Earth and Planetary Sciences at UC Santa Cruz

Fall 2009

New Idria field trip, 2008

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Chair's Welcome

Dear Alumni and other friends: Yes, it's been a very long time. Our last message went out in 2001, but we plan to make this an annual feature in the future. We write to assure you that, notwithstanding erroneous statements in the New York Times this fall, the Earth and Planetary Sciences Department at UCSC is alive and well. The times are challenging – tuition is rising rapidly, class sizes are growing, and state support for research is dropping. Still there are many positive signs. The number of declared majors is at an all time high (>150), and offerings of field- and laboratory-intensive courses are expanding. Faculty, students, and former students are receiving professional honors. Grant support is extremely strong. Since 2000, we've hired an outstanding cohort of new faculty, about one-third of our total. The Department grew in new areas and made hires in response to departures (Bob Anderson, Univ. of Colorado; Justin Revenaugh, Univ. of Minnesota) and retirements (Ken Cameron, Casey Moore). We profile 4 new faculty members here, and wish faculty member Marcia McNutt well in her new job as director of the USGS. Finally, thanks to the generosity of our alumni and supporters, endowment and gift funds have begun to grow considerably, allowing us to offer more support for student research, field trips, and other departmental needs. We hope the newsletter will inform you of current happenings, bring back memories of past events, and encourage you to send us information about yourselves for future newsletters. In spite of budget cuts the department continues to thrive, thanks to the intellectual wealth of our students, faculty, staff and alumni. We hope that during these difficult times, we can count on your continued support of the Department's endowment and gift funds. Finally, we look forward to seeing you at the Thirsty Bear on December 15 in San Francisco, or in Santa Cruz at any time.

Paul Koch, chair

Left to right: Rob Coe, Eli Silver, Jim Gill, Gary Griggs, Kathy Sullivan, Bob Garrison, and Gerry Weber on the occasion of the dedication of the main atrium of the Earth and Marine Sciences Building in Kathy's honor.

Marcia McNutt

"Three of the biggest challenges facing the U.S. are water, energy and climate, and the USGS will be at the forefront of those issues."
Marcia McNutt

Lisa White

Department News

Marcia McNutt was confirmed as the Head of the US Geological Survey by the Senate. In 2007 she was awarded the Maurice Ewing medal of the AGU.

Rob Coe received the 2007 William Gilbert medal from the AGU, and a Humboldt Award to carry out research in Germany.

Another Humboldt Award was given to **Jim Zachos**, who was also elected an AGU Fellow in 2008.

Thorne Lay was elected to the American Academy of Arts and Sciences.

Emily Brodsky and **Francis Nimmo** were both awarded the Macelwane medal of the AGU, in 2008 and 2007 respectively. Emily was the inaugural winner of the Seismological Society of America's Richter Award in 2005 and Francis received the Urey Award from the American Astronomical Society in 2007.

Gary Griggs named 2009 California Coastal Hero and in 2007 received the Ed Ricketts Memorial Award and Lecture from the Monterey Bay Aquarium.

Slawek Tulaczyk received the distinguished alumni award from Northern Illinois University

Alumni News—Graduate Alums

Lisa White received the first Bromery Award for the Minorities from the Geological Society of America.
Judith Totman Parrish was elected president of the Geological Society of America.
Ian Howat (now a professor at Ohio State) was awarded the AGU Young Investigator award in cryospheric science.
Christie Rowe (formerly a professor at Cape Town, South Africa) was awarded an NSF Margins Fellowship, to be taken at UCSC.
Kena Fox-Dobbs is a professor at the University of Puget Sound.
Catherine Plesko is a Director's Fellow at LANL
Erin Kraal and Jake Sewall are assistant professors at Kutztown University
Joe Galewsky is an assistant professor at the University of New Mexico
Pete Adams is an assistant professor at the University of Florida
Mike Loso is an assistant professor at Alaska Pacific University
Cindy Shellito is an assistant professor at the University of Northern Colorado
Kena Fox-Dobbs is an assistant professor at the University of Puget Sound
Sarah Hall is an assistant professor at McGill University
Chris Pluhar is an assistant professor at California State University at Fresno
Mark Clementz (Assistant professor at University of Wyoming) won an NSF career award (2009)
Fred Phillips (Professor at New Mexico Tech) was elected Fellow of the American Geophysical Union and Fellow of the AAAS in 2008.
Greg Beroza (Professor at Stanford University) was elected Fellow of AGU in 2008.
Andrew Jacobson (Associate Professor at Northwestern University) was awarded a Packard Foundation fellowship in 2007 and the Clarke Medal of the Geochemical Society in 2008.
Heather DeShon is a researcher at the University of Memphis
Greg Stock is a Park Geologist at Yosemite

New Faculty

Noah Finnegan's research is focused on the dynamics of river incision and coarse sediment transport in mountainous environments, and on quantifying rates and patterns of tectonic and volcanic deformation from the analysis of topography and its evolution. Finnegan's research generally relies on a combination of numerical and analog modeling, geochronology, remote sensing (InSAR, LiDAR), surveying, and field observations. Ongoing projects include investigating why coastal California rivers alternate between periods of lateral and vertical incision (thereby creating bedrock terraces), and quantifying volcanic uplift from fluvial and lacustrine terrace deformation in California, and Bolivia.

Noah received his BA in Geology from Carleton College in 1999. During college, he thru-hiked the ~ 2100 mile Appalachian trail, which propelled him into a career in geoscience. After working for the U.S. Geological Survey and the National Marine Fisheries Service, Noah entered graduate school at the University of Washington in 2001, where he completed a PhD in 2007. Noah was a post-doctoral researcher at both Cornell University from 2007-2008, where he focused on geodesy and tectonic geomorphology, and at Berkeley from 2008-2009, where he focused on fluvial geomorphology

Annual Alumni Event at Fall AGU

Tuesday, December 15, 2009
Thirsty Bear Brewing Company
661 Howard Street
San Francisco, CA 94105
http://www.thirstybear.com/

Matthew Clapham joined the faculty in January 2008 after completing a PhD at the University of Southern California and a postdoc at Queen's University in Kingston, Ontario. Prior to that he obtained a BSc at the University of British Columbia and studied the oldest known animals, the Ediacara biota, for an MSc degree at Queen's University. Despite growing up in the shadow of the Coast Plutonic Complex in Vancouver, Matthew's childhood interest in fossils was nurtured by many visits to dinosaur museums in Alberta and hiking trips in fossiliferous Paleozoic strata in the Rocky Mountains. Several decades later he is still pursuing that love of paleontology – although not studying dinosaurs, much to his mother's disappointment!

Matthew's research concentrates on marine paleoecology during mass extinction intervals, especially the Permian-Triassic extinction, and other times of significant environmental change such as the Carboniferous-Permian late Paleozoic ice age. The P/T interval also triggered substantial restructuring in marine ecosystems in addition to the well-publicized loss of nearly 95% of all marine life. Those paleoecological changes have particular importance (for the quality of seafood available in our diet among other things!) because they played a major part in the rise of "modern-style" marine ecosystems dominated by clams and snails. Before that time, unappetizing groups like brachiopods and bryozoans were by far the most abundant invertebrate groups in the ocean.

Matthew particularly enjoys the fact that his research takes him to interesting places around the world. He has collected fossils from Australia, Greece, and south China and will be traveling to Bolivia later in summer 2009 for continued study of the late Paleozoic ice age in sections exposed around Lake Titicaca. He is also an avid bicyclist and rides everywhere around town including (very slowly) uphill to campus every day.

New Faculty

Jeremy Hourigan's research seeks to obtain an understanding the tectonic evolution and growth of continental crust at convergent margins through integrated studies involving field mapping, structural analysis, petrology and geochronology and thermochronology. His focus is the exhumation history of orogenic belts and chronostratigraphy of sedimentary basins utilizing He-Pb zircon dating of detrital zircons.

He uses U/Th: U-Th/He double dating techniques to study arc-continent collision processes in Kamchatka, including collision timing, exhumation, and cooling history. He also studies sediment fluxes, particularly those of high-quality quartzofeldspathic sands, to understand the petroleum reservoir potential in deltaic systems at the terminus of transcontinental drainages. Jeremy and co-workers have quantified long-term sediment dispersal rates using U-Pb: (U-Th)/He double-dating of detrital zircons in the Amazon River where the Andes provide a continuous source of zero-age, first -cycle volcanic zircon grains that can be readily identified with the double-dating technique. They use first-cycle volcanic grains to quantify downstream aging of the detrital zircon population in bedload samples from throughout the Amazon River basin, providing a direct measure of transport time from source to sink.

Jeremy obtained his BS degree from the University of Vermont in 1996 and his PhD from Stanford in 2004. He was a postdoctoral researcher at Yale in 2003-04 and an Associate Researcher at UCSB in 2005. He began teaching at UCSC in 2006.

Emily Brodsky is a geophysicist with a short attention span. Her research focuses on rapid phenomena like earthquakes and volcanic eruptions. She is best-known for her work on earthquake triggering. In these studies she use seismic data to determine the processes linking successive earthquakes. Other work focuses on the friction on faults during earthquakes and the seismic effects of explosive eruptions.

Emily combines a variety of geo-disciplines in her work including seismology, geodesy, hydrogeology and structural geology. She and her research group have ongoing projects measuring the temperature of faults in Sichuan, recording the seismic waves from eruptions in Alaska and performing laboratory experiments on the flow of Cowell's beach sand.

Emily graduated from Harvard Magna cum Laude in 1995. She earned her PhD from Caltech in geophysics and went on to a short postdoc at the University of Oregon followed by a Miller Fellowship at UC Berkeley. She joined the faculty of UCLA in 2002 and moved to UC Santa Cruz in 2006. She is the inaugural recipient of the Seismological Society of America's Richter Award in 2005 as well as the recipient of the 2009 James T. Macelwane Medal of the American Geophysical Union. Emily's favorite aspect of being a professor is spending time advising students.

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Casey and Hilde

Figure 1. Earth Sciences Faculty circa 1977. Top Row, L-R: Al Smith, Rob Coe, Eli Silver, Ken Cameron, Gary Griggs, Jim Gill, Bottom Row, L-R: Othmar Tobisch, Aaron Waters, Bob Garrison, Casey Moore, Leo Laporte. Photo by Parke Snavley III, then a graduate student in Earth Sciences, now Supervisor, Africa New Opportunities at ExxonMobil Exploration Co.

Overall it was a sound program centered around a core of geology and geophysics...

Students educated in the Earth Sciences at UCSC during these first two decades have gone on to remarkable careers...

