DEPARTMENT OF EARTH & PLANETARY SCIENCE

DEPARTMENT UPDATE
2019-2020

Berkeley
UNIVERSITY OF CALIFORNIA

FROM THE CHAIR

Welcome to our annual update. This is an opportunity to reflect on the past year and to showcase the exciting science within EPS. We begin with a celebration of 30 years of cross-disciplinary discovery at the Center for Isotope Geochemistry (page 3). Fundamental research is being done at all levels. In line with the new campus strategic plan to make discovery a focal point of the Berkeley experience, we advance research opportunities for undergraduates, such as department citationist Maryn Sanders (page 14), Valedictorian Cy David (page 15) and Association of Women Geoscientists Awardee Fran Meyer (page 18). We also welcomed two new adjunct professors, Benjamin Gilbert and Kanani Lee. Our faculty, students, staff and alumni continue to make our department one of the world's best.

Accolades continue to pour in, and I highlight a few. Daniel Stolper (page 8) was selected as a Sloan Fellow in Ocean Sciences and was presented with the Clarke Award from the Geochemical Society for outstanding contributions to geochemistry. Postdocs Alex Turner and Sarah Arveson received named early career awards from AGU. The more senior members of the department are doing OK as well, with Roland Burgmann and Michael Manga being elected fellows of the American Association for the Advancement of Science. Continuing a department tradition of striving for excellence in teaching, Nick Swanson-Hysell was awarded the Noyce Prize for Excellence in Undergraduate Teaching (page 12).

These are challenging times for the Earth Sciences as we face rollbacks of environmental protections and the denial of scientific data and the facts we uncover through our research. Yet the geosciences remain as important as ever, from identifying new resources (page 10) to mitigating natural hazards (page 11). And the new fundamental discoveries enabled by space exploration (page 6), the ability to model climate systems (page 7), and making new and precise geochemical measurements (pages 3 and 8) remind us how much more there is for us in EPS to learn and contribute.

Michael Manga

Our department has a mission statement:
Research, education and service in EPS is driven by a fundamental human curiosity about the past, present and future of Earth and other planets. We underpin our intellectual mission with a comprehensive dedication to equity, accessibility and inclusion for all.

As the rise of nationalism creates new barriers to supporting international students and collaborations we were pleased to grant the first Houtzager award to Michelle Devoe (page 19) to support field research in developing nations.

Our department's legacy is the success of our alumni. So please keep us informed and share your advice. Our collective achievements are not possible without your continued involvement and help.

In closing, I highlight the remarkable resilience of our students, staff, postdocs, researchers and faculty over this past year. The teaching evaluations this past spring were the best we have ever seen. While the challenges and tragedies are too many to recount, this report shares some of our successes and visions.

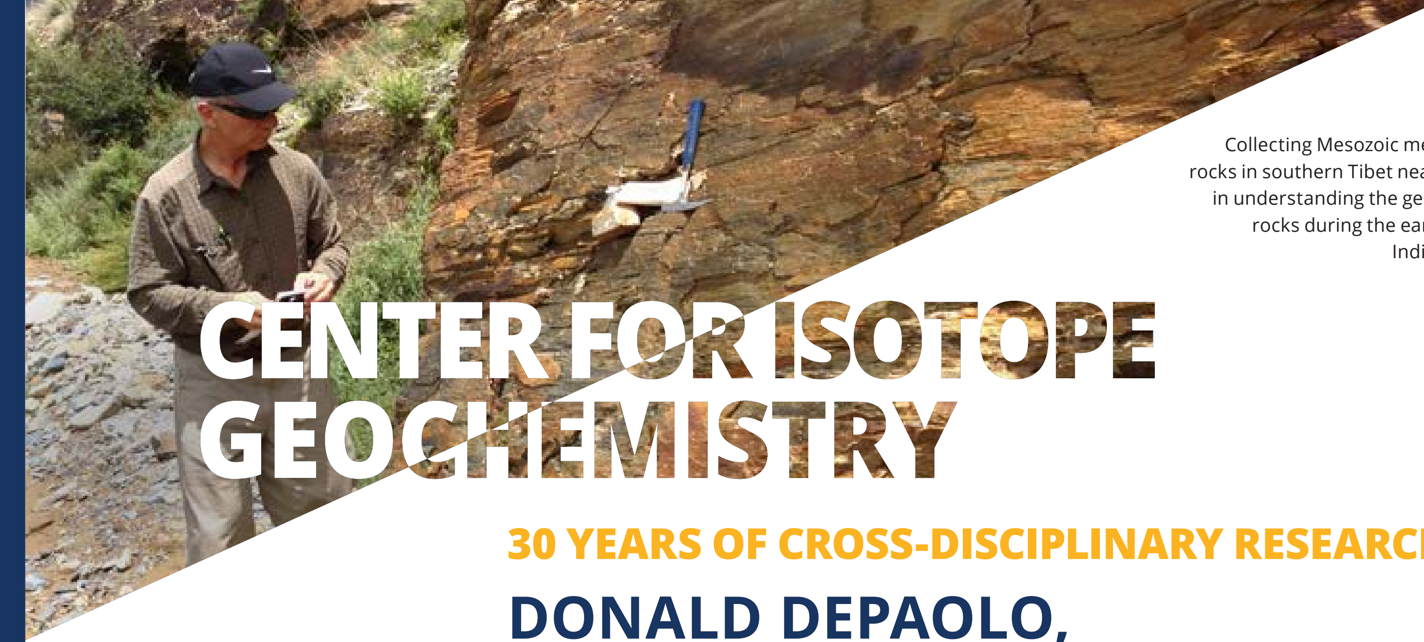
CONNECT WITH US

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. Feel encouraged to share your suggestions and recommendations. Alumni can request to join our LinkedIn group; please find the group here: https://www.linkedin.com/groups/6927573.

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. Our collective achievements are not possible without your continued involvement and help.

Photo: Heading up Llaima volcano, Chile, in January 2020 to sample the Curacautín Ignimbrite. Photo by Michael Manga.

Cover Photo: Students in Prof. Swanson-Hysell's EPS 39 "Earth Science in the Field" freshman seminar course make observations of the Santa Cruz Mudstone at Shark Fin Cove.
Photo credit: Nicholas Swanson-Hysell.



Collecting Mesozoic metasedimentary rocks in southern Tibet near Zedang to aid in understanding the genesis of granitic rocks during the early stages of the India-Asia collision.

CENTER FOR ISOTOPE GEOCHEMISTRY

30 YEARS OF CROSS-DISCIPLINARY RESEARCH

DONALD DEPAOLO,

CHANCELLOR'S PROFESSOR, EMERITUS & PROFESSOR OF THE GRADUATE SCHOOL

Donald DePaolo

The Center for Isotope Geochemistry was built in what is now McCone Hall in 1988 through 1989, just as I was moving to Berkeley from UCLA. At the time, the department was called Geology and Geophysics, and the building was "Geology." The labs built on the 4th floor were the first major renovation project in the Geology building since its completion in 1960. The laboratory was first fully operational in 1990, so this year (2020) marks the 30th anniversary.

The idea that early career faculty at major research universities would need extensive start-up support from both the University and NSF first started to take hold in the 1980s. NSF Earth Sciences did not yet have an Instrumentation and Facilities program. Electron microprobes were the only relatively expensive pieces of analytical equipment that were regularly funded. In 1979 I received $180k from NSF at UCLA to purchase a new thermal ionization mass spectrometer (TIMS) and this was the first time NSF had ever provided funding for a mass spectrometer. Universities did not provide "startup" packages, or if they did, they were tiny by today's standards. By 1988, partly as a result of the new excitement that had been generated by studies of Nd isotopes, it had already become more commonplace for NSF to partially fund mass spectrometers, and for universities to provide laboratory renovation and instrument matching funds for new faculty. Through the efforts of George Brimhall and Tom McEvilly, and because UC had implemented a new statewide program, Berkeley was able to offer the support needed to build a lab on campus, and start a new research program concurrently at what was then called "LBL." So the Berkeley Center for Isotope Geochemistry (BCIG) came into being as a joint UC Berkeley – LBL effort in the 1988-1990 time period.

