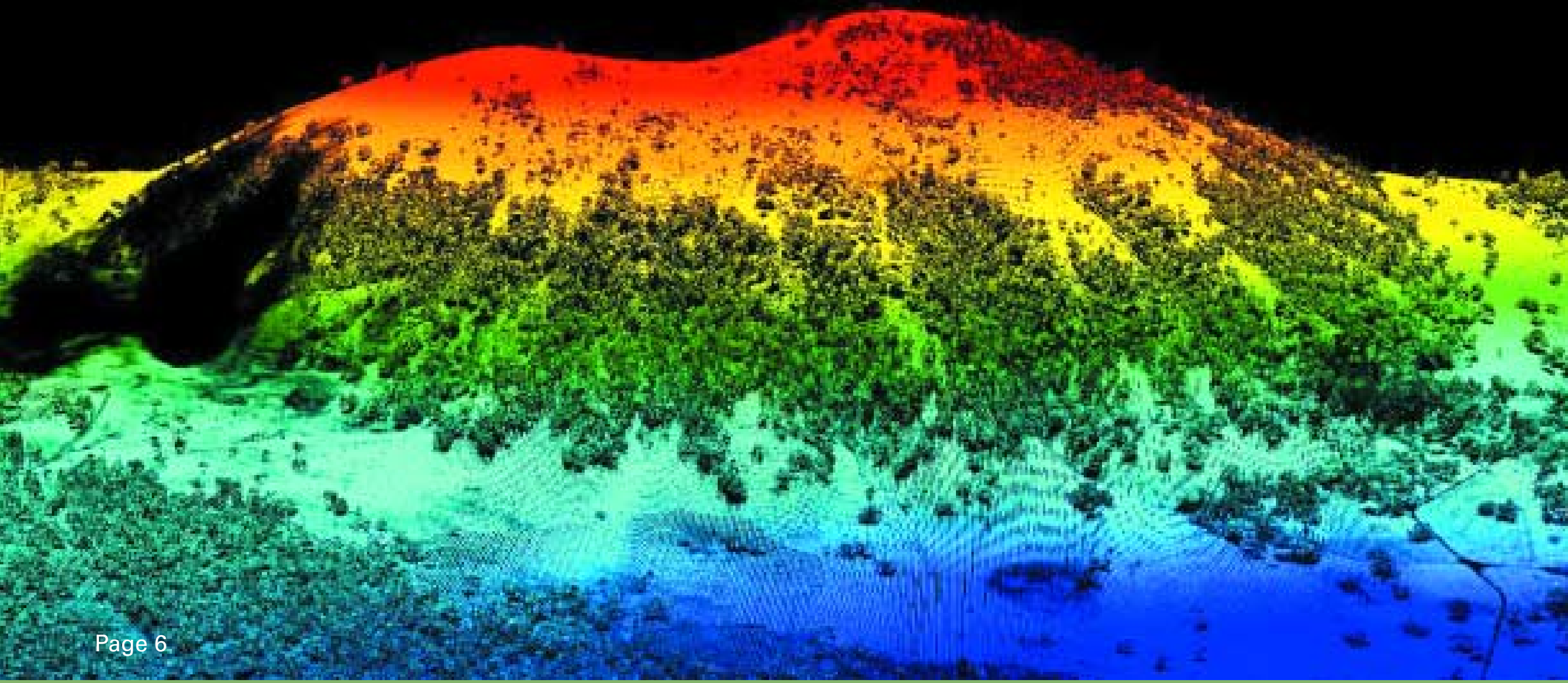
CarnegieScience

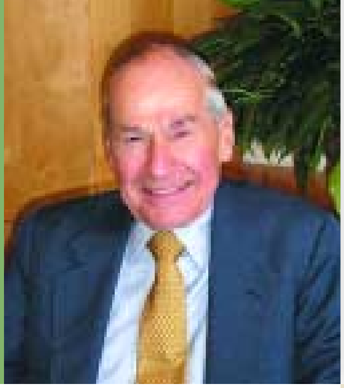
THE NEWSLETTER OF THE CARNEGIE INSTITUTION [SPRING 2007]

Inside



Page 6

DEPARTMENT OF EMBRYOLOGY
GEOPHYSICAL LABORATORY
DEPARTMENT OF GLOBAL ECOLOGY
THE OBSERVATORIES
DEPARTMENT OF PLANT BIOLOGY
DEPARTMENT OF TERRESTRIAL MAGNETISM
CASE/ FIRST LIGHT



CARNEGIE INSTITUTION FOR SCIENCE

Carnegie Institution of Washington
1530 P Street, NW
Washington, D.C.
20005-1910

202.387.6400
www.CarnegieInstitution.org

The *Carnegie Campaign for Science* concluded on December 31, 2006, having raised $60 million and accomplishing critical objectives essential to the future of the institution. Although our endowment and related income are the primary funding sources for Carnegie science, generous organizations, foundations, and individual benefactors are increasingly important to our success in fulfilling our mission. The campaign allowed us to build two state-of-the-art buildings and upgrade critical facilities, to purchase next-generation scientific instrumentation, to secure ongoing support for new initiatives, and to embark on far-reaching future capital projects. I thank everyone who contributed; Carnegie is much stronger because of your generosity.