The Founding of Earth and Planetary Sciences At Santa Cruz: The First Decades By Casey Moore and Bob Garrison

UC Santa Cruz was established in 1965, and its first Chancellor, Dean McHenry, persuaded Aaron Waters to move from UC Santa Barbara to UCSC in 1967 to create a program in the Earth Sciences. Waters, at the peak of his career after having built a very strong geology program at UCSB and following his election to the National Academy of Sciences. He was restless for new challenges and was attracted by the prospect of interdisciplinary teaching and research at UCSC. Once at Santa Cruz and the sole faculty member in Earth Sciences, he moved quickly to build a critical mass of students during his first year here by teaching Geologic Principles twice and a course in Historical Geology once, and leading numerous field trips that acted as a magnet to draw in students from various other disciplines. Later this first year, he received help when Rob Coe arrived in April of 1968 and immediately started teaching a course on the then new paradigm of plate tectonics. Also later during this challenging year Waters was supported by the advice and presence on campus of two eminent earth scientists, James Gilluly of the USGS and the paleontologist Adolf Seilacher from Germany. Later in 1968 Bob Garrison came to UCSC in sedimentary geology, and in 1969 Othmar Tobisch was hired in structural geology and Gary Griggs in oceanography. Together this group provided a small but impressively credentialed nucleus for the then "Board of Studies in Earth Sciences[1]", embarking on an ambitious program despite shortages of space, equipment, and teaching materials.

Earth Sciences established a graduate program in 1968 and recruited the first class of three graduate students that Fall. To diversify graduate offerings, Waters, a former Stanford faculty member, arranged an instructional exchange with Stanford, allowing our students to take classes there and vise versa[2]. We were also greatly helped by Waters' close connections with the USGS in Menlo Park, who supplied temporary lecturers as well as many research opportunities for students. The program continued to grow rapidly in the early 1970's.

Léo Laporte (paleontology) and Casey Moore (structure-stratigraphy) arrived in 1970-71. Jim Gill (geochemistry-petrology) was hired in January of 1972 and Eli Silver (marine geophysics) and Ken Cameron (petrology) came on board in 1973. This group honed a curriculum including introductory geology, mineralogy, optical mineralogy, petrology, structural geology, stratigraphy-sedimentation, paleontology, marine geology, environmental geology, applied geophysics, and paleomagnetism. Overall it was a sound program centered around a core of geology and geophysics. From the beginning there were strong ties to the Marine Sciences program at UCSC and to international projects involving ocean drilling.

The Earth Sciences program was originally housed in Thimann Labs, the only Science Building on campus in 1967. We moved to Nat Sci II in 1968. During 1967-68 an engineering building was being planned on the current site of the Baskin Engineering Building. Because of the obvious and still-present evidence of sinkholes in that region, Waters strenuously objected to the building site. He argued that it should be moved, from its current location, up the hill to approximately where Engineering 2 is now located. Waters arranged for a gravity survey (by a Stanford geophysics student) that indicated low-density fill from collapsed caves and filled sinkholes beneath the proposed building location. Moving the building up hill would have placed it on schist with better foundation potential. Nevertheless, Waters' recommendations were ignored; and, as he had predicted, construction of the building encountered substantial foundation problems that required a network of three-foot diameter columns that in places extend to 140 feet subsurface to reach solid marble basement.

The cost overruns on the foundation prevented finishing of the first two floors of the building for about a decade. In addition, during the construction the planned engineering program at UCSC was canceled, and Earth Sciences was unceremoniously moved into the renamed "Applied Sciences Building". We remained in Applied Sciences until 1992-1993 when we moved to the current Earth and Marine Sciences Building. A silver lining of the Applied Sciences Build-

The First Decades, continued

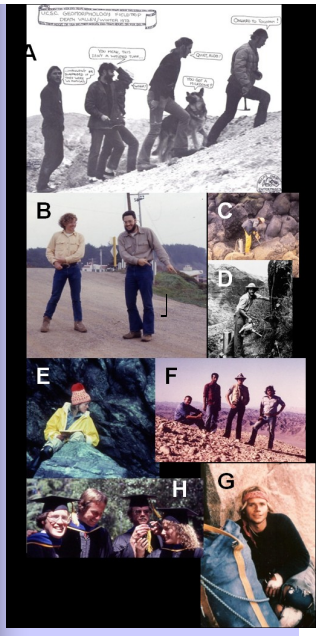


Figure 2. Scenes from the First Decades: A. Jerry Weber leading a geomorphology field trip in Death Valley in 1973, followed by Neal the dog, Rob Williams, Alan Allwardt, Andrew Tarsis, and Steve Davenport. B. Kevin Biddle and Alan Busaca investigating a landslide scarp in Moss Beach, CA circa 1971. C. Tim Byrne drilling pillows in Kodiak Islands circa 1980. D. Scott Bogue drilling basalts in Kauai. E. Sarah Roeske contemplating blue-greenschist in the Kodiak Islands, 1984. F. from left to right, Bob Garrison, Salim Mansour, Craig Glenn, and Parke Snavely, in the Eastern Desert of Egypt, near the Red Sea, 1978. G. Marty Garrison, checking out the granitic rocks in Yosemite, 1970s. H. Graduation 1981. Gary Griggs with Ph.D. graduates Jeff Mount on left, Jerry Weber, and Debbie Bliefnick.

strength and connection to the earth. It suffered minimal damage during the 1989 Loma Prieta earthquake while our former home in Nat Sci II nearly collapsed.

Al Smith, UCSC's first seismologist, was hired in 1974. Though growth of the program slowed for the next decade, there were important faculty additions with the hiring of Shirley Dreiss (hydrogeology) in 1979, Karen Mc Nally (seismology) in 1982, and Ken Collerson (geochemistry) in 1986. Gerry Weber took charge of the field program on a continuing basis in the early 1980's. These hires rounded out a faculty about a dozen, supporting teaching and research based on traditional geology and geophysics.

