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EOS

Earth & Space Science News

Slice of Time from a New Zealand Lake Core

A New Definition for Magma

Ice Sheets and Sea Level Rise

Geological Activity on Ceres

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AGU PUBLICATIONS

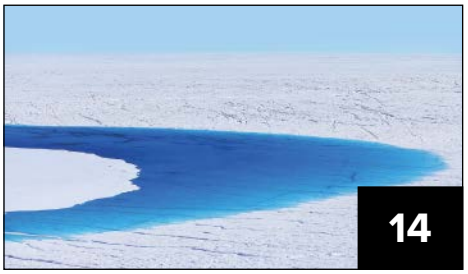
1 NOVEMBER 2016
VOLUME 97, ISSUE 21

COVER

Probing the History of New Zealand's Orakei Maar

A team of scientists drilled into the bed within a northern New Zealand explosion crater lake to gain insights into volcanic hazards and past climates.

PROJECT UPDATE



Charting Ice Sheet Contributions to Global Sea Level Rise

An international team produced an integrated assessment of polar ice mass losses in 2012. Now efforts to provide an up-to-date assessment are under way, with an open invitation for participation.

OPINION

We Need a New Definition for "Magma"

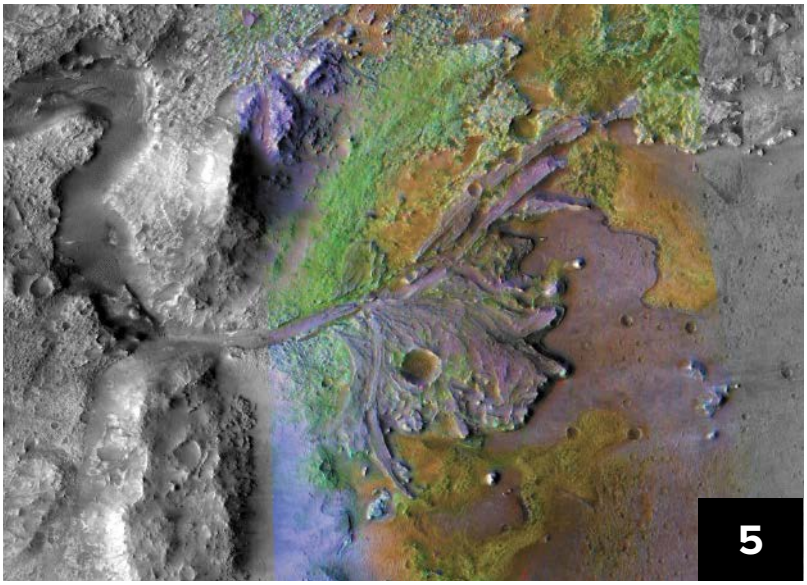
Confusion over the meaning of "magma" can generate popular misperceptions, including a nonexistent molten sea underneath Yellowstone National Park. We propose a different definition.

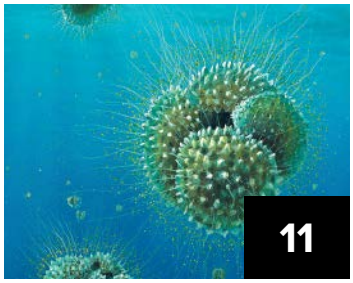
AGU NEWS

24 AGU-Sponsored Workshop Targets Sexual Harassment in the Sciences

During the past 2 years, scientific societies and universities have faced increasing pressure to address a problem that has grown more visible.

DEPARTMENTS





Eos

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Christine W. McEntee, Executive Director/CEO

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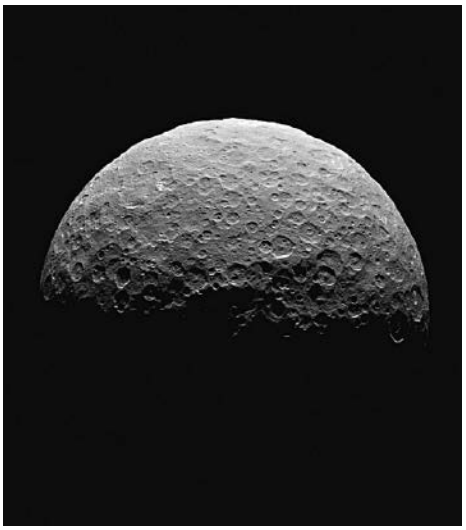
New Findings Suggest Dwarf Planet Ceres Is Geologically Active



NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

NASA's Dawn probe entered Ceres's orbit on 6 March 2015. This image, taken in mid-April of that year, shows Ceres's northern end.

When scientists got their first close-up glimpse of Ceres in 2015, they expected to find a large, inert rock orbiting along with the millions of other inert rocks in the asteroid belt. What they did not expect was evidence of geologic activity on the dwarf planet's dark surface.

In a suite of six papers published on 1 September in *Science*, scientists from the Dawn mission, which has a spacecraft circling Ceres, catalog a bounty of surface features pointing to one conclusion: "Ceres appears to be geologically active," said Carol Raymond, the mission's deputy principal investigator. The Dawn spacecraft entered Ceres's orbit in March 2015.

Volcanic Ice

One of these surface features is a 17-kilometer-wide, 4-kilometer-high volcano that once erupted ice. This "cryovolcano" rises half the height of Earth's Mount Everest in the Himalayas.

The researchers spotted the cryovolcano using Dawn's Framing Camera, which took images of 99% of the dwarf planet's surface. The feature's angled slopes with flow-like structures and concave summit are reminiscent of lava domes on Earth, said Ottaviano Ruesch, a postdoctoral researcher at NASA's Goddard Space Flight Center and lead author on the paper detailing the feature (see http://bit.ly/cryovolcanism).

Ruesch compared the Ceres prominence to a lava dome found in Washington State's Mount St. Helens volcanic crater. Although features of cryovolcanic origin have been spotted on other bodies in the solar system, the newly named Ahuna Mons on Ceres stands out as the first observed cryovolcanic dome, he said.

On Earth, lava domes form when sticky, viscous, molten rock bubbles slowly to the surface, solidifies, and piles up around the vent. On Ceres, where temperatures average about 160 K (−113°C), volatile, rich, salty water "erupts," the researchers suggest. The presence of salts on Ceres lowers the freezing temperature of water, said Ruesch. The lowered freezing temperature keeps the water a liquid that slowly rises to Ceres's surface. There it solidifies and has piled up into a 4-kilometer-high mound.

Although Ahuna Mons is no longer active, by analyzing the number of craters around the feature, scientists estimate that it's only about 200 million years old, Ruesch said, which is considered geologically young.

Bright Spots

Ceres sports well-known bright spots on its surface—the newly released findings point to these as signs of more geologic activity, Raymond said. The team had already established that Ceres's bright spots are composed mainly of sodium carbonate, a salt found abundantly at the bottom of Earth's oceans. Because no crashing asteroid could have brought this material to the dwarf planet, the scientists suspect that it rose to the surface from within.

On Earth, we know how magma rises to the surface: The hot interior transfers heat to rock above it, which rises as it becomes more buoyant; meanwhile, colder rocks farther away sink down to be reheated. This process continues until hot, molten rock breaks through the stiff, cold crust.

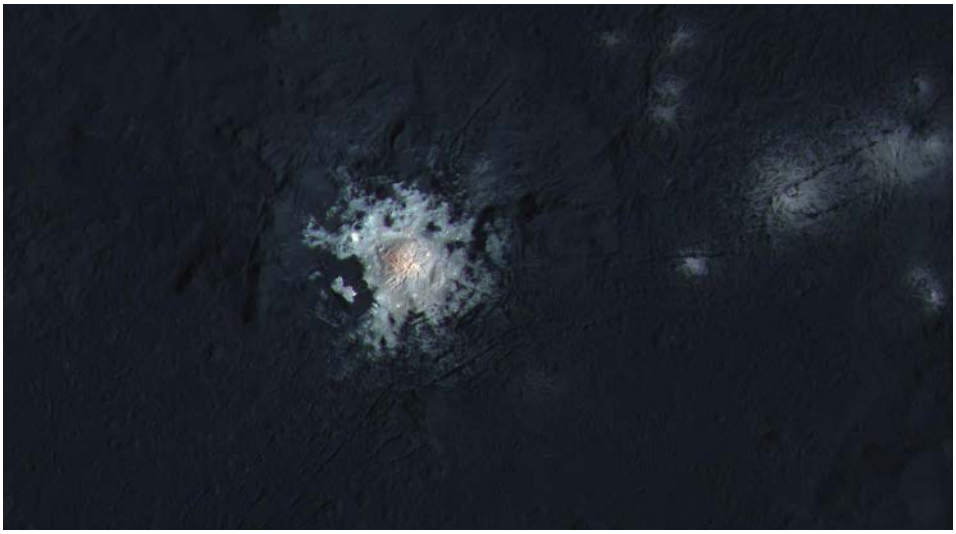
In a similar fashion, the bright spots may represent patches where brines upwelled, spilled out onto the surface, and dried, leaving the salts behind. But in Ceres's case, the Dawn team isn't quite sure how the melted brine moves upward.

"We have, we believe, some partially melted brines at depth," Raymond said, but "we don't have an obvious mechanism by which those cryomagmas can get to the surface."

Impacts and Flows

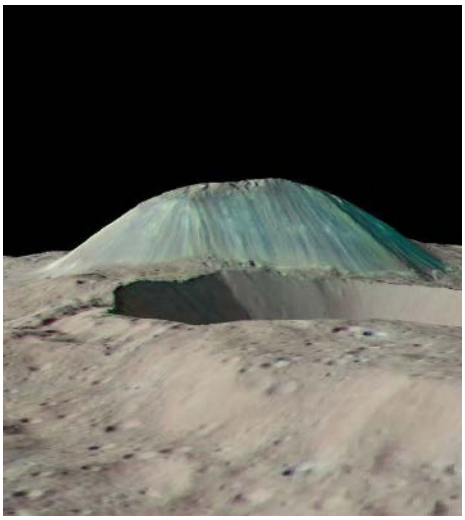
Evidence for other bursts of geologic activity shows up near impact craters, as detailed in another paper on the dwarf planet's geomorphology (see http://bit.ly/geo-morph).

On a geologically inactive world, an impact would hurl material into the air that would then settle down around the crater. But on Ceres, features in the vicinity of many impact



NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/PSI/LPI

Enhanced color view of the bright spot within Ceres's 92-kilometer-wide Occator crater. The image was produced by overlaying high-resolution images obtained in February 2016 with color images obtained in 2015.



NASA/JPL-Caltech/MPS/DLR/IDA

In a false-color image from the Dawn probe's Framing Camera, blue streaks on Ceres's cryovolcano Ahuna Mons indicate a chemical composition different from the rest of the landscape.

craters suggest that material flowed for many tens of kilometers, indicating that the crust contains some ice, which melted from the crash of an incoming meteor.

The researchers spotted many extensive examples of such impact-induced flow that lasted longer than would be expected on an inert world, said Chris Russell, Dawn's principal investigator.

Landslides also appear to occur on Ceres, as evidenced by the team's discovery of surface water ice on the steep slopes inside a crater called Oxo (see http://bit.ly/H2O-exposed). Dawn data suggest that a pliable, ice-rich layer lies underneath the stiffer, rocky surface. Because ice would sublimate from an inert planet's surface within roughly a century, finding exposed ice raises the possibility that a series of landslides or very slow slippage of the surface is currently exposing fresh ice.

"We have no idea how long [the landslide] has been active," Russell said. But the fact that Dawn scientists see ice suggests that the process is ongoing, he noted.

A Dynamic World

The team expected to find a completely cooled-off, geologically dead world, with possible features of past activity, Raymond said.

"Finding evidence for ongoing activity is surprising," she continued, "and it's clearly giving us a lot to think about in terms of how this body works."

By **JoAnna Wendel,** Staff Writer

Next President Must Name Science Leaders Fast, Report Urges

The next U.S. president should move quickly to appoint a nationally recognized scientist or engineer as science adviser, according to a recent set of recommendations from an academic policy think tank on the presidential transition.

The incoming administration should also rapidly install a leadership team for the White House Office of Science and Technology Policy (OSTP) and ensure that the office has access and resources to help integrate science and technology (S&T) advice at the White House and across federal agencies, according to "The Vital Role of the White House Office of Science and Technology Policy in the New Administration" (see http://bit.ly/vital-role).

The Baker Institute for Public Policy at Rice University in Houston, Texas, issued the recommendations on 14 September.

Why Focus on OSTP?

The document says that "the next administration will need to address a number of public policy challenges necessitating immediate S&T expertise," including environmental concerns and natural disasters. It adds that "the presidential transition is a critical period for ensuring S&T is responsibly and effectively represented in policymaking in the White House."

The Rice University recommendations call OSTP "the one place in the federal government that focuses on the efficiency and impact of the collective federal S&T effort." It urges the White House to have OSTP promptly draft an administration strategy paper on S&T goals. The new president should also seek counsel from the White House science adviser, who heads OSTP, in filling other senior positions relating to S&T.

Steering Clear of Policy Recommendations

The Rice document avoids providing the next administration with guidance about how to deal with specific S&T issues, although the conclusion lists a sampling of policy areas warranting attention, including climate change.

"It's a nonpartisan document. What we are trying to say, in a way that doesn't create kneejerk reactions, negative reactions, is [that climate change] is a very important issue," said Baker Institute senior fellow Neal Lane at a 14 September briefing. Lane was OSTP director and science adviser to President Bill Clinton from 1998 to 2001.

> Science and technology "are embedded in almost every issue that the president deals with."

Lane told *Eos* that because of the significance of climate change and because there are laws, regulations, and international agreements about it, "whatever your political stripe is coming in, you're going to have to deal with [climate change]. It's just a fact. That's how we tried to treat it, and not use this document to try to push a priority in some area of health care, some biomedical or geosciences [area], or anything else."

Science and Technology Embedded in Issues

At the briefing, Rush Holt, CEO of the American Association for the Advancement of Science in Washington, D. C., said that science and technology "are embedded in almost every issue that the president deals with," including issues not traditionally associated with science such as justice, diplomacy, and social welfare. "We want this person and this office fully integrated in that process, for the president's own good, and for the country's," he said.

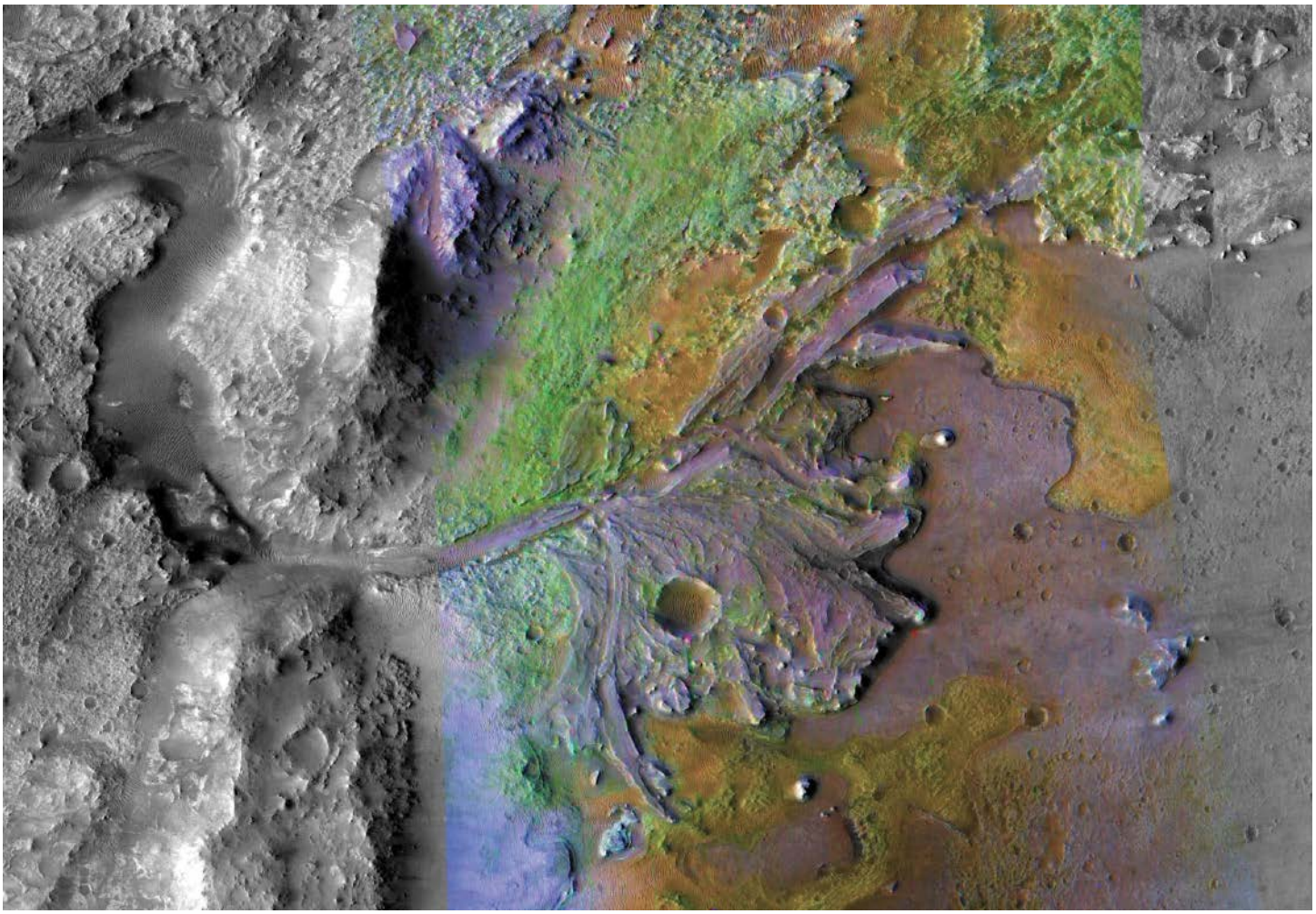
Norman Augustine, retired chairman and CEO of the aerospace company Lockheed Martin, said that the Rice recommendations deserve serious consideration. Now is "a very critical moment in the nation's history" for U.S. research and competitiveness, he asserted, because of falling funding as other nations are increasing their investments.

Although neither Augustine nor Holt was a contributor to the recommendations, they reviewed them and appeared at the briefing to show their support, a Rice spokesperson said.

Specifically regarding space research, Augustine—who once advised OSTP on the subject—told *Eos* that a new administration should resist the temptation to "start from scratch" in defining NASA's goals. He added that NASA's goals should be matched with adequate funding and other resources. "If we don't, it's just a way to waste money," he said.

By **Randy Showstack,** Staff Writer

A Flip-Flopping Climate Could Explain Mars's Watery Past



NASA/JPL/JHUAPL/MSSS/Brown University

Scientists have long debated how enough water could have existed on Mars—with its thin atmosphere and great distance from the Sun—to create such features as this apparent delta in Jezero Crater. The feature may have formed when rivers shepherded claylike minerals (green) into a crater lake early in Mars's history.