Campus was well organized, and planning for the new labs started quickly. Construction started in 1988 and the labs were finished in early 1990 under budget! A significant issue was that the labs took up about 2000 square feet of space, and required fume hoods (there are 7 total), as well as an HVAC system that could provide HEPA-filtered air and keep the temperature controlled. The space was obtained by using a large lecture /lab room on the fourth floor (think of room 365 and imagine an identical room on the 4th floor) and an office at the southeast corner of the building. These rooms were reconfigured into 5 rooms, the main ones being a clean chemistry lab, a mineral separation room, and a mass spectrometer lab. A large air handling unit was needed, so there is a separate room that houses the fan unit and is also used for other purposes. The fume hoods were another issue. The hoods need to vent through the roof of the building, so 7 separate risers needed to be built that would go up through the 5th floor to the roof. The Berkeley Seismographic Stations (as it was then known) occupied the 5th floor over the soon-to-be chemistry and mass spec labs. The inhabitants needed to weather several months of demolition and construction and loss of significant floor space.

continued on next page

Gathering of some isotope center stars at the Goldschmidt meeting in Cologne, Germany in 2007. L to R Sarah Aciego, Ken Sims, Vicky Lee, Kate Maher, Ethan Baxter, Matt Fantle, Maureen Feineman, John Christensen, John Lassiter, Brian Marshall, and Stephanie Ewing.

At the time the lab was built it was one of the most modern and well-equipped clean chemistry and mass spectrometry labs in the world. There were two thermal ionization mass spectrometers (TIMS) and ample space for carrying out chemical separations from dissolved rocks and minerals. Tom Owens was in charge of the labs, and the first Berkeley graduate students who worked in it were Tom Johnson, John Lassiter, Ken Sims, and Sean McCauley, who were also joined by Eric Wendlandt and Ellen Daley who moved up to Berkeley from UCLA. Scott Borg was the first postdoc to use the lab, followed by Jo Lin, Chang-Hwa Chen, and Steve Getty.

Research in BCIG started with a focus mostly on igneous and metamorphic rock geochemistry with a second theme related to sedimentary provenance studies and Sr isotope stratigraphy and paleoceanography. These studies, which have continued to the present, produced fascinating results relating to extensional volcanism (Daley) and ignimbrites (Frank Perry) in the western U.S., layered intrusions (Brian Stewart) and flood basalts (Lassiter), melting rates in mantle plumes (Sims), deep crustal xenoliths from the Four Corners area (Wendlandt), active volcanoes (Chen), Antarctic (Borg) and Himalayan (Chen) granites, deformation rates in Alpine schists and gneisses (John Christensen), and new approaches to Quaternary geochronology (Getty) and Cenozoic stratigraphy (Rose Capo). Dan Schrag used the stable isotope facilities built at LBL and deep sea pore fluids to estimate the mass of the continental glaciers in the last Ice Age.

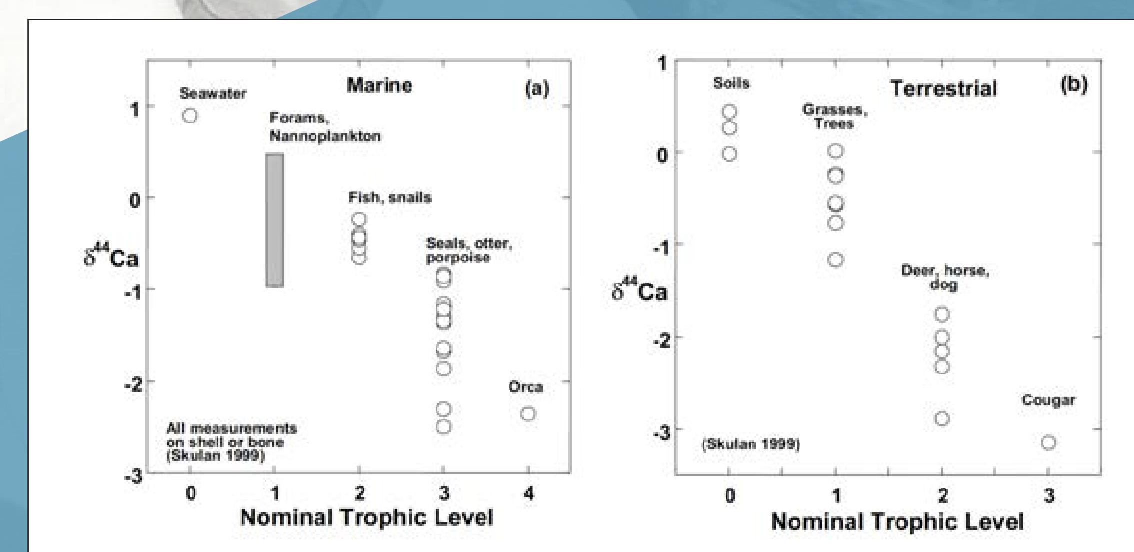
By the late 90s there was more work being done in groundwater hydrology (Johnson) and paleoclimate (McCauley). Joe Skulan came over from Integrative Biology to work on Ca isotopes in vertebrates, and effectively started an international effort in Ca stable isotope research that is still expanding after 25 years.

One attraction of isotope geochemistry is that it is applicable to such a broad range of Earth science problems. The combination of excellent facilities, high quality students, and the intellectual atmosphere of Berkeley has combined to make the BCIG an eclectic, evolving, and exciting research environment. Each of the students and postdocs has worked on his/her own project, following their particular interests. The breadth of research topics has been stimulating, but it has been a challenge to have useful group meetings!

In the 2000s a group of talented students produced a spurt of entirely new research developments. Sr isotopes were used to measure how fast rocks recrystallize during greenschist and amphibolite grade metamorphism (Ethan Baxter). Ca and Sr isotopes were used to measure how fast deep-sea carbonates recrystallize during diagenesis (Matt Fantle). Kate Maher worked out new ways of measuring sediment transport times and vadose zone infiltration rates using U isotopes. Maureen Feineman worked with Rick Ryerson at Lawrence Livermore National Laboratory on experiments related to subduction zone processes, beginning a series of experimental studies that have continued to the present. Sarah Aciego, working with Mack Kennedy at LBNL, showed that U-Th-He could be used to date volcanic rocks that are too old to date with radiocarbon and too young to date with Ar-Ar. Jim Watkins, also working with Ryerson, showed that isotopic fractionation caused by diffusion in silicate liquids could be used to probe silicate liquid structure and diffusion processes.

Highlights since 2010 include new models for how calcite incorporates isotopes and trace elements, and how that depends on growth rate and fluid chemistry (Laura Nielsen Lammers, Jim Watkins, Jenny Mills, and Liz Mitnick), how Ca isotopes can help understand processes in the earliest stages of the solar system (Justin Simon), how fast CO_2 can be turned into carbonate minerals during subsurface carbon sequestration (Shuo Zhang), and how uranium can be tracked in groundwater at sites that have been used for uranium solution mining (Anirban Basu and Shaun Brown). Michael Antonelli continued the high temperature geochemistry theme using Ca isotopes to characterize chemical transport processes in amphibolite and granulite facies metamorphic rocks. Shaun Brown and Sasha Turchyn, followed later by Antonelli and Nick Pester, made the discovery that certain aspects of the chemistry of ancient seawater changed the chemical exchange between seawater and the ocean floor. Jenny Druhan was able to demonstrate how isotope fractionation can be incorporated into reactive transport models for groundwater, and Anna Clinger used U isotopes to measure how long it takes sediment to be transported from the Himalaya to the Bengal Fan.

In 30 years the BCIG labs have provided the focus for this large range of fundamental Earth science studies. In the meantime, isotope geochemistry has gone through extraordinary growth such that almost every element in the periodic table is now the subject of isotopic studies. Fancy new labs are found on 5 continents and new ones continue to be built. At Berkeley, there has also been a major expansion, in EPS, in related departments, and at the Berkeley Geochronology Center. We are proud to have contributed, and continue to contribute, to the excitement around isotope geochemistry, and to have helped to keep Berkeley in the middle of the conversation.

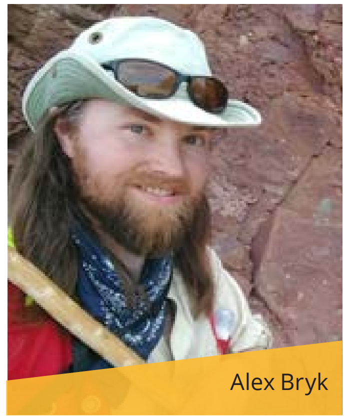


First calcium isotope data showing trophic level effects in marine and terrestrial organisms, from Joe Skulan's Ph.D. thesis and a paper in Reviews in Mineralogy.

RESEARCH SPOTLIGHTS

PLANETARY SCIENCE

ALEX BRYK, GRADUATE STUDENT


Alex Bryk

I joined the NASA's Mars Science Laboratory (Curiosity Rover) team in January 2018, about 5 years after the rover landed in Gale Crater and began its journey of exploration for habitable environments. At this time, the rover had ascended Vera Rubin Ridge, a wind scoured, diagenetically altered outcrop of ancient lake sediments. Before us lay a shallow 500m wide trough that remote sensing indicated was rich in clay and thus may record an ancient habitable environment here at the foot of Mt. Sharp. Beyond the trough lay some isolated buttes, and then a several km long 10 m high escarpment cut by wind and preserving a remnant planation surface (pediment) that had developed at the foot of Mt. Sharp and likely once extended right across to where the rover was sitting. This was the first sighting of a pediment by a rover on Mars and it became a hope, shared with my advisor, Bill Dietrich, that the rover would have an opportunity to investigate it close up. At this distance, we could see that the pediment truncated the lake sediments and was probably overlain by a sandstone. Above the topographic plain rose a 70 m high ridge of sediment that had been interpreted to be a remnant of a once more extensive alluvial fan.

For the next year 1.5 years, I participated in planning and analysis that guided the rover beyond Vera Rubin Ridge across the clay-rich valley as we headed towards the pediment edge. Then in the past year, Bill Dietrich and I were given the opportunity to lead the rover to the landform now known as the Greenheugh pediment. We found the capping unit of the pediment to be lithified cross-bedded aeolian sandstone, and that it had undergone patchy diagenetic alteration. To our amazement, the mission determined we could ascend up a local 30 degree slope onto the pediment surface. There we obtained extensive imagery (see figure), drilled the capping sandstone, and confirmed a rich environmental history of transition from lake deposition through an erosion phase capped by wind-blown sand all later overrun by an alluvial fan.

Curiosity has now traveled back down from atop the pediment in search of more organic compounds hosted in the sediments below the unconformity. Based on geologic mapping we did while crossing the clay-rich trough, we were able to predict and guide the rover to a specific stratigraphic zone where we are now drilling, demonstrating that core principles in geology are effective even when applied through a robot 225 million kilometers away from Earth!


Photo: JPL-Caltech MSSS

ATMOSPHERIC SCIENCE

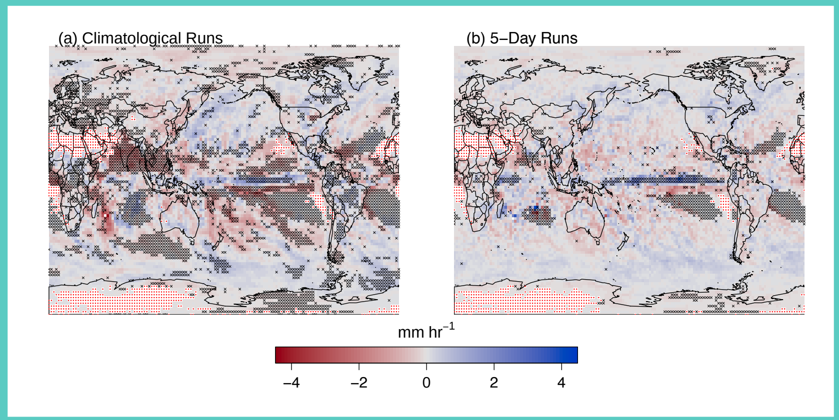
ALEXANDER CHARN, PhD 2020


Alexander Charn

Microphysical processes involving water droplets and ice particles in the atmosphere are responsible for significant events such as extreme precipitation and lightning. However, as their name implies, they are difficult to observe in the real world and represent within weather and climate models. Regarding the latter, superparameterized climate models strike a balance between the cloud-resolving capability of high-resolution models and the computational efficiency of standard climate models, allowing a unique way to probe the effects of climate change on atmospheric processes where clouds and convection are important. While superparameterization has been shown to be superior to conventional approaches in simulating extreme rainfall, it is still unable to match the magnitude of observed extreme precipitation in many places. In a pair of studies, we show that, while the choice of microphysics leads to statistically significant differences in precipitation, particularly in the tropics, neither of two commonly used schemes is able to appreciably improve in this regard.

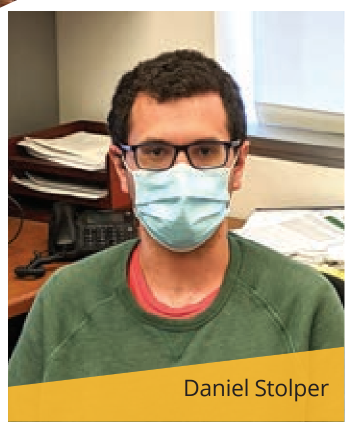
Lightning is generally considered to be the result of collisions involving ice particles, but most predictors of flash rates consist of correlations with larger-scale variables. We compare the performance of such a large-scale proxy with several ice-based ones within a superparameterized model and find the latter to generally be superior in reproducing the observed global distribution of lightning. We also test the sensitivity of climate change-related predictions of lightning to the microphysics representation and find that the simpler scheme predicts decreases in many parts of the world, while the more complex one predicts more in the way of increases. In a final study we test the claim that lightning within clouds is dependent on precipitating ice particles by using satellite observations of cloud-top temperatures and three sets of lightning observations. The individual datasets yield a fraction of "warm-lightning" candidates smaller than their reported false alarm rates, so we attempt to find robust instances by cross-validating candidates across datasets. Because this effort results in zero matches, we deem there to be insufficient evidence to refute the hypothesis that lightning within clouds can occur in the absence of ice.

Photo: Comparison of precipitation extremes using 1-moment and 2-moment microphysics for (a) climatological (5-year) runs and (b) short (5-day) runs. The quantity plotted is the 2-moment 2-year return value minus that from the 1-moment. Grid cells with statistically significant differences between the two extreme precipitation distributions are stippled in black. Grid cells where parameter estimation failed are stippled in red.



RESEARCH SPOTLIGHTS

DANIEL STOLPER, ASSISTANT PROFESSOR



Daniel Stolper

The presence of oxygen in the atmosphere (O_2) fuels complex life, allows for combustion, leads to the oxidation of surface materials, and is inextricably tied to the activities of photosynthetic life. Although present at high levels in our atmosphere today (21%), this has not always been the case. For example, sometime between 800 million and 400 million years ago, oxygen is thought to have risen from ~1% of modern levels to the high levels seen today. This rise has been of longstanding geologic interest as it occurred at approximately the same time that animals, which require appreciable oxygen to live, evolved and diversified. As such the evolution of animals has for decades, to some controversy, been causally related to this rise in oxygen. So how do geochemists go about estimating when this change occurred? One approach has been to look to the oceans. Today, the deep ocean generally contains dissolved oxygen that was originally derived from the atmosphere. However, when oxygen levels were lower (<10-50% of modern), the deep ocean is predicted to have been devoid of oxygen. Thus if one could measure when the deep oceans became oxygenated, it would in turn help constrain when the atmosphere finally approached modern oxygen levels. In an ideal world, one could study ancient rocks formed in a deep ocean setting as a direct monitor of the deep ocean's geochemistry. Problematically, due to plate tectonics, most of these rocks have been subducted into the mantle. However, a small amount of deep-ocean-derived rocks are preserved in so-called ophiolites where oceanic crust is scraped off onto and preserved on continental crust. Many of you reading this will have visited such rocks during your time at UC Berkeley on departmental field trips to the Coast Range Ophiolite in Marin County — if you remember seeing pillow basalts as a student, you likely have seen an ophiolite.

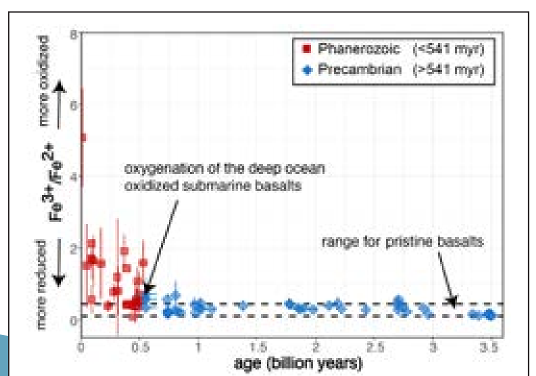


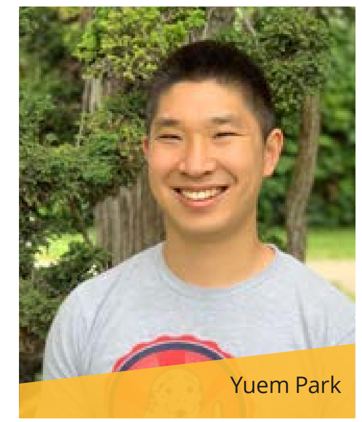
Fig. 1: Change in Fe^{3+}/Fe^{2+} in submarine pillow basalts through time.

