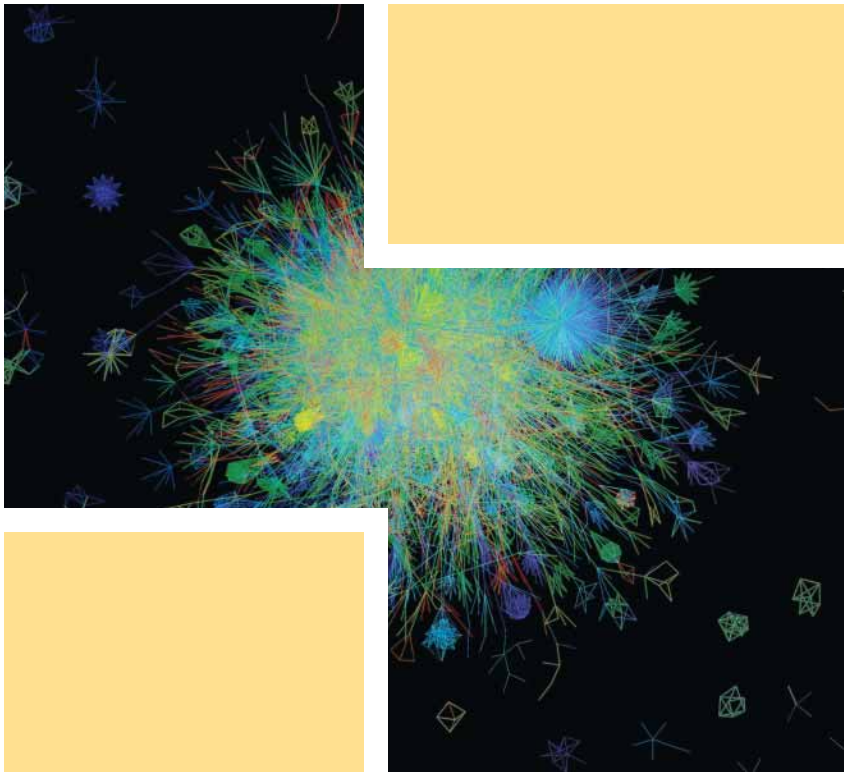
Carnegie Science

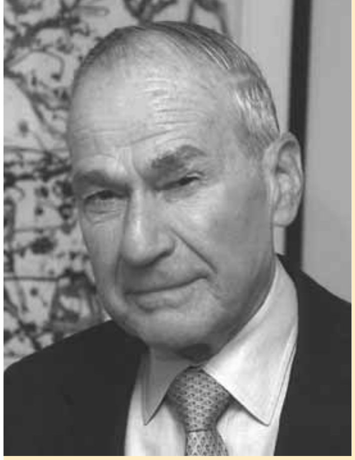
The Newsletter of the Carnegie Institution

SPRING 2010

EMBRYOLOGY ◻ GEOPHYSICAL LABORATORY ◻ GLOBAL ECOLOGY ◻ THE OBSERVATORIES ◻ PLANT BIOLOGY ◻ TERRESTRIAL MAGNETISM ◻ CASE: CARNEGIE ACADEMY FOR SCIENCE EDUCATION



On the Inside



Science has always been a collaborative enterprise. Increasingly, these collaborations are global. According to a National Science Foundation report,* international collaborations now account for more than 20% of all scientific research papers, up from less than 10% twenty years ago. This should not be surprising. Global problems like climate change and flu pandemics are of global interest. E-mail and the web now make it as easy to share data with colleagues on the other side of the world as with those on the other side of town.

Judging from this issue of *Carnegie Science*, our scientists are, if anything, ahead of the curve on this trend toward international collaboration. The science reported here reflects work with colleagues from a dozen countries on four continents. For example, Douglas Rumble of the Geophysical Laboratory and his colleagues traced the origin of nickel ores in Australia and Canada. Observatories researcher Ivo Labbé teamed up with astronomers from the Netherlands and Switzerland to discover distant blue galaxies. Plant Biology's Zhi-Yong Wang cooperated with researchers from Asia to understand antagonistic genes in rice plants. Whether on a global, cosmic, or cellular scale, Carnegie research invariably has an international reach.

Of course, science at Carnegie has always been a global affair. More than a century ago, the Department of Terrestrial Magnetism (DTM) launched globe-trotting expeditions to measure variations in the Earth's magnetic field. Today, DTM researchers and their international collaborators can be found studying earthquakes in Japan, probing mineral resources in Africa, or searching for new planets with telescopes in Australia and Chile.

Carnegie scientists in Embryology and Plant Biology have been key members of international efforts to sequence the genomes of important model organisms such as *Drosophila* (fruit fly) and *Arabidopsis* (mustard plant). The *Arabidopsis* Information Resource (TAIR), directed by Plant Biology's Eva Huala, is one of biology's most valuable databases, serving researchers in over 180 countries.

Carnegie's Observatories lead a consortium of institutions from the United States, South Korea, and Australia seeking to build the revolutionary 24.5-meter Giant Magellan Telescope, which will be sited at our Las Campanas Observatory in Chile, already an international mecca for astronomers.

Carnegie's newest department, the Department of Global Ecology, has "global" in its name. Not surprisingly, its scientists are international leaders in global issues such as climate change, ocean acidification, and rain-forest destruction. Director Chris Field cochairs a key working group of the Nobel Prize–winning Intergovernmental Panel on Climate Change. Ken Caldeira has testified before the British Parliament, and at the recent Copenhagen climate meetings Greg Asner unveiled a partnership with Google to help tropical nations monitor rain forests via the World Wide Web.

Among Carnegie's new international initiatives, one of the most exciting is the Deep Carbon Observatory, a bold international project funded by the Alfred P. Sloan Foundation to investigate carbon in Earth's deep interior and its impact on the global carbon cycle (including our beleaguered atmosphere). Geophysical Laboratory's Robert Hazen and Russell Hemley are overseeing the project, coordinating hundreds of researchers from more than two dozen countries.

I am sure Andrew Carnegie would be delighted by all this. The two main themes of his philanthropy were support for exceptional individuals and strengthening the friendly ties between nations. The work of our scientists exemplifies both visions.

Michael E. Gellert, *Chairman*

**Science and Engineering Indicators: 2010*, Chapter 5, "Academic Research and Development," available at http://www.nsf.gov/statistics/seind10/c5/c5h.htm

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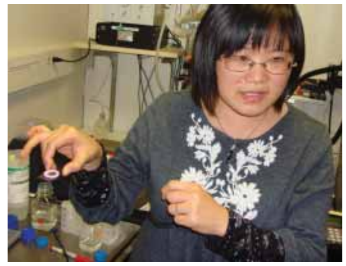
Trustees Meet and Learn About Plant Biology

Plant Biology hosted the 131st board of trustees meeting on Thursday and Friday, November 19 and 20, 2009, in Palo Alto. The Finance and Development committees and the first session of the board met Thursday in Plant Biology's seminar room. Afterward, four Plant Biology scientists discussed their work. Arthur Grossman talked about using algae for biofuels. He was followed by Devaki Bhaya, who discussed her research into the evolutionary strategies of microbes in the extreme conditions of Yellowstone's hot springs. Zhi-Yong Wang explained how steroid hormones control plant growth. And Dave Ehrhardt completed the lineup by showing dramatic images of molecules at work inside plant cells during cell-wall growth and expansion. Following the talks, attendees broke into several groups to tour Plant Biology labs and hear lab staff describe their research. That evening trustees and guests dined in the Schwab Center, where Kathryn Barton gave her talk about how genes called *LITTLE ZIPPERs* are responsible for giving plant leaves their unique organization, ensuring that cells responsible for capturing light are located on top and that cells involved in gas exchange are located on the bottom. The second session of the board concluded the meetings on Friday. □



(Top) Woei-Jiun Guo of Wolf Frommer's lab talks about how the FRET glucose sensor images glucose in living cells.

(Center) Scanning electron microscopy images, shown next to Brenda Reinhart of Kathryn Barton's lab, reveal the structure of mutant plant tissue in exquisite detail.

(Bottom) Department director Wolf Frommer hosted his first trustees' meetings as director. He is standing in front of trustees, staff, and students as they enjoy lunch outside on Thursday.

CARNEGIE TRUSTEE EMERITUS RICHARD HECKERT DIES

Richard E. Heckert, former chairman of the Carnegie board of trustees and former chairman of E. I. du Pont de Nemours and Company, died after a long illness on Sunday, January 3, at his home in Pennsylvania. Heckert was born in Oxford, Ohio, on January 13, 1924. The son of a college professor, he received his B.A. in chemistry from Miami University in Ohio in 1944, then joined the U.S. Army and worked on the Manhattan Project. After his military service, he obtained an M.A. and a Ph.D. in organic chemistry from the University of Illinois. Heckert joined the Carnegie Institution board in 1980 and was elected chairman in 1986.

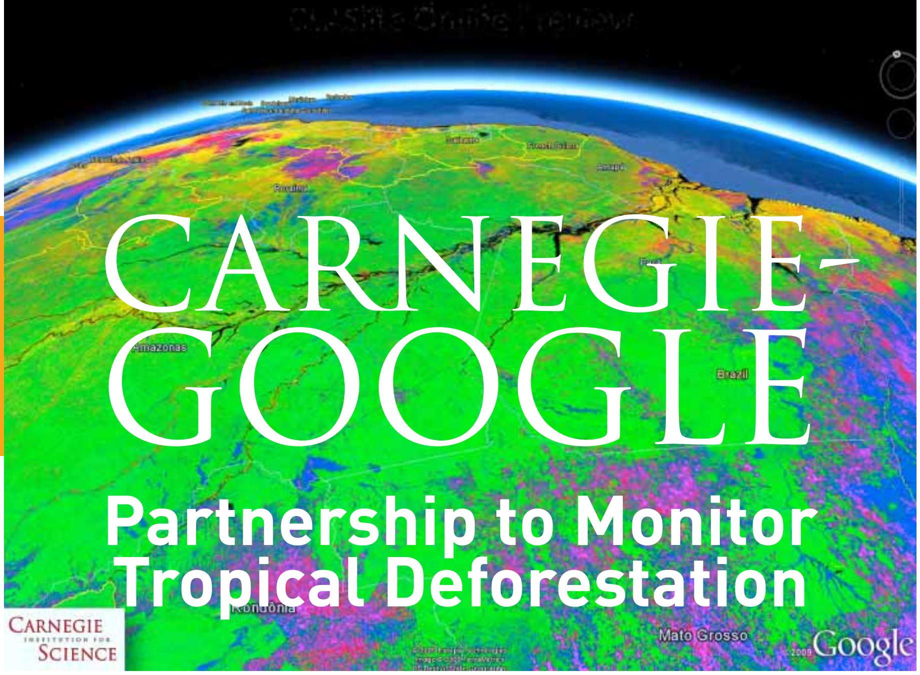
Heckert had a keen appreciation for Carnegie's scientific accomplishments and recognized the institution's need to adapt to the changing world of science. Under his leadership, the board embarked on the first capital campaign in 1989 to revitalize its scientific infrastructure and programs. With his hands-on style and dedication to research, Heckert was enormously successful in the $50 million fund-raising effort. His tireless work helped the Magellan telescope project at Las Campanas, Chile, to succeed. Even after he stepped down as Carnegie chairman in 1992, he continued to lead the campaign to its successful completion in 1996.

Heckert remained an active trustee until 1997. In addition to his distinguished fund-raising efforts and wise counsel, Heckert supported the institution generously over the years. He was a member of the Edwin Hubble Society, which honors individuals who contribute between $1 million and $10 million to Carnegie during their lifetimes.

His first wife, Barbara K. Heckert, died in 1995. Survivors include his wife, Joanna C. Heckert, a son and daughter from his first marriage, Alex Heckert of Connecticut and Andra Rudershausen of Pennsylvania, and six grandchildren. A memorial service was held at the Westminster Presbyterian Church in West Chester, Pennsylvania, on Saturday, January 16. □

(Background) Night view of the Magellan telescopes.

(Above left) Former chairman of the Carnegie board of trustees Richard Heckert, shown in the Carnegie administration library, died in January. He was a tireless advocate for the Magellan telescopes and revitalized the institution's infrastructure and programs.



CARNEGIE-GOOGLE

Partnership to Monitor Tropical Deforestation

Greg Asner's team at Carnegie's Department of Global Ecology has developed new technology that is revolutionizing forest monitoring. It marries satellite imagery and powerful analytical methods in an easy-to-use, desktop software package called CLASlite. Thus far, 70 government, nongovernment, and academic organizations in five countries have adopted the technology, with more on the horizon. Carnegie has also teamed up with Google.org to provide "CLASlite Online" via the Web (see http://claslite.ciw.edu/en/index.html). Both the new CLASlite Web site and the Carnegie-Google partnership were announced at the Copenhagen climate meetings in December 2009.

