

UC Santa Barbara Earth Science



Chair's Letter: Andy Wyss

Alumni & Friends,

How tumultuous, disruptive, and disheartening 2020 has proven! To write about departmental highlights, as I ordinarily would, against the cascading crises enveloping our country and planet, would be inappropriate and disrespectful. COVID-19 forced UCSB to cease in-person instruction in early March, and we have only the dimmest sense of when campus life might return to normal. Even more profound is society's latest cycle of efforts to stamp out systemic racism, efforts precipitated by the abominable murder of George Floyd. Regrettably, we must acknowledge that the geological sciences are among the, if not *the*, STEM field(s) farthest behind in evolving the membership of its practitioners to one reflecting the diversity of our population as a whole. Please know that, after far too many years of passivity, our faculty, staff, students, and campus are fully committed to taking meaningful action that builds on the moral imperative of this moment.

Geologists have an unusually long temporal perspective. One disadvantage of this frame of mind, perhaps, is the temptation to expect that conditions will eventually change for the better on their own. At the same time, geologists uniquely appreciate the power of small, inexorable changes, operating locally but summed over vast distances, to literally reshape what existed before, even in the geological snap of a finger. They also know that cataclysms can permanently reconfigure landscapes overnight. With vigorous, concerted, and sustained effort, we are committed to, and optimistic about, working on an intermediate timescale to make our department and science more just, equitable, and inclusive. Department life didn't stop in 2020, necessity being the mother of invention, but I will leave you to discover its signal moments on your own.

Wishing you health, fulfillment, and hope.

Graduate Student News

Earth Science Grads Investigate COVID-19 Response

With many research projects stalled by the coronavirus pandemic, doctoral students Elizabeth Erickson and Han Xiao swiftly pivoted to channel some of their energies towards their own investigation of the human impact of COVID-19.

Elizabeth Erickson aims to create a space to acknowledge the life of grads through COVID-19 and provide them the cathartic experience of recording their feelings into words for a virtual community of peers, affirming their existence and togetherness, even in isolation.

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Photo: Oman. Photo by Matt Rioux

New Field Course (Field Petrology): The 2020 Edition

by *Matt Rioux and Susannah Porter*

A highlight of the past academic year was a field trip to Oman in the fall of 2019. The field trip was part of a new course called Field Petrology (EARTH127-227), which integrates classroom, lab, and field experiences to study igneous, metamorphic, and tectonic processes. For the first offering of the class, Professors Matt Rioux and Susannah Porter focused on the geology of Oman, which is known for the spectacular Semail ophiolite—a massive thrust sheet of oceanic crust and mantle—and world class Neoproterozoic exposures (550 to 750 million years old).

Ten undergraduate and eleven graduate students spent the quarter learning about Oman geology through lectures, labs, and seminars at UCSB. Given the diversity of the geology, Susannah and Matt wanted the class to be highly interdisciplinary, covering everything from the formation of oceanic crust, to the evolution of early life, to carbon sequestration. Professors Francis Macdonald and Phil Gans attended many of the lectures, adding their expertise. In addition, Professors Juan Campo (Religious Studies) and Sherene Seikaly (History) gave guest lectures on the history of Islam and the Middle East.

The course culminated in a two-week field trip to Oman in December, 2019, led by Matt, Susannah, Phil, and teaching assistant Alex Johnson. Students flew into Muscat, the capital of Oman. After a day touring the city

(and recovering from jetlag), the group spent the next two weeks touring the Oman Mountains and camping in the desert. During the trip, the students studied all aspects of the ophiolite, walking through complete sections of lower oceanic crust, visiting exposures of the crust-mantle boundary (the 'moho'), observing sheeted dikes and pillow basalts formed when lavas erupted onto the sea floor, and carrying out a two-day mapping exercise to study metamorphic rocks formed at the base of the ophiolite. Outside of the ophiolite, the group studied Neoproterozoic sedimentary rocks and debated their implications for the Snowball Earth Hypothesis, led by graduate students Adrian Tasistro-Hart, Eliel Anttila, Judy Pu, and Sam LoBianco; hiked along the edge of the spectacular Grand Canyon of Oman, which cuts into the highest mountains on the Arabian Peninsula; and observed km-scale sheath folds and ultra-high pressure rocks formed in a subduction zone related to ophiolite formation.

The trip was an amazing experience for everyone involved. It was made possible by the generous donation of Professor York Mandra, a former instructor in the department. We are very grateful to have had the late Alex Johnson as a TA, who added so much to the class and trip. He will be dearly missed.

Grand Canyon of Oman.
Photo by Susannah Porter



Earth Science on (and beneath) the Open Ocean

by Zach Eilon and Morgan Raven



Morgan Raven and crew aboard the R/V Sally Ride in San Diego, California

Our department has a proud tradition of fieldwork, addressing scientific questions by collecting new data in remote locations. Assistant Professors Morgan Raven and Zach Eilon bring a fresh perspective on this legacy: in addition to their land-based research programs, both venture out in the open ocean. Picture yourself grabbing onto a desk, one hand steadying your laptop as the floor pitches 20° first one way... then the other... and the nearest land is a mere 1,000 km away. Data gathering doesn't get much more remote or dramatic than this!

Prof. Raven investigates how CO₂ and organic matter cycle through the ocean. Nearly a quarter of the CO₂ released by humans into the atmosphere over the last 20 years has dissolved into the ocean, where it can be used by tiny marine plants and microbes to build their cells. When they die, some of these carbon-

rich cells stick with tiny shells, fecal pellets, and other snotty goo to form particles dense enough to sink to the seafloor and get buried. Spread over the entire ocean, this mechanism is crucial for removing carbon out of the ocean-atmosphere systems, which has profound consequences for global climate. The question

is: how much organic carbon gets buried, and what factors control this? At sea, Prof. Raven and her group collect samples of surface organisms, sinking particles, and seafloor mud. They spend their time carefully slicing sediment from tubes of mud, layer by layer, and tracking floating particle traps as they float along with the currents. In December 2019, her group teamed up with microbiologists in UCSB's EEMB department (Profs. Santoro and Wilbanks), to collect samples right here in the Santa Barbara Basin on the UCSD research ship Sally Ride. We're lucky to have this field site on our doorstep: the SB Basin is world-famous for burying tons of organic carbon in its sediments. Fieldwork at sea is just the beginning, though; the freezer full of (smelly, exciting) mud will gradually reveal its secrets in coming months.

Prof. Eilon views the oceans

Continued on page 10



Zach Eilon and crew aboard the R/V Kilo Moana in the Southwest Pacific Ocean

Alex Johnson

by John Cottle



Oman, photo by Layia Asakawa-Ekeland

Alex Johnson, a PhD candidate in our department, tragically passed away on July 21st 2020, after a short illness. Alex was a larger-than-life character who, in his short career, had a significant impact in research and undergraduate teaching and mentorship. In recognition of his achievements, Alex was awarded a posthumous PhD on July 29th 2020.

I first met Alex in February of 2017 when he interviewed for a PhD position at UCSB. I still vividly remember listening to Alex explain his research with such knowledge and enthusiasm that it immediately became apparent he was an exceptional Earth scientist, and I knew I had to try as hard as possible to recruit him. Fortunately, after some arm-twisting, he decided to join our program, and I'm so glad he did, because he enriched my life, and also that of so many people in Earth Science.

As I'm sure do many of you, I have countless great memories of Alex that I will cherish forever. Time spent with him, be it in the field, laboratory, or the corridors of Webb Hall, was always entertaining and educational in equal measure. I distinctly remember an afternoon spent on top of a hill on Santa Cruz Island, staring out over the Pacific Ocean discussing everything from the merits of various British 90's comedy shows, to the latest developments in garnet geochronology, and everything in between!

As a scholar, Alex was a sheer delight to interact with. He would come into my office with a certain look on his face that

meant he'd either solved a problem, or thought of ten more he'd like to solve. Either way, I was sure to learn something new! I was continually amazed by the breadth of projects he was working on. His depth of knowledge was equally phenomenal. In his brief career, he had already published six papers and garnered numerous research awards. He was on his way to the top of our field, and Earth Science is much poorer for his loss.