These pillow basalts bring us to the research part of this story. When I first arrived at UC Berkeley about 3 years ago, it became clear that my experimental geochemistry laboratory was going to take some time to build and I needed to find something to do with myself in my first year. An idea I had had relates back to those pillow basalts exposed in Marin and the history of atmospheric and oceanic oxygen levels. When pillow basalts erupt on the ocean floor, they are derived from magmatic melts that are relatively reduced compared to seawater. This can be seen by looking at their iron chemistry. Iron (Fe) today on the Earths' surface exists largely as either Fe^{2+} or Fe^{3+}. When oxygen reacts with reduced Fe^{2+}, it makes oxidized Fe^{3+} (picture rust). Iron in freshly erupted pillow basalts is mostly reduced Fe^{2+} (85%) — this is something that the late Prof. Ian Carmichael worked on extensively here at Berkeley. In the oceans, after pillow basalts erupt, seawater carrying dissolved oxygen flows through these basalts, reacting with them and oxidizing them. By the time this circulation finishes, much of the iron can be converted to oxidized Fe^{3+} (>50% in some places).

So my idea was relatively simple: Compile measurements of Fe^{3+} vs Fe^{2+} values in pillow basalts preserved over geologic time (which exist back to ~3.5 billion years) and see if there are any obvious changes with time. A clear increase in oxidized Fe^{3+} would be indicative of the accumulation of oxygen in the deep ocean that then reacted with and oxidized these basalts. After a few months of digging through old papers, the data was compiled and it told an apparently coherent story. Pillow basalts suddenly became oxidized ~500 million years ago, indicating that not until this time did the oceans become largely oxygenated (Fig. 1). Given that animals evolved well before this time, this removes a causal link between the evolution of animals and the large-scale oxygenation of the ocean and atmosphere. Now why did this oxygenation occur when it did? This work does not answer that, but it provides constraints on plausible ideas. And as for my lab? I'm happy to report it was successfully built and became operational in early 2018, including the delivery of about 3000 pounds of mass spectrometers through the 4th floor balcony (Fig 2).

Fig. 2: Delivery of mass specs to McCone Hall.

YUEM PARK, PhD 2020

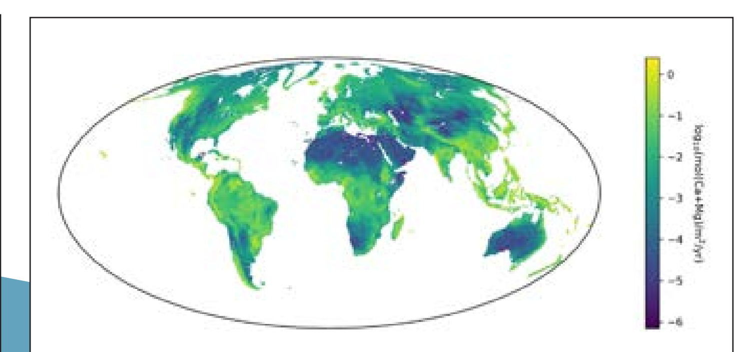


Yuem Park

On million year time-scales, Earth's climate fluctuates between three stable states: a warm state in which the poles are ice-free, a cold state in which finite ice caps exist at the poles, and a "snowball" state in which Earth's entire surface is covered by ice. My research, under the guidance of Nicholas Swanson-Hysell, seeks to understand the mechanisms that are responsible for controlling Earth's climate state over these geologic time-scales.

I take a multi-faceted approach to my research, combining computational, geochemical, geophysical, and field-based methods to both examine specific documented shifts in Earth's climate state, as well as to take a step back and investigate changes in Earth's surface environment over the past one billion years as a whole. To-date, my research has broadly followed 3 distinct, but related, threads. The first thread involves examining whether the distribution of the continents and notable tectonic events on Earth's surface are correlated with shifts in Earth's climate state. To do so, I develop paleomagnetic data from ~800 million year old rocks in China that can be used to constrain the position of the South China continent at that time, then combine this data with similar existing constraints from other localities to refine models of the distribution of Earth's continents over the past one billion years. The second research thread investigates whether the ongoing collision of volcanic arcs with the Australian continent in the Southeast Asian islands may have been responsible for cooling Earth's climate over the past 15 million years. In this project, I feed a model of tectonic changes in the Southeast Asian islands into a spatially-resolved silicate weathering model that calculates CO_2 consumption resulting from rock weathering reactions. The final research thread involves understanding the drivers behind a dramatic "snowball" glaciation ~717 million years ago. This project involves developing stratigraphic and chemical data from ~800-700 million year old rocks in Ethiopia that can tell us about the evolution of the local and global surface environment during the lead up to severe glaciation. Together, these three research threads so far suggest that the collisional uplift of volcanic arcs in the tropics are important for driving shifts in Earth's climate state over the past one billion years.

In Ethiopia, investigating the evolution of Earth's surface environment during the lead up to severe glaciation ~717 million years ago. From left to right: Scott MacLennan, Mulubrhan Gebreslassie, Yuem Park, Eliel Anttila (EPS alumnus).



GEOCLIM model output of pre-industrial CO_2 consumption due to silicate rock weathering.

RESEARCH SPOTLIGHTS

MARINE SCIENCE

XIAOJING (RUBY) FU, POSTDOCTORAL SCHOLAR

Ruby Fu

New fluid mechanics insights to how methane gas migrate through deep marine sediments, feeding widespread methane vents in world ocean.

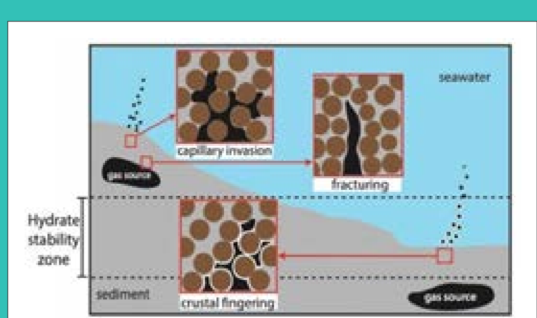
Methane represents a major contributor to atmospheric greenhouse warming, and is, per unit mass, about 50 to 100 times more potent than carbon dioxide. In determining the relative importance of methane to greenhouse warming, the biogeochemistry of the ocean and the global carbon budget, methane hydrates play a particularly important role. Methane hydrates — an ice-like solid substance made of methane and water molecules — are formed and commonly found in ocean sediments. While methane hydrates are stable over a range of depths that is hundreds of meters thick, widespread seafloor methane gas venting has been reported in many parts of the world ocean. Given the intuition that solid hydrate would likely clog the pore space within the sediment and prevent gas flow, how such gas migration pathways can be sustained over long periods of time is a long-standing puzzle (Figure 1).

In this study, we present evidence of a new phenomenon of solid-crusted gas percolation, which we term crustal fingering that, we believe, could be the key mechanism that explains the long-standing question of how free-gas methane migrates through the hydrate stability zone in deep marine sediments around the world.

We address this question using controlled laboratory experiments developed in Los Alamos National Lab, as well as theory and simulations developed with colleagues at Technical University of Madrid, Swiss Federal Institute of Aquatic Science and Technology and Massachusetts Institute of Technology. We demonstrate that, contrary to intuition, the formation of hydrate does not always clog gas-flow pathways, but rather often facilitates the migration process (Figure 2). Further, complementing and contrasting the established theory that most marine hydrates on earth have formed out of dissolved methane, here we suggest that some subsurface hydrate fabric observed today could be a record of the dynamic history of methane venting coupled with hydrate formation along the gas migration pathway over long periods of time.

This work provides a unifying theory that will allow the community to make progress on connecting the increasing amount of seafloor sonar data of methane venting dynamics with the seismic data on subsurface hydrate-derived plumbing structure to answer the question of where and how much methane is being released into the ocean through these naturally occurring methane seeps.

Below (Figure 1): Methane gas migration through shallow marine environment and the hydrate stability zone. Representation of a methane-rich gas reservoir (black) feeding the upward migration of methane gas through the seafloor sediments (grey) into the ocean water column (blue), forming seafloor methane seeps (bubbly plume). The methane hydrate stability zone (HSZ) on earth is approximately 600m to 1400m below the ocean surface. Top two insets: two primary modes of gas migration in shallow sediments are (a) capillary invasion in a rigid-like sediment, where gas pressure over- comes capillary force to move between sediment pores and (b) fracturing, where gas pressure is sufficient to mobilize sediment grains to initiate and propagate fractures. Bottom inset: a new mode of methane gas migration within the HSZ proposed in this work: crustal fingering.



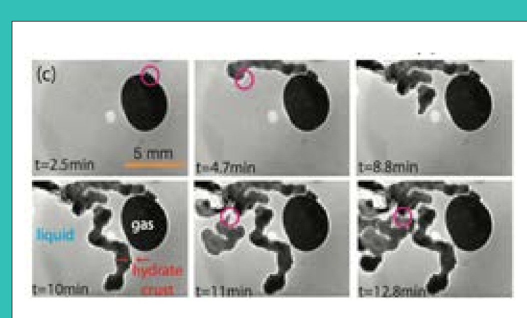
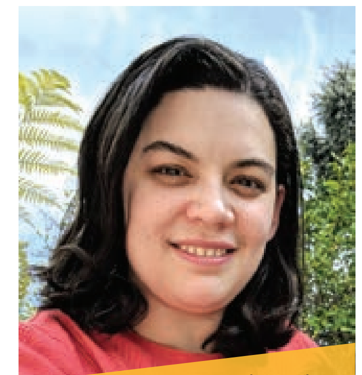


Figure 2: Experimental snapshots of crustal fingering process captured in a microfluidic device, demonstrating how hydrate crust formation can, counterintuitively, facilitate rather than clog gas flow pathways.

GEOPHYSICS

EARTHQUAKE HAZARDS WITH NOEL BARTLOW, RESEARCHER

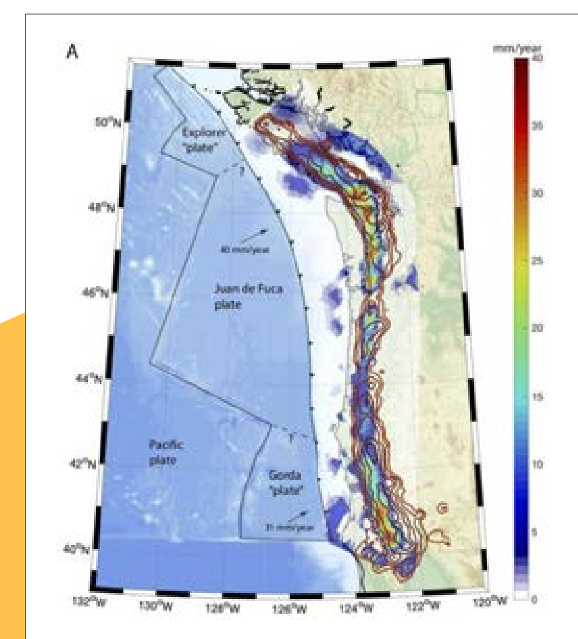


Noel Bartlow

Subduction zones are capable of generating very large and destructive earthquakes, but not all of the tectonic motion accommodated on these plate boundaries cause earthquakes that can be felt. Episodic tremor and slip, a type of aseismic fault slip or slow slip, accounts for a large amount of fault motion on the deeper extent of the Cascadia Subduction Zone in the Pacific Northwest. The Cascadia Subduction Zone generates large earthquakes with magnitudes approaching or even above 9.0 every few hundred years. The last such event in the Cascadia region occurred more than 320 years ago on January 26, 1700.

In between large earthquakes, episodic tremor and slip occurs regularly, at least once per year somewhere along the subduction zone. In these events, the plate interface slips as it would in an earthquake but takes much longer to do so. These events do not produce dangerous shaking, but they do contain information about how the subduction zone is behaving. Studying and monitoring episodic tremor and slip events in Cascadia may hold the key to better forecasting the next great earthquake, as recent evidence suggests that some large earthquakes begin as slow slip events and episodic tremor and slip events are predicted to change in size or recurrence interval as the time of a large earthquake approaches.

I have been studying these episodic tremor and slip events using GPS data from the western U.S. In a recent paper, I added up the cumulative effect of all the episodic tremor and slip events across the subduction zone, and time-averaged the result to quantify the role of these slow slip events in the overall plate motion. The results vary widely across the subduction zone, with the greatest episodic motion occurring in the southern section – precisely where large earthquakes occur most often in this region according to paleoseismic data. The main region of episodic tremor and slip in Cascadia is in an area with no locking. In the majority of the subduction zone where episodic tremor and slip takes up less than the full “slip budget” – that is, the full rate of convergence between the two plates, the plate interface must be creeping along at a slower rate between these events. This has important implications for the frictional mechanics of this part of the subduction zone.



Time-averaged episodic tremor and slip rate (colors) and contours of density of tremor detections (brown lines) on the Cascadia plate interface.

IN THE CLASSROOM

EPS 39 with NICK SWANSON-HYSELL, ASSOCIATE PROFESSOR

Nick Swanson-Hysell

Berkeley's freshman and sophomore seminars provide an opportunity for students pursuing lower division coursework to get to know a faculty member in a small group and be introduced to new fields of study. Here in EPS, we have a tradition of teaching seminars that introduce students to Earth science in the field. It was in one such seminar that Prof. David Shuster (now an EPS faculty member) first became enthused about pursuing Earth science as his field of study. This year's Association for Women Geoscientists Outstanding Student Award winner Fran Meyer (Page 18) took such a seminar with Prof. Swanson-Hysell and subsequently became an EPS major. We are glad they both took the seminar to get started on their Earth science journeys!

In Fall 2019, Prof. Swanson-Hysell taught a seminar entitled "Earth Science along the California Coast." The focus of this seminar was to provide an opportunity for students to learn about the Earth through direct field observation. The central aspect of the course was a four-day field trip along the California coast. On the first day of the trip, the students visited classic exposures of the Marin Headlands terrane. With stunning views of the Golden Gate and dissipating fog, the students got their first experiences making observations of pillow basalt, radiolarian chert, and greywacke sandstone as well as thinking about these rocks in the context of California's tectonic history. After a night at Big Basin State Park, day two was spent on coastal outcrops in the vicinity of Santa Cruz observing Miocene and Pliocene sedimentary rocks. The fascinating injectite complex at Yellow Bank Creek led to stimulating discussion and there was excitement when students found marine vertebrate fossils at Capitola Beach. We stayed that night and the next in Carmel Valley at Hastings Natural History Reservation which is part of the UC Reserve system. A day at gorgeous Point Lobos gave us the opportunity to observe the guts of an ancient submarine canyon system that cut into Salinian Block granite. On day four, we crossed Salinas Valley and hiked through dramatic landforms composed of volcaniclastic breccia of the Pinnacles Volcanic Formation — a formation that famously journeyed northward from its sibling Neenach Volcanic formation in southern California on the other side of the San Andreas Fault. On our last stop in Hollister, students made observations and measurements on the active trace of the Calaveras Fault — a further reminder that tectonics are actively shaping California's landscape today.

Graduate student instructors were key to the success of the course. Danielle Lindsay, Claire Doody, Yiming Zhang as well as Postdoctoral scholar Maggie Avery all brought knowledge and enthusiasm that encouraged the students to make their own observations and connect the geological record to Earth processes. We are all looking forward to when we are through the pandemic and in-person field instruction can safely resume.

Point Lobos State Natural Reserve: Students in the seminar make observations of the Carmelo Formation just above its unconformity with Salinian granite.

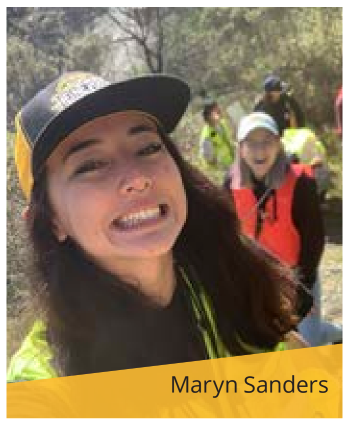
Baker Beach: EPS 39 students observed modern sand, Pleistocene dunes and Franciscan turbidites all with a great view of the Golden Gate.

Pinnacles National Park: The seminar group uses their arms to illustrate the tilt of bedding.

GSI crew: L to R, Maggie Avery, Yming Zhang, Danielle Lindsay, Claire Doody.

COMMENCEMENT 2020

DEPARTMENTAL CITATION: MARYN SANDERS



Maryn Sanders

Hello! My name is Maryn and I received my bachelor's degree in geophysics from the EPS department this May. I was awarded the departmental citation and am excited to share my work with department members and alumni. My love of Earth science began when I took earth science as a breadth class during my last year at community college, and I transferred to UC Berkeley the next year as a junior and intended geophysics major.

During my first semester in the department I took geomorphology, taught by Bill Dietrich. I learned about cross-disciplinary science of landscapes as Bill derived equations, showed the class photos of field sites, and led field trips. For the first time, I participated in the entire scientific process, from hypothesis generation to data collection to scientific writing. By the time I completed my end-of-semester project on rill formation, I was hooked on geomorphology.

