By Jennifer Schieltz, Office of the Dean for Research

On a ship off the coast of Bermuda, Frederik Simons, an associate professor of geosciences, fastens a rope around a six-foot-tall white cylinder affixed with solar panels and various wires suspended in a metal frame. As everyone scrambles into position, a crane slowly raises the device and prepares to lower it into the ocean. After three years of work on design modifications and fine-tuning, the researchers are preparing to test the apparatus for the first time.

The instrument, named Son-O-Mermaid, will detect and record waves, but not the kind that are rolling under the research vessel and making Simons seasick. Son-O-Mermaid measures sound waves created by the quaking of the earth far beneath the ocean surface. Just as a CAT scan can enable physicians to “see” inside the human body, geologists can use earthquake data to survey the interior structure of the planet. With

Simons and his team took two Son-O-Mermaid instruments to Bermuda last summer, where Princeton has a partnership with the Bermuda Institute for Ocean Sciences. Here, the instruments are secured on deck before deployment in the water. Unlike traditional ocean-bottom seismometers, which are placed in stationary locations and must be retrieved to obtain their data, Son-O-Mermaid drifts with ocean currents and regularly reports data back to scientists using wireless technology. Several can be deployed for the same cost as one ocean-bottom seismometer. (Photos by Frederik Simons)
two-thirds of the Earth covered by water, Son-O-Mermaid is one of only a few instruments able to record earthquakes in the ocean.

The origins of Son-O-Mermaid began more than two decades ago with an idea from collaborator Guust Nolet, who was then a professor at Princeton and is now the George J. Magee Professor of Geoscience and Geological Engineering, Emeritus. He is also Professor of Geophysics, emeritus, at the University of Nice-Sophia Antipolis in France.

While on sabbatical at the Scripps Institution of Oceanography in San Diego, California, Nolet met a colleague who was measuring sound waves in the ocean. Among the whale songs and passing freighters, Nolet detected the signal of an earthquake that came all the way from Alaska. He realized that it might be possible to use sound waves — which are the audible equivalent of seismic waves that travel through the Earth — to build a better picture of the planet’s structure in regions inaccessible underneath the oceans.

This is important because geoscientists can use seismic waves, the elastic vibrations emitted by earthquakes, to map the structure of Earth’s interior. These waves travel faster when passing through colder, denser regions deep inside the Earth, such as subduction zones where tectonic plates collide and one slides under the other, and slower in hotter regions such as mantle plumes, which are upwellings of hot rock. By careful analysis of how the waves travel and change, geophysicists can create 3-D maps of the inside of Earth’s crust and mantle. On smaller scales, similar principles are used to prospect for oil, gas and other mineral deposits.

Although many seismic stations dot the continents, few have been installed in the oceans. “If you think of the Earth as a patient in the hospital, the present situation is like trying to do a CAT scan with two-thirds of the sensors broken,” explained Nolet.

Nolet realized that hydrophones, which are microphones that record sound in water, could be deployed on mobile devices floating in the oceans. But at the time, the technology did not exist to make the project workable, and Nolet put the idea aside.

Ten years later, Nolet brought the project to Simons, who was then a postdoctoral researcher in the Department of Geosciences at Princeton. “Guust sent me a brown envelope marked ‘confidential,’” Simons recalled. “Inside was a picture of a seismogram — the record of a seismic wave — and a proposal to build a dedicated instrument that could record earthquakes in the ocean.” Simons and Nolet

When it decides that it is an earthquake, MERMAID comes to the surface, takes a GPS measurement of its location, and sends a seismogram by email.

Frederik Simons, a associate professor of geosciences, has developed an instrument named Son-O-Mermaid that detects and records sound waves in the ocean created by distant earthquakes.

A Son-O-Mermaid instrument is attached to a crane and lowered into the ocean. The researchers next reel out 1,000 meters of cable that connect the surface buoy to hydrophones, microphones that record sound in water, which “listen” for earthquakes in the ocean. When an earthquake is detected, the device sends a seismograph by email to the scientists.
envisioned deploying tens or hundreds of these instruments throughout the world’s oceans. They built the first version of the device with colleagues at Scripps in 2008 and named it MERMAID, for Mobile Earthquake Recording in Marine Areas by Independent Divers.

Here is how it works: Once in the water, MERMAID sinks to about a mile deep, drifts along deep ocean currents, and “listens” to acoustic signals. “When there is a ship passing or a whale singing it will analyze the signal and decide whether the sound is due to an earthquake or not,” Nolet explained. When it decides that a signal is an earthquake, MERMAID comes to the surface, takes a GPS measurement of its location, and sends a seismogram to the researchers by email.

Before MERMAID, undersea earthquake data could be obtained only by traditional ocean-bottom seismometers, which are placed in stationary locations and must be retrieved to obtain their data. “And sometimes when one gets those instruments back,” Simons explained, “something might have gone wrong and months of waiting would have been in vain.” The high cost of manufacturing and ship time required for ocean-bottom instruments also greatly restrict their use.

MERMAIDs, in contrast, regularly report data back to scientists using wireless technology, and several can be deployed for the same cost as one ocean-bottom seismometer. Last August, Nolet, Simons and colleagues published a paper in the journal Nature Communications reporting that the divers successfully recognized earthquakes and transmitted the seismograms more or less in real time.

Meanwhile, Simons had already started to design adjustments and new features to overcome some of MERMAID’s limitations. He developed Son-O-Mermaid with colleague Harold “Bud” Vincent, a research professor at the University of Rhode Island. Both MERMAID and Son-O-Mermaid possess a series of hydrophones, but Son-O-Mermaid’s hydrophones are suspended from a long cable that connects to a drifting buoy that stays at the surface.

This new design has some advantages. MERMAID uses an electrically powered buoyancy pump to bring itself to the surface each time it reports an earthquake, so it functions only as long as the battery lasts. Son-O-Mermaid is equipped with solar panels to supply it with power. In addition, Son-O-Mermaid can maintain continual contact with a satellite, instead of only connecting when it surfaces. It always knows where it is and exactly what time it is. Comparing the exact arrival time of a seismic wave with predictions based on how waves travel through different materials is a crucial
step in using seismogram data to create models of the interior of the Earth.

Despite these advantages, Son-O-Mermaid does have drawbacks. The buoy is at the surface, in the waves, so it can get run over by ships — or be hit by a hurricane, as the very first Son-O-Mermaid prototype was during its maiden voyage three years ago.

“Off the coast of the Bahamas,” Simons recalled, “we successfully deployed it. It was reporting its position faithfully every hour for a number of days until it went silent, which was when it ran right through the eye of Hurricane Sandy.”

Over the next few days they heard nothing and feared it was lost. Eleven days later it came back online and started communicating again. “It reported that it was indeed alive and had survived the hurricane, but alas, its reporting package hadn’t, so we lost the data from that very first trip,” Simons said.

Over the next three years, Simons and Vincent worked to fine-tune Son-O-Mermaid, adjusting part of the design to make it more robust to withstand events like Sandy.

The latest Son-O-Mermaid deployment took place in the summer of 2015. Simons and Vincent took two Son-O-Mermaid instruments to Bermuda, where Princeton has a partnership with the Bermuda Institute for Ocean Sciences. The team included graduate students, technicians and undergraduates who were on deck helping to move the instrument. They hooked it to the pulley and crane system, lowered it into the ocean, and reeled out the 1,000 meters of cable that connect the surface buoy to the hydrophones.

Joel Simon, a Princeton graduate student in geosciences whose research focuses on analysis of the Son-O-Mermaid and MERMAID data, went to Bermuda ahead of the deployment with the engineers to unpack the pieces of the instrument from the shipping container and assemble them. “My current research focuses on answering the question, ‘Given a signal, can you automatically (1) tell if the signal is from an earthquake or other source, and (2) precisely tell the arrival time of the signal at the detector,’” he said.

He continued: “Probably the most excited I’ve been during this research was when I saw the first core phase returned in the data — an earthquake on the complete opposite side of the Earth generated a seismic wave that passed through the inner core [of the Earth] and then was detected as a sound wave at a MERMAID float. Seeing that for the first time blew my mind. Now, logging into my computer every morning and downloading new seismograms is exciting because I never know what interesting waveforms I will get.”

The research team deployed and retrieved the buoys several times to test that everything was working and identify remaining kinks that are now being addressed. “As a proof of concept, Son-O-Mermaid proved its seaworthiness,” Simons said. “Now the task ahead is to construct a robust new generation of Son-O-Mermaid instruments to add to the growing number of earthquake recorders, including MERMAID, in the oceans.” With each new instrument deployed, Simons and colleagues will help fill in the picture of our planet’s interior.

Partial funding for Simons’ work was provided by the National Science Foundation and by the A.H. Phillips Fund in the Department of Geosciences at Princeton.
From May 20-26, 2016, thirty-four members of the department participated on a field trip to Iceland. This group of eight seniors, eight juniors, one sophomore, nine graduate students, six faculty, and two staff members spent six full days exploring the southern coast of the island country, following an itinerary developed by the three of us over the previous year.

In preparation for the trip, participants met every Monday of the spring semester for a colloquium during which faculty and grad students lectured on the geologic processes at work in Iceland and the sites to be visited during the trip. Additionally, undergraduates and graduate students worked in groups that were assigned a specific day of the trip. These groups generated a chapter of the field guide dedicated to their assigned day, including maps and directions to locations, the geoscientific context of stops, ongoing research, and a risk assessment with safety information for each site (www.princeton.edu/geosciences/Iceland-field-guide.pdf). Group members then served as leaders on their assigned days. This group work helped invest participants in the trip and expose them to new fields of geoscience outside of their expertise.

The motivation behind the trip was to foster community within the department and to familiarize members of the department, especially students, with research that happens in the department in particular and in geosciences overall. Having participated in several impactful class field trips during our Princeton careers, we realized the potential of field trips to be inspirational and educational opportunities to interact directly with the world we study abstractly in the classroom, and also with experts in the department whom we might otherwise never have met.

The trip itself went better than we could have imagined, with only one day of rain and otherwise clear skies — somewhat unusual weather for Iceland! The following day-by-day recap provides an overview of the places we went and experiences we shared.

Day 1, May 20
After landing at the Keflavik Airport at 7:00 AM, the group hit the ground running with a post-breakfast lookout over the city of Reykjavik from “the Pearl,” a series of hot water storage tanks on a hill topped with a viewing deck. We were introduced to Dr. Sigurður Steinþórsson *74, who gave us a visual tour of the capital city and its immediate surroundings, and who accompanied us for the better part of the day. After leaving Reykjavik, we headed to the “Law Rock” at Pingvellir, the meeting place for Iceland’s judicial authority from 930-1262 AD.

Eruption of Stokkur Geysir
Geologically, Þingvellir is unique because it lies directly on one of the rift axes where the North American and Eurasian plates are moving apart. The next stop was the Great Geysir geothermal area. Despite the water in the geyser shaft being heated almost to the boiling point, we were able to get close enough to Stokkur Geysir to experience and appreciate the power of multiple eruptions.

We ended the day at Gullfoss (“Golden Falls”), a 70 meter high, two-tiered waterfall that many consider to be the most beautiful in Iceland. The waterfall formed when water carved a fissure in a cooled lava flow that is now 2.5 km in length! We then headed to Laugarvatn to spend the night at a hostel and recover from the long day of travel.

Day 2, May 21:
We began the second day with a brief stop at Kerið Crater, a phreatic crater hosting a small pond in the Grímsneshraun lava field. The crater was on the way to the Hveragerði region, where we toured a geothermally active valley, guided by Dr. Snædis Björnsdóttir of the University of Iceland. We learned about the thermophilic biota that thrive in the extremely hot waters, which are warmed by magmatism from the local Hengill volcanic center.