Alex, the consummate mentor, delighted in seeing his students learn, develop new skills, and succeed. Watching him interact with undergraduate researchers was a pleasure. His memory will live on in those students, who today, are thriving, in no small part because of the time and energy Alex devoted to their development as people and scientists. For his sustained teaching and mentoring efforts, Alex was awarded the Muckers 2018 "TA of the Year" prize, an Honorable Mention in the 2018 GSA national Excellence in Teaching Awards, and the 2018–2019 UCSB Fiona and Michael Goodchild Graduate Mentoring Award.

There is so much more to say about Alex than I can possibly express here. Alex was witty, intelligent, articulate, deeply thoughtful, curious, driven, generous, humble and so many more superlatives. In short, he was the best possible colleague and friend I could have hoped for. I am going to miss him terribly. His impact on so many people—students, staff and faculty alike—was so profound, that his passing leaves a massive hole in our community. It's hard for me to imagine that Alex's knee-slapping full-volume laughter will no longer fill the corridors of Webb Hall, but I am certain his enormous impact on each one of us will not be forgotten.

When I told one of Alex's Nepali friends of his passing, he offered me this Buddhist mantra, and I'd like to think Alex would approve:

*Yesterday is a memory, tomorrow is a mystery, and today is a gift,
which is why they call it the present.
What the caterpillar perceives as the end;
to the butterfly is just the beginning
Everything that has a beginning has an end;
make your peace with that and all will be well.*

So long my friend. Go well. You will be truly missed.

Bruce Tiffney Retirement

After 34 years on the Earth Science faculty at UCSB, Bruce Tiffney retired, July 1st, 2020

by *The Editors*

After 34 years on the Earth Science faculty at UCSB, Bruce Tiffney retired, July 1st, 2020.

Bruce obtained his undergraduate degree in Geology from Boston University, and his Ph.D. in Botany from Harvard.

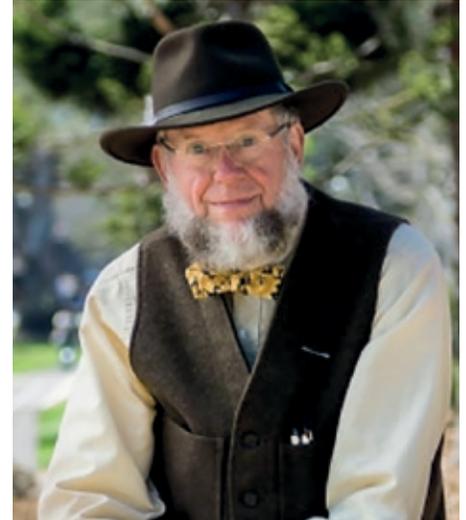
Bruce was lured to UCSB from Yale University, where his multidisciplinary career began. To this dedicated New Englander, and wife Robin, who lived many years in Nigeria and has deep farming ties in New Hampshire, Santa Barbara represented quite a transition.

Bruce and Robert Norris (then freshly retired) had many parallels, including deep affinities for teaching, gardening, and bow ties. This friendship ultimately led Bruce and Robin to be invited to buy the “mini farm” next door.

Bruce’s research specialty, fossil fruits and seeds, was tied (until then) to East Coast localities. Bruce and Robin soon eliminated this “challenge,” at classic localities in the western Sierra. Remarkably, they almost immediately uncovered what previous observers had simply overlooked—a rich trove of late Eocene fruits and seeds, most new to North America. Beyond his fascination with fruits and seeds, and what they reveal about shifting Cenozoic climates and biogeography, Bruce is deeply interested in plant-animal interactions, how changing plant communities affect the evolution of herbivores, and the role animals play in dispersing seeds.

UC Santa Barbara, known for its research strength, is equally highly committed to education. Bruce enthralled huge numbers of UCSB student, particularly through GE courses. This put him in frequent contact with students from the College of Creative Studies (see below). His classroom skills earned him the Academic Senate’s coveted Distinguished Teaching Award.

