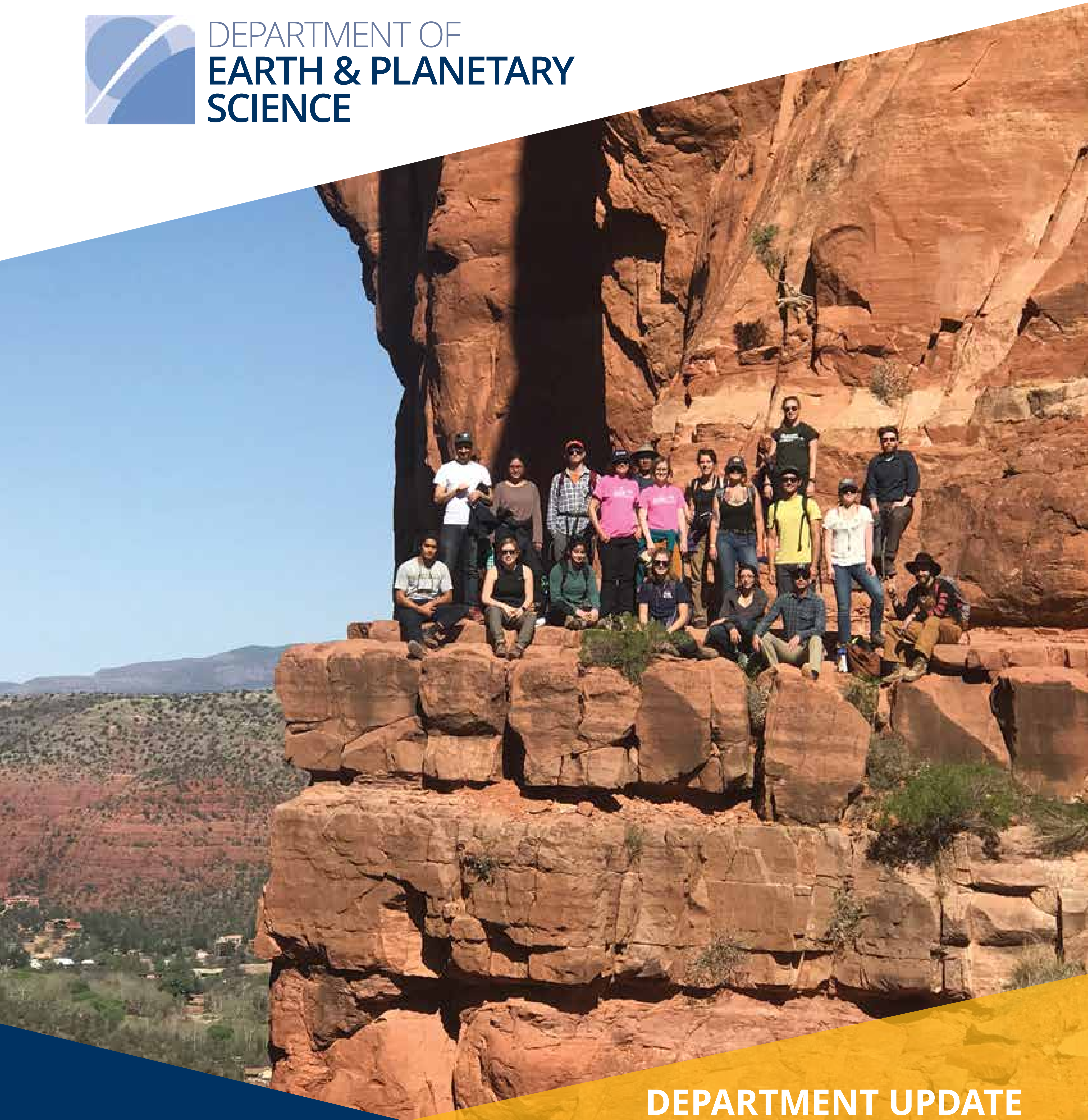
DEPARTMENT OF
EARTH & PLANETARY SCIENCE



DEPARTMENT UPDATE
2017 -2018

Berkeley
UNIVERSITY OF CALIFORNIA

FROM THE CHAIR

WELCOME TO OUR ANNUAL UPDATE

I write this introduction after returning from our summer geology field camp. What a treat. I met many of the students when they took their first geoscience class, EPS 50. The capstone field course showed how much these new alumni have grown during their time in EPS to develop into creative and talented geoscientists. On page 13 we hear from one of our 66 new graduates, Departmental Citation recipient Theresa Sawi, about her efforts to understand how earthquakes influence volcanic eruptions.

Our faculty, students, staff and alumni continue to make our department one of the world's best. Our newest faculty member, Bethanie Edwards (page 3), broadens the department's expertise to include marine biogeochemistry. Along with the arrival of Bill Boos and Daniel Stolper two years ago, we continue to expand our efforts to understand all aspects of Earth's changing climate.

There have also been some losses. After 36 years, Tim Teague retired. He may be irreplaceable, but we will try. After three years of dedicated service, always with a smile, Richard Allen's term as chair ended, and he will continue to direct the Seismological Laboratory. Mark Richards moved to Seattle where he is the University of Washington's provost.

Accolades continue to pour in, and I highlight a few. The American Geophysical Union recognized recent Alumnus Leif Karlstrom with the Kuno Award (page 16) and Professor David Romps with the Atmospheric Sciences Ascent award. Former student Laura Lammers received the Mineralogical Society of America Award. Professor Inez Fung received the American Meteorological Society's highest honor, the Rossby Medal. Professor Jill Banfield was elected to the Royal Society. Professors Ron Cohen and Paul Renne became fellows of the American Association for the Advancement of Science. Professor Bruce Buffett was elected to the American Academy of Arts and Sciences in the same class as President Obama. Kristie Boering and I were elected to the National Academy of Sciences bringing the department total to 10 National Academy members. Faculty and students are being recognized across all the fields covered by the department, and featured in this year's update: geology, geophysics, atmospheric science, marine science, environmental earth science, and planetary science.

Michael Manga

The geosciences remain as important as ever, from mitigating natural hazards to understanding those we bring upon ourselves. And the new fundamental discoveries enabled by space exploration (page 7), big data (page 8), interdisciplinary science (page 6) and new instrumentation (page 9) show how much more there is for us in EPS to learn. I am honored to be part of the group that is leading the way.

CONNECT WITH US

Please keep us updated and share a sentence or two for next year's annual update at eps.berkeley.edu. Our department's legacy is the success of our alumni. So please keep us informed and feel encouraged to share your suggestions and recommendations. The costs of field experiences remain a barrier to providing an inclusive education. We remain committed to providing the best field education we can to all students.

Photo: Mud volcanoes in the southern Imperial Valley, California. Taira et al. (Science Advances 2018) showed that monitoring ambient seismic noise can be used to monitor changes in the underlying geothermal system.
Cover Photo: Don DePaolo's EPS 119 field trip to Arizona with the Spring 2018 class standing on 272Ma Fort Apache Limestone, interbedded with sandstones of similar age to the Schnebly Hill Formation.

WELCOME

GET TO KNOW OUR FACULTY

Bethanie Edwards

BETHANIE EDWARDS

I am a sea-going microbial oceanographer who takes an integrated approach to my research, pairing various meta'omics analyses with biogeochemical techniques to query the marine biological pump from multiple angles. My overarching research objective is to understand how microbial interactions impact the fate of carbon in the ocean.

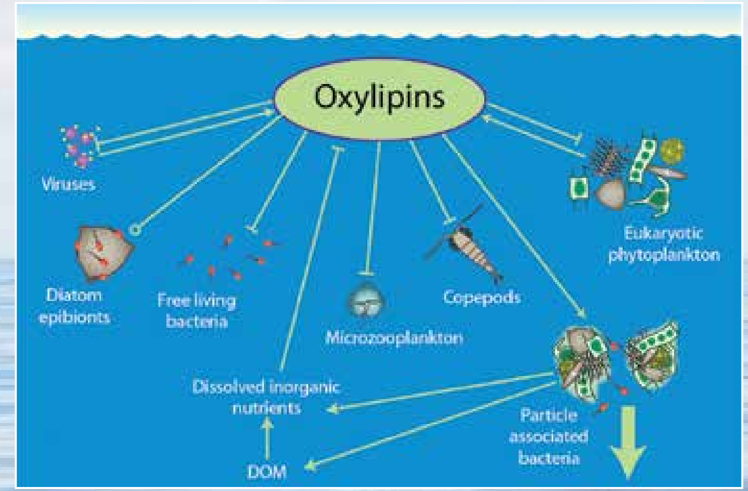
The ocean acts as a sink in the global carbon cycle largely because of the complex interactions between the microscopic organisms that make up the biological carbon pump. Phytoplankton in the surface ocean fix CO_2 into organic carbon which is exported to depth when these organisms die due to nutrient stress, grazing by micro- and meso-zooplankton, or viral infection. As this exported organic carbon sinks to the deep ocean, it is degraded by heterotrophic bacteria and grazed by zooplankton. It is estimated that between 9-22% of carbon fixed by phytoplankton in the surface ocean actually makes it below 500 m where it can be sequestered from the atmosphere for an appreciable amount of time. Understanding the processes that control the efficiency of the biological carbon pump and variability in carbon sequestration is centrally important to constraining the ocean's role in global carbon cycling.