The geothermal activity displayed at Hveragerði was a great introduction to the next stop: the Hellisheiði Geothermal Power Station. The group took a tour of the power station, which is the third-largest geothermal energy plant in the world. This station is capable of producing over 303 MW of electricity and also transports geothermally-heated water to Reykjavik for use by the city’s residents. Geothermal energy makes up 62% of Iceland’s energy usage, and
Day 3, May 22:
The third day began with an early start, since we had to make the 9:30 AM ferry to the island of Heimaey. This island, the subject of a chapter in Control of Nature by John McPhee ’53, is home to the Eldfell volcanic cone that was created during the 1973 Heimaey eruption. McPhee describes a several month effort to prevent the eruption from closing off Iceland’s most important fishing port. This effort involved the pumping of millions of cubic meters of seawater onto the lava to cool it and divert the flow. We were able to see the fruits of this epic battle from the top of the 43-year-old cinder peak ourselves. We were also able to walk on basalt-covered neighborhoods that were destroyed by the eruption, offering a more sobering perspective of the victory over the eruption. Back on the mainland, we continued east, stopping at the Seljalandsfoss and Skógafoss waterfalls. Both of which are fed by the Eyjafjallajökull glacier. Seljalandsfoss is so heavily undercut that we were able to actually walk behind the falls! Our last stop for the day was the Sólheimajökull glacial tongue, and was the first time many members of the group had been to a glacier! We spent the night in a hotel in Vik, in the shadow of Eyjafjallajökull, known for its 2010 eruption and straightforward pronunciation.

Day 4, May 23:
After a rejuvenating stay in Vik, we kicked off the fourth day at Reynisfjara beach, where pillars

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**Geosciences Student Research Fund**

We are pleased to announce that thanks to the generosity of our alumni donors, a faculty committee has made the first round of awards for student research. Over the past few years, the Department of Geosciences has received donations for our Geosciences Student Research Fund (undergraduate and graduate) and our Geosciences Graduate Research Fund (graduate students only). We are very grateful for the generous support we have received from our alumni. We look forward to reporting on these student projects in the next issue of the Smilodon!

The Geosciences Student Research Fund (GSRF) was announced in the Smilodon in May 2015. The GSRF will support both graduate and undergraduate research opportunities in the Department of Geosciences. These funds will allow students to pursue research topics that are of most interest to them, independent of the availability of federal grant funding. The GSRF will help students to investigate the most promising avenues of science and undertake entirely new, and unproven, areas of research that may be too speculative to receive government funding. This support might also supplement grant funding by serving as seed money to pursue related new ideas and proposals. Students may apply to use the funds for purposes that include, but are not limited to, field research, ocean voyages, Arctic/Antarctic research trips, lab analysis and computational studies.

A second fund, the Geosciences Graduate Research Fund (GGRF) will support graduate student research with an emphasis on field work, including graduate student led group expeditions. At least 50% of the funds allocated every year will be committed to field work, unless the applications for field work support do not reach that level.

For further information, please contact Nora Zelizer (nzelizer@princeton.edu) or Bess Ward (bbw@princeton.edu). The funds are administered and managed by the Department, and used to benefit solely Department of Geosciences students.
of basalt rise out of the water just offshore. Legend has it that these pillars were ancient trolls, frozen in place by the sun! Science, on the other hand, suggests that they are the remnants of the interiors of volcanic cones. We then drove to Fjaðrárgljúfur (Feather River) Canyon, where the group split into two. The more adventurous of the group hiked through the bitterly cold stream flowing through the base of the canyon, while others walked along the top. Many smaller creeks flowing into the canyon contained iron-oxidizing bacterial mats, and we collected samples of these iron-coated mats for analysis at Princeton.

From Fjaðrárgljúfur, we made a brief stop at Kirkjugólf (“the church floor”), an outcrop of planed-off columnar-jointed basalt that resembles a tile floor. We then headed to Dverghamrar, the “Dwarf Cliffs,” a protected site significant in Icelandic lore as the abode of dwarves and elves. We encountered more columnar joints there, capturing a group photo with everyone on their own column.

We drove the rest of day four across the vast and desolate Skeiðarársandur glacial outwash plain, which is the largest in the world. On the way, we passed Lómagnúpur, a cliff just under 700m high towering over the plains below. We arrived at the Skátafell campground in Vatnajökull National Park, where we stayed for two nights.

Day 5, May 24:
The fifth day of the trip was focused on exploring the national park near Skátafell, on the southern end of the Vatnajökull, the largest ice cap by volume in Europe. Small groups went on various hikes, including one to the Svartifoss waterfall which cascades over magnificent columnar basalt, and another to a lookout over the mighty Skátafell glacier.

Everybody gathered in the late afternoon for a drive to Jökulsárlón, a glacial lake that is growing as the Breiðamerkurjökull melts. We dodged extremely territorial birds on the walk to the lake’s edge, where we could watch seals play and icebergs flow to and fro in the tidal outlet. The group then returned to Skátafell for our last night in the park after a thoroughly exhausting day.

Day 6, May 25:
On the sixth day, we drove all the way back west, tracing the same route to Reykjavík. The group split into two, with one group returning to the Hveragerði geothermal area. This group hiked to a spot where geothermal springs enter a river, producing a naturally heated swimming area that had been recommended by Dr. Björnsdóttir. The rest of the group, opting for a more luxurious and cultural experience, went to the geothermally heated community pool in town (these pools, called sundlaugs, have an important role in Iceland’s culture). Everybody returned to Reykjavík for dinner in the city and an early bedtime before the morning flight back to JFK.

Trip organizers Alison Campion ’16, Adrian Tasistro-Hart ’17 and Atleigh Forden ’16 with staff member Laurel Goodell *83 atop Edfell, the volcano formed during the 1973 eruption on the island Heimaey; in the background stands Eyjafjallajökull which erupted in 2010 and shut down air traffic over Europe for a week.
FROM THE CHAIR

As this issue of the Smilodon shows, it has been a busy year in Geosciences. Perhaps the biggest news is the continuing evolution of the faculty. Three new people joined the Geosciences faculty this year, all in the broad area of climate/biogeochemistry. Laure Resplande, Xinning Zhang and Gabe Vecchi are introduced elsewhere in this issue and you will hear more about them in the future. The hiring of the “climate cluster” represents continued growth in this vital area of research, and was made possible by generous support from the University.

In February, we celebrated Professor George Philander, who won the 2017 Vetlesen Prize in recognition for his research on El Niño. Awarded for “scientific achievement resulting in a clearer understanding of the Earth, its history, or its relation to the universe,” the prize was designed to be the Nobel Prize of the earth sciences and is awarded once every few years. (Our own Jason Morgan won it in 2000.) The official celebration of the award was held in New York City in April.

Philander and Mark Cane of Columbia are co-recipients of the 2017 award. Working separately but synergistically, they figured out the interaction of winds and currents that disrupt the Pacific every few years, causing the global phenomenon known as El Niño/Southern Oscillation. Their work led to fundamental advances in oceanography and meteorology, and enabled the long-term forecasting of severe seasonal weather phenomena. George’s work on El Niño continued through his time at GFDL (1971–1989) and the University (1990–present). He is one of the founders of the climate group at Princeton. When he retires in July this year, he leaves a powerful legacy and a vibrant climate group in the department.