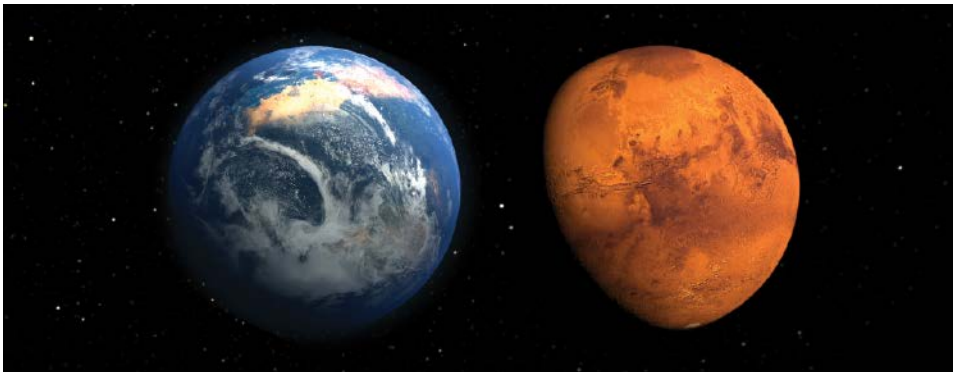
In the 1970s, images of Mars taken by the Mariner and Viking spacecraft revealed enormous channels and valley networks—both of which are reminiscent of catastrophic floods and river drainage systems on Earth. The fluvial features were the first sign that 3.8 billion years ago, the planet was once a lush oasis, awash with oceans, lakes, and rivers.

But how was early Mars so wet? That question sparked a 40-year-long debate that has divided planetary astronomers into two camps: those who think that Mars must have once contained a thicker and warmer atmosphere—which made the Red Planet hospitable to liquid water and potentially the evolution of life—and those who think that Mars was mostly cold save for short bursts of warmth.

> "We now agree with the geologists who say that Mars had to be cold most of the time."

A new hypothesis might reconcile both camps, some scientists say. In a study accepted for publication in *Earth and Planetary Science Letters*, Natasha Batalha, a graduate student from Pennsylvania State University in University Park, and her colleagues suggest that Mars flip-flopped between a deep-freeze climate and a habitable one (see http://bit.ly/Marscycle).

Batalha's adviser at Penn State, coauthor James Kasting, said that he previously supported the hypothesis that early Mars was long enshrouded in a thick, warm atmosphere, but he no longer does. "We now agree with the geologists who say that Mars had to be cold most of the time," he said, speaking of himself, Batalha, and their coauthors. However, Mars somehow got "warm enough for long



NASA's Goddard Space Flight Center

Artist's conception of a lush, early Mars (left) with a thick atmosphere and abundant water compared to arid, present-day Mars (right) with its thin atmosphere. A new hypothesis suggests that lush periods just long enough to form water-created surface features, such as canyons, punctuated much longer, planet-wide frozen spells.

enough to form the valleys" and other fluvial features we see today.

A Climate That Oscillates

Although multiple theories have tried to explain how these fluvial features formed on early Mars, Batalha and her colleagues assert that those explanations all overlooked a phenomenon that is crucial for Earth: the carbonate-silicate cycle.

Volcanoes on Earth spew carbon dioxide into the air, creating an atmosphere that's thick with greenhouse gases. This increases the temperature of the planet, which increases rainfall. The precipitation then scrubs the carbon dioxide from the air by forming carbonic acid. When the acid splashes the surface, it dissolves silicate rocks and creates carbonate, which is then carried into the oceans, where it is eventually subducted into the Earth's mantle. The cycle completes itself—a half a million years later or so—when volcanoes spew carbon dioxide back into the air.

Could a similar cycle have existed on Mars? Batalha thought it was worth investigating. But when she and her colleagues added the cycle to an atmospheric model for early Mars, they found a stark difference from the Earth.

Because the Red Planet is so far from the Sun, the cycle begins on a world coated with glaciers. Volcanoes spew greenhouse gases into the atmosphere, increasing the temperature until it's finally warm enough to rain. Downpours then scrub the potent gases from the atmosphere rapidly, shutting down the greenhouse and plunging the planet back into its glaciated state. Whereas on Earth the cycle acts as a built-in temperature control system, keeping our planet habitable on million-year-long timescales, the team's simulations showed that on Mars it forces the planet to oscillate between a glaciated world and a habitable one.

"We were really surprised to see that when you add this to these early Martian atmospheric models you get these dramatic climate cycles that give you about 10 million years of warmth in between these 120-million-year frozen states," Batalha said. "And 10 million years is exactly the amount of time that you need to form all these fluvial features that we see on Mars."

"The idea is a happy medium," said Ramses Ramirez, an astronomer at Cornell University in Ithaca, N.Y., who was not involved in the study. "Maybe Mars was mostly cold, but then you had very transient warm periods, marrying the two hypotheses."

Where Are All the Carbonates?

But simulating such climate cycles on early Mars doesn't mean they actually happened. To model them, Batalha and her colleagues had to endow the Red Planet with an early history of plate tectonics. Plate tectonics on Mars is still a speculation, although there is some evidence for linear volcanic zones and steep cliffs that could have been generated by fault lines. The researchers also had to add a lot of carbon dioxide and hydrogen to the Martian atmosphere that scientists aren't certain were present in the planet's early days.

"There's no way to go back 3.8 billion years ago and study what the atmosphere was made of then," said Batalha. "In fact, we have a hard time nailing down what's going on in the Martian atmosphere today," she continued, referring to the mysterious methane signatures that scientists have seen belching from the Red Planet but can't yet explain.

Still, Batalha and her colleagues are pretty sure the young planet once outgassed plenty of hydrogen. Previous studies have found that meteorites from Mars are rich in hydrogen compared to rocks on Earth, supporting the notion that abundant outgassing of the element may have occurred there.

But whether the planet also outgassed a lot of carbon dioxide is a harder question to answer. Itay Halevy, an astronomer at the Weizmann Institute of Science in Israel, who was not involved in the study, and Ramirez both told *Eos* that if that outgassing occurred, Mars should be overrun with carbonate rocks—and it isn't.

But Batalha and her colleagues have a reply to that too: An atmosphere laced with carbon dioxide would also form highly acidic rain, they say, which would remove any carbonates from the surface and place them soundly underground. And Ramirez agrees that this is plausible. "There are some craters where you can see that there could be some carbon dioxide [locked in the rocks in the form of carbonates] in there," he said. "It's hard to tell how much there is."

"You just have to dig deeper"—metaphorically and physically, Batalha said.

By **Shannon Hall,** Freelance Writer; email: hallshannonw@gmail.com

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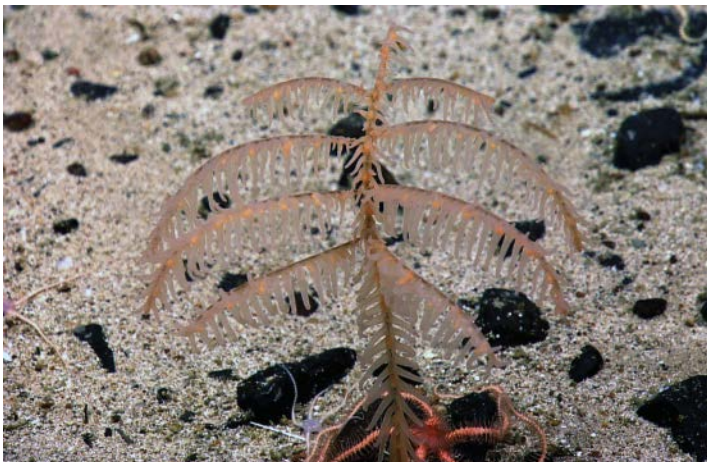
http://www.cvent.com/d/wfq4zq

Obama Unveils First Marine National Monument in the Atlantic

At a recent international conference on oceans, U.S. president Barack Obama announced the establishment of a unique Atlantic Ocean sanctuary off the coast of New England. It provides habitat for a wide variety of fish and other marine creatures, including rare and endangered species.

The first U.S. marine national monument in the Atlantic protects two areas about 200 kilometers from the New England coast that total 12,696 square kilometers (4913 square miles). One of the areas contains four underwater seamounts that the administration says are biological hot spots. The other includes three underwater canyons.

At the Our Ocean Conference 2016 in Washington, D. C., on 15 September, dozens of other countries also announced new protected marine areas and other ocean conservation commitments.



NOAA Okeanos Explorer Program, Our Deepwater Backyard: Exploring Atlantic Canyons and Seamounts 2014

A 2014 NOAA research cruise investigating the Atlantic Ocean region designated in September as the Northeast Canyons and Seamounts Marine National Monument photographed marine creatures including this small colony of the black coral Bathypathes.

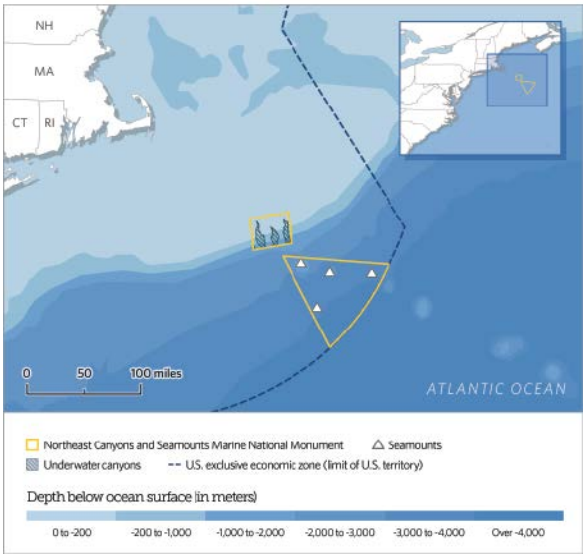
Climate Change Resilience

Obama said that the new Northeast Canyons and Seamounts Marine National Monument will protect fragile ecosystems and also help to make the oceans more resilient to climate change. "This will help fishermen better understand the changes that are taking place that will affect their livelihood, and we're doing it in a way that respects the fishing industry's unique role in New England's economy and history," he said.

The president noted that conservation efforts and "our obligations" to combat climate change "go hand in hand." He added that the more that threats such as overfishing and pollution can be eliminated through conservation, "the more resilient those ecosystems will be to the consequences of climate change."

In 2004, the National Oceanic and Atmospheric Administration's (NOAA) research vessel *Okeanos Explorer* investigated the region, which NOAA and the Department of the Interior will jointly manage as a national monument.

Environmental groups, including the Pew Charitable Trusts, applauded the measure to protect "biologically important areas." However, some fishing groups oppose the plan, with the Atlantic Offshore Lobstermen's Association calling it "deplorable."



Pew Charitable Trusts

A map locating the new Northeast Canyons and Seamounts Marine National Monument.

Additional Commitments to Marine Protection

The administration's designation of the Atlantic preserve follows its expansion in August of the Papahānaumokuākea Marine National Monument, off Hawaii, which made that Pacific sanctuary the world's largest marine protected area.

Other commitments unveiled at or just prior to the conference include the United Kingdom's designation of an approximately 830,000-square-kilometer marine reserve around the Pitcairn Islands in the South Pacific Ocean, Malaysia's establishment of the 10,000-square-kilometer Tun Mustapha Park marine protected area, a plan by the Seychelles to establish a protected area of up to 400,000 square kilometers by 2020, and Cambodia's establishment of its first marine protected area covering 405 square kilometers.

Industry Presence "Minimal"

The conference, held at U.S. State Department offices in Washington, D. C., brought together governments, scientists, the environmental community, and foundations. However, industry presence at the conference was "minimal," according to Paul Holthus, president and CEO of the World Ocean Council.

"A key component to the future of the oceans is ensuring that we've got the private sector involved as a leader" addressing sustainable development and environmental challenges in the oceans, Holthus told *Eos*.

He urged the governments of the United States and other countries "to think about the role of industry and how [to] develop partnerships" with shipping, fishing, oil and gas, and other maritime industries. Such partnerships could work on solutions based on science and risk assessments "that need to be developed and implemented as a way to do business in the ocean," he said.

By **Randy Showstack,** Staff Writer

Congressional Caucus Launched for Earth and Space Sciences

REUTERS/Jonathan Ernst

The new bipartisan House Earth and Space Science Caucus could bring greater visibility to Earth and space sciences among U.S. lawmakers. Pictured are members of Congress taking the oath of office on the House floor of the U.S. Capitol in 2014.

A new congressional caucus has formed to bring greater visibility on Capitol Hill to the Earth and space sciences and their effects on science, policy, and society.

The House Earth and Space Science Caucus launched in mid-September, a year after federal legislation threatened to restrict funding for the sciences that the new group represents. The caucus plans to support strong and sustained funding for those disciplines and their inclusion in science, technology, engineering, and mathematics (STEM) educational curricula, according to information from caucus organizers. Reps. Jared Polis (D-Colo.) and David Jolly (R-Fla.) cochair the group, which also aspires to be an information resource for members of Congress and their staffs.

Educating the Congressional Community

At a 14 September event marking the debut of the new caucus, Polis expressed excitement about the bipartisan group and its goals. He said that the caucus wants "to keep members of Congress in the loop" about developments in the Earth and space sciences.

"In the 21st century, it's crucial to continue to broaden awareness and align policy with Earth and space sciences," Polis told *Eos*. The caucus "will focus on placing scientific research and evidence in the forefront of congressional and national discussions, while also continuing to support ideas that will promote STEM education programs for the next generation."

The caucus, which currently has six members of Congress, aims "to help educate the broader congressional community about all of the important values that [the geosciences] bring to our national security, to the economy, and to our public health and safety," said Lexi Shultz, director of public affairs at AGU. AGU played a leading role in organizing the caucus and chairs the alliance of groups that support it.

"We want to make sure that members of Congress know what Earth and space science is and how many policy issues it really touches on," added Julie McClure, science policy manager for the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, which are part of the alliance supporting the caucus.

The caucus wants "to keep members of Congress in the loop" about developments in the Earth and space sciences.

Home on the Hill

Some proposed appropriations and authorization legislation in 2015 would have restricted and deprioritized geoscience funding. That draft legislation galvanized AGU and others to successfully convince lawmakers to strike the language and to organize a new caucus, AGU public affairs specialist Brittany Webster told *Eos*.

"We needed some kind of mechanism where we could keep up the drumbeat about the importance of the geosciences," she said. "The caucus will serve as a way to bring a lot of very disparate groups and disparate interests and organizations together because we all do Earth and space science in a variety of ways." The caucus "gives the geosciences a home on the Hill," she added.

"A little over a year ago, we fought very hard to make sure science got funded," caucus member Rep. Mike Honda (D-Calif.) told the crowd of scientists, policy experts, and congressional staffers at the September launch event. "Count on us to be your colleague and your advocate," added Honda, who is the acting ranking member of the House Appropriations Committee's Commerce, Justice, Science, and Related Agencies Subcommittee. Jolly is also a member of the subcommittee.

Kasey White, director for geoscience policy at the Geological Society of America, said that although a congressional hazards caucus and others have addressed geoscience research, the new caucus will "raise the visibility" of the geosciences on Capitol Hill and show broad bipartisan support for geoscience research.

Accepting the Science

Speaking at the launch event, Jolly said that science should not be debated. "I don't understand why politicians sit up here and debate science. Let's accept it," he said. "I've got a law degree; I don't have a science degree. My job is to accept the science, and then let's fight over the policies that ensure we are doing right by the research community and also doing right for long-term solutions for our country and the globe."

Jolly told *Eos,* "There should not be any partisanship when it comes to science. There shouldn't be politicization of science." He added that he believes that conservative solutions about climate change, for instance, are right for the environment, economy, and country. "My friends on the left have more progressive solutions, and that's fine too. But we can't have that debate until we agree to accept the science. And that's the point of this caucus: to accept the science."

An industry representative at the launch told *Eos* that the caucus could make a difference by having "a conversation" about the geosciences on the Hill. "To see bipartisan support and recognition of the need for science when we are talking about policies in the realm of Earth science—meteorology, oceanography, atmospheric science, space weather—is refreshing," said Jamison Hawkins, director of civil space and environmental programs with Lockheed Martin's government affairs group.

By **Randy Showstack,** Staff Writer

Adam M. Dziewonski (1936–2016)

Dmitry Storchak

Adam M. Dziewonski

Adam Dziewonski was a giant in solid Earth geophysics, a major contributor to our knowledge of Earth's internal structure, and a relentless advocate for the infrastructure needed to support research.

Early Years

Adam was born in Lwów, then part of Poland, in 1936. While he was studying at the University of Warsaw, he participated in the Polish International Geophysical Year Scientific Expedition to Vietnam (1958–1959), where he was in charge of operating a remote geomagnetic observatory. The harsh conditions in the field gave him a keen appreciation for observatory science.

After earning a doctorate from the Academy of Mines and Metallurgy in Kraków (1965), Adam left for the Southwest Center for Advanced Studies in Dallas, Texas, where Anton Hales became his cherished mentor. In 1972, he moved to Harvard University and settled there for the rest of his career, retiring from teaching in 2009.

During his time in Dallas, Adam worked on mathematical techniques to quantify the dispersion of seismic surface waves. Notably, he developed the "multiple-filter technique" to extract single-mode group velocity dispersion by moving window analysis, an approach still used today.

With Freeman Gilbert, he collaborated on the measurement and analysis of normal mode eigenfrequencies from records of vibrations from the 1964 Alaska earthquake, obtaining the first direct proof that Earth's inner core is solid (1971). Digitizing the Alaska data set took 2 years, something hard to conceive for young researchers entering the field today.

Global Earth Models and Preliminary Reference Earth Model

Combining the 1964 normal mode data set with other available data provided unprecedented constraints for the development of several one-dimensional global Earth models. Then, in 1977, the International Union of Geodesy and Geophysics asked Adam and Don L. Anderson to construct a reference Earth model for the benefit of the community.

The resulting Preliminary Reference Earth Model (PREM, 1981; http://bit.ly/IRIS-PREM), which, for the first time, included radial anisotropy and depth-dependent attenuation, met with resounding success. It was called "preliminary" because, as Adam said in his 2015 tribute to Don Anderson (see http://bit.ly/Anderson-tribute), "we thought that it would be improved in a few years." At present, PREM is still a reference model of choice in seismology and is widely used by the mineral physics community to test candidate mantle and core compositions.

A Pioneer in Global Seismic Tomography

In 1976–1977, Adam spent a year at the Lincoln Laboratory at the Massachusetts Institute of Technology, where he could access and analyze the unique global travel time data set assembled by the International Seismological Centre, then freshly available on magnetic tapes. Using 700,000 *P* travel time residuals (differences between the observed and predicted travel times of seismic *P* waves), he obtained the first global long-wavelength three-dimensional (3-D) model of Earth's lower mantle (1977).

With then graduate student Brad Hager and Hager's adviser Rick O'Connell, Adam discovered the negative correlation between degrees 2 and 3 structure seismic structure in the deep mantle and the geoid. The robustness of this striking deep structure was later confirmed in a higher-resolution study (1984), highlighting, for the first time, the presence, near the core-mantle boundary, of a ring of high velocities surrounding two large antipodal and equatorial low-velocity regions. These features, now awkwardly named "large low-shear-velocity provinces"—Adam recently preferred the term "pillars of the Earth"—are still the focus of many deep-Earth studies.

The arrival at Harvard of John Woodhouse in 1979 started a decade of fruitful collaborations, producing some major achievements. These include the following:

- development of the centroid moment tensor (Harvard CMT; http://www.globalcmt.org) methodology using long-period waveforms to infer earthquake source parameters (1981)
- development of the first global 3-D upper mantle model entirely based on long-period teleseismic waveforms (1984)
- discovery, with graduate student Andrea Morelli, of inner core anisotropy (1986) to interpret the travel times of inner core–sensitive *P* waves

Adam, a tenacious workaholic, and John would work late at night because "things were most quiet then." Adam chain-smoked during these late-night sessions, until he suddenly decided to quit on 16 January 1987, a date he still remembered 30 years later. Still further discoveries were in store, notably, with graduate student Miaki Ishii in 2002, the identification of a region of distinct anisotropy in the central part of the inner core, which they called the innermost inner core.