The first two decades of Earth Sciences at UCSC established thriving undergraduate and graduate programs. Undergraduate majors peaked at 140 in the in the early 1980s, in part due to the energy resources boom. Earth Sciences enrolled an average of 58 graduate students during the 80s. In a 1982 National Academy of Sciences study of academic departments UCSC ranked as 36th out of about 91 earth sciences programs reviewed nationwide[3]. In departments of comparable size (10 faculty at the time of the review), we ranked in the upper 10 to 20% (depending on the range of size comparison).

Students educated in the Earth Sciences at UCSC during these first two decades have gone on to remarkable careers, which have included chief of exploration for a major international oil company, the first American woman astronaut to walk in space (and former Chief Scientist of NOAA), and founders of successful environmental geology and Silicon Valley "Green" technology firms. Additionally, UCSC produced numerous research scientists in the USGS including several in high-level leadership positions, the Chief Geologist of Colorado and faculty members at more than 50 universities and colleges, including institutions such as Stanford, Yale, and Rice.

Research achievements during this early period included seminal work on the petrology and geochemistry of volcanic arcs, on the tectonic history of convergent margins & volcano-plutonic arcs, on impact textures of lunar rocks returned by Apollo 12, on the nature of paleomagnetic reversals, on paleohomind footprints in Kenya, on structure and sedimentation along continental margins, and on fluid flow in porous media. Faculty published highly regarded books on andesites, environmental and coastal geology, and the history of geology. First-rate analytical facilities were established for geochemical and paleomagnetic research. The creation of the Richter Seismological Laboratory (now the Keck Seis. Lab.) provided the basis for subsequent expansion of seismological and other geophysical research at UCSC.

Overall the first 20 years of the program produced students and research of a caliber that drew attention and strong support from UCSC administrators. These years thus established a firm base for expansion into the Earth and Marine Sciences Building early in the 1990's and significant growth and diversification of the faculty and student body.

Footnotes and References

[1] The Earth and Planetary Sciences Department was originally called the Board of Studies in Earth Sciences, then the Department of Earth Sciences, and finally the Department of Earth and Planetary Sciences.

[2] This program still exist but is rarely utilized now. Although Santa Cruz students mostly took advantage of the exchange, there were notable exceptions when Stanford students trekked Highway 17 to enroll in specialized offerings available here.

[3] Jones. L.V., Lindzey, G., and Coggeshall, P.E., eds, 1982. An assessment of research-doctorate programs in the United States: Mathematical and Physical Sciences: National Academy Press, Washington, D.C., 243p.

Ecuador volcano field course by Sara Meyer (class of 2010)

"It's better when she's roaring like that – when she goes quiet, that's when you have to worry." These words, spoken by my class TA, were the closest we received to a safety assurance while on the slopes of an active stratovolcano. The course, hosted by New Mexico Tech, introduced students to volcanic seismicity via a three-week intensive field course in Ecuador. I decided to use the course as an alternative to the department's field camp capstone option, and in early June found myself boarding a plane headed for Quito, the capital of Ecuador.

After being thermal-imaged for swine flu at the airport, I entered Quito and joined up with the 14 other students enrolled in the course. We came from very diverse places and situations: Undergraduates, Masters students, and Ph. D. students from Hawaii, New Mexico, New York, Alaska, Arizona, Mexico, etc. Although we all had different educational backgrounds, the desire to learn about volcanic seismicity (on another continent!) had drawn us all together, and we quickly became friends during the course.

One word drew us all running: "LAHAR!"

Tungurahua Volcano-watching: fun for everyone!

The first week of the course consisted of fieldwork near the Baños, a touristy town inhabited by 18,000 people. One of the main reasons for Baños' tourism are popular hot springs – heated by the activity of Tungurahua, an active stratovolcano rising 3280 meters above the town (with a summit altitude of 5023 meters above sea level). The government temporarily evacuated the entire population of Baños in 1999, after the volcano started emitting strombolian eruptions. Hundreds living on the flanks of the volcano itself were also evacuated, and much of these rural populations remain

Inspecting seismograms at Tungurahua Volcano Observatory.

despite consistent volcanic activity ever since.

We installed two arrays to monitor Tungurahua; one composed of seismometers and infrasound sensors a little over five kilometers from the crater, and another across a valley from the volcano comprised solely of infrasound sensors. On a particularly rainy day of installation, one of my classmates spotted a muddy river in a nearby canyon, and one word drew us all running: "LAHAR!" We watched in awe as the volcano's wetted ash spilled down the canyon, roaring like a large mountain stream. As the cliff we stood upon started mass wasting into

Ecuador field course

the lahar, we stepped back a few paces in order to still observe the torrent of vol-

Classmates watching the lahar from a relatively "safe" distance.

canic mud. I will never forget that moment, watching my first lahar and hoping it wouldn't be my last.

After establishing our data stations, the second week of the course consisted of a physical volcanology road trip throughout Ecuador's Andean cordillera. In a matter of days we visited half a dozen stratovolcanoes, learning about their eruptive histories and placing them into the grander scheme of the northern Andes' geologic setting. Our class experienced the serious scale of these magmatic monsters, daring to push snow-capped peaks toward the Sun in a clime where everything lays low and sweats out the heat of the day. It was easy to see how the population of Ecuador could widely forego the dangers of living next to active volcanoes; the mountains we visited seemed figments of my imagination in such surroundings.