The death of Bill Bonini in 2016 was the end of an era. Bill retired in 1996, but his contributions to the department did not cease then, and he is greatly missed. A memorial gathering for Bill will be held in Guyot during Reunions – see elsewhere in this issue for more information on Bill and his life and contributions.

Thanks to the efforts of former students and colleagues, Emeritus Faculty Lincoln Hollister was honored at last Fall’s annual meeting of the Geological Society of America in Denver with both a field trip and technical sessions. Before the meeting, 31 participants from across the USA and beyond, spent four days exploring “Regional Al₂SiO₅ triple point metamorphic rocks of northern New Mexico: A field trip to honor the career contributions of Lincoln Hollister to petrology and tectonics,” organized by Chris Daniel (Hess Fellow 1998–2000), Chris Andronicos *99 and Ruth Aranoff. Lincoln’s students and colleagues have worked in these rocks of the Picuris Mountains, and he has led many Princeton field trips to the area.

At the meeting itself, Harold Stowell *87

Emeritus Lincoln Hollister

Three of Lincoln Hollister’s graduate students on Rincanada Schist: Harold Stowell *87, Chris Andronicos *99 and Cameron Davidson *91.
and Bernardo Cesare (postdoc 1993) chaired a day-and-a-half of oral and poster sessions entitled “Fifty years of Innovation in Petrology and Orogenic Systems: A Tribute to Lincoln Hollister.” The 44 invited and contributed presentations highlighted wide-ranging research by former students, students of former students — professional grandchildren — and even one professional great-grandchild! Many of the presentations featured photos of Lincoln in the field over the course of his 50-year career. And it’s not over yet — Lincoln presented his current work on a quasicrystal-bearing meteorite that contains several unique minerals, including the newly recognized hollisterite!

Last year we said good bye to our multitalented much appreciated safety and facilities manager, Bob Koenigsmark. Bob reports that retirement suits him just fine! This year, we welcome Mike Morris as our new safety and facilities manager, and are glad to report that he has already proven himself invaluable. Many thanks to Mike for his adept and timely handling of myriad space and instrument challenges, and many just plain oddball requests, with which GEO is blessed. Keeps the job interesting.

This year we say goodbye to George Rose, who ran the GEO machine shop for 37 years. He did not leave us with a tally of the many custom built items he provided for the faculty and their lab groups over the years, but he contributed immensely to the research of the department with his creative solutions and highest caliber work. The diamond anvil community in particular will miss him, and we all wish him well in retirement.

Geosciences undergraduates have led several activities within the department. Last year’s trip to Iceland, largely organized and led by Princeton University Geosciences Society (PUGS), is covered elsewhere in this issue. This year, PUGS has organized a spring trip over Memorial Day weekend. A group of undergraduate and graduate students are headed to Baxter State Park in Maine during the week between the end of exams and reunions. They’ll camp, hike and climb Mount Katahdin and see features ranging columnar jointing in rhyolite to the state fossil of Maine, Pertica quadrifaria, a Devonian plant.

On April 22, PUGS organized a contingent of students and scientists to stand with science at the March for Science in Washington, D.C. Twelve students from GEO made the trip. Please visit the News Archive on the GEO web page for photos.

The 2nd Annual Theresa’s Trails event to benefit the Greater Philadelphia Chapter of ALS took place on Sat. Apr. 29, 2017 on Princeton University’s campus. This event was dedicated to former Geosciences grants manager Theresa Autino, who is supported by the ALS Philadelphia organization. Sadly, Theresa passed away on May 26, just as this issue was going to press. PUGS hosted the run and Mary Rose Russo did most of the organization. Over 100 people participated and raised funds for ALS.

The next installment of the GeoGrad Alumni reunion field trip series will be held June 17-23. A couple of dozen alumni of the Graduate School will be led by Scott Wood ‘85 through the channeled scablands and Columbia River basalts of eastern Washington, the Clarkia fossil beds and star garnets of northern Idaho, and the Lewis and Clark Caverns and Butte mining district in Montana. One highlight is certain to be the jet boat tour into the Hell’s Canyon of the Snake River.

Two years ago we announced the creation of two new funds intended to support field work by our students. I thank all of those who have contributed; we deeply appreciate your dedication and continued interest in and support of our students. The funds have already made a difference in providing opportunities for our students, and some of their work and experiences supported by these funds are highlighted elsewhere in this issue. For more information about the funds, please contact Nora Zelizer (nzelizer@princeton.edu) or Bess Ward (bbw@princeton.edu).
Gabriel Vecchi, in geosciences and the Princeton Environmental Institute, joined the faculty in spring 2017 after having served as a lecturer at Princeton since 2012 and as a researcher at the National Oceanic and Atmospheric Administration’s Geophysical Fluid Dynamics Laboratory since 2003. From 2001 – 03, Vecchi was a research scientist at the University of Washington, where he earlier was a postdoctoral research associate and completed his Ph.D. He earned his B.A. from Rutgers University. Vecchi’s research foci include the impact of climate variability and change on hydroclimate and extreme events, and the predictability of climate and its regional impacts.

Laure Resplandy, in geosciences and the Princeton Environmental Institute, joined the faculty in spring 2017 from the Scripps Institution of Oceanography at the University of California-San Diego, where she was a postdoctoral researcher since 2014. Resplandy also completed postdoctoral work at the Laboratoire des Sciences du Climat et de l’Environnement, Paris and at the National Oceanography Center, Southampton. She earned her Ph.D. at the University of Paris-Sorbonne and her M.A. and B.A. at the École Normale Supérieure, Paris. Her research focuses on oceanography and biogeochemistry.

Xinning Zhang, in geosciences and the Princeton Environmental Institute, joined the faculty in spring 2017 after serving as an associate research scholar since 2014 and postdoctoral fellow at Princeton from 2011 – 14. Zhang also completed a postdoctoral fellowship at the California Institute of Technology. An environmental microbiologist focusing on microbial nutrient and energy transfer in past and present environments, she earned her Ph.D. from the California Institute of Technology and B.S. from Cornell University.