Bruce has served the campus indefatigably. He championed the Library—a two-decade-long campaign over three librarians culminated in the recent new addition. He developed the campus flora as a teaching tool, and coordinated UCSB’s sustainability infrastructure. He preserved the architecturally iconic Faculty Club Building, while bringing it into broader service. On the Biology faculty in the College of Creative Studies he took on various committee assignments, chaired its Faculty Executive Committee, and served as Dean from 2006 to 2016. Although he co-taught courses on field painting and botanical illustration, his primary focus was ensuring the strength of the eight (now nine) CCS majors and student success. Given that some 75% of CCS students go on to higher degrees, and often very productive and important careers, Bruce is proud to have accelerated the growth of human knowledge and understanding as its Dean.



Meanwhile, Robin’s appreciation for the California landscape blossomed into local renown as a plein-air painter—many of her works grace the front office. Robin and Bruce host the department’s acclaimed annual welcome party for new graduate students at their “mini farm” (too bad about COVID-19 this year!). Bruce presides over the fires and smoker, while Robin’s breads, baked beans, salmon, and extraordinary range of pies and cakes have a fervent following. In recognition, Robin was named a Department “Fellow” some years back.

With Bruce now formally retired he is diving back into research. Delightful possibilities await.

We Wish For...



Alex Johnson, a beloved graduate student in our department, passed away on July 21st 2020, after a brief illness. Over the course of his tragically short meteoric career, Alex carried out an abundance of impactful research, and served as inspiring teacher, mentor, and role model. In recognition of his achievements, Alex was posthumously awarded a PhD. The Department set up the Alex Johnson Memorial Fund to sustain and promote one of his passions: the mentorship of undergraduates in Earth Science. Donations can be made online (www.geol.ucsb.edu) under GIVE, or the old-fashioned way using the enclosed envelope.



We are deeply grateful to our many alums, colleagues, and friends of the department who have helped us financially this past year!

Staff Spotlight: Tracee Davis



After 8 years on campus, Tracee joined our staff as Academic Personnel and Student Affairs Manager. Tracee's previous work experience was in Graduate Division and Psychological & Brain Sciences, along with

membership on campus committees: Chancellor's Staff Advisory, Professional Women's Association, United Way, and Academic Advising Solutions. As a student, Tracee studied abroad in Copenhagen and continues her positive relationship with UC Education Abroad. Tracee can be found taking her nieces to Disneyland, or out on road trips to national parks. Before Webb Hall quieted, she appreciated "everyone in the halls was always smiling and happy to be here!"

UCSB ES-Friends

A special mailing list for our alumni and other friends of the department that delivers special news and announcements about our department and its faculty, alumni, and student accomplishments.

To sign-up, please send a request to grad@geol.ucsb.edu.

With Appreciation

The Department of Earth Science profoundly thanks the following individuals and institutions for their generous donations between July 2019 and June 2020

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

Graduate Student Spotlight



Chandler Adamaitis

Before starting my master's at UCSB, I attended Ohio State University, where I received a BS in

Earth Science in 2018. During my undergraduate studies, I found I had a great interest in geomorphology and Earth surface processes, specifically those related to natural hazards. Such began my search for graduate school advisors that studied these subjects, where I came across Ed Keller and his work on debris flows. I packed up my car and headed out West.

My research investigated the chronology of past high-magnitude debris flows in the Santa Barbara-Montecito, CA areas. After the 2018 debris flow event in Montecito, the community feared the possibility of another event happening in the near future. Prior to my study, the recurrence interval of these events was largely unknown, despite evidence for them in nearly every canyon in the area. A major limitation to

understanding how often these events happen is the limitation of traditional dating methods. As an alternative, we used the calibrated rate of weathering rind thickness development to estimate the age of the boulders in debris flow deposits around town. In doing so, we concluded that high-magnitude debris flows occur on the order of every 1 to 2 ky. Overall, this study has improved the understanding of the chronology of high-magnitude debris flows and the general understanding of the geomorphic history of our local area.