Tropical forest destruction accounts for some 20% of global greenhouse gas emissions. But quantifying these emissions has not been easy, particularly for tropical nations. To support international policy discussions and to solve on-the-ground needs for forest monitoring, CLASlite is being rapidly disseminated through a tailored, demand-driven technology transfer to government, nongovernment, and academic institutions of the Andes and Amazon regions.

"We're providing CLASlite to support the UN program for Reduced Emissions from Deforestation and Forest Degradation [REDD] and other tropical forest monitoring efforts," said Asner. "My team has already trained more than 240 users from 70 organizations in the Andes-Amazon region, and we will do more workshops in 2010."

The CLASlite software package can automatically identify deforestation and forest degradation from satellite imagery. It has a unique ability to convert seemingly green "carpets" of dense tropical forest cover in raw satellite images into highly detailed maps that can be readily searched for deforestation, logging, and other types of forest degradation. CLASlite is also a key component of a cost-effective new method developed by Carnegie that integrates satellite and airborne Light Detection And Ranging (LiDAR) mapping to support high-resolution forest carbon mapping.

"It is how we use CLASlite that will make the difference," said Guayana Paez-Acosta, the CLASlite coordinator for capacity building. "The new CLASlite user Web site is a space for collective knowledge building to improve forest monitoring and management in the Andes-Amazon region."

In 2010, the group plans to extend the training and technology transfer to other countries in the Amazon region, and will provide the Web-based version to support tropical forest mapping anywhere in the world. □

(Above) This CLASlite image of the Amazon Basin shows deforested regions in pink and blue and intact forests in green.

Image courtesy Greg Asner and the CLASlite partnership.

The CLASlite project is supported by the Gordon and Betty Moore Foundation, Google.org, and the John D. and Catherine T. MacArthur Foundation.

Carnegie Clones

With the information explosion, it's remarkable that so little is known about the interactions that proteins have with each other and the protective membrane that surrounds a cell. These interactive, so-called membrane proteins regulate the transfer of nutrients and water, sense environmental threats, and are the communications interface with neighboring cells and within the cell. With National Science Foundation funding, researchers at Carnegie's Department of Plant Biology have cloned genes to produce membrane proteins that may initiate the instructions for genes to turn on in the nucleus. They donated 2,010 of the clones for genes involved in the cell's interaction with its environment to the Arabidopsis Biological Resource Center at Ohio State University for use by other scientists to help advance fields from medicine to farming.

Recent research at Plant Biology has shown that cells across different species use the same mechanism at the cell membrane to regulate the uptake of the vital nutrient nitrogen. Previous Carnegie work indicated that plants have a novel regulatory mechanism that controls nutrient uptake—neighboring porelike structures at a plant cell's surface physically interact to control the uptake. "Since plants, animals, bacteria, and fungi all share similar genes for this activity, we wanted to see in this study if the same mechanism could occur across species," explained Dominique Loqué, former postdoc and lead author of a study published in the *Journal of Biological Chemistry*.

In this study, the researchers focused on the underlying mechanism of the pore activity by studying the effects of mutant proteins that cannot shut off pores in yeast and immature eggs of the frog *Xenopus* in the presence of ammonium.

The researchers were totally surprised that the same mechanism was found in both primitive and advanced organisms. This means that the mechanism evolved billions of years ago and was necessary for life when toxic ammonium accumulated on the early Earth. □

(Above) Dominique Loqué, former Plant Biology postdoc

This work was made possible by grants from NSF 2010 in addition to support from Carnegie.

Climate Change Puts Ecosystems on the Run

Global warming is causing climate belts to shift toward the poles and to higher elevations. To keep pace, the average ecosystem will need to shift about a quarter mile each year, says a new study led by Global Ecology scientists. For some habitats, such as low-lying areas, climate belts are moving even faster, putting many species in jeopardy, especially where human development has blocked migration paths.

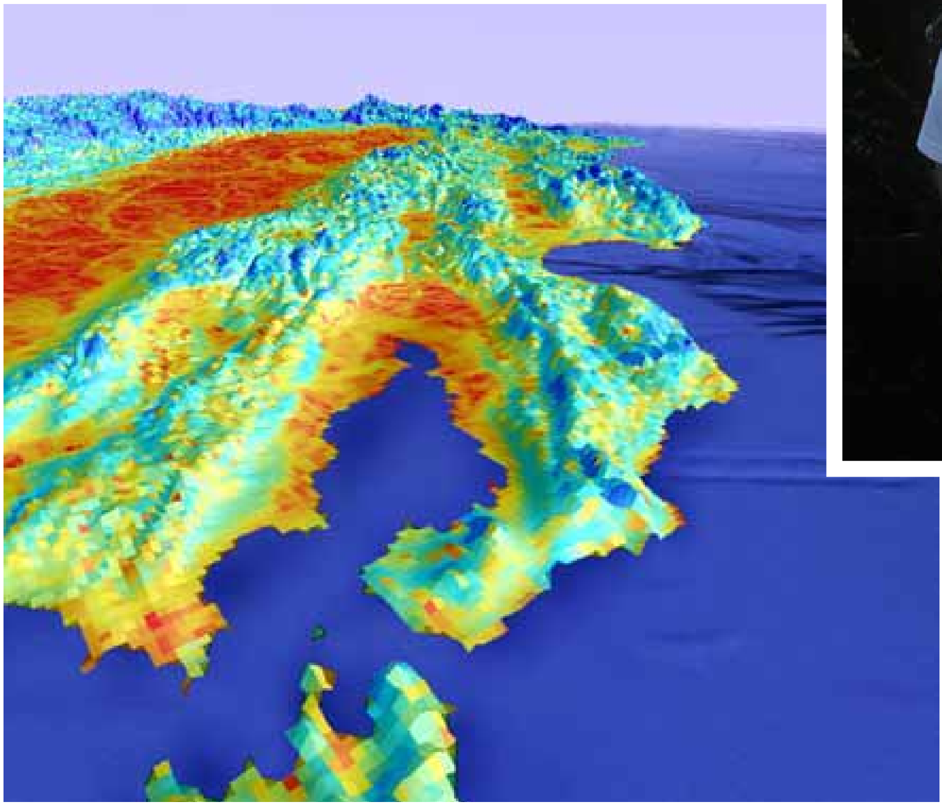
"Expressed as velocities, climate-change projections connect directly to survival prospects for plants and animals. These are the conditions that will set the stage, whether species move or cope in place," remarked director Chris Field, a coauthor of the paper.

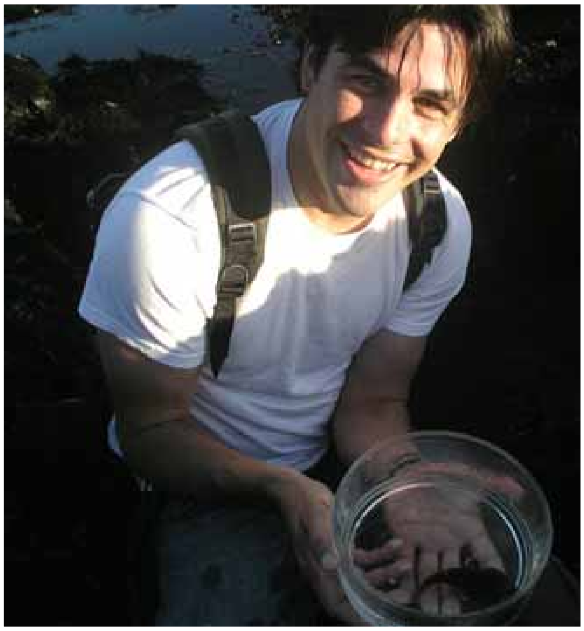
The research team, which also included postdoc Scott Loarie and Greg Asner, combined data on global climate gradients with model projections for the next century to calculate the "temperature velocity" for different regions of the world. This velocity is a measure of how fast temperature zones are moving across the landscape as the planet warms—and how fast plants and animals will need to migrate to keep up.

The researchers found that as a global average, the expected temperature velocity this century is 0.42 kilometers (0.26 miles) per year. But this figure varies widely. In areas of high topographic relief, where species can find cooler temperatures by climbing a nearby mountain, velocities are relatively low. In flatter regions, such as deserts, grasslands, and coastal areas, species will have to travel farther to stay in their comfort zone and velocities may exceed a kilometer per year.

Can ecosystems keep up? Plants and animals with broad tolerances may not need to move. But for others, survival becomes a race. After the last Ice Age, forests may have spread northward as quickly as a kilometer a year. But current ecosystems are unlikely to match that feat. Nearly a third of the habitats studied have velocities higher than even the most optimistic plant migration estimates. More problematic is the extensive fragmentation of natural habitats by human development, which will leave even mobile species with nowhere to go.

Loarie points out that understanding climate velocities could stimulate discussions about sound management for climate change, from the design of nature reserves to the planning of assisted migrations for affected species. It should also stimulate discussion about strategies for minimizing the amount of warming and thereby help slow climate velocity. □





(Left) This oblique view of California, looking south from the San Francisco Bay, shows the high climate velocity (red) in the Central Valley, with lower velocities (blue) in the mountains.

(Above) Global Ecology postdoc Scott Loarie was lead author of the paper "The Velocity of Climate Change" published in the December 24, 2009, issue of *Nature*.

Images courtesy Scott R. Loarie

Stem Cells
Don't Work as Expected

A predoctoral researcher at the Department of Embryology is the lead author on a study that overturns previous research concerning critical genes for making muscle stem cells. The study found that genes that make muscle stem cells in the mouse embryo are not needed in adult muscle stem cells to regenerate muscles after injury. The finding challenges the current course of research into muscular dystrophy, muscle injury, and regenerative medicine, and favors using age-matched stem cells for therapy. The research was published in the June 25 advance online edition of *Nature*.

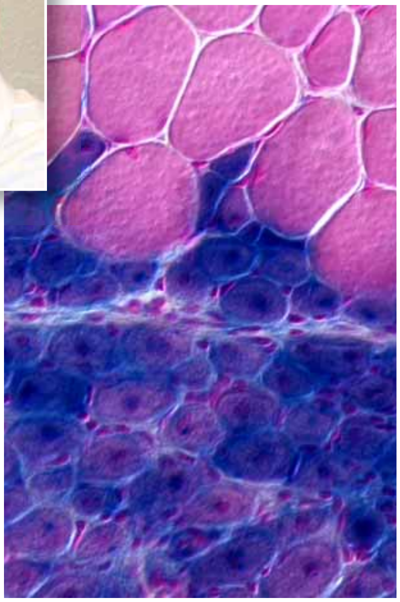
Previous studies have shown that two genes, *Pax3* and *Pax7*, are essential for making embryonic and neonatal muscle stem cells in the mouse. Lead researcher Christoph Lepper, a Johns Hopkins student in Chen-Ming Fan's lab, looked at the role of these two genes in promoting stem cells at varying stages of muscle growth in live mice after birth.

"The paired-box genes *Pax3* and *Pax7* are involved in the development of the skeletal muscles," Lepper explained. "It is well established that both genes are needed to produce muscle stem cells in the embryo. I thought that if they are so important in the embryo, they must be important for adult muscle stem cells. Using new genetic tricks, I was able to suppress both genes in the adult muscle stem cells. I was totally surprised to find that the muscle stem cells behave normally without the genes."

The researchers then looked at whether the same was true upon injury; that is, whether the repair process requires muscle stem cells to make new muscles. They were surprised again that without the two key embryonic muscle stem cell genes they were able to generate muscles as well as normal muscle stem cells.

The scientists then wondered at what point these embryonic genes are no longer needed, and found that they are involved in creating muscle stem cells only through the first three weeks after birth. They believe that the two embryonic genes also tell the stem cells to become quiet as the organism matures and then hand over their jobs to a different set of genes. Unlike embryonic and neonatal muscle stem cells, the adult muscle stem cells are activated only when an injury occurs, and hence may rely on a different set of genes. □

The research was funded by the Carnegie Institution, NIH, and the Riley Children's Foundation.



(Above) Predoctoral student at Embryology Christoph Lepper.

(Right) This cross section of hind limb muscle tissue is from a mouse five days after injury. The uninjured cells (top) are stained red. The blue cells (below) are regenerating muscle cells. They are labeled with a blue stain and formed from muscle stem cells.