New Faculty Members

2017 Ph.D. Recipients and Dissertation Titles

Pathikrit Bhattacharya
Examination of the Rate-State Friction Equations under Large Perturbations from Steady Sliding: A Theoretical and Experimental Study
Adviser: Allan Rubin

Qixing (Jimmy) Ji
Nitrous Oxide Production in Marine Environments with Strong Oxygen Gradients
Adviser: Bess Ward

C. Brenhin Keller
Geochimical Evolution of Earth’s Continental Crust
Adviser: Blair Schoene

Dario Marconi
Use of the Nitrate Isotopes in the Ocean Interior to Explore the Isotopic Composition of Sinking Nitrogen and its Implications for Marine Biogeochemical Cycles
Adviser: Danny Sigman

Ryan Modrak
Acoustic and Elastic Waveform Inversion Best Practices
Adviser: Jeroen Tromp

Kyle Samperton
Portrait of a Pluton: Magmatic Perspectives from the Mid-Crustal Bergell Intrusion, Central Alps
Adviser: Blair Schoene

Yanhua Yan
Adjoint Seismic Tomography Using Full-Waveform and Envelope Inversion
Adviser: Frederik Simons
ALUMNI NEWS

Jon Husson *14 is finishing up his postdoc at the University of Wisconsin, Madison before packing up the family to move to beautiful Vancouver Island, where in August he will start as an assistant professor at the School of Earth and Ocean Sciences at the University of Victoria in British Columbia, Canada.

Yifeng Wang '11 will graduate with an MBA from Harvard Business School this summer, and start working for Kraft Heinz in Chicago in the fall.

Katy Barnhart '08 was recently awarded funding for an NSF EAR postdoc for collaborative work at the Universities of Colorado and Kansas using geomorphology, applied mathematics, hydrology and drone technology to study debris initiation zones in the Chalk Cliffs on the southeast flank of Mt. Princeton, CO.

Laura Smith '05 has spent the last decade working all over the world for Schlumberger/Western Geco on marine seismic vessels, most recently as Party Chief. In 2014, she and her husband started Quixote Expeditions, an adventure tourism company that takes guests to Antarctica via sailboat — and this year via plane, then meeting up with the sailboat. On every trip, a guest scientist doing active research in the area is given a berth gratis. Laura will miss Reunions this year as she will be in Brazil with their vessel for dry dock.

As Chief Development Officer for Origin Energy in Australia, Maia Schweizer '04, looks after everything from exploration and appraisal of new gas resources to drilling and completions — everything to get unconventional gas out of the ground. This includes extracting gas from Jurassic coal seams in Queensland before sending it up a pipe to be liquefied and shipped to Asia, and also developing some of the oldest economic hydrocarbon reserves, in Proterozoic shales of the Northern Territory.

Naomi Levine '03 thoroughly enjoys running her lab as a faculty member at the University of Southern California. Her research group focuses on understanding interactions between climate and marine ecosystem function and she just graduated her first 2 Ph.D. students. She was recently awarded a Sloan Research Fellowship and a Simons Foundation Early Career Investigator Award.

Bill Langin '99 is still working for Royal Dutch Shell but has moved to Brisbane, Australia from Muscat, Oman. Bill is the General Manager, Upstream for Queensland Gas Company (QGC), a Shell company.

After over 10 years abroad, Ann Marie Lavigne '98 has returned to the U.S. to head Google’s Americas Strategy & Operations for SMBs (Small and Medium Businesses). Her previous positions at Google have been in Partnerships in Australia, Japan, and Korea, and Asia-Pacific Ads Strategy in Japan and Singapore. While it may be a different kind of “field work,” all of the problem-solving skills she picked up from geology get used every day.

In April, Marybeth Price *95 became Dean of Graduate Education at the South Dakota School of Mines and Technology. She reports that it interesting to step away from being a teacher and professor, but looks forward to fostering education in a different way. She retains her appointment as Professor of Geology and Geological Engineering and has a few graduate students still to shepherd through their degrees. As always, it seems to her, she is working on the next edition of her Mastering ArcGIS textbook, along with teaching GIS workshops.

Scott Wood *85 is organizing and leading the upcoming GeoGrad field trip to Idaho and Oregon for alumni of the Graduate School; the next Smilodon will have a recap. Atholl Sutherland Brown *53 and his wife were slated to attend as they have several previous trips. Sadly, Atholl passed away last December at the age of 93 (see Deaths).
Bob Odom, research staff 1983-1986 writes of an inflatable boat trip he recently took on Ross Lake in the North Cascades; the lake is formed by Ross Dam, which provides power to Seattle. The boats were so small that packs had to be tied to the front of them. He fondly remembers a 2005 climb of Mt. Rainier that he did with Tony Dahlen (faculty 1970-2007) and Tony’s son Alex.

Last August, geophysicist Kate Miller ‘82 was named Provost and Vice President for Academic Affairs at the University of Wyoming. After her Ph.D. from Stanford, Kate worked at Amoco before starting her academic career which has included being a faculty member and then Associate Dean of the College of Science at the University of Texas El Paso, and an appointment as Dean of the College of Geosciences at Texas A&M.

Catherine McVay Hughes ‘82 finds her civil engineering degree and hydrogeology major indispensable in addressing the impact sea level rise and climate change on the urban environment. Recently she moderated the Trinity Institute 2017 Water Justice Panel Response entitled “The Global and the Local” that used New York City’s challenges as a lens through which to examine national and worldwide issues (www.trinitywallstreet.org/video/trinity-institute-2017-water-justice-panel-response). Catherine served 19 years on Manhattan Community Board One (CB1), and after 9/11 she chaired its World Trade Center Redevelopment Committee. After Superstorm Sandy, she was appointed Co-chair of NY Rising Community Reconstruction Program for Southern Manhattan, is a founding member of CB1's “Manhattan Tip” Resiliency Task Force and a member of the NY/NJ Metropolitan Storm Surge Barrier Working Group. She also serves on the Institute Advisory Board at Columbia University, the CERES Presidents Council, The Trust for Governors Island and the World Trade Center Scientific Technical Advisory Committee.

Lydia Fox ’81, Associate Professor of Geological & Environmental Sciences, Director of Environmental Studies, and Director of Undergraduate Research at the University of the Pacific, was named a Fellow of the Geological Society of America at the annual meeting in Denver last October.