Those of us who have had the privilege of spending time in the two new buildings know that the *Carnegie Campaign for Science* provided facilities of the quality deserved by our scientists. The new building for the Department of Global Ecology was custom designed and built to meet the needs of our newest department; moreover, it is the only fully "green" building on the Stanford campus. The dazzling and functional Maxine F. Singer Building, including the 105-seat Rose Auditorium, will serve the scientists in that Nobel Prize-winning department for years to come. Additionally, we completed renovations in the David Greenewalt Building on the campus shared by the Geophysical Laboratory (GL) and the Department of Terrestrial Magnetism (DTM), and we significantly upgraded the headquarters for the Observatories in Pasadena.

Advanced instrumentation is critical to our scientific program. The *Carnegie Campaign for Science* enabled the acquisition of instruments of critical importance to the work of our scientists.

- Researchers at DTM now have the use of a NanoSIMS ion probe, which has been vital to the DTM/GL team studying the composition of dust grains from the comet Wild 2 returned by the Stardust mission.
- The High Pressure Collaborative Access Team and the diamond group at GL were able improve their equipment, keeping them world leaders in unraveling the mysteries of matter under extreme conditions and developing new 21st century materials.
- The Observatories developed instrumentation for the Magellan telescopes to address some of the most pressing questions in astronomy today. They also created new technology for correcting atmospheric aberrations at the ground level, which could improve telescopes' performance around the world.
- The campaign contributed to a variety of projects at Global Ecology, including the one-of-a-kind Carnegie Airborne Observatory. With its sophisticated imaging and laser remote sensing technologies, researchers can study regional ecosystems anywhere in the world to better understand land-use change, climate change, and the impact of natural disturbances on the structure and function of ecosystems.

Progress was also made in growing our endowment. Endowed funds raised will maintain the new buildings, support growth in the Department of Global Ecology, provide postdoctoral fellowship support, and underpin the general work of the institution. Endowments created through the campaign, along with the extraordinary performance of our investments over the six-year period of the campaign, put us in a strong financial position.

Maintaining excellence is a never-ending task. As a result, we must continue to seek resources to provide the best support for the great scientists at Carnegie. If Andrew Carnegie were here today, he would be proud to see how like-minded contemporary friends of his institution share his vision and support its future. Without their support in the past six years and on into the future, the Carnegie Institution could not maintain its world-class status. To our generous benefactors, I extend my heartfelt thanks.

—**Michael E. Gellert,** *Chairman*

TRUSTEE News

Global Ecology Hosts Board of Trustees Meetings

The 125th meeting of the Carnegie board of trustees took place in the Department of Global Ecology's state-of-the-art "green" building, on the campus shared with the Department of Plant Biology in Stanford, California. At its first session, on December 7, the board unanimously elected its newest trustee, Remi Barbier. The Finance, Development, and Research committees also met. Tours of the Global Ecology labs followed the meetings. Trustees, guests, and faculty from both departments gathered for dinner at which senior Carnegie trustee and chairman of the Stanford board of trustees Burton McMurtry was the featured speaker.

The second session of the board took place on the following day, preceded by the meeting of the Nominating Committee. President Richard Meserve then reported on the state of the institution. Plant Biology staff member Sue Rhee followed with a talk about her work developing and directing the popular biological database, TAIR (The Arabidopsis Information Resource). She also described how the database is used in gene research. The meetings concluded with each director summarizing significant work at the departments.

Board of trustee members Suzanne Nora Johnson (left) and Steve Fodor tour the labs at Global Ecology.

Global Ecology staff member Joe Berry describes a CO_2 monitoring system, designed for remote regions, to better understand how the global carbon cycle works.

New Trustee Remi Barbier, Founder and CEO of Pain Therapeutics, Inc.

The Carnegie board of trustees has elected Remi Barbier, president and CEO of Pain Therapeutics, Inc., to its board on December 7. Founded by Barbier in 1998, Pain Therapeutics is a publicly traded (NASDAQ: PTIE) biotechnology company based in South San Francisco, California.

"Remi Barbier brings an impressive array of knowledge and experience from the science and business communities to our board," commented Carnegie president Richard Meserve. "He will be invaluable to the growth of the institution."

Pain Therapeutics develops novel drugs in the areas of pain management and oncology. For more information please visit the company's Web site, www.paintrials.com.

A lifelