

UC Santa Barbara Earth Science



Chair's Letter: Andy Wyss

Alumni & Friends,

We've enjoyed another eventful year in Earth Science. Although we can't convey everything that was accomplished, our hope is to provide a flavor of our traditional events, along with a few absolute highlights. In the latter category, I am thrilled to announce the arrival of three new faculty members, Francis Macdonald, Morgan Reed Raven, and

Matt Rioux (pp. 5, 6). Professor Dave Valentine now holds our first endowed Chair, the Robert M. Norris Presidential Chair in Earth Science (p. 3). Beyond commemorating Professor Norris, this Chair broadcasts and honors the research and myriad other contributions of one of UCSB's most esteemed scholars. Wishing you health and fulfillment in 2019.

Annual Trip to Santa Cruz Island

by Mary Ringwood

The annual trip to Santa Cruz Island was led by Dr. Jim Boles, who fearlessly took our eclectic group of 22 graduate students, professors, family members, and children on a 3-day tour of the island and its superb geology.

We started the trip at Prisoner's Harbor on Friday morning and were picked up and transported across the island to Christy Ranch on a bumpy, but exciting ride courtesy of the UC Field Station trucks. Once at Christy Ranch, we went on a short hike down the beach to examine the local rocks and take a look at a wonderfully conspicuous fault contact.

The second day saw our group hike up a dry wash through the Rincon and Vaqueros formations and into the San Onofre Breccia. Everyone then headed south to the beach where we examined the steeply dipping strata characteristic of the southwest corner of the island.

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Faculty Awards



ALEX SIMMS

Alex Simms was awarded a Fulbright Fellowship to help support his sabbatical visit to the UK. There, Dr. Simms spent 11 months at Durham University working with colleagues on the Late Pleistocene/Holocene glacial and sea-level history of Antarctica, as well as conducting fieldwork locally on the deglacial sea-level history of western Scotland. Read about Alex's trip to Antarctica on page 10.

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Photo: Santa Cruz Island by Scott Condon

Summer Field 2018: Santa Cruz Island

by John Cottle

For the first three weeks of UCSB's summer field course, 18 students traveled by Exxon crew boat to Santa Cruz Island with Prof. John Cottle. The group focused on further developing digital geologic mapping skills. They used a combination of iPhones, iPads and GIS to produce digital geologic maps and cross sections of Laguna Canyon, Saucos-Posa canyons, and the Santa Cruz Island volcanics. The western portion of Santa Cruz Island continues posing excellent challenges for undergraduates, exposing them to a wide range of rocks and structures, from exposures of metamorphic and plutonic rocks, to highly variable sedimentary and volcanic units, Quaternary geology and active tectonics. Students left the Island with better core field mapping skills and experience with a broad range of digital mapping techniques—all useful in their post-UCSB endeavors.

We are indebted to Lyndal Laughrin at the UC Santa Cruz Island Reserve for logistical help, The Nature Conservancy for use of Christy Ranch, and Exxon for transportation.

Summer Field 2018: Nevada

by Alex Wrobel

The second half of field camp involved mapping a broad spectrum of rock types and structures in the Snake Range metamorphic core complex, eastern Nevada (taught by PhD student Alex Wrobel). There we integrated the 'tried and true' tools of field mapping (Bruntons and topographic maps), technology (mobile GIS Software), and digital compasses capable of processing large data sets.

For the final project, students working in pairs mapped previously unstudied regions of the Snake Range core complex, which encouraged them to develop their own geologic questions and answers. With the help of FieldMove software, mapping groups amassed large structural data sets enabling them to glean unforeseen spatial trends in unit orientations. Groups presented their results to the rest of the class, prompting spirited debate about the local geologic history.

In their spare time, students enjoyed soaking in warm springs and alpine creeks. Everyone returned from their summer adventure exhausted but in great spirits. For many, this was the last credit needed before receiving their degree.



Students and instructors enjoy a day off at the crest of the Schell Creek Range, eastern Nevada.