It is spring, and Doug Jones ’80 again longs for his days playing for the Coprolites. He is a faculty member in the Department of Geosciences at the University of Florida, and Director of the Florida Museum of Natural History. Doug is also active on the national museum scene, as Past President of the Association of Science Museum Directors and as current Chair of the Board of the American Alliance of Museums in Washington, DC.

Charlotte Allen ’79 is Senior Research Fellow at Queensland University of Technology (QUT), “the MIT of the south.” Last February, QUT hosted the biennial meeting of the Australian Microbeam Analysis Society. One of the keynote speakers was Edward Vicenzi, a former manager of the Imaging and Analysis Facility at Princeton who now works at the Smithsonian Institution’s Museum Conservation Institute.

Tommy D. Dickey ’77 earned his Ph.D. in the nascent Geophysical Fluid Dynamics Program and has focused his career on interdisciplinary ocean observations and modeling. He retires in November after more than 38 years on the faculty of the University of Southern California and the University of California at Santa Barbara (UCSB). In 2008, he was awarded the Secretary of the Navy and Chief of Naval Operations Chair in Oceanographic Sciences, a lifetime appointment that is awarded to two distinguished oceanographers every four years. Tommy also received the UCSB Distinguished Teacher Award in 2016.

In addition to continuing research in the Apennine Mountains of Italy and on the end-Cretaceous extinction, Walter Alvarez ’76 is just finishing a book about “Big History,” the unified study of all of the past (the cosmos, Earth, life, and humanity) that is just emerging as a new academic field. The book is A Most Improbable Journey, and should be published in November by Norton.

The July 4-10, 2015 edition of The Economist magazine features an article about paleotsunamis, based on paleo-seismological work in Aceh Province, Indonesia by Harvey Kelsey ’71. Harvey, a long-time faculty member in the

Bonini, a pre-Beltway, fourth generation Washingtonian, came to Princeton in 1944 from Western High School. He was the first in his family to complete college. After earning his bachelor's and master's degrees in geological engineering at Princeton, he joined George Woollard *37 at the University of Wisconsin, Madison, where he completed his Ph.D. in 1957 based on a seismic refraction study of the coastal plain of the Carolinas. It was in Madison that he met Rose Rozich, his wife of 62 years.

His first widely recognized scholarly contribution was an accurate map of the Earth's gravitational field. Working with Woollard, Bill shepherded a pair of Worden gravimeters around the world six times in six years, measuring the force of gravity at hundreds of airfields. This involved hopping in and out of a C-130 Hercules, and catching rides in bush planes on mail runs to remote villages. On one four-month trip, Bill visited 39 countries, logging an average of 1000 miles a day. The Woollard and Bonini survey produced the first standardized description of the Earth's gravitational field, some-
thing essential for the navigation of guided missiles and satellites. Bill also applied geophysical modeling to regional and local geology, with many notable contributions to the geology of the western U.S. and northern South America.

Bill's 43 years on our faculty were distinguished by his dedication to students and alumni and his ability to work well with absolutely everybody. This included being a very effective calming presence during sometimes stressful departmental discussions.

He taught the core introductory course GEO225: Engineering and Environmental Geology, for 25 years and for 30 years was the major advisor for every geological engineering graduate. Over his last 15 years of advising, 10% of Princeton's geo-engineers won NSF fellowships. For 35 years he directed and taught the summer field course at the Princeton-Yellowstone Beartooth Research Association (YBRA) camp at Red Lodge, Montana. Combined with 21 years as Departmental Representative in Geosciences, Bill had a lasting impact on generations of geology and geological engineering majors. For his contributions to undergraduate teaching, Bill received the President's Distinguished Teaching Award at Opening Day Ceremonies in September 1992.

Many of the Ph.D. students supervised by Bill were supported by a collaboration with Venezuela's Ministerio de Minas e Hidrocarburos. One of these students, Rick Vierbuchen ’79, reminisces fondly, “At the start of my first field season, in the mountains of Venezuela, Bill came with me to help find a reliable field assistant, secure decent shelter and even obtain a steady supply of anti-venom for snakebites. He wouldn’t leave until he knew I was prepared. Bill was not rigid as a scientist and a thinker. He encouraged students to take risks and explore new techniques or challenging disciplines. He always just wanted to get the right answer, even if it wasn’t the answer he anticipated. The skills that Bill taught were quite useful, but the flexibility, the broad interest in subjects, the excitement of learning new things and the lack of personal identification with a given solution — all those things profoundly affected my approach to science. He’s the role model you think of when you’re in a difficult situation.”

Bill’s commitment to his students extended beyond the Princeton campus and the academic calendar. Students were a frequent presence at the Bonini household and the four Bonini children, themselves members of the Princeton undergraduate classes of 1979, 1981, 1985, and 1991, grew up with them. The house was always open for students stranded for the holidays, and daughter Jen writes, “he had a positive, outgoing personality with a sharp intellect and a huge heart. Anyone who needed a place to stay was welcome to stay at (our) home.”

In the late 1970’s Bill started using the YBRA camp as a base for a series of highly successful alumni colleges. Department alumni also benefited hugely from Bill’s long stewardship of the Departmental alumni newsletter, The Smilodon. In recognition of these and other contributions to alumni he received the Princeton Award for Excellence in Alumni Education in 2010.

Bill’s interests in science education extended beyond the university. Long before government funding agencies mandated such outreach, Bill developed and taught inquiry-based summer workshops for local school teachers. These programs and their descendants have enhanced the teaching of hundreds of teachers and continue today as the QUEST Institute run by Princeton’s Program in Teacher Preparation. Two editions of their introductory level lab manual, The Lab Book: Problem Solving in Geology extended the impact of Bill and his co-authors even further. Bill also held leadership positions in the National Association of Geology Teachers, YBRA, the Princeton chapter of Sigma Xi and the Geologic Society of America, of which he was a Fellow.

For 15 years after retirement, Bill shared brown-bag lunch with 3 or 4 “regulars” nearly every day in his office on the 4th floor of Guyot. Unlike most of us, Bill’s office was organized, with an uncluttered table on which we could comfortably have lunch. There we talked about everything under the sun. He spoke with experience, having served on just about every University committee, including the Council on Science and Technology from its inception in 1989 until his retirement. One triumph arising from these lunches was Bill’s orchestration of the placing of the Guyot Stone in front of Guyot Hall. It had been removed to a field from the front of Nassau Hall where it had resided for 110 years.