Images courtesy Christoph Lepper

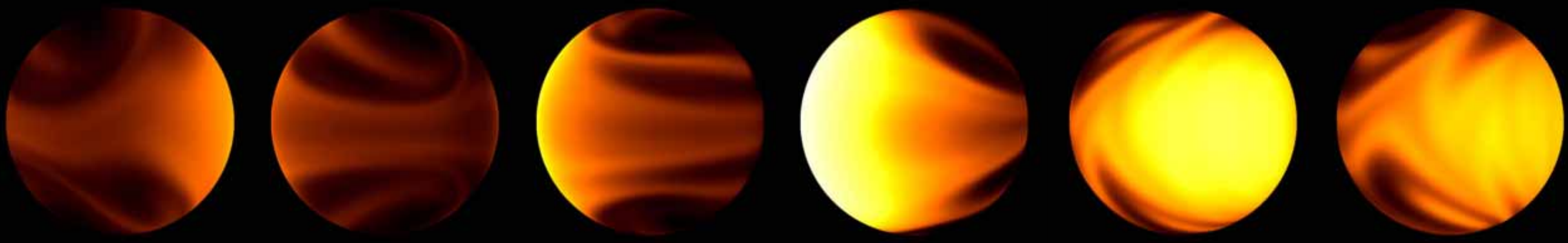
Super-Earths in the Neighborhood

Two nearby stars have been found to harbor "super-Earths"—rocky planets larger than the Earth but smaller than ice giants such as Uranus and Neptune. Unlike previously discovered stars with super-Earths, both of the stars are similar to the Sun, suggesting to scientists that low-mass planets may be common around nearby stars.

"Over the last 12 years or so nearly 400 planets have been found, and the vast majority of them have been very large—Jupiter mass or even larger," said Terrestrial Magnetism's Paul Butler, a coleader of the research team that discovered the planets. "These latest planets are part of a new trend of finding much smaller planets—planets that are more comparable to Earth."

The bright star 61 Virginis, in the constellation Virgo, is only 28 light-years from Earth and closely resembles the Sun in size, age, and other properties. Earlier studies had ruled out the existence of Jupiter-sized planets around the star, but the team found evidence of three low-mass planets. The smallest is five times the mass of Earth and orbits the star once every four days.

The other new system orbits HD 1461, a star some 76 light-years



Oxygen-Poor Atmosphere Makes for Rich Ores

Much of our planet's mineral wealth was deposited on the early Earth when chemical cycles were different from today's. Using geochemical clues from rocks nearly 3 billion years old, Carnegie scientists made the surprising discovery that the creation of economically important ore deposits was linked to sulfur in the ancient oxygen-poor atmosphere.

These ores—specifically iron-nickel sulfide deposits—yield 10% of the world's annual nickel production. They formed between 2 and 3 billion years ago when hot magmas erupted on the ocean floor. Yet scientists have puzzled over the origin of the rich deposits. The ore minerals require sulfur to form, but neither seawater nor the magmas were thought to be rich enough in sulfur for this to happen.

The Geophysical Laboratory's Doug Rumble, with former Carnegie Fellow Andrey Bekker (now at the University of Manitoba) and colleagues, used advanced geochemical techniques to analyze rock samples from major ore deposits in Australia and Canada. They found that to help produce the ancient deposits, sulfur atoms made a complicated journey from volcanic

(Above left) Sulfur in the ancient oxygen-poor atmosphere played an important role in creating economically important ore deposits. Sulfur atoms vented from volcanoes into the atmosphere found their way to hot springs on the ocean floor, where they were later absorbed by molten, ore-producing magmas.
Illustration by Peter Sawyer © Smithsonian Institution

(Above right) Isotopic anomalies in nickel minerals such as pentlandite (pictured) helped scientists understand the source of sulfur in the ore deposits.
Image courtesy U.S. Geological Survey

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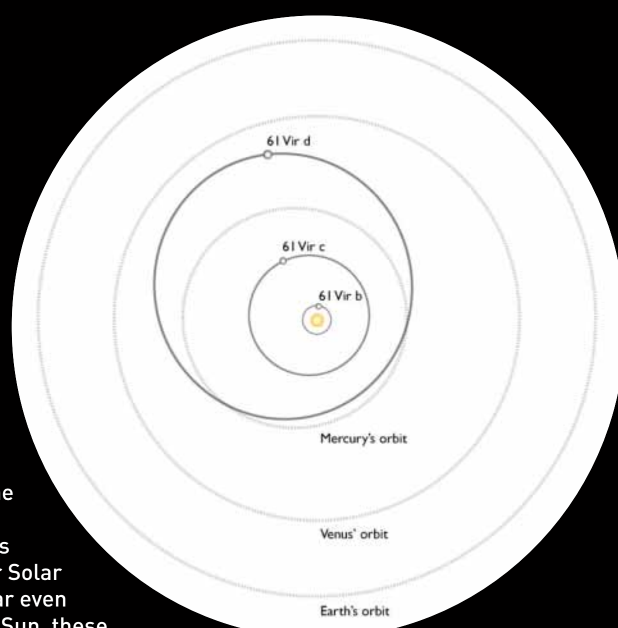
from Earth visible in the constellation Cetus. It also closely resembles the Sun. The researchers found strong evidence for one planet and possibly two others. The confirmed planet is intermediate in size between Earth and Uranus and orbits its star every six days.

The new planets in both systems are too close to their stars and too hot to support life or liquid water. But Butler said that they point the way toward similar planets in similar orbits around nearby M dwarfs, small stars that typically put out less than 2 percent of the Sun's energy. "These sorts of planets around M dwarfs actually would be in a liquid water zone," he remarked. "So we are knocking on the door right now of being able to find habitable planets."



(Left) The smallest of the planets discovered in the 61 Virginis system is also the closest to the star, orbiting it in little more than four days. These images are stills from an animation of the flow of hot gases in the atmosphere as the planet orbits the star, heating up enough to glow at visible light wavelengths.
Image courtesy J. Langton, Principia College

(Right) This diagram shows the orbits of the newly discovered super-Earths in the 61 Virginis system to scale with the inner Solar System. Approaching their star even closer than Mercury does the Sun, these planets are far too hot to support life.
Image courtesy Greg Laughlin

"Ultra-Primitive" Dust Came from Comet Tail

Stratospheric dust samples have yielded an unexpectedly rich trove of relicts from the ancient cosmos, including minute grains that likely formed inside stars that lived and died long before the birth of our Sun. This "ultraprimitive" material most probably wafted into the atmosphere after the Earth passed through the trail of an Earth-crossing comet in 2003, giving Carnegie scientists a rare opportunity to study cometary dust in the laboratory.

At high altitudes, most dust in the atmosphere comes from space, rather than from the Earth's surface. Thousands of tons of interplanetary dust particles (IDPs) enter the atmosphere each year. "We've known that many IDPs come from comets, but we've never been able to definitively tie a single IDP to a particular comet," said Terrestrial Magnetism's (DTM) Larry Nittler, a coauthor of the study.

Comets are thought to be repositories of unaltered matter left over from the formation of the Solar System. Material held for eons in cometary ice has largely escaped the heating and chemical processing that has affected other bodies, such as the planets.

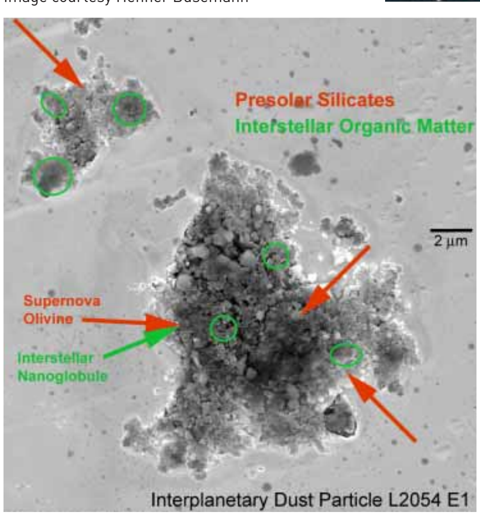
The IDPs for the current study were collected by NASA aircraft in April 2003, after the Earth passed through the dust trail of comet Grigg-Skjellerup. The research team, which included DTM scientists Nittler, Henner Busemann (now at the University of Manchester, U.K.), and Ann Nguyen, plus the Geophysical Lab's George Cody and seven other colleagues, analyzed a subsample of the dust to determine the chemical, isotopic, and microstructural composition of its grains.

"What we found is that they are very different from typical IDPs," said Nittler. "They are more primitive, with higher abundances of material whose origin predates the formation of the Solar System." The distinctiveness of the particles, plus the timing of their collection after the Earth's passing through the comet trail, points to Grigg-Skjellerup as their source.

The biggest surprise was the abundance of so-called presolar grains—tiny particles that formed in stars and supernova explosions before the formation of the Solar System. Presolar grains have unusual isotopic compositions and are generally extremely rare, with abundances of just a few parts per million in even the most primitive meteorites, and a few hundred parts per million in IDPs. "In the IDPs associated with comet Grigg-Skjellerup they are up to the percent level," Nittler remarked. "This is tens of times larger abundance than we see in other primitive materials." □

(Above) DTM's Larry Nittler was one of four Carnegie scientists to study the interplanetary dust particles from the comet Grigg-Skjellerup.
Image courtesy Larry Nittler

(Below) Scanning electron image of interplanetary dust shows particles containing presolar silicate grains and interstellar organic matter.
Image courtesy Henner Busemann



(Above) Comets, such as the comet SWAN shown here, are thought to be repositories of unaltered matter left over from the formation of the Solar System and earlier. Atmospheric dust from the tail of Grigg-Skjellerup had an unusually high abundance of presolar grains. NASA/Image courtesy nasaimages.org

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Oxygen-Poor Atmosphere Makes for Rich Ores

eruptions to the atmosphere, to seawater, to hot springs on the ocean floor, and finally to molten, ore-producing magmas.

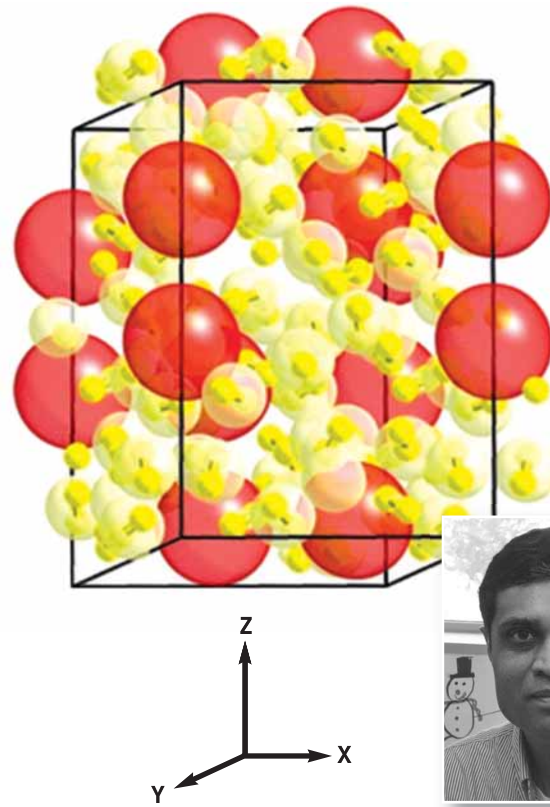
The key evidence came from sulfur-33, an isotope containing one more neutron than "normal" sulfur (sulfur-32). Both isotopes act the same in most chemical reactions, but ultraviolet light (UV) rays can cause isotopes in the atmosphere to sort, or "fractionate," into different reaction products, creating isotopic anomalies.

"If there is too much oxygen in the atmosphere, then not enough UV gets through and these reactions can't happen," said Rumble. "So if you find these sulfur isotope anomalies in rocks of a certain age, you have information about the oxygen level in the atmosphere."

Understanding the origin of the anomalies and the source of the sulfur in the ore minerals will help geologists track down new deposits, Rumble said, because the presence of sulfur can determine whether or not a deposit will form.

"Ore deposits are a tiny fraction of a percent of the Earth's surface, yet economically they are incredibly important. Modern society cannot exist without specialized metals and alloys," he continued. "But it's all a matter of local geological circumstance whether you have a bonanza—or a bust." □

Homing In On Hydrogen Storage



(Left) This schematic shows the structure of the new material, $Xe(H_2)_7$. Freely rotating hydrogen molecules (yellow) surround xenon atoms (red).

Image courtesy *Nature Chemistry*, November 22, 2009, advance online edition

(Below) Lead author, Carnegie's Maddury Somayazulu

Carnegie scientists have paved the way for an entirely new way to approach the hydrogen-storage problem by finding that high pressure can be used to make a unique hydrogen-storage material. Under pressure the normally unreactive, noble gas xenon combines with molecular hydrogen (H_2) to form a previously unknown solid with unusual bonding chemistry. The experiments mark the first time these elements have been combined to form a stable compound.

Noble gases do not typically react with other elements, and xenon has some particularly unusual properties. It's used as an anesthesia and in lighting, and it can even preserve biological tissues.

