SPRING 2016

Earth & Planetary TIMES

HARVARD UNIVERSITY DEPARTMENT OF EARTH AND PLANETARY SCIENCES

R/V *Knorr* at sunset in the Atlantic. This vessel was used during a recent five-week MARPEX cruise to collect samples from the Mid-Atlantic Ridge.

CEDRIC HAMELIN

Exploring Earth's Final Frontier

What mid-ocean ridges reveal about tectonics and magmatism

BY JOCELYN FUENTES, THIRD-YEAR GRADUATE STUDENT

When most people think of the ocean, they imagine a vast expanse of calm blue water with little thought for what lies below, or they think of the water that fills the ocean basins. For many ocean scientists, however, what is most interesting lies beneath the water on the seafloor. Two-thirds of the geology of the planet is there, obscured by the water above. The most prominent feature of the seafloor is the mid-ocean ridge system, one of Earth's most active tectonic, volcanic, and biologic features. There exist deep rifts that would dwarf the Grand Canyon, continuous volcanic eruptions, and giant hot springs teeming with biology unlike anything on land. The ocean ridge system is the largest continuous mountain chain on Earth, and it wraps around the globe for over 65,000 km and is the site of 80 percent of active volcanism. As divergent plate tectonic boundaries, ocean ridges are an essential part of the Earth system where the seafloor is constantly being created through magmatism and faulting.

Since the first map of the ocean floor was created, in 1977 by Marie Tharp and Bruce Heezen, many advances have been made in the field of marine geology and geophysics. In particular, our ability to map and image the seafloor has improved greatly. Unfortunately, these techniques generally require a ship, which is costly and time-consuming. The result is that approximately 90 percent of the seafloor has only been mapped by satellites, which have limited resolution under water. There are more accurate maps of the surface of Mars than there are of Earth's seafloor. This leaves the majority of the ocean unexplored and unsampled by humans, including much of the mid-ocean ridge system. This is one

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FROM THE CHAIR JOHN H. SHAW

EPS concentrators pose in front of Opal Mountain during last August's undergraduate field trip to the Southern Canadian Rockies.

KUN WANG

This issue of *Earth & Planetary Times* comes to press as we celebrate Commencement for another generation of talented graduate and undergraduate students. They have plans to pursue an incredible diverse set of opportunities—from careers in the private sector, academic positions, government service, NPOs, and yes—for some—even more graduate studies! The passing of these "academic seasons" is one of the great pleasures I enjoy as a member of EPS: welcoming new cohorts of students in the fall, the ramp-up in research and course work through the year, and the hectic pace of trying to finish a senior thesis or that last dissertation chapter without sleep in far-too-short a time.

Our faculty and staff also have seasons—albeit on longer time scales. David Johnston was awarded tenure, and we are fortunate to have recruited three excellent new junior faculty this past year: Marine Denolle, Rebecca Fischer, and Roger Fu. We also strengthened our academic programs through the hiring of preceptors Esther James and Annika Quick. On a much sadder note, we lost two distinguished colleagues, Adam Dziewoński and Richard O'Connell. Both served as monumental leaders in our field and were mentors to generations of students and scholars. They were also dear friends, and will be sadly missed.

Please enjoy reading of all these comings and goings—and much more—in this latest issue of the *Times*.

Harry C. Dudley Professor of Structural & Economic Geology | Harvard College Professor | Chair EPS

Letters to the Editor

I very much enjoyed the last issue. The tributes to Rick (who was on my committee), Dick Holland, and JBT, with whom I worked and knew well brought back many pleasant memories. The piece on Adam's symposium was especially meaningful. Adam was the lead of my committee, and we remained close until his untimely passing. My association with EPS continues as an affiliate supporting instrumentation research at the Adam Dziewoński Observatory in Harvard, MA. I was grateful to help sponsor the get-together in Adam's honor along with fellow students George Chou and Dick Sailor. Adam had a profound impact on seismology, and an even more profound impact on the lives of those of us whom he mentored.

A photo taken of the Steim family in 2009 when the Seismic Station was renamed the Harvard–Adam Dziewoński Observatory shows Anna Steim '09, Adam, Joe Steim '78, AM '82, PhD '86, and Ella Steim '05.

I was surprised to learn, however, that my Harvard GSAS career ended with an AM, and so recently, in '09. Could it be that the perennial student's archetypal recurring nightmare of being unable to graduate because of a missing course credit was actually true? I checked, and sure enough, I really had graduated with a PhD in '86. I was Adam's third PhD student. Whew.... Maybe the author was confused by the many Steims who have been the beneficiary of Adam's teaching, including my two daughters (see photo), Ella, AB '05, and Anna, AB '09, who were also alumnae of Adam's EPS core course. We all miss him and Sybil immeasurably.

Keep up the good work and best wishes!

Joseph M. Steim '78, AM '82, PhD '86
President, Quanterra Inc.
steim@quanterra.com

Editor's response: Dr. Steim did indeed have a PhD in the first round of newsletter proofs, but for some unfathomable reason, we took away his hard-earned doctorate and replaced it with a newer, more moderate master's. We apologize for any nightmare we may have induced.

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of the main reasons I enjoy being part of the marine science community: the oceans are truly Earth's last unexplored frontier and new discoveries are being made all the time.

My primary focus as an igneous petrologist is understanding the processes that lead to the formation of the volcanic rocks at mid-ocean ridges. As the plates separate, hot mantle rises to fill the void and melts due to the release of pressure. The melt then migrates to the surface, often recrystallizing minerals as it cools in a magma chamber, before it erupts on the cold seafloor. The end result is a volcanic rock known as a mid-ocean ridge basalt, which covers the entirety of the seafloor. Because these rocks come up continually from Earth's interior, the ocean ridge is sometimes referred to as a "window into Earth's interior." By looking at the rocks under a microscope and measuring the rocks' chemical compositions (elemental abundances and isotopes), one can answer a variety of questions about the processes that created a particular suite of rocks and the properties of the mantle beneath the ridge. For instance, at what temperature and pressure was the magma chamber prior to eruption? Did the magma interact with the surrounding wall rock while migrating through the crust? How much did the mantle melt to produce this magma and at what temperature and pressure? What was the composition of the mantle source that melted to produce these rocks?

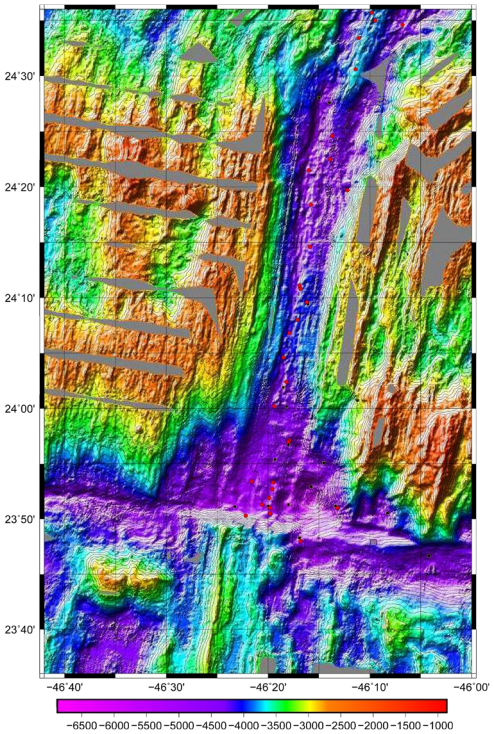
The ocean ridges are very diverse, ranging in spreading rate from about 1 to 20 cm per year. They are also influenced by other factors such as hot spots and proximity to continents. Understanding all these effects is a massive undertaking, and ocean ridge basalts provide a means to investigate a vast number of questions. For example, mapping over the past decades has shown that ocean ridges are segmented, with discrete segments of ~15-~100 km separated by offsets of varying distance. What is the origin of this segmentation, and how does it relate to magmatism? Why are ridges not continuous? Is segmentation caused by faults in the lithosphere? Is it caused by the amount of melting in the underlying mantle? Might segmentation be influenced by variations in mantle composition?

In addition to differing scales of segmentation, there also exist different styles of spreading at ridge segments expressed in the topography and ridge morphology. This is particularly evident at slow-spreading ridges where there are huge variations in ridge morphology over relatively short distances. Some ridge segments have very deep rift valleys with abyssal hills symmetric about the ridge. This is a textbook slow-spreading ridge segment where spreading is dominated by magmatism. In contrast, other segments have large-scale low-angle faults (detachment faults), which accommodate spreading tectonically on one side of the ridge segment. And still others do not seem to fit into any category, and the process of accretion at these segments is unclear. Many studies have suggested that the style of segmentation could be related to melting or magma chamber processes, which should be reflected in the compositions of the erupted basalts. However, other studies have suggested hydrothermal circulation and faulting are the main influences on the style of accretion, which would lead to basalt compositions unrelated to the tectonic features nearby.

Questions about these diverse aspects of segmentation and mid-ocean ridge accretion can all be informed by the geochemistry and petrology of the basalts erupted along the segments. Chemical compositions of basalts reflect the mantle temperature, mantle source composition, extent and depth of mantle melting, and crustal processes. By studying the chemistry of the rocks as well as the geology, one can constrain magmatic and tectonic processes happening along the various segments.

> *Because these rocks come up continually from Earth's interior, the ocean ridge is sometimes referred to as a "window into Earth's interior."*
>
> *~Jocelyn Fuentes*

To investigate these questions, I am working with collaborators on the area of the Mid-Atlantic Ridge between 23° and 30° N, which spans approximately 800 km and consists of 13 ridge segments with diverse morphology. This area is particularly useful for this study for a variety of reasons. Most importantly, it is a very normal stretch of ridge far from hot spot influence with relatively constant obliquity and spreading rate. This eliminates many variables such as large thermal and compositional anomalies, which would make it less applicable to a global segmentation study. It also consists of multiple types of segments adjacent to each other, allowing for easy comparison.



Slow-spreading ridge segment. A portion of the study area showing a classic slow-spreading ridge segment. Depth scale is in meters below sea level. Area of image is 110 x 70 km.

Using the high density of samples collected on the recent MARPEX cruise led by my advisor Charles Langmuir, Higgins Professor of Geochemistry, in combination with existing samples, our work attempts to address these questions with geochemical and geophysical data. We are currently in the process of analyzing over 50 different elements and five different isotopes for each sample. The complete dataset will hopefully demonstrate whether there are indeed differences in the compositions of erupted basalts across segments boundaries or at various tectonic features. Furthermore, this dataset could be a launching point to explore other questions related to mantle geochemistry.

Over the coming years, I hope to develop a better understanding of the relationship between tectonics and magmatism at mid-ocean ridges. My hope is that understanding my particular study area will provide a clue to global-scale problems of segmentation across the entire range of spreading rates.

KUN WANG

Jocelyn Fuentes is a third-year graduate student working with Charlie Langmuir on understanding the relationship between tectonics and magmatism at mid-ocean ridges.

Food, Movies, Earthquakes, and Sailing

Freshman Seminars offer students—and EPS faculty—something different

They've been meeting since fall, exploring connections between climate and food security, looking specifically at the idea of drought and conflict in Syria and sub-Saharan Africa through analysis of climate and food data. Their class officially ended before the winter break, but the students and faculty member continue to gather, now with the addition of other undergraduate and graduate students, and now working on a paper to submit for publication.

"It's become a mini-research group," says Peter Huybers, professor of Earth and planetary sciences and environmental science and engineering, of the evolution of his Freshman Seminar, **Food, Climate, and Data.**

The depth of participants' involvement in the seminar is unusual—but not completely unheard of in Harvard's Freshman Seminars Program, where seminar students and faculty often form bonds that last through the students' college years (and beyond), meeting up for reunion meals, for example, long after their semester-long seminar has finished.

Freshman Seminars—established in 1963—are one of Harvard's best-loved academic traditions. Offered only to freshmen, the seminars bring together a faculty member with up to 12 students for two to three hours weekly to explore a topic of shared interest.

This coming year, Harvard will offer more than 140 Freshman Seminars, representing every School and every discipline, says Toni Trainor, department administrator of the program. The 2016–17 catalog was being finalized at the time of writing, but past EPS-related seminars range from the above-mentioned investigation into climate and food security, to looking at earthquakes as they've been studied throughout history, to delving into the mechanics and science of sailing, to exploring what's real—and what's not—in natural disaster movies.

Graded sat/unsat, the seminars draw freshmen of different interests and from different backgrounds to study a subject that might be outside their primary focus. (Though it might become their focus: Trainor knows of one career that was launched from a Freshman Seminar.) Faculty, too, enjoy the small-group setting and the opportunity to take on subjects outside normal Harvard College fare. "It's a chance for them to be creative," Trainor explains. "Sometimes the seminar topic is the faculty member's hobby, sometimes it's their passion or research."