Over the next decades, as he and his students developed several generations of global mantle shear velocity models, Adam always insisted on the significance of "degrees 2 and 3 structure"—the longest wavelength heterogeneity in the mantle—for mantle dynamics.

Adam, Ved Lekic, and I recently continued investigating this topic. Until shortly before his death, Adam had been advising us on the construction of a 3-D reference Earth model, a critical step beyond PREM for further advances in the understanding of mantle mineralogy and dynamics. We will miss his insight and wisdom as this project develops!

An Advocate for Broadband Seismology Infrastructure

When broadband digital seismology became a reality in the mid-1970s, Adam embraced the quest for developing a new generation of state-of-the-art global seismic observatories. With a handful of midcareer seismologists from academia, with whom he shared enthusiasm, vision, and energy, he worked relentlessly on the establishment of the Incorporated Research Institutions for

Seismology (IRIS; https://www.iris.edu). When IRIS was finally established in 1984, he served on its first executive committee and later chaired several others.

Adam contributed in other ways toward the seismological infrastructure of today. With graduate student Joe Steim, he initiated and supported the development of the Very-Broadband Seismometer (1986; http://bit.ly/Very-Broadband-Seismometer), which became the gold standard for the International Global Seismographic Network. He was a founding member of what's now the International Federation of Digital Seismograph Networks (FDSN, 1986; http://www.fdsn.org), which still coordinates instrument standards and data exchange internationally. He was also a founding member of the International Ocean Network (ION, 1992; http://msg.whoi.edu/ION), which aimed to extend the deployment of broadband seismic observatories to the ocean floor. He advised the International Seismological Centre and served as chair of its governing council from 1998 to 2005.

Adam was a man of relatively few words, which he chose carefully. He defended his vision with a strong and deep voice that made a lasting impact. Most recently, he proposed the Global Array of Broadband Arrays (widely known as GABBA; see http://bit.ly/GABBA-meeting) as the next ambitious endeavor for global seismology, a concept that is making its way in the community.

Adam's influence reached well beyond global seismology. He was keenly aware of the importance of combining different disciplines to really understand "how the Earth works." In this context, he was a key player in the development of the now thriving Cooperative Institute for Dynamic Earth Research (CIDER; http://www.deep-earth.org/).

Honors

Adam shared the 1998 Crafoord Prize with Don L. Anderson "for their fundamental contributions to our knowledge of the structures and processes in the interior of the Earth." He received the 2002 Bowie Medal from AGU and many other honors, including the Gold Medal of the Ettore Majorana Foundation and Centre for Scientific Culture (1999) and the Harry Fielding Reid Medal of the Seismological Society of America (1999). He was elected to the National Academy of Sciences in 1995.

Adam greatly inspired several generations of young researchers and unselfishly supported the careers of those in whom he recognized talent. I had the privilege of closely collaborating with him on many infrastructure endeavors since the mid-1980s, notably FDSN, ION, and, most recently, CIDER, and I enjoyed many stimulating research discussions with him, even as we often sparred. I will miss him as a mentor, collaborator, and close friend.

By **Barbara Romanowicz,** Department of Earth and Planetary Science, University of California, Berkeley; e-mail: barbara@seismo.berkeley.edu

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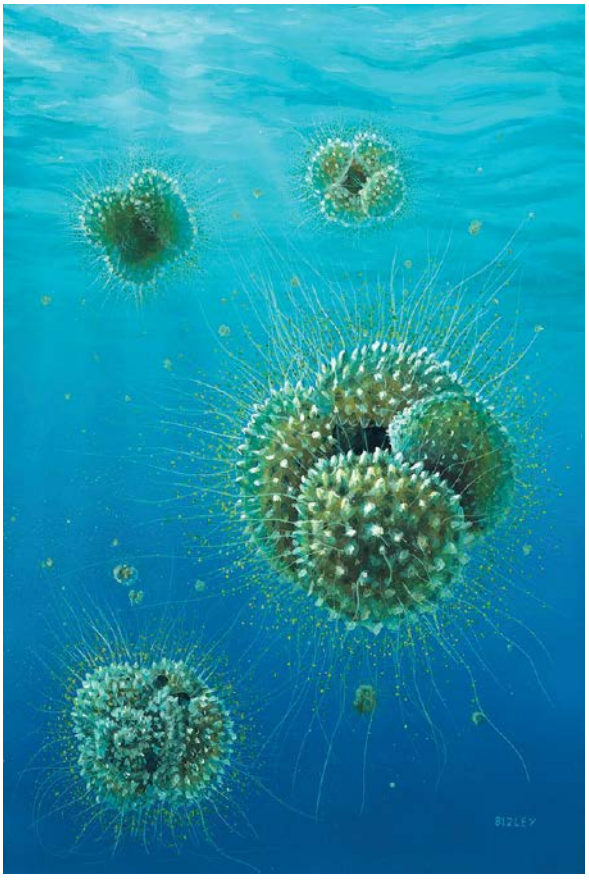
DeepMIP Kickoff Meeting
Boulder, Colorado, 14–15 January 2016



Richard Bizley and Paul Pearson

Artist's reconstruction of how the fossil planktonic foraminifer Acarinina mcgowrani *from the Eocene epoch might have looked. Geochemical analysis of fossil foraminifer shells is used to reconstruct the temperature and acidity of the ocean surface.*

Periods of climate extremes in Earth's history provide an exciting natural laboratory in which to explore. As anthropogenic greenhouse gas emissions warm our planet, it becomes important to look to past periods of extreme warmth to challenge our understanding of the relevant mechanisms and to test our climate models.

To this end, 36 scientists from across the modeling–observational spectrum met at the National Center for Atmospheric Research to share their latest research and to plan the Deep-Time Model Intercomparison Project (DeepMIP; http://bit.ly/DeepMIP). This model-data intercomparison focuses on the superwarm early Eocene period (about 50 million years ago), when average yearly temperatures were as much as 10°C warmer than today.

DeepMIP—where "deep" refers generally to climates of the pre-Pliocene, more than 5.3 million years ago—is a working group within the larger Paleoclimate Modelling Intercomparison Project (PMIP; http://bit.ly/PMIP3), itself an official component of the Coupled Model Intercomparison Project Phase 6 (CMIP6; http://bit.ly/CMIP-Phase-6). DeepMIP ultimately aims to evaluate state-of-the-art climate models under warm paleoclimate conditions, informing model developers and the Intergovernmental Panel on Climate Change (see http://www.ipcc.ch).

The meeting began with a series of short talks in which all members were able to share their recent research. One of the most exciting revelations was the possibility of resurrecting previously discredited temperature records derived from measuring the oxygen-isotopic composition of calcite in the shells of microscopic marine surface-dwelling organisms, such as foraminifera.

Many such records were thought to be rendered useless because of postdepositional changes in the calcite not connected to the original temperature (diagenesis). However, by making detailed measurements of single specimens in which microscopic regions of calcite are better preserved, such records might be remeasured. This measurement could ultimately provide a comprehensive global data set of sea surface temperatures during the superwarm climate of the early Eocene. Such a data set would be an invaluable tool for evaluating climate model simulations of this time period.

Another goal of the meeting was to come to a consensus on a model experimental design, describing in detail the experimental protocols for the intercomparison. This design, which was the main outcome of the meeting, has been published in the journal *Geoscientific Model Development* (see http://bit.ly/DeepMIP-design).

Such discussions are normally carried out by the modeling community in isolation. However, the expertise of the data community present proved hugely useful, ensuring not only that the core model simulations would be as realistic as possible but also that associated sensitivity studies would fully reflect the uncertainty in our knowledge of the key forcings that made the Eocene so warm. In this regard, working groups were set up to focus on reconstructing atmospheric carbon dioxide levels, assessing uncertainty in paleogeography, and developing the marine and terrestrial data reconstructions.

Finally, the meeting highlighted the fact that our climate models are still not reproducing the level of high-latitude warmth seen unequivocally in the proxy records. This is a decades-old problem in paleoclimate science. The challenge to the data community over the coming years of DeepMIP is to rigorously characterize the uncertainties in the proxy records, using multiple proxies where possible, and to target new records in undersampled regions.

The meeting highlighted how climate models are still not reproducing the level of high-latitude warmth seen unequivocally in proxy records.

The challenge to the modeling community is whether the recent increases in model resolution and in the scope and complexity of Earth system components and the improved process-based representation of processes such as convection will mean that, finally, our models will be able to re-create the superwarm climate of the Eocene. If they do, the scientific community's confidence in future climate simulations will also increase.

By **Daniel J. Lunt,** School of Geographical Sciences, University of Bristol, Bristol, U.K.; email: d.j.lunt@bristol.ac.uk

We Need a New Definition for "Magma"

"Magma," definition 5: A confused or disordered body or mass of something.
Oxford English Dictionary Online [20 September 2016; http://bit.ly/OED-magma]

Magma is a fundamental constituent of the Earth. Issues as diverse as volcanic hazard assessment and planetary evolution studies rely on knowledge of magma's properties, origin, evolution, and significance. Thus, the definition of "magma" should be simple and universally agreed upon, but the term means fundamentally different things to different people.

This inconsistency has led to miscommunication between petrologists, geophysicists, the press, and the public, making the "confused or disordered" definition of the word unintentionally appropriate. It is time to agree on a clearer geologic definition of "magma."

To the public, magma is the stuff of lava—hot, glowing red liquid that flows out of volcanoes—and such lava is unquestionably magma that has reached the surface. The point of contention is whether partially molten rock that resides below the surface and is too crystalline to flow should also be called magma.

Because this distinction is critical when geologists communicate about magma, especially to the press and public, we contend that highly crystalline immobile material should not be called "magma." Rather, "magma" should mean material that is capable of moving within the Earth and onto its surface.

iStock.com/Justin Reznick

Lava forms ropy pāhoehoe textures. How molten must the subsurface rock that fueled this lava be to get classified as "magma"?

Can Magma Be Mostly Solid?

"Magma" is commonly used to mean any rock that is at least a little bit molten. For example, a recent seismic study of areas around Yellowstone National Park published in *Science* [*Huang et al.*, 2015] reported a "lower-crustal magma body [that] has a volume of 46,000 cubic kilometers." That is a lot of magma!

Several national news outlets picked up on this figure, including National Public Radio, NBC News, the *Washington Post*, and Fox News. All of them reported that there is enough magma "to fill the Grand Canyon 11 times."

This may have created a public perception of a vast pool of liquid perched under Yellowstone, waiting to explode. However, the authors of the scientific study were careful to note that nothing has changed—the amount of molten material under Yellowstone is the same, and the risk has not changed—but they had produced an improved image of the partially molten rock.

The study also noted that this large volume in their image contains only a small percentage of molten material. That is still a lot of melt—enough to fill 20% of the Grand Canyon—but it is dispersed through a large volume of rock, not gathered for an eruption. It is unlikely that the features that Huang's group imaged could produce an eruption unless the molten material were collected into a much smaller volume with a much higher melt fraction.

> Magma should mean material that is capable of moving within the Earth and onto its surface.

What's in a Name?

Whether rock that contains a small percentage of partial melt should be called magma is debatable. Indeed, use of the word "magma" to refer both to material that can flow across the Earth's surface and to a largely solid volume that contains a small fraction of melt is akin to using the same word to refer to a river and to an aquifer. To do so ignores and obscures fundamental differences, and broad usage of "magma" is clearly causing such conceptual problems.

The term "magma" was used in pharmacy as early as the 17th century for suspensions such as magnesia magma (now called milk of magnesia). George Scrope was among the first to use the term in a geological context [*Scrope*, 1862, p. 121]. He wrote that lava "is not a homogeneous molecular liquid, such as any melted or completely fused substance, but…a '*magma*' or compound of crystalline or granular particles to which a certain mobility is given by an interstitial fluid." Scrope clearly viewed the ability to flow or intrude as a defining quality.

Should I Stay or Should I Flow?

A critical control on mobility in a crystal–liquid mixture is the volume ratio of crystals to liquid; the apparent viscosity of a mixture (the ratio of how much shear stress is applied to the rate at which the material deforms) depends upon the proportion of particles suspended in it. For a low percentage of solid particles, less than 20% by volume, for example, the particles are sufficiently dispersed that they scarcely interact during flow.

However, when the percentage of particles reaches approximately 40%–60% by volume, the apparent viscosity of the suspension increases by several orders of magnitude as crystals lock up and jam together. Crystals within these logjams hold one another in place in a phenomenon called force chains [*Cates et al.*, 1998], and the system transitions from a melt with suspended crystals to a crystal network with interstitial melt (Figure 1) [*Lejeune and Richet*, 1995].

During cooling, crystals grow onto one another and interlock to produce a welded framework that is even stronger than one produced by nonreactive particles such as pebbles in water. Such a material can flow only by processes such as crystal plasticity and solution-reprecipitation, at rates dramatically slower than those at which even highly viscous silica-rich melts can flow. Collecting melt from such a material is a slow process.

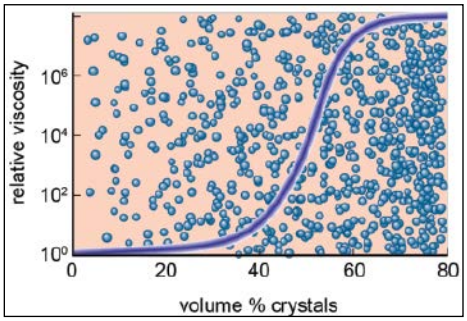
Two Names for Two Materials

This fundamental difference in deformation and flow (rheology) between partially molten rock that is melt rich (more than about 50% melt by volume) and its melt-poor counterpart (less than about 50%) is reason to give the two materials different names. Here we suggest that the term "magma" be reserved for melt-rich materials that can flow as fluids on timescales consonant with volcanic eruptions. We suggest that more crystal-rich and largely immobile partially molten rock be referred to by another name such as "crystal mush" or "rigid sponge" [*Hildreth*, 2004].

By this definition, highly viscous materials such as water-poor rhyolite lavas (Figure 2), with viscosities that can reach 10^{10} pascal seconds or greater [*Pinkerton and Stevenson*, 1992], are magma, whereas highly crystal rich materials are not. The former can ascend to the Earth's surface sufficiently rapidly to be erupted, whereas the latter cannot. This is consistent with the general observation that volcanic rocks with more than about 50% crystals by volume are rare [*Marsh*, 1981].

This distinction is not, and cannot be, precise, yet it is useful for reasons both internal and external to the magma community. For example, many interpretations of plutonic rocks depend on the inferred existence of large bodies of melt-rich magma in which processes such as crystal settling play out—the "big tank" model, illustrated in myriad textbooks and papers. Such processes are largely impossible in a system such as the body imaged under Yellowstone, which consists of more than 90% solid rock with melt in its pore spaces. The magma research community intuitively understands this distinction, but using "magma" as a one-size-fits-all term for rock with any proportion of melt obscures it.

For the press, the public, and even Earth scientists who do not specialize in magmatic systems, "magma" conjures up dramatic images of lava flowing down hillsides. Using the same term to describe large rock volumes that contain small melt fractions as well as large bodies of mobile magma can engender such mistaken perceptions as a sea of potentially eruptible magma underneath Yellowstone.



Lejeune and Richet [1995]

Fig. 1. Schematic illustration (background, two-dimensional (2-D) representation of a 3-D crystal framework) of the transition from liquid with suspended crystals to a rigid crystal framework with interstitial liquid, with a plot (foreground) of the increase in viscosity that accompanies a greater percentage of crystalline material. Lockup occurs when the crystal framework gains enough connectivity that shear deformation can occur only through processes governed by deformation of the solid fraction.

A Better Definition

We want to start a conversation about a more precise definition of "magma." We suggest this as a starting point:

> ***Magma:*** *naturally occurring, fully or partially molten rock material generated within a planetary body, consisting of melt with or without crystals and gas bubbles and containing a high enough proportion of melt to be capable of intrusion and extrusion.*

This proposed definition naturally reflects our particular scientific perspective and concerns; we hope that it will stimulate a broad-based discussion that will yield a consensus definition.

Allen Glazner

*Fig. 2. Aerial view to the south of a rhyolite dome in the Mono Craters chain of eastern California. This dome erupted about 600 years ago. Although lavas such as these have viscosities that can range up to 10^{10} pascal seconds or greater [*Pinkerton and Stevenson, *1992], they are clearly capable of movement on eruption timescales and thus would be considered erupted magma by the definition proposed here.*

Acknowledgments

Conversations with numerous geologists and geophysicists over the years have helped to clarify various viewpoints about the meaning of "magma," and Christoph Breitkreuz and Bernard Bonin offered interesting German and French perspectives. Comments by anonymous reviewers are greatly appreciated. Supported by NSF grant EAR-1250505 to A.F.G.

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Charting Ice Sheet Contributions to Global Sea Level Rise

By Kate H. Briggs, Andrew Shepherd, Anna E. Hogg, Erik Ivins, Nicole Schlegel, Ian Joughin, Ben Smith, Gerhard Krinner, Gorka Moyano, Sophie Nowicki, Tony J. Payne, Eric Rignot, Isabella Velicogna, Ted Scambos, Michiel R. van den Broeke, and Pippa L. Whitehouse

The Greenland and Antarctic ice sheets hold enough water to potentially raise the global sea level by 65 meters in total [*Bamber et al.*, 2013; *Fretwell et al.*, 2013]. Mitigating the consequences of sea level rise effectively requires accurate monitoring and prediction of the contribution from the polar ice sheets.

In 2012, the first community assessment of ice mass losses from Antarctica and Greenland demonstrated confidence in our estimates, showing that measurements based on data from different classes of satellite sensors agreed with one another and that the combined rate of loss had tripled over the previous 2 decades. Now we've begun a second phase of this assessment, with an open call for participation and an ambitious schedule to deliver annual updates.

In the past, there has been apparent disagreement among different satellite-based assessments of mass loss from the ice sheets, and even the most advanced global climate models struggle to resolve the detailed pattern of ice sheet imbalance. Consequently, future changes in sea level remain among the most uncertain of all climate projections. To make progress, we require a better understanding of the processes and mechanisms controlling ice sheet mass imbalance. This, in turn, relies on detailed and accurate observations.

Today there are well over 150 individual assessments of ice sheet mass balance based on measurements acquired by at least 15 different satellite missions. Perhaps unsurprising, it has proven difficult to collectively interpret this observational record, not just because of differences in processing methods but also because of differences in the geographical and temporal extent of each survey.

The Ice sheet Mass Balance Inter-comparison Exercise (IMBIE; http://imbie.org) was established in 2011 with the dual aim of understanding the apparent differences in the results of ice sheet mass balance studies and providing a single consensus assessment. Supported by the European Space Agency (ESA) and NASA, the IMBIE project, for the first time, brought together experts in the different satellite geodetic techniques for measuring ice sheet mass balance and also experts in modeling of the ancillary data sets in order to collectively tackle this problem.

Satellites Measure Ice Mass Loss

Scientists assess the contribution of Earth's polar ice sheets to global sea level rise by determining changes in their mass—their mass balance. Because of the vast size and inaccessibility of the ice sheets in Greenland and Antarctica, these mass balance assessments are best made with measurements collected from satellite platforms.

There are three main ways in which data from satellites are used to measure ice sheet mass balance: by directly measuring the changes in mass using gravimetry, by measuring the changes in volume using altimetry, and by measuring the changes in the mass inputs and outputs

Joe Raedle/Staff/Getty Images News/Getty Images

Melted ice, like this pool on Greenland's ice sheet, will eventually drain into the ocean and affect sea levels worldwide. An international group of scientists is comparing numerous ice sheet mass balance studies to develop an up-to-date assessment of polar ice mass losses.