The Robert M. Norris Presidential Chair in Earth Science



Robert M. Norris, an honored professor in our department and an instrumental force during its formative years, was especially celebrated for his field-based courses. In this setting he provided an engaging blend of hard science, striking geologic images, and engaging stories about how geologists have unraveled some of Earth's enduring mysteries. How does plate tectonics work? How can Earth's geologic history and the evolution of life be deciphered through the rock record? What forces have shaped the remarkable changes of Earth's climate? Bob's courses inspired generations of students to pursue geological studies at UCSB, while simultaneously opening a new realm of understanding to many students outside the discipline or the sciences altogether. Among those non-majors were Alec Webster and Claudia Murphy, who met in the 1970s on one of Professor Norris's legendary field trips. That experience, coupled with their coincidentally identical birthdays, catalyzed a relationship that ultimately blossomed into marriage years later. Alec and Claudia's fervent commitment to environmental causes and their championing of field studies in general, inspired their financial backing (along with that of Rachel and Douglas Burbank, Susan Dougherty, and UC's Office of the President) of the Robert M. Norris Presidential

Chair in Earth Science. It's probably no coincidence that the Websters also greatly admired Bob's brother, Ken, a marine mammalogist and professor of Natural History at UC Santa Cruz, where they have strongly supported his intellectual legacy. With a Norris Chair at UCSB, the Websters, the Norris brothers, and the two UC campuses have achieved beautiful symmetry.

Along with honoring Bob, the Robert M. Norris Presidential Chair enables the department to spotlight and celebrate the scholarship and myriad other contributions of one of our most esteemed colleagues. The Norris Chair provides its holder the financial flexibility to catalyze innovative research initiatives that might otherwise be impractical.

We are pleased to announce Professor David L. Valentine as the first Robert M. Norris Presidential Chair. Dave, a blue-and-gold-blooded product of the University of California, earned his BS and MS in Chemistry/Biochemistry from UC Davis and UC San Diego, and his MS and PhD in Earth Systems Science at UC Irvine. He joined UCSB's faculty in 2001 following a Postdoctoral Fellowship at the Scripps Institution of Oceanography.

The overarching focus of Dave's research, the interactions between microbes and Earth, encompasses chemistry, microbiology, evolution, ecology, oceanography, marine robotics, and geology. Interpreting scientific knowledge for societal benefit is another of Dave's prime motivations. He has given hundreds of media interviews; participated in numerous activities at the interface of science, policy and emergency response; and spearheaded creation of UCSB's new Marine Science major in the College of Creative Studies.

He has published over 110 research articles including one patent and three books coauthored with his father. He received an NSF CAREER award and has been continuously funded by NSF since graduate school. He is an Aldo Leopold Leadership Fellow, an American Chemical Society Expert, and has twice served on National Academy of Sciences study panels.

DISTINGUISHED ALUMNI 2018

Annually, the department honors two of its alumni—one from academia, and one from elsewhere—celebrating their accomplishments and providing our current students exemplary role models.

BEN BENUMOF



Since graduating from UCSB with degrees in Geological Sciences (BS) and Geography (BA), Ben Benumof's professional adventures have taken him in many directions, but the core of his success has always remained rooted at UCSB.

After UCSB, Ben served as a staff geologist at the Hawaiian Volcano Observatory, where he honed his field skills mapping Mauna Loa and Kilauea lava flows with Jack Lockwood, a dear mentor and friend ever since. There, he became committed to applied geology (how geology relates to people and land use) and, as a life-long surfer, to working in the coastal environment.

At UCSC, funded as a graduate researcher by FEMA, he was fortunate to investigate first-hand

one of the largest El Niño seasons to ever impact the California coast, performing field work under the extreme conditions optimal for studying coastal erosion. Only belatedly did he realize how well his training at UCSB by Art Sylvester, Jim Boles, and many other great professors, had prepared him. He completed his PhD on the coastal geology and erosion history of the San Diego County coast under Gary Griggs, (also a UCSB alum) and Gerald Weber.

Thereafter, while working as a consulting engineering geologist, Benumof was invited to join Jack Lockwood and a group of talented USGS geophysicists on a expedition to Isla Del Coco in Central America

(Continued on page 9)

BARBARA JOHN



Barbara (Bobbie) John earned her BA at UC Berkeley, and worked for 3 years at the USGS mapping in the Southwest, before attending UCSB. The choice of graduate programs was influenced by a number of Survey geologists/UCSB alums (including Gordon Haxel, Dan May, Dave Sherrod, Tom Sisson, and Dick Tosdal), whose enthusiasm for the faculty and allied field-based research at UCSB was contagious. Cliff Hobson, John Crowell, and Rick Sibson were fundamental to her growth as an Earth scientist, as was the influence of her graduate cohort, particularly the loosely organized 'Moosehead Lodge'.