In February 2019, I reached out to Mariel Nelson, Bill's course reader (and EPS department alumni), to ask about potential research opportunities. Coincidentally, I asked right after a field site in Northern California was hit by dozens of shallow landslides—relatively thin landslides that involve only the soil layer but can become massive debris flows. Landslides also occurred at the site in 2017, but in different locations. I worked with Bill to understand the relationship between these two events through the Summer Undergraduate Research Fellowship program.

We compared the two landsliding events by analyzing landslide size, location, and the intensity of the storms that triggered them. To map the landslide locations, I used GIS software and aerial photographs of the field site to outline all 92 landslides that occurred in 2019. I then used detailed digital maps of the landscape (derived from airborne lidar) to extract topographic characteristics, like surface slope and drainage area, where landslides occurred. The 2019 landslides were the same size as 2017 landslides, but occurred at higher slopes and greater upslope drainage areas. Additionally, I ran a field campaign to measure 25 landslides and make observations of landslide processes that were impossible to see in the digital maps.

To look at rainfall patterns, I used data from rain gauges at the field site and a model made by researchers at Oregon State University to calculate cumulative rainfall and rainfall intensity. Rainfall can be highly variable from one hillslope to the next, so looking at multiple data sources allowed us to capture this variability. We compared our data to NOAA estimates of storm recurrence intervals from historical data, effectively telling us how rare the storms we recorded were. The 2017 and 2019 landslide-triggering storms were almost identical in size and intensity; however, prior to the storm, 2019 was much drier than 2017.

This year, I am happy to continue working with Bill as a staff member at the Eel River Critical Zone Observatory at Angelo Reserve, part of the UC Natural Reserve System. We plan to conduct field experiments to analyze how the additional precipitation in 2017 initiated more landslides. I have also begun to study how grass roots strengthen the grassland soil at our site.

I could not be more appreciative of the EPS department, both for supporting me as an undergraduate and for recognizing my hard work this year. I am thrilled to have the opportunity to be affiliated with the department for another year and look forward to continuing research with Bill. Graduating during these intense times was emotional, but the department did a great job at providing spaces where we could celebrate our accomplishments and support each other online.

Maryn Sanders conducting fieldwork.

VALEDICTORAN: CY SRISAWAS DAVID

Cy Srisawas David

Hi, my name is Cy Srisawas David and I am honored to have been selected as this year's EPS valedictorian. My undergraduate path has been somewhat circuitous, with classes in evolutionary biology, geology, and mechanics eventually leading me to geophysics, my major. I am grateful and I feel incredibly fortunate to have been provided wonderful research and design opportunities in EPS along the way.

My most involved research opportunity was part of an effort to experimentally validate a new analytical solution for runoff on curved hillslopes[1] developed by Dana Lapides, a graduate student in EPS. Models for hillslope runoff are used by engineers and urban planners to predict the timing and magnitude of peak flows in channels after the onset of rain. Traditional hydrologic techniques that rely on empiricisms (such as the Rational Method[2]) are easy to use but potentially less accurate, whereas numerical solutions of the 2D flow equations have greater fidelity but are computationally expensive. Previous efforts[3] to strike a balance between ease-of-use and fidelity have employed 1D flow equations on a planar hillslope, and the project I was part of generalized this method to hillslopes with modest curvature.

The approximation of 2D shallow water flow on a curved surface by 1D equations requires validation. Since numerical solutions contain inherent uncertainty and natural hillslopes have non-ideal geometry, we validated the analytical solution with constructed scale model hillslopes. We CNC-milled table-sized hillslopes out of foam and built a budget-friendly rainfall simulator using plastic tubing and misting nozzles. Using our laboratory set-up, we collected runoff measurements from convergent, divergent, and planar hillslopes.

As predicted by the analytical solution, the behavior on convergent and divergent hillslopes differed greatly. On divergent hillslopes, the greater surface area near the outlet leads to a faster initial response to rainfall but a slower approach to the peak flow. For the convergent case, the funneling effect of the hillslope leads to a delayed initial response followed by a rapid approach to the peak flow. Moreover, the analytical solution for curved hillslopes has a significantly better fit to the experimental data than does a solution for a planar hillslope.

So, the analytical solution in this project provides a simple and intuitive way to quantify the effect of landscape curvature on runoff. The upshot of this development may be that engineers and planners could be better equipped to predict flash floods and fluvial erosion.

For me, this project was a fascinating application of fluid mechanics in an Earth science context, and an incredible research experience that taught me about theoretical development, scale modelling, data processing, and scientific writing. I am grateful to Dana Lapides, the Department of Earth and Planetary Science, and the Undergraduate Research Apprenticeship Program for giving me this opportunity and providing us with the resources and lab space.

Cy David coats a machined foam hillslope with sand to improve flow.

1 Lapides, D.A., David, C., Sytsma, A., Dralle, D., and Thompson, S.. (2020) Analytical solutions to runoff on hillslopes with curvature: numerical and laboratory verification, Hydrological Processes, doi:10.1002/hyp.13879 https://www.fs.fed.us/psw/publications/dralle/psw_2020_dralle001_lapides.pdf.

2 Kuichling, E. (1889). "The relation between the rainfall and the discharge of sewers in populous districts." Transactions of the American Society of Civil Engineers, 20(1), 1–56.

3 Giráldez, J. V. and Woolhiser, D. A. (1996). "Analytical integration of the kinematic equation for runoff on a plane under constant rainfall rate and Smith and Parlange infiltration." Water Resources Research, 32(11), 3385–3389.

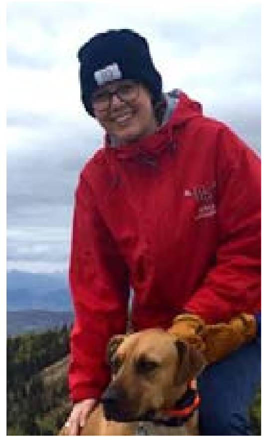
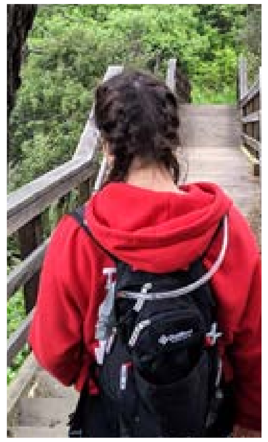
COMMENCEMENT 2020

COMMENCEMENT 2020

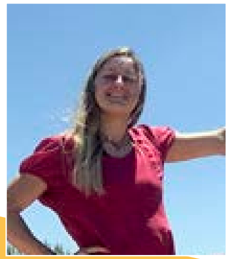
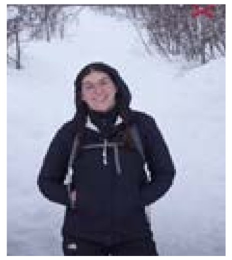
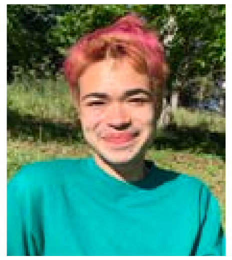
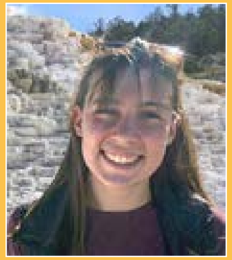
THIS YEAR EPS AWARDED 31 BAS, 1 MA, AND 11 PhDS

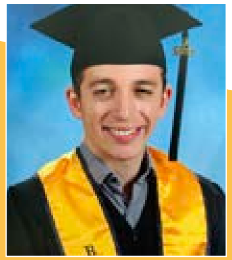


Geology: Abby Jackson-Gain, Fran Meyer and Erik Vides; not pictured: Aaron Tolopilo.

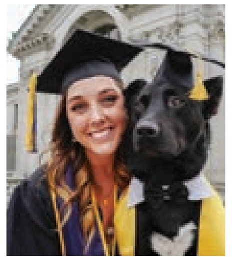



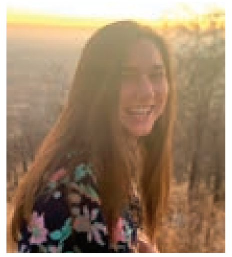
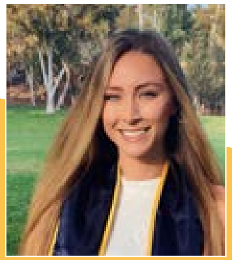
Atmospheric Science: Madeline Knauer and Anna Tarplin; not pictured: Rafael Castro.