In the third week, we returned to Tungurahua and retrieved our equipment amidst constant gas-emitting roars and intermittent strombolian eruptions. At night we ascended a nearby hill in taxis and waited breathlessly for a break in the clouds to witness one of the most amazing sights of my life: just under the blazing stars of the Southern Cross constellation, molten blocks the size of VW Bugs were being tossed effortlessly out of the volcano's crater. At that moment, I knew I'd find myself in Ecuador again someday.

"Molten blocks the size of VW Bugs were being tossed effortlessly out of the volcano's crater"

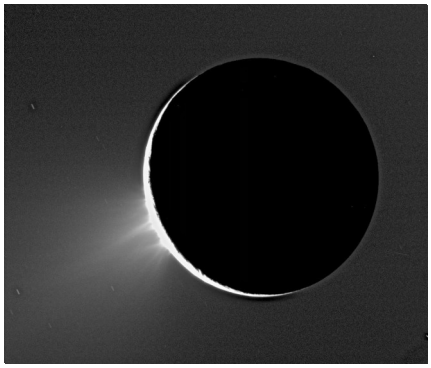
Sara holding a ball of snow near the Equator, 15,000 feet from sea level

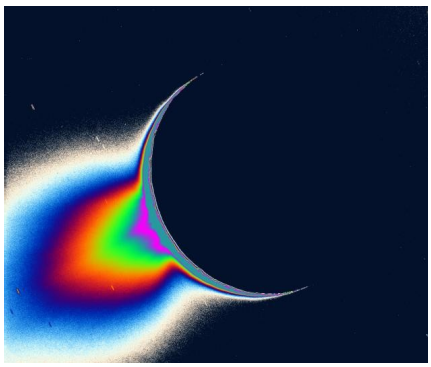
Classmates walking on a pyroclastic flow from 2006 on the way to an installation

Francis received his PhD from Cambridge University in 1996 and joined the faculty at UCSC in 2005. Most of his work involves the application of geophysical techniques to other planetary bodies, including Venus, Mars, Mercury and the icy satellites. . .

Saturn's surprising moon by Francis Nimmo

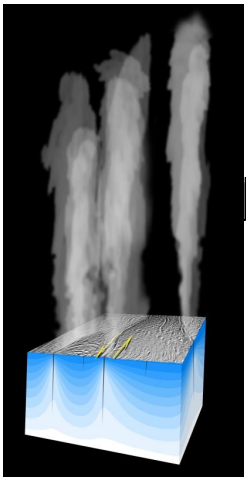
In Greek mythology Enceladus, a rebellious giant, was buried beneath Mount Etna and caused that mountain's volcanic eruptions. It is therefore appropriate that the icy moon of Saturn called Enceladus should also show prodigious volcanic activity. To be sure, these geyser-like eruptions are of ice and water vapour, not rock, but they still extend several hundred miles into space. They were first detected by the *Cassini* spacecraft in 2005, and rank as one of the most important discoveries of that mission: Enceladus now joins the Earth and the moons Io and Triton as the only places in this solar system which are volcanically active right now.





Two views of the geysers emanating from the South Pole of Enceladus (radius 252 km).

In retrospect, we could have guessed that Enceladus would be active. Astronomers have known for some time that it is at the centre of a faint ring; the source of the ring particles is now revealed as ice crystals, jetted out by the geysers, which escape the puny gravity of Enceladus. But several other large puzzles remain. Most importantly, *why* is it active? Enceladus is tiny – about the size of England – and should by rights be stone (or ice) cold after four billion years of steady cooling. Second, the geysers are all clustered along linear fractures, nicknamed "tiger stripes", near the south pole – why should this be? And finally, if the interior of Enceladus is warm and active, then is there liquid water, and potentially even life, somewhere down there?



Artist's impression of Enceladus geysers arising from fractures in the ice shell which are heated by back-and-forth motion (shear heating). The colours indicate cold (blue) and warm (white) ice.

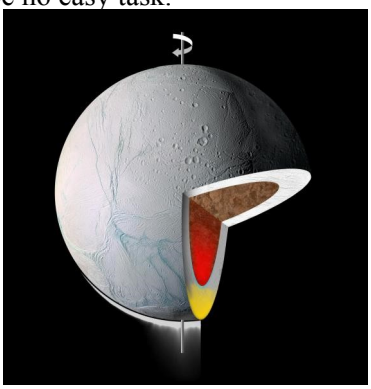
Much of my recent work has focused on answering these questions. The fact that the tiger stripes are warm and the source of the geysers can be explained quite simply: just as rubbing one's hands backwards and forwards generates heat, so back-and-forth motion along these fractures is capable of generating heat and producing vapour. The force driving this back-and-forth motion is gravity: the distance between Enceladus and Saturn gets bigger and smaller over the course of each orbit, and as a result Enceladus gets squeezed and stretched, driving fault motion. This model, although simple,

. . . Although his undergraduate degree was in geology, fieldwork in Bolivia convinced him that he was better suited to science conducted from behind a computer.

Saturn's surprising moon

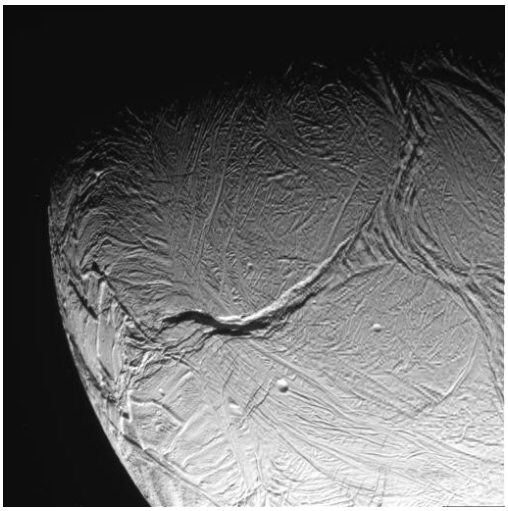
explains the observations, and also makes predictions which will be tested during *Cassini*'s extended mission
What about the fact that the geysers are located at the South Pole? One possibility is that these features started somewhere else, then caused the satellite to roll over until they reached their current position. This rather dramatic reorientation could happen if the area beneath the geysers had a lower density – which is exactly what one would expect if the ice there was unusually warm.

One way of testing this hypothesis is to look for tectonic fractures which this rolling-over is predicted to create. Unfortunately, Enceladus is a structural geologist's nightmare: almost everywhere you look, there is a tangled network of folds and fractures, overlapping and crosscutting each other with bewildering complexity. Sorting out the tangled history recorded by this deformation is going to be no easy task.



Hypothetical structure of Enceladus, with a warm ice blob (yellow) causing the satellite to reorient.

Perhaps the most important question is whether Enceladus contains a liquid water ocean somewhere deep beneath the frigid surface. If it does, then that leaves open the possibility that Enceladus could harbour living organisms.
Right now, we can't say for sure whether or not an ocean is down there. Nonetheless, to generate the amount of tidal flexing needed to drive the geysers requires



Close-up view of a mid-latitude region on Enceladus. The image is about 200 km across.

that Enceladus is rather weak. An ice shell floating on a liquid ocean would work just fine; a completely solid, cold Enceladus would be too strong to deform appreciably. Furthermore, the geyser particles are not pure ice: some are salty, which strongly suggests that there is an ocean somewhere down there.

However, even if Enceladus does have an ocean now, it's not clear how long-lived a feature it is. Because Enceladus is so small, it should lose heat rapidly, and calculations show that an ocean is unlikely to last for more than a few tens of millions of years.

So although we've learnt a lot about Enceladus, many mysteries remain. In particular, understanding how it evolved to its current active state, and what it tells us about the broader evolution of the Saturnian satellites, is likely to keep us busy for some time to come.

Hilde (front) and the 2009 Summer field class

Jeremy (large hat and the one with a hand lens) and 2008-09 Structure class.

Melissa Usack preparing to attack outcrop with a hammer, 2008

Degrees and Awards

Commencement 2009

BS/BA

Jamal Alnagem
Geidy Baldeon*
Tyler Boyes*
Jonathan Buzan
Benjamin Cassady
Christina Crume
Seth Edman
Sean Farnum
Angela Frinfrock*/***
Jon Gamble
Lisa Gerencher
Robert Grebe
Noah Hammond*/***
Ryan Haupt
Lucas Joel***
Laura Jury
Shayna Kram
Charlie Lewis
Aaron Masters**
Kathleen McIvor
Devon Orme*/***
Matthew Panconi
Charlie Richmond
Scott Rohlf
Lauren Shumaker**
Paul Talmage
Chris Taylor*
Katharine Turkle
Melissa Usack**
Wesley Yuen

* Honors

** Highest Honors

*** Thesis Honors

Undergraduate Awards

Kathryn D. Sullivan scholarship
Devon Orme
Lauren Shumaker

Holly Day Barnett Memorial Grant
Alicia Muirhead
Devon Orme

Kenneth and Ann Thimann Scholarship
Aaron Masters

Association of Women Geologists Outstanding Woman Geoscientist
Melissa Usack

Santa Clara Valley Gem & Mineral Society Scholarship
Alicia Muirhead

Weber-Holt Grants
Jon Gamble, Lisa Gerencher, Ryan Haupt, Lia Lajoie, Aaron Masters, Jessica Tibor, Katherine Turkle, Kevin Walker

NAGT Field Grant Award
Lauren Shumaker

Dean's Award for Honors Thesis
Noah Hammond
Jamye Simmons

Graduate Awards

Waters Award
Nicholas Van der Elst
ARCS Award
Calla Schmidt
Campus-wide outstanding TA
Darren Tollstrup
Chevron Fellowships
Yaofeng He
Jacob Walter
Guangshen Zhuang

Melissa, Lauren, Devon, Alicia

Left to right: Sora Kim, Katie Snell, Rachel Brown, and Megan

Casey and a group of ancient graduate students.

Recent Graduate Degrees

Megan Avants, *Shear-wave velocity structure of the D" region beneath the Central Pacific*, MS 2005

Steve Bohaty, *Middle Eocene to Early Oligocene Paleoceanography of the Southern Ocean: Critical events in the greenhouse to icehouse transition*, Ph.D. 2006.

Lindsey Chambers (Bruesch), *Numerical Modeling of Saturn's Satellites and Ring System*, Ph.D. 2008.

Sarah Bryant, *Regional climate response to three different representations of preindustrial land cover in the western US*, MS 2005

Jun Cao, *Toward a Wave-equation Based True-reflection Imaging*, Ph.D. 2008.

Carla D. Chenault, *Understanding the Implications of Changing Sediment Supply and Climate Oscillations on Beach Width in the Oceanside Littoral Cell*, Ph.D. 2007.

Sarah Clifthorne, *Modeled climate sensitivity to vegetation distribution in the early Eocene*, MS 2005.

Brooke Crowley, *Tracing the isotopic rainshadow and elevation history of the Sierra Nevada mountains, CA*, MS 2005.

Martha Evonuk, *Numerical modeling of convection in the interiors of giant planets*, Ph.D. 2006.

Kena L. Fox-Dobbs, *The Foraging Ecology of Late Quaternary Mammalian and Avian Carnivores: A Stable Isotope Approach*, Ph.D. 2006.