Ian Joughin, University of Washington

A large iceberg floating in Disko Bay near the town of Ilulissat in West Greenland is one of many stranded in this shallow region where the fjord meets the ocean. Much of Greenland's contribution to global sea level rise occurs through calving of icebergs such as this.

using satellite measurements of the ice flow speed and modeled estimates of the surface mass balance (the mass budget method).

The First Ice Sheet Mass Balance Intercomparison Exercise

In the first exercise, the IMBIE team designed and carried out intercomparison experiments using common time periods and common definitions of ice sheet extent to understand the differences in the mass balance measurements. By adopting this consistent approach, the team found that there was, in fact, excellent agreement between estimates of ice sheet mass balance determined using entirely different approaches.

This consensus paved the way for the production of a single reconciled estimate of ice sheet mass balance [*Shepherd et al.*, 2012], which was a timely contribution to the *Intergovernmental Panel on Climate Change* [2013] assessment report. The IMBIE results showed that the Antarctic and Greenland Ice Sheets contributed 3.7 and 7.4 millimeters to global sea levels, respectively, between 1992 and 2011, and—alarmingly—the combined contribution rose from about 10% to 30% of the global sea level trend over the same period [*Beckley et al.*, 2010].

Progress Since 2012

In the years since the first IMBIE assessment, the launch of new satellites, the development of new techniques and geophysical corrections, and the emergence of new teams have led to a growing body of mass balance assessments. In total there have been an additional 52 published mass balance estimates for Greenland and 34 for Antarctica, which point to continuing mass losses from both ice sheets since 2011 (Figure 1). (A full list of references for the estimates included in the figure may be found at http://bit.ly/IMBIE-refs.)

In Greenland, where substantial interannual variability in mass balance has been common throughout the satellite record, a swing between extreme melting and accumulation events from 2012 to 2013–2014 [*Tedesco et al.*, 2015] is consistent with large recorded mass loss followed by a temporary abatement. In Antarctica, the latest measurements from the European Space Agency satellite, CryoSat-2 [*McMillan et al.*, 2014], point to further increases in ice losses. In light of all of these developments, it is now time for an updated community assessment of ice sheet mass balance.

The Next Assessment

Now that a framework for IMBIE has been established, we are conducting a second assessment this year, with rolling annual updates planned for thereafter. As in the first exercise, the general approach is to integrate, interpret, and report satellite estimates of ice sheet mass balance, with the overall aim of producing a community assessment of Greenland's and Antarctica's ongoing contributions to global sea level rise. IMBIE will also conduct additional experiments to improve our understanding of any differences that may emerge and of the processes that are driving ice sheet imbalance.

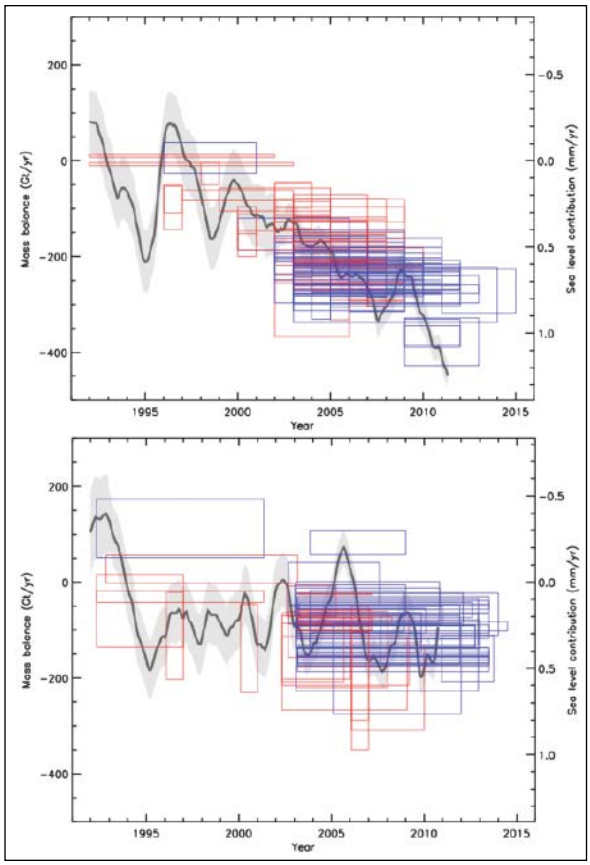

Fig. 1. Estimates of (top) Greenland and (bottom) Antarctic ice sheet mass balance in gigatons per year published before (red) and after (blue) the first Ice sheet Mass Balance Inter-comparison Exercise (IMBIE) assessment (gray). There are more than 150 estimates of ice sheet mass balance, more than half of which have been published since 2012.

As in the first assessment, the exercise will be structured around five main experimental teams based on the techniques of gravimetry, altimetry, the mass budget method, and surface mass balance and glacial isostatic adjustment modeling. The exercise continues to be supported by ESA and NASA.

A key objective of this next phase of IMBIE is to broaden participation across the scientific community. We invite any team able to contribute a unique data set to one of our five experimental groups to join in our future assessments.

We will analyze unique data sets submitted to the assessment using technique-specific experiments before comparing and combining them with measurements from the other techniques. Our aim is to present the initial analysis at a community discussion meeting in December 2016, which all participants are invited to attend. In addition to discussing the experimental outcomes, this meeting will plan future assessments. The results of the assessment will then be reported in the peer-reviewed literature and released as a single record of ice sheet mass balance.

At this time, we invite members of the scientific community to register their interest in participating in future assessments via the IMBIE project website (http://bit.ly/IMBIE-2016), where further details on each experimental group can be found. The deadline for currently registered users to submit data sets has already passed. If you still wish to participate in the exercise, however, we have designed IMBIE so that you can join in future years—gaining the involvement and support of the entire community is crucial for the project's success.

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Submit an IODP Workshop Proposal

The U.S. Science Support Program (USSSP), in association with the International Ocean Discovery Program (IODP), is currently accepting workshop proposals. The submission deadline is **December 1, 2016**.

Proposed workshops should promote the development of new ideas and strategies to study the Earth's processes and history using scientific ocean drilling. Workshops may focus on a specific scientific theme, or they may focus on a geographic region, integrating multiple topics. Regionally-focused workshops offer opportunities to develop drilling proposals for future target areas or to synthesize scientific results from past expeditions. Funding may be requested for small meetings or to support participants at larger international workshops. Broad-based scientific community involvement, co-sponsorship by related programs, and the active participation of graduate students are strongly encouraged. For more information, please visit:

http://usoceandiscovery.org/workshops/

Deadline: December 1, 2016

IODP INTERNATIONAL OCEAN DISCOVERY PROGRAM

U.S. SCIENCE SUPPORT PROGRAM

Probing the History of New Zealand's Orakei Maar

By Paul C. Augustinus

Bruce W. Hayward

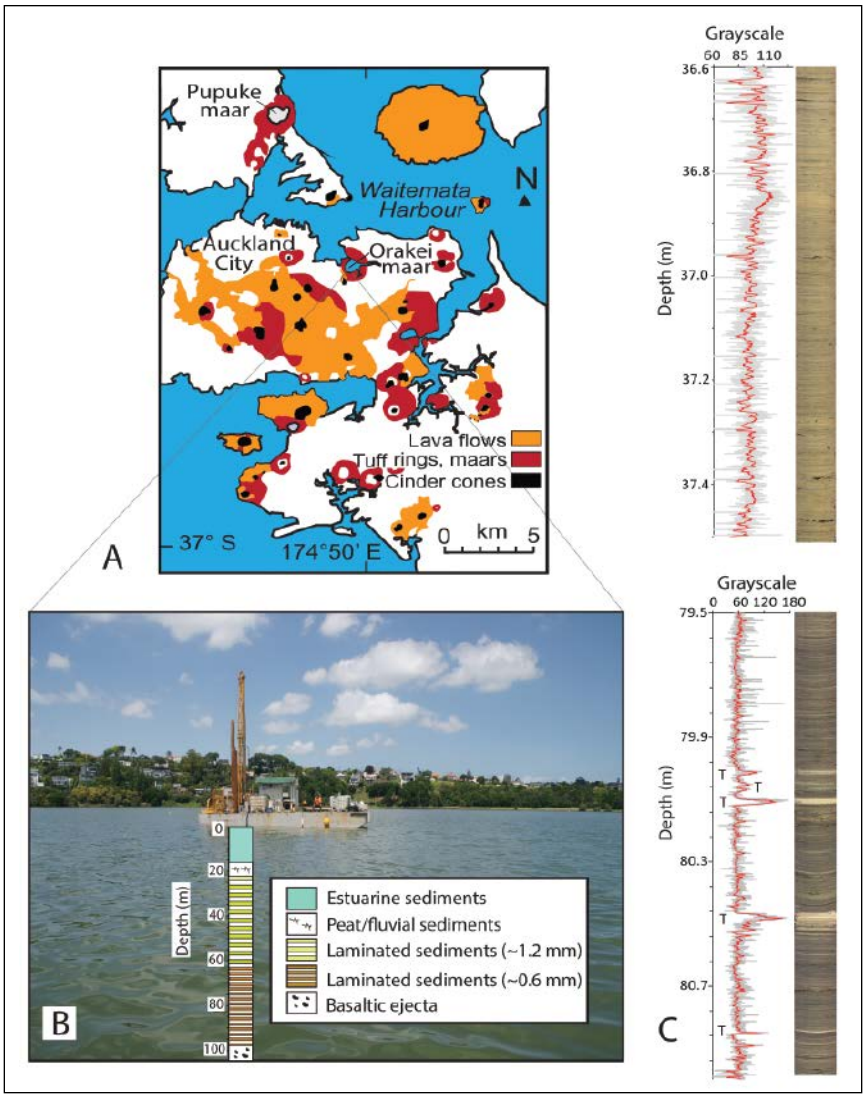
Reconstructing the history of Earth's climate is easier when the story is one long, detailed narrative rather than scattered fragments. Unfortunately, long, continuous, high-resolution terrestrial records of past climate are scarce, with the exception of polar region ice cores and mineral deposits in tropical caves (speleothem records).

The midlatitudes also offer detailed histories that can span the gap in records of past climate between the higher and lower latitudes. Many studies of deep, stable maar lakes—water-filled explosion craters from past volcanic eruptions—in the midlatitudes have demonstrated that these lakes provide exceptionally detailed and continuous records spanning back as far as the past few 100,000 years.

The maar lake sediment records in New Zealand's Auckland Volcanic Field (AVF) extend back about 250,000 years with variable resolution. These records allow us to construct detailed histories of subtle changes in the nature and timing of AVF volcanism, geomagnetic field intensity, and past climate that will eventually enable us to examine the nature of intrahemispheric and interhemispheric climate linkages in the context of the Southern Hemisphere midlatitudes.

(facing page) A core from the Orakei maar lake, collected from a depth of 81 meters below the lake bed. The core rests on a cradle that moves it through high-resolution scanners. (above) Aerial view of Orakei basin, near Auckland, New Zealand, where a research team took core samples near the center of the large lake. This lake is a maar—a volcanic explosion crater—and its sediments contain a continuous, high-resolution record of past climates extending as far back as the onset of the last glacial cycle, starting about 120,000 years ago.

Paul C. Augustinus



Paul C. Augustinus

Fig. 1. (a) Map of the Auckland Volcanic Field, North Island, New Zealand. (b) Photo of Orakei maar showing drill rig and essential elements of the core stratigraphy. (c) Typical sections of laminated lake sediments with grayscale trends from upper and lower parts of the sequence. T = ash layers.

Here we describe the extraction of the most complete record of sedimentation in any Auckland maar lake, the Orakei maar (Figures 1a and 1b). The cores, obtained in 2016, give us the opportunity to produce the most detailed record yet of regional volcanic hazards and drivers of past climate changes spanning most of the last glacial cycle (between about 120,000 and 12,000 years ago) from mid-latitude New Zealand.

Past Studies on AVF Maar Lakes

Auckland, New Zealand's largest and most densely populated center, is home to a dense cluster of about 50 basaltic volcanoes (Figure 1a). The AVF includes lava flows and cinder (scoria) cones, but it also features 13 maars, most of which were lakes and swamps that have since been filled with sediment.

Only one of these maar craters contains a modern deep lake—Lake Pupuke—where continuous lake sediment accumulation has occurred since its formation (Figure 1a). Core samples from this lake have provided geomagnetic, volcanic, and past climate records that serve as the basis for much of the current knowledge of this region.

Geologists have taken core samples from several of the AVF maar lake systems to assess volcanic hazards and study paleoclimate [e.g., *Molloy et al.*, 2009; *Augustinus et al.*, 2011]. However, most work to date has focused on lakes in which slow sedimentation rates create thin layers over the course of many years, making it difficult to narrow down the time frame of any given event from these records.

Also, the sections of these records that we have examined so far go back no more than about 46,000 years. Thus, the Orakei maar represents a unique chance to more than double this time slice.

Why Drill at Orakei Maar?

We intend to develop high-resolution paleoclimate records from Orakei and other Auckland maars that can be correlated with polar ice core and southeast Asian speleothem isotopic records of paleoclimate from the last glacial cycle. Identifying long-distance climate connections between our Auckland maar lake sediment sequences, the polar regions, and the tropics would enhance our ability to identify climate leads and lags, as well as latitudinal changes in the nature of the signals and their drivers.

What Time Slice Does the Orakei Maar Represent? Evidence from Earth's Magnetic Field

Previous work on Lake Pupuke cores identified relative geomagnetic intensity changes associated with the Laschamp geomagnetic excursion, which occurred about 41,000 years ago. This short-lived decrease in Earth's magnetic field intensity was accompanied by a shift in the orientation of Earth's magnetic poles. Because the paleomagnetic directional data from Lake Pupuke are not reliable enough to link them directly to the Laschamp geomagnetic excursion, geomagnetic field intensity records and isotopic concentration data serve as proxies to establish this linkage indirectly [*Nilsson et al.*, 2011].

Paul C. Augustinus

Drillers (left and center) along with a Ph.D. student (right) examine sediment from the Orakei maar lake as it extrudes from a core barrel on the barge adjacent to drilling rig.

The weakening of the magnetic field during the excursion and the transition periods before and after reduced shielding against galactic cosmic rays, allowing higher than normal production of beryllium-10 (^{10}Be) in the atmosphere. The resulting ^{10}Be nuclides attached to aerosols and rained out from the atmosphere, depositing on Earth's surface and accumulating in Lake Pupuke sediments.

We compared ^{10}Be concentration trends in the Lake Pupuke cores with ^{10}Be concentration trends during the Laschamp excursion recorded in Greenland ice cores. This comparison enabled us to directly correlate the records of past climate between these northern polar and southern midlatitude cores [*Nilsson et al.*, 2011].

We intend to extend this approach to the Orakei record back through the entire last glacial cycle so that we can identify precise linkages to the global climate system.

A Chance to Examine Volcanic Ashfalls, Past and Future

Previous work shows that the Orakei maar contains well-laminated lake sediment and the highest sedimentation rates of any of the Auckland maar lakes cored to date [e.g., *Molloy et al.*, 2009]. Rapid deposition ensures that each sediment layer represents a narrower time frame than is available from layers deposited more slowly. This record includes far-traveled ash that originated in the various volcanic centers in the Taupo Volcanic Zone of the central North Island, as well as the local AVF volcanoes [*Molloy et al.*, 2009].

In addition to the visible ash layers, there are plentiful microscopic ash layers (cryptotephra) that significantly increase both the number of identified ashfall events and their frequency. This approach is changing scientific assessments of the volcanic hazards and risks that the Auckland region faces [*Shane et al.*, 2013; *Zawalna-Geer et al.*, 2016].

The cryptotephra work undertaken thus far has focused on Holocene sediment records (about 9000 years ago to the present) from Pupuke maar lake. Orakei maar's potential to extend the tephra record through the entire last glacial cycle, in combination with development of a robust chronology, will further refine our understanding of the present-day volcanic and ashfall hazards. This extension will also provide new information on the poorly known earlier stages of the evolution of the AVF as well as the tephra sourced from Taupo Volcanic Zone volcanic centers.

Collecting the Orakei Maar Core

Orakei maar is a nearly symmetrical explosion crater, about 1 kilometer wide and close to modern sea level. This crater is phreatomagmatic—the explosion that created it contained gases and steam. In February 2016 a consortium of geologists and paleoclimatologists from the University of Auckland and other New Zealand, German, and U.S. universities began drilling to sample the Orakei maar sediment record.

We used a drilling rig mounted on a floating barge in the middle of the Orakei basin (Figure 1b) to recover about 19 meters of Holocene estuary muds that overlie about 7 meters of peat and river sediments. Below these sediments, a suite of laminated lake sediments extends downward from about 26 to 99.5 meters (Figure 1b). We were able to produce close to 100% recovery because we drilled

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CIDER announces their annual summer program on behalf of the geosciences Community (*http:://www.deep-earth.org*). *Organizers:*

Doug Wiens, Erik Hauri, Christy Till, Peter van Keken, Jessica Warren.
Significant progress has been made in recent years on unraveling the structure and dynamics of subduction zones, with strong support in the US from geophysical ' investigations supported by Earthscope and interdisciplinary research opportunities provided by GeoPRISMS.

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The program includes a 4 week tutorial program for about 35 advanced graduate students and post-docs, (June 25- July 21, 2017), while more senior scientists are also welcome at any point in the program, including the first "informal" week.

The tutorial program will include lectures and hands-on tutorials. Concurrently, junior and senior scientists will engage in collaborative multidisciplinary research ventures defined on site. This summer program will be held at the University of California, Berkeley. It is supported by the NSF/FESD program. Applications are invited for both senior and junior participants at:

http://www.deep-earth.org/summer17.shtml
Application deadline: February 1, 2017

two overlapping cores that are being combined with a shorter and incomplete record obtained from the basin previously [*Molloy et al.*, 2009].

We extended the sedimentation rate measurements between known age marker tephra from about 60- to 80-meter depth to the base of the maar lake sequence. Our measurements suggest that the paleolake sequence began at least about 120,000 years ago (sediment compaction compresses the lower part of the record, so older layers are thinner). The mean thickness of the lamina in this part of the paleolake sequence averages about 1.2 millimeters. Within these lamina, volcanic ash sourced from a range of eruptions from the AVF and volcanic centers associated with the Taupo Volcanic Zone are well preserved (Figure 1c) [see also *Molloy et al.*, 2009].

A significant change in the character of the sediments occurs at about 60-meter depth—from this level down to about 99.5 meters, the lamina become darker and thinner, and the average thickness is about 0.6 millimeter. Below this depth, angular and poorly sorted sediments dominated by porous volcanic scoria and fragments of locally sourced rock (country rock clasts) probably represent the material that erupted during the birth of the maar (Figure 1b). Drilling stopped at 105-meter depth in the basaltic ejecta because the laminated lake muds were the primary target of this study.

Our measurements suggest that the paleolake sequence began at least about 120,000 years ago.

Analyzing the Cores

An expanded team is now working to analyze the core samples from the Orakei maar using various paleoclimate proxies and dating methods. We will combine high-resolution geochemical scans (down to 0.1-millimeter scale) with X-ray density and magnetic susceptibility scans of the Orakei core to enable us to match the overlapping core sections with confidence, as well as to construct a robust composite stratigraphy. We will also use these scans to help identify events in the sequence (e.g., turbidites) and changes in character of the lamina that may have paleoclimatic significance.

We will be using a suite of dating tools to produce a reliable chronology that extends beyond the limit of carbon (^{14}C) dating methods. These tools include luminescence dating, paleomagnetism, and meteoric ^{10}Be flux. In addition, we will attempt to define the ages of zircon-containing tephra that we encounter using an ion probe to measure uranium and its radioactive decay products ((U-Th)/He dating).

Subsequently, we will conduct high-resolution paleoclimate analyses using a range of proxies: climate-correlated measurements that provide climate information indirectly. Pollen, diatoms, and chironomids provide information on the ancient environments and temperature regimes in which they lived. Lipid biomarkers provide additional information on paleotemperature. We will also analyze bulk and compound-specific organic matter isotopes to learn more about rainfall patterns (paleoprecipitation) and the distribution of nutrients (paleoproductivity).

Using this approach, we eventually hope to have the first reliably dated and high-resolution paleoclimate record spanning the last glacial cycle from New Zealand and probably the best available from the Southern Hemisphere midlatitudes.

Acknowledgments

The drilling investigation team included Paul Augustinus, Jan Lindsay, and Phil Shane (University of Auckland), Jenni Hopkins and Graham Leonard (GNS Science), Valerie van den Bos (Victoria University of Wellington), Tim Shanahan and Natalia Piatrunia (University of Texas at Austin), and Frank Sirocko (University of Mainz). A larger team is now working on the various paleoclimate proxies and dating methods being used on the Orakei maar sediments. The project was funded by New Zealand's Earthquake Commission, the Auckland Council, and a grant from the Royal Society of New Zealand Marsden Fund.

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Graduate Student Fellowship Opportunities

The U.S. Science Support Program (USSSP), in association with the International Ocean Discovery Program (IODP), is currently accepting applications for the Schlanger Ocean Drilling Fellowship Program. The submission deadline is December 2, 2016.

The Schlanger Ocean Drilling Fellowship Program offers merit-based awards for outstanding graduate students to conduct research related to the International Ocean Discovery Program. Fellowship awards are $30,000 for a 12-month period and are intended to support the student's stipend, tuition, benefits, and, if necessary, related travel. Award dates are generally based on the academic year and following summer. For more information please visit:

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Deadline: December 2, 2016

IODP INTERNATIONAL OCEAN DISCOVERY PROGRAM

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Four Position Statements Approved by AGU Board of Directors

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Position statements on K–12 education, U.S. government support for basic research, free and open communication of scientific findings, and the centrality of the theories of evolution and the history of the Earth to science education received approval from AGU's Board of Directors on 7 September.

The organization had updated one of these newly approved statements, entitled "Earth and Space Sciences Should Be Taught in K–12 Education," from its previous version to reflect more current educational standards (see http://bit.ly/ESS-K12). The original statement adopted in 2001 referenced the 1995 National Science Education Standards and the 1994 American Association for the Advancement of Science Benchmarks for Science Literacy. The revised and newly approved version references the 2013 Next Generation Science Standards (see http://bit.ly/next-gen-13) and the 2012 National Research Council document "A Framework for K–12 Science Education" (see http://bit.ly/Framework12).

Statements Reaffirmed

The other three position statements had come due for review this fall at the ends of their 4-year terms. The AGU Position Statement Task Force recommended renewing the statements as written, an action approved by the AGU Board at its September meeting.

Of those statements, one, entitled "The U.S. Government Has a Critical Role in Supporting Basic Research in the Earth and Space Sciences," focuses on the critical importance of federally funded research to provide societal benefits (see http://bit.ly/govt-role).

A second statement, called "AGU Supports Free and Open Communication of Scientific Findings," promotes unfettered communication of scientific findings, as well as the research process (see http://bit.ly/free-and-open).

The third statement, with the title "The Scientific Theories of Biological Evolution and History of the Earth Should Be Central Elements of Science Education," notes that the scientific theory of evolution is noncontroversial within the scientific community and is fundamental to science education (see http://bit.ly/evolution-history).

AGU develops and maintains position statements to provide scientific expertise on significant policy issues related to the understanding and application of the Earth and space sciences. AGU encourages its members to use position statements to convey the sense of the scientific community to policy makers, students, or other members of the public.

AGU develops and maintains position statements to provide scientific expertise on significant policy issues.

All AGU position statements reside online on the AGU Position Statements and Letters website (see http://bit.ly/psL-site), along with AGU's advocacy policy and information about the adoption and renewal history of each statement.

By **Elizabeth Landau,** Public Affairs Manager, AGU; email: elandau@agu.org

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AGU-Sponsored Workshop Targets Sexual Harassment in the Sciences

The definition of research misconduct should include sexual harassment of students, employees, or colleagues. This proposal is one of many solutions to the problem that were discussed at a workshop recently convened by AGU entitled "Sexual Harassment in the Sciences: A Call to Respond."

In the wake of several high-profile sexual harassment cases within the past 2 years across the sciences, more than 60 leaders in science, government agencies, and professional societies gathered in Washington, D. C., on 9 September to talk about the causes and prevalence of sexual harassment and assault in research institutions and other scientific settings and to begin to draft solutions.

The American Association for the Advancement of Science (AAAS), the American Chemical Society, the American Geosciences Institute, the Association for Women Geoscientists, and the Earth Science Women's Network (ESWN) joined AGU as cosponsors of the workshop. The National Science Foundation funded the event.

How We Got Here

The workshop began with discussions about how the master-apprentice relationship between students—particularly those in graduate school—and their scientific advisers has the potential to set the stage for harassment and allow it to perpetuate, workshop speaker Erika Marín-Spiotta told *Eos* after the event. (To encourage attendees to speak candidly about this sensitive subject, media were not invited to attend the workshop. Moreover, participants agreed to refrain from live tweeting or otherwise reporting in real time.)

Students may risk retaliation against their careers if they call out or report harassment, noted Marín-Spiotta, who is a biogeochemist at the University of Wisconsin–Madison and a member of the leadership board of ESWN.

Harassment and Fieldwork

Fieldwork tends to exacerbate the harassment problem, she added. Students may be isolated from their community and from their friends and often don't have anyone to turn to.

Anthropologist Kathryn Clancy of the University of Illinois at Urbana-Champaign—who was also a workshop speaker—and her colleagues recently conducted a survey of more than 650 scientists about sexual harassment and assault during fieldwork. The researchers reported in *PLOS One* in July 2014 that 64% of respondents said they had experienced sexual harassment in the field; 22% had experienced sexual assault. Women in training positions were often the targets; scientists above them in the hierarchy of the field site often committed the offenses, the team found. With regard to men who reported experiencing harassment and assault, perpetrators tended to be peers rather than superiors (see http://bit.ly/field-harass).

At the workshop, participants also discussed the "cult of the celebrity scientist," which makes harassment more likely to take place and to go unpunished, Marín-Spiotta said. "Universities are really loath to do anything if the person who is being accused is bringing a lot of fame, or especially a lot of research funding, to the university," she explained.

Less Heard Voices

It's important not to forget especially marginalized communities, such as women of color, Clancy told *Eos*, recalling a concern she raised at the workshop.

She currently studies how women of color experience sexual harassment in the sciences. In not-yet-published research, Clancy has found that "the degree of negative experiences [women of color] have [is] relatively far greater" than that of white women.

> "The degree of negative experiences [women of color] have [is] relatively far greater."

"I do think a lot of people [at the workshop] did a lot of hard thinking at that moment" when she presented her research, Clancy said.

She hopes that other researchers and leaders will embrace an "intersectional" approach—considering not only gender but also race when thinking about how to address sexual harassment in the sciences.

"Women of color have been pointing this out for decades," Clancy said. She emphasized that as the conversation continues, researchers need to promote a climate in which women of color can take a leading role in the conversation.

Possible Solutions

Throughout the workshop, attendees and speakers discussed possible solutions tailored to different settings, such as on campus, in the field, or at professional meetings, Marín-Spiotta said.

Providing funding to graduate students that is independent of a particular adviser or lab might help combat harassment, some workshop attendees suggested. This way, if a student had a negative experience in a research group or lab, she could move and work somewhere else more easily.

Participants also considered classifying sexual harassment as a form of research misconduct to discourage wrongdoing, Marín-Spiotta said. Funding agencies already punish universities if scientists abuse data, but scientists don't get punished "if they abuse people," she told *Eos*. "Institutions aren't going to do anything until they're afraid of losing funding," she continued.

Further Action

Looking beyond the workshop, which she also attended, AGU CEO and executive director Chris McEntee said that her organization and its collaborators now "have a responsibility to figure out a really strong course of action" to eradicate sexual harassment in the sciences.

She told *Eos* that she has experienced sexual harassment—which she regards as "unacceptable"—throughout her career. "It shouldn't be happening," she said.

Eric Davidson, AGU's president-elect, also took part in the workshop. "It's our responsibility to provide members, employees, and constituents with the awareness and tools needed to create an inviting, safe culture for science," he said.

By the end of 2016, the organizations that cosponsored the workshop intend to release a set of guiding principles to help scientific societies, academic institutions, and other organizations improve workplace climate, better respond to sexual harassment, and better support victims.

By **JoAnna Wendel,** Staff Writer

Which Greenhouse Gas Does the Most Damage to Crops?

User:H2O

Wheat, growing here in the Hula Valley in northern Israel, feeds much of the world, but anthropogenic emissions are threatening crop production around the globe to varying degrees.

Scientists and policy makers alike have recognized that agricultural yields are at risk from climate change and human-caused emissions. Carbon dioxide is the largest driver of climate change, but in a new study, *Shindell* found that other anthropogenic, or human-sourced, emissions cause more damage to crop yields.

Methane (mainly from natural gas production and livestock), halocarbons (used in refrigeration and air conditioning), and black carbon (from fossil and biomass fuels) all contribute to climate change to varying degrees. But until now, studies have not attempted to attribute agricultural impacts to individual pollutants; instead, many focused on how downstream processes, like increasing temperature, affect the globe.

Here the author sought to create a more complete picture of the effects of human-caused emissions. Using climate data from his previous studies and the Intergovernmental Panel on Climate Change's fourth and fifth assessment reports and crop yield data from previous work, the author created a model to determine the effect that individual greenhouse gases have on global temperature, precipitation, carbon dioxide, and ozone—all of which affect crop success.

The model revealed that in the short term—in the first decade after emissions are released—the greatest damage to crops per ton comes from black carbon and from gases used in refrigeration. Methane emissions are also very harmful to plants because the gas increases surface ozone, which causes harmful chlorosis, or a yellowing of the leaves.

The effects of carbon dioxide are more complicated. Carbon dioxide fertilizes plants, which means that as the amount of the gas in the atmosphere increases, crop yields initially increase as well. But as carbon emissions continue to contribute to climate warming, the overall impact becomes negative and will outweigh the benefits of fertilization after only 10 years.

Overall, the model suggests that approximately 93% of crop losses throughout the rest of this century will be caused by non–carbon dioxide emissions, the most damaging of these being methane. Even if the impact of surface ozone is taken out of the results, the non–carbon dioxide damage is still 9 times greater than that caused by carbon dioxide.

Finally, to see how policy and societal actions to mitigate pollutant emissions might affect crops, the author compared two future scenarios: one with low emissions and another with high emissions. If strong emission mitigation techniques are implemented, the results show that crop yields will improve by about 3% for reduced carbon dioxide, 5% for a reduction in hydrofluorocarbons, and 16% if methane is reduced. Under the high-emission scenario, crop yield losses will be about 25% greater by the end of the century, threatening global agriculture.

This is the first study to look at the relative contributions of individual pollutants to climate change and crop yield losses, and the findings here fill an important gap for policy makers, who can limit specific pollutant emissions. The author suggests that policy makers should strengthen efforts to reduce methane and hydrofluorocarbons in the atmosphere to help prevent severe crop loss by the end of the century. (*Earth's Future*, doi:10.1002/2016EF000377, 2016) **—Alexandra Branscombe, Freelance Writer**

The Quest to Understand Reversals in Earth's Magnetic Field

Evidence of frequent reversals in the direction of Earth's magnetic field is preserved in the rock record, and it has played a fundamental role in deciphering our planet's tectonic history. However, the processes that cause these polarity reversals—and the properties of the transitional magnetic field itself—remain topics of vigorous debate.

Now *Valet and Fournier* review the major features of reversals and evaluate their compatibility with recent numerical modeling results. They conclude that in spite of the increasing number of paleomagnetic records collected during the past 50 years, varying interpretations of the transitional fields still exist. Uncertainties, the authors argue, arise from the rapidity of the reversals—which often occur faster than the age resolution of the rocks that record them. In addition, the observed decrease in transitional field intensity can reduce the fidelity of the magnetic record, particularly in sedimentary rocks.

Despite multiple attempts to collect and model the data from the last reversal, which occurred about 779,000 years ago, the authors conclude that the behavior of the transitional field during that event is still poorly constrained, partly because of the varying resolution of each paleomagnetic record. In addition—and in spite of recent progress—it is still not possible to predict when the next magnetic reversal could occur. The researchers argue that the science is not yet advanced enough to evaluate whether the decreased magnetic field strength measured during the past 800 years is an indication that the next reversal is imminent or whether it falls within the typical range of long-term variability.

Present-day reversal forecasts are still a challenge because of the limited scientific understanding of the processes that generate Earth's magnetic field. These processes are estimated to occur on the scale of several decades to a century—at least an order of magnitude shorter than the time frame during which a reversal occurs. However, advanced physics-based models could increase the predictability of the processes that scientists believe are responsible for the reversals. Likewise, studies that characterize the Sun's magnetic reversals, which occur about every 11 years, could also shed light on Earth's longer-term events.

Future progress in understanding Earth's magnetic reversals will depend upon several types of additional studies, according to the researchers. These include estimates of cosmogenic radionuclide production—which may confirm the existence and characterize the strength of oscillations prior to reversals—as well as advanced technologies like new, highly sensitive magnetometers that are capable of scanning magnetization at submillimeter scales. (*Reviews of Geophysics*, doi:10.1002/2015RG000506, 2016) **—Terri Cook, Freelance Writer**

How Vague Historical Writings Help Scientists Predict Floods

Eduard Gurk

Flooding in Vienna after an ice dam failed on the Danube River in March 1830, captured here in a watercolor painting by Eduard Gurk (Roßau, Schmidgasse am 2 März 1830).

When scientists assess environmental risk in any particular geographical region, they need as many data as possible relating to the area's past. Often, though, those data are limited by the existence of scientific instruments: Precise measurements go back only so far in history. When scientists predict the likelihood and severity of future flooding in particular, historical data are often limited to imprecise written descriptions of past flood events. In a new paper, *Salinas et al.* build a framework to incorporate historical records written before the advent of scientific instrumentation into the estimation of flood probabilities.

There are many different types of historical flood records, all of them with differing degrees of imprecision. For example, a recollection of "the river left its banks" yields less information than "the flood covered the ground, ruining the crops," which is less precise still than "the river rose to the city walls, so high that people standing on the bridge could wash their hands in the floodwaters." The new framework applies a membership function to each written record, defining the likelihood that the event described belongs in a fuzzy set. Each set represents the approximate size of the flood, and the degree of the set's "fuzziness" is proportional to the degree of the record's vagueness.

Once the imprecision of the historical record has been accounted for, the framework must also account for stochastic uncertainty, which reflects the natural variability of floods between years, and integrate systematic data from later scientific measurements. The authors do this using a Bayesian framework, a flexible method that combines a fuzzy sample of imprecise historical information and the nonfuzzy sample of systematic data. The Bayesian framework returns a range of predicted flood discharges associated with various return periods—the probabilities of floods of different sizes.

In case studies, the researchers found that this method reduced stochastic uncertainty by up to 60% compared with methods using only systematic data for a 100-year return period flood discharge—the reduction was closer to 35% for 10-year and 1000-year return periods. Practically, this could decrease overall uncertainty for "fuzzy" flood risk maps that take into account vague historical records. By accounting for imprecise data and putting flood risk estimates into long-term context, this method brings linguistic nuance into scientific flood estimation. (*Water Resources Research*, doi:10.1002/2016WR019177, 2016) **—Leah Crane, Freelance Writer**

Searching for Lightning's Signature on Venus

Doug O'Neill, CC BY 3.0 (http://bit.ly/ccby3-0)

Cloud-to-cloud lightning on Earth. Could such flashes be detected on Venus?

Venus—Earth's closest sibling—is a hellish planet with surface temperatures that regularly reach 460°C and an atmosphere that bears down with nearly 100 times the pressure at Earth's surface. Sulfuric acid haze laces its carbon dioxide atmosphere. But whether to add lightning into the mix of inhospitable ingredients remains controversial.

The debate began in December 1978 when the Soviet Venera 11 and 12 probes descended into Venus's atmosphere and detected a large number of electromagnetic pulses that could have been produced by remote lightning. That same month, the Pioneer Venus Orbiter detected "whistlers," electromagnetic pulses created by lightning strikes that echo their name. But the findings were questioned when flybys by the Galileo and Cassini probes failed to detect lightning's distinctive radio static in the 1990s. The evidence took another zigzag in 2007 when the Venus Express Orbiter once again appeared to detect whistlers.

Still, most scientists claim that only detectable emissions of lightning from the nightside of Venus would be unambiguous proof of the electromagnetic discharge. So *Pérez-Invernón et al.* built a model that could predict any lightning signatures and analyze whether they might be detectable by the various probes currently keeping a watchful eye on the planet. Modeling the lightning on Venus, however, is no easy feat. Venus's atmosphere lacks the vigorous vertical convection that leads to lightning on Earth. It also lacks the water clouds. Instead, lightning—if it exists at all—likely jumps between the sulfuric acid clouds in an atmospheric band that ranges from 40 to 65 kilometers in height.

The authors suggest that one way to detect lightning on Venus is to look far above the lightning itself and observe enhanced glows at around 100-kilometer altitude. On Earth these enhancements can also be spotted from orbit. In fact, they were first spotted by the space shuttle *Discovery* in October 1990 when the astronauts saw a sequence of sudden brightenings in coincidence with the lightning flashes. The team's new model shows that the Lightning and Airglow Camera (LAC) on board the Japanese Venus Climate Orbiter could spot something similar if lightning on Venus is energetic enough.

Future lightning detections not only will end a 40-year-old controversy but also will shed light on the chemistry of Venus's toxic atmosphere and give researchers clues to storm activity on the planet. (*Journal of Geophysical Research: Space Physics*, doi:10.1002/2016JA022886, 2016) **—Shannon Hall, Freelance Writer**

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BIOGEOSCIENCES

Tenure-Track Faculty Position in Geobiology

The Department of Earth and Planetary Sciences (www.mcgill.ca/eps) at McGill University invites applications for a full-time, tenure-track position in Geobiology. McGill University is one of Canada's leading research and teaching institutions, located in the heart of vibrant Montreal, Quebec.

The position, with a start date of August 1, 2017 or later, is at the rank of Assistant Professor, although an appointment at a higher level will be considered in the case of an applicant with exceptional qualifications. We seek a candidate who uses quantitative field, laboratory, and/or modeling methods to study interactions between life and geologic, geochemical or hydrological processes. Applicants should have a doctorate at the time of appointment, a record of excellence in research, and the capacity for outstanding teaching.

Applications should include a detailed curriculum vitae, a research plan, a statement of teaching interests, a list of three references, and up to two examples of recent publications. The application package should be sent in electronic form to the Department Chair. Additionally, the applicant should arrange for the three letters of reference to be submitted directly to the Department Chair.

Review of applications will begin November 1, 2016 and continue until the position is filled.

Contact:
Jeffrey McKenzie, Chair
Earth and Planetary Sciences
McGill University
3450 University Street
Montreal, Quebec H3A 0E8
Canada
jeffrey.mckenzie@mcgill.ca

McGillUniversity is committed to diversity and equity in employment. It welcomes applications from: women, Aboriginal persons, persons with disabilities, ethnic minorities, persons of minority sexual orientation or gender identity, visible minorities, and others who may contribute to diversification.