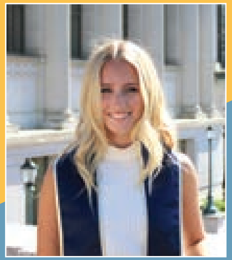
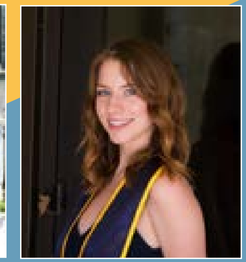








Geophysics: Ariane Arndt, Lea Bartlett, Cy David, Jessica Gagliardi, Kevin Gao, Saeed Mohanna and Maryn Sanders; not pictured: Kira Rodriguez.

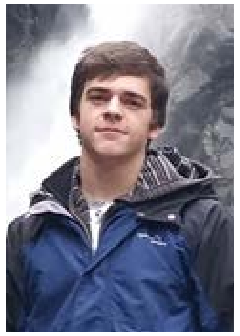


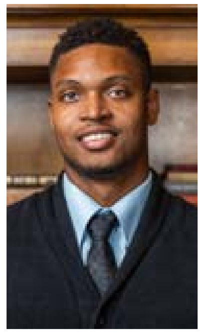




Marine Science: Katrina Carter, MacKenzie Davey, Lexi Dobson, Chloe Luyties, Kaori Nguyen, Nannaphat Sirison, Camille Stepanof and Daisy Stock; not pictured: Alexandra Houston.

Smith Peak: EPS 39 field trip group photo in Yosemite National Park with Professor Rudy Wenk (at lower right). Photo credit: Daisy Stock, 2017.

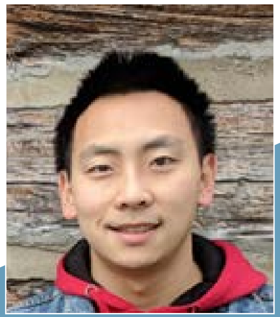


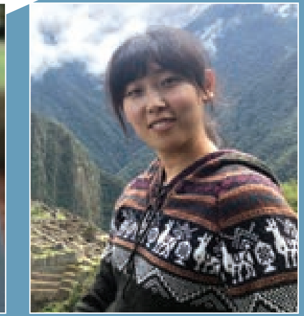

Planetary Science: Colin Domnauer, Moshammat Mijjum.

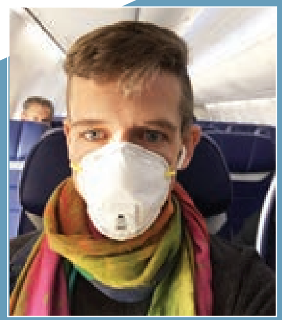




Environmental Earth Science: Edward Ramirez, Louis Walker and Miao Yidong; not pictured: Mariela Hernandez, Marco Perez.

MA: Ryan Caspary.

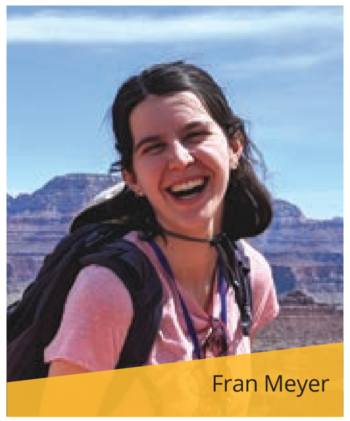





PhD: Stephen Breen, Alexander Charn, Isabel Fendley, Jinsol Kim, Dana Lapides, Nathaniel Lindsey, Jiabin Liu, Yuem Park and Chelsea Willett; not pictured: Nick Knezek, Prabhat.

AWARDS

ASSOCIATION OF WOMEN GEOSCIENTISTS OUTSTANDING STUDENT AWARD: FRAN MEYER



Fran Meyer

Hi, my name is Fran Meyer and I graduated from the Earth and Planetary Science department this Spring. I am so fortunate to have been selected for the Association of Women Geoscientists Award, and am immensely grateful to the EPS department for helping me get to where I am today. I started my independent research with Nicholas Swanson-Hysell my sophomore year, and completed an honors thesis with this research project. I studied the paleoclimate of the Ordovician period by using existing oxygen isotope data from conodont elements, as well as collecting and analyzing new data. The Ramsden fund gave me the opportunity to go to Oklahoma and collect limestone samples for my own conodont element analysis. I also had the opportunity to go to UC Merced to conduct oxygen isotope analysis on my samples.

The Ordovician is a unique part of Earth history because it contains a major interval of biodiversification followed by a mass extinction that occurred at a time of global glaciation. It is well-established that the beginning of the Ordovician was characterized by a warm climate and the end of the period by a major glaciation, yet the trajectory of cooling through the period remains unclear. Because of this, it is still unknown to us what geologic mechanisms were driving ice sheet formation, and when cooling mechanisms originally began. With the help of many other researchers before me, I was able to produce a new oxygen isotope curve that communicates steady, gradual cooling of sea surface temperatures throughout the Ordovician. In contrast to a prevailing interpretation of cooling, stasis, and further cooling for the Ordovician climate, these compiled oxygen isotope data reveal a progressive cooling trend that resulted in an 11 °C change from the start of the Ordovician to the end of the Katian. This gradual trend supports a driving geologic mechanism that would cause long-term cooling towards the Hirnantian glaciation, and can be applied to assess the relationship of biodiversity and paleoclimate in the Ordovician.

Fran Meyer and Abby Jackson-Gain in Arbuckle Mountains region, Oklahoma. The wind turbines were used as a reference along the highway for the Viola Springs formation. Picture taken by Nick Swanson-Hysell.

CERTIFICATE FOR DISTINGUISHED TEACHING

- **Tyler Cadena**

OUTSTANDING GRADUATE STUDENT INSTRUCTOR AWARD

- **Nathaniel Tarshish**

LOUDERBACK AWARD FOR 2019-20

- **Yuem Park**

ESPER LARSEN JR. RESEARCH FUND GRANTS FOR 2019-20

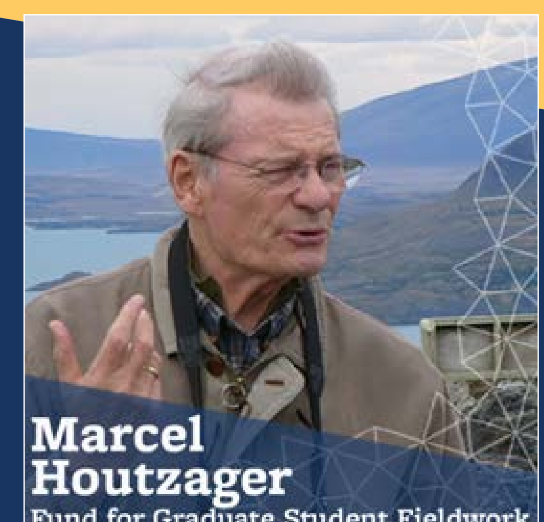
- **Nicholas Swanson-Hysell (EPS)** *Constraining ancient paleointensity through quantum diamond microscopy applied to anorthosite*
- **Paul Renne (EPS)** *Paleomagnetism of the Baird Formation: Constraints on the kinematic history of the Eastern Klamath "Suspect" terrane*
- **Stephen Self (EPS)** *Exploring the nature and age of the Lower Deccan Traps, India*
- **Celine Pallud (ESPM)** *Selenium oxidation by birnessite: Rates, mechanisms and isotopic ratios*
- **Ronald Amundson (ESPM)** *Tertiary and Quaternary Paleoclimate of the Cima Volcanics and the Eastern Mojave Desert*

CHARLES H. RAMSDEN ENDOWED FUND GRANTS FOR 2019-2020

- **Nannaphat Sirison:** Travel grant for research conference, Fall 2019
- **Rafael Castro:** AGU Registration, Fall 2019
- **Shaye Hong:** To develop a standard for the acidification step in sample preparation using a new standard, Fall 2019
- **Anna Tarplin:** AGU Registration, Fall 2019
- **Zaiyo Zhang:** AGU Registration, Fall 2019
- **Saeed Mohana:** AGU Registration, Fall 2019
- **Nonnie (Carly) Coelho:** AGU Registration, Fall 2019
- **Yueyi Che:** AGU Registration, Fall 2019
- **Erik Vides:** AGU Registration, Fall 2019
- **Maryn Sanders:** AGU Registration, Fall 2019
- **Ciara Dorsay:** AGU Registration, Fall 2019
- **Frances Meyer:** AGU Registration, Fall 2019
- **Yuan Lin:** AGU Registration, Fall 2019
- **John Lamb:** AGU Registration, Fall 2019
- **Moe Mijjum:** AGU Registration, Fall 2019
- **Nicole Keeney:** AGU Registration, Fall 2019
- **Lucy Sandoe:** AGU Registration, Fall 2019
- **Leyla Namazie:** For research at the BGC in paleomagnetism, Spring 2020
- **Nonnie (Carly) Coelho:** support the continuation and furthering field-based research to understand how landscape evolution affects the groundwater reliability and variability in montane meadows, Spring 2020
- **Gabriella Petrocelly:** For research equipment on the island of Moorea, French Polynesia Spring 2020
- **James Pierce:** Research in Long Island Sound, Nunavut, Canada; Spring 2020

NADINE TANG AND BRUCE SMITH GRADUATE FELLOWSHIP IN EARTH AND PLANETARY SCIENCE

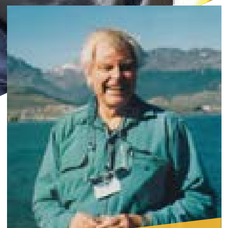
EPS is pleased to announce a new fellowship made possible with the generosity from Nadine Tang and Bruce Smith. The first award will be granted next year. The continued support of our friends and alumni have a real impact on our research and teaching missions.