LIPIDOMICS

My expertise is in lipidomics, the youngest -omics subfield. Most people are familiar with lipids as fats in our food and as fuel sources. Or, perhaps you remember from General Biology that lipids play an important structural role in cellular membranes making up the phospholipid bilayer. Many chemical signaling molecules such as hormones and compounds used in cellular stress response are lipid derived. Lipids are quite diverse both structurally and functionally.

My lab looks at lipids as biomarkers of microbial community composition, cellular stress, and environmental conditions in marine systems. Membrane lipids and pigments can be used to describe the community composition. Furthermore, isotopic analysis of fatty acids can be used to differentiate between chemoautotrophic and heterotrophic lifestyles. Membrane lipids and their breakdown products, oxylipins, can be used as biomarkers of various types of stress (nutrient limitation, viral infection, grazing, UV damage, temperature). As a PhD student at Woods Hole Oceanographic Institution, I developed a lipidomic approach that allows for the quantification of the wide range of lipid species that might be encountered in culture and in seawater. My lab is pushing the field of environmental lipidomics forward by integrating more sophisticated mass spectrometry and bioinformatics pipelines. We are interested in developing an index based on these biomarkers to quantify phytoplankton bloom dynamics such as bloom decline due to grazing or viral infection.

continued on next page



The impact of lipid-derived chemical signals, oxylipins, on various levels of the marine microbial food web. Oxylipins are produced by eukaryotic phytoplankton called diatoms and are known to inhibit the growth of competing phytoplankton, inhibit the growth of free-living marine bacteria, stimulate organic matter degradation by particle associated bacteria, deter microzooplankton grazing, and decrease the reproductive success of copepod grazers. All of these marine microbes play central roles in the biological pump by which carbon is cycled through the ocean.

I am building an integrated meta'omics lab which means we will be integrating metabolomics, proteomics, genomics, and transcriptomics into our laboratory experiments and field work. We hope to utilize the strong local technological community to harness network learning analysis and machine learning in our data analysis as integrating multiple big data sets presents unique challenges. Proteomics, genomics, and transcriptomics will be done in collaboration with QB3 facilities on campus. Metabolomics will be a new venture for the lab. However, our lab is equipped with an Orbitrap Tribrid ID-X High Resolution Accurate Mass (HRAM) mass spectrometer which came on the market this year for small-molecule discovery making it ideal for analyzing lipids and metabolites. The instrument used by QB3 facilities for proteomics is a predecessor to this instrument and both use Fourier transform algorithms to detect the exact mass of compounds to the 5th decimal place. Such precision allows us to confidently assign an elemental formula to each species and fragmentation and retention time allows us to have enough information to assign an identity to each molecular species. Compared to DNA and RNA based 'omics which have sequences of only five chemical compounds (G, A, T, U, C), metabolomics and lipidomics have tens of thousands.

UPCOMING FIELD CAMPAIGNS

While I do experiments in culture including genetic engineering of lipid synthesis in model diatom species using CRISPR, our laboratory work is always geared towards testing hypotheses about ocean biogeochemistry and microbial dynamics observed on research cruises. The first phase of developing my field program relies on tapping into existing time-series along the California Coast. We expect to start sending people to sea in early 2019. Our future field expeditions include the San Pedro Ocean Time-series (SPOT; USC), Monterey Bay Aquarium Research Institute (MBARI), and the California Current Ecosystem-Long Term Ecological Research Station (CCE-LTER). I was recently asked to be a part of the working group on Coastal Blue Carbon led by Professor Jiao from Xiamen University. We are hoping to build a network of coastal time-series that share data, sampling protocols, and research opportunities. Most research efforts to constrain Blue Carbon have been focused on mangroves and seagrass environments. However, carbon fixed by phytoplankton in coastal ecosystems can be important especially in regimes were water can be advected off the continental shelf to offshore environments where depths reach greater than 500 m.

~~BOYS~~ GIRLS AND THEIR TOYS

As we learn more about the physiology of marine microbes, developing new sampling modalities has become a crucial part of ocean exploration and the field of ocean biogeochemistry. We are collaborating with Jim Bishop in EPS at Berkeley to study carbon export in the CCE-LTER using his autonomous sampling robots, the Cal-Carbon Flux Explorer. We will use integrated meta-omics to tease apart mechanisms of phytoplankton bloom collapse and the distinct impact of each mechanism on carbon export. The Edwards lab is also collaborating with Rick Keil at University of Washington to build sediment trap chambers for in situ isotopic labeling experiments. We will use the 3D printing resources at Berkeley as we develop these new sampling devices. Lastly, I have an interest in using sail-powered research vessels to collect data, putting our money where our mouth is as oceanographers and some of the biggest proponents of climate focused policies. As an alumna of the Sea Education Association (SEA), I am working out collaborations to create opportunities for Berkeley students to sail with SEA and collect 'omics data on cruises and apply bioinformatics to their large dataset reaching back as far as 1973. Furthermore, I hope to build stronger relations with the Gump Research Station which lies in the Eastern Tropical South Pacific Cold Tongue, a biogeochemically important feature related to La Niña years of ENSO cycling (SEA's SSV Robert C. Seamans periodically does cruises through this region).

Long term I am interested in microbial dynamics in areas of Deepwater formation. This idea actually came to me through conversations with Don DePaolo during my interview at Cal. If we are interested in carbon export, what better environment to study than the regions where water is transported to depth and carbon is more efficiently exported. Therefore, I expect to expand my research program into polar regions in the next five years.

DIVERSITY OF THOUGHT IN EARTH SCIENCE

I am an unlikely oceanographer, a biracial child born to a decidedly blue-collar family in the 1980s rural South. However, education is a powerful thing. It has afforded me socio-economic mobility, agency over my future, and the opportunity to do work that I find fulfilling and meaningful. As a visible minority in science, this is a gift that I feel compelled to share with others. I look forward to being a springboard for any Berkeley student with an inkling of interest in science and increasing the diversity of thought within the larger earth science community. I have a strong academic service record, organizing several events during graduate school aimed at advancing women in STEM and co-founding the Society for Women in Marine Science (SWMS) with Sophie Chu (University of Washington) and Penny Chisholm's postdoc Alexis Yelton (MIT). SWMS just held their 5th annual Fall symposium and has expanded to 9 chapters and 400 members across 80 institutions. I have an enthusiastic group of undergraduate female scientists that are meeting to organize a Berkeley chapter of SWMS. Our first order of business is to plan an informal networking event, "Swimming Lessons", where female faculty from the Bay area will give short talks on their career trajectories. The idea of these events is to create an environment where women can network and exchange scientific ideas, combating the 'Old Boys Club' that has been oceanography. I am also plugged into Bay Area non-profits Brown Girl Surf and Black Girls Code with the aim of increasing the intersectionality of the feminist movement in STEM fields. In addition to increasing social equity, recent research efforts in the areas of psychology have shown that collaboration amongst people from diverse backgrounds leads to diversity of thought, higher output, and overall better science[1]. I am excited to contribute as an agent of organization and action, as we push to optimize the scientific community in terms of novel discovery and inclusion.

1 Medin DL and Lee CD. 2012. Diversity Makes Better Science. Association for Psychological Science Observer

Dr. Edwards climbing the ratlines aboard the SSV Robert C. Seamans on a transect from Puerto Vallarta, Mexico to Papette, Tahiti in 2007-2008 with Sea Education Association SEA. (Photo credit: Amy Comer Flowers)

Aboard the HMS Atlantic Explorer in 2011, retrieving a surface tethered net trap that was used to collect sinking particles exported from the surface ocean to 150 m deep in the Sargasso Sea.

CTD rosette equipped with Niskin bottles which are used to collect seawater at various depths in the ocean.

MARINE SCIENCE

RESEARCH SPOTLIGHTS

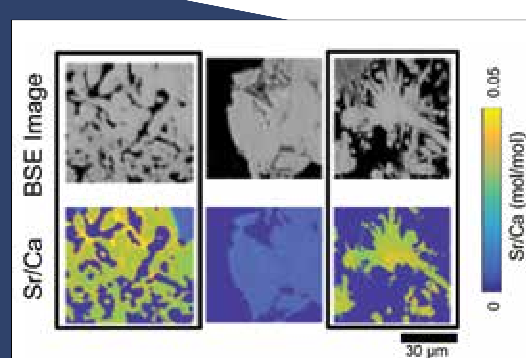
GEOLOGY

GEOLOGY
LIZ MITNICK, GRADUATE STUDENT


Liz Mitnick

I am a PhD candidate working with Don DePaolo (EPS) and Laura Lammers (EPS alumna, currently Assistant Professor in the Department of Environmental Science, Policy, and Management). Over the past five years, I have had the opportunity to work on a variety of interesting projects related to the formation of abiogenic carbonates in terrestrial and marine environments, as well as in the lab. I address questions relating to Earth history and interpreting isotopic signatures in the geologic record, diagenesis and recrystallization of marine sedimentary carbonates, calcite and aragonite formation in travertines, and trace element and metal isotope partitioning into carbonate minerals. These topics may seem disparate, yet they are intimately tied to one another. Large-scale processes are simply the integrated effect of many small-scale processes and reactions linked together. Working at different scales is a useful means of bridging the divide between what we understand at the molecular scale and what we observe in the field or a global context, and similarly, what happens in a nanosecond and what has occurred over Earth's history.

One of my favorite approaches is to use spatially resolved measurements with the electron microprobe in conjunction with bulk analyses of natural materials to understand trace element partitioning into different mineral phases. I am currently employing this technique to quantify the relative amounts of calcite and aragonite (two polymorphs of $CaCO_3$) that form along the crestal conduit of an active travertine deposit in the eastern Sierras. In concert with bulk measurements of calcium isotopes using thermal ionization mass spectrometry, we can then quantify kinetic fractionation of calcium isotopes into calcite and aragonite from the surrounding fluid at temperatures between 50 and 70°C. In conjunction with results from my calcite growth experiments in the lab, we hope to be able to tease apart kinetic fractionation effects due to temperature from those due to fluid chemistry.



Sr/Ca elemental ratio and backscattered electron (BSE) maps of aragonite and calcite found in travertine ridge. Map dimensions approximately 60 x 60 μm.


Looking down the crestal conduit of a "whaleback" travertine fissure ridge (conduit width ~3 cm).

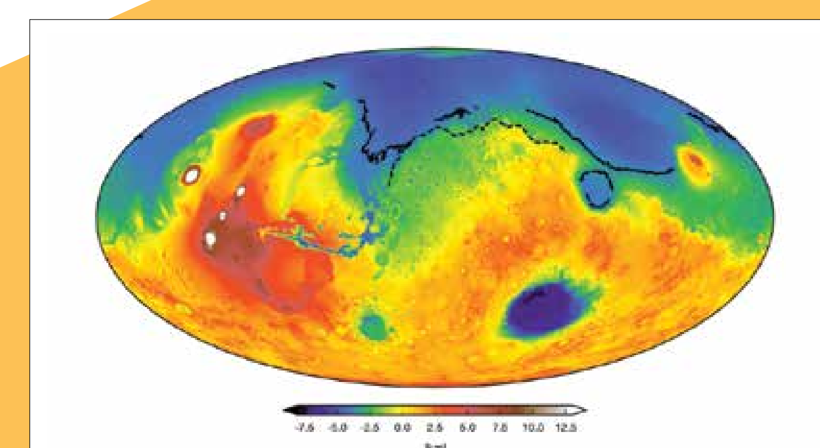
PLANETARY SCIENCE
ROBERT CITRON, GRADUATE STUDENT


Robert Citron

Whether or not Mars was warm enough in its early history to support large oceans remains controversial. Perhaps the most compelling evidence for ancient Martian oceans are hypothetical paleo-shorelines that border the northern lowlands. However, the shorelines fail to follow an equipotential surface, which would be expected if they formed via an ocean. I explored how global dynamics can explain the variations (of up to several kilometers) in shoreline topography.

We found that the variations in shoreline elevation can be explained by planetary deformation due to the growth of Tharsis, a large volcanic province that dominates the topography and gravity of Mars. The growth of Tharsis and its associated loading caused global flexure of the planet, and the expected deformation matches the observed deviations of two shorelines, Arabia and Deuteronilus, from original equipotential surfaces. The amount of deformation for each shoreline suggests that the older (~4 Ga) Arabia shoreline was emplaced prior to or during the early stages of Tharsis formation, and the younger (~3.6 Ga) Deuteronilus shoreline was emplaced during the late stages of Tharsis growth.

The notion that the shorelines trace equipotentials when Tharsis loading is included provides evidence that the hypothetical shorelines were emplaced by an ancient ocean. The timing of the shorelines relative to Tharsis volcanism also suggests a close link between the stability of oceans on Mars and volcanic activity. Atmospheric models predict a cold and icy early Mars, however, it is possible oceans may be more sustainable during periods of heightened volcanism. Tharsis activity has also been associated with outflow channels indicative of catastrophic flooding that may have inundated the northern plains with water. Further examination of the link between Tharsis volcanism and oceans could provide insight into early Mars habitability.



Mars topography: The massive Tharsis volcanic province (red) is situated on the boundary between the southern highlands (orange) and northern lowlands (blue). The lowlands may have been covered by one or more ancient oceans, and are bordered by hypothetical paleoshorelines. Two of the most prominent shorelines to be mapped are the older Arabia shoreline (dashed line) and younger Deuteronilus shoreline (solid line). Adapted from Citron et al. (Nature 2018).

PLANETARY SCIENCE

RESEARCH SPOTLIGHTS

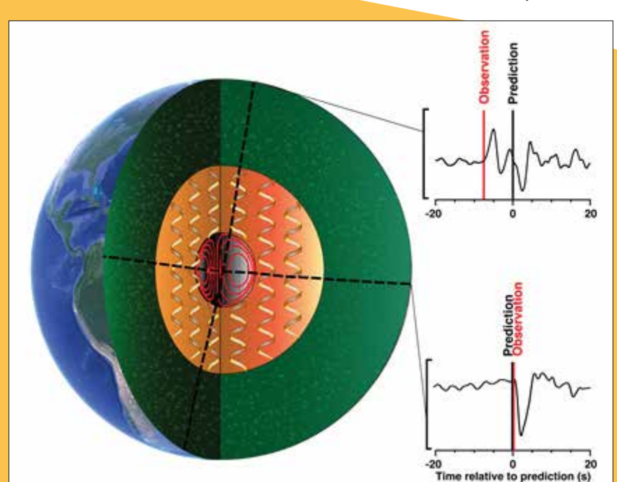
GEOPHYSICS
DAN FROST, POSTDOCTORAL SCHOLAR


Dan Frost

Living on the Earth's surface, it's hard to imagine that our world is sustained by something as remote as the centre of the Earth. But in addition to the existence of a stable atmosphere, which owes its existence to plate tectonics, here on the surface we feel the influence of behaviour of the deep Earth through the magnetic field. The field shields the Earth from charged particles of the Solar Wind, which causes the Auroras. The field is generated deep in the Earth by the core. The Earth's solid inner core is gradually freezing out of the liquid iron outer core. Locking the fluid iron into solid bonds releases heat, which drives rapid movement in the outer core. The motion of the conductive iron sustains the magnetic field, which projects up to the surface. Thereby the growth of the inner core sustains life on Earth.

Much of the research at the Berkeley Seismological Laboratory focuses on the hazards presented by earthquakes. But such events, and the seismometers used to record them, can be used to learn more about the internal structure of our planet. The energy released by earthquakes propagates through the planet, travelling into its very centre. The speed of seismic waves depends on the material through which they travel, thus by observing the seismic wave speed within the core we can determine the properties of the material.

Analysis of earthquakes has shown that speed of waves travelling through the inner core depends on their direction: parallel to axis of rotation waves are faster than those in the plane of the equator. This implies that the material properties are also different, depending on the direction. Our work measuring the variation of travel times of seismic waves has revealed greater details about the structure of the inner core. While most properties of the Earth depend on depth into the centre in concentric shells, our new analysis shows that the material properties depend on distance from the rotation axis in parallel cylinders, with the greatest velocity offset into the western hemisphere of the inner core. Working with other members of EPS we simulate how the growth of crystals of iron in a freezing inner core would affect the seismic wave speed. We propose that slow convection and lateral translation in the inner core, where one hemisphere slowly melts and the other freezes, causes iron crystals to flow in cylindrical patterns, generating wave speeds that match our observations. The pattern of freezing of the core will affect the release of heat into the outer core, and, therefore, the convection and magnetic field. We may be able to track the growth of the inner core in the fluctuations of our magnetic field. Through listening to the sounds of the Earth we will discover how it works today, and how it evolved to its present state.



Left: Model of the convection in the inner and outer cores, based on seismic observations. **Right:** Seismograms demonstrating the earlier arrival of inner core waves travelling north-south relative to traveling east-west, and thus the greater wavespeed parallel to the rotation axis relative to in the equatorial plane.

ATMOSPHERIC SCIENCE
RUSEN OKTEM, RESEARCHER


Rusen Oktem

Shallow cumulus clouds -- those cotton balls that drift overhead on a mostly sunny day -- play a large role in Earth's radiation balance. Their main effect is to cool Earth by reflecting sunlight to space, and this keeps the planet from getting too hot. But, because they play such a large role in today's climate, even small changes to their abundance could lead to big changes in that cooling effect. In fact, climate scientists have identified shallow cumulus clouds as among the greatest sources of uncertainty in the future amount of global warming. If the clouds become more abundant as the planet warms, that would counteract some of the warming (although, not eliminate it). If they become less abundant, that would exacerbate the warming.

One of the key challenges in climate science is to develop accurate theories of these shallow clouds. Because these clouds are much smaller than the grid spacing used in global climate models (GCMs), we must build algorithms that determine how much shallow cloud should be in each grid cell of the GCM at each time step. To build those algorithms, however, we need observational data. And, despite their ubiquity, shallow cumulus clouds are difficult to observe with radar in part because their small water drops reflect very little of the radar pulse. As a result, radar has a hard time seeing these clouds at all.

But, Dr. Rusen Oktem has a solution. As a Project Scientist in the Department of Earth and Planetary Science, Dr. Oktem uses her expertise in computer vision to design stereo-photogrammetric techniques for measuring clouds. Although the details are complicated, the principle is simple: by measuring the position of an object's image in the photographs of two widely spaced cameras, the precise location (x, y, and z) of that object can be calculated by triangulation. This is the same principle that allows our eyes to generate a perception of depth.

Most recently, Dr. Oktem has worked with engineers at the Department of Energy to install a ring of six cameras around the Southern Great Plains (SGP) Atmospheric Radiation Measurement (ARM) site in Oklahoma. These cameras provide views of shallow clouds from all sides; when these data are combined, they allow for a complete stereo reconstruction. The result, called the Clouds Optically Gridded by Stereo (COGS) product, is a 4D grid of cloudiness covering a 6 km x 6 km x 6 km cube at a spatial resolution of 50 meters and a temporal resolution of 20 seconds. This is providing scientists with an unprecedented set of data on the sizes, lifetimes, and life cycles of shallow clouds.


Stereo setup onsite in Oklahoma.

IN THE CLASSROOM

FIELD CAMP WITH BEHNAZ HOSSEINI

Behnaz Hosseini

UC Berkeley's Advanced Field Course (EPS 118) is the capstone course for all geology majors in the Earth and Planetary Science Department. Unlike many traditional field camps, EPS 118 takes a multidisciplinary approach to teach students about the geological history of Long Valley and the surrounding area in the Eastern Sierra Nevada. Among the suite of methods applied by students are geological field mapping, petrographic analysis, and near-surface geophysics including seismic refraction, resistivity, and gravity surveys. Students integrate field observations and measurements with existing data to produce geological maps, models, and stratigraphic columns to address many questions over the course of four weeks:

- What is the relative timing of emplacement and deformation of metasediments, plutons, and dikes in the Benton Range and how does it relate to regional tectonics?
- How is the residual gravity within the Long Valley caldera changing over space and time and what are the subsurface implications of these changes?
- What do macro- and microscopic flow textures reveal about the processes that created the domes at Panum Crater, and what evidence is present for continual ash venting during lava extrusion?
- How are ignimbrites and fall deposits of the Bishop Tuff differentiated, and what does the eruption sequence at the Chalfant Valley reveal about the timing of ignimbrite and fall emplacement?

In addition to addressing these central questions, students learn about other relevant aspects of geology and hydrology in and around Long Valley by visiting hydrothermal areas such as Casa Diablo and Hot Creek. This year, interested students were invited to observe the installation of a helium isotope detector near Horseshoe Lake and to learn about the history of gas monitoring at Mammoth Mountain.

I had the opportunity to be the teaching assistant for EPS 118 this summer after having taken the course two years prior. As a teaching assistant, I became aware of some of the great successes of the course structure:

- Due to the multidisciplinary and collaborative nature of the course, students introduce one another to different methods of reasoning to address questions.
- Students are encouraged to form original hypotheses that are supported by their field observations, measurements, and breadth of knowledge. In other words, the objective of the assignments is not necessarily to substantiate existing literature.
- Students are advised to frame problems in a broader context by considering analogs at other geological field sites.

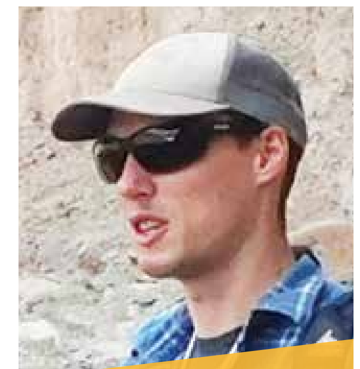
EPS 118 was as invaluable to me as a teaching assistant as it was to me as an erstwhile student. I often learned from the students more than I could impart to them, and was impressed by the critical thinking and teamwork that will give these students a leg up in their science careers.

Students approach the east-central shore of Lake Crowley to examine the evenly-spaced columns within the Bishop Tuff. Photo credit: Mary Lonsdale. June 18, 2018.

Lake Crowley. Photo credit: Steve Self. June 18, 2018.

Students and instructors take a break from mapping block-and-ash flow deposits to convene for a group photo to the north of Panum Crater. Photo credit: Behnaz Hosseini. June 15, 2018.

NICK'S DEATH VALLEY TRIP

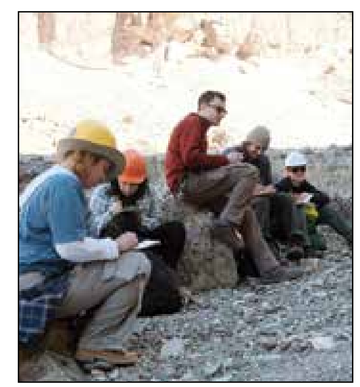


Nicholas Swanson-Hysell

The Death Valley region is host to remarkable modern-day surface processes, active tectonics, sedimentary successions and ancient crystalline basement of the Mojave Province. Among the many lines of geological investigation that the curious Earth scientist can pursue in Death Valley, the region has emerged as a natural laboratory for understanding a crucial period of Earth history known as the Neoproterozoic (1000 to 541 million years ago), when animals emerged on Earth's surface and during which there were the most extreme shifts in climate that have been documented in the geologic record. Led by Prof. Nick Swanson-Hysell and graduate students Yuem Park and Alex Bryk, students in EPS 115 (Stratigraphy and Earth History) spent Spring Break in the Death Valley region for a course field trip. The instructors and students stayed south of the park at the Shoshone Education and Research Center (SHEAR) and pursued investigations both within the park and on public lands to the south of it. They investigated modern and geologically recent alluvial and lacustrine depositional processes in the Badwater and Tecopa Basins. They measured stratigraphic sections through ancient Pahrump Group sedimentary rocks that record the conditions before, during and after Snowball Earth glaciation ca. 700 million years ago. Their stratigraphic logging skills had been developed closer to Berkeley on the Miocene Orinda and Mulholland Formations on previous course field trips and were put to good use through a thick succession of the glacigenic Kingston Peak Formation.

As a capstone to the field trip and the course, the students conducted group research projects utilizing the interpretive field skills and knowledge of sedimentary processes they have been building up in order to develop new insights into Earth history. In contrast to field trips that are conducted in a "show and tell" style focused solely on transmitting content, these projects provided students with a research experience focused on student-led discovery. In the field, students developed data through geologic mapping, the measurement of stratigraphic sections and sample collection paired with careful observation. Back in Berkeley, students generated petrographic, magnetic and geochemical data within labs in the EPS Department and Berkeley's Center for Stable Isotope Biogeochemistry. One group, Team Olistolith, mapped out large slide blocks that had been deposited into an active extensional basin during Snowball Earth glaciation for their project. Through observations of lithofacies and the development of carbon isotope data, they were able to document changing source formations for the blocks and inferred that this change was likely due to progressive erosion of the footwall of a basin-bounding normal fault. Another group, Team Tecopa, investigated Pleistocene lake sediments containing multiple volcanic tuffs. They used magnetic susceptibility measurements to develop fingerprints of the different tuffs and combined these data with petrographic data to determine the transition from airfall ash to reworked ash containing detrital grains within the lake sediments. They also discovered beautifully preserved ripples within the Lava Creek Tuff (sourced from Yellowstone) that revealed the currents within the lake at precisely the moment of the Tuff airfall. Team Oncoid focused on shallow water carbonate sedimentary rocks hosting beautiful microbially-induced sedimentary structures. They used lithostratigraphic and carbon isotope data to constrain time variability associated with a major flooding event that drowned the ancient carbonate platform. Team Dropstone used paleocurrent measurements and petrographic data to determine the source locations of clasts that were delivered by both debris flows and ice-rafting into a Neoproterozoic glacial deposit.

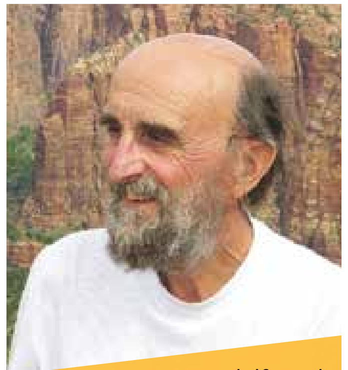
Student evaluations highlighted the significant and unique educational value of the hands-on experience they gained during the field trip. The importance of an interdisciplinary approach to advances in the geological sciences demands that the current generation of geoscience students are trained with an approach that combines field-based exposure to geology with the quantitative skills necessary to apply geochemical and geophysical data to Earth science problems. Field trips like this one that seek to implement such an approach are therefore a priority of our teaching efforts in EPS.



EPS 115 students take notes of their observations and measurements within an incised debris-flow-dominate alluvial fan above Badwater Basin in Death Valley National Park.

Exposure of the Badwater alluvial fan within a recent fault scarp leads to excitement in the field. Right, Dakota Churchill (EPS undergraduate); Left, Alex Bryk (EPS PhD student).

RUDY'S FRESHMAN EPS 39 TRIP


Hans Rudolf Wenk

It was back in 1990 when UC Berkeley introduced freshman seminars. The Department decided to approach this with a 4-day fieldtrip to get new students enthusiastic about geology in a state where geology is not taught in high school. Davey Jones prepared us for a field trip through the goldrush country with spectacular sites, combining history and field geology. For almost 30 years these courses have been heavily oversubscribed and attracted many majors. Looking at rocks and landscapes is an excellent environment for students to communicate with instructors and exchange ideas.

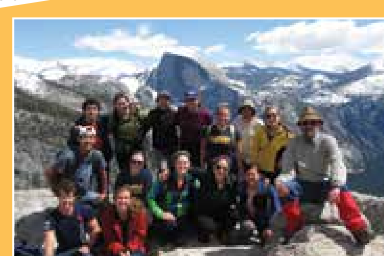
I have been teaching EPS 39 in different settings, often ending in Yosemite, sometimes crawling in snow. Other destinations included Telescope Peak in Death Valley, exploring basin-and-range plate tectonics and volcanism in the Eastern Sierra, such as the spectacular pillars at Crowley Lake. This year we went to Southern California, driving south in heavy rain.

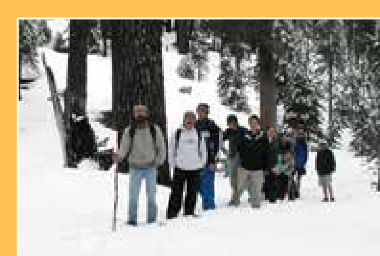
Our first stop was Boron, currently the largest open pit mine in California with unique minerals such as kernite, ulexite and colemanite. We camped in the Kelso dunes in the Mojave Preserve and the next day watched a spectacular sunrise from the highest dune with fresh snow on peaks in the background. Then a stop at Amboy Crater, now within the new Mojave Trails National Monument – the largest National Monument in the U.S. after the President closed Monuments in Utah. From this young volcano on to granites of Joshua Tree National Park, and the San Andreas Fault East of Indio.

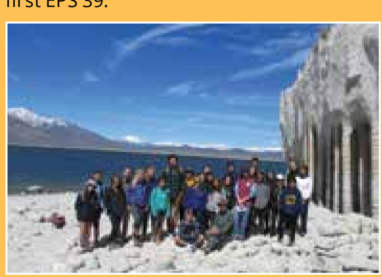
The next day we explored the large Martinez Mtn. landslide, the amazing red desert varnish on surface pebbles caused by organic manganese oxides, and pseudotachylites, caused by frictional melting during earthquakes. I first came in contact with these mysterious rocks when I explored mylonites in Central Australia with Lionel Weiss in 1974.

The field trip included a visit to the Salton Sea mud volcanoes that were investigated in detail by Michael Manga and our alumnus Max Rudolph (see page 2). Overall this trip included a wide variety of geological features, from borax mines to mud volcanoes, sand dunes to landslides, active faults to fossil earthquakes. Hopefully, it inspired students to become involved in solving some of the many remaining puzzles about the Earth. Fieldwork of students at all levels has been greatly helped by support from alumni.


1990 Davey Jones, George Brimhall, Rudy Wenk and Don DePaolo preparing the first EPS 39.


2014 EPS 39 on Yosemite Point.


2004 On the way to North Dome.


2015 Pillars at Crowley Lake.


2018 Sunrise on Kelso Dune.


2018 Salton Sea mud volcanoes.

COMMENCEMENT 2018
THERESA SAWI, DEPARTMENTAL CITATION


Theresa Sawi

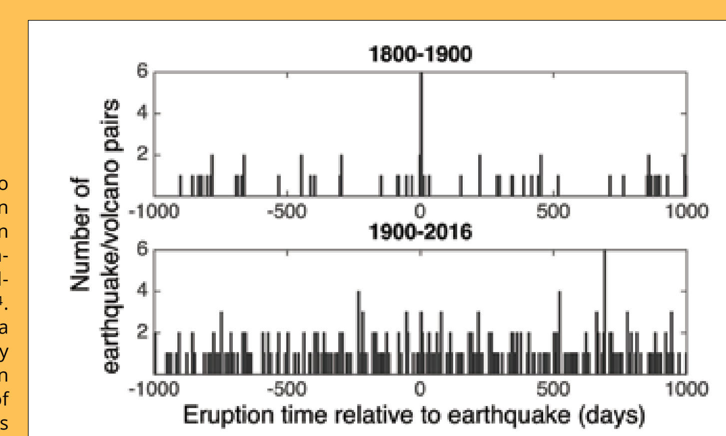
Greetings all, my name is Theresa and I am honored to be among the most recent alumni of EPS. I began my academic career relatively late in life after working as a musician and music teacher out of high school, but a combination of National Public Radio's "Science Friday" and some well-timed popular science books inspired me to pursue higher education. I transferred to UC Berkeley from community college as a junior, intent on using science to help communities facing geologic hazards. My work has covered wastewater disposal-induced earthquakes in Oklahoma, and I will be examining the seismicity within glaciers and ice sheets in graduate school at Columbia University this fall. Here I will discuss my work from a recently-published paper on earthquake-triggered volcanism[1]:

Reports of short-term earthquake triggered volcanism ("short-term" meaning within a few hours or days) date back to Pliny the Younger[2] and Charles Darwin[3], and even modern studies have shown that volcanoes are more likely to explosively erupt within days of nearby major earthquakes[4]. However, working with Michael Manga as part of the Undergraduate Research Apprenticeship Program, I reanalyzed earthquake and eruption catalogs and discovered that previous indications of short-term earthquake triggered volcanism were skewed by pre-20th century reports, and that over a hundred years of more modern records could not replicate this trend.

Furthermore, we found that many of these so-called triggered volcanoes were located in subduction zones, that is, extremely seismogenic regions, and tended to be more active in general than their non-triggered counterparts. Simulations showed that the number of seemingly-triggered eruptions could occur randomly just by virtue of erupting frequently in seismically active areas. These same simulations, however, revealed that there was a 5-12% increase in the number of explosive eruptions in the two months to two years following major (magnitude six or larger) earthquakes that could not be explained by random chance. We concluded that short-term seismically triggered explosive eruptions occur less frequently than previously inferred; an important consideration when evaluating volcanic hazards and for understanding the nature of earthquake-volcano interactions.