All qualified applicants are encouraged to apply; however, in accordance with Canadian immigration requirements, Canadians and permanent residents will be given priority.

GEOCHEMISTRY

Assistant Professor

The Department of Geology at the University of Georgia seeks to fill a position for a tenure-track assistant professor in the field of petrology/mineralogy, welcoming applications from scientists in both the Earth and Planetary sciences to complement the department's growing focus in planetary sciences. We encourage applications from petrologists/mineralogists with strong backgrounds in chemistry and physics who may employ unconventional and interdisciplinary approaches to address big-picture questions including but not limited to petrologic and/or mineralogical aspects of planetary evolution involving core, mantle, and/or crustal processes. A Ph.D. in Geology, Earth or Planetary Science or other related discipline is required by August 1, 2017. The successful candidate must be comfortable teaching our undergraduate core curriculum classes in mineralogy and/or petrology, a graduate course in their specialty, as well as introductory courses in geology. The successful candidate will be expected to establish an externally funded research program to attract outstanding graduate students in their field, and our core electron microprobe facility with dedicated, long-standing technical support may be critical to that effort. Applicants should submit a cover letter, curriculum vitae, a statement of research and teaching interests and contact information for 3 references. Application materials should be uploaded to facultyjobs.uga.edu. Review of applications will begin January 16, 2017. The position will remain open until filled, but to ensure full consideration, all application materials should be submitted by 5 PM January 16, 2017.

The Franklin College of Arts and Sciences, its many units, and the University of Georgia are committed to increasing the diversity of its faculty and students, and sustaining a work and learning environment that is inclusive. The University is an Equal Opportunity/Affirmative Action employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability, gender identity, sexual orientation or protected veteran status. Georgia is well known for its quality of life in regard to both outdoor and urban activities (exploregeorgia.org). UGA is a land and sea grant institution located in Athens, 90 miles northeast of Atlanta, the state capital (www.visitathensga.com; www.uga.edu).

Marine Organic Geochemistry

The Interdepartmental Graduate Program in Marine Science (IGPMS: www.igpms.ucsb.edu) at the University of California, Santa Barbara invites applications for a tenure-track or tenured faculty position in marine organic geochemistry at the rank of Assistant or Associate Professor starting July 1, 2017. We are searching for an innovative, collaborative marine scientist who focuses on the geochemistry of organic molecules in marine habitats ranging from the water column to sediments and from coastal zones to the open ocean. Research covering timescales ranging from the geologic past to the modern, and topics ranging from natural cycles to anthropogenic impacts will be con-

Assistant/Associate/Full Professors - Physical and Biological Oceanography, Marine Geophysics/Geology, and Ocean Engineering

South University of Science and Technology of China

The school of oceanography at the South University of Science and Technology of China (SUSTC) invites applications for several tenure-track (or tenured) faculty positions at the ranks of Assistant, Associate, and Full Professor. Applicants must have earned Doctoral degrees in marine geophysics/geology, physical oceanography, biological oceanography, ocean engineering or closely related field. Successful applicants will be expected to establish a robust, externally funded research program and demonstrate a strong commitment to undergraduate and graduate teaching, student mentoring, and professional service. These positions will be open until filled.

SUSTC is a young university at Shenzhen in southern China since 2010 which is set to become a world-leading research university, to lead the higher education reform in China, to serve the needs of innovation-oriented national development and the needs of building Shenzhen into a modern, international and innovative metropolitan. These positions are created with a significant development to establish a vigorous research program in oceanography at SUSTC to serve the national call for China's important role in deep sea research and resource-oriented exploration in the world oceans.

To apply submit a cover letter, complete vitae with list of publications, and three names of references via http://talent.sustc.edu.cn/en/, or to Dr. Y. John Chen, Chair Professor at School of Oceanography, South University of Science and Technology of China, No 1088, Xueyuan Rd., Xili, Nanshan District, Shenzhen, Guangdong, China 518055.

sidered, with the ideal candidate proposing a strong analytical or computational research program. The successful candidate will hold an appointment in one or more academic departments that participates in the IGPMS, and is expected to develop an internationally recognized research program, mentor graduate and undergraduate students in the candidate's area of expertise, and teach both graduate and undergraduate courses. A Ph.D or an equivalent degree in Marine Science, Chemistry or a related area is required at the time of appointment.

Applicants should submit the following: 1) cover letter; 2) curriculum vitae; 3) statement of research accomplishments/plans; 4) statement of teaching experience/interests; and 5) up to three publications. Applicants should also request three referees to send letters of evaluation by the date listed below. Submit applications and reference letters online at: https://recruit.ap.ucsb.edu/.

For primary consideration apply by December 19, 2016; review of applicant files will continue until the position has been filled.

The school is especially interested in candidates who can contribute to the diversity and excellence of the academic community through research, teaching and service.

The University of California is an Equal Opportunity/Affirmative Action Employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

W. O. Crosby Postdoctoral Fellowship

The Department of Earth, Atmospheric and Planetary Sciences at the Massachusetts Institute of Technology (MIT) invites applications for the W. O. Crosby Postdoctoral Fellowship. The two-year fellowship supports exceptional early-career scientists with research interests in the fields of geology, geochemistry, or geobiology. Crosby Fellows pursue independent research but are encouraged to collaborate with one or more researchers in the department. A faculty mentor hosts each fellow. Prospective fellows are strongly encouraged to contact members of the department to discuss possible collaborations. The fellowship includes an annual stipend of $64,000, full coverage of premiums for affiliate health, dental and vision insurance, and an allowance of $5,000 per year for research and relocation expenses. The start date of the fellowship is flexible, but should ideally fall between June 1, 2017, and January 31, 2018. Applicants must have obtained a Ph.D. by the start date, but not more than three years before the start date.

Applications are due by December 1, 2016, and must include a curriculum vitae with a list of publications, a two-page plan of research to be conducted during the fellowship, and three reference letters.

A description of the application process is at http://eapsweb.mit.edu/crosby.

MIT is an equal employment opportunity employer. All qualified applicants will receive consideration for employment and will not be discriminated against on the basis of race, color, sex, sexual orientation, gender identity, religion, disability, age, genetic information, veteran status, ancestry, or national or ethnic origin.

GEOPHYSICS

Faculty Position in Solid Earth Geoscience

The School of Earth and Atmospheric Sciences at Georgia Tech invites applications for a tenure-track faculty position in solid-earth geosciences, broadly defined. This includes, but is not exclusive to, research focuses in tectonophysics, electric field methods, quantitative geomorphology, rock mechanics, physical petrology, hydrology, seismology, geodynamics, geodesy, volcanology, glaciology, marine geophysics and processes related to geologic hazards. Applicants at the Assistant Professor level are sought, although outstanding individuals at all levels will be considered. We seek individuals who are interested in working in a dynamic interdisciplinary environment that includes geophysics, planetary sciences, geochemistry and geobiology, atmospheric science, oceanography, and paleoclimatology.

The Georgia Institute of Technology, located in the comfortable, diverse, and thriving metropolis of Atlanta, is consistently a top-ranked educational and research institution. Georgia Tech prides itself on its engineering resources and collaborations, and its quantitative and rigorous undergraduate student body. The School of Earth and Atmospheric Sciences currently has 29 faculty members, 11 postdoctoral fellows and 96 graduate students, and has excellent facilities in the 265,000 square-foot Environmental Science and Technology Building. For more information about our School and academic programs, visit www.eas.gatech.edu. Applicants should send an application letter, curriculum vitae, a statement of research and teaching interests, and the names and contact information for at least three references. Application materials should be submitted as PDF files to https://academicjobsonline.org/ajo/jobs/8193. Requests for information, including pre-application enquiries from senior candidates, should be directed to geophysics_search@eas.gatech.edu. Applications will be considered beginning December 1, 2016 but the search will continue until the positions are filled. An earned doctorate is required

Water Resources Systems Engineering for a Changing World: Water, Energy and the Environment

Cornell is a community of scholars, known for intellectual rigor and engaged in deep and broad research, teaching tomorrow's thought leaders to think otherwise, care for others, and create and disseminate knowledge with a public purpose.

Cornell's School of Civil and Environmental Engineering (CEE) invites applications for a tenure-track faculty position in the area of sustainability related to water, energy and the environment. We are seeking an individual who takes a systems approach towards addressing sustainable water resources and energy issues. Resilient systems engineering solutions are needed to address the strongly interdependent challenges of global change, water availability, food security, energy systems, sustainable development, and human health. Ideal candidates will work at the interfaces of several of these domains with contributions at the global and/or regional water management scales. Applicants should be capable of contributing fundamental advances in one or more of the following systems areas: optimization, risk analysis, computational science, data analytics, and large scale data assimilation.

The position will be filled at the Assistant, Associate or Full Professor level. It is anticipated the successful candidate will begin in August 2017, although alternative arrangements can be made. Review of applications will continue until the position is filled. The candidate should contribute to undergraduate and graduate teaching in the Environmental and Water Resource Systems area within the CEE School. Potential graduate courses might address Sustainability Issues, Risk Analysis, Decision Analysis, or Water Resource Systems Analysis. The successful applicant will be expected to conduct an internationally recognized and well-funded research program. Research activities at Cornell in these areas are enhanced by the opportunity to interact with faculty and students within the Civil and Environmental Engineering School, the College of Engineering, and other colleges including the College of Agricultural and Life Sciences, which has several environmental programs.

Visit CEE website to view a full detailed job description at **www.cee.cornell.edu**

The School of Civil and Environmental Engineering and the College of Engineering at Cornell embrace diversity and seek candidates who can contribute to a welcoming climate for all students. Ezra Cornell announced, "I would found an institution where any person can find instruction in any study."

To apply: Application materials must be submitted on-line at **https://academicjobsonline.org/ajo/jobs/7846**

Through this web site, applicants are to submit a curriculum vita, a research statement, a teaching statement, one to three publications or manuscripts, graduate and undergraduate transcripts and complete contact information for at least three references. Questions can be directed to cee_search@cornell.edu

Review of applications will begin immediately and continue until the position is filled.

Cornell University is an innovative Ivy League university and a great place to work. Our inclusive community of scholars, students and staff impart an uncommon sense of larger purpose and contribute creative ideas to further the university's mission of teaching, discovery and engagement. Located in Ithaca, NY, Cornell's far-flung global presence includes the medical college's campuses on the Upper East Side of Manhattan and in Doha, Qatar, as well as the new CornellNYC Tech campus to be built on Roosevelt Island in the heart of New York City.

Diversity and Inclusion are a part of Cornell University's heritage. We are a recognized employer and educator valuing AA/EEO, Protected Veterans, and Individuals with Disabilities.

by the start of the appointment. Georgia Institute of Technology is an equal education/employment opportunity institution.

Postdoctoral Fellowship in Geophysics

Applications are invited for Carnegie postdoctoral fellowships to conduct independent research in geophysics at the Department of Terrestrial Magnetism (DTM). The geophysics group at DTM currently consists of researchers working in the fields of mantle and core geodynamics, seismology, and volcanology. Related research fields on our campus include geochemistry, cosmochemistry, planetary astronomy, and mineral physics. The successful applicant's primary field of research should overlap with those of the geophysics group, but collaboration with other research areas on campus is encouraged.

Our fellows have access to a wide range of facilities. Scientific computing resources include the Carnegie Memex cluster in addition to local computing resources. DTM fellowships provide support for conference and meeting travel, computing, and the publication of results from postdoctoral work.

Applicants should have a Ph.D. in a relevant field by the time of appointment and a promising record of research and publication. Fellows are expected to begin in Fall 2017. A C.V., list of publications, short description of thesis research, brief (2-3 page) statement of research plans during the postdoctoral fellowship, and three letters of recommendation by those familiar with your work should be submitted online at https://jobs.carnegiescience.edu/jobs/dtm/ by 1 December 2016. Creativity in the proposed research figures heavily in the evaluation of the application. Fellowships are for one year and are normally renewable for a second year. Address any questions you have to dtmfellowships@carnegiescience. The Carnegie Institution is an equal opportunity employer. All qualified applicants will receive consideration for employment and will not be discriminated against on the basis of gender, race/ethnicity, protected veteran status, disability, or other protected group status.

GLOBAL ENVIRONMENTAL CHANGE

Assistant Professor

The Department of Geography at Dartmouth College seeks an ASSISTANT PROFESSOR with a specialty in climate science, biogeochemical cycling, and/or earth systems modeling. We welcome applications from candidates with an established record of excellence in teaching and research to augment and complement the department's strengths in physical/environmental geography. Candidates should hold a Ph.D. or be in the final stages of a Ph.D. program. Application review will begin November 15th and will continue until the position is filled.

Dartmouth College is an equal opportunity/affirmative action employer with a strong commitment to diversity and inclusion. We prohibit discrimination on the basis of race, color, religion, sex, age, national origin, sexual orientation, gender identity or expression, disability, veteran status, marital status, or any other legally protected status. Applications by members of all underrepresented groups are encouraged. Please submit a letter of application, C.V., writing samples, and contact information for three referees. Inquiries should be directed to Search Committee Chair Frank Magilligan.

HYDROLOGY

Assistant Professor of Hydrometeorology–Ecohydrology

The Department of Geography and Earth Sciences at the University of North Carolina at Charlotte (UNC Charlotte) is recruiting a tenure-track Assistant Professor specializing in hydrometeorology or ecohydrology with expertise broadly related to characterizing water–land–atmosphere interactions across a range of spatial and/or temporal scales. The position will begin August 2017. Required qualifications are: 1) a Ph.D. in Geography, Atmospheric Sciences, Environmental Sciences, or a related discipline by the time of appointment; 2) the ability to develop and maintain an externally-funded research program; 3) the ability to contribute to undergraduate and graduate curricula consistent with departmental needs; and 4) the ability to contribute to the Department's interdisciplinary research mission. We encourage candidates whose experience in teaching, research, and community service has prepared them to contribute to our commitment to an environment of diversity and academic excellence. The successful candidate will play an important role in the atmospheric sciences and the earth and environmental sciences components of our graduate and undergraduate programs, will contribute to the department's interdisciplinary teaching and research missions in the geographical and natural sciences, and will maintain an active, scholarly research agenda that includes advising students in the department's graduate programs. The successful candidate is expected to teach courses that contribute to the B.S. in Meteorology program and the B.S. in Earth and Environmental Sciences program, particularly the Atmospheric Sciences and Hydrological Sciences Concentrations. The Department offers undergraduate degrees in Geology, Earth and Environmental Sciences, Meteorology, Environmental Studies, and Geography. At the graduate level, the Department offers an M.S. in Earth Sciences and participates in an interdisciplinary Ph.D. program in Infrastructure and Environmental Systems. The Department also offers

Environmental Processes Engineering
School of Civil and Environmental Engineering, Cornell University

Cornell is a community of scholars, known for intellectual rigor and engaged in deep and broad research, teaching tomorrow's thought leaders to think otherwise, care for others, and create and disseminate knowledge with a public purpose.

The School of Civil and Environmental Engineering (CEE) at Cornell invites applicants for a tenure-track faculty position in the area of Environmental Processes (EP) engineering. The EP faculty at Cornell have historically focused on the fundamental biological, chemical, and physical phenomena that affect the behavior and fate of contaminants in soil and aquatic environments along with the planning, design, and operation of the engineering facilities needed to ensure effective control of environmental quality. While we wish to maintain this focus, our vision is to broaden the application of these fundamental processes to address the pressing needs of society.

We seek exceptional candidates with strong experimental skills in the biological, chemical, and physical aspects of environmental engineering. Candidates with strong complementary capabilities in modeling and theory are particularly desirable. The School of CEE at Cornell has great strengths in the related areas of Environmental Systems, Water Resources, and Environmental Fluid Mechanics. Candidates displaying a potential to collaborate with research in these areas or other fields at Cornell (including our colleagues in the Department of Biological and Environmental Engineering in the College of Agriculture and Life Sciences) are especially welcomed. Efforts to build these collaborative connections at Cornell are greatly aided by a variety of funding opportunities available at the Atkinson Center for a Sustainable Future (**https://www.acsf.cornell.edu**). A list of examples of research foci that are of particular interest may be found at: **www.cee.cornell.edu**.

Applicants should have a Ph.D. in Engineering or a related field. While we anticipate hiring at the tenured Associate or Full Professor level, tenure-track appointments at the level of Assistant Professor will be considered. Salary and rank will be commensurate with qualifications and experience. Cornell is committed to finding attractive solutions for dual career couples (see **https://hr.cornell.edu/jobs/relocating/dual-career-program**) and provides generous family services, such as parental leave and on campus daycare. Successful applicants will be expected to lead a thriving research program, catalyze collaborative research efforts across campus, and provide excellence in teaching at both the undergraduate and graduate levels. This is an exciting time at Cornell and applications are encouraged from individuals with the skills and enthusiasm to build on our storied past and lead during this new era of discovery and teaching.

The School of Civil and Environmental Engineering and the College of Engineering at Cornell embrace diversity and seek candidates who can contribute to a welcoming climate for all students. Ezra Cornell announced, "I would found an institution where any person can find instruction in any study."

To apply: Application materials must be submitted on-line at **https://academicjobsonline.org/ajo/jobs/7988**

Through this web site, applicants are to submit a curriculum vita, a research statement, a teaching statement, copies of official undergraduate and graduate transcripts, one to three publications or manuscripts, and complete contact information for at least three references. Questions can be directed to **cee_search@cornell.edu**

Review of applications will begin November 15, 2016 and will continue until the position is filled.

Cornell University is an innovative Ivy League university and a great place to work. Our inclusive community of scholars, students and staff impart an uncommon sense of larger purpose and contribute creative ideas to further the university's mission of teaching, discovery and engagement. Located in Ithaca, NY, Cornell's far-flung global presence includes the medical college's campuses on the Upper East Side of Manhattan and in Doha, Qatar, as well as the new CornellNYC Tech campus to be built on Roosevelt Island in the heart of New York City.

Diversity and Inclusion are a part of Cornell University's heritage. We are a recognized employer and educator valuing AA/EEO, Protected Veterans, and Individuals with Disabilities.

an M.A. in Geography, a Ph.D. in Geography and Urban Regional Analysis, and participates in an interdisciplinary Ph.D. program in Public Policy. The Department of Geography and Earth Sciences is an interdisciplinary community of social and physical scientists with over 30 faculty members and more than 100 graduate students, and is housed within the College of Liberal Arts and Sciences. As the largest college at UNC Charlotte, the College of Liberal Arts & Sciences comprises 20 departments in the humanities, social sciences, natural sciences, and military sciences, as well as 24 applied research centers and interdisciplinary programs. It offers eight doctoral degrees, 34 master's degrees and graduate certificates and 34 undergraduate degrees. UNC Charlotte is a rapidly growing doctoral-granting urban university located in the state's largest metropolitan area. The University is a Carnegie Foundation Community Engagement campus. More than 27,000 culturally diverse students are currently enrolled at the University. Review of applications will begin October 28, 2016, and continue until the position is filled. Applications must be submitted electronically at https://jobs.uncc.edu and include: 1) a letter of application, 2) a curriculum vitae, 3) a statement of research interests, 4) a teaching statement, 5) a diversity statement and 6) the names and contact information of three references. All applicants are subject to criminal background checks. As a college with diverse faculty, staff, and students, finalists will be asked during their screening interviews to discuss how the topics of diversity and inclusion are incorporated into their teaching, research, and service. As an EOE/AA employer and an ADVANCE Institution that strives to create an academic climate in which the dignity of all individuals is respected and maintained, the University of North Carolina at Charlotte encourages applications from all underrepresented groups. We strongly encourage prospective candidates to visit the Department website (http://geoearth.uncc.edu) prior to applying. For additional information, contact Dr. Sara Gagné, Search Committee Chair, at 1-704-687-5911 or sgagne@uncc.edu.