Lead author, research scientist Maddury Somayazulu at the Geophysical lab, explained the experiments: "Elements change their configuration when placed under pressure, sort of like passengers readjusting themselves as the elevator becomes full. We subjected a series of gas mixtures of xenon in combination with hydrogen to high pressures in a diamond anvil cell. At about 41,000 times the pressure at sea level (1 atmosphere), the atoms became arranged in a lattice structure dominated by hydrogen but interspersed with layers of loosely bonded xenon pairs. When we increased pressure, like tuning a radio, the distances between the xenon pairs changed—the distances contracted to those observed in dense metallic xenon."

The researchers imaged the compound at varying pressures using X-ray diffraction and infrared and Raman spectroscopy. When they looked at the xenon part of the structure, they realized that the interaction of xenon with the surrounding hydrogen was responsible for the unusual stability and the continuous change in xenon-xenon distances as pressure was adjusted from 41,000 to 255,000 atmospheres.

Why was the compound so stable? "We were taken off guard by both the structure and the stability of this material," said Przemek Dera, the lead crystallographer who looked at the changes in electron density at different pressures using single-crystal diffraction. As electron density from the xenon atoms spreads toward the surrounding hydrogen molecules, it seems to stabilize the compound and the xenon pairs.

"Xenon is too heavy and expensive to be practical for use in hydrogen-storage applications," observed Somayazulu. "But by understanding how it works in this situation, researchers can come up with lighter substitutes." □

The research, published in the November 22, 2009, advance online publication of *Nature Chemistry*, was funded by the Department of Energy, Office of Basic Energy Sciences hydrogen storage, and the National Science Foundation, Division of Materials Research.

Hawaiian Hot Spot Has Deep Roots

▽ The source of Hawaii's spectacular volcanic eruptions, seen here at Hawaii Volcanoes National Park, may be a plume of hot rock reaching 1,500 kilometers (932 miles) into the Earth's interior.
Image courtesy USGS

Hawaii may be paradise for vacationers, but for geologists it's a puzzle. Plate tectonic theory readily explains the volcanoes at boundaries where plates split apart or collide, but midplate volcanoes such as those of the Hawaiian island chain have been harder to fit into the theory. A classic explanation has been that magma is supplied to the volcanoes from upwellings of hot rock, called mantle "plumes," deep in the Earth's mantle. Evidence for these deep structures has been sketchy, however. Now, a sophisticated array of seafloor seismometers has provided the first high-resolution images of a mantle plume at depths of at least 1,500 kilometers (932 miles).

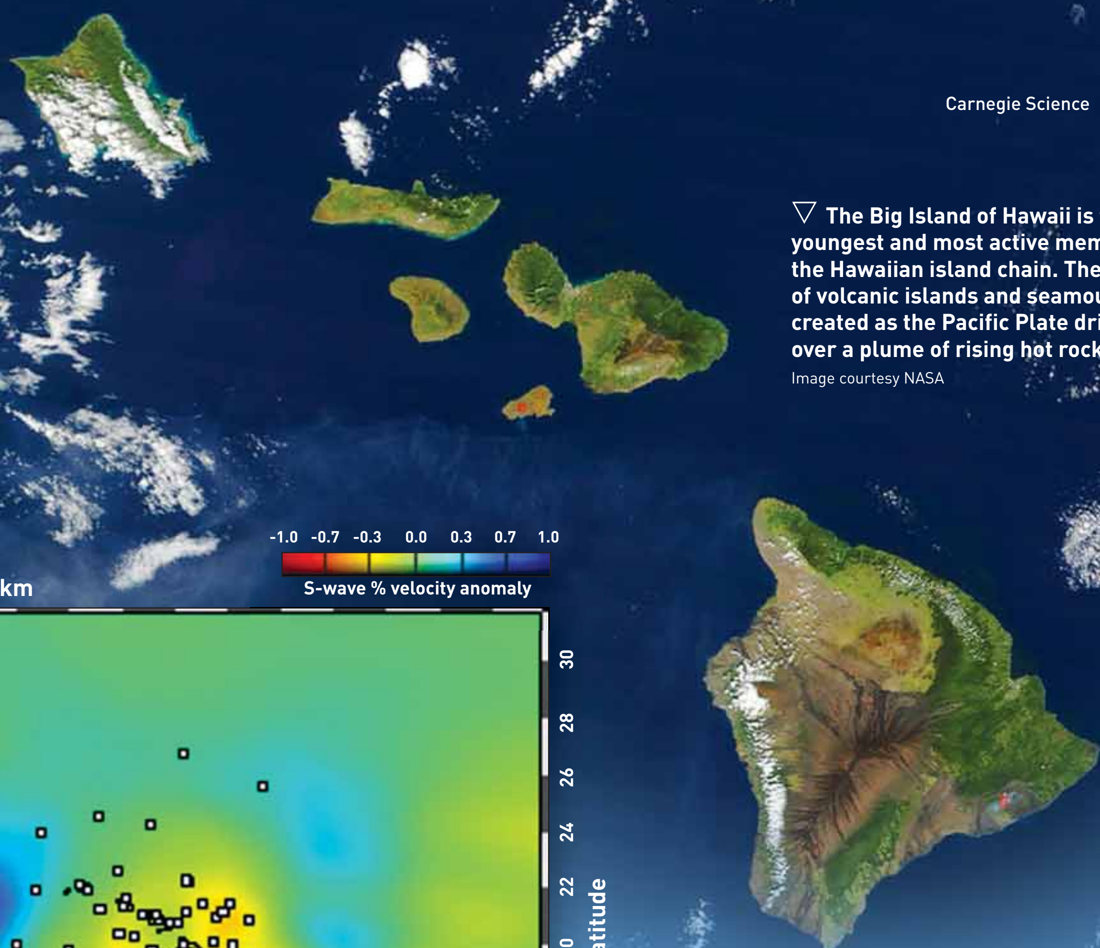
This unprecedented glimpse of the roots of the Hawaiian "hot spot" is the product of an ambitious project known as PLUME, for Plume-Lithosphere Undersea Melt Experiment, which collected and analyzed two years of data from seafloor and land-based seismometers.

"One of the reasons it has taken so long to create these kinds of images is because many of the major hot spots are located in the middle of the oceans, where it has been difficult to put seismic instruments," said study coauthor and Department of Terrestrial Magnetism (DTM) director Sean Solomon. "The Hawaiian region is also distant from most of the earthquake zones that are the sources of the seismic waves that are used to create the images. Hawaii has been the archetype of a volcanic hot spot, and yet the deep structure of Hawaii has remained poorly resolved. For this study we were able to take advantage of a new generation of long-lived broadband seismic instruments that could be set out on the seafloor for periods of a year at a time."

The PLUME seismic images show a seismic anomaly beneath the island of Hawaii, the chain's largest and most volcanically active island. Critics of the plume model have argued that the magma in hot spot volcanoes comes from relatively shallow depths in the upper mantle (less than 660 kilometers, or 410 miles), not deep plumes, but the anomaly observed by the PLUME researchers extends to at least 1,500 kilometers.

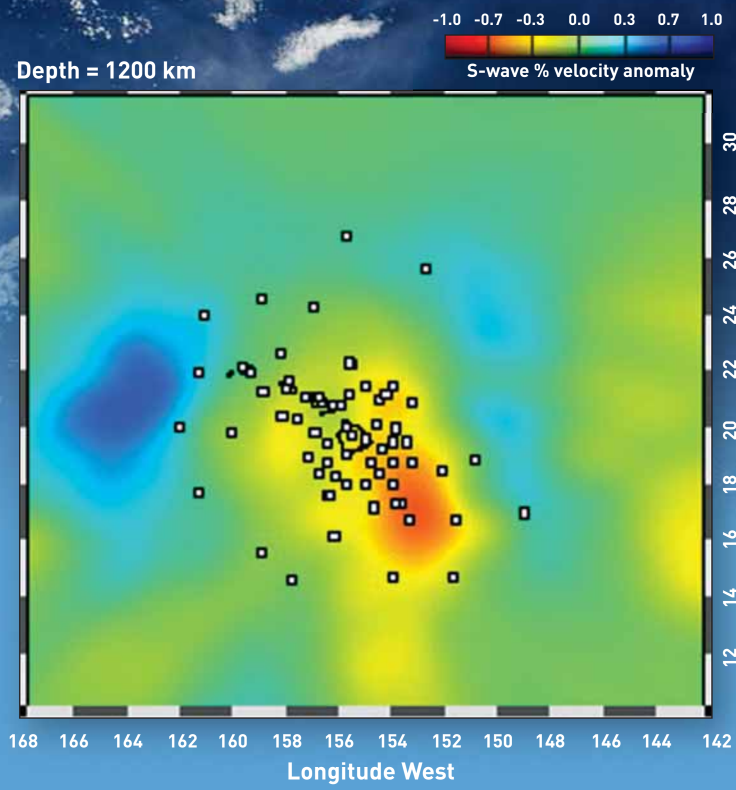
DTM's Erik Hauri led the geochemical component of the research. "We had suspected from geochemistry that the center of the plume would be beneath the main island, and that turns out to be about where the hot spot is centered," he remarked. "We also predicted that its width would be comparable to the size of the island of Hawaii, and that also turned out to be true. But those predictions were merely theoretical. Now, for the first time, we can really see the plume conduit."

Has the question of hot spots and mantle plumes been settled at last? "We believe that we have very strong evidence that Hawaii is underlain by a plume that extends at least to 1,500 kilometers depth," Solomon said. "It may well extend deeper; we can't say on the basis of our data. But that is addressable with global datasets, now that our data have been analyzed. So it's a very strong vote in favor of the plume model." □



▽ **The Big Island of Hawaii is the youngest and most active member of the Hawaiian island chain. The string of volcanic islands and seamounts was created as the Pacific Plate drifted over a plume of rising hot rock.**

Image courtesy NASA

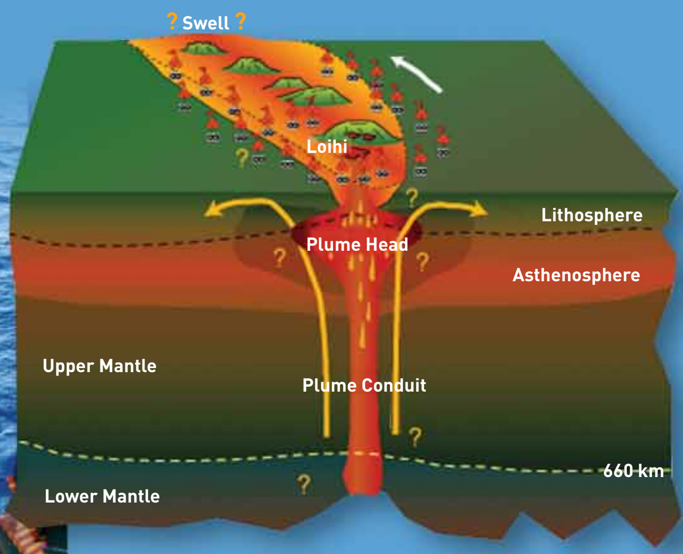


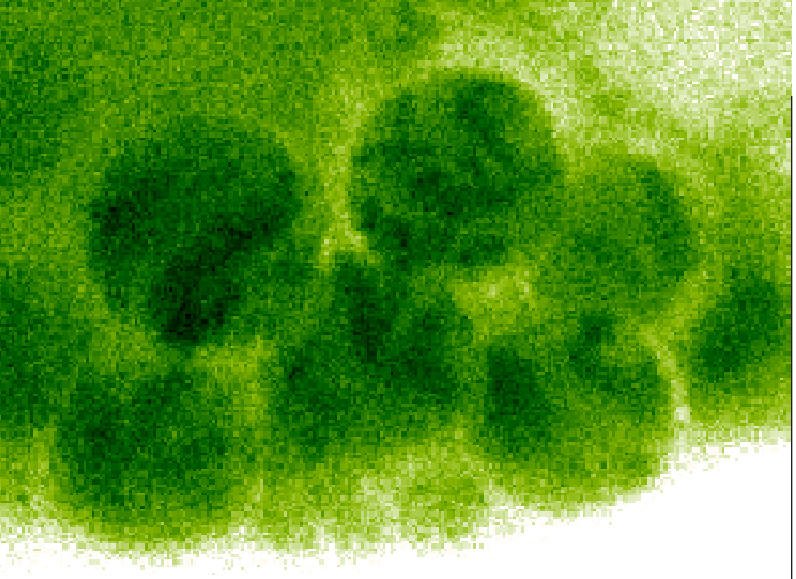
◁ This seismic image shows the location of seismic velocity anomaly beneath the Hawaiian Islands at a depth of 1,200 kilometers (745 miles). Orange color indicates low seismic velocities, implying higher rock temperatures. Open boxes show sites of seafloor seismometers. Outlines, such as the one at center, indicate islands.

Image courtesy *Science*

▽ This diagram shows the plume of rising hot rock hypothesized to be the source of magma for Hawaiian volcanoes. The PLUME project used an array of land-based and ocean-bottom seismometers (orange, with flags) to create the first high-resolution images of the plume reaching depths within the lower mantle. Image courtesy Gabi Laske

▽ Researchers retrieve an ocean-bottom seismometer in May 2007. The dangling silver sphere houses the actual seismic sensor; orange containers house the electronics and lithium batteries. Image courtesy Gabi Laske





Too Much Light? Algae Has "Safety Valve"

Arthur Grossman

Photosynthetic organisms need to cope with a wide range of light intensities, which can change over timescales of seconds to minutes. Too much light can damage the photosynthetic machinery and cause cell death. Scientists at the Department of Plant Biology were part of a team that found that specific proteins in algae can act as a safety valve to dissipate excess absorbed light energy before it can wreak havoc in cells.

The researchers used a mutant strain of the single-celled green alga *Chlamydomonas reinhardtii* originally isolated at Carnegie to show that a specific protein of the light-harvesting family of proteins plays a critical role in eliminating excess absorbed light energy. A mutant lacking this protein, designated LHCSR, suffered severely when exposed to fluctuating light conditions. "Photosynthetic organisms must be able to manage absorbed light energy," says study coauthor Arthur Grossman, "and the LHCSR proteins appear to be critical for algae to eliminate absorbed light energy as heat as light levels in the environment fluctuate."

Grossman points out that photosynthetic organisms have developed a number of different mechanisms to manage light energy and that these different mechanisms may be tailored to the diversity of environments in which the organisms have evolved. Some have evolved in hot, bright deserts, while others have evolved in cool, cloudy mountains, for example.

CONTINUED ON PAGE 14

(Top) *Chlamydomonas reinhardtii* has a protein that protects its photosynthetic apparatus from too much light energy. Learning more about such "safety valves" could help plant biologists tailor biofuel-producing algae that use light energy more efficiently under extremely bright conditions, such as in deserts.

Images courtesy Arthur Grossman

Genes: Guilt by Association

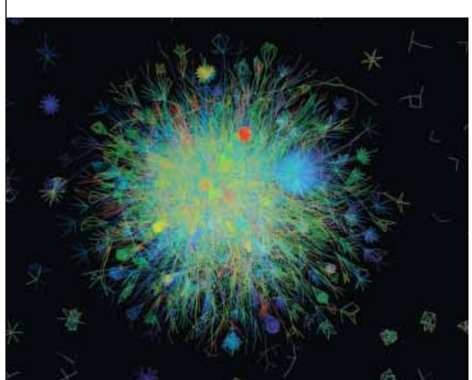
Hanging out with the wrong crowd can lead to guilt by association. Now scientists, including Plant Biology's Sue Rhee, have found that the same thing is true for plant genes. They created a new model to predict the gene function of uncharacterized plant genes with unprecedented speed and accuracy. The network, dubbed AraNet, has over 19,600 genes associated with each other by over 1 million links. It can increase the discovery rate of new genes affiliated with a trait tenfold and is a huge boost to fundamental plant biology and agricultural research. The research was published in the January 31, 2010, advance online edition of *Nature Biotechnology*.

Despite immense progress in functional characterization of plant genomes, over 30% of the 30,000 *Arabidopsis* genes have not yet been functionally characterized. Another third have little evidence regarding their role in the plant.

"In essence, AraNet is based on the simple idea that genes that physically reside in the same neighborhood, or turn on in concert with one another, are probably associated with similar traits," explained Rhee. "We call it guilt by association. Based on over 50 million scientific observations, AraNet contains over 1 million linkages of the 19,600 genes in the tiny, experimental mustard plant *Arabidopsis thaliana*. We made a map of the associations and demonstrated that we can use the network to propose that uncharacterized genes are linked to specific traits based on the strength of their associations with genes already known to be linked to those characteristics."

The network allows for two major types of testable hypotheses. The first uses a set of genes known to be involved in a biological process, such as stress responses, as a "bait" to find new genes involved in stress responses. The bait genes are linked to each other based on over 24 different types of experiments or computations. If there are more frequent or stronger linkages than would exist by chance, it is likely that genes that are well linked to the bait genes are involved in the same process. The second testable hypothesis is to predict functions for uncharacterized genes.

The scientists tested the accuracy of AraNet with computational validation tests and laboratory experiments on genes that the network predicted as related. The researchers found that the network is much stronger in forecasting correct associations than previous small-scale networks of *Arabidopsis* genes. □



Each line of this AraNet network represents a functional link between two genes. The colors indicate the strength of the link using a red-blue heat map scheme. The image includes about 100,000 functional links made between about 10,000 *Arabidopsis* genes.

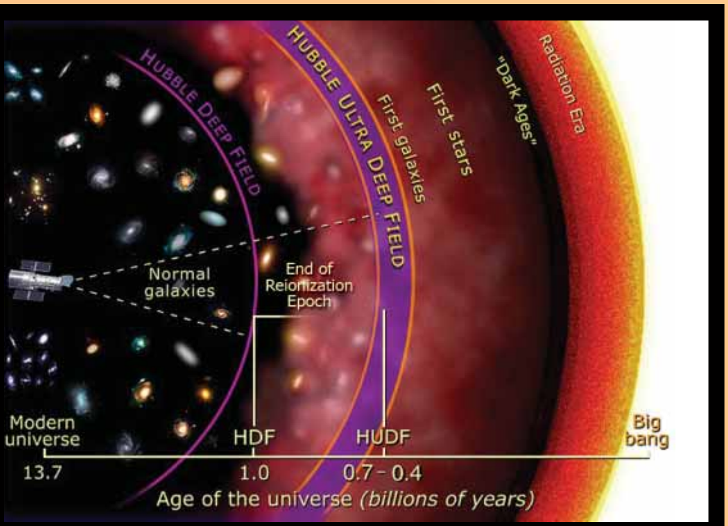
Image courtesy Sue Rhee

The work was supported by the Carnegie Institution for Science, the National Research Foundation of Korea, Yonsei University, the National Science Foundation, the National Institutes of Health, and the Packard Foundation.

RACE TO THE EARLIEST GALAXIES

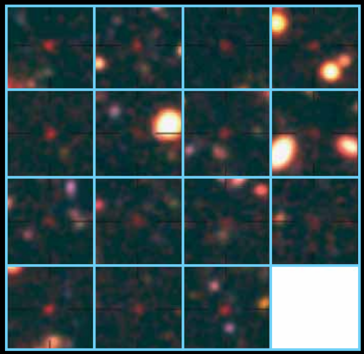
New technology has caused an explosion of research into a cosmological epoch called the reionization era. It is the farthest back in time that astronomers can observe. And two researchers at the Observatories, Masami Ouchi and Ivo Labbé, are at the forefront of uncovering what's there.

The Big Bang, 13.7 billion years ago, created a hot, murky universe. Some 400,000 years later, temperatures cooled, electrons and protons joined to form neutral hydrogen, and the murk cleared. Some time before 1 billion years after the Big Bang, neutral hydrogen began to form stars in the first galaxies. They radiated energy and caused some hydrogen to be ionized again. Though not the thick plasma soup of the earlier period just after the Big Bang, this star formation started the reionization epoch. Astronomers know that this era ended about 1 billion years after the Big Bang, but when it began has been elusive.



This artist's rendering shows the stages in the evolution of the universe and where the Hubble Deep Field and Ultra Deep Field images are located in distance and time.

Image courtesy NASA, GSFC



This composite of false-color images shows galaxies found around 800 million years after the Big Bang. The upper left panel presents the galaxy confirmed in the 787-million-year-old universe. These galaxies are in the Subaru Deep Field.

(Images, created by M. Ouchi et al., are the reproduction of Fig. 3 in the article published in the *Astrophysical Journal*.)

GALACTIC DROPOUTS

Masami Ouchi recently led a team that conducted the broadest survey to date of galaxies from about 800 million years after the Big Bang. It yielded 22 early galaxies, and confirmed the age of one at 787 million years post-Big Bang. The finding is the first age confirmation of a so-called dropout galaxy at that distant time.

As Ouchi explained: "We look for 'dropout' galaxies by using progressively redder filters that reveal increasing wavelengths of light and watch which galaxies disappear from, or 'drop out,' of images made with those filters. The specific wavelengths can tell us the galaxies' distance and age. What makes this study different is that we surveyed an area that is over 100 times larger than previous ones and, as a result, had a larger sample (22) of early galaxies than past surveys. Plus, we were able to confirm one galaxy's age."

Ouchi's team was able to conduct such a large survey because they used a custom-made, super-red filter and other unique advancements in red sensitivity on the wide-field camera of the 8.3-meter Subaru Telescope. They made their observations in the Subaru Deep Field and Great Observatories Origins Deep Survey North field from 2006 to 2009. They then compared their observations with data gathered in other studies.

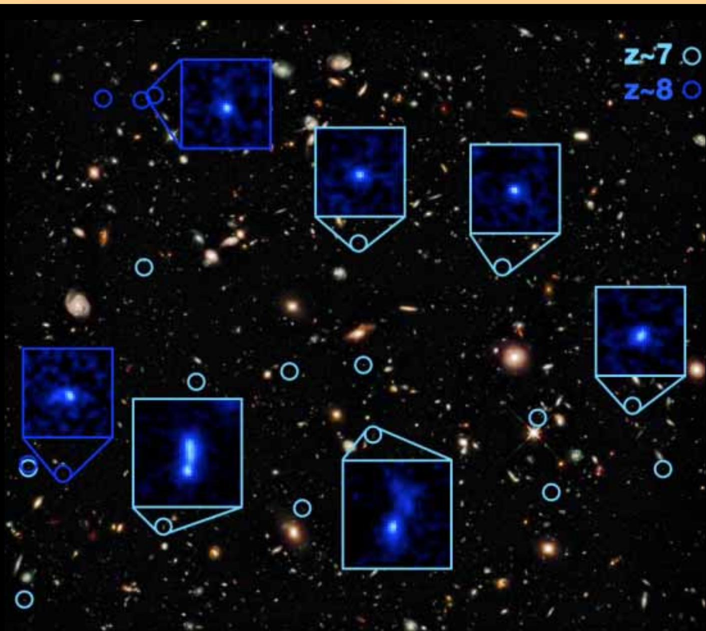
Astronomers have tried to isolate when the universe began reionization. Galaxy density and brightness measurements are key to calculating star-formation rates, which tell a lot about what happened when. The astronomers looked at star-formation rates and the rate at which hydrogen was ionized. Using data from their study and others, they determined that the star-formation rates were dramatically lower from 800 million years to about 1 billion years after the Big Bang than thereafter. They calculated that the rate of ionization would have been very slow during this early time. The research was published in the *Astrophysical Journal.*

CONTINUED ON PAGE 14

The work was funded by the Carnegie Institution. The research is based on data collected at the Subaru Telescope, which is operated by the National Astronomical Observatory of Japan; the Hubble Space Telescope, operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under NASA contract NAS5-26555; and the Spitzer Space Telescope, managed by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA.

CONTINUED FROM PAGE 13
Race to the Earliest Galaxies

COMPACT ULTRABLUES



This composite color image is of the new infrared Hubble Ultra Deep Field taken at 1.0 micron (blue), 1.25 micron (green), and 1.6 micron (red) with the Wide Field Camera 3 (WFC3/IR) aboard the Hubble Space Telescope. Highlighted are the record-breaking high-redshift galaxies, where the redshift "*z*" indicates the amount of stretching the light underwent on its voyage through the expanding universe, yielding distance and age. Higher redshift means larger distance and hence looking farther back in time. The newly found objects are at *z*~7 (700 million years after the Big Bang, light blue circles) and z~8 (600 million years, dark blue circles).

Meanwhile, Ivo Labbé, a member of the Hubble Ultra Deep Field 2009 (HUDF09) team, used NASA's Hubble Space Telescope to uncover a primordial population of compact and ultrablue galaxies that have never been seen before. They are from 13 billion years ago, just 600 to 800 million years after the Big Bang.

These objects will help understand the evolutionary link between the birth of the first stars, the formation of the first galaxies, and the sequence of evolutionary events that resulted in the assembly of our Milky Way and other galaxies.

The HUDF09 team combined their Hubble data with observations from NASA's Spitzer Space Telescope to estimate the ages and masses of these primordial objects. "The masses are just 1 percent of those of the Milky Way," observed Labbé. He further noted that "to our surprise, the results show that these galaxies existed at 700 million years after the Big Bang and must have started forming stars hundreds of millions of years earlier, pushing back the time of the earliest star formation in the universe."

The deepest-ever near-infrared view of the universe—the HUDF09 image—was combined with the deepest-ever optical image—the original HUDF taken in 2004 with the Advanced Camera for Surveys—to push back the frontier of the search for the first galaxies. The fact that the faintest galaxies are so blue means that they are probably extremely deficient in heavy elements—a hallmark of ancient age.