Days after submitting her PhD, John assumed a lectureship at the

University of Cambridge. There she adapted to a completely new (old) education system, began research in the Pyrenees, Alps, and West Africa, and met her husband, Mike Cheadle, a geophysicist. In 1993, she took a position at the University of Wyoming, where she remains. Her research interests include processes of lithospheric deformation (continental and oceanic), especially extension. Seizing on the expertise of her mentors (Hobson, Mattinson, Sibson and Tilton), she combines petrologic, geochemical, microstructural and geophysical studies, to constrain the nature of extension processes (magmatic and structural), to assess rates of tectonic processes, and the space-

(Continued on page 9)

MATT RIOUX

Matt Rioux is a field geologist who uses geochronology, geochemistry, and petrology to study tectonic processes and the formation of igneous rocks. His research has included work on subduction zones, mid-ocean ridges, and other magmatic settings in Alaska, New Mexico, the Middle East, and the modern oceans.

Over the past several years Matt has done extensive work on the Semail ophiolite in Oman and the United Arab Emirates. Ophiolites are pieces of oceanic crust and mantle that have been thrust onto the continents and are important analogues for studying mid-ocean ridge processes. He has used precise



dating and geochemistry to study the magmatic and tectonic setting during ophiolite formation.

Matt is also currently working on a series of drill cores from the seafloor in the Indian Ocean. Here he is using high-precision dating to study the distribution and timescales

of magmatism. By studying three closely-spaced drill sites, Matt seeks to generate a four-dimensional record of how the lower oceanic crust is formed at mid-ocean ridges.

Born and raised in Berkeley, California, Matt completed his undergraduate work at Boston University in 2000 and his PhD in the Department of Earth Science at UCSB in 2006. Following his PhD, Matt spent 5 years as a post-doctoral scholar at MIT, before returning to UCSB as a researcher in the Earth Research Institute in 2011. As a researcher, he has regularly taught classes in the Department of Earth Science since 2013.

Matt is excited to join the Department of Earth Science and looks forward to teaching a range of field and laboratory-based courses.

MORGAN REED RAVEN

Morgan Reed Raven, an organic geochemist and geobiologist, is thrilled to have joined the faculty of the Earth Science Dept. at UCSB this fall. Her research focuses on sulfur cycling in oxygen-limited environments, particularly on how the sulfur cycle affects how organic matter is consumed, transformed, and stored in sediments. These processes have enormous implications for the global carbon cycle, and they are quite dynamic on both human and geologic timescales. Currently, Morgan is working on oxygen-limited zones of the modern ocean, coastal mangrove sediments, and extreme organic matter burial events during the Mesozoic.

The main analytical tools in NOISE Lab (for 'Natural Organics Interacting with Sulfur in the Environment') will be a pair of mass spectrometers for measuring sulfur isotope ratios in a wide diversity of sample types and sizes. The name for NOISE Lab is also inspired by Morgan's love of rock music; she played keyboards in an LA indie rock band during her PhD and will be happy to turn it down if you ask.

Morgan was raised in Appleton, Wisconsin and moved to California for undergraduate studies at Stanford, where she happily discovered geology after spending a few years studying chemistry and political science. She worked as an environmental consultant at a small construction company in South San Francisco for nearly five years before starting her PhD at



Caltech, where she studied organic matter sulfurization in the modern ocean. Since finishing in 2016, she has been in St. Louis as an Agouron geobiology postdoctoral fellow.

We Wish ...

Bruntons: These are vital to our field work.

New field equipment: camp stoves and new field-oriented technologies.

Revitalization of department's space: especially the main office, tectonic work room, computer lab, and seminar rooms.

Your Ideas Welcome

We truly welcome your thoughts. What were the most important lessons that you take away from here? How could the student experience be most improved? We are very interested in your input, and greatly value your perspective.

Thank you!

Your Donation Dollars at Work



We are deeply grateful to our many alums, colleagues, and friends of the Department who have helped us financially this past year! We are especially grateful to Alec and Claudia Webster for their generous donation of a new departmental van. It has already been put to indispensable service in our field program.

FRANCIS MACDONALD



Francis Macdonald's research focuses on the interactions of tectonics, climate, and biological evolution through Earth's history. This work begins with geological mapping, and uses stratigraphic analysis, isotope geochemistry, geochronology, paleomagnetism, and paleontology to reconstruct paleoenvironments and tectonic histories. Recent projects have focused on the initiation and duration of Snowball Earth events, the chemical evolution of the ocean leading up to the Cambrian explosion, and the Neoproterozoic to Paleozoic tectonic evolution of North America and Asia. Macdonald was awarded the Geological Society of America Young Scientist Award (Donath Medal) in 2014 and the Star Family Prize for Excellence in Advising in 2012. He holds a PhD in Geology from Harvard University and a BS in Geology from Caltech.

WHAT ARE OUR ALUMNI DOING?

We'd love to hear from you. Send us your information and we'll include it in our next issue, as space permits.

With Appreciation

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The Earth Science Department thanks the following for their generous donations.

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Although we've endeavored to make our list of donors complete, please excuse any oversights.

Thank you

... I appreciate it sincerely and cannot thank you enough for the help it is giving me. Thank you!—JB

... It is so generous of you to support international students with limited funding opportunities.

Thank you very much!—NL

... Thank you for your generosity in supporting and promoting graduate research like mine. I am investigating the magmatic history of the Ross Orogen in Antarctica from 3.1 to 0.5 Ga. This award will help me focus on continuing my research over the next summer months....—EE

... I am so fortunate to be a part of a department that cares for its student's field education. This award speaks volumes to how our department and its donors care for the academic opportunities of the undergraduates here...—CG

Graduate Student Spotlight



JENNA ADAMS

I am a fourth-year PhD candidate studying igneous petrology and geochemistry. I earned my BS in Bio-

chemistry at the University of Washington, but after taking a few geology electives, I became captivated by the processes and forces influencing our planet. Ultimately, I pursued this passion in earnest by enrolling at Central Washington University, where I earned a BS in Geology and studied magma dynamics beneath Arenal Volcano, Costa Rica.

At UCSB, working with Frank Spera, I aim to unravel the origin and evolution of lavas erupted at the Samoan hotspot track. I use integrated geochemical analyses of erupted lavas with thermodynamic, mineral equilibria modeling to decipher temperature, pressure, and compositional changes of Samoa's dynamic magmatic system. Beyond simply clarifying the history of these interesting lavas, my larger goal

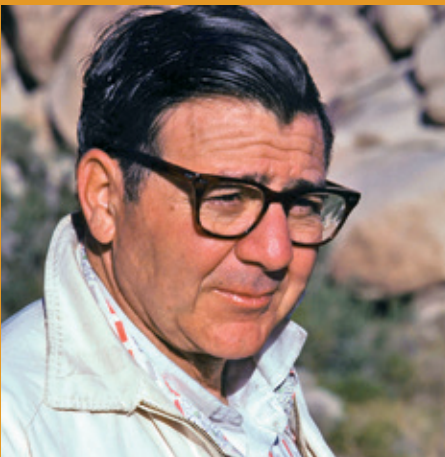
is to better constrain models of Earth's interior over various spatial and time scales.

To that end, I participate in the collaborative project "Enabling Knowledge Integration," which seeks to broaden the applicability and accessibility of thermo- and fluid-dynamic models to Earth and planetary scientists. My contribution involves developing web-based tools allowing the newest mineral equilibria models to be incorporated in computational programs easily.

This collaboration, involving diverse scientists around the globe, has helped me build a "toolkit" applicable across disciplines, while simultaneously engaging me in broad questions about Earth Science that attracted me to the discipline in the first place.

YORK MANDRA MEMORIAM

THE BLANCHE SIMON, HIGHOOHI & YORK MANDRA SCHOLARSHIP



York Mandra was an extraordinarily dedicated and skillful teacher, having an almost magical ability to motivate students. During the 1960s the department (then Geology) hired professors from other schools to teach a Summer Session course, usually a

different person each year. That is, up until about 1970 when York first taught at UCSB. His performance was so superb that we changed our policy, and brought York back to teach in summer for the next 20 or more years.

Although micropaleontology was York's research specialty, his grasp across the field of Earth Science (he began college as a Physics major) was remarkably broad. This breadth of expertise, in fact, was a key strength of his teaching.

York came to have high regard for our department and for UCSB. He felt as much at home here, as we welcomed having him. The Department benefited greatly from his graciousness and generosity. He once mentioned to me during offhand conversation, that he

intended to leave our department a large sum.

Therefore I wasn't surprised when, after York's recent passing, we received word of a substantial bequest. This gift named in his, his sister-in-law's, and his beloved wife's honor, is expressly to support graduate and undergraduate students. Under the terms of this fund, we are deciding how best to meet York's intentions in the expenditure of its annual income.