Sarah Hall *Observational Studies of Microphysics and Dynamics of Warm Cumulus Clouds*, Ph.D. 2009.

Samantha Hansen, *Crustal and Upper Mantle Structure of the Red sea and Arabian Peninsula*, Ph.D. 2007.

Shawn Hart, *Exploring an impact origin for the Martian crustal dichotomy,* MS 2007

Christine E. Hatch*, Spatial and Temporal Dynamics of Surface Water-Groundwater Interactions Using Time -Series Analysis of Streambed Thermal Records in Coastal Streams*, Ph.D. 2007.

Ian Howat, Physical *controls on the sensitivity of snow and ice to climate change*, PhD 2006

Alexamder Hutko, *Deep reflections: Imaging Reflectors in the Lowermost Mantle Using One-and Three-dimensional Stacking Techniques*, Ph.D. 2008.

Michael Hutnak, *Heat and Fluid Flux at a Crustal Scale; Observations and Models of Coupled Transport in Young Oceanic Lithosphere*, Ph.D. 2007.

James Jacobson, *Using Master Multispectral to Detect CO2 and Methane above a Virtual Pipeline,* MS 2007

Erin Kraal, *Alluvial fans and shorelines: Using geomorphology to understand the climate history of Mars*, PhD 2006

Patrick Limber, *A sediment budget for the Santa Cruz littoral cell, revisited*, MS 2005

Heather McCarren, *Paleoceanographic Variability of Extreme Climates in the Early Paleogene,* Ph.D. 2009.

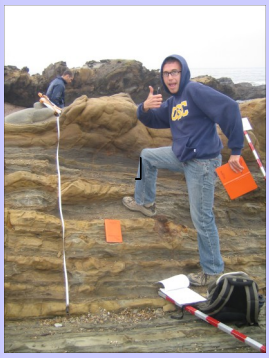
Neomi M. Mustain, *Grain Size distribution of Beach and Nearshore Sediments of the Santa Barbar Littoral Cell: Implications for Beach Nourishment*, MS 2007.

Seth Newsome, *The shifting baselineof fur seal ecology in the Northeast Pacific Ocean*, PhD 2005

Darcy Ogden, *Explosive Volcanic Eruptions: Does Vent Pressure Change Everything?* Ph.D. 2008.

Lissa Ong, *Volatile Retention and Atmospheric Erosion from Cometary Impacts,* MS 2007.

Justin D. Peterson, *Geophysical Survey of Great Slave lake, Canada: Evaluation of its Potential as a Subglacial Paleolake*, MS 2007.



Lucas Joel happily measuring a strat section at Point Lobos

How do you map in this stuff??

Recent Graduate Degrees

Eleyne Philips, *Exploring Rippled Scour Depressions offshore Huntington Beach, CA,* MS 2007

David L. Revell, *Regional Beach changes and Storm Event Response in the Santa Barbara Sandshed*, Ph.D. 2007.

Catherine Plesko, *Automated Feature Detection and Hydrocode Modeling of Impact-Related Structures on Mars, PhD*

Juliana M. Rokosky, *The Anisopropic Structure of the Lowermost Mantle Beneath the Cocos Plate*, MS 2007.

Christen Rowe, Snapshots *of the Earthquake Cycle: An approach to Subduction Zone Paleo-seismicity*, PhD 2007

Christopher Ruehl, *Stream Bed Seepage, River Chemistry, and Nitrogen Cycling in the Pajaro River, Central California,* PhD 2007

Delia L.. Santiago, *Eruptive Hydrologic Climate Change on Mars: Climatic Impact and Water Transport After Outflow Events*, MS 2007

Robert G. Sigler, Surface *Water-Groundwater Interactions in the Pajaro Valley as Determined Using Natural and Injected Tracers*, MS 2007.

Jennifer Small, *Observational Studies of the Mocrophysics and Dynamics of Warm Cumulus Clouds*, PhD 2009

Bridget Thrasher, *Regional Climate Modeling Studies of Western North America under Early Eocene Conditions,* 2009

Darren Tollstrup, *Hotter than You'd Think: What Backarc Basalts Tell Us about the Fate of the Subducting Slabs,* PhD 2009

Jason Woodcock, *Petrogenisis of Enriched Mid-Ocrean Ridge Basalts at the Endeavour Segment, Juan de Fuca Ridge,* MS 2007

Yingcai Zheng, *Imaging Upper Mantle Discontinuities and Earth's Small-scale Heterogeneities*, PhD 2007

Hellatite returns . . .

Some of you might remember Hellatite and I think you will be happy to know that a geology club has found its way back to UCSC. I started this club with two goals, I wanted to bring together all students that were passionate about geology and create a group that would stand the test of time. This year we have had a lot of professors talk about their research and give us tours of their labs. Watching documentaries at meetings has been a great way to learn more about topics that the club finds interesting. We also went on a field trip up highway 1 with the infamous Jerry Weber and learned all about the geology of the central coast. Lately we have been taking advantage of our seniors in the club and having them talk about their research and show us the labs they work in. We also went on a rock climbing excursion to Pacific Edge. After one year on campus we have found a great core group of students who are ready to continue the club next year.
Alicia Muirhead, President

Annual Alumni Event at Fall AGU

Tuesday, December 15, 2009
Thirsty Bear Brewing Company
661 Howard Street
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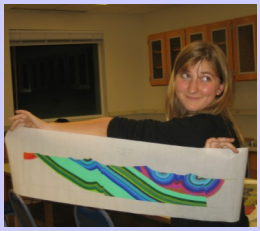
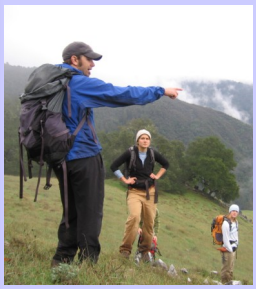
Katharine Turkle Doing field work



Lauren Schumaker demonstrates her cross-section.