Postdoctoral Research Associate in Understanding Cryosphere-Aerosol Interactions Over High Mountain

The Atmospheric and Oceanic Sciences Program at Princeton University, in association with NOAA's Geophysical Fluid Dynamics Laboratory (GFDL), seeks a postdoctoral or more senior candidate for research related to how cryosphere-aerosol interactions affect hydroclimate variability over High Mountain Asia. A key focus will require comparing observations and high-resolution global climate model output to understand hydroclimate variability over High Mountain Asia with a particular emphasis on the cryosphere-aerosol interactions and related processes. This will include an assessment of presently available and future developmental satellite-based data products and other regional observational or model-based reanalyses. This will also include an assessment of aerosol-climate interactions in the region and targeted analysis to better understand how aerosol deposition and its variability may affect regional hydroclimate in both the historical record and the future. The research will also examine how the cryosphere and hydroclimate respond to natural variability and radiative forcing changes over the next 100 years. This position will provide the opportunity for collaboration within GFDL and Princeton University, as well as with members of the NASA High Mountain Asia Team at various institutions. Travel to meet with collaborators will be encouraged, but not required.

The selected candidate will have one or more of the following attributes: (a) a strong background in hydroclimate, climate dynamics, snow hydrology, cryosphere science, or a closely related field; (b) experience using and analyzing advanced climate models and observational datasets (including remote sensing data); (c) strong diagnostic skills in analyzing large data sets.

Candidate must have a PhD. Initial appointment is for one year with the possibility of renewal subject to satisfactory performance and available funding.

Complete applications, including a CV, publication list, at least 3 letters of recommendation, and a short statement of research interests should be submitted by December 1, 2016 for full consideration.

Applicants must apply online to http://jobs.princeton.edu, Requisition #1600844. For additional information, you may contact Dr. Sarah Kapnick (sarah.kapnick@noaa.gov) or Dr. Paul Ginoux (paul.ginoux@noaa.gov).

This position is subject to the University's background check policy. Princeton University is an equal opportunity/affirmative action employer and all qualified applicants will receive consideration for employment without regard to age, race, color, religion, sex, sexual orientation, gender identity or expression, national origin, disability status, protected veteran status, or any other characteristic protected by law.

INTERDISCIPLINARY

Assistant Professor

Department of Earth and Environmental Sciences at California State University East Bay invites applications for an assistant professor tenure-track position in Environmental Geoscience to begin in Fall 2016. The successful candidate will be broadly trained in geoscience, with a specialization related to surficial processes and sustainability, such as the effects of landslides and mass wasting, sea level rise, urban riparian landscape restoration, etc. The person filling this position should be qualified to teach a range of undergraduate courses in the department's Geology and/or Environmental Science programs, and courses in the candidate's area of expertise. Candidates with expertise and advanced degrees in Earth science, environmental science, geomorphology, civil/environmental engineering, etc. are strongly encouraged to apply. Applicants should have a Ph.D., outstanding teaching skills, and a commitment to pursue an active research and teaching program in partnership with other faculty engaged in sustainability issues at CSUEB. Review of applications will begin November 1, 2016, and the position will be considered open until filled (applications after November 1 will be accepted). Please see the full position announcement at: https://apply.interfolio.com/35239. CSUEB is an Equal Opportunity Employer.

Questions? Please contact Mike Massey at mike.massey@csueastbay.edu.

Endowed Chair

The Department of Earth, Atmospheric, and Planetary Sciences at Purdue University invite applications for the Steven and Karen Brand Chair in unconventional energy resources. Candidates with a core expertise in unconventional energy with a strong and consistent track record of applying this expertise to unconventional petroleum resources will be considered. Candidates with expertise including, but not limited to, unconventional exploration and production, tight reservoir characterization, geophysics and seismic data analysis, subsurface integration, hydraulic fracture mechanics, pore/fluid interactions, water and environmental issues, and enhanced oil and gas recovery are encouraged to apply. Excellence in and/or commitment to multi-disciplinary research and teaching is a requirement. It is expected that the candidate hired would significantly enhance Purdue's visibility and impact in this key area; increase opportunities for industry collaboration and grant funding; and inspire and train the next generation of leaders in the field.

This is an open-rank search; senior or mid-career scientists with academic, national laboratory, and industry background are all encouraged to apply. Applicant must hold a doctorate in an appropriate field; salary and rank are commensurate with qualifications and experience. The Department of Earth, Atmospheric, and Planetary Sciences, and the College of Science at Purdue embrace diversity and seek candidates who will have experience working with diverse groups.

The department, in collaboration with other departments, has expertise in solid earth geophysics and crustal seismology, fracture mechanics, fluid flow in porous media, hydrogeology,

NANYANG TECHNOLOGICAL UNIVERSITY

Smithsonian-NTU Programme Coordinator

Young and research-intensive, Nanyang Technological University (NTU Singapore) is ranked 13th globally. It is also placed 1st amongst the world's best young universities. In 2015 the newly established Asian School of the Environment (ASE) at NTU embarked on a long-term partnership with the Forest Global Earth Observatory programme of the Smithsonian Institution (ForestGEO) to capitalise on the strengths and dynamism of both institutions. Together, NTU and ForestGEO will collaborate on research, training and capacity development in forest science, and to create a cosmopolitan hub for forest ecology in Asia.

ASE and ForestGEO invite applications for the position of Programme Coordinator for the ForestGEO Asia Programme. The position will oversee and coordinate ForestGEO activities in Asia, implement and guide future research directions, foster collaboration that encourages broad use of the regional network, conduct independent research related to the ecology of Asian forests, lead training and capacity strengthening activities for students and researchers associated with ASE and ForestGEO sites, seek external funding, and promote ForestGEO and ASE to diverse audiences.

The successful candidate will have a PhD in ecology or related field (including but not limited to population and community ecology, physiological ecology, ecosystem science, global change biology, and plant systematics and evolution), at least 5 years' experience working on the forests of tropical Asia, and have knowledge on data management and ecological analysis.

Application Procedure:
Interested candidates should submit a single PDF containing a summary of research accomplishments and interests, curriculum vitae, thee significant reprints, and the names and contact information of three referees to Ase_humanresources@ntu.edu.sg. We regret that only shortlisted candidates will be notified. More information can be found at www.ase.ntu.edu.sg/careers and http://www.forestgeo.si.edu/ or by contacting Stuart Davies (daviess@si.edu).

www.ntu.edu.sg

clay mineralogy and surface chemistry, and basin analysis. The department has a long tradition of training students for careers in the petroleum industry and is part of a new multidisciplinary initiative at Purdue University aimed at addressing the energy needs of the country and is affiliated with the newly established Enhanced Oil Recovery Laboratory located in Discovery Park. Faculty members have a long history of working closely with and providing leadership to various Purdue University Discovery Park Centers (www.purdue.edu/DP). The successful applicant will conduct research, will advise graduate students, will teach undergraduate and graduate level courses, and will perform service. The successful applicant will be expected to work across these existing areas of Purdue expertise and build on them with a focus on unconventional resources. Applicants should have a vision for the design and execution of a cross-functional program that achieves the intended mission as described above.

Interested applicants should visit https://hiring.science.purdue.edu; submit a curriculum vitae, a research statement, a vision statement, a teaching statement, and complete contact information for at least 3 references. Review of applications will begin October 31, 2016, and continue until the position is filled. Questions related to this position should be sent to Ken Ridgway, Chair of the Search Committee, email ridge@purdue.edu. Applications will be accepted until the position is filled.

Purdue University is a dynamic, growing university and a great place to work. Our inclusive community of scholars, students and staff impart an uncommon sense of larger purpose and contribute creative ideas to further the university's mission of teaching, discovery and engagement.

Purdue University is an EOE/AA employer. Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. All qualified applicants for employment will receive consideration without regard to race, religion, color, sex, national origin or ancestry, genetic information, marital status, parental status, sexual orientation, gender identity and expression, disability or status as a veteran.

Lindahl Ph.D. Scholarships

Lindahl Ph.D. Scholarships: The University of Alabama, Department of Geological Sciences seeks Ph.D. students with specializations that complement faculty research interests. Exceptional students will receive Research or Teaching Assistantships and a Lindahl Scholarship totaling $22,000 for a nine month appointment, and the cost of non-resident tuition is covered. Funding is renewable for 4 years if expectations are met. Other fellowships are available from the Graduate School. Further details are at http://www.geo.ua.edu/. Applicants should contact Dr. Robinson (dmr@ua.edu) to express interest. Review of applications for Fall 2017 admission will begin January 15, 2017.

Open Rank Faculty

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN (UIUC). The Department of Civil and Environmental Engineering (CEE) at the University of Illinois at Urbana-Champaign invites applications for multiple full-time tenured or tenure-track faculty positions; all ranks will be considered. The Department seeks to expand its expertise in emerging interdisciplinary areas that are critical in addressing global challenges through innovative education and research and aligned with CEE cross-cutting programs related to sustainability, resilience, risk mitigation, and water and energy systems research. Desired areas of expertise are: Sustainable and Smart Infrastructure. Development of innovative materials, technologies, and models for the design, construction, and management of sustainable and functional civil infrastructure, encompassing one or more of the following areas: smart materials that enable adaptive, multi-functional, self-repairing or sensing properties; sustainable materials including alternative and green binders, materials that enable carbon sequestration, advanced polymeric and nanoscale materials, and those with enhanced durability; multi-scale computational material models for sustainable performance; life cycle assessment; sensing and monitoring technologies; construction management; and development of intelligent and automated systems for the design, construction, and management of infrastructure including smart structures, roads, and energy grids. Multimodal Transportation. Development of transformative methods for observation, forecasting, planning, management, and control of complex multimodal transportation; integration of peta-scale computing, networked sensing, big data applications, and other interdisciplinary approaches for enhanced mobility, resilience, and sustainability of next-generation transportation systems; infrastructure and systems supported by emerging technologies such as autonomous and connected vehicles. Qualified candidates may be considered for one endowed chair-level position funded under the $100-million Grainger Engineering Breakthroughs Initiative (http://graingerinitiative.engineering.illinois.edu), in the following area: Climate-Driven Risks to Natural and Built Environments in the Age of Big Data. Environmental and earth system sensing, monitoring, and modeling, including Big Data approaches. The research should focus on topics related to air, water, and/or earth surface and subsurface modeling to characterize and pose solutions to problems including, but not limited to, increase in demand for energy, variability in extreme hydroclimatic events, ecosystem and climate changes, climate-driven migration, interactions between natural and built environment, and emergence and control of environmental pathogens associated with climate change and human activities. The successful candidates are expected to develop and maintain an internationally recognized research program, to contribute fully to teaching of undergraduate and graduate courses, and to provide service to the profession and university. Successful candidates are also expected to develop interactions with faculty across the department, college and campus. Opportunities exist to participate in related CEE and campus-wide communities, such as the Micro and Nanotechnology Laboratory, Prairie Research Institute, Illinois Center for Transportation, MAE Center (Creating a Multi-hazard Approach to Engineering), the National Rail Transportation Center, the Information Trust Institute, the National Center for Supercomputing Applications, the Institute of Genomic Biology, the Safe Global Water Institute, the Illinois State Geological Survey, as well as nine other Engineering Departments. Applicants must hold an earned doctorate in an appropriate field. Salary and rank will be commensurate with qualifications. Please create your candidate profile through https://jobs.illinois.edu and upload your application cover letter (addressed to Professor Benito J. Mariñas, Department Head, Department of Civil and Environmental Engineering, 1114 Newmark Civil Engineering Laboratory, 205 North Mathews Avenue, Urbana, IL 61801. Telephone: 217-333-6961), curriculum vitae, a concise summary of past research accomplishments and any teaching experience, a statement of future research and teaching plans, and complete contact

FACULTY POSITIONS IN GEOPHYSICS
University of Southern California

Director of the Southern California Earthquake Center and Professor of Earth Sciences, University of Southern California

The Dana and David Dornsife College of Letters, Arts and Sciences of the University of Southern California in Los Angeles, California, seeks a senior earthquake scientist to lead the **Southern California Earthquake Center (SCEC)** as its director and principal investigator. The appointment will be made at the tenured faculty level (Associate Professor or Professor) in the Department of Earth Sciences (http://dornsife.usc.edu/earth/). The SCEC director will oversee a world-leading program in earthquake system science that currently involves over 1000 earthquake experts at more than 70 universities and research institutions. The successful candidate will have a strong record of federally funded earthquake research, innovative ideas about the future of earthquake science, and the ability to articulate scientific results to end-users and the general public. She or he will be knowledgeable about the application of advanced computational methods to solve system-level problems, including the use of physics-based methods for earthquake forecasting. Doctoral degree and teaching experience is required.

Applications should include a curriculum vitae, publication list, statement of teaching and research interests, and three names of individuals familiar with the applicant's work who could be contacted for letters of reference. It should also include a vision statement on how, as SCEC director, the applicant would move forward the Center's research program. In order to be considered for this position, applicants are required to submit an electronic USC application through the following link: http://jobs.usc.edu/postings/68664 .

Tenure-Track Faculty Position in Global Geophysics, University of Southern California

The **Department of Earth Sciences** in the Dana and David Dornsife College of Letters, Arts and Sciences of the University of Southern California in Los Angeles, California, invites applications for a faculty position in global geophysics at the tenure-track Assistant Professor or tenured Associate Professor level. We seek candidates who will develop a program of fundamental research on the structure, deformation, and/or evolution of the lithosphere and its interactions with the Earth's deep mantle and fluid envelopes. The successful candidate will bring new approaches—observational, experimental, computational, and/or theoretical—to lithospheric studies and will demonstrate a strong commitment to both graduate and undergraduate teaching. We are particularly interested in candidates who can connect research on lithospheric problems to other areas of departmental interest, which include global environmental change, geobiology, and earthquake system science (http://dornsife.usc.edu/earth/). Applicants must have a PhD in a related field.

Applications should include a curriculum vitae, publication list, statement of teaching and research interests, and three or more names of individuals familiar with the applicant's work who could be contacted for letters of reference. In order to be considered for this position, applicants are required to submit an electronic USC application through the following link: http://jobs.usc.edu/postings/67388 .

Tenure-Track Faculty Position in Earthquake Science, University of Southern California

The **Department of Earth Sciences** of the Dana and David Dornsife College of Letters, Arts and Sciences of the University of Southern California (Los Angeles, California) invites applications for a tenure-track Assistant Professor position in earthquake science at the junior level. We seek exceptional individuals who can develop a world-class program of research, and have a strong commitment to both graduate and undergraduate teaching. Candidates specializing in any aspect of earthquake science, including seismology, tectonic geodesy, earthquake geology, and computational geophysics, will be considered. The successful candidate will bring new approaches—observational, experimental, computational, and/or theoretical—to earthquake studies. We are particularly interested in candidates whose research links earthquake science to the fundamental issues of lithospheric deformation and geodynamics and to other areas of departmental interest (http://dornsife.usc.edu/earth/). The candidates will be evaluated based on their overall originality and promise of work over any specific area of specialization.

Applicants must have a doctoral degree by time of appointment. Applications should include a curriculum vitae, publication list, statement of teaching and research interests, and three or more names of individuals familiar with the applicant's work who could be contacted for letters of reference. Review of complete applications will begin November 1, 2016. In order to be considered for this position, applicants are required to submit an electronic USC application through the following link: http://jobs.usc.edu/postings/74983 .

Inquiries can be directed to: Chair, Search Committee, c/o Karen Young (kayoung@usc.edu). Review of complete applications will begin November 1, 2016.

USC is an equal-opportunity educator and employer, proudly pluralistic and firmly committed to providing equal opportunity for outstanding persons of every race, gender, creed and background. The University particularly encourages women, members of underrepresented groups, veterans and individuals with disabilities to apply. USC will make reasonable accommodations for qualified individuals with known disabilities unless doing so would result in an undue hardship. Further information is available by contacting uschr@usc.edu .

Applied Geoinformatics—Dartmouth College

The Department of Earth Sciences at Dartmouth College invites applications for a junior rank tenure-track position in the area of geoinformatics with application to one or more of our core research areas including i) ice and climate systems, ii) water and environmental biogeochemistry, and iii) planetary evolution and surface processes. We especially welcome applications from candidates who link traditional geologic approaches and state-of-the-art computational geoinformatics in their research. Particular attention will be given to candidates who combine a focus on understanding fundamental processes with laboratory and/or field research programs that complement and contribute to ongoing research activities in the Departments of Earth Sciences, Mathematics, and Computer Sciences, as well as the Thayer School of Engineering. The successful candidate will continue Dartmouth's strong traditions in graduate and undergraduate research and teaching. Teaching responsibilities consist of three courses spread over three of four ten-week terms.

The Department of Earth Sciences is home to 11 tenured and tenure-track faculty members in the School of Arts and Sciences, and enjoys strong Ph.D. and M.S. programs and outstanding undergraduate majors. To create an atmosphere supportive of research, Dartmouth College offers new faculty members grants for research-related expenses, a quarter of sabbatical leave for each three academic years in residence, and flexible scheduling of teaching responsibilities.

Dartmouth College has undergraduate and graduate student populations that are diverse by many measures. We seek applicants with a record of successful teaching and mentoring of students from all backgrounds (including first-generation college students, low-income students, racial and ethnic minorities, women, LGBTQ, etc.). Dartmouth provides opportunities to participate in undergraduate diversity initiatives in STEM research, such as our Women in Science Program, E. E. Just STEM Scholars Program, Academic Summer Undergraduate Research Experience (ASURE), and the Mellon Mays Undergraduate Fellowship.

Dartmouth, a member of the Ivy League, is located in Hanover, New Hampshire (on the Vermont border). Dartmouth has a beautiful, historic campus located in a scenic area on the Connecticut River. Recreational opportunities abound all year round.

To learn more about Dartmouth College and the Department of Earth Sciences, visit http://www.dartmouth.edu/~earthsci.

To submit an application, upload a cover letter, curriculum vitae, statements of teaching and research interests and objectives, reprints or preprints of up to three of your most significant publications, and the name, address (including street address), e-mail address and fax/phone numbers of at least three references to: https://apply.interfolio.com/37126

Application review will begin November 1, 2016, and continue until the position is filled. The appointment will be effective July 1, 2017.

Dartmouth College is an equal opportunity/affirmative action employer with a strong commitment to diversity. In that spirit, we are particularly interested in receiving applications from a broad spectrum of people, including women, minorities, individuals with disabilities, veterans or any other legally protected group.

information of at least three references by November 1, 2016 to ensure full consideration. The starting date is negotiable, but is preferred to be August 16, 2017. Information about the department may be found at our website at http://cee.illinois.edu/. Urbana-Champaign offers the residential advantages of a medium-sized university city, excellent cultural opportunities, and a high quality of life as reflected by its ranking as one of the Great Neighborhoods in America by the American Planning Association: http://www.planning.org/greatplaces/neighborhoods/2007/westurbana.htm. The University of Illinois conducts criminal background checks on all job candidates upon acceptance of a contingent offer. Illinois is an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, religion, color, national origin, sex, sexual orientation, gender identity, age, status as a protected veteran, status as a qualified individual with a disability, or criminal conviction history. Illinois welcomes individuals with diverse backgrounds, experiences, and ideas who embrace and value diversity and inclusivity. (www.inclusiveillinois.illinois.edu). We have an active and successful dual-career partner placement program and a strong commitment to work-life balance and family-friendly programs for faculty and staff (http://provost.illinois.edu/worklife/index.html).