1 Sawi TM, Manga M (2018) Revisiting short-term earthquake triggered volcanism. Bulletin of Volcanology. doi:10.1007/s00445-018-1232-2
2 Pliny the Younger, Epistulae VI, circa 106 CE, Letter 20
3 Darwin C (1840) On the connexion of certain volcanic phenomena in South America; and on the formation of mountain chains and volcanoes, as the effect of the same power by which continents are elevated. Trans. Geol. Soc. Lond. 5, (2nd ser.), 601–631
4 Linde AT, Sacks IS (1998) Triggering of volcanic eruptions. Nature. doi:10.1038/27650

Histograms of eruptions with Volcano Explosivity Index values greater than or equal to 2, and their time of eruption relative to magnitude 8 and greater earthquakes within 800 km, recreating the analysis performed by Linde and Sacks (1998)[4]. Bin width is five days. The absence of a peak above background levels near day zero in the bottom panel that is present in the top panel shows that the majority of possible short-term triggered eruptions were documented prior to 1900.



COMMENCEMENT 2018

Master of Arts: (left and right) Luis Erick Aguirre Palafox, Carlos Torres Lua; **Doctor of Philosophy** (center) Qingkai Kong

THIS YEAR EPS AWARDED 66 BAs, 3 MAs, AND 11 PhDs

Atmospheric Science: Rory French, Andrew Beecher, Jake Yung

Planetary Science: Danica Adams, Morgan Welch

Environmental Earth Science: (back row) Shayla Calleros, Steve Anthony Reyes, Jennifer Marlene Garza, Mara Janelle Arroyo, Holly Barnhart, Kevin Ji, Ved N. Bhoot, John Whalley Huson III; (front row) Alexis Ajello, Claudia Louise Lopez, Maria Fernanda Hernandez Juarez

Marine Science: (back row) Mauricio Rafael Vazquez, Cecily Tye, William Kumler, Elizabeth Connors, Ashley M. Poindexter, Valerie Rochelle Bednarski; (front row) Anna Smuda, Lyvette Cristina Martell

Professor Barbara Romanowicz, Keynote Speaker (front);
Theresa Sawi, Departmental Citation (middle);
Professor Kristie Boering, newly elected to N.A.S. (back)

Geology: Kaci Jane Lederer, Michael Alonzo Bustillo-Sakhai, Matthew William Kirk, Mary Lonsdale, Madeleine Little, Alexis Maria Williams, Yujia Tao

Geophysics: (back row) Jia Zhen Yap, Christopher Ibbotson, Christina Ong, Evan Anderson, Mariel Diane Nelson, Kenneth Christopher Gourley, Jayson Barker, Romy Lily Attias, Katarina Henderson Floyd, Hayden MacArthur; (front row) Theresa Sawi, Eric Christiani, Sara Aislinn Lopez, Anna Mikheicheva, Abraham Aguilar

Commencement 2018 photos courtesy of Mohabbat Ahmadi, EPS staff

AWARDS

LEIF KARLSTROM, THE AGU KUNO AWARD

Leif Karlstrom

Leif did his undergrad at the University of Oregon, receiving degrees in physics, mathematics, and violin performance in 2006. A summer undergraduate research opportunity with Michael Manga at UC Berkeley was his first exposure to volcanology, doing experiments deforming wax in the basement of McCone Hall as an analog to rifting processes on lava lakes. This two-month project resulted in a publication and opened up an opportunity to enter the PhD program at UC Berkeley. Leif began graduate school in 2006, working with Michael Manga and Mark Richards. Like these advisors, his research interests were diverse, and over the course of his PhD, Leif worked on volcanology problems related to magma chamber dynamics and eruption mechanics, but also problems in glaciology, such as how meanders form in supraglacial streams. His graduate work involved numerical and analytical modeling, fieldwork, and some lab experiments. After graduating in 2011, Leif received an NSF Postdoctoral Fellowship which he conducted at Stanford University. Leif joined the faculty in the Department of Earth Sciences at the University of Oregon in 2014.

Leif's work still follows themes begun at UC Berkeley. His research group includes students and postdocs that work on crustal magma transport and geomorphology at a range of temporal and spatial scales. Current projects include how magma reservoirs form plutons such as the Sierra Nevada Batholith in California, how dikes fed eruptions during the Columbia River Flood Basalt Province in Eastern Oregon and Washington, and how acoustic-gravity waves in volcanic conduits leads to seismic signals at Kilauea volcano Hawaii. His group also maintains active work in geomorphology, including how topography of the Greenland Ice Sheet encodes ice flow, basal sliding, and surface meltwater routing, and how magmatic eruptions and intrusions compete with surface erosion to shape bedrock landscape form in volcanic provinces.

Leif Karlstrom and research team at the lip of Halemaumau crater, Kilauea volcano, Hawaii, in March of 2018. Right to left: Eric Dunham (Stanford), Leif Karlstrom (U. Oregon), Josh Crozier (U. Oregon, PhD candidate), Chao Liang (Stanford, PhD candidate).

2017 AWARDEES OF THE CERTIFICATE FOR DISTINGUISHED TEACHING

Steve Breen (EPS 50, Spring 2017)
Behnaz Hosseini (EPS 50, Spring 2017)
Yuem Park (EPS 50, Spring 2017)
Jennifer Mills (EPS 100, Fall 2017)

ESPER LARSEN JR. RESEARCH FUND GRANTS FOR 2017-18

- **Roland Bürgmann,** Geometry and slip rates of the Hilina fault zone, Hawaii
- **William Dietrich,** Testing a model for predicting the weathering front into bedrock under hillslopes
- **Mark Richards,** Volcanoes, iguanas, finches, and snails: geological/biological co-evolution in the Galápagos
- **Nicholas Swanson-Hysell,** Evaluating the iron speciation proxy with petrographic and magnetic approaches to elucidate the redox state of Earth environments during the evolution of early eukaryotes

CHARLES H. RAMSDEN ENDOWED FUND GRANTS FOR 2017-18

- **Donald DePaolo,** EPS 119 Field Trip to Northern Arizona, Spring 2018
- **Douglas Dreger,** EPS 118 Geophysics Field Projects
- **Nicholas Swanson-Hysell,** Enriching undergraduate education and EPS outreach through improved McCone Hall displays; and Field Safety
- **Jake Yung,** on behalf of Atmospheric Science Association of Berkeley, Atmos weather station
- **William Kumler,** Society of Integrative and Comparative Biology conference in San Francisco, California
- **Mariel Nelson,** Fieldwork to conduct shallow landslide surveys and attend the 2017 American Geophysical Union Fall Meeting in New Orleans, Louisiana
- **Theresa Sawi,** High resolution satellite imagery and travel expenses to attend European Geophysical Union (EGU) 2018 Meeting in Vienna, Austria
- **Evan Anderson,** Summer of Applied Geophysical Experience (SAGE) in Santa Fe, New Mexico
- **Michael Bustillo-Sakhai,** Advanced short course on the Ecological and Geomorphological Principles of River Restoration
- **Dakota Churchill,** EPS 118 Summer Field Camp
- **Beth Connors,** 2018 Ocean Sciences Meeting in Portland, Oregon and 6th Annual Marine Debris Conference in San Diego, California
- **Irene Liou,** Geothermal Development in Taiwan
- **Frances Meyer,** Field research on cooling trend in the Middle and Late Ordovician, in Oklahoma
- **Robert Sherwood,** Paleomagnetic analysis of dikes within the East-central Minnesota batholith: development of a pre-Rodinian paleomagnetic pole for Laurentia
- **Thao Tran,** California Extreme Precipitation Symposium at UC Davis and research trip to Barrow, Alaska
- **Cecily Tye,** Fossil specimen analyses for Eocene paleoclimate reconstruction
- **Abigail Jackson-Gain,** Botany 2018 Conference in Rochester, Minnesota

Frances Meyer doing field work in Oklahoma, with field assistant Abigail Jackson-Gain

Dakota Churchil during EPS 118 field camp

ALUMNI UPDATES

KRISTIN BENNETT,
GREETINGS FROM THE FIELD, 30 YEARS LATER


Kristin Bennett

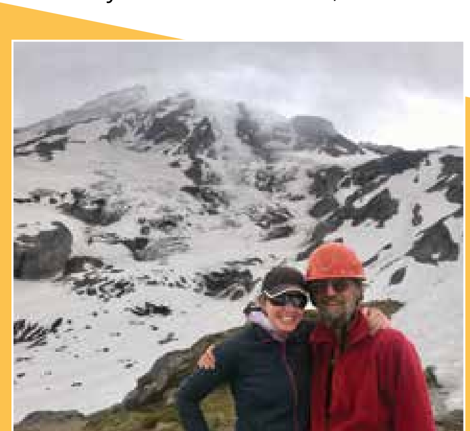
From the Santa Rosa Mylonite Zone, Palm Desert CA (Field Camp 1990) to The Kautz Glacier, Mount Rainier (Fundraiser Climb 2018)... Lessons from the field with Professor Hans-Rudolf ("Rudy") Wenk – or How I spent my July 4, by Kristin A. Bennett (Ph.D. Class of 1994)