This project combined my interests in land surface processes and natural hazards, quantitative GIS analysis, and field work, plus it included research that has societal and real-world importance. Moving forward, I plan to pursue a career that involves these interests and applies the many skills I learned while at UCSB.

Graduate Student News

Continued from Page 1

Han Xiao repurposed his expertise in analyzing seismic data. Seismic noise includes "cultural noise" reflecting human activity. As human activity decreases, so does the energy recorded by seismic instrumentation, thus providing real-time monitoring and spatial mapping of activity patterns in response to the pandemic.

These two projects are supported by grants from the Multidisciplinary Research on the Coronavirus and its Impacts (MRCI) initiative, and the College of Letters and Sciences.

Melissa Scruggs was named a participant of AGU's 2020 Voices of Science program, an honor bestowed on just 40 scientists annually. AGU commended Melissa for her enthusiastic promotion of science's societal benefits, an effort capitalizing on her enviable communication and advocacy skills.

Brian Penserini received a 2020 GSA Graduate Student Research Grant. This grant is designed to support graduate student research in the geosciences and ultimately enhance

the geoscience workforce. This grant will help support his ongoing work studying the fluvial evolution of the Sutlej River drainage network in the northwest Himalaya.

Melissa Scruggs received the ScienceLine Earth Science Award, as the outstanding answerer of K-12 students' questions in our field for 2019–20.

Sarah Gerenday, having received the ScienceLine Earth Science Award last year, was recognized for her continued exemplary participation in the program.

Amy Moser received a 2020 Graduate Student Association Excellence in Teaching Award, which recognizes graduate students who have shown excellence and gone above and beyond as teachers at UC Santa Barbara. Amy was one of only eleven students selected from among the more than 200 nominees for this distinction.

Rodrigo de Negri

As a kid, every summer, we used to camp near Quizapu volcano, in the south of my country, Chile. I'd go up river jumping through colorful rocks, looking at Quizapu. I had so many questions about what was around me.

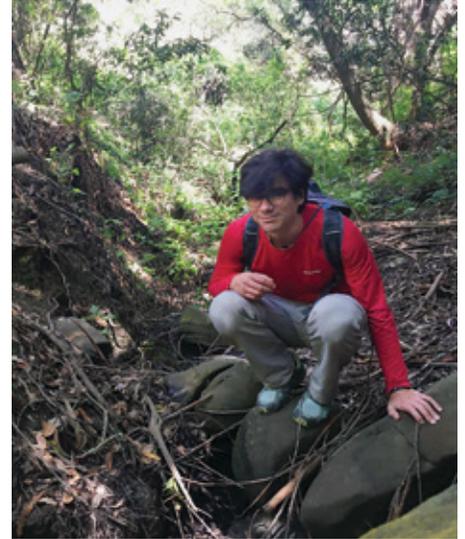
I studied physics at the University of Chile, but pure physics was far away from my original questions. One day, the giant magnitude 8.8 Maule Earthquake (2010) helped me shake my confusion away: why not look for some answers in geophysics?

I went to the National Autonomous University of Mexico (UNAM) to do a master's in geophysics. I modeled the wave propagation of any centered explosive source in an arbitrary-shaped axis-symmetrical "magma chamber" embedded in an elastic space. I could finally use what I learned to get a deeper

understanding of volcanoes!

Back home, at the University of Chile, I was trying to figure out how to use infrasound data from the International Monitoring System (IMS) to track volcanic eruptions and earthquakes on the continent. You see, infrasound is a kind of acoustic wave, below the audible level (20 Hz), that's all around us. Imagine giant musical instruments (earthquakes, volcanoes, and even human-made sources) making intricate sound effects, constantly. As practically no one in Chile was part of the handful of experts in this specialty, I came to work at UCSB with my current advisor, Robin Matoza.