INAUGURAL MARCEL HOUTZAGER FUND FOR GRADUATE STUDENT FIELDWORK

First Awardee: Michelle Devoe
EPS thanks the Houtzager family for establishing this fund to honor the memory of geologist Marcel Houtzager. The fellowship supports students from developing nations and fieldwork in developing nations. Recipients will use the support to develop new research skills and produce data that will contribute to their dissertations of theses.

ALUMNI UPDATES


Richard Nielsen

RICHARD L. NIELSEN (1964) Richard L. Nielsen passed away on December 5, 2019 in Golden, Colorado. He won his PhD in Geology at Cal in 1964, following BA and MA degrees at CalTech. Richard embarked on a career in mining geology, working for major corporations (Kennecott, Anaconda) and consulting in Colorado and Australia from 1990. In 1996 he was President of the Society of Economic Geologists, the premiere international society of mining geologists. He was President of the S.E. G. Foundation in 2001-2003. Richard was a very successful and highly-regarded professional, who shared his enthusiasm for earth sciences with his colleagues, family, and wider society.
-By Fred Barnard (B.A. Geology, 1963)


Priscilla Grew

PRISCILLA C. GREW (1967) The Galuskina et al. preprint for my new garnet is now online at American Mineralogist in press. Here is the link to a University of Nebraska news story about a new mineral being named in my honor: https://news.unl.edu/newsrooms/today/article/new-mineral-priscillagrewite-named-in-honor-of-renowned-husker-geologist/ In the story, I describe an all-nighter on the probe in fall 1966 analyzing Tiburon garnets. Best wishes and thanks for the memories!
Photo credit: Greg Nathan, UNL Communications

JIM MURRAY (1968) I'm working mostly at my emeritus home office as UW is closed except for essential work. My book project on Chemical Oceanography is essential for me, but not for UW. I also just wrote a paper on "Carbonate System Geochemistry of the Arabian Gulf." pCO_2 in surface seawater is supersaturated so ocean acidification is not a present problem. The question is why? Coral reefs produce CO_2 but have been severely damaged. We make a good case for abiological $CaCO_3$ formation.


Jim Murray

MARC SEELEY (1969) After graduating from UCB in 1969 I was in the USAF as an Air Intelligence Officer using my geology acquired air photo interpretation skills. Then I was a staff geologist for the USDA - Soil Conservation Service. I worked on California north coast river basin erosion studies related to timber harvesting practices and working with ranchers and farmers on the design of small dams. I then completed my MS in Geology at Cal State Hayward (now East Bay) and was hired by Woodward-Clyde Consultants (WCC) where I worked as an engineering geologist on projects including the Trans Alaska Pipeline, PG&E nuclear power plant siting studies, regional fault studies in Costa Rica, geotechnical investigations for facilities development in Saudi Arabia, and evaluations of Dam Safety Policies and Procedures for the USDA. In the late 70s I started a Geotechnical Engineering and Geology consulting business with a WCC colleague (Merrill & Seeley, Inc.). My focus was on active fault, landslide and geologic hazards investigations until the early 80s when the emphasis of my work transitioned to soil and groundwater environmental investigations and remediation. In 1991 I started Environmental Geology Services, specializing in engineering and environmental geology and groundwater resources. After 45 years as a full time professional geologist I am now semi retired, doing selective work as Seeley & Associates. I will always remember Professor Charles Meyer who taught my introductory geology class at Berkeley, inspired me to major in geology and set me off on a most interesting and enjoyable career.


Robert Barker

ROBERT BARKER (1971) It is nearly fifty years since I received my PhD in Economic Geology at Berkeley. After a career in international mineral exploration, I tell people that I am a "geologist by training". I now consider myself a writer. My first book was The Devil's Chosen, examining decision processes of the Holocaust. More recently I have written two international thrillers, with a geologist as the hero. Still looking for the movie contract. robertwbarker.com

Have an update you would like to share in next year's publication? Go to eps.berkeley.edu and click on Connect With Us, or email eps_alumni@berkeley.edu. Alumni can also request to join our LinkedIn group; please find the group here: www.linkedin.com/groups/6927573

EVENTS


Halloween party, October 31, 2019.


Thanksgiving potluck, November 25, 2019.


Santa Barbara's Day annual holiday event, December 18, 2019.


Adapting staff birthday to virtual platform, April 8, 2020.


MPS Dean Frances Hellman singing at holiday event in December 2019.


Still from Twelve Days of Santa Barbara video showing lyrics of "three French men", for Santa Barbara's Day, December 18, 2019.

EPS staff celebrate finishing an escape room challenge for a lively team building exercise, December 12, 2019.


Still from Twelve Days of Santa Barbara video showing lyrics of "and a student in a Bear tee", for Santa Barbara's Day, December 18, 2019.

DONORS

Albe, Monica Jane
Bacon, Charles Robert
Barker, Cynthia C
Barker, Robert Wadhams
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Bilodeau, Bruce Joseph
Boering, Kristie A
Borg, Iris Yvonne
Buffler, Richard T
Cebull, Shirley
Cebull, Stanley E
Charlton, John Douglas
Clarke, Samuel Harvey
Cohen, Robert J
Cohen, Ronald Carl
d'Alessio, Matthew Adam
De Luchi, Denis A
De Luchi, Joanrae
Depaolo, Donald
Dewey, James William
Doerschlag, Mark Gregory
Doerschlag, Nancy
Dresselhaus, Carl D
Dusel-Bacon, Cynthia D
Ferencz, Robert M
Ford, Sean Ricardo
Fournier, Kelly
Fournier, Thomas John
Fujisaki, Jill Mie
Garnett, Susan J
Garnett, William Allan
Gil, Jesse
Henshaw, Carol R
Henshaw, Paul Carrington
Higashida, Donna Sato
Higashida, Neil T
Hjelm, Maria Louise
Howard, Ann F
Howard, Kenneth L
Kaiser, John Eric
Knapp, John Stafford
Lai, Voon Hui
Lancelle, Karen Mariposa
Lopez-Morillas, Consuelo
Louie, Kendall Bong Hu
Louie, Susan C
Lowe, Wallace Taylor
Manga, Michael
Marsh, Bruce D
Marsh, Judith A
Mccabe, Steve
McLean, Tracey A
Merino, Enrique
Michon, Alfred Edgar
Murray, James Wray
Murray, Pamela G
Nguyen, Newton Huy
Ohlmann, Barbara May
Ohlmann, John P
Padilla, Veronica Moreno
Perron, Taylor Taylor
Plumb, Patricia C
Plumb, Robert E
Romanowicz, Barbara A
Rudolph, Maxwell Lutman
Savina, Mary Elizabeth
Simila, Gerald Wayne
Smith, Alan Lewis
Smith, Bruce L
Stanwyck, Rebecca Armstrong
Storch, Susan
Swanson-Hysell, Nicholas
Tang, Nadine May-Ing
Taylor, Roger L
Taylor, Sherry Lewis
Templeton, Dennise Christine
Templeton, Jeremy
Walchuk, Nicholas Peter
Whitson, Amelia Danielle
Woodard, Suzanne
Xie, Yanxia

OPPORTUNITIES TO HELP

Financial support from current members of EPS and alumni play a critical role in providing opportunities for all our students in the classroom, in our labs, and outdoors. A pressing need is to make our field education and experiences accessible to all – there are real costs to providing these opportunities and we remain committed as a department to providing the best geoscience education we can to all students.

Give to EPS Page (https://give.berkeley.edu/fund/FN7220000)

EPS 50 students (and Prof. Lau) mapping intrusive igneous rocks at Point Reyes National Seashore. Photo by Michael Manga.

FACULTY & STAFF

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