sponsored study of manganese deposits. Jim has edited two well-received books on siliceous sediments, and spearheads the USGS sedimentological programs in the South Pacific, which have supported a number of UCSC students. **Keith Long** (B.S. '79) is at the Arizona Field Office of the USGS in Tucson where he works with the Interamerican Mineral Resources Institute; this summer he will receive a Ph.D. in Mineral Economics from the Dept. of Mineral Engineering at the Univ. of Arizona. After receiving an M.S. in geology at the University of Connecticut in 1983, **Carole Sakamoto** (B.A. '79) worked as a marine research specialist at the University of Rhode Island and then at the University of California, Santa Barbara. Since late 1988, Carole continues her work in marine sciences as a Senior Research Technician at the newly established Monterey Bay Aquarium Research Institute in Pacific Grove. **Debbie Bliefnick** (Ph.D. '80) recently joined ARCO Oil & Gas in Plano, Texas where she does carbonate reservoir studies, working in research teams with petroleum engineers.

Among former geophysics students at UCSC, **Sergio Barrientos** (Ph.D. '87) is Assistant Professor at the Departamento de Geología y Geofisiíca, Universidad de Chile in Santiago, where he teaches and continues research on crustal deformation and earthquake sources in Chile. Having completed a Ph.D. in geophysics at M.I.T., **Greg Beroza** (B.S. '82) continues research on the generation of near-field strong ground motion as a postdoctoral research fellow there. **Klaus Bataille** (Ph.D. '87), a postdoctoral fellow at Memphis State University, has been working on the seismicity and tectonics of the Andes, and recently spent several months maintaining a seismographic network in Argentina. Other news from Latin America is that **Federico Guendel** (Ph.D. '86) has been appointed as Vice-Rector de Investigacion (= Vice Rector in charge of research) at the Universidad Nacional in Heredia, Costa Rica; prior to this appointment, Federico served as Director of the Seismological Institute of the university.

Reflections on a Santa Cruz Education *(continued from page 2)*

In my search for greener pastures I came across "Geologic Principles" in the catalog. Having had the good fortune to grow up almost in the middle of UCSC's field camp locality (I was born and raised in Bishop, CA) and having taken an informal geology course while in high school, I knew that geology had to be more interesting than card punch machines. It was thus that I fell into the capable clutches of Casey Moore and Steve Rowland (as lab TA). The lectures all made beautiful sense (unlike a lot of the other classes I was taking) and it was the only class (besides Art History) where looking at slides was an important requirement. The labs were really enjoyable (again, in contrast to a lot of other classes) and Steve really succeeded in communicating his enthusiasm for geology. We didn't just go through the motions of lab outlines; he really discussed and explored with us the concepts the labs were meant to teach.

As a result, I did very well on most of the tests and labs. In particular, I remember one lab that had the objective of teaching how to read topographic maps. We were divided into teams and each given a topo map of the campus without any buildings or roads indicated. Numbered stations were marked on the map. Each station had a token and some clue to the location of the next station. The stations were numbered so that we had to criss-cross the campus to locate them all in order. The first team to return with all the tokens won a prize, which as I recall, involved some sub-rosa beer. Well, I had been using topo maps on an almost weekly basis for backpacking and mountain climbing since I was about twelve years old, so after perusing the map for a few minutes, I figured out where all of the stations were in relation to the buildings on campus. I then led the team to them over the shortest possible distance (not in numerical order) and we cashed in our tokens, propped up our heels, and sipped beer for about an hour before the next team arrived. I remember thinking smugly that I had finally found a field in which I was really qualified. When the quarter ended and I read my evaluation I found out that I had received the highest grade in the entire class. I sat down in the empty Natural Sciences lecture hall with the realization that the finger of fate (God?) was pointing at me. I no longer had to search for a vocation; if anything, I had to try to justify why I should not be a geologist. Nevertheless, I did try. I couldn't decide whether I wanted to be a technocrat or an Educated Person. So I tried to be both. I completed a double major in earth science and ancient history (minor: history of the American West). I learned Attic Greek (and optical mineralogy). I studied Late Antique historiography (and marine geology). I wrote a senior thesis on salt water intrusion in coastal aquifers (and one on the exploration of the Great Basin, which was later published as a short book). It wasn't just a double major, it was sort of a double life.