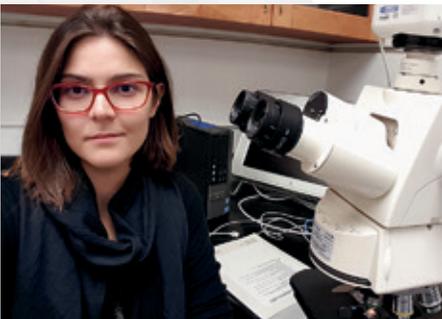
I want to bring some of this knowledge to Chile, to complement seismic analysis of volcanic eruptions with their acoustic counterpart. All our territory is prone to "big natural events" that could lead to a catastrophe, and I'd like to



help prevent that. Using historical infrasound data from the IMS, I'm trying to improve the localization of volcanic sources at long ranges (more than 600 km). This could be especially useful for eruptions in remote areas and could also help us better monitor and characterize regional volcanic activity.

Researcher Spotlight

Heda Agić



Heda Agić joined the Department in mid-2017 as a Postdoctoral Researcher investigating evolution and paleoecology of early complex life. Heda completed her PhD at Uppsala University in Sweden in 2016, applying a variety of microscopy techniques to study Precambrian organic-walled

microfossils—remains of the earliest cells of eukaryotic organisms, before the rise of visible life like plants, animals, and fungi. Earlier, she received MSci and BSc degrees in palaeobiology and Earth Science at University College London in UK, using small shelly fossils (skeletal remains of earliest animals) to correlate early Cambrian strata. Before moving to Santa Barbara, Heda briefly served as a Geological Survey curator. Fieldwork often takes her to remote places around the globe. To collect fossils, she evaded polar bears and reindeer in areas that are also a home to one billion-year-old rocks on Baffin Island in Arctic Canada, or sites exposing the Ediacaran-Cambrian

boundary and preserving the Ediacara biota in Arctic Norway.

Heda's main research interests are major transitions in the history of life. She uses the fossil record to understand interactions between the biosphere and the environment during those intervals. Remains of microbes and chemical signatures that record information about the environment they inhabited inform us about the conditions under which complex life evolved and thrived. Precambrian microfossils are crucial for understanding key events in Earth's past, from the origin of the eukaryotic cell, to the evolution of multicellularity.

Continued on page 11

Faculty Awards

David Valentine

Dave Valentine was elected a Fellow of the American Association for the Advancement of Science. AAAS Fellows are a distinguished cadre of scientists, engineers and innovators who have been recognized for their achievements across disciplines, from research, teaching, and technology, to administration in academia, industry and government, to excellence in communicating



and interpreting science to the public. Newly elected Fellows are recognized for their extraordinary achievements. Election as an AAAS Fellow is a lifetime honor.

Matt Rioux

Matt Rioux received the Academic Senate 2019–2020 Distinguished Teaching Award which acknowledges the efforts of faculty members who successfully combine excellence in teaching with excellence in creative and scholarly work. His commitment to student engagement, enthusiasm,



and caring attitude, create a rich learning experience for all.

Morgan Raven

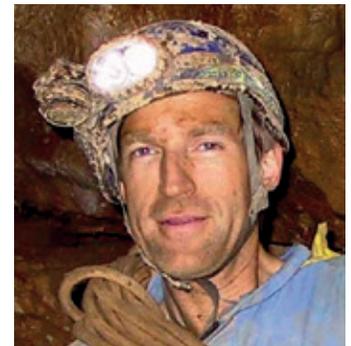
Morgan Raven was selected as a Fellow for Research Corp’s “Scialog-Signatures of Life in the Universe” program. This award is sponsored by the Research Corporation for Science Advancement and the Heising-Simons Foundation. This group of early-career faculty, specializing in fields ranging from data science to geobiology, will meet regularly over the next three years to develop



interdisciplinary proposals that will expand our ability to seek and identify life in extreme and ancient Earth environments as well as on other planets.

Brad Hacker

Brad Hacker was awarded the Norman L. Bowen Award from the AGU’s Section of Volcanology, Geochemistry and Petrology, for his outstanding contribution to the discipline. Awardees are selected on the basis of a single outstanding paper published in any journal, a series of papers, or any



other contribution the Bowen Awards Committee deems worthy.

Open Ocean

Continued from Page 3

quite differently: the water isn’t nearly as exciting to him as what lies under it: the oceanic tectonic plates. These plates are the main driver of mass transport on the planet, and—due to the pulling force of subducting slabs—are ultimately responsible for Earth’s mobile surface. Recent advances in ocean bottom seismic (OBS) technology allow seismologists to image entirely new tracts of the Earth’s subsurface by emplacing geophysical instruments on the seafloor. Eilon is a co-PI on the Pacific OBS Research into Convecting Asthenosphere project. He and his collaborators have deployed 60 OBS instruments in two

large arrays, each spanning ~200,000 square kilometers of the Pacific Plate. These arrays are in deliberately remote locations, each more than a thousand kilometers from the nearest land. The goal of the experiment is to use recordings of global seismicity detected on these OBSs to peer into and “through” the oceanic lithosphere, testing for signatures of multi-scale convection beneath the plates. Along the way (when not rescuing a stranded catamaran or fleeing storms) Eilon’s team mapped large swaths of seafloor, discovering large underwater volcanoes and seafloor fabrics never before seen.

A New Geochemistry Clean Lab Facility at UCSB

by Matt Jackson

A long-awaited modern geochemistry clean lab in the Earth Science Department is nearing completion, and will serve as a new facility for carrying out chemistry on rocks for geochemical and geochronological research. The lab will enable cutting-edge geological research focusing on geochemical analysis of ultra-small samples, including isotopic characterization of single mineral grains, and the tiny (<100 micron, or roughly the width of a human hair) individual melt inclusion trapped in minerals. The new research will provide unprecedented resolution into processes operating in magma chambers, melting of the Earth's interior, and processes that operate to shape both Earth's surface and deep interior.

A primary goal of the lab is to foster student training in state-of-the-art chemistry and mass spectrometry, and to advance fundamental research into processes that shaped Earth's evolution, from terrestrial accretion to the present. A primary value of a science education is learning how to think about (and be skeptical of) data and uncertainties associated with data. Equally important is learning how to make difficult measurements in the laboratory, and to evaluate factors that contribute to the quality of a measurement. This can only be learned through hands-on experience, and the true value of the new geochemistry clean lab at UCSB will be in training future scientists.

The new clean lab features a porthole to an adjacent, temperature-controlled room that is purpose-built to house the Thermo Triton Plus Thermal Ionization Mass Spectrometer (TIMS) that arrived at UCSB two years ago. The instrument is outfitted with high-ohmage ($10^{13} \Omega$) amplifiers to precisely measure isotope ratios for the smallest samples. Ultra-clean conditions in the new lab, including ISO class 100 rooms with class 10 work spaces, will permit analysis of even smaller samples with greater confidence of avoiding environmental contamination. Methods for precise and accurate isotopic analysis of <100 picogram quantities of strontium and neodymium have been developed at UCSB. However, at these small sample sizes, the microparticles in the air, which also accumulate on laboratory surfaces and in acid reagents, contribute to sample contamination and become a primary limiting factor in the sample sizes that can be characterized. With trial and error, we have reduced our environmental contamination (or "blank") to ~500 femtograms of Nd, or



a half of a trillionth of a gram. The ultra-clean conditions in the new lab will help reduce the blank (and, thus, the size of samples that we can characterize) even further.

The lab design and construction has been a 7-year endeavor but, like a fine California wine, it should be well worth the wait. Jackson and his students look forward to ramping up new research in the newly-minted lab.

Heda Agić

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At UCSB, Heda is working with Prof. Susannah Porter to understand early eukaryotic ecology by measuring stable carbon isotope values of individual microfossils from the 780–720 million-year-old Chuar Group, Grand Canyon, Arizona. Tiny, soft-bodied fossils constitute the bulk of the Precambrian fossil record, but little is known about their habitats or metabolism. It is unclear whether early eukaryotes were restricted to oxygenated surface waters or also inhabited the rest of the water column, which was predominantly anoxic and ferruginous throughout the Proterozoic. This information is critical to understand how the environment (e.g., stepwise ocean oxygenation) impacted eukaryotic evolution. Organic carbon isotope analyses of single microfossils can also yield insights into short-term environmental variability, as well as the paleoecology of ancient microbes.

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Oman Coast. Photo by Susannah Porter

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