I learned many lessons from Professor Rudy Wenk during my time at Cal (Ph.D. 1989-1994): how to measure a strained xenolith in the sweltering heat of his field site, Palm Desert's Palm Canyon mylonite zone (and watch a king snake digest a rattlesnake); the best way to use a Brunton through polished, textured marbles in Death Valley's Mosaic Canyon (i.e., the field option of his Geology 135 Mineralogy-Crystallography class); how to identify the steepest incline for running down the side of the Valles Caldera in the Jemez mountains after a week of shooting neutrons at the LANL Neutron Scattering Center (think like a mountain goat); do not forget noise-blocking headphones on classified airstrips in Nevada or New Mexico when waiting for your experimentally-deformed, preciously-textured deuterated ice samples to arrive; and how to plot [1 0 0](0 0 1) slip systems of olivine on a stereographic net. Still to this day, I can hear Rudy's voice showing me how to calculate and plot the projections. "And then you invert them".

Rudy and I kept in touch over the years, working jointly on various neutron projects, building 'HIPPO', a high-pressure preferred orientation time of flight spectrometer, tag teaming talks in Vienna, or joining forces in DC. But the biggest lesson (so far) came nearly 30 years after our first lessons: how to put on your crampons perched precariously on a 40-degree ice pitch with 60-pound pack at 2-am (use only one axe). And, under no circumstance, look down. This July, I was 'In the Field'—again—with Professor Rudy Wenk. I had the honor to hear Rudy's voice (and follow his nimble mountaineering boots) for three days as he roped me up the icy-mantled side of The Kautz Glacier, the less climbed more technical route of the iconic Mount Rainier in the Northern Cascades. An active stratovolcano, Mount Rainier is the most glaciated peak in the contiguous U.S.A. and an incredible field camp for cataclysmic lava flows, andesite-dacite structures and foundational granodiorite outcrops, thanks to the subduction of the Juan de Fuca Plate off the western coast of North America. My dissertation with Rudy on 'the deformation, texture and microstructure of high–pressure ice' may not have fully prepared me for the complete 'orientation distribution function' of 'ice' (or my apprehension) as we crossed through the precarious penitentes (thin blades of snow ice spires found at high altitude, oriented to the sun) in the Rainier turle snow field. What a thesis in the esteemed Wenk Group did equip me with, however, was a strong sense of persistence and inquiry: if the experimental indium jacket for your deuterated ice sample fails at 400 MPa at 77K in the HP-deformation rig, find another way. If you almost drop your ice axe into the Kautz crevasse, find a better way to secure it, even if it takes an extra year (smile). I have no doubt it was this trained logic at Cal that kept me climbing (or gripping my ice axe in fear) the eve of July 3 towards the summit of arguably one of the most scenic freestanding volcanoes in the world. As the dawn lit our way, July 4 on Mount Rainier, together with my friend and mentor, the only lesson I could think of was – gratitude.

We got three full consecutive days together in the field, so there was admittedly non-stop shoptalk, ranging from textures in shales, modeling of concrete, Pseudotachylite, the advanced light source, the state of our Union, and more.

For me, this is mainly a story 30 years later 'in the field' with my continued teacher and friend, Professor Rudy Wenk. While it is true, the biggest lesson I learned from him this summer on the towering icy-clad andesitic slopes of Mount Rainier may have been about dynamic crampon application, and (definitely) 'do not look down'; along with this wisdom was my real life lesson: it is not so much about what is in the field, be it dacites, ice, arnica, snakes or marmots; it is fully about who you are with. My gift this July 4, was being with Rudy in the field again, and time spent together.

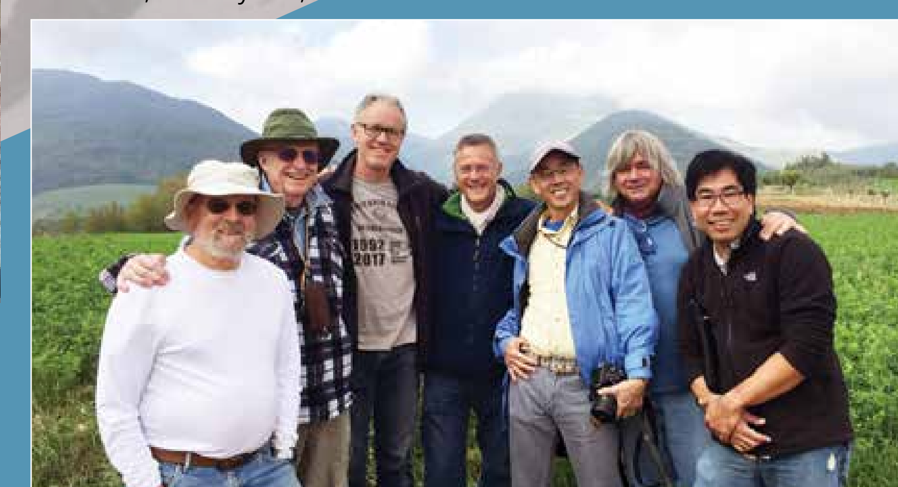

Rudy and KB, Mount Rainier National Park, July 4, 2018

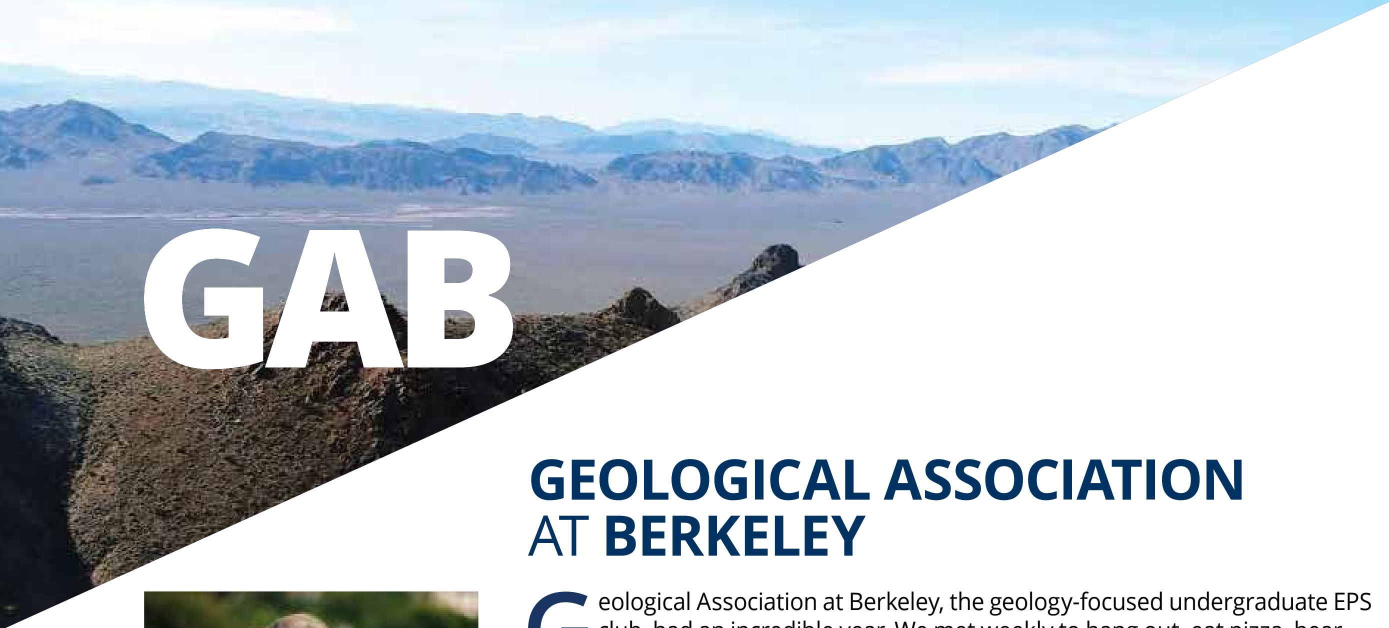

Rudy and KB, Bergell Alps, circa 1995. Photo by Julia Wenk

WALTER ALVAREZ, PROFESSOR


Walter Alvarez

My colleagues and I getting ready for a field day in Italy during September 2017, for the 25th anniversary celebration of the Geological Observatory of Coldigioco, founded in 1992 by Sandro Montanari, Berkeley PhD, 1986.