I last saw York three years ago, when my wife and I had dinner with him at the Cliff House in San Francisco. We are grateful for the great legacy he has left us here in Earth Science, and we look back on his era with fondness and appreciation.

Cliff Hopson

DANNY MOREL

I graduated from Macalester College in St. Paul, MN, in Geology. After two years working at the USGS Water Science Center in Minnesota, investigating how mineralized bedrock affects water quality, I came to UCSB to pursue an MS with Ed Keller.

My research, concerning the marine terraces west of campus, aims to determine the region's uplift history. I calculate uplift rates from terrace elevations relative to paleo-sea level, and the ages of raised beaches using radiocarbon and optically stimulated luminescence. My results indicate that the first emergent terrace along the Gaviota Coast is ~45 ka, far younger than previously assumed (80 ka). Accordingly, uplift rates here (~1.1 m/ky), are over five times higher



than prior estimates. East of Gaviota Canyon, uplift rates increase to ~1.5 m/ky. These findings are significant for implying increased seismic risk for the Santa Barbara region, and the need to reassess local seismic hazard models.

This project combines my interests in tectonic geomorphology,

quantitative GIS analysis, field geology, and Quaternary geochronology, in a project with "real-world" importance. I presented preliminary findings at the GSA meeting in 2017, and just filed my thesis in August. I look forward to applying the skills I have gained from this experience to my next workplace, wherever that might be!

Ben Benumof

(Continued from Page 4)

to search for ancient artifacts. It was an unbelievable project ... scuba diving, jumping out of helicopters, mapping landslides and lava flows, looking for buried treasure ... every kid's dream!

His consulting work involved ever more land use issues, construction, and real estate. With his growing involvement in litigation support, melding his geologic expertise with a law degree became the next logical step professionally. Ben lives in San Clemente, California, just a short stroll to the beach, where he has a thriving "geo-law" practice, about which more can be learned at: www.GEO-LAW.com.

Barbara John

(Continued from Page 4)

time distribution of deformation and/or magmatism. Her most recent work advances our understanding of crustal growth and plate spreading processes at ultra-slow to super-fast spreading mid-ocean ridges.

John has taught a spectrum of courses in the UK and US including mineralogy and petrology, structural geology, tectonics (Alpine to mid-ocean ridges), mineral resources, and summer field geology courses (in Scotland, the Alps, and western North America). When not an academic, she enjoys exploring western North America on foot and by kayak, as well as open water swimming, passions she developed at UCSB.

STAFF SPOTLIGHT: JAIMA ORTEGA



Jaima joined the Earth Science department this June as the Academic and Student Affairs Manager. She has worked within the UC system for 13 years, splitting her time between UC Irvine and UCSB and is happy to be back in Santa Barbara and at UCSB. With UCSB employment in the family for multiple generations it certainly feels like home! She is a lover of the outdoors whether it be hiking the local trails, going to music festivals, riding horses, snowshoeing in the winter or spending the summer on the water. When she is not outdoors, you can find her baking up a storm in the kitchen and using her hidden talent of decorating cakes.

Antarctic Peninsula

by Alex Simms

In February and March of 2018, three members of the UCSB Sedimentology and Coastal Geology group, Associate Professor Alex Simms, PhD student Julie Zurbuchen, and Dr. Laura Reynolds, along with a professional guide and a physics PhD student from East Carolina University, were part of a research expedition to southern Joinville Island along the eastern Antarctic Peninsula. The goals of the research expedition were to survey, map, and date raised beach ridges in order to reconstruct the late Holocene sea-level history of the region. The new sea-level record will provide constraints on the glacial history of the region as well as the structure of the underlying Earth.

The anticipated 14-day deployment was extended by a couple days due to a change in the ice conditions. Following a shift in the winds, ice from the Weddell Sea moved in and the ocean around the peninsula on which camp was based froze. As a result the research vessel (R/V Laurence M. Gould), which had deployed the team, was unable to reach the island. Luckily, the Argentine Navy was close by and sent a pair of Sea King helicopters to retrieve the field party and all its gear.

Despite the added excitement, and the unexpected time aboard the A.R.A. *Alte Irizar* (the captain and crew made everyone feel very welcome aboard the Argentine ship), all made it back safely with the geologic samples and equipment. We look forward to cutting the rock samples in the dark (for optically stimulated luminescence dating) and seeing what interesting results emerge from the data.