A long-standing question is whether these early galaxies put out enough radiation for reionization. Astronomers still don't know which sources of light caused reionization to happen or how much light exactly is needed.

Spectroscopy is needed to provide definitive distance and age values, but the newly detected objects are too faint for spectroscopic observations using current telescopes. However, distances can be inferred by the galaxies' apparent colors through a well-established technique. "We are reaching the limit of what we can do with Hubble," says Labbé. "To witness the emergence of the first galaxies requires bigger facilities such as the future James Webb Space Telescope and large telescopes on the ground, such as the planned Giant Magellan Telescope." □

The project team consists of Ivo Labbé, Carnegie Observatories; Garth Illingworth, University of California, Santa Cruz; Rychard Bouwens, University of California, Santa Cruz; Marcella Carollo, Swiss Federal Institute of Technology, Zurich; Dan Magee, University of California, Santa Cruz; Marijn Franx, Leiden Observatory; Valentino Gonzalez, University of California, Santa Cruz; Mariska Kriek, Princeton University; Pascal Oesch, Swiss Federal Institute of Technology, Zurich; Massimo Stiavelli, STScI; Michele Trenti, University of Colorado, Boulder; and Pieter van Dokkum,Yale University.

CONTINUED FROM PAGE 12
Too Much Light? Algae Has "Safety Valve"

"As we understand more about the ways in which the environment impacts the evolution of the photosynthetic machinery, we may be able to introduce specific mechanisms into plants that allow them to better manage absorbed light energy, which in turn would let them survive harsher environmental conditions. This would have obvious benefits for agriculture," Grossman says.

He also notes the possibility of cultivating algae for biofuels in deserts, where solar input can be extremely high. "If we are going to attempt this we have to make sure that we use the right algae that can thrive and produce oils at high levels under harsh environmental conditions. It's possible that we can also tailor various features of the photosynthetic machinery to let algae use light energy more efficiently and suffer less damage under extremely high light and temperature conditions, but I would emphasize that there are many extreme challenges associated with the creation of such robust, commercially viable strains." □

InBrief

❶ As part of the Carnegie Medal of Philanthropy events, Carnegie president Richard Meserve gave an overview of Carnegie science.

Image © H. Thompson

❷ Zehra Nizami

TRUSTEES AND ADMINISTRATION

❶ Carnegie president **Richard A. Meserve** attended the Council and Trust of the American Academy of Arts and Sciences on Oct. 9-11 in Cambridge, MA, and moderated a session on the future of global energy. He attended the Carnegie Medal of Philanthropy ceremony Oct. 14-15 in New York with trustees **Deborah Rose** and **William Turner.** He participated in the external advisory panel to the MIT Nuclear Fuel Cycle Study on Oct. 26. He gave welcoming remarks at the Balzan Lecture at P Street on Nov. 12, and attended a board meeting of Carnegie Canada Dec. 8. He chaired a meeting of the National Academies' Nuclear and Radiation Studies Board (NRSB) on Dec. 9-11. Meserve participated in the National Academies' Science Ambassador Advisory Board on Jan. 6. On Jan. 20 he attended a climate-change symposium in New York led by Global Ecology's **Chris Field** and hosted by chairman of the board **Michael Gellert**. He spoke at the Nuclear Regulatory Commission's 35th Anniversary Celebration on Jan. 28 and attended the annual meeting of the American Association for the Advancement of Science in San Diego Feb. 20-21, where he moderated a session on advanced nuclear energy concepts. He attended a briefing by Greg Asner, hosted by trustee **William Hearst**, at the Dept. of Global Ecology on Feb. 22.

EMBRYOLOGY

In Sept. department director **Allan Spradling** coorganized an inaugural Cold Spring Harbor Meeting on fundamental stem cell biology, versus stem cell research for medical applications. He gave lectures at U. Minnesota, Carnegie's Dept. of Plant Biology, and U. Missouri, and was an invited speaker at two stem cell symposia—one at Duke and one at Harvard Medical School. He participated in the lecture series and graduate student course in stem cell biology at Rockefeller U. and attended the Packard Fellows Meeting, the Carnegie board of trustees meeting, and the directors' retreat.

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Doug Koshland presented seminars at Washington U., U. Pennsylvania, and U. Oklahoma. He gave an HHMI Scholars Lecture and attended the American Society for Cell Biology annual meeting in Dec.

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Yixian Zheng attended the Sept. Cold Spring Harbor stem cell meeting with lab members and participated in the *Xenopus* resource meeting at Woods Hole. She also lectured at Indiana U.

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Marnie Halpern and **Steve Farber** coorganized the Mid-Atlantic Zebrafish Meeting at Carnegie Dec. 4. Farber presented a lecture, "Obesity from Yeasties to Beasties," at the Obesity Society and at the Children's Hospital of Philadelphia.

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Chen-Ming Fan gave lectures at Duke U. and Columbia U.

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Alex Bortvin lectured at the Johns Hopkins U. Dept. of Biology retreat, U. Illinois at Urbana-Champaign, and the Keystone Symposium on RNAi Silencing.

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David MacPherson lectured at U. Toronto at the 1st International Retinoblastoma Meeting in Nov.

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❷ Spradling graduate student **Andrew Skora** defended his Ph.D. thesis. Gall lab visiting investigator **Sveta Deryusheva** and graduate student **Zehra Nizami** both gave talks at the American Society for Cell Biology annual meeting in Dec.

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Halpern lab postdoctoral associate **Dan Gorelick** rejoined the Halpern group in Sept. after a year as an AAAS Science and Technology Policy Fellow at the State Department. He also serves on the board of directors for the National Postdoctoral Association. Postdoctoral associate **Lucilla Facchin** spoke at the Mid-Atlantic Zebrafish Meeting Dec. 4.

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Farber graduate student **Juliana Carten** presented her work on intestinal fatty acid transport in zebrafish at the 2009 Annual Mid-Atlantic Diabetes Research Symposium in Sept.

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Fan graduate student **Christoph Lepper** successfully defended his Ph.D. thesis and will begin his postdoctoral studies later this year.

Arnold Pryor Retires after a Half-Century of Service!

Arnold Pryor was a young man half a century ago (left) when he started work at Carnegie's administration building. During his tenure he worked in many different capacities and under six presidents. Most recently, he helped keep the headquarters building in top running order. He showed the building to prospective renters, ensured trustees' meetings went smoothly, and much, much more. A retirement luncheon hosted by Carnegie president Richard Meserve (right) was held for him in the boardroom in January.

Bumper Crop at the American Geophysical Union

Carnegie scientists Kenneth Caldeira of Global Ecology, Yingwei Fei of the Geophysical Laboratory, and Steven Shirey of the Department of Terrestrial Magnetism were elected 2010 Fellows of the American Geophysical Union (AGU). Only one in a thousand members is elected a fellow each year.

Ken Caldeira, Yingwei Fei, and Steven Shirey (shown left to right) are new AGU Fellows.

GEOPHYSICAL LABORATORY

On Sept. 4 director **Russell Hemley** helped kick off the EFree held at the Geophysical Laboratory (GL). On Sept. 23 he chaired a panel at the 21st Century Needs and Challenges in Compression Science workshop held in Santa Fe. On Sept. 30, along with **Connie Bertka**, **Robert Hazen**, and **Yingwei Fei**, he took part in the Deep Carbon Observatory

On Jan. 29 Secretary of Energy Steven Chu formed a Blue Ribbon Commission on America's Nuclear Future as part of President Obama's efforts to restart America's nuclear industry. The 15-member commission includes Carnegie president **Richard A. Meserve.** The body is chartered to review policies to manage nuclear waste. The members will provide recommendations on alternatives for safely storing, processing, and disposing of defense and civilian spent fuel and nuclear waste. An interim report is due within 18 months, and a final report within 24 months.

Joe Gall was an invited guest at the **2009 Nobel Prize** ceremony in Stockholm.

Two corecipients of the prize in medicine/ physiology were Elizabeth Blackburn and Carol Greider. Elizabeth Blackburn was a postdoctoral fellow in Joe Gall's Yale lab when they first identified the telomere sequence in the ciliated protozoan *Tetrahymena*. Carol Greider was Elizabeth's graduate student at UC-Berkeley when she discovered telomerase, the enzyme that adds telomere sequences to the ends of chromosomes. Gall poses with Carol Greider, below left. Shown below right are Gall, Elizabeth Blackburn, and her husband, John Sedat, after the Nobel Prize ceremony. Images courtesy Joe Gall

❸ George Cody (left) and Sung Keun Lee, former GL Fellow, now a professor at Seoul National U. (SNU), are standing in front of an 11.7 Tesla magnet, part of Lee's solid-state NMR facility at SNU. Lee did pioneering work of highly pressurized materials in the W. M. Keck Solid State NMR facility at GL during his postdoctoral fellowship.
Image courtesy George Cody

Founders Meeting, On Oct. 1 he participated in a briefing with the secretary of energy on the future of the National Laboratories. He gave an invited talk at the 3rd UT Horiba International Symposium and the 11th ISSP International Symposium on Hydrogen and Water in Condensed Matter Physics in Chiba, Japan, Oct. 12-16. At the Geological Society of America Annual Meeting on Oct. 19 he delivered the citation when **Robert Hazen** was awarded the 2009 Distinguished Public Service Medal of the Mineralogical Society of America. On Nov. 11 Hemley gave a talk at the Geological Society of Washington on the Deep Carbon Observatory. On Dec.11 he gave one of the Smith Lectures at U. Michigan, and on Dec. 17 he took part in the NIF Science Team's Exploring Giant Planet Interiors workshop.

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Doug Rumble attended the Geological Society of America meeting in Portland, OR, in Oct. He also attended the board of directors meeting of GeoScience World. In Dec. he attended the AGU meeting in San Francisco.

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Ho-kwang (Dave) Mao gave an invited talk at the Advances in X-ray Scattering and Diffraction Workshop at U. Guelph, Guelph, Ontario, in Oct. He also gave an invited talk at the Laser Heating the DAC workshop at the Advanced Light Source in Berkeley on Dec. 12.

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Bob Hazen delivered the Baldwin Lecture on "Genesis" at Miami U. in Ohio, as well as giving invited lectures at Marquette U. and at the annual meetings of the Geological Society of America and the AGU.

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Marilyn Fogel and **Dominic Papineau** traveled to Rajasthan, India, in early Nov. to study the Aravalli Supergroup, Precambrian rocks formed by biological processes almost 2 billion years ago. Fogel started a rotating position at the NSF as program director in geobiology and low-temperature geochemistry. In Dec. she led two workshops cosponsored by NSF and the Earth Science Women's Network on Information for Early Career Geoscientists. More than 100 attended the workshops held in San Francisco coincidentally with the AGU.

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❸ **George Cody** visited Seoul National U. in Nov., where he presented three lectures on topics including the origin of life, the organic history of the early Solar System, and biogeochemistry at nanoscales. He also attended the AGU meeting, where he presented his research linking organic matter in the interstellar medium to organic solids in comets and meteorites.

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Anat Shahar gave a talk at the AGU and at U. Maryland late last year.

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❹ In Sept. NAI Fellow **Neal Gupta** joined the Cody lab. He is learning solid-state nuclear magnetic resonance (NMR) spectroscopy and X-ray absorption near-edge structure (XANES) spectroscopy.

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Research scientist **John Armstrong** gave two invited talks on atmospheric particle analysis and the development of standards for microanalysis of geological materials at the AGU meeting.

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❺ NAI Fellow **Dina Bower** presented a talk at the Geological Society of America annual meeting in Portland, Oct. 18-21 about her projects with Andrew Steele.

High Pressure Collaborative Access Team (HPCAT)

❻ On Jan. 11 **Changyong Park** gave an invited talk, "Molecular Processes at Mineral-Aqueous Interfaces," for the GL seminar series.

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❼ Beamline associate **Wing Shing Au** arrived from Kiangsu-Chekiang College on Jan. 18.

BUSY BIOEYES!

BioEYES, Carnegie's outreach program in Baltimore, has a new Web site at www.bioeyes.org, a new Facebook page, BioEYES, and it has reached even more students than last year. Baltimore County now has a full-time Baltimore County BioEYES educator, and BioEYES is an official part of the science curriculum in Title I schools. **Bo Dunlap**, the Baltimore County BioEYES Educator, will reach more than 3,400 Baltimore County fifth graders this year.

Susan Artes and **Rob Vary** added 7th and 10th grades to the fifth grade schedule and will be working with the Gateway School to develop a curriculum for students with disabilities. They are hosting an event for Building Steps, a program that exposes minority inner-city students to science-and-technology-based careers and helps them get into college. They also continue with programs in the Howard County Schools and in the Baltimore City Catholic Schools.

BioEYES will come to D.C. with the help of Sidwell Friends School. Sidwell's upper school students have an active zebrafish facility, and several are BioEYES Master Teachers. These Master Teachers will teach their own lower school students and students from at least one public school.

BioEYES is entirely supported by grants and gifts.

(Right) Embryology staff member Joe Gall trains teachers in the BioEYES program.

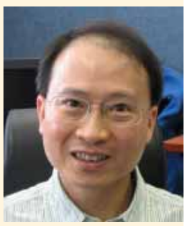
Former staff associate James Scott, 48, died at home of a heart attack on Jan. 11. At the time of his death he was at Dartmouth, where he led the Earth sciences dept.'s geobiology group. Scott had worked for Dartmouth since 2006, doing research on the effects of pressure on anaerobic microbes. At GL he met Anurag Sharma, and the two collaborated on research that led to the discovery that microbes can survive extreme pressure conditions.

Former staff associate James Scott died in January.

❹ Neal Gupta

❺ Dina Bower

❻ Changyong Park



❼ Wing Shing Au

❽ Chris Field

❾ Juna Kollmeier

❿ Josh Simon

⓫ Masami Ouchi

High Pressure Synergetic Consortium at the Advanced Photon Source (HPSynC)

Yang Ding gave an invited talk at the Materials Science and Technology 2009 Conference and Exhibition Oct. 25-29 in Pittsburgh, PA.

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Lin Wang gave a poster presentation, "Size-Dependent High Pressure Induced Amporphization in Nanoscaled Y_2O_3," at the AGU meeting Dec. 14-18 in San Francisco.

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Wenge Yang was chair of the Advanced Technologies for Advanced Characterizations of Minerals under High Pressure session at the Dec. 14-18 AGU meeting, where he also presented a talk.

GLOBAL ECOLOGY

❽ Director **Chris Field** was awarded the prestigious Heinz Award on Sept. 15 for extraordinary achievements in a field that was of particular interest to Senator Heinz. In Oct. he attended an IPCC Plenary Session in Bali. He was a keynote speaker on the first day of the 6th Annual California Climate Change Symposium at the Sacramento Convention Center in Sept., where he talked about his working group's preparations for the Impacts and Adaptation Report of the next IPCC Assessment. Field and **David Lobell** were chair and speaker, respectively, in the Biofuels and Bioenergy Conversion Section of the Global Climate and Energy Project annual meeting Sept. 30-Oct 2.

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Chris Field, **Greg Asner**, and **Guayana Paez-Acosta,** along with **Kris Ebi** (IPCC) and Stanford student **Matt Colgan**, attended the Copenhagen climate conference Dec. 7-18.

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Greg Asner and **Robin Martin** were in Peru, Panama, and Costa Rica collecting leaf samples for the spectranomics project. The first CAO airborne campaign was held in Oct. in the Amazon. A YouTube video was made of the effort. Asner gave a talk at the World Wildlife Fund Jan. 14.

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In Nov. **Ken Caldeira** addressed the U.S. House of Representatives Committee on Science and Technology on geoengineering. From late Oct. through late Dec., he and three current and former postdocs (**Jack Silverman**, **Steve Davis**, and **Kenny Schneider**) were in Australia's Great Barrier Reef studying effects of ocean acidification on rates of coral reef growth.

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Luis Fernandez gave testimony at Peru's Ministry of Energy and Mines on issues related to deforestation, illegal gold mining, and mercury contamination in the Peruvian states of Madre de Dios, Piura, and Puno.

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Julia Pongratz attended the 8th International Carbon Dioxide Conference in Jena, Germany, in Sept., where she gave a plenary talk about the effects of land cover change on the carbon cycle.

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In Dec. staff scientist **Joe Berry** and current and former postdocs **Kimberly Nicholas-Cahill**, **Chris Doughty**, **Eve Lynn Hinckley**, **Ben Houlton**, **Ulli Seibt**, and **Adam Wolf** spoke at the AGU meeting in San Francisco. **George Ban-Weiss**, **Long Cao**, **Kyla Dhalin**, **Steve Davis**, **Julia Pongratz**, and **Ted Raab** presented posters.

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Caldeira lab's **Ho-Jeong Shin** attended the GEWEX conference in Australia in Sept., and then proceeded to the Indian Institute for Science in Bangalore.

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Arrivals: John Clark joined the Asner lab in Oct. as a lab technician. **Pablo Garcia del Real** joined the Caldeira lab as a lab assistant from Oct. through Dec., and **Luis Fernandez** joined the Field lab as a postdoc in Oct.

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Departure: Kerry Lampbrecht left the Asner lab in Nov. to join a musical tour of Europe.

OBSERVATORIES

On Sept. 25 director Wendy Freedman gave a talk, "Dark Energy at the Turner-Fest," celebrating Michael Turner's 60th birthday at KPTC, Chicago. She gave a colloquium on the GMT at Cambridge U. and delivered the Sackler Public Lecture on Oct 8. She attended the Exploring the High Energy Universe symposium honoring Roger Blandford Nov. 6. Freedman met with the Hon. Paul Simons, U.S. ambassador to Chile, and Chilean government officials in Santiago to enhance Carnegie's relations with the Chilean government and scientific community. She gave a colloquium at Caltech on Dec. 2. On Dec. 4 she attended the dedication ceremony for the George P. and Cynthia Mitchell Physics Building at Texas A&M.

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❾ Staff astronomer **Juna Kollmeier** gave talks at U. Texas at Austin, a cosmology seminar at Texas A&M, a colloquium at U. Michigan, and seminars at Michigan State U. and U. Barcelona Institut de Ciències del Cosmos. She was also featured in the Dec. issue of *Astronomy Magazine*.

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This fall Spitzer Fellow **Jane Rigby** attended the Gas in Galaxies conference in Charlottesville, VA; the Reionization to Exoplanets: Spitzer's Growing Legacy conference in Pasadena, CA; and the science team meeting for the NuStar hard X-ray telescope. In mid-Oct. she gave a seminar at Georgia Tech.

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❿ On Sept. 4 Carnegie Fellow **Josh Simon** gave a talk at the meeting "The Milky Way and the Local Group—Now and in the Gaia Era" in Heidelberg, Germany. On Sept. 17 he gave a talk at the Keck Science Meeting in Pasadena. On Oct. 20 he gave an invited review talk at the Frank N. Bash Symposium in Austin, TX. He gave a colloquium at U. Arizona on Nov. 12 and a guest lecture Nov. 20 at the Ventura County Astronomical Society meeting.

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⓫ Carnegie Fellow **Masami Ouchi** gave two invited talks at Ringberg Castle, Germany, Nov. 15-18, and at the Universitätszentrum Obergurgl, Austria, Dec. 12-17. As a member of the scientific organization committee he arranged an international workshop, "Focus Week on the Epoch of Reionization," held at U. Tokyo Nov. 30-Dec. 3. He was invited to Observatoire de Genève and Eidgenössische Technische Hochschule Zürich in Switzerland for seminar talks on Dec. 9 and 11. He visited the Subaru Observatory in Hawaii in Oct. and Las Campanas Observatory in Chile in Dec. to observe.

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Postdoctoral associate **Victoria Scowcroft** gave a talk on Dec. 16 at the Astrophysics Research Institute, John Moores U., Liverpool, England.

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⓬ NSF fellow **Karín Menéndez-Delmestre**, a member of the Spitzer Survey of Stellar Structure in Galaxies team, attended a team meeting in early Oct. in Marseille, France. She also participated in the Women in Astronomy 2009 Conference at College Park, MD, and presented a poster of her work on submillimeter galaxies at the Oct. 2009 Spitzer meeting in Pasadena. In Nov. she served on the User Panel for the NASA/IPAC Infrared Science Archive to provide feedback and suggestions to IRSA management. In Dec. she gave an invited colloquium talk at U. Puerto Rico in Humacao. As part of her outreach efforts, she presented a fifth-grade lesson on the Solar System at the San Rafael School in Pasadena in Nov., and in Dec. she presented an invited public talk for the closing ceremony of the International Year of Astronomy in Puerto Rico at the Interamerican U., Bayamón Campus.

Director Emeritus **Winslow Briggs** was awarded the prestigious International Prize for Biology from the Japan Society for the Promotion of Science at a ceremony in Tokyo on Nov. 30, held in the presence of the Emperor of Japan. Briggs was honored for his work on light sensing by plants. In the photo Briggs receives the award with the emperor and empress seated on the platform at back. His wife, Ann, is standing at left.

⓬ Karín Menéndez-Delmestre

Jan. 31 marked **Glenn Ford's** last day at Carnegie. Ford, who is retiring after 37 years, started as a lab technician in 1971 after graduating from Stanford with B.A. in chemistry. He eventually became Plant Biology's health and safety manager and IT manager. A retirement luncheon attended by the faculty and staff members was held on Jan. 27. On the left are Susan Cortinas, Ford, Winslow Briggs, Wolf Frommer, Linda Longoria, and Joe Berry. On the right are Paul Sterbentz, Kathi Bump, Zhi-Yong Wang, Martin Jonikas, Matt Evans, and Kathy Barton.

PLANT BIOLOGY

Director **Wolf Frommer** was recognized as an ISI Highly Cited Researcher by the ISI Web of Knowledge. These individuals are the most highly cited within different categories and comprise less than one-half of 1 percent of all publishing researchers. On Sept. 23-25 Frommer attended the 11th Annual Fall Symposium, "Cellular Signaling: Advances and Applications," in St. Louis and gave the keynote address. He attended the 9th International Plant Molecular Biology Congress held in St. Louis on Oct. 26-27, giving two talks each day. On Jan.14 he attended the III Pan American Plant Membrane Biology Workshop in Puebla, México, and chaired the session "Diversity and Regulation of Transporters." He also gave the plenary talk about FRET sugar sensors.

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Arthur Grossman gave a seminar at UC-Berkeley on Dec. 9. He participated in an RCN meeting at U. Connecticut Jan. 15-17 to organize the analyses of Porphyra cDNA and EST information. He gave an invited talk for an EMBO Workshop on New Frontiers in Ocean Science on Oct. 10 in Ischia, Italy. He participated in a Moore Foundation workshop on Microbiological Targets for Ocean Observing Laboratories held Jan. 12-14 in Palo Alto. Grossman also taught a freshman course on "Photosynthesis: From Mechanisms to Biofuels."

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David Ehrhardt gave the keynote talk at the III Pan American Plant Membrane Biology Workshop held in Puebla, México, in Jan.

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On Sept. 16 **Zhi-Yong Wang** gave a talk at the Lanzhou U. Centennial Celebration Symposium on omics and biotechnology, held in China. On Sept. 25 he gave a talk at the Weill Institute of Cell Biology, Cornell U. He also gave a talk at the 9th International Plant Molecular Biology Congress held in St. Louis in Oct., and a series of talks in China. On Oct. 21 he spoke at Zhejiang U., on Oct. 24 at Shanghai Jiao Tong U., and on Nov. 13 at Shangdong U. On Nov. 14 he spoke at the International Frontier in Plant Molecular Biology Symposium held in Suzhou. He also gave a talk at the Chinese Biological Investigator Society CBIS symposium "Frontiers in Life Sciences and Biotechnology" on Dec. 28 in San Diego. He gave invited seminars on Feb. 1 at the Institute of Developmental Biology, Chinese Academy of Sciences, Beijing, and on Feb. 2 at the National Institute of Biological Sciences, Beijing.

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Kathy Barton received an NSF 2010 grant to define and understand the network that regulates up and down movement in the leaf. This work is being done in collaboration with Stanford U. and Rutgers U. and uses high-throughput sequencing and computational technology to build a model of a gene regulatory network.

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On Oct. 11 **Devaki Bhaya** was an invited speaker at the EMBO workshop on "Eco Devo Meets Ocean Sciences" held in Ischia, Italy. She was an invited speaker at the Dec. 3 Microbiology, Cell, and Molecular Biology Colloquium Series at San Francisco State U. On Feb. 7 she was an invited speaker at Stanford U.'s Darwin Day.

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Eva Huala gave an invited talk at the International Plant Molecular Biology Congress Oct. 25-30 in St. Louis. She also presented a workshop at this conference on "Working with TAIR." **Kate Dreher**, a member of the TAIR group, presented another workshop titled "Putting the Plant Metabolic Network (PMN) to Work for You." On Jan. 8 Huala attended and gave a talk at the Joint USDA-DOE Plant Genomics Knowledgebase Workshop in San Diego. Also in San Diego on Jan. 9-13 she spoke at a plant phenotypes workshop, "Plant and Animal Genomes."

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The Frommer lab's **Sylvie LaLonde**, senior postdoctoral research associate and director of the microscopy lab, presented a poster at the 2009 Cold Spring Harbor Laboratory meeting on Systems Biology: Networks. She also presented a talk at the 2010 III Pan American Plant Membrane Biology Workshop held at Puebla, México.

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Guido Grossmann, a postdoc in the Frommer lab, was awarded a European Molecular Biology Organization Long Term Fellowship. He participated at the FEBS-EMBO Advanced Lecture Course, "Cellular and Molecular Biology of Membranes," in Cargese, Corsica, June 8-19. He was granted a Youth Travel Grant Award and won the first prize for a poster and oral presentation. For achievements during his doctoral thesis he won the 2009 Ph.D. Award of the German Society for Biochemistry and Molecular Biology (GBM). On Sept. 28 Grossmann gave a talk at the Trinational Fall Meeting of The Biochemical Societies: Signal Transduction and Disease, held in Aachen, Germany.

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Clara Bermejo, a postdoctoral associate in the Frommer lab, attended the Yeast Genetics and Molecular Biology Conference 2009 in Manchester, UK, and gave a talk.

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Donghui Li, a member of the TAIR group, spoke at the Frontiers in Plant Molecular Biology conference held Nov. 14-18 in **Suzhou, China**.

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Carnegie scientists have been collaborating with **Jane McConnell**, a former postdoctoral research associate in Barton's lab, to teach Castilleja School students the basics of genetics.

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⓭ **Arrivals:** On Jan. 6 **Rumi Asano** started her position as the health and safety/IT manager for the depts. of Plant Biology and Global Ecology, replacing Glenn Ford, who retired. Asano was a senior lab manager at UC-Berkeley before joining Carnegie. On Aug. 1 the Frommer lab welcomed **Guido Grossman** from Universität Regensburg, Germany, and **Xiaoqing Qu**, a visiting predoctoral student, on Oct. 28 from the China Agricultural U. **Erika Valle** joined the lab as a laboratory technician on Nov. 16; graduate student **Spencer Alford** arrived from U. Alberta on Jan. 4 and will spend three months at the lab. **Leonardo Magneschi**, from Scuola Superiore Sant' Anna, Pisa, joined the Grossman lab as a visiting researcher on Sept. 1. The lab also welcomed **Eva Nowack**, a visiting postdoctoral researcher from Biowissenschaft-Liches Zentrum Universität, Cologne. Stanford graduate student **Zubin Huang** joined the group in Jan. to work on imaging of the photosynthetic apparatus using atomic force microscopy; visiting researchers **Xenie Johnson** and **Jean Alric** arrived from Francis-Andre Wollman's lab in France in Nov. for one month. The Wang lab welcomed three new arrivals: Carnegie fellow **Eunkyoo Oh** arrived

A New Face at Plant Biology

Martin Jonikas has joined Plant Biology as a young investigator. His lab is studying photosynthesis by using new functional genomics strategies with the green alga *Chlamydomonas reinhardtii.* Jonikas received his Ph.D. in genetics from UC-San Francisco. After attending UC-Berkeley for two years, he received his B.S. in aerospace engineering at MIT. The combination of engineering and genetics promises some interesting surprises in his photosynthetic work.

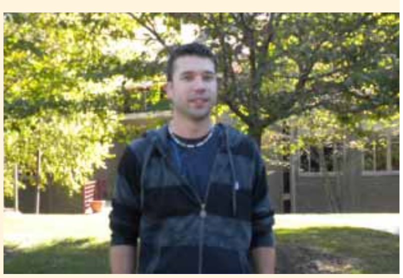
Image courtesy Kathi Bump

⓭ Rumi Asano

⓮ Director Sean Solomon

⓯ Rick Carlson

⓰ Mercedes López-Morales



⓱ Jonathan O'Neil

from the Korea Advanced Institute of Science and Technology, Seoul, on Nov. 19; **Shouling Xu** arrived on Aug. 17 from UNC- Chapel Hill as a DOE postdoctoral research associate; on Sept. 1 predoctoral student **Jianxiu Shang** arrived from the China Scholarship Council. The Rhee lab was joined by postdoctoral research associate **Chang hun You** from Washington State U., Pullman, on Aug. 13, and **Hye In Nam** started Jan. 6 as a laboratory technician.

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Departures: Christine Chang left the Frommer lab on Aug. 14 for a project manager position at the Inst. of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden. Carnegie Fellow **Wenqiang Tang** left the Wang lab on Sept. 24 for a faculty position at Heibei Normal U., Hebei, China. **Ruiji Wang** also left the Wang lab, returning to Heibei Normal U. on Aug. 31. On Nov. 19 the Wang lab bade farewell to visiting researcher **Zhiguang Zhao,** who returned to Lanzhou U., China. Postdoctoral research associate **Jin Chen** left the Rhee lab on Aug. 14 to take an assistant professor position at Michigan State U. Postdoctoral research associate **Kun He** left the lab on Dec. 21 to become a researcher for the Monsanto Company in Beijing. The TAIR group bade farewell to **Vanessa Swing** on Nov. 30. Programmer **Anjo Chi** left on Jan. 22 to be a database/application programmer at the Stanford Genome Technical Center.

TERRESTRIAL MAGNETISM

⓮ **Sean Solomon** organized and spoke at a special keynote symposium on the geology of Mercury at the Geological Society of America (GSA) Annual Meeting in Portland, OR, in Oct. He chaired a meeting of the MESSENGER Science Team in Columbia, MD, in Nov. At the Fall Meeting of the American Geophysical Union (AGU) in San Francisco in Dec., he organized and chaired sessions on MESSENGER's third flyby of Mercury, and one on the scientific directions influenced by **Paul Silver**. In Jan. he delivered a seminar on results from the three MESSENGER flybys at the NASA Goddard Space Flight Center, and he gave a keynote talk at a Workshop on Ground-based Geophysics on the Moon at Arizona State U.

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In Jan. **Alan Boss** hosted Science Team meetings for NASA's Kepler Mission at Carnegie and spoke about the search for habitable worlds at the AstroBio2010 conference in Santiago, Chile.

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⓯ In Nov. **Rick Carlson** hosted **Alicja Wypych**, graduate student of former postdoctoral fellow **Bill Hart**, to work on isotope analyses of rhyolites from the High Lava Plains (HLP). In Dec. Carlson was elected vice president of the Geochemical Society. After two years he will become society president. After participating in the GSA Annual Meeting in Oct., Carlson and colleagues from the HLP seismic experiment led a field trip from Bend to Burns, OR.

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Erik Hauri coorganized the first Reservoirs and Fluxes Directorate Workshop of the Deep Carbon Observatory, held in San Francisco in Dec.

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In Oct. **David James** was invited by the U.S. State Department to give lectures on seismology for the general public in Myanmar and Yangon, Burma.

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Alan Linde, **Selwyn Sacks**, IT systems engineer **Michael Acierno**, electronic design engineer **Brian Schleigh**, and visiting investigator **Tetsuo Takanami** installed water-level sensors at the Sacks-Evertson strainmeter stations in Hokkaido, Japan, in Nov. Linde then gave a colloquium at the Hokkaido U. Institute of Seismology and Volcanology about the 40-year collaboration between the two institutions.

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Larry Nittler gave an invited talk on presolar stardust in meteorites at the 3rd Joint Meeting of the American Physical Society Division of Nuclear Physics and the Physical Society of Japan in Waikoloa, HI, in Oct.

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Vera Rubin attended the third meeting (since 1992) of Women in Science, held in Oct. at U. Maryland. The meeting ended with a visit to the White House, where discussions were held on increasing progress for women. In Jan. she gave an invited talk at a meeting of the American Astronomical Society's Historical Astronomy Division describing the life of Charlotte Moore Sitterly (1898-1990). In Jan. Rubin attended ceremonies in Padua marking the close of the 2009 Year of Astronomy as well as the 400 years since Galileo perfected his telescope and discovered the large moons of Jupiter. **Sandro d'Odorico**, Rubin's first postdoctoral fellow, also attended. After the meeting, former DTM visitor **Francesco Bertola** took Rubin and his 14 graduate students to a villa where Galileo had lived; over lunch, Rubin talked with each student about his or her work.

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In Nov. **Steve Shirey** gave invited colloquia at the Johns Hopkins U. and U. Florida on the start of subduction and plate tectonics on Earth from the perspective of isotopes and trace elements. Shirey hosted **Adrian Van Rythoven** of U. Toronto to examine diamonds from the Kelsey Lake locality.

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⓰ Hubble Fellow **Mercedes López-Morales** spoke at the Center for Astrobiology, Madrid, in Nov. In Dec. she joined the science working group of Near-infrAred High-resolUtion spectrogrAph for pLanet hunting (NAHUAL), a new high-resolution near-infrared spectrograph to be installed on the new 10-meter GranTeCan in the Canary Islands, to discover and characterize exo-Earths.

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In Dec. and Jan. Carnegie Fellow **Nick Moskovitz** presented research on asteroids at NASA Goddard Space Flight Center, U. Maryland, and at the Johns Hopkins U. Applied Physics Laboratory.

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Nick Moskovitz and **Scott Sheppard** attended the 41st annual meeting of the Division for Planetary Sciences of the American Astronomical Society in Fajardo, Puerto Rico, in Oct.

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⓱ DTM presenters at the AGU Fall Meeting included **Rick Carlson**, **Erik Hauri**, **David James**, **Alan Linde**, **Larry Nittler**, **Selwyn Sacks**, and **Steve Shirey**, visiting investigator **Tetsuo Takanami**, postdoctoral fellows **Chin-Wu Chen**, **Natalia Gómez Pérez**, **Matt Jackson**, **Wendy Nelson**, **Jonathan O'Neil** (whose presentation was named one of the top 10 by a student first author in the Volcanology, Geochemistry, and Petrology section), **Nick Schmerr**, **Jessica Warren**, **Wen-che Yu**, and field seismologist **Steven Golden**. A special session, with talks and posters, was held on the science of **Paul Silver**. Silver's former postdoctoral fellows and colleagues included personal reminiscences and lessons learned.

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Alycia Weinberger, postdoctoral fellows **Guillem Anglada**, and **Nick Moskovitz**, and predoctoral fellow **Justin Rogers** presented papers at the 213th meeting of the American Astronomical Society in Long Beach, CA, in Jan.

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Arrivals: In Oct., postdoctoral fellows **Jonathan O'Neil**, who recently received his Ph.D. at McGill U.; **Wendy Nelson**, who received her Ph.D. at Pennsylvania State U.; and **Frank Gyngard**, who obtained his Ph.D. at Washington U. In Nov., **Stella Kafka**, who completed a Ph.D. at Indiana U., and **Chin-Wu Chen**, who defended his Ph.D. at MIT. **Daoyuan Sun** arrived in Jan. after obtaining his Ph.D. from Caltech.

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Departures: Postdoctoral fellows **Matt Jackson**, **Liping Qin**, and **Wen-che Yu** departed in Dec. Jackson began an assistant professor position at Boston U. in Jan. Qin started work as a staff scientist at the Lawrence Berkeley National Laboratory, and Yu began an assistant research fellow position at Academia Sinica, Taiwan.

DTM/GL

Librarian **Shaun Hardy** participated in the GSA meeting in Oct. □

Carnegie Institution for Science
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Geoengineering on the Hill

Can technology save us from global warming? Carnegie's Ken Caldeira addressed this question November 5, 2009, at the first-ever congressional hearing on geoengineering. In his testimony, Caldeira explained to members of the House Committee on Science and Technology the pros and cons of various geoengineering approaches. □

Image courtesy House Committee on Science and Technology

Carnegie Diamonds on World Museum Tour!

Some of the Geophysical Laboratory's single-crystal diamonds are traveling with a major museum exhibit, *The Nature of Diamonds*. The display focuses on diamond beauty, geological origins, and diamond science. *The Nature of Diamonds* opened in October 2008 at the Royal Ontario Museum. It was on display since October 2009 at the Field Museum in Chicago, and moved to Singapore on March 28, 2010.

The gas-to-gem CVD diamonds, grown and polished at Carnegie, surprised curators at the American Museum of Natural History. They expected large, crude diamonds, not "brilliant" gems. The Carnegie diamonds are produced for high-pressure research, which requires purer and stronger stones than natural gems. The Carnegie diamonds can be fabricated to possess optical characteristics at least comparable to conventional diamond anvils used for high-pressure research. But the single-crystal CVD is more durable because of its enhanced toughness.

The new generation of diamonds possesses extraordinary optical, mechanical, and electrical properties and will likely have a huge impact on science and technology. The exceptional semiconductor properties of single-crystal diamonds have enormous potential for high-power electronics used in the transportation, manufacturing, and energy sectors. They can also significantly expand the range of applications of optical materials required for third- and fourth-generation synchrotrons, free-electron lasers, and advanced neutron spallation sources. □

A Carnegie CVD diamond is included in *The Nature of Diamonds* exhibition material.