Left to Right: Peter Geiser (an old field colleague, not from Berkeley); Walter Alvarez, Berkeley Professor of the Graduate School; Dave Bice, Penn State, Berkeley PhD, 1988; Enrico Tavarnelli from Siena (Italy), Berkeley postdoc, 1995; Lung Chan, University of Hong Kong, Berkeley PhD, 1984; Philippe Claeys, Free University of Brussels (Belgium), Davis and Berkeley PhD, 1993; David Shimabukuro, Cal State Sacramento, Berkeley PhD, 2012



GAB

GEOLOGICAL ASSOCIATION AT BERKELEY

Mariel Nelson

Geological Association at Berkeley, the geology-focused undergraduate EPS club, had an incredible year. We met weekly to hang out, eat pizza, hear GeoNews, play Geopardy, and trade academic advice. Meeting attendance increased from previous years and several new members joined from other departments. We also held joint events with Ocean Society and Atmospheric Science Association. We took field trips to Black Diamond Mines Regional Preserve, the Exploratorium in San Francisco, and Whiskeytown National Recreation Area, but my favorite field experience with GAB was visiting Big Sur in December. We spent one day driving in the Santa Lucia Mountain Range near Gorda to check out the massive landslide that destroyed a section of Highway 1 in May 2017. We also hiked in Julia Pfeiffer Burns State Park and looked at evidence of older deep-seated landslides that occurred along the coastline. I found the experience particularly engaging and relevant because I studied landslides for my senior thesis. Though I have just graduated (page 15), I am excited to let Owen Nelson take on the role of club president and can't wait to meet new GAB members this year.

Meli, Mari, Lea, and Julia looking at sedimentary bedding in Black Diamond Mines Regional Preserve.

Tevin, Matt, Julia, and Abby at Black Diamond Mines Regional Preserve.

FACULTY & STAFF

FACULTY

Richard Allen
Walter Alvarez
Jill F. Banfield
James Bishop
Kristie A Boering
William Boos
George Brimhall
Bruce Buffett
Mark Bukowinski
Roland Bürgmann
Eugene Chiang
Ronald Cohen
William Collins
Kurt Cuffey
Imke De Pater
Donald DePaolo
William E. Dietrich
Douglas Dreger
Bethanie Edwards
Inez Fung
Lynn Ingram
Raymond Jeanloz
James Kirchner
Michael Manga
Charles Marshall
Burkhard Militzer
Steven Pride
James Rector
Paul Renne
Mark Richards
Barbara A Romanowicz
David Romps
Stephen Self
David Shuster
Doris Sloan
Daniel Stolper
Nicholas Swanson-Hysell
Chi-Yuen Wang
Hans-Rudolf Wenk

STAFF

Mohabbat Ahmadi
Jerry Alvarado
David Elvins
Jill Fujisaki
Kristie Kern
Siti Keo
Rachel Kowalik
Lily Law
Heezin Lee
Emily Martinez
German Moran
Veronica Padilla
Charley Paffenbarger
Nadine Spingola-Hutton
Tim Teague
Julie Wang
David Wemhaner
John Werner
Margie Winn

EPS Department standing in front of McCone Hall, taken from 5th floor balcony by Mohabbat Ahmadi, organized by Rachel Kowalik, 02/15/2018.

EVENTS

Rong Yu, Postdoctoral Researcher, at the grill for Welcome BBQ, September 6th, 2018.

Millie and Walter Alvarez, Professor of the Graduate School, at Welcome BBQ, September 6th, 2018.

Left to Right: Professor Inez Fung, staff member Margie Winn, and PhD student Hannah Bourne at Santa Barbara's Day 2017

Sarah Slotznick, Postdoctoral Researcher, and Daniel Stolper, Professor, at Welcome BBQ, September 6th, 2018.

Professor David Shuster playing the piano at Santa Barbara's Day 2017.

Thomas Smart, PhD student, sports PPE while teaching Rong Yu how to grill at Welcome BBQ.

Chelsea Willett and Liz Mitnick, both EPS PhD students, emceeing Santa Barbara's Day, December 7th, 2017.

Veronica Padilla, EPS staff, awarded the Excellence in Management Award, May 31st, 2018.

Nadine Spingola-Hutton at an EPS staff event, Thursday, March 22, 2018.

Professor Bruce Buffett presenting The Next Geomagnetic Reversal as part of events for Cal Day 2018.

Jake Yung '18 (page 15) and Atmos club member, Lisa Perrine, at EPS table for Cal Day 2018, on Saturday, April 21st.

DONORS

Albe, Monica Jane
Aldrich, Terry Mark**
Allen, Mary Elizabeth
Alvarez, Walter
Araki, Sayaka
Bacon, Charles Robert*
Bevc, Dimitri
Bilodeau, Bruce Joseph*
Boering, Kristie A
Boos, William R
Borg, Iris Yvonne***
Borsari, Christina
Boyd III, Nicholas G K
Brown, Edwin H
Butler, Paul Ray
Cebull PhD, Stanley Edward
Charlton, John Douglas
Cheney, Richard Stephen
Chevron Corporation*
Clarke Jr., Samuel Harvey
Depaolo, Donald
Desormier, William Leo
Dewey, James William
Dieffenbach-Carle, Heidi Lydia
Dynes, Linda L
Ensey, Charles Hartwell *
Exxon Mobil Foundation *
Ferencz Ph.D., Robert Mark
Ferencz, Stephen Bruce
Fidelity Charitable Gift Fund
Finn, Devin P
Fournier, Thomas John *
Foxall, William
Fujisaki, Jill Mie
Galehouse, Jon Scott
Gilbert, Neil Jay
Gillerman, Virginia Sue
Gregor, Nicholas John
Grew, Priscilla Croswell*
Hall Family Trust
Heming, Robert Frederick
Henshaw Jr., Paul Carrington*
Herkenhoff, Kenneth Edward
Hillhouse, John Weldon
Hirsch, Lee Mark
Holdaway, Michael Jon
Hoskins, John Allen
Howard Jr., Kenneth L
Hwang, Lorraine Joyce
Irvine, Pamela Jo
Johnson, Brann
Johnson, Thomas Martin
Kaiser, John Eric
Kaneshiro, Jon Yoshiaki
Kellogg, George Reinhart
Knapp Jr., John Stafford
Lai, Voon Hui
Lathon, Robert Bruce
Lee, Cin-Ty Aeolus*
Link, Percy Anne
Liston, James Michael
Louie, Kendall Bong Hu
Ma, Jie
Manga, Michael *
Marcus, Kim Lance
Marsh, Judith Ann Congdon
McCauley, Sean Edward *
Merino PhD, Enrique
Moore, Donald Bruce
Mote, Timothy Isnardi
Muramoto, Frank Shigeki
Murray Jr., James Wray *
Nord Jr., Gordon Ludwig
Odlum, James*
Ohlmann, John Philip
Pexton, Robert Edward
Pride Mountain Vineyards LLC***
Randolph, Michael Xavier
Reis, Arthur
Rivers, Mark Lloyd
Roering, Joshua Joseph
Roger & Sherry Taylor Trust
Rudolph, Maxwell Lutman
Salter, Dayna J*
Savina, Mary Elizabeth
Schetter, William Cameron
Schwartz, Morgan Francis Georg*
Seeburger, Eileen Marie
Shell Oil Company Foundation Inc*
Shuster, David Lawrence
Silver, Nathalie Valette
Simila, Gerald Wayne
Smart, Edward Stuart
Smith, Alan Lewis
Smith, Rebecca Jean
Stoddard Holmes Ph.D., Martha
Swann, Abigail Lynn Segal
Swanson-Hysell, Nicholas
Templeton, Dennise Christine
Thacher, Anson Blake
The Nolan Family Trust
The Schwab Fund for Charitable Giving
Theiss, Richard Robert *
Welsh, Thomas Beall *
Whitson, Amelia Danielle
Winn, Margaret

*Donations of $1,000 or more **Donations of $20,000 or more ***Donations of $40,000 or more

Back Cover: Jayson Barker '18 (page 15) at the Grand Canyon during EPS 119 field trip led by EPS Professor Don DePaolo.

Earth & Planetary Science
University of California, Berkeley
307 McCone Hall
Berkeley, CA 94720-4767
510-642-3993
eps.berkeley.edu