Jeremy Hourigan, points downslope to Melissa Usack

Casey tends the BBQ at summer field

Some notes on this year's graduating class (by Devon Orme)

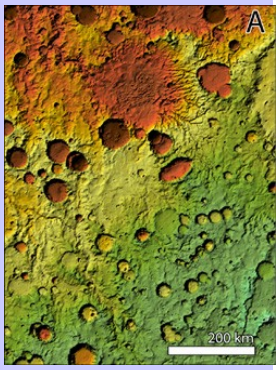
As always, this year's graduating class comprise a myriad of scholars. From those who model lunar impacts to those who study microfauna, each is leaving UC Santa Cruz with a unique perspective of Earth Science systems and processes. In addition, each of us leaves with countless memories of late nights in Earth and Marine Sciences, death marches across the slopes of California and endless campfire stories. I know I can speak for most when I say that the minerals in 110 B "wowed" us, the applied calculus in 110C pushed us, and the capabilities of technology in 107 amazed us. Field classes were exhilarating and computer classes brought new perspectives. Regardless of what path each graduate took through the Earth Science major, each has specific memories they will never forget.

Personally, it is hard to speak of only a few moments that have stood out in my mind as everyday I seem to find myself telling a new story. Nevertheless, here are a few memories

Summer field class, 2009: Hat throwing contest

that I share with this year's senior class: (1) Pudding wrestling at summer field camp last July! Without a doubt, this has to be the most ridiculous thing I have done during an Earth Science field class. UCLA professor, An Yin, challenged us to a pudding wrestling match right smack in the middle of the White Mountains! Girls, boys and An Yin had an absurd time making an absolute mess of a "kiddy pool"; (2) Melissa Usack falling into the San Lorenzo River on a hydrology field trip. While attempting to survey the stream profile, Melissa took a dip, fully clothed into the river. The sight was hilarious and made the rest of the work day a lot of fun; (3) Jeremy Hourigan towing two porta-potties with his Subaru Forester out to New Idria and back for his first field class in 2007—the key words here, "and back". Although somewhat disgusting, it made for some really good jokes; (4) finally, ice skating during the middle of the day at AGU this past December. A group of us undergraduates had the thrill of attending AGU either as poster presenters or simply as students who wanted to see what the bigger world of Earth Science academia really entailed. It may seem silly, but leaving the hustle and bustle of the Moscone Center for a quick ice skating adventure between sessions was unforgettable.

Fond memories aside, I must speak specifically about a few of the accomplishments of this year's undergraduate class. Noah Hammond had the great opportunity of giving a talk at LPSC in March for his senior honors thesis work of lunar impacts. Melissa Usack was named this year's AWG award winner and honored at an award ceremony in Oakland. Lauren Shumaker was accepted to a NAGT-USGS program in Denver, Colorado, where she started in June, 2009. I have a feeling many of the graduates will be pursuing graduate school in the future, but for now myself and Aaron Masters will be beginning the next stage in our education at the University of Arizona and the University of Wisconsin, Madison respectively. Noah, Melissa, Lauren, Aaron and I only represent a small portion of our senior class, but we hope that our accomplishments inspire our fellow graduates, as well as younger classmen, to continue pursuing the field of Earth Science. The knowledge we have acquired provides the basis for an understanding of Earth's future and the need for careful management of its resources.



Ancient river-like features called valley networks carve the surface of Mars, as seen in the image above of the Parana Valles, which cuts across a region roughly the size of California.

By Charles Barnhart

Why Earth and Planetary Sciences?

By Eli Silver

Many departments have changed their names in recent years, in order to be more trendy, attract more students, or to try to reinvent themselves. However, the Earth Sciences department at UCSC, which for many years has offered an outstanding program to a large number of students (see article by Casey Moore and Bob Garrison in this issue) has recently changed names to actually express the nature of the present department. In addition to existing faculty who study the planet as a whole (Thorne Lay, Quentin Williams, Elise Knittle, Gary Glatzmaier, and Rob Coe) we have recently hired three outstanding new faculty whose focus is planetary science: Erik Asphaug (Asteroids and Planet Formation), Francis Nimmo (dynamics of planetary surfaces), and Ian Garrick-Bethell (the Moon).

Actually, the change is catching. Around 10 years ago I became interested in airborne and satellite remote sensing, and now teach a course in remote sensing. One of my graduate students, Nancy McKeown, is using remote sensing data from the Mars Reconnaissance Orbiter to map the distribution of phyllosilicates in ancient Martian deposits, showing the history of abundant water on that planet. So we truly are an Earth and Planetary Sciences department.

Annual Alumni Event at Fall AGU

Tuesday, December 15, 2009
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661 Howard Street
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View of the Earth and Marine Sciences Building, as seen from the main entrance.

Photo taken October 23, 2009 by Marissa Marciel

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This new fund (established in 2007) honors Emeritus Prof. Casey Moore. It supports targeted grants for independent research by graduate and undergraduate students.

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This fund is a tribute to undergraduate alumna Holly Day Barnett. Awardees (advanced undergraduates) have traits in common with Holly's: outdoor hobbies, leadership skills, and interests in environmental Earth Sciences.