Muckers' Corner



The word "mucker" has two meanings: a person who shifts through rock and dirt; a comrade or a friend. This is why the name "Muckers' Coterie" was chosen to represent the undergraduate Earth Science Club at UCSB. Muckers' Coterie is a great way to meet other students with the same enthusiasm for Earth Science, the outdoors, and adventure. During weekly meetings, students spend time with other Earth Science majors and learn about the various activities the club has to offer. To raise money for trips and events, we have a fundraising table in Webb Hall every Thursday.

Muckers' Coterie provides opportunities and transportation for many camping and field trips. Last spring, we hosted a trip to Joshua Tree National Park, where we spent two days in the desert sleeping under clear, unpolluted skies. We did some hiking, rock climbing, and lots of sightseeing throughout the unique geology of Joshua Tree. At night, a big, roaring campfire provided us with light and warmth while we munched on burritos and gazed at the stars.

To learn more about Muckers' Coterie and what we have to offer, join us at our meetings in the Webb Hall tectonic room (room 1030). Exact meeting day and times will be announced in early fall, so watch out for an e-mail with this information!



Professor Emeritus Profile



RALPH J. ARCHULETA

Chris Scholz once observed how few seismologists actually study earthquakes. Most study the internal structure of Earth by investigating how seismic waves propagate through it. Nonetheless, earthquakes are a key source of such waves, “the clapper that [rings] the bell,” so to speak. Ralph’s focus has always been on the clapper—the seismic source—an interest sparked by his PhD research (with Professor James Brune) modelling strike-slip earthquakes using a high-speed camera to record “ground” motion on precut foam-rubber blocks.

Watching his dad lug around

100 lb. bags of cement in Reliance, Wyoming—a small coal mining camp near Rock Springs, convinced Ralph early on that intellectual labor was a preferable way of making a living. His dream was to become a nuclear physicist. He studied physics at the then Western Wyoming Community College, and the University of Wyoming. He then moved to UCSD, earning an MS studying the magnetosphere. Serendipitously, a consultant to the software company in San Diego where Ralph worked, introduced him to Brune of UCSD’s Institute for Geophysics and Planetary Physics. As they say, the rest is history.

After completing his PhD and postdoc at IGPP, Ralph was awarded a National Research Council Fellowship to work at the USGS in Menlo Park, CA. There he produced his magnum opus—a fault model for the 1979 Imperial Valley earthquake. Remarkably, this paper showed that the rupture velocity exceeded the shear wave speed of the medium. Although theory had predicted this unusual behavior, most seismologists remained highly skeptical. The 1999 Izmit, 2001 Kunlun, and 2002 Denali Fault earthquakes, among others, have now confirmed Ralph’s discovery.

Ralph came to UCSB as an Associate Professor in 1984, after seven years at the USGS. To assess

how ground motion is affected by local geological conditions, one of his first major projects at UCSB involved placing accelerometers below ground, some as deep as 1800 ft. This borehole project, greatly expanded by Dr. Jamie Steidl (his PhD student), now includes seven geotechnical arrays from California to Alaska.

The large-scale structure of subsurface geology also profoundly affects ground motion. Using one of the first parallel computing systems, a team headed by Ralph produced the first numerical simulation of a M 7.8 earthquake on the San Andreas in a three-dimensional medium that included the deep basin structure in Southern California. The motivation for this work was to provide ground motion predictions useful in designing seismically safe structures.

Ralph taught a host of popular classes at UCSB, including Geological Catastrophes, which he started with R.V. Fisher following the Loma Prieta earthquake. To this day it remains one of the favorite classes on campus.

Ralph has garnered a satchel-full of awards and honors over his illustrious career. These, and other accomplishments mercilessly excised from the text above, may be accessed at the URL below.

Professor Archuleta: For Whom Earth’s Clapper Tolls!

Read full article at: www.geol.ucsb.edu/people/ralph-archuleta

Santa Cruz Island Trip

(Continued from Page 1)

The final day was a sad one, as it meant a return to the real world, but that didn’t stop us from having one last outing to Saucos Canyon and Beach, where we explore the area and check out the amazing concretions found there. After a final ride across the island, we boarded the boat at Prisoner’s Harbor and were whisked back to civilization.

Other highlights of the trip include multiple dolphin sightings, foxes stealing our food, and a student running the 16 miles back to the boat!



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Santa Cruz Island. Photo: Scott Condon

EARTH SCIENCE NEWS