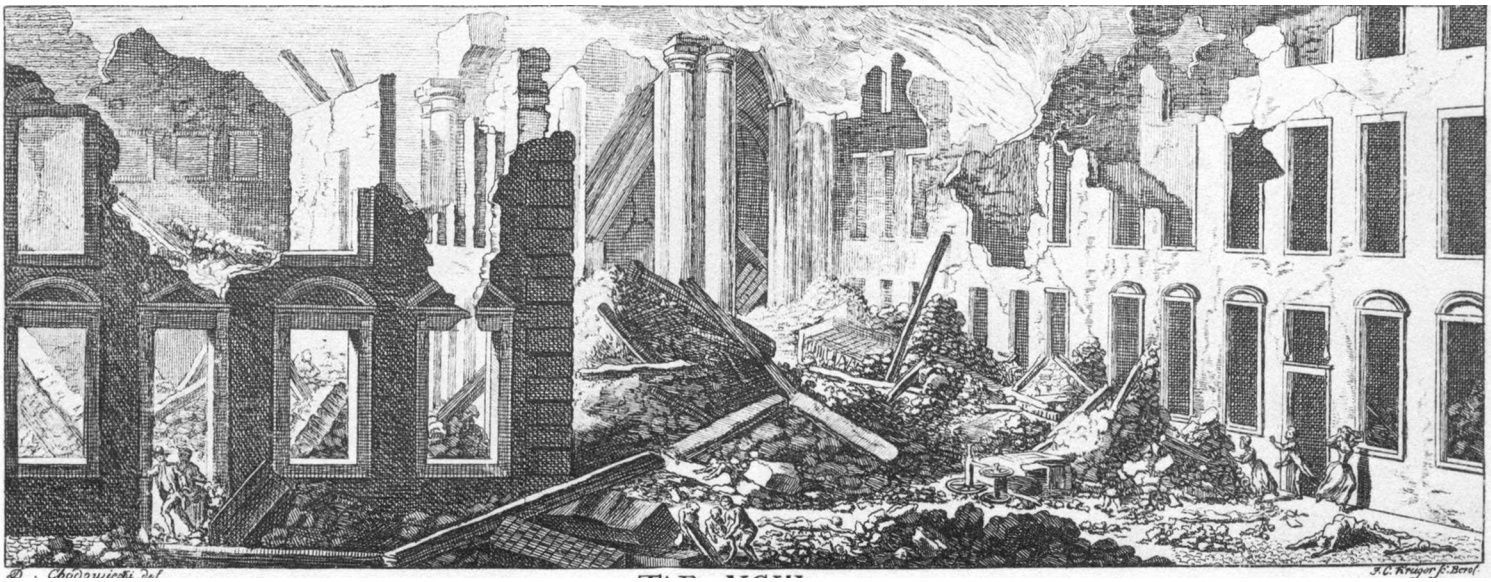
Brendan Meade's Freshman Seminar, **On Broken Ground: The Science and Impact of Earthquakes**, looks at the Earth through the lens of earthquake history and the impact of earthquakes on humans historically and today. Normally, Meade, professor of Earth and planetary sciences, teaches the General Education course "Natural Disasters" and graduate classes on earthquake science and tectonics; the seminar offers a different angle on earthquakes.

"The class represents an opportunity to see earthquakes not only as natural phenomena and objects of scientific inquiry but also as shapers of history. Modern earthquake science has deep roots preceding the plate tectonics revolution," Meade explains.

Trainor refers to Professor of Earth and Planetary Sciences Miaki Ishii's Freshman Seminar, **GeoSciFi Movies: Real vs. Fiction**, as an example of how Freshman Seminars are an opportunity for faculty to "try something new."

"I was looking for a good tool to teach Earth science to students who may not necessarily be interested in Earth science," says Ishii of her idea for the seminar.

"It was really fun. I am not a moviegoer, so viewing these sometimes unsettling scenes wasn't necessarily always enjoyable, but watching them critically to identify correct and incorrect features was interesting.



COURTESY WIKIMEDIA COMMONS.

A copperplate, republished in 1909, of the destruction from the 1755 earthquake that devastated Lisbon.

The students were fantastic, and I learned a lot from them, too," Ishii says.

In addition to watching movies and discussing the science involved (for example, how many helicopters and firetrucks would really be needed to address the lava in the movie *Volcano*?), the course used the Montserrat role-playing game to act out government, scientists, and society responding to a volcano as well as the NOAA's role-playing game about Hurricane Island.

Ishii adds that her teaching methodology can be different because the class is longer and smaller. "I also didn't have set topics I needed to cover (which would be very different from a foundational course on, say, math), and that meant that I could focus more on making the class enjoyable and memorable."

And the classes are memorable. Comparing Freshman Seminars with other undergraduate offerings, Trainor says, "They are typically very different from other learning experiences in the first year in that they are more intimate, a lot more interactive, and hands-on, for the most part." She notes that seminars have taken field trips to the Arnold Arboretum, to the Mystic River in Medford, and even to Nantucket (for a seminar on *Moby-Dick*, of course) and to the American Museum of Natural History in New York City.

For Jeremy Bloxham, Mallinckrodt Professor of Geophysics and dean of science in the Faculty of Arts and Sciences, the Freshman Seminar he has led several times, **The Science of Sailing**, builds on his interests and a desire to "show freshmen how simple physics can be applied to real-world problems rather than simply solving the highly contrived problems that they may have encountered in high school."

> *"I saw [it] as a way to show freshmen how simple physics can be applied to real-world problems rather than simply solving the highly contrived problems that they may have encountered in high school."*
>
> *~Jeremy Bloxham*

Noting "fun and sometimes animated debate," Bloxham adds that the seminar "also provides an opportunity to show them that the popular literature on a subject, for example, the generation of lift by a sail (or equally, the generation of lift by the wing of an airplane) is not always correct—misinterpretations of Bernoulli's principle abound." The seminar also considers basic meteorology, water waves, and tides, he says, "none of which requires more than basic Newtonian mechanics."

Freshman Seminars are special for students, too. "For the students it's a great way to develop a relationship with a faculty member," Trainor says. "Here, there are 12 [students]; they're going to get to know the faculty member on a much more personal, intimate level. And, hopefully, that relationship will kindle mentorship and a relationship for their entire time at Harvard."

Faculty feel the same. Ishii says that in Freshman Seminars, "I really get to know the students and they get to know me." Huybers agrees. "I get to know the students much better in such a small seminar formation, appreciating better where they are coming from, how they are thinking, and what they can uniquely contribute to the course."

For example, one of the members of Huybers's seminar had experience farming in Kenya and had firsthand knowledge of growing maize; others had experience in computer programming and statistical analysis.

"A lot of faculty love the Freshman Seminars Program," says Trainor. "They develop personal relationships with the students. I think sometimes there can be learning from both faculty and students." And students, too, rate the program highly. "Normally the feedback is—when you ask seniors to reflect on their four years at the College—it's one of their favorite classes."

» Cathy Armer

An Old Title for a New Role

Meet the department's new preceptors: Esther James and Annika Quick

You may see them setting up the rotation tank for weather demos in EPS classrooms or constructing volcanoes in front of the Museum of Natural History, find them accompanying student excursions to places like World's End (south of Boston), or stumble upon them mentoring college seniors writing theses or meeting with teaching fellows in the Faculty Lounge. You may see them teaching General Education (Gen Ed) sections, or pass them tucked away in their offices in the Geological Museum pondering the best methods for presenting course materials, carefully reviewing syllabi, or finessing course websites.

These ubiquitous new folks at EPS are Esther James and Annika Quick, department preceptors.

Preceptors? Evoking historic educational institutions like Oxford and Cambridge, or even somewhat mystical entities, such as the Knights of the Templar, preceptors exist in some Harvard departments providing language, skill-oriented, or other special instruction, and can also be found at a few other American universities, generally taking on the role of head TF. But at EPS, the role of preceptor is much greater: rather than focus on just one course, EPS preceptors assist broadly with a host of courses and curricular activities.

The department hired its first preceptor in 2009 (and expanded to two positions in 2013), and the role has evolved to become arguably the ultimate behind-the-scenes position, its academic support integral to the EPS experience. As department chair John Shaw notes, "Preceptors in EPS play a central role in enabling us to deliver exciting new learning opportunities in our classes. Many of us were drawn into Earth science through opportunities to be in the field, or

work in the lab, and preceptors help to develop a continuous stream of these activities for our courses that provide similar inspirations to current students."

Agreeing that they "hit it off immediately," as Esther puts it, Annika (who started in January) and Esther (who came to EPS in fall 2015) have been working closely together to learn about the department and identify the places where they can bring their skills to the preceptor mission. Among many tasks, they each currently assist faculty members with five to six classes, in whatever capacity the faculty member feels most helpful, and together they are designing a series of workshops for training EPS teaching fellows. Both also share in the support of 10 undergraduates researching and writing senior theses, and they help out with a variety of other tasks.

"It's an evolving, fluid role," explains Annika. "Right now we are getting familiar with the courses and how things work in EPS." This summer both will work with faculty to prepare for the coming academic year, helping with small things like improving individual labs or field trips to bigger tasks, like designing a new course or overhauling an existing one. "Faculty often know they'd like to improve an aspect of a course but don't have the time or may not know where to start," Annika says. "That's where we come in."

ANNIKA QUICK

Originally from Lexington, KY, the second of five children in a family that loved to travel, hike, and camp, Annika participated in a specialized math and science program in high school, but it was an introduction to geology class she took with her roommates in college that set her course.

"They didn't love it, but I did," she says. "It was a perfect fit. Geology involves all kinds of science, and I got to go hiking and camping at the same time."

She earned bachelor's and master's degrees at Brigham Young University, focusing on glaciology and paleoclimate—and teaching a couple of classes per year as a TA. "I loved teaching," she says.

After a brief stint mapping for the US Forest Service and teaching courses on natural disasters and environmental geology at Bloomsburg University, in Pennsylvania, Annika headed to Boise State for a PhD. There, her focus shifted to a project involving hydrology, geochemistry, and microbiology. She is currently wrapping up her dissertation on the human impact on the nitrogen cycle in streams (via fertilizer runoff, for example) and measuring the resulting microbial processes, producing nitrous oxide (N_2O), an important greenhouse gas, and what that means for climate change. (Hint: "It shouldn't be overlooked.")

At EPS, Annika's dissertation research and background in a broad range of the sciences make her a natural for assisting with a hydrology class as well as the Gen Ed course "Energy and Climate: Vision for the Future," where she is functioning as head TF.

ESTHER JAMES

In her native Trinidad and Tobago, Esther studied sciences in an advanced, extra-two-year high school program, then taught high school math and physics for three years. "I loved math and science, and I loved teaching them even more," she says.

She then ventured to the US—to Florida A&M University—to earn bachelor's degrees in math and physics. "I was very good at the math and I enjoyed doing it, but I wanted to be able to see what I was doing be applied in some physical way," she says. "I wanted to use the math skills I developed during my undergraduate career to apply math to Earth processes."

That desire led her to Boston University to pursue a PhD in geophysics (seismology), to experience snow for the first time, and, it turned out, to revisit a childhood interest in geography and meteorology, while serving as a teaching assistant. (When she was 11, she'd considered a future as a meteorologist.) In January, she defended her dissertation, on using seismic waves to study a portion of the Earth's interior by deriving shear velocity models for the upper mantle beneath the Atlantic Ocean. She'll graduate this spring.

"I have explored how temperature influences the shear velocity structure in oceanic upper mantle, but I would like to do a little more work in that area to explore how other factors such as composition, melt, and volatile content contribute to the observed structure. Hopefully, I can come up with something concrete that defines the upper mantle in the Atlantic in the near future!" Esther says.

Now head TF in a course on natural disasters, in the longer term she also hopes to share her interest in and knowledge of seismology with EPS students. More generally, she hopes to have a greater impact in terms of the structure of some EPS courses, using all she has learned about teaching, math, and the sciences.

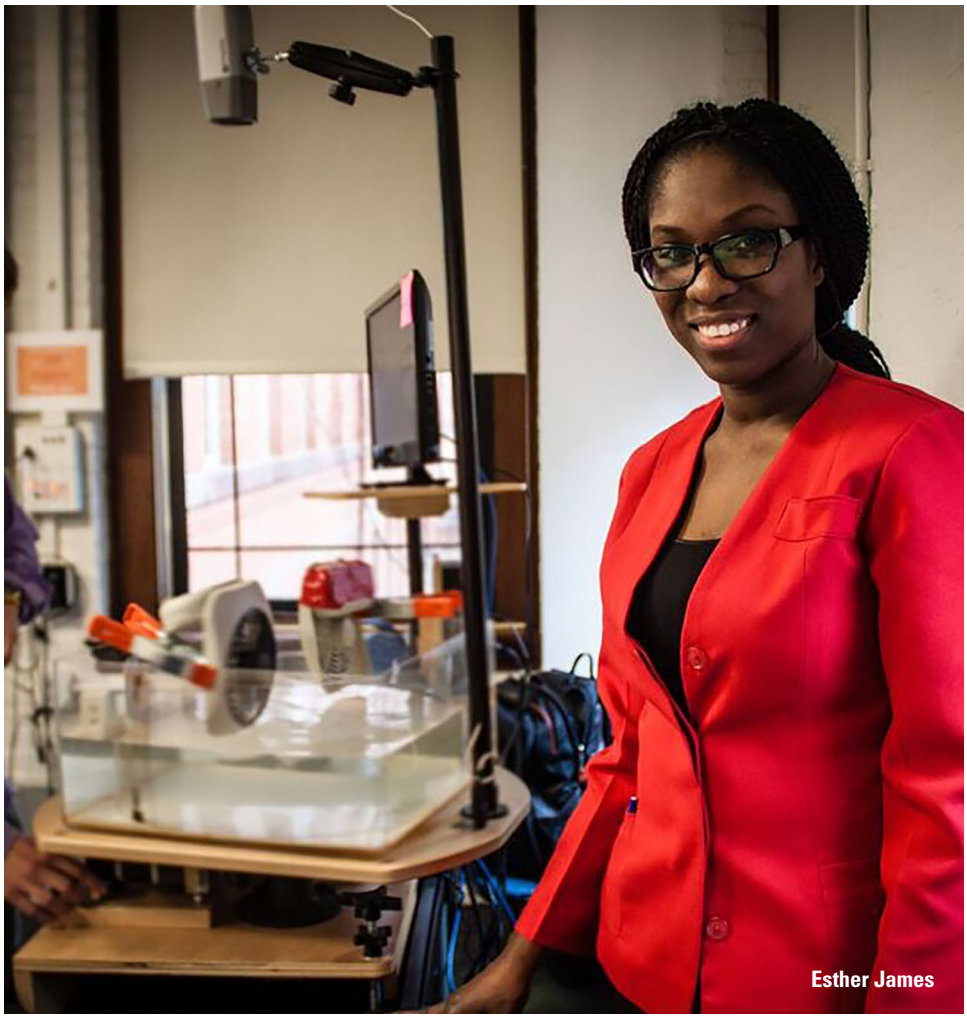
"I love teaching. I honestly feel like one of the things I was placed on this Earth to

KUN WANG

Annika Quick

"It's an evolving, fluid role. … Right now we are getting familiar with the courses and how things work in EPS."

~Annika Quick



KUN WANG

Esther James

"I honestly feel like one of the things I was placed on this Earth to do is to help people; teaching allows me to fulfill that purpose."

~Esther James

do is to help people; teaching allows me to fulfill that purpose," Esther says.

Esther and Annika will be doing just that, supporting the department and each other, too, dividing projects and responding to needs based on their individual backgrounds and strengths, and, in some cases, working together. "If I can't do something at one point, Annika is always willing to cover it for me, and I'm willing to do the same for her or help her with some of her projects if needed. We communicate a lot," Esther says.

» *Cathy Armer*

Where are former EPS preceptors now? **Jennifer Rivers Cole** (2013–14) is at Boston College and is also teaching at Harvard Extension School; **Hillary Jenkins** (2010–14) is an assistant professor II at University of Redlands; and **Jeff Standish** (2009–10), the first of the EPS preceptors, is assistant director of strategic development and training at Flavor Research and Education Center, University of Minnesota.

LETTERS CONTINUED FROM PAGE 2

I enjoyed the spring '15 issue of the newsletter! I was interested to read the letter from Bob Kamilli about the Department's talent shows in the 1970s, and can add to the history of that tradition. I was in the department from 1960-63 (started as a student of John P. Miller, whose career was tragically cut short when he died of bubonic plague in the summer of 1961). In those years we had an annual show in which professors were spoofed in lyrics set to Tin-Pan Alley and Broadway tunes, accompanied by a guitar or two. Most of the lyrics were written by Pat Wilde PhD '65, with contributions from later moon-landing astronaut Harrison H. "Jack" Schmitt and others. Some of the lyrics cut quite close to the bone, making the performers (including me) a bit nervous, but no academic casualties resulted (as far as I know).

Larry Dingman, PhD '70
Professor of Earth Sciences *Emeritus*
University of New Hampshire

The spring 2015 issue of *Earth & Planetary Times* reminded me of the Retirement Symposium in honor of H.D. Holland held in May 2000. I have attached a photograph taken on that occasion with Dick Holland (left), Larry Brush PhD '81 (center), and myself.

Bikash C. Raymahashay, PhD '67
Retired Professor of Geology
Indian Institute of Technology Kanpur

Your thoughts? *Earth & Planetary Times* welcomes letters on its contents. Please send your comments to **epsnl@fas.harvard.edu**. Letters may be edited to fit the available space.

Faculty CHRONICLES

Three Junior Faculty Join EPS

New assistant professors coming on board in 2016 and 2017

The Earth and Planetary Sciences Department welcomes three new junior faculty—Marine Denolle, Rebecca Fischer, and Roger Fu—as assistant professors, beginning in 2016 and 2017. Here, these scholars are introduced with brief descriptions of their work.

MARINE DENOLLE

Marine Denolle, who joined the Earth and Planetary Sciences Department as an assistant professor this January, studies seismic waves, and she has developed a model for understanding past earthquakes and for predicting ground motion, largely with the objective of better understanding the shaking hazard and helping engineers design buildings that can better withstand shaking. But despite years of thinking about earthquakes, she has experienced just a handful of them—and she'd like to keep it that way.

"The more you study them, the more dangerous you realize they are," she says.

Earthquakes are not an obvious academic focus for a teenager in northwestern France (though one of the earthquakes Denolle experienced was in Brittany, her home province); it was the 2004 Indian Ocean earthquake that opened her eyes to their potential impact (and, in that instance, the accompanying tsunami) on human populations. She wanted to understand earthquakes better—and help people living in areas at risk of earthquakes. At the time, she was studying university-level math and physics in an exclusive, two-year program. Almost by chance, she learned of a special three-year bachelor's-plus-master's degree program in geology at the Ecole Normale Supérieure (ENS) in Paris. In addition to the field of study, the program appealed to her realization that she'd like her future to include research rather than engineering, the usual next step for her classmates.

She enrolled in ENS in 2005, studied subjects ranging from oceanography to atmospheric science, to planetary sciences, to more traditional geology, and stayed for a master's degree in geophysics. As a master's student, she did an internship at Yale University with David Bercovici that found her spending six weeks on a research vessel in Hawaii with a group working to recover scientific instruments that had been deployed on the seafloor. On board, her English blossomed and she thrived in the collegial atmosphere of faculty, graduate students, and postdocs. She came ashore feeling that her education "would be more complete" were she to come to the US for doctoral work rather than stay in France, where three-year PhD programs are the norm. "In five years, you have more time to build solid academic foundations, design your own research topic, and expose yourself to other research fields," she explains.


Marine Denolle

An excellent and welcoming geology program and advisor (Gregory Beroza) who became a great mentor ("We clicked right away") in addition to lots of sunshine (not a given in Brittany), drew her to Stanford, where her research involved installing sensors on faults and developing computer analysis of large data sets to study the ambient seismic field to understand how waves propagate underground. She eventually developed what she has named the virtual earthquake (VEq) method, "a method to predict the ground motion using that noise."

Her pilot experiment on the San Andreas Fault allowed her to predict long-period ground motion in downtown Los Angeles with large virtual earthquakes: "I found strong coupling between source directivity and sedimentary basin structure, and confirmed simulations that suggest a waveguide-to-basin geometry that would funnel seismic waves from a San Andreas earthquake into the Los Angeles Basin," she says.

Following graduation from Stanford in 2013, a postdoc position at the Institute of Geophysics and Planetary Physics at the Scripps Institution of Oceanography shifted her focus from understanding the amount of shaking likely to occur owing to an earthquake to understanding what happens at the source of an earthquake—"what are the stresses that are released during the earthquake, what is the amount of seismic radiation," she explains.

Currently, Denolle is setting up her Harvard office and Cambridge home with her husband, Brad Lipovsky, a glaciologist, who has started a three-year postdoc at EPS. (In fact, they married just this March at Lake Tahoe, a "ski wedding" that drew family as well as geologists and scientists from around the globe and also featured an unexpected five feet of snow. "It was pretty epic," Denolle says, and agrees with the suggestion that her wedding planning likely drew on skills she acquired organizing parties—sometimes for more than 2,000 guests—and ski weekends when she was president of the Stanford Graduate Student Council.) She is enjoying Cambridge's cultural-intellectual environment, and looks forward to exploring New England.

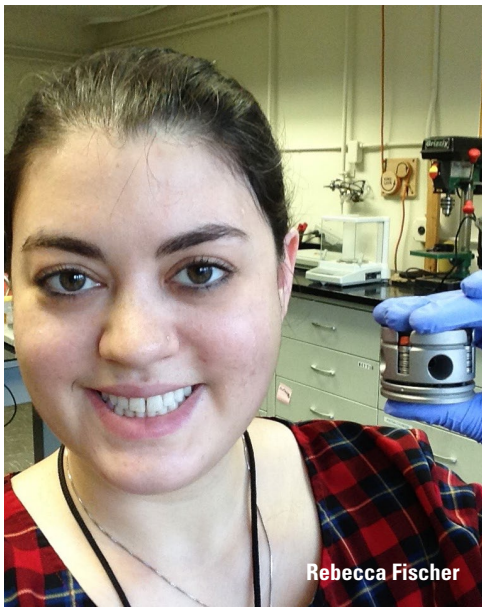
Most of all, she is excited about working with highly qualified graduate students and bright undergraduates.

"You feel almost limitless in the ambitions you can have in a place like EPS at Harvard. And this is where you cannot put any wall to your ambitions in science—in trying to do important science. This is where I really want to be," she says.

REBECCA FISCHER

Over the years, Rebecca Fischer's research has gotten her deeper and deeper into the Earth.

While she was an undergraduate, a summer internship at the Smithsonian's National Museum of Natural History and the Carnegie Institution of Washington involved small melt inclusions within volcanic rocks that act as snapshots of the Earth's mantle; a graduate school project focused on chemical reactions between minerals in the Earth's


Rebecca Fischer

mantle and the metal that's found in the Earth's core; a related graduate school project examined the physical properties of iron-rich alloys that represent compositions that might be in the core; and another added numerical simulations of the accretion of Earth and other terrestrial planets, coupled with a numerical model of Earth's core formation to calculate how the core's composition might have evolved as the Earth was forming.

"I gradually worked my way down through the Earth in terms of the research problems I investigated," Fischer says, a smile conveyed over the phone from Washington, DC, where she is based while on a two-year National Science Foundation fellowship doing a joint postdoc at the National Museum of Natural History of the Smithsonian Institution and the University of California, Santa Cruz. As she got to the core, she realized it was for her "the coolest, and the most exciting."

Fischer will bring her excitement about the Earth's core to Harvard when she joins the Earth and Planetary Sciences Department in July 2017.

Noting that her research directions are varied ("If you talk to me on a different day of the week, you'll get a completely different answer about what problems in Earth and planetary science I am working on"), she summarizes them as trying to understand the formation of the core of the Earth (and other planets); the light element composition of the core of the Earth (and other planets); and the origins of the Earth's volatile elements (especially carbon) and where they reside in the Earth (and, also on other planets) today.

"My research focuses on the formation and chemical evolution of the Earth," she concludes. "I'm interested in the composition of the Earth's core, how it forms, and how planets form more generally."

"I also work closely with seismologists, geodynamicists, geochemists, and meteoriticists to try to understand questions like the bulk composition of the Earth and what it is made of, how we can explain observable seismic properties and layering of the Earth, and how Earth's magnetic field is generated, for example."

Fischer grew up in Rockville, Maryland, just outside Washington, DC, and took her high school interest in science to Northwestern University, intending to major in integrated science, a program of study that focuses on math and all areas of science. A physics of the Earth class as a sophomore got her hooked on Earth and planetary sciences, however, and she double-majored in integrated science and Earth and planetary sciences in 2009.

She returned East for graduate school at the University of Maryland, but found herself back in the Midwest to follow her adviser, Andy Campbell, to the University of Chicago. There, she fully developed her interest in the Earth's core and its composition.

"I love doing experiments in the lab. I love writing scientific papers, teaching, and working with students on research," she says. "One of my favorite things about teaching is conveying information about the things that I'm passionate CONTINUED ON PAGE 10

Dave Johnston Named Full Professor

The department is delighted to announce Johnston's promotion

Six years ago,* Earth & Planetary Times *interviewed David Johnston when he joined the EPS faculty as an assistant professor, providing a brief snapshot of his academic background, his interest in skiing, and his Harvard research. This spring, Johnston, formerly the John L. Loeb Associate Professor of Natural Sciences, was promoted to full professor with tenure. Below is an update on his research and teaching.

In 2010, David Johnston was curious about the timing of the origination of animals; his finding that there was more sulfur in ancient ocean sediment and thus more oxygen in the atmosphere than previously thought inevitably led to the question "Why didn't animals come about earlier?"

That question has formed the basis of one of his main areas of activity over the past few years. He also has been working to understand the biology involved in isotope chemistry, and he has been developing a new method for measuring oxygen isotopes. And in the classroom, he is exploring more methods-based, hands-on teaching approaches and the use of new media to help explain complex information to his students.

All these projects factor into his response to a query about how much he's been skiing lately: "Not nearly as much as I'd like to be, but that's OK," he says, chuckling.

Returning to the question of animals, he says, "We have spent much of the last five years pursuing this question about animal evolution and animal origination—when they first arrived and then what happened in the tens to millions of years that immediately followed."

The established thinking (since the mid-20th century) was that a massive change in Earth surface conditions, in atmospheric oxygen concentrations in particular, catalyzed the biological innovation of animals, he says.

"Given the new tools that we have at our disposal, we could go in and better quantify


JOHN HAYES

Dave Johnston

these sorts of storylines," he notes, referring to his group's focus on iron in marine sediments and a database they created to test hypotheses without biases. "However, what our work has revealed is that animals are actually very sensitive to thresholds rather than requiring massive changes CONTINUED ON PAGE 10

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and that the Earth became modern-like in atmospheric composition about 100 million years later than what had been proposed," meaning that the original animal life didn't require these modern-like conditions.

Interestingly, this timeframe had been proposed in the 1960s, but was quickly replaced thereafter. Johnston's group has published articles—highly scientific and for the more general scientist—on the findings, and, he says, "People are picking up on it, which is great."

A second project has been to understand cellular-level mechanisms for generating isotope effects. "Normally, isotope geochemists view biology more or less as a 'black box' that generates a signal," Johnston explains, "and what we've asked is what is it about the biochemistry of that organism—or what's happening in the black box—to learn something about what environmental controls, as they pertain to that geology, are modulating or setting the isotopic signal that we can see, both in laboratory experiments and also as preserved in the geologic record."

"We think we might have an opportunity to measure certain mineral phases that still carry a little bit of tropospheric O_2 in them. So it would be a way of directly accessing paleoatmospheric information."

~Dave Johnston

A third research area, which has taken his focus for the past 18–24 months, has been work to develop "a new method for measuring oxygen isotopes that may—*may* is the important word—actually allow us to more directly extract paleoatmospheric composition."

What this means, he says, is that rather than (the usual) proxy studies, "We think we might have an opportunity to measure certain mineral phases that still carry a little bit of tropospheric O_2 in them. So it would be a way of directly accessing paleoatmospheric information."

Meanwhile, Johnston is finding new ways to connect with students. "We're targeting our undergrads—who are absolutely amazing," he says. "We've been playing with different 'flavors' of content for explaining complicated concepts," he adds, pointing to a video cartoon posted on his website as an approach he's considering developing further.

From research to teaching, Johnston says, "It's fun. I get up every morning because I know I'm going to learn something new."

"One of the things that I've fallen in love with in this department is the community and the family that exists in EPS; it's really special," he adds. ✱

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about and getting students excited about those things too, and seeing the connections forming in students' minds when they're starting to understand things."

"Harvard has some of the best students in the world, and I am really excited about working with them—both in the classroom and the laboratory," she says. "Research collaborations with students and engaging in dialogue with students in the classroom can lead to new ideas and directions for research and teaching."

At Harvard, she also looks forward to pursuing her research (she will continue traveling to the synchrotron she uses the most, at Argonne National Laboratory Advanced Photon Source outside Chicago) and working with faculty in EPS and across the University, bringing together her interests in physics, geochemistry, and planetary science.

To a question about whether she'd be joining the cadre of EPS faculty who ski, Fischer responds, "I can't ski to save my life." However, she says, at Chicago she enjoyed playing intramural sports. "Usually our department would put together a team of graduate students, and we were always the worst team in the league, because we were all big science dorks, and none of us were very good at sports. … It was really fun."

ROGER FU

It's not every day that an *Earth & Planetary Times* interview takes place on a ship anchored in the Weddell Sea off Antarctica. But that's where EPS assistant professor-to-be Roger Fu spent five weeks this spring, sampling Cretaceous-age rocks on and near James Ross Island while based on the RVIB *Nathaniel B. Palmer.*

"These results feed into my interest in true polar wander and deep earth geodynamics as well as my interests in the mechanism by which sedimentary rocks become magnetized," says Fu, a paleomagnetist whose work encompasses both planetary and terrestrial questions.

The location was bound to be interesting: In addition to the ice-worthy research vessel mentioned, Fu has called everywhere from Beijing to Chicago to Virginia to California to Cambridge to Chile home, and his research ranges from paleomagnetics (his PhD dissertation, "Magnetic Fields in the Early Solar System," involved laboratory measurements of meteorites to understand the types of magnetic fields in the early solar system and what they tell us about planetary formation), geodynamics, and ethnoastronomy. (However, in the interests of full disclosure, this interview was conducted via email.)

Roger Fu

Fu, who will join the Earth and Planetary Sciences Department in July 2017, first came to Harvard as an undergraduate—in 2005—curious about environmental science and protection. Once on campus, his focus turned to astrophysics, but a class with Paul Hoffman and Dan Schrag, the well-loved EPS 8, History of the Earth, brought him into the EPS fold, though he kept astrophysics as a joint concentration.

The pursuit of geodynamics started his sophomore year with EPS 204, Global Seis-

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mology (taught by Miaki Ishii and the late Adam Dziewoński), bolstered by EPS 161, Global Tectonics, and EPS 201, Physics of the Earth's Interior (both taught by the late Richard O'Connell). "Rick was very good about offering insightful advice but at the same time let his students find their own interests," Fu says. "So I ended up working on exoplanet ice mantle convection for my senior thesis, which he advised and which was published in 2010."

But long before geodynamics, Fu says he was fascinated with folklore connected to geology: "I liked reading about Native American myths as a kid, and I was fascinated by the idea that some myths have historical grounding, like the legends about great floods in the Pacific Northwest, which turn out to be based on actual megathrust earthquakes and their tsunamis."

Following graduation, Fu traveled to Chile on a fellowship to study geological folk stories. He lived in Trapa Trapa, an isolated community of the Mapuche-Pewenche people, but didn't find the folk stories he sought and thus switched his focus to ethnoastronomy. "I've been a stargazer since age 10; it's definitely my 'main' hobby, so it was a natural thing to study."

Returning to the US, Fu began graduate school at MIT's Department of Earth, Atmospheric, and Planetary Sciences, where, in the interest of trying "something experimental," he focused on paleomagnetism, working with MIT's Benjamin Weiss, in planetary sciences. "I like paleomagnetism's combination of basic physics, ever-advancing techniques, and wide applicability to the Earth sciences," Fu explains.

In the midst of graduate work, in 2014, Fu traveled to Guatemala to pursue "a funny combination" of paleomagnetics and his childhood interest in Native Americans. "There's some evidence that the builders of some statues in Guatemala were aware of magnetism centuries before civilizations in the Old World. I went there with Joe Kirschvink [Weiss's adviser, at Caltech] to measure those statues in much greater detail than before." A paper summarizing their findings is on Fu's agenda.

In his upcoming position at Harvard, Fu looks forward to maintaining a mix of planetary and Earth topics, collaborating with a broad array of faculty. "I see myself at the intersection of a lot of interests in the department. Paleomagnetics can be widely applied to a number of questions that other faculty are pursuing."

Fu also looks forward to interacting with EPS students. "Our cohort (when I was an undergraduate) was also very friendly and cohesive and made a great community. It would be nice to be part of that again and to advise some very motivated students. … I think people don't select EPS as a major unless they really are passionate about it. I like that self-selection."

» Cathy Armer

RICHARD O'CONNELL (1941–2015)

Richard (Rick) O'Connell, professor of geophysics and faculty member in EPS since 1971, passed away on April 2, 2015. Rick came of age in the years immediately following the wide acceptance of the theory of plate tectonics, and if that paradigm signals the dawn of modern geophysics, then he was undoubtedly a giant of postmodern geophysics. In that fertile, quickly evolving period in the history of our field, many important scientists came to prominence; that which distinguished Rick from many of his contemporaries was the breadth of his scholarly work, the remarkable generosity he showed toward his colleagues and students, and his love of the logic, precision, and discourse of science. He was a polymath who made enduring and transformative contributions to our understanding of mantle structure, dynamics, and rheology; the link between mantle processes and plate tectonics; plumes and hot spot tracks; subduction zone dynamics; sedimentary basin evolution; Earth rotation, and postglacial rebound.

In both a figurative and literal sense, Rick's world always extended well beyond Cambridge, MA. He was raised on the family ranch in Montana, and returned to it throughout his life. This upbringing gave him an abiding affection for America's wide-open spaces and the value, and values, of those who live within them. He was a student of history, and this provided him with context for both his life and his research, and a scientific philosophy that avoided trends and focused, instead, on fundamental problems at the edge of understanding. To borrow a phrase from another American who was deeply rooted to his country, Walt Whitman, Rick's scholarship was "loos'd of limits and imaginary lines."

His profound legacy in science is reflected in the prestigious honors he received (the Love Medal from the European Geophysical Union, the Inge Lehmann Medal from the American Geophysical Union, and the Arthur L. Day Medal of the Geological Society of America), the generations of scientists he supervised, and the many, many more that he influenced. His legacy in life includes, first and foremost, his family: his wife, Susan, whom he adored and who happily shared both his world of ideas and his adventurous spirit on both land and water, their daughter Lily and his son Brian. Those of us who were lucky enough to call Rick a friend will all miss his incomparably sharp wit, his sage advice, and the sense, whenever we spoke to him, that we were sharing time with a human being of great substance.

A portrait of Rick-cum-Indiana Jones taken during the undergraduate field trip to Hawaii in 2011. As his wife, Susan Playfair, notes, "He would enjoy the sobriquet although he was always molding the crease in his hats to reflect the 'Montana' look that he grew up with."

» Jerry X. Mitrovica, Frank B. Baird Jr. Professor of Science

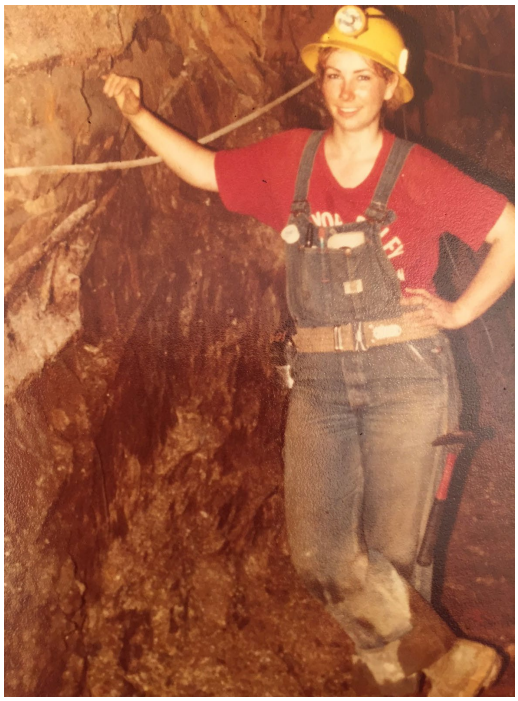
Slated for Geology

Claudia Hackbarth's journey from gravel to EPS and beyond

When she was a young girl growing up in Chicago, Claudia Hackbarth's family would take driving vacations all over the country. As her parents pointed out spacious skies and amber waves of grain, Hackbarth, keeping her head down, noticed that the gravel in the different parking lots the family car pulled into were (a) pretty, (b) different, and (c) interesting.

This is a portrait of the young scientist, now vice president for unconventional resource technologies at Shell Oil, doomed to geology.

Hackbarth PhD '84 stuffed her pockets with gravel from those family trips, and had a large rock (or pebble) collection in her bedroom closet before going to college—and taking geology classes—at the University of Virginia. Eventually, her mother put the stones she collected from parking lots all over America into the garden, guaranteeing, says Hackbarth, that "some future geologist will be really confused."



Then. Claudia Hackbarth in 1983 in a Peruvian silver mine during one of her summer trips with advisor Ulrich Petersen.

Now. Claudia in 2015, in front of an experimental oil well in the Permian Basin, West Texas. (Of note: Claudia is "flaunting the flannel." See page 27.)

By the time she arrived as a graduate student at Harvard's then–Department of Geological Sciences (the department became Earth and Planetary Sciences in 1986), Hackbarth's early fascination with rocks, enriched by visiting the "old geological museum with its amazing basement," had deepened into a desire "to do something" for society. At EPS she met Professor Ulrich Petersen, who became her thesis advisor, and the match was perfect. She could learn about rocks, combine that with what was economically important to society, and further her understanding that "everything we live with in the world comes from the earth."

Petersen, Hackbarth recalls, was the son of a mining geologist in Peru. He actively consulted for the Peruvian mining industry each summer, occasionally taking students (including Hackbarth) along to visit silver mines in the high Andes. Hackbarth's dissertation—on the geochemistry of the sulfosalt minerals in the silver mines of Coeur d'Alene, Idaho, and how zoning gave clues to the geological processes that formed them—involved spending two summers a mile below ground.

Hackbarth thought that after leaving graduate school she would work for a mining company. However, in the early 1980s the bottom fell out of the domestic mining industry, and North American mines and operations closed down. Consequently, after graduation she went to work in 1984 for the research branch of the Nuclear Regulatory Commission, studying the long-term disposal of high-level nuclear waste—which needs to stay undisturbed for 10,000 years. Shortly thereafter, in 1985, she got a call from Shell R&D and has worked there ever since, celebrating her 30th anniversary last December, even though, as she says, she had never studied anything about oil and gas in school.

"I knew nothing about the industry," Hackbarth says, "but I knew rocks," and she learned stratigraphy "on the job."

At Shell, Hackbarth has spent a lot of time—and is right now—working on developing new technologies to find, develop, and extract unconventional resources. That includes fraccing (the spelling, Hackbarth explained to the editor, is used by those in exploration and production circles "to avoid any subliminal connection to a vulgar word"), or, more properly, hydraulic fracture stimulation, the injection of a fluid at high pressure into the subsurface to create fractures. These fractures provide high-permeability pathways for fluids (oil, gas, and brine) to reach the wellbore and hence the surface.

Regarding the controversy surrounding fraccing, Hackbarth says, "I know fraccing has a poor public perception, but I also know what's true and what isn't. You know what's interesting? In 2001 the US refused

to sign the Kyoto Protocol in part because we felt the carbon emissions target would be too challenging. It turns out that the huge natural gas resource unlocked by modern fraccing techniques has caused the commodity price of natural gas in North America to plummet; gas has displaced a lot of coal for electricity generation and thus by 2014, United States CO_2 emissions had fallen to 1996 levels. That's a huge improvement for the environment."

About the time Hackbarth started at Shell, the oil and gas industry entered an enormous downturn. Between November 1985 and March 1986 the price of crude fell 67 percent. Sound familiar? It should. Between June 2014 and March 2016, the price of crude dropped 70 percent. The first drop was due to a flood of oil from the Middle East outstripping demand. Today the root cause, according to Hackbarth, is that "the price of oil has cratered due to abundant domestic supply driven by fraccing." OPEC, led by the Saudis, decided to fight back in November 2014 by pumping oil aggressively—despite the oversupply issue. The thinking was that strong OPEC output would cause prices to drop to uncomfortably low levels that U.S. shale producers would struggle to cope with.

> *"I knew nothing about the industry … but I knew rocks."*
>
> *~Claudia Hackbarth PhD '84*

Today the country Hackbarth crisscrossed long ago with her parents, picking up stones, has returned to an oil production level that is the highest since 1972. Going forward, Hackbarth will continue working to improve shale gas and oil technologies, including better models for exploration and development, while enjoying being surrounded by, and working with, "really smart people." That's why she enjoys working at Shell; that's why she was delighted by her time at EPS.

» David Rosenbaum

Three Siblings, One Department

Trevor, Anika, and Tanya Petach reflect on their time in EPS

"So you could say we were—depending on how you look at it—either lucky enough to be spending lots of our free time in the mountains, or we were free labor who couldn't say no."

That's Trevor Petach '10, describing his family's off-the-grid cabin–building project that consumed his summer weekends—and those of his two younger sisters—throughout their childhoods.

With their parents, the Petach children undertook almost all of the tasks of constructing the 500-square-foot solar-powered cabin, high in the Colorado Rockies and accessible only by dirt road in the summer and a five-mile ski trip in the winter.

"It was a place where we got to explore the mountains and slowly start falling in love with nature and wild places," Trevor's youngest sister, Tanya '15, says, recalling hanging rope swings, building tree houses, and making dams in the creek to create fish pools with her siblings.

The Petachs are a close family and share interests beyond cabin building and an appreciation of nature. All five—Trevor, Tanya, Anika '13, their mother, Helen, and their father, Marty—ski, and all have an interest in science. (Helen has a background in biochemistry and physical chemistry, and has had a varied career; currently she is a fellow for the American Association for the Advancement of Science [AAAS] for the US Agency for International Development [USAID] and teaches high school part time. Marty is an environmental consultant, focusing on GIS and groundwater pollution.)

Trevor, Anika, and Tanya also all went to Harvard—and all even ended up in the Department of Earth and Planetary Sciences: Trevor graduated with a joint degree in physics and EPS, Anika in EPS and Environmental Science and Engineering, and Tanya also in EPS and Environmental Science and Engineering.

TREVOR: EARTH AS A SYSTEM

In his role as the first Petach to head East to Harvard, Trevor is self-deprecating—"This story is not as interesting as it might be," he notes, as he recounts thinking the University of Colorado, Boulder, in his hometown, was his likely college destination until an interview with a Harvard alumnus dispelled East Coast stereotypes and a campus visit introduced him to Harvard's cross-country skiing team and gave him a fuller understanding of Harvard's educational—and financial—resources.

"There were a lot of reasons to go and not a lot of reasons not to go," he says, of a decision he has no regrets about now. On arrival in fall 2005, Trevor immediately joined the ski team, walked onto the men's lightweight crew, and considered physics his likely concentration. He skied all four years and rowed two, but his academic pursuits broadened to include geochemistry as he found EPS by his sophomore year.

"In my opinion the Earth and Planetary Sciences Department is one of the most interesting departments at Harvard," he says. "There's such a clear tangibility to most of the things that they're doing. It really is that part of science that I like, where you get to learn about the things that go on all around you."

Trevor participated in the Hawaii and Canadian Rockies field trips, and also counts as an EPS highlight working as a field assistant for Francis Macdonald PhD '09 (Macdonald is the John L. Loeb Associate Professor of the Natural Sciences and was then a graduate student advised by Paul Hoffman, now Sturgis Professor of Geology *Emeritus*) in the Canadian Yukon, where Macdonald led a small group (Trevor was the only undergraduate) for five weeks doing fieldwork to study the geochemistry of a potential snowball Earth event. "That was … my introduction to EPS research … carrying rocks through the Yukon," says Trevor, fondly remembering Macdonald's "cowboy coffee," grizzly bears, rock slides, and days spent hiking with packs loaded with collected and labeled rocks.

In fact, Trevor's senior thesis involved rocks from the Yukon: Using a mass spectrometer, he looked at trace elements of the rocks to see whether any of them co-varied with the carbon isotope variation correlated with a snowball Earth event.

After graduation, Trevor taught math at his former high school, then went to Stanford, where he earned a PhD in physics in spring 2016. This coming year will see him in Oregon, where his significant other is taking a faculty position at the University of Portland.

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A contemporary snapshot of the Petach clan at Fisher Towers, Utah: Marty, Trevor, Helen, Tanya, and Anika.

PETACHS CONTINUED FROM PAGE 13

Despite his recent doctoral focus, Trevor values the Earth and planetary sciences approach and hopes to return to it. "My EPS background informs a way of thinking about the Earth as a system and highlights a set of problems that I think are relevant and important today," he says. In the coming years he hopes to combine his foundation in EPS and physics to work on renewable energy and carbon sequestration technologies.

ANIKA: MID-ATLANTIC SAMPLES

Anika's freshman year was Trevor's senior year, and his experience "opened me up to the idea of Harvard," she says. But in retrospect, she adds, she had no idea "how amazing it was going to be."

Anika also skied as a first-year Harvard student, but with an established strong interest in environmental work (in high school she took a three-years-in-the-making project on mountain pine beetles to the Intel International Science and Engineering Fair and to the Siemens Competition), she began taking classes at EPS as a freshman.

"One of the first projects that I worked on in Colleen Hansel's lab was looking at the role of *Thiobacillus* bacteria in the oxidation/reduction of mercury, resulting in solubility changes, which can have big implications for health and the transport of mercury in the environment. This was a very interesting project; we got to do microbiology and mineral work, which gave me important research skills," she says. (Anika worked on the project with Adiari Vasquez-Rodriguez, a graduate student advisee of Hansel, who was then an associate professor of environmental microbiology with an EPS affiliation and is now an associate scientist at Woods Hole Oceanographic Institution.)

Anika's senior thesis, meanwhile, took her in an entirely different direction: For it, she worked with Associate Professor Andrew Richardson, of the Organismic and Evolutionary Biology Department, on the phenology of plants.

She recalls "so many good classes," but Higgins Professor of Geochemistry Charlie Langmuir's course on ocean petrology and mid-ocean ridges stands out, particularly working on the *Knorr*, one of the research vessels, collecting samples in the mid-Atlantic as part of the class. She also participated in the Hawaii and Canadian Rockies field trips.

Another likely highlight for Anika was getting to know her now-husband, Anthony Staccone '13, a history concentrator from Schenectady, NY. For the first two years after graduation, they taught in China at the Western International School of Shanghai (Anika taught middle school physics and science), and this spring they are winding up a year of teaching at the United Nations International School (Anika teaching high school physics) in New York.

"I really enjoy teaching, doing hands-on activities and lab work—and working with students who are excited about learning science," she says. This fall, she'll return to being a student: She's entering a graduate program at Columbia in biogeochemistry.

"Being part of the EPS Department was an unparalleled experience. I was at Harvard at the same time as Trevor during his senior year. He already knew his way around Harvard and was involved in lots of activities so it was neat to be there with him, meet some of his friends, and he was always a good source for advice. I was also at Harvard for two years with Tanya, which was very fun. Tanya and I are very close sisters so we could go running together and talk about classes," she says.

Tanya agrees. "All three of us were really close growing up, and getting to spend extra time with Anika was wonderful. We would go running together and bake in the dorms a lot, but there were also times when we would go for long bike rides to go apple picking or take the T to the end of the line and explore the Greater Boston area together."

TANYA: PLANET COMPLEXITY

But Tanya didn't know that being the third Petach at Harvard would be a positive experience. "I thought for a while that I wouldn't go to Harvard explicitly because I was so desperate to be my own person and was worried about withering in the shadow of Anika and Trevor," she says.

When she did come, attracted by the University's energy, "the wild change from growing up in the Colorado Rockies," the lure of the East Coast and the city, and "being surrounded by motivated, curious, and inspiring people," she planned to study mechanical engineering. She joined the women's crew, and later became involved in the Harvard Outing Club and the GeoSociety (the student-run organization whose activities complement EPS in and out the classroom). Initially, she had no intention of Earth and planetary sciences becoming an area of concentration.

"But I ended up fortuitously working with Francis Macdonald and Emmy Smith [PhD '15, at the time a graduate student at EPS and now a postdoc at the Smithsonian National Museum of Natural History] as a field assistant in Mongolia that summer, and it epitomized everything I enjoyed," she says. "They fostered curiosity about the Earth and asked specific research questions with broad implications about the planet's history." In fact, Tanya returned to Mongolia the next summer, and her senior thesis, which tested hypotheses for why the Cambrian Explosion occurred when it did, drew from the work there.

"If there were ever a good way of kindling a raging curiosity for geology, running around stunning landscapes with your nose glued to outcrops for a season has to be it. It really made me appreciate the complexity of the planet," she says.

"Spending time outside has never really been the same since. Once you know what to look for, you can't just say 'Oh, it's a rock' and keep walking. Instead, you start wondering

The young trio: Trevor, Anika, and Tanya.

what it is and how it was formed and why it is located where it is now."

After graduating in May 2015, Tanya took her appreciation of geology and math to Zermatt, Switzerland, where she taught in a high school semester abroad program. This spring she has been in New Zealand, "chasing active volcanoes and honing my sailing and fishing." In the fall, she'll return to the US to begin a graduate program at Cornell, where her focus will be on soils and sediments.

THE GREAT UNCONFORMITY

And now, dispersed around the country (and sometimes even farther afield), Trevor, Anika, and Tanya periodically get together with their parents (who still live in Boulder) at the cabin in the mountains. EPS has joined the list of experiences and interests they share. "It is absolutely wonderful being able to regroup and discuss the department and our research and feel as though it is an experience we can all relate to," says Tanya.

For example, she tells of a family rafting trip through the Grand Canyon, during which they experienced an "ubiquitous appreciation for the Great Unconformity."

"Nobody tells you to stop dorking out about rocks or make more miles downriver, but instead we all hiked around and chatted geology for an afternoon," Tanya says.

Reflecting on their time at EPS, Anika adds, "It's funny because although we ultimately all did do something similar, I think all of us did it in a slightly different way. Everyone had their own spin on it, and their own unique parts. For instance, Trevor also studied physics, but Tanya was quite dedicated with her geology work going to Mongolia for two summers of fieldwork. We all found different interests outside of classwork as well: Tanya rowed crew while I was more involved with peer counseling and the running club."

Did the path to EPS start with that cabin in the mountains? It's impossible to say; there are, however, more opportunities for summer weekends spent working on it. "The Petach cabin is never really finished," Tanya explains. "Just this past summer I went up with our Dad to help install his woodstove-fired hot tub on the deck. I'm pretty confident there are still a few more decades of projects up there."

» Cathy Armer

ADAM MARIAN DZIEWOŃSKI (1936–2016)

Adam M. Dziewoński, Frank F. Baird Jr. Professor of Science, *Emeritus,* passed away on March 1, 2016, after a brief battle with cancer. Dziewoński was born on November 15, 1936, in Lwów, in what was then Poland (now Ukraine), and received his MS in 1960 from the University of Warsaw and the Doctor of Technical Sciences degree in 1965 from the Academy of Mines and Metallurgy in Krakow, Poland. He moved to the US in 1965 as a research associate at the Southwest Center for Advanced Studies in Dallas, Texas, and became an assistant professor at the University of Texas at Dallas in 1969. In 1972, he moved to Harvard University as an associate professor and was promoted to a full professor in 1976. He was named the Frank B. Baird Jr. Professor of Science in 1994. He retired in 2009, but remained actively engaged in research until his death.

Dziewoński was a pioneer in many aspects of geophysics, in particular, seismology. Some of his important contributions include the development of a method for characterizing earthquakes, the Preliminary Reference Earth Model, which is still the most popular model used by the geophysical community today, the introduction of tomographic techniques for imaging of the Earth's deep interior, and the discovery of important properties of the inner core (solidity, anisotropy, super rotation, and innermost inner core). In addition to his vigorous research program, Dziewoński devoted much effort for the establishment of facilities and resources for the Earth science community. He was instrumental in the founding of the Incorporated Research Institutions for Seismology, a prospering US research consortium with more than 100 university members, and the Federation of Digital Seismic Networks, an international organization based on the principle of international cooperation and the sharing of seismological data. He was also a significant member in establishing the Cooperative Institute for Deep Earth Research, which promotes interdisciplinary and collaborative research and trains and educates the next generation of Earth scientists.

Adam and his wife Sybil during a London visit in March 1996.

Dziewoński's fundamental contributions to Earth science were recognized nationally and internationally. His list of awards includes the Crafoord Prize from the Royal Swedish Academy of Sciences, the Harry Fielding Reid Medal of the Seismological Society of America, and the William Bowie Medal from the American Geophysical Union. He was a member of the National Academy of Sciences and a fellow of the American Academy of Arts and Sciences and the American Association for the Advancement of Sciences.

» Miaki Ishii PhD '03, Professor of Earth and Planetary Sciences

Around *the* DEPARTMENT

Faculty

James G. Anderson, Philip S. Weld Professor of Atmospheric Chemistry, received the Polanyi Medal from the British Royal Society of Chemistry. The Polanyi Medal is awarded every two years for outstanding contributions to the field of gas kinetics.

In 2015, at age 73, **Paul Hoffman**, *emeritus* Sturgis Hooper Professor of Geology, celebrated 51 years since his first marathon (Boston) by finishing first in the 60+ age division in the Richland, WA, marathon. This summer he will return to Namibia for the 24th year, accompanied by EPS concentrator **Sam Lobianco** '18, and in November 2016, he will receive the Gold Medal from the Royal Canadian Geographical Society.

Professor of Earth and Planetary Sciences and Environmental Science and Engineering **Peter Huybers** was awarded an inaugural AAAS Public Engagement Fellowship for 2016–17, sponsored by the Alan I. Leshner Leadership Institute for Public Engagement with Science, which, in its first year, is focused on climate change. This new fellowship program "convenes mid-career scientists who demonstrate leadership and excellence in their research careers, and interest in promoting meaningful dialogue between science and society, in order to build their capacity for public engagement leadership."

Andrew H. Knoll, Fisher Professor of Natural History and professor of Earth and planetary sciences, was elected in 2015 a Foreign Fellow of the Royal Society. Fellows are eminent scientists, engineers, and technologists elected for life through a peer-review process on the basis of excellence in science.

Frank B. Baird Jr. Professor of Science **Jerry Mitrovica** received the 2015 Day Medal from the Geological Society of America. The Day Medal was "established in 1948 by Arthur L. Day to be awarded for outstanding distinction in contributing to geologic knowledge through the application of physics and chemistry in the solution of geologic problems."

Murray and Martha Ross Professor of Environmental Sciences **Ann Pearson** was selected by Dean of the Faculty of Arts and Sciences Michael Smith as one of five FAS faculty to be a Harvard College Professor in recognition of her "distinguished contributions to undergraduate teaching and to creating a positive influence in the culture of teaching in the FAS." Her five-year term begins July 1, 2016.

▲ The department gathered on October 28, 2015, to celebrate EPS Visiting Scholar **W. Jason Morgan's** 80th birthday. The festivity included champagne, an "official" Harvardian happy birthday certificate signed by attendees, and a tectonic-volcano cake complete with special effects baked by lab coordinator Marisa Reilly. Jason, pictured above, is joined by his daughter Michèle Morgan, Museum Curator of Osteology and Paleoanthropology and senior osteologist at Harvard's Peabody Museum of Archaeology and Ethnology.

This past November, **James R. Rice**, Mallinckrodt Professor of Engineering Sciences and Geophysics, received the American Society of Mechanical Engineers (ASME) Medal, the highest award that the society can bestow to recognize "eminently distinguished engineering achievement." In addition, Jim also received the Sigma Xi Monie A. Ferst award in December 2015. This national award honors science and engineering teachers who have inspired their students to significant research achievements.

Carl Wunsch, the Cecil and Ida Green Professor of Physical Oceanography *Emeritus*, MIT, and visiting professor of physical oceanography and climate in EPS, received the 2015 Walter Munk Award for Distinguished Research in oceanography related to sound and the sea. This award is presented jointly by The Oceanography Society, the Office of Naval Research, and the Office of the Oceanographer of the Navy.

Academic & Administrative Staff

Mineralogical and Geological Museum curator **Raquel Alonso-Perez** and her staff Research Assistant **Kevin Czaja** and Curatorial Assistant **Theresa Smith** attended the annual Tucson Gem and Mineral Show and presented a display case in line with this year's theme "Shades of Blue." Their exhibit featured a variety of blue minerals such as beryl, labradorite, and azurite that demonstrate the various physical and chemical ways their color is produced.

Upon **Ganna Savostyanova's** move to sponsored research administrator for the department, **Gina Armstrong** joined EPS in August 2015 as the financial associate. Gina has been with the University for 25 years in the finance field and most recently came from the Office of Finance at the Faculty of Arts and Sciences.

Isadora Berlanga Mora studied chemistry at Universidad de Valencia. She received her PhD in Chemistry at Universidad Autonoma de Madrid in September 2013 with the thesis "Synthesis and Characterization of 0,

1 and 2D Nanomaterials." After her PhD, she joined Professor V. Fuenzalida's group at the Department of Physics, Universidad de Chile, where she worked as a postdoc on self-assembled monolayers, single-molecule magnets on a surface, as well as her own project, "Controlling the Surface Growth of Covalent Organic Frameworks on Functionalized Self-Assembled Monolayers." Isadora joined Juan Perez-Mercader's group as a postdoc in September 2015. Her research includes the origins of life, synthesis of block copolymers vesicles, polymerization-induced self-assembly, and self-oscillation systems driven by B-Z reaction.

Debojyoti Das received his MS in 2010 and his PhD in 2015 from Jadavpur University, India. His thesis was titled "Study of Nonlinear Dynamics of Some Chemical Reactions and Reaction-Diffusion Systems." He joined the Perez-Mercader group in March 2016, and will be focusing his research on computational aspects of the chemistry of the Belousov-Zhabotinsky oscillatory chemical reaction and its role in the polymerization of copolymers. He is a part of a group that is working on constructing biologically inspired chemically operated synthetic systems.

A microbial biogeochemist, **Felix Elling** studies the lipid "fingerprints" of archaea and bacteria—microorganisms that control the cycling of elements such as carbon and nitrogen on the planet. His research focuses on reconciling microbiological lab experiments with geochemical observations from the modern ocean to improve the application of microbial lipids for the reconstruction of past environments. He received a BS in 2009, an MS in 2012, and his PhD in 2015 from the University of Bremen, Germany. Felix joined Ann Pearson's lab in January 2016, where he investigates the use of stable isotopes of archaeal lipids as tracers for changes in the oceanic carbon cycle in the past and modern ocean.

Yanxin Jia earned his BS degree in chemistry from Nanjing University, China. In 2015 he earned his PhD in chemistry from Saint Louis University, MO, under the supervision of István Z. Kiss. He defended his PhD thesis, "Collective Behavior of Oscillatory Electrochemical Reactions on Micro Scale," in July 2015. Yanxin joined the Perez-Mercader group in October 2015, and he is researching synchronization in chemical and biological systems, microfluidics, self-organized behaviors, and the origins of life.

Microbial biogeochemist and oceanographer **Jenan Kharbush** is interested in the important connections between microbial ecology and marine biogeochemical cycling. Originally from Wisconsin, Jenan obtained a BA in biology and chemistry from Ripon College in Ripon, WI. Subsequently she earned her PhD from Scripps Institution of Oceanography in La Jolla, CA, studying chemical oceanography in the lab of Lihini Aluwihare. Her thesis research focused on the use of molecular signatures to investigate microbial metabolic diversity and function in marine environments, and specifically targeted two important classes of microbial lipid biomarkers: bacterial hopanoids and intact polar diacylglycerols. Jenan joined Pearson's research group in November 2015. She is currently working on investigating the partitioning of nitrogen during chlorophyll biosynthesis in microalgae, using a combination of proteomics and natural abundance 15N isotopic analyses.

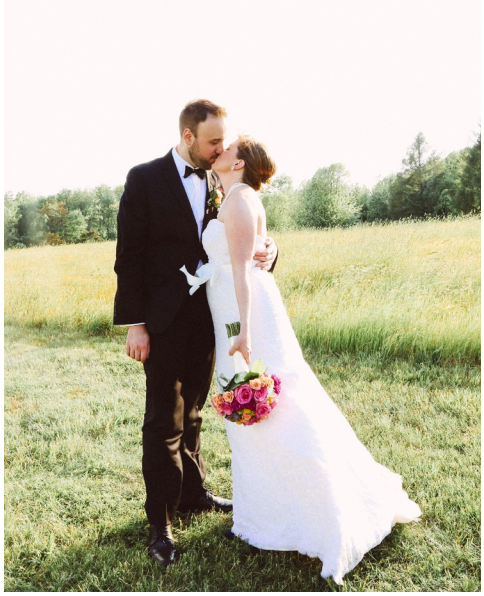
In 2011, **Bradley Lipovsky** received his MS from the University of California, Riverside; the anticipated award date of his PhD from Stanford is June 2016. He studies the physics of Earth's great ice sheets. His research agenda is to use judicious mechanical analyses to understand the components of the ice sheet system. Recent research topics include the dynamics of liquid water in ice sheets, seismicity in glaciers and ice sheets, the physics of sliding at the ice-bed interface, and ice sheet-solid earth interactions. Brad joined EPS as a postdoc in January 2016, and as the department's sole full-time glaciologist, he looks forward to working with Jim Rice, Eli Tziperman, and Jerry Mitrovica. Currently, he is especially focusing on the fracture mechanics of ice shelves.

EPS Postdoctoral Fellow **Nagissa Mahmoudi** was recently awarded a C-DEBI (Center for Dark Energy Biosphere Investigations: http://www.darkenergybiosphere.org/), a postdoctoral fellowship to investigate the bioavailability and degradation of sedimentary organic matter. She will continue her work at Harvard with the Pearson group.

Milena Perez started her professional endeavors as an intern in the Department of Health Policy and Management at the Harvard T.H. Chan School of Public Health. In September 2015, she started working as the department assistant in EPS's front office, taking over for **Noreen Morrissey,** who is now payroll appointments coordinator for EPS. Milena helps to coordinate the logistics of academic and administrative events and provides general administrative support to EPS members, including students, researchers, and staff.

In July 2015, **Kaixuan Ren** earned her PhD in polymer chemistry and physics from Changchun Institute of Applied Chemistry, Chinese Academy of Sciences. Her research focused on the design and synthesis of polypeptide-based copolymers, and fabrication of hydrogels as 3-D scaffolds for cartilage tissue engineering. She joined the Perez-Mercader group as a postdoctoral fellow in November 2015. Currently, she works on the Belousov-Zhabotinsky reaction, polymerization-induced self-assembly of amphiphilic block copolymers, and the origins of life.

Kun Wang, who has "enjoyed the EPS community for the last three years," is leaving for a tenure-track assistant professorship in Washington University, St. Louis. He came to Harvard in 2014 as an Origins of Life Initiative Postdoctoral Fellow working with Stein Jacobsen, and has been developing a new high-precision isotopic tracer to test different theories of the origin of the Moon. Other than working in the lab, Kun also went on two department field trips to Hawaii and Canadian Rockies, as the self-appointed "official" photographer. He made "friends with many undergraduates, graduate students, faculty, and staff in EPS," and he will be happy for any EPS member to visit



MEG HALEY PHOTOGRAPHS

▲ Lab manager for the Schrag Lab for Geochemical Oceanography **Sarah Goff** (née Manley) and Chris Goff, video editor for the New England Patriots, were married last May at The Red Barn at Hampshire College.

NASA/BILL INGALLS

Last October, graduate student **Ben Boatwright** G2 gave a talk at the First Landing Site/Exploration Zone Workshop for Human Missions to the Surface of Mars at the October Lunar and Planetary Institute in Houston. The NASA Science Mission Directorate solicited proposals from the scientific community for "exploration zones" on Mars that would have regions of interest for both science and resource utilization. Ben's presentation focused on a site in the southern hemisphere of Mars that included fluvial, impact, and ice-related features. The workshop organizers prepared and submitted a report to NASA headquarters with recommendations from workshop participants and an outline of future steps toward ultimately selecting a landing site for a future human Mars mission.

him at WashU in the future. "Meet me in St. Louis, meet me at the Arch!"

Li Zeng PhD '15 (astronomy), postdoctoral fellow in Earth and Planetary Sciences, recently published a paper with Professor of Geochemistry **Stein Jacobsen** and Phillips Professor of Astronomy Dimitar Sasselov in *Astrophysical Journal* on "Mass-Radius Relation for Rocky Planets based on PREM." Using a computer model known as the Preliminary Reference Earth Model (PREM), which is the standard model for Earth's interior, they adjusted it to accommodate different masses and compositions, and applied it to six known rocky exoplanets with well-measured masses and physical sizes. The paper documents their findings that the other planets, despite their differences from Earth, should all have a nickel/iron core containing about 30 percent of the planet's mass.

Graduate Students

Nine graduate students began their first year in the department in the fall 2015. We extend a hearty welcome to:

Chris (Duo) Chan, *Nanjing University*
Packard (Pak Wah) Chan, *Peking University*
Jessica Don, *Colorado School of Mines*
Cody Floerchinger, *Montana State University*
Laura Kulowski, *Brown University*
Evelyn Powell, *University of Texas, Austin*
Anna Waldeck, *University of Chicago*
Scott Wieman, *Williams College*
Sam Wilson-Fletcher, *University of Oxford*

Phoebe Robinson Devries '09, G6 was one of eight chosen to be a Harvard Horizons Scholar for 2016. This is the fourth year the Graduate School of Arts and Sciences has selected a cohort of PhD students whose "ideas, innovations, and insights have the potential to reshape their disciplines." In April, Phoebe presented her topic, "Time-Dependent Stress Transfer and Earthquake Triggering along the North Anatolian Fault in Turkey," during the Harvard Horizons Symposium in Sanders Theatre.

Teachers Extraordinaire

The winners of the 2014–15 Shaler Teaching Award are **Harriet Lau** G4, who was a teaching fellow for EPS 52, Introduction to Global Geophysics, in fall 2014, and **Sarah Hurley** G6, who was a TF for EPS/OEB 56, Geobi-

TABLE TALK

In many ways, the fourth floor of Hoffman Labs is the hub of the Earth and Planetary Sciences Department. With coffee available 24/7, cookies served daily at 3 p.m., and pizza delivered at 5 p.m. on Fridays, the student lounge with its 11-foot-long oak table serves as a gathering spot for faculty, students, and staff throughout the day. The friendly and collaborative nature of the department often makes for interesting conversations, snippets of which are captured below.

"If it were in a vacuum chamber you wouldn't want to do that … but in a pressure chamber it would be OK."

"Snakes feel mad—they have only one feeling."

"I spilled coffee on my computer, so I bought a new laptop this morning … there goes my tax refund!"

"… and he wanted to find the biggest moose he could and ship it to Paris …"

"Now, I like drones as much as the next guy …"

"When you do the inversion it's weird—it's like anti-smoothing."

"Then the question is: What do you do with the spectrometer? You can't strap it to a chair."

"I think I will teach my students today about spherical coordinate systems."

"I never know when he's happy."
"I know, man, shih tzus are weird."

KUN WANG

EARTH BOWL MMXV

Last June, EPS graduate students, undergraduates, and postdocs gathered for the first annual EPS Earth Bowl. The two-hand-touch football game pitted solid Earth scientists "Rock Hard Bodies" against the "Meanhouse Effect," climate and atmosphere scientists. EPS's lab director Paul Kelley and graduate coordinator Sarah Colgan officiated, and after four 15-minute quarters the Rock Hard Bodies prevailed, beating their opposition 21 to 9. Although both teams were exhilarated by the contest, as captured above, Meanhouse Effect player Yanina Barrera G4 declared, "It's not over. Climate change is here and the Meanhouse Effect awaits the Rock Hard Bodies with new temperature anomalies, so much so that countries will be running back for a new Paris agreement. Temperatures are rising higher and much faster than anticipated. The MeanHouse Effect will bring new heat to the EPS Earth Bowl II this summer."

ology and the History of Life, in spring 2015. The Shaler Teaching Award is given annually to teaching fellows who exhibit excellence in teaching. Each recipient of this award receives an "Outstanding EPS Teaching Fellow" certificate, an engraved Estwing rock hammer, and $500. Congratulations—and thank you—to Harriet and Sarah.

Three EPS graduate students and one EPS postdoctoral fellow received the Fall 2015 Harvard University Certificate of Distinction in Teaching. The Bok Center for Teaching and Learning reserves this award for outstanding teaching fellows. All scored 4.5 or higher (out of a total of 5) on their teaching evaluations.

Phoebe Robinson Devries '09, G6, EPS 21, The Dynamic Earth
Harriet Lau G4, EPS 152 and EPS 252, Global Geophysics: A Primer
Yanpeng Sun G3, EPS 171, Structural Geology and Tectonics
Tom Laakso '06, PhD '15, SPU 29, The Climate-Energy Challenge

Undergraduate Students

EPS secondary fielder **Katie Gibson** '17 will spend the summer working with Stephanie Pierce in the Vertebrate Paleontology Lab tracing the evolution of galloping in mammals through 3-D modeling of fossil vertebral columns. As Katie noted, "It's not very EPS-related but I'm going to look at the depositional environment and paleogeography as well."

CONTINUED ON PAGE 23

In SITU & In SILICO

1. Thirty-two undergraduates were joined by four students visiting from Zhejiang University for the department's field trip to the Southern Canadian Rocky Mountains. Although smoke from wildfires burning in the Northwest US obscured views, necessitating changes to the trip's itinerary, the group was still able to see firsthand what trip leader John Shaw refers to as "some of the most spectacular examples of fold-and-thrust belt geology anywhere in the world." After hiking an hour up steep bighorn sheep trails, four friends share the view of Opal Mountain.