Of course, all that work only deferred the ultimate decision. I loved both fields and I did well in both of them. Now I had to make up my mind to what kind of graduate school I wanted to apply. I thought hard about it and finally, from the basest of motives, opted for the earth sciences. I simply could not get over my fondness for regular meals, and a person with that materialistic a mind set is not qualified to be an ancient historian. Unfortunately, I have never recovered from my pretensions to Education, and sometimes I still go home and read books on history, theology, or literature in a state of lonely intellectual splendor.

Next, I had to decide to what earth science specialty I would tailor my grad school applications. I wanted to work in some practical area that would benefit mankind. But I regarded the oil and mining companies as evil incarnate, so I chose groundwater hydrology. In large part on the advice of Bob Garrison, I accepted admission to the Master's program at the Hydrology and Water Resources Department at the University of Arizona. The advice proved sage.

Santa Cruz did a good job of preparing me for my career. Today there is a great danger of fearing that we have to prepare undergraduates with the tools they will need for every possible specialization within the core of classical geology. In contrast, my UCSC education emphasized the fundamentals. My philosophy is that undergraduate earth science curricula should have two thrusts: (1) math, physics, and chemistry, and (2) historical and field geology. All of the specialized tools (e.g., optical mineralogy, petrography, X-ray, laboratory geochemistry, seismographs, electron microscopy, etc.) should be kept to a minimum so that the students can obtain the fundamental physical science education necessary to truly understand whatever specialization they choose to enter. In one sense, earth science is just application of physics and chemistry (and thus mathematics, too) and a firm foundation in these is necessary to do it quantitatively. On the other hand, geology has something almost unique, that physicists and chemists do not understand at all, and that is history, the "arrow of time". In application, this can only be taught in the field. There can be no replacement for the actual experience of converting physical relations between rocks into time and history.

At Santa Cruz, I really did get this basis for my life's work, with one exception, and that was mostly my own fault. After making straight A's in math in high school, I flunked out of calculus my freshman year. In retrospect, I realize that it happened not because the material was too difficult, but because it was presented at about ten times the rate I was used to from high school, and I couldn't adjust fast enough, and because it was presented in a most abstract fashion by a pure mathematician. My confidence

Reflections . . .

in my mathematical abilities was shaken to the extent that I avoided quantitative courses as much as I could. In some ways that experience held up my intellectual development by about five years. I am quite sure that I am not the only geology major to suffer in this way, and I think that geology departments should consider alternative approaches. I find that I am much stronger in physical reasoning than analytical reasoning, and I think that most geologists share this trait. Special math courses taught at a slower pace (but not slighting the content) and with more physical examples would ultimately do much to enhance the rigor of geological research. Geologists used to like to claim that geological processes were so complex that it was useless to try to quantify them, but digital computers have now robbed us of this excuse, and I ultimately had to come to terms with that fact. Unfortunately, mathematicians are probably the very worst choice for imparting math to geologists.

Also unfortunately, my hopes of benefiting society through applied research have foundered on an addiction to esoteric problems. I have finally accepted that if research problems are rated in terms of their practical application (versus basic importance), my interest declines in direct proportion to the rating. Thus my research topics today include the isotopic systematics of 36C1 in the earth, Quaternary geochronology, the nature and origin of hydrologic fluctuations during the Quaternary, and the spatial statistics of permeability distributions and how they relate to geological processes (you can see that I am still leading the double or triple life that I started at UCSC). But I am studying what I find interesting to study, and I am having fun doing it, a hell of a lot of fun. Science is a great adventure. In fact, if I could spend my time doing anything I could imagine, I can't think of anything that would be more fascinating. My education at Santa Cruz was one of the basic things that made this possible, and for that I am grateful."

Sand dunes in the Panamint Valley; these dunes act to dam debris flows from the adjacent mountain front, giving rise to characteristic debris flow benches (photograph by Bob Anderson).

EARTH SCIENCES AT SANTA CRUZ is published by the Board of Studies in Earth Sciences of the University of California, Santa Cruz, for its alumni and friends.

Editors: Susie Barber and Bob Garrison

Prepared using Aldus PageMaker

For help in assembling this newsletter, we are grateful to Laurie Babka, Ellen Bennett, Judy Ward, Jeannie Dusheck Wilkes, Carolyn Strange, and George Zemora.

Please take a moment to let us know where you are and what you are doing. Also, please enclose a check, no matter how small, payble to "UCSC Foundation," annotated "For Earth Sciences Board."

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Can you tell us anything regarding the whereabouts and activities of other UCSC alumni in the earth sciences?

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