Throughout his career at Princeton and with impacts far beyond the University, Bill Bonini exemplified all that is best in scholarship and teaching. He was a Gentleman with a capital G.

This resolution was prepared by Professors of Geosciences Emeriti Lincoln S. Hollister and W. Jason Morgan, Professors Tullis Onstott and George Philander, Chair of Advisory Committee Rick Vierbuchen ’79 and Laurel Goodell ’83, Manager of Undergraduate Labs and Lecturer in Geosciences.
I found the Department of Geological and Geophysical Sciences in the fall of 1967, through a work-study job doing XRD for Hiroshi Ohmoto ’69. Russ Wheeler ’73 took me as a field assistant to his thesis area in central Norway in the summer of 1968, teaching me about fieldwork, structural geology, and metamorphic petrology. I took sedimentology with Hollis Hedberg (faculty 1959-1971) who organized a summer’s fieldwork on a Gulf Oil seismic party. Then followed with mineralogy and petrology from Rob Hargraves ’59 (faculty 1961-64) and Fred Vine (faculty 1967-70), and structural geology from John Maxwell ’46 (faculty 1946-1970).

The Department was alive in those days over the paradigm shift to plate tectonics, and in addition to our own departmental specialists and offerings, there were seminars, seemingly weekly, from leading researchers around the world. Because I started early, I was able to take 500-level classes in geochemistry (Dick Holland ’47, faculty 1952-1972), mineralogy (David Waldbaum, faculty 1970-74), and petrology including the lunar work with Hargraves and Lincoln Hollister, faculty emeritus.

In terms of how my Princeton Geosciences background affected my professional life, the key was the transition in the late 1960s by Holland from his research agenda on thermodynamics as a basis for understanding ore genesis, to his return to his own research roots in low-temperature geochemistry. Because I spent so much time with him as a research assistant, in classes, and doing independent work, the underlying synthesis between the high-T and low-T work never seemed odd to me; thermodynamics and crystal chemistry would express themselves, and that story needed to be framed in a physical description of the system — intrusion and groundwater flow, gravity-driven depositional environments, or diffusion-dominated environments. What we imagined from calculations or measurements in the lab had to fit in the field-scale system, and vice versa.

Professionally, I would make my way with the fundamental tools to which I was introduced at Princeton: field mapping and air-photo analysis; measuring sections; the petrographic microscope; hand-sample identifications of field samples and drill-cores; calculating Eh-pH diagrams; preparing and running samples through X-ray diffraction and atomic absorption spectroscopy. And junior and senior independent work gave me experience in writing and orally defending my science to managers and clients, as I had to Princeton faculty.

As time and opportunities presented themselves, I became a man of the West, and eventually well beyond. I have seen the moon rise over the Missouri Breaks and the sun set over the Gulf of Davao; jumped from a Twin Otter to the dirt runway in the NWT, and from a six-seat Cessna in the Sierra Madre of Durango State; and walked through the rainforest in New Guinea, the desert of the Pilbara Block in Western Australia, and the Gobi Desert.
Class of 2017 Senior Thesis Titles

Abstracts and full theses can be obtained through the University’s Library at pulse.search.princeton.edu. Simply search the student’s name and limit the search results by category (Senior Theses).

Scott Bechler
Exploring the Relationships Between Marine Cloud Brightening, the Walker Circulation, and Boreal Summer Asian Monsoon Precipitation
Adviser: Michael Oppenheimer

Kate Begland
Weak Inner Core Anisotropy Along Polar Paths Under the Western Pacific Ocean
Adviser: Jessica Irving

Kenny Hulpach
Interior Structure of Jupiter’s Satellite Io Based on Thermal Equation of State Data
Adviser: Tom Duffy

Casey (Catherine) Ivanovich
Uncovering the Sources of Elevated Arsenic in Classic Maya Human Remains: Implications from Antiquity to Modernity
Adviser: Satish Myneni

Christianese Kaiser
Estimating Atmospheric Methane Emission by Mineral Cryosols in the Arctic Region Using the Explicit High Affinity Methanotroph (XHAM) Model
Adviser: Tullis Onstott

Sydney Mandelbaum
Potential Sources of Hemispheric Energetic Asymmetry
Adviser: Stephan Fueglistaler

Lauren Santi
A Calcium and Strontium Analysis of Shark Teeth to Constrain Past Ocean Chemistry
Adviser: John Higgins

Jana Suriano
Survival and Metabolism of Methanosarcina Solfedigidi Under Simulated Martian Subsurface Conditions
Adviser: Tullis Onstott

Kellie Swadba
Wave Profile Analysis of the Behavior of SiO₂ Under Shock Compression
Adviser: Tom Duffy

Adrian Tasistro-Hart
Astronomically Forced Hydrology of the Late Cretaceous Sub-Tropical Potosí Basin
Adviser: Adam Maloof

Anna Van Brummen
Calibration and Noise Characterization of a Newly Installed Seismometer at Princeton University
Adviser: Frederik Simons and Jessica Irving

Will Van Cleve
Modeling the Relationship Between Climate and Conflict: Nigerian Intergroup Conflict, Boko Haram Violence, and the Israel/Palestine Conflict
Adviser: Michael Oppenheimer

Vivian Yao
Stable Isotopic Signatures in Symbiotic Bermuda Corals: A Study of Nutrient and Light Variability on δ15N in Porites Astreoides at Bermuda
Adviser: Danny Sigman

Paul Yi
Numerical Investigation of the Dependence of Tidal Mixing by Wave-Wave Interaction on Topographic and Flow Parameters
Adviser: Sonya Legg

Congratulations to all of the members of the Class of 2017 for a job well done!
The Department wishes you all the best. Be sure to keep in touch, as we are excited to hear where your careers take you. We hope that you have enjoyed your experience as a Geoscience major and look forward to seeing you at Reunions 2018.
UNDERGRADUATE NEWS
We’d like to congratulate the Juniors and Seniors for their special achievements over the past year and to wish all of the graduates well as they continue their careers.

After graduation, Sydney Mandelbaum ’17 will join the sports division team at Creative Artists Agency in NYC, where she will perform analytics. Creative Artists Agency is a full-service agency that represents professionals working in a wide variety of entertainment and sports fields.