Postdoc Fellowships in Cosmochemistry, Geochemistry, Geophysics, Planetary Science, and Volcanology

Applications are invited for postdoctoral fellowships in the fields of cosmochemistry, solid-Earth geochemistry and geophysics, planetary science, and volcanology at Carnegie's Department of Terrestrial Magnetism. These fellowships provide salary, travel, and research support for creative independent research. Details on DTM research staff, laboratory facilities, and ongoing research can be found at http://dtm.carnegiescience.edu. Fellowships begin in Fall 2017 and are for one year, but are normally renewable for a second year.

Applications should be submitted online at https://jobs.carnegiescience.edu/jobs/dtm and should include a curriculum vitae and bibliography, description of thesis research, and a short (2–3 page) statement of research plans for the fellowship period. Creativity in the proposed research figures heavily in the evaluation of the application. Three letters of recommendation by those familiar with your work should also be submitted online. Submission details are available when you click on "Apply Now." Application deadline is December 1, 2016. Please email any questions you have to dtmfellowships@carnegiescience.edu.

Georgia Institute of Technology
Faculty Position in Climate Sciences

The School of Earth and Atmospheric Sciences at Georgia Tech invites applications for tenure-track faculty positions in climate sciences. We are seeking candidates interested in understanding the mechanisms of the climate system through a variety of approaches, including theory, development and application of models of variable complexity, and synthesis of observational data. Areas of particular interest to the department include atmospheric and climate dynamics, ocean-atmosphere interactions, extreme weather events, land-atmosphere interactions, hydroclimate, cryosphere, and paleoclimate. We anticipate several climate-related hires in coming years, and are seeking to establish the school as a leader in both the fundamental science of climate and in addressing climate change with scientifically driven solutions. Applicants at the Assistant Professor level are sought, although outstanding individuals at all levels will be considered. The successful candidate will develop a vibrant research program in a dynamic interdisciplinary environment, teach, support and mentor students from diverse backgrounds at both undergraduate and graduate levels.

Georgia Institute of Technology is located in Atlanta, Georgia and is consistently a top ranked educational and research institution. For more information about our School and academic programs, visit www.eas.gatech.edu. Applicants should send an application letter, curriculum vitae, a statement of research and teaching interests, and the names and contact information for at least three references through the online portal at: https://academicjobsonline.org/ajo/jobs/8099. Requests for information and pre-application enquiries from senior candidates should be directed to Dr. Jean Lynch-Stieglitz, Search Committee Chair, at jean@eas.gatech.edu. Applications will be considered beginning December 1, 2016, but the search will continue until the positions are filled. An earned doctorate is required before start of employment. Georgia Institute of Technology an equal education/employment opportunity institution.

The Carnegie Institution is an Equal Opportunity Employer. All qualified applicants will receive consideration for employment and will not be discriminated against on the basis of gender, race/ethnicity, protected veteran status, disability, or other protected group status.

Weiss Visiting Professor

We are soliciting applications for the Wiess Visiting Professor in the Department of Earth Science at Rice University. Our department has lively research programs in

1. Carbonate and Clastic Sedimentology and Coastal Processes
2. Paleoclimatology
3. Atmospheric Chemistry
4. Biogeochemistry
5. Geobiology
6. Low and High Temperature Geochemistry
7. Petrology
8. Rock Physics and Geomechanics
9. Environmental, Exploration, Solid Earth and Theoretical Seismology
10. Crustal and Mantle Structure and Geodynamics
11. Planetary Science

We invite applications from established scientists whose research falls in any of these areas, and request that you identify one or more of our faculty whose research interests overlap yours. The department is characterized by collegiality and interdisciplinary research. Our faculty have ties to the Rice Departments of Biosciences, Chemistry, Computational and Applied Mathematics, Mechanical Engineering, and Physics and Astronomy. We also have strong ties to the local petroleum industry, the NASA Johnson Space Center, and the Lunar Planetary Institute.

The Wiess Visiting Professorship provides travel expenses to and from Rice, and living expenses while in residence, details are negotiable. Visiting Professors are typically in residence from a few months to a full academic year. Ideally Wiess Visiting Professors interact at a high level with members of our department, often through topical seminars. We particularly encourage women and minority geoscientists to apply.

See: http://earthscience.rice.edu for more details about our Department, and http://earthscience.rice.edu/directory/wiess-visiting-professor/ for a list of previous Wiess Visiting Professors.

Please provide a curriculum vita, research statement, and indication of availability. Applications and inquiries can be sent to

Chair, Wiess Visiting Professor Committee

Department of Earth, Environmental and Planetary Science

Rice University, MS-126

6100 Main Street

Houston, TX 77005

or

esci-search@rice.edu

Please put Wiess Visiting Professor on the subject line.

Rice University, located in Houston, Texas, is a private, coeducational, nonsectarian university that aspires to path-breaking research, unsurpassed teaching, and contributions to the betterment of our world. Rice fulfills this mission by cultivating a diverse community of learning and discovery that produces leaders across the spectrum of human endeavor. From its beginning in 1912, Rice has been dedicated to excellence in all regards.

Rice University is an Equal Opportunity Employer with commitment to diversity at all levels, and considers qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national or ethnic origin, genetic information, disability or protected veteran status.

Wiess Post-Doctoral Research Fellowship

The Department of Earth Science at Rice University is inviting applications for the Wiess Post-Doctoral Research Fellowship in the broad fields of Earth, atmospheric, and planetary sciences.

Applicants must have a Ph.D. awarded within three years of the time of appointment.

The research fellowship will be supported by the Department of Earth Science for two years pending satisfactory progress in their first year. The fellowship covers an annual stipend of $60,000 with a benefits package and an additional annual discretionary research allowance of $3,500.

Applicants are requested to develop a proposal of research to be undertaken during the fellowship period. The principal selection criteria are scientific excellence and a clearly expressed research plan to address questions at the forefront of Earth science, broadly defined. Applicants are encouraged to explore possible research synergies with faculty in the Department of Earth Science (http://earthscience.rice.edu), but the proposed research should encompass independent research ideas and explore new directions beyond the applicant's Ph.D. Preference will be given to candidates whose proposals demonstrate independence and originality, and also the potential for collaboration with one or more faculty in the Department of Earth Science.

Candidates are required to submit:

1. A cover letter addressed to the search committee chair
2. A research proposal of no more than 3 pages (single-spaced) including figures
3. A current CV, including a list of publications

All documents should be submitted as a single PDF file by 15 November, 2016, to the chair of the fellowship search committee (esci-postdoc@rice.edu). In addition, three letters of reference should be submitted separately by each referee to the chair of the fellowship chair committee (esci-postdoc@rice.edu) by 15 November, 2016.

The highest ranked candidates will be invited to visit Rice in early 2017. Following acceptance, the appointment may begin anytime before January 1st 2018. For further information or questions contact the chair of the search committee at esci-postdoc@rice.edu.

Rice University, located in Houston, Texas, is a private, coeducational, nonsectarian university that aspires to path-breaking research, unsurpassed teaching, and contributions to the betterment of our world. Rice fulfills this mission by cultivating a diverse community of learning and discovery that produces leaders across the spectrum of human endeavor.

Rice University is an Equal Opportunity Employer with commitment to diversity at all levels, and considers for employment qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national or ethnic origin, genetic information, disability or protected veteran status.

PALEOCEANOGRAPHY

Assistant Professor

The Colby College Department of Geology invites applications for a tenure-track position in marine geology/geochemistry at the level of Assistant Professor to begin September 1, 2017. This position is part of a cluster hire in support of Colby's new Environmental Science initiative. Colby requires strong, innovative teaching at all levels of the undergraduate curriculum and an active research program involving undergraduate collaborators. Ideal candidates for this position also will: (1) teach a 200-level, low-temperature-geochemistry or biogeochemistry course in addition to other courses in the Geology Department; (2) present ambitious research plans focusing on the marine/coastal record of environmental change over 100–1,000,000-year timescales; and (3) strengthen collaborations between Colby College and the Bigelow Laboratory for Ocean Sciences on the coast of Maine (www.bigelow.org). There also are opportunities for collaborations with scientists at Colby and other nearby institutions including the University of Maine Climate Change Institute, Bowdoin College, and Bates College. A Ph.D. is required at the time of appointment. The search committee is especially interested in candidates with diverse perspectives and backgrounds, and candidates who have a record of success advising and mentoring individuals from groups under-represented in higher education.

Tenure-track faculty at Colby receive competitive startup packages and are eligible for a pre-tenure sabbatical. Female U.S. citizens are eligible for a Clare Booth Luce Endowed Chair

RUTGERS
Institute of Earth, Ocean, and Atmospheric Sciences

EOAS
EDUCATION. RESEARCH. DISCOVERIES.

Graduate Student Opportunities in Earth, Ocean, and Atmospheric Sciences

Rutgers University's new Institute of Earth, Ocean, and Atmospheric Sciences (EOAS) offers an exciting, interdisciplinary environment for the integrated study of our planet's atmosphere, oceans, cryosphere, solid Earth and biosphere. EOAS's strong research programs include focuses on global climate change, ocean modeling and observations, paleoceanography and Earth history, planetary science, geobiology, marine ecology, molecular ecology, and environmental biophysics. EOAS welcomes applications for graduate study toward a Ph.D. degree in Atmospheric Science, Ecology and Evolution, Geography, Geological Sciences, and Oceanography. For more information and to apply, please visit our website at **http://eoas.rutgers.edu.**

Rutgers is an Equal Opportunity/ Affirmative Action Employer.

that provides additional research funding throughout their pre-tenure probationary period. Colby faculty are afforded professional travel funding, and can apply for divisional research grants and summer research-assistant funding on a competitive basis. More information about the resources and instrumentation available at Colby and collaborating institutions can be found at: http://www.colby.edu/geologydept and http://www.colby.edu/environmentalstudies.

Complete applications will include a brief cover letter, curriculum vitae, statements of teaching philosophy and research interests, three letters of recommendation, and reprints of recent journal articles. Please submit all materials via Interfolio at: apply.interfolio.com/37632. Applications received by November 30, 2016 will receive full consideration, but applications will be reviewed until the position is filled. Inquiries may also be directed to Marinegeo@colby.edu.

Colby is a private, coeducational liberal arts college that admits students and makes employment decisions on the basis of the individual's qualifications to contribute to Colby's educational objectives and institutional needs. Colby College does not discriminate on the basis of race, color, gender, sexual orientation, gender identity or expression, disability, religion, ancestry or national origin, age, marital status, genetic information, or veteran's status in employment or in our educational programs. Colby is an Equal Opportunity employer, committed to excellence through diversity, and encourages applications from qualified persons of color, women, persons with disabilities, military veterans and members of other under-represented groups. Colby complies with Title IX, which prohibits discrimination on the basis of sex in an institution's education programs and activities. Questions regarding Title IX may be referred to Colby's Title IX coordinator or to the federal Office of Civil Rights.

For more information about the College, please visit our website: www.colby.edu.

PLANETARY SCIENCES

Assistant Professor of Planetary Materials

The Department of Earth, Atmospheric, and Planetary Sciences (EAPS), within the College of Science, Purdue University, invites applications for a tenure-track faculty position at the rank of Assistant Professor in the area of Planetary Materials. The Planetary Science Group within EAPS has an international reputation, extensive involvement in spacecraft missions, and newly developed undergraduate and graduate programs. We seek to grow and are looking for someone who conducts laboratory analysis of planetary materials or their terrestrial analogues. Candidates must have completed their PhD in an appropriate field. The appointee is expected to develop and maintain a vigorous, externally funded, internationally recognized research program and to teach and mentor students at the undergraduate and graduate levels.

Applications should be submitted electronically at https://hiring.science.purdue.edu. Applications should include a curriculum vitae, a statement of research, a teaching statement, and contact information of three individuals who can provide letters of reference. Questions related to this position should be addressed to Dr. Chris Andronicos (candroni@purdue.edu), Chair of the Search Committee. Review of applications will begin on December 1, 2016, and continue until the position is filled.

Purdue University is an EOE/AA employer. All individuals, including minorities, women, individuals with disabilities, and veterans are encouraged to apply.

Faculty position

The Department of Earth & Planetary Sciences at The University of Tennessee seeks to fill a faculty position in mineralogy/ petrology/geochemistry with emphasis in planetary geoscience at the rank of Assistant Professor. The position begins August 1, 2017. The University of Tennessee, Knoxville, is a Research I University and the flagship campus of the UT system. The Department (http://eps.utk.edu) focuses on geology and has an active emphasis on planetary research, including the study of terrestrial analogs, through its Planetary Geosciences Institute (http://web.utk.edu/~pgi). Requirements for the position are: Ph.D. in geology or a related field, and demonstrated research experience in planetary/terrestrial geoscience.

The successful candidate is expected to conduct a robust, funded program of planetary/terrestrial research, mentor graduate students, effectively teach courses in mineralogy and/or petrology at the undergraduate and graduate levels, and collaborate in department research dealing with mineralogy, petrology, geochemistry, and solar system exploration. Salary and benefits are competitive and commensurate with experience. The Knoxville campus of the University of Tennessee is seeking candidates who have the ability to contribute in meaningful ways to the diversity and intercultural goals of the University.

To apply, please email the following to jmoersch@utk.edu, with the subject line "Planetary faculty application": C.V., cover letter describing research and teaching experience and plans, and names of 4 references with contact information. Applications received by November 15, 2016, are ensured review, but earlier submission is encouraged. The position will remain open until filled. Questions about the position should be directed to J. Moersch.

The University of Tennessee is an EEO/AA/Title VI/Section 504/ADA/ADEA institution in the provision of its education and employment programs and services. All qualified applicants will receive equal consideration for employment without regard to race, color, national origin, religion, sex, pregnancy, marital status, sexual orientation, gender identity, age, physical or mental disability, or covered veteran status.

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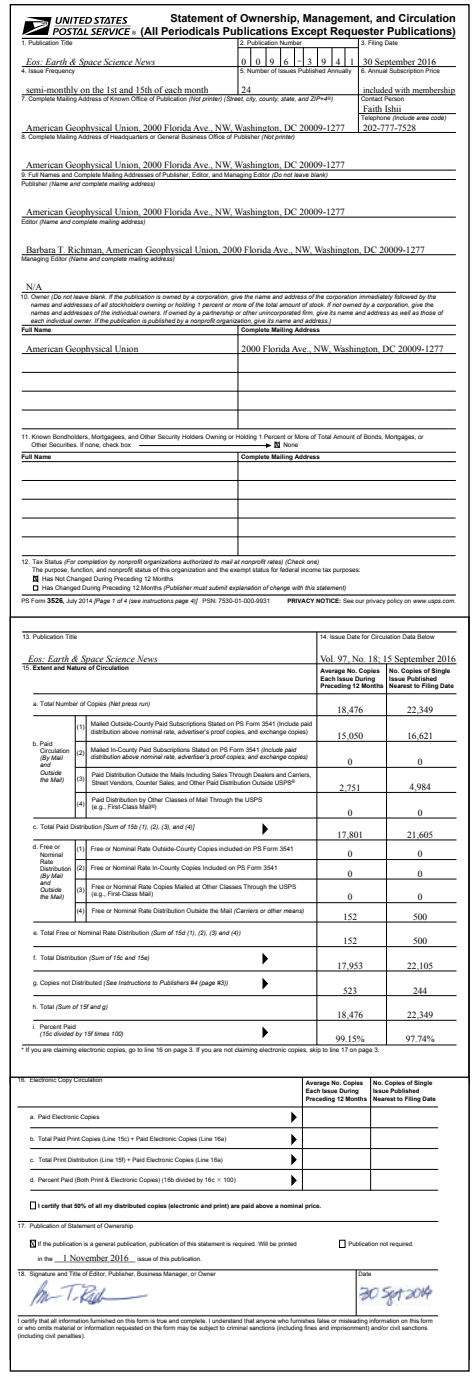

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f. Total Distribution (*Sum of 15c and 15e*)			17,953	22,105
g. Copies not Distributed (*See Instructions to Publishers #4 (page #3)*)			523	244
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i. Percent Paid (*15c divided by 15f times 100*)			99.15%	97.74%

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Postcards from the Field

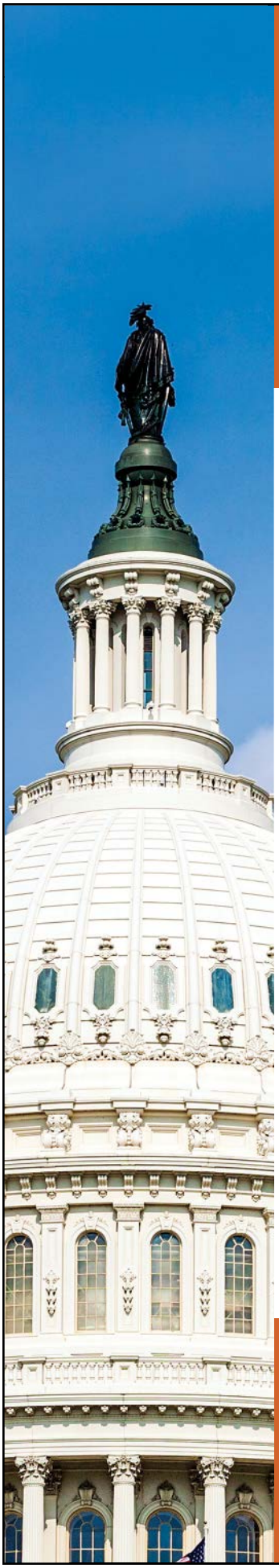
Dear Science Enthusiasts,

Here is our camp in northern Nevada, USA, where we are taking sediment cores for an NSF-sponsored paleoclimate study of the last 3000 years. This part of the world seems to be a transition zone for shifts in northern hemisphere circulation regimes, and we are obtaining samples with an array of sites that should provide insight into the spatial and temporal behavior of major climate transitions in the region.

The dark skies of the Great Basin offer capital star-gazing, and we wanted to share this view with you! When the Sun comes up, we are back to getting wet and muddy.

Cheers!
—**Scotty Strachan,** Department of Geography, University of Nevada, Reno

View more postcards at
http://americangeophysicalunion.tumblr.com/tagged/postcards-from-the-field.



Science Policy at Fall Meeting:

New Congress, New Opportunity

Monday, 12 December

One-on-One with an Attorney
8:00 A.M. – 3:00 P.M.
Moscone South: Mezzanine, Room 216

How to be a Mass Media or Congressional Science Fellow
12:30 P.M. – 1:30 P.M.
Marriott Marquis: Golden Gate B

Wednesday, 14 December

One-on-One with an Attorney
8:00 A.M. – 3:00 P.M.
Moscone South: Upper Lobby

AGU - CSLDF Legal Symposium
8:00 A.M. – 1:00 P.M.
Marriott Marquis: Salon 2

Science Policy 101: A Field Guide to Congress
12:30 P.M. – 1:30 P.M.
Moscone North: Room 120–121

Tuesday, 13 December

One-on-One with an Attorney
8:00 A.M. – 3:00 P.M.
Moscone South: Mezzanine, Room 216

Science Policy Networking Lounge
12:00 P.M. – 1:30 P.M.
Moscone West: Room 2001A

Thursday, 15 December

One-on-One with an Attorney
8:00 A.M. – 3:00 P.M.
Moscone South: Mezzanine, Room 216

Science Policy 201: Advocacy in Action
11:30 A.M. – 12:30 P.M.
Moscone West: Room 2001A

Schedule Your One-on-One with an Attorney

These brief 30-minute consultations provide an opportunity to ask any legal questions regarding your scientific work. Email lawyer@climatesciencedefensefund.org to set your appointment.

AGU
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