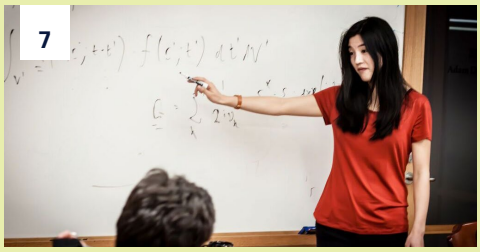
2. This past summer **Dan Skarzynski** '16 joined EPS postdoctoral fellow **Alan Rooney** in central and southern Sweden to measure sections of Ordovician age carbonates and siliciclastic rocks and collect samples for his senior thesis project. Dan and Alan were part of a team including sedimentologists, stratigraphers, paleontologists, and geochemists from US and Swedish universities. Dan stands above his oil find sourced from the Cambrian-Ordovician Alum Shale.

3. Twenty-nine graduate students spent a day hiking through the canyons and learning about hoodoos at Bryce Canyon in southwestern Utah while on the annual field trip in August 2015. The trip, partially funded by a generous alumnus donation, was organized and led by three current graduate students who had originally planned a trip to Puerto Rico. Days before departure, Hurricane Danny threatened to make landfall and the resourceful student leaders swiftly changed plans. The southwestern US did not disappoint with its remarkable geologic history and stunning landscapes. Students camped in the Kaibab National Forest in northern Arizona and explored Zion National Park, Meteor Crater, Lake Powell, and the Grand Canyon.

4. Block modeling is commonly done on a regional scale (e.g., in Japan and Southern California). A block model can be used to take GPS velocities and solve for fault slip rate deficit across known faults, which can indicate the earthquake hazard for a given area. During her postdoc with Brendan Meade, **Shannon Graham** has been working toward creating a global scale block model that simultaneously accounts for faults across the entire Earth. In order to accomplish this, she combines regional models with new models based on mapped faults and crustal seismicity to create one very large block model. Unifying large-scale plate motions with local earthquake cycle effects at known faults, she has been able to explain ~19,500 global GPS velocities to within ~2 mm per year.

5. Kaitlyn Gibson '17, **Alyssa Chan** '16, and **Leore Lavin** '17 pose in folds in the Andes. Their trip was under the auspices of Cornell's field course during which students from Harvard, Cornell, and the University of Buenos Aires spent the summer learning the regional geology and uplift history of the Argentinian Andes. Students conducted field exercises, received lectures in Spanish and English, and toured the geological exposures of the Andes. As Leore noted, "It was seriously an incredible and invaluable experience in field and structural geology."

6. This past January, Mineralogical and Geological Museum Curator **Raquel Alonso-Perez** and EPS alumnus **Lyle Nelson** '15 went to Madagascar to collect reference material for the museum's permanent collections and to study further the genesis of the emerald mineral deposit in the Manandjary area, which, as Raquel notes, is not yet fully understood. She adds, "Our most sincere thanks to John Ferry '98, CEO of Prosperity Earth, a Madagascar company, for funding the trip and the acquisition of specimens for the collections."



7. Harriet Lau G4 works with Jerry Mitrovica on solid Earth dynamics. Topics she works on include understanding how the solid Earth dissipates energy on a variety of timescales, and also inferring large-scale mantle structure using novel observations. In the top photo, Harriet explains one such observation: the deformation of the crust due to periodic gravitational forcings from both the sun and moon, also known as body tides. Turns out that an underinflated soccer ball can be squeezed in a similar manner as the Earth when the moon pulls on it, as demonstrated in the second photo.

8. EPS graduate student **Jenny Middleton** G5 and researcher **Robert Ackert** along with Seth Campbell, a ground penetrating radar expert from the University of Washington, and mountaineer Jen Erxleben (right to left) spent last Christmas in the Ohio Range, near the center of the West Antarctic Ice Sheet. The ice sheet has partially collapsed during warmer climates in the past and could potentially raise global sea level three meters. The research project "Constraining Plio-Pleistocene West Antarctic Ice Sheet Behavior at the Ohio Range" awarded to Sujoy Mukhopadhyay, now at UC Davis, aims to test model predictions of past decreases in the elevation of the ice sheet. As part of her dissertation, Jenny will measure cosmogenic isotopes in samples collected from bedrock outcrops exposed above the ice surface and in crevasses. The concentrations of these isotopes depends on the length of time the rocks were exposed at the surface and buried by ice.

9. Rachel Hampton '17 spent last summer working with **Tom Benson** '09, currently a Stanford PhD student, to map margins of the newly defined Pole Canyon Caldera, which at ~16.5 Ma is the oldest known caldera of the Yellowstone/Snake River Plain hotspot track. They collected samples of tuffs and lavas for geochemical and geochronological analyses. This experience has inspired Rachel to "learn more about the rocks around Boston since they too are volcanic," and she will write her senior thesis on the origin of the volcanic formations in the Middlesex Fells outside of Boston.

COURTESY OF HARVARD PUBLIC AFFAIRS & COMMUNICATIONS

10. Abbott Lawrence Rotch Professor of Atmospheric and Environmental Science **Steven Wofsy** is leading a project to find the sources of unburned natural gas that escape into the atmosphere in the Boston region. The work, which recently received funding from the Harvard President's Climate Change Solutions Fund, builds on earlier studies by Steve and Boston University Associate Professor **Lucy Hutyra** PhD '07 and Research Scientist at CIRES/NOAA **Kathyrn McKain** (SEAS PhD '15), which found that some 2 percent of the natural gas shipped to the Boston area is lost before it gets burned. In addition, Steve's group is working with faculty and students from Harvard Law School to design technical, legal, and/or regulatory solutions to reduce the emissions. SEAS graduate student **Taylor Jones** G2 prepares to launch a helikite, a hybrid of a helium balloon and kite used to collect measurements.

11. EPS concentrator **Sam LoBianco** '18 sits down to enjoy a breakfast of goat head soup in Ayaviri, southern Peru, where he was serving as field assistant to second-year graduate student **Blake Hodgins** last June. The pair were working in a nearby district, measuring and sampling the stratigraphy of the Umachiri beds. Blake's recollection of the day: "On a winter morning at 13,000 feet elevation in the Peruvian Altiplano you need something warm to get you going in the morning. In the marketplace of Ayaviri we found it in the form of local character and steaming hot goat head soup. This is what a boisterous shopkeeper offered me and Sam for breakfast. He sat with us, taught us Quechua phrases, and filled the air with laughter. We carried the warmth with us, working nearby on exposures of Cambrian volcaniclastic rocks that are linked to the assembly of southwestern South America. The samples we gathered show promising results, so we plan to return this July to undertake a more detailed paleomagnetic study and to eat some more goat head soup."

NEXT STEPS: 2014–15 SENIORS

When we checked in with the 15 concentrators who graduated last year to see what their next-step plans were, we were not surprised to hear the wide range of answers:

Jay Alver: "I'm working as a space policy intern at the National Academy of Sciences in Washington, DC, and trying to figure out what comes next. In the meantime, I successfully petitioned the IAU to name an asteroid after Charles Eliot!"

Reid Bergsund: "I am working for Bain & Company in their San Francisco office. I hope to get involved in their energy, utilities, and resources practices."

Florence Chen: "I received a Fulbright Fellowship to fund a one-year MPhil in Earth Sciences at Cambridge University with Dr. Alexandra Turchyn PhD '05. After that, I will move out to San Francisco to work as a business analyst at McKinsey."

Larissa Davis: "Currently, I am spending one year as an intern for Cru, a campus ministry organization, in Boston. I am also in the process of pursuing further education."

Jon Jackson: "I am pursuing a PhD in astronomy and astrophysics at Penn State where I am studying exoplanet dynamics and evolution."

Katherine Kulik: "After a road trip in the western USA and travel to the East Indies last summer, I am excited to be working as an energy trader at Alphataraxia Management LP (ATX), a fast-growing investment management group based in Washington, DC."

Amy Lorber: "I am currently in Palo Alto, CA, working for a lab studying the microbiota of the human gut. (Read, working with poop samples, why not?)"

Sarah Moon: "I'm currently working at McMaster-Carr in Chicago with an unfortunate lack of rocks in my life!"

Li Murphy: "I am in Chiang Mai, Thailand, learning the language and working with a Muay Thai (traditional kickboxing) group … waiting for the return of my teacher so I can learn traditional massage."

Lyle Nelson: "I am working as an exploration geologist for Teck Resources in northwest Alaska through September, and then I will be using a Booth Fellowship award to work on a geologic mapping project in the Mojave Desert during the academic year."

Tanya Petach: "I am first teaching geology to high school students at a field school in Switzerland, then traveling in New Zealand. In fall 2016, I'll start grad school at Cornell to continue studying soil and sediments."

Joe Shaffer: "I've moved to New York to work at Oscar, a startup focused on changing the way health insurance works in America. I'm an operations analyst—I've been writing software to track my department's efficiency, and it's been both fun and interesting!"

Jason Smith: "I have come home to start managing our family cattle ranch in rural Montana."

Tyreke White: "After I complete my Fulbright Fellowship in Warsaw, Poland, I will attend Stanford in the fall to obtain my master's in management science and engineering."

Jessica Yap: "I will be working as a missionary for two years with FOCUS (the Fellowship of Catholic University Students) and invite you to follow my vlog on YouTube: Quo Vadis Jess.

CONTINUED FROM PAGE 19

Sam Goldberg '16 will be enjoying a double-graduation celebration by going on a two-month canoe trip in Quebec and Labrador with his twin brother, Nat Goldberg '16 (chemistry).

This summer **Caroline Juang** '17 will be working in Washington, DC, with the Space Studies Board of the National Academies of Sciences, Engineering, and Medicine. As an intern, she will contribute to the board's ongoing projects in space policy over 10 weeks.

Matt Miller '18 has enrolled for the Juneau Icefield Research Program, which runs from June to August.

This summer EPS concentrator **Mattie Newman** '17 will be a junior analyst intern at GMO Renewable Resources LLC, an investment management firm in Boston that manages 1 million acres of land and timber resources.

Katie Polik '18 will be researching the thermal acclimation of soil respiration in response to prolonged soil warming at the Harvard Forest this summer through the REU program.

Joint ESPP-EPS concentrator **Renwick Wilson** '18 has accepted a summer internship with Connecticut's Department of Energy and Environmental Protection (DEEP). Working in the Office of Climate Change, Technology and Research, Renwick's main project will be to benchmark and analyze DEEP's own greenhouse gas emissions, and then find ways to reduce these emissions.

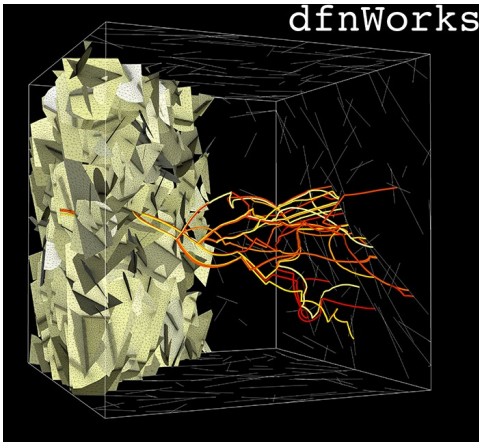
"I have come home to start managing our family cattle ranch in rural Montana."

~Jason Smith '15

Alumni NOTES

Graduate Students

▲ **Patricia H. "Tricia" Kelley** PhD '79, kelleyp@uncw.edu: In 2014 I was thrilled to be named one of four US Professors of the Year by the Council for Advancement and Support of Education (CASE) and the Carnegie Foundation for the Advancement of Teaching. I was named the 2014 Outstanding Master's Universities and Colleges Professor. Since 1997 I have been a professor of geology at the University of North Carolina Wilmington, primarily teaching undergraduate and graduate courses in paleontology and the history of Earth and life.



COURTESY OF LOS ALAMOS NATIONAL LABORATORY

▲ A visualization of a dfnWorks software suite model showing a three-dimensional discrete fracture network (DFN) used to model flow and transport in fractured rock subsurface environments. The fracture geometry is shown in yellow with the triangular mesh superimposed. The paths of particles moving in the flow field are shown by red and yellow lines. dfnWorks is developed by the Los Alamos National Laboratory's Computational Earth Science Group, led by Carl Gable PhD '89.

Carl Gable PhD '89, cwgable@post.harvard.edu: Since 2011, I've been working as group leader of the Computational Earth Science Group in the Earth and Environmental Sciences Division at Los Alamos National Laboratory. The group is made up of 23 staff scientists, 12 postdocs, and, during the summer, as many as 25 students from many different institutions. The group focuses on computational methods for modeling flow in porous media as well as atmospheric dynamics, wildfire, and ecosystem modeling. The focus of my research is in development and application of discrete fracture modeling (DFN) for flow and transport in fractured rock systems.

COURTESY OF DR. CARLO ARCILLA

▲ On March 8, 2016, Philippine President Benigno Aquino III appointed **Ben Austria** PhD '75 to the Professional Regulation Commission (PRC) Board of Geology. Ben is shown here at his oath-taking on March 9, 2016, before PRC Chair Teofilo Pilando Jr. and commissioners Angeline Chua Chiaco (left) and Evelyn Reyes.

Undergraduate Students

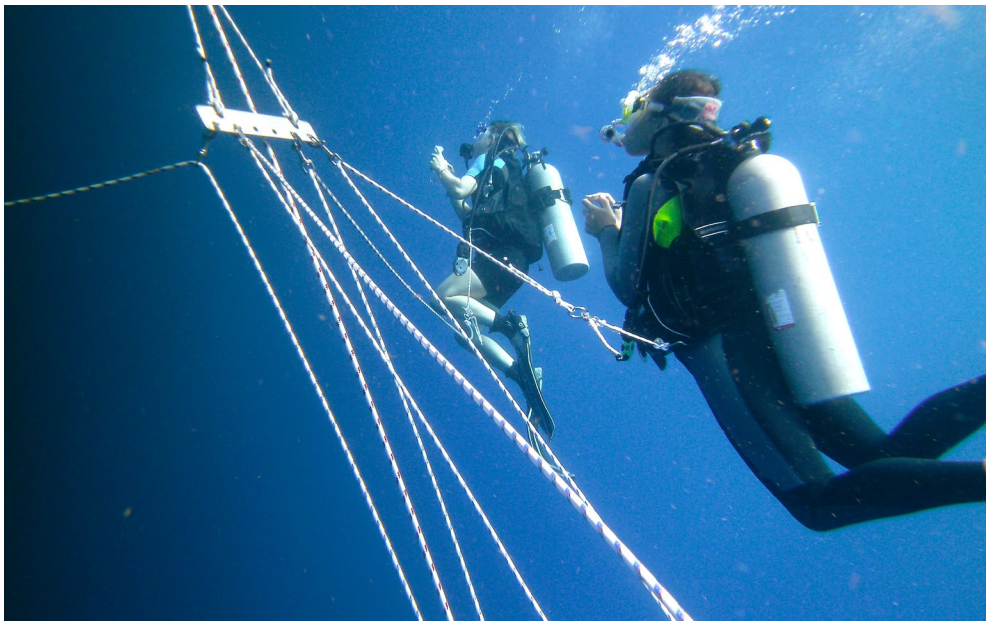
David Jackson '82, djackson@uga.edu: I loved my time in what was then called the geological sciences concentration, especially the year ('79–80) I took off from classes to work full time at the Museum of Comparative Zoology (MCZ), measuring 32 different dimensions of each Cerion in exchange for the privilege of the occasional opportunity to soak up the collective wisdom—and humor—of my professors and TAs Stephen Jay Gould, Peter Williamson, **Chuck Mitchell** PhD '83, **Tricia Kelley** PhD '79, and **Tony Arnold** PhD '83. I also worked as a volunteer field assistant for Chuck (then a doctoral student) in the summer of 1980, collecting the specimens that he studied for his dissertation and also, I believe, for quite a few years afterwards—three-dimensionally preserved graptolites from the Viola Formation in the Arbuckle Mountains region of central Oklahoma (just in case there's anyone out there who might be mildly interested in such details). He went on to become a professor and longtime department head at SUNY Buffalo, and, according to the SUNY Buffalo Department of Geology website, is still there, with the title of Distinguished Teaching Professor (http://www.geology.buffalo.edu/people/faculty/dr-charles-e-mitchell).

Upon graduation, however, I decided that in the long term I wanted to spend more time with people, especially younger ones, and less with fossils (meaning the snails, not the paleontologists), so I became a seventh-grade Earth science teacher, eventually also migrating downwards and upwards to the fifth- and ninth-grade levels. After earning a doctoral degree in science education at the University of Michigan, I ended up

Tidings

EPS is always pleased to hear from our alumni and friends. Send us your comments or news to **epsnl@fas.harvard.edu**. So that we may print your notes and photographs, please include with your submission:

1) your affiliation and year; and
2) the following statement:
I give consent for display of the note, my email address and/or web-link and any associated photo, which may or may not appear in print and electronic versions.



◀ **Carina Fish** '13, carinaf@ldeo.columbia.edu: I've been working at Lamont-Doherty Earth Observatory for almost two years under Dr. Bärbel Hönisch. I finish up work this summer on a project I began with fieldwork last spring where I dove to collect live planktic foraminifer specimens and analyzed them for their symbiont photosynthesis levels. The fluorescence data were aimed to elucidate one aspect of the biological controls (vital effects) that affect the geochemical signals recorded within foram tests. I'm writing up the results now and plan to submit the manuscript for review within the next few months. The big news is that I'm heading to grad school this fall! I'll be starting a PhD in Geology at UC Davis.

at my current home of 26 years, the University of Georgia, preparing future middle school science teachers, often co-teaching with a delightful geologist some of you may know, Ray Freeman-Lynde, and occasionally completing projects that, in the world of education as an academic field, pass for research. It's a strange little professional niche, but I still love it. If any of you should have occasion to pass through "the Athens of Georgia," please look me up and I'll take you out for barbecue and sweet tea. I still make it to meetings at Harvard several times a year as a result of my service on the board of the Harvard Glee Club Foundation.

Chris Leggett '93, chris.leggett@bedrock-statistics.com: I am an economist (PhD,

NEXT STEPS: 2014–15 PHD GRADUATES

Nine EPS graduate students received their doctorate in academic year 2014–2015. With dissertations electronically bound (available online at http://dash.harvard.edu/) and PhD diplomas in hand, our most recent alumni have dispersed around the globe.

Ethan Butler
Dissertation: "American Maize: Climate Change, Adaptation, and Spatio-Temporal Variation in Temperature Sensitivity"
Advisor: Peter Huybers
Current position: Postdoctoral Associate, Department of Forest Resources, University of Minnesota

Patrick Kim
Dissertation: "Particulate Matter and Ozone: Remote Sensing and Source Attribution"
Advisor: Daniel Jacob
Current position: Consultant at McKinsey & Company

Tom Laakso
Dissertation: "A Theory of Atmospheric Oxygen"
Advisor: Daniel Schrag
Current position: Postdoctoral Fellow, Department of Earth and Planetary Sciences, Harvard University

Karen McKinnon
Dissertation: "Understanding and Predicting Temperature Variability in the Observational Record"
Advisor: Peter Huybers
Current position: Postdoctoral Fellow, NCAR Advanced Study Program

Scot Miller
Dissertation: "Emissions of Nitrous Oxide and Methane in North America"
Advisor: Steve Wofsy
Current position: Postdoctoral Fellow, Department of Global Ecology, Carnegie Institution at Stanford University

Sierra Petersen
Dissertation: "Rapid Climate Change in the Cenozoic: Insights from Geochemical Proxies"
Advisor: Daniel Schrag
Current position: Postdoctoral Fellow, University of Michigan

Maria Peto
Dissertation: "Application of Noble Gas Isotopic Systems to Identify Mantle Heterogeneities"
Advisors: Sujoy Mukhopadhyay and Stein Jacobsen
Current position: Conducting research in Hungary

Justin Strauss
Dissertation: "The Neoproterozoic and Early Paleozoic Tectonic and Environmental Evolution of Alaska and Northwest Canada"
Advisor: Francis Macdonald
Current position: Assistant Professor of Earth Sciences, Dartmouth College

Stephen Turner
Dissertation: "Constraining Subduction Zone Processes Through Local, Regional, and Global Chemical Systematics"
Advisor: Charles Langmuir
Current position: Postdoctoral Fellow, Department of Earth Sciences, University of Oxford

VALERIE SHEN: HERE, THERE, AND EVERYWHERE

This past year, **Valerie Shen** '14, who works with McKinsey & Company, traveled to almost all corners of the Earth. **Valerie** (left) and **Florence Chen** '15 in front of Trinity College at Cambridge. Valerie was in London for work and went to Cambridge for the day to visit Florence, who received a Fulbright Fellowship to fund a one-year MPhil in Earth Sciences at Cambridge University with **Dr. Alexandra Turchyn** PhD '05.

This past winter, **Valerie** and **Andrew Miller** '04, AM '04, met up in Lesotho in southern Africa where they "examined (well, looked at) footprints of the Lesothosaurus." Andrew was in South Africa working on performance improvement for a major South African company.

And back in the US (San Francisco, where she lives) **Valerie** with her roommates Ida Hempel (ESPP '14), left, and Viroopa Volla (Economics '14), center.

▲ **Li Murphy** '15, in Chiang Mai, Thailand, about to navigate a wooden four-wheeled cart down Mon Jam, a little mountain settlement in northern Thailand. As Li notes, "This is relevant only to rocks because of how many bruises I have on my backside after the ride, also of course because I am wearing my trusty EPS hat."

▲ **Harvard Hilux.** *Emeritus* Professor Paul Hoffman, flanked by Audrey (left) and Leo (right) Halverson (daughter and son of **Pippa Halverson** PhD '03 and Alayne Moody, now living in Montreal), lean against the vintage vehicle parked at Zebra River in the Nama basin, Namibia. The Toyota, now 21 years old, "ran faultlessly last summer," according to Paul, and has been "home" to more than 50 geologists and students over the years. Paul also noted that "Hilux's of this vintage are much sought-after for their strength and durability. Recent offers for the vehicle (turned down) amount to more than Harvard originally paid for it new."

University of Maryland) doing consulting work for Bedrock Statistics LLC related to outdoor recreation, mainly for US federal agencies (the National Oceanic and Atmospheric Administration [NOAA], the National Park Service, the Department of the Interior [DOI], etc.). I have been involved in assessments of recreation-related economic losses associated with oil spills and hazardous waste sites. I also get involved in a lot of surveys and count studies designed to characterize and quantify outdoor recreation on public lands.

I live in Gilford, NH, with my wife, Sydney, and three kids. Sydney is an educational consultant for Youth, Education, Tomorrow (http://www.yetnh.com) who was recently a principal at public schools in Alton, NH, and Gilford, NH.

Chrissy Benson Schwartzstein '04, benson.chrissy@gmail.com: I have been working at Goldman Sachs in the commodities division since graduation (almost 12 years), and I'm now a managing director in energy sales. In 2010, I married Pete Schwartzstein, also Harvard Class of 2004. We live in Greenwich, CT, and have two children, Morgan (3.5 years old) and Grant (1).

Danny Kim '10, dankim15@gmail.com: Hello all! I'm still in school, with one more year of medical school left at the University of California, San Francisco, and I'm pursuing a master's in public health at the University of California, Berkeley, focusing on policy opportunities for funding community health workers. I'll be applying into family medicine residency programs this coming fall.

Florence Chen '15, fychen12@gmail.com: I'm at Cambridge University completing an MPhil in Earth Sciences with Dr. Sasha Turchyn and measuring the calcium isotopic composition of calcium carbonate veins. I'll be giving a talk on this work at Goldschmidt 2016. It will be on Friday, July 1, in session 14c on "Sources and Fate of Carbon in Hydrothermal Systems." I would definitely love to see some familiar Harvard faces there! Additionally, I've recently had a paper accepted in *Chemical Geology* on the sulfur isotope research that I conducted with Dr. Turchyn three summers ago on the Harvard-Cambridge Summer Fellowship. During my time at Cambridge, I have made some great friends and got to go on some cool trips to Berlin, Bremen (to get samples from the core repository), the southwest coast of England (as a field trip teaching assistant), and London many times.

The Call *of the* Flannel

Once a year, EPS concentrators select a bit of swag to demonstrate their allegiance to the department. In the past, they've chosen T-shirts, union suits, and baseball caps, but flannel shirts (see photo) have been the most popular by far. So we would like to make these now-classic shirts available at cost to our alumni. If you would like to proudly proclaim your connection to EPS by acquiring an EPS flannel (plaids may vary), please complete and mail the order form below, including a check for $25 (per shirt) made payable to Harvard University.

Questions? Please send an email to epsnl@fas.harvard.edu.

TOPHER LAMOND

Snapshots of EPS alumni flaunting the flannel include … Lisa Nousek '02, left, Apple (the pony), Amanda Wise, and Larry Loustaunau at Pennyless Farm (https://www.facebook.com/pennylessfarm/), Wagener, South Carolina. For our full collection of photos, visit our website: http://eps.harvard.edu/campus-and-beyond.

EPS Flannel Shirt Order Form

☐ Small ☐ Medium ☐ Large ☐ X-Large

Please make checks payable to Harvard University, with a note indicating that it is for EPS flannel shirts. *Each shirt costs $25.*

I am enclosing a check for $ _____ to pay for _____ (number) of shirts and cost of shipping. *(Check should be made payable to Harvard University.)*

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STUMP THE SCHOLAR

GRAVITAS

Sam Goldberg '16, EPS Concentrator

The puzzle: Earth's gravitational acceleration decreases as you move upwards into space from the surface. At the very center of the Earth, the gravitational acceleration is 0, and increases as you move outwards. However, the surface does not have the strongest gravity.

Your challenge: To identify where the highest gravitational acceleration from Earth's mass is found and explain why.

Submit your answer to epsnl@fas.harvard.edu. The winner will be selected by the time-tested method of placing all correct answers in a hat and with closed eyes the editor will draw one name. The winner will receive an EPS mug and the honor of having his or her name listed in the next issue of *Earth & Planetary Times*—along with the correct answer, of course.

LAST ISSUE'S ANSWER

GLOBAL DISPOSAL: NIMBY TO THE NTH DEGREE

The puzzle: For those of you with long memories, you may recall in our last issue, graduate student Jonathan Tucker presented the challenge of disposing of radioactive waste into space with just two options using the least rocket power: launching directly into the Sun or launching directly out of the solar system.

The answer: Escaping the solar system is much easier. Once low Earth orbit is achieved, falling into the sun requires losing all of Earth's orbital velocity (30 km/s). Escaping the solar system only requires adding 12 km/s to reach the solar escape velocity of 42 km/s.

The outcome? The scholar, EPS concentrator Katie Polik '18, provided the correct answer and has received her EPS mug. An honorable mention goes to Matt Luongo '17, EPS-ESE joint concentrator, whom Jonathan noted came very close to solving the puzzle.

Giving to EPS

EPS undergraduate and graduate programs have grown substantially in recent years, in part reflecting society's growing interest in energy and climate but also reinforced by our efforts to maintain strong foundational programs in geology, geophysics, geochemistry, and atmospheric and oceanographic sciences. Our goal is to continue to enhance these educational programs and expand our research in ways that will lead to exciting discoveries that benefit society.

If you are able and interested in making a financial contribution to EPS, please send a check made payable to Harvard University, with a note indicating that it is for the Department of Earth and Planetary Sciences, to:

Department of Earth and Planetary Sciences
Hoffman Labs, Attn: Kathleen McCloskey
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