In the Fall of 2017, Lauren Santi ’17 will continue her educational career at UCLA where she will perform research. She will begin working towards a Master of Science degree in Geochemistry.

Jana Suriano ’17 received a High Meadows Fellowship from Princeton’s Pace Center (a center for civic engagement) and will be working for two years as a Cuba Sustainable Ecosystems Fellow at the Environmental Defense Fund. The position is headquartered in Raleigh, NC and will involve monthly travel to Cuba. After the fellowship, Jana plans to attend to graduate school.

Over the past year, Casey Ivanovich ’17 received both the Henrietta S. Treen Scholarship and the New Jersey Licensed Site Remediation Professionals Association’s (LSRPA) Elmeryl Davies Memorial Scholarship. Casey will spend this summer performing climate research with Professor Gabe Vecchi. At the end of August, she will relocate to Washington D.C. where she will serve as a Climate Science Fellow at the Environmental Defense Fund, a position award through the High Meadows Fellowship program of Princeton’s Pace Center for Civic Engagement.

Will Atkinson ’18 has been awarded a fellowship through Princeton’s PEI Environmental Scholars Project and will spend the summer performing field sampling in Alaska, after which he will be on campus analyzing samples as he transitions from his Junior Project to his Senior Thesis work.

After graduation, Adrian Tasistro-Hart ’17 plans to spend three months traveling the world before he heads to Switzerland to begin a Master of Science program in Geophysics at ETH Zurich. Adrian received funding from ETH Zurich’s Excellence Scholarship & Opportunity Program to pursue this degree.

Starting this fall, Vivian Yao ’17 will head to University of California, Berkeley where she will pursue both a Ph.D. and an OD (Doctor of Optometry).

Anna Van Brummen ’17 made U.S. Fencing history with a gold medal at the Suzhou World Cup in China, as the first U.S. women’s épée fencer to win World Cup gold since women’s épée was added to the Olympic program in 1996. This win makes Anna a contender for the 2020 Tokyo Olympic Games. This summer, she
will be competing at the Fencing World Championships in Leipzig and World University Games in Taipei. Join us in congratulating her and wishing her the best of luck at these competitions. In the fall she will begin a Master’s program in Geophysics at ETH Zurich, Switzerland.

Paul Yi ’17 received a Graduate Fellowship from Stanford University’s Civil and Environmental Engineering Department to pursue a Master’s Degree in Environmental Fluid Mechanics and Hydrology.

After graduation, Scott Bechler ’17 will be teaching English in Malaysia, with funding provided by the Fulbright English Teaching Assistant program.

Joshua Murray ’18 will spend the first part of the summer in Washington and Oregon collecting samples for paleomagnetic analysis. He plans to spend the remainder of the summer analyzing the data in Princeton.

Kate Begland ’17 was honored at the Gulf Coast Undergraduate Research Symposium at Rice University with an award for “Best Oceanography Presentation.” After graduation, she will enter the Ph.D. program in the Department of Earth Sciences at Rice University where her research will focus on seismology.

Walker Darling ’18 will spend the beginning of the summer collecting coral samples in Bermuda that he will bring back to the Sigman Lab to make nitrogen isotopic measurements of coral tissue and skeletons. These isotopic data will be used to determine the degree to which the corals are recycling nitrogen with their endosymbiotic algae.

As part of a potential senior research project, Hannah Tandy ’18 will be working at the Geophysical Fluid Dynamics Laboratory to test model sensitivities of Paleocene-Eocene Thermal Maximum climate conditions.

Erin McCabe ’18 has been selected as a Princeton Environmental Institute intern. She will spend the summer working with Climate Central to develop geographically-specific estimates of land-based negative greenhouse gas emissions in the US, which includes afforestation, carbon storage in soils, and biomass energy integrated with CO₂ capture and storage.

Through a Princeton Environmental Institute internship, Nicole Rinaldi ’18 will be working with the Sarmiento Group this summer using Earth System Models to assess the occurrence of extreme heat and acidification events at coral reef habitats in the Pacific Ocean.

DEATHS

Frederick Schall, Jr. ’37
1/11/16
paw.princeton.edu/memorial/frederick-m-schall-jr-37

Joseph G. Lambert ‘46
4/19/2013
paw.princeton.edu/memorial/joseph-g-lambert-%E2%80%946

William Hall ’47
6/16/2014
paw.princeton.edu/memorial/william-b-hall-%E2%80%947

John R. Bermingham ’47
9/21/2014
paw.princeton.edu/memorial/john-r-bermingham-%E2%80%947

John S. Warriner ’47
7/27/2013
paw.princeton.edu/memorial/john-s-warriner-%E2%80%947

12/13/2016

E. Frederick Roots *49
10/18/2016
ottawacitizen.com/news/local-news/obituary-revered-explorer-fred-roots-was-also-key-to-development-of-environment-ministry

William H. Tonking ’49 *53
3/3/2014
paw.princeton.edu/memorial/william-h-tonking-%E2%80%949-53

Arthur Mudge ’51
5/23/2014
paw.princeton.edu/memorial/arthur-w-mudge-ii-%E2%80%9451

Paul Yi ’17

12/13/2016

E. Frederick Roots *49
10/18/2016
ottawacitizen.com/news/local-news/obituary-revered-explorer-fred-roots-was-also-key-to-development-of-environment-ministry

William H. Tonking ’49 *53
3/3/2014
paw.princeton.edu/memorial/william-h-tonking-%E2%80%949-53

Arthur Mudge ’51
5/23/2014
paw.princeton.edu/memorial/arthur-w-mudge-ii-%E2%80%9451
DEATHS, cont.

Atholl Sutherland Brown *53
December 9, 2016

John Van Trube *54 *60
2/24/2014
paw.princeton.edu/memorial/john-v-trubee-%E2%80%9954

John Bauhan *55
6/22/2014
paw.princeton.edu/memorial/john-h-bauhan-%E2%80%9955

Roy A. Stuart *56
9/14/2013
paw.princeton.edu/memorial/roy-stuart-56

Hal G. Kuntz *60
8/18/2014
paw.princeton.edu/memorial/hal-g-kuntz-%E2%80%9960

James Woodhead *77
February 12, 2017
www.alumni.caltech.edu/in-memoriam/2017/2/28/james-woodhead-bs-69

D.C. “Bear” McPhail *91
March 14, 2017
regolith.org.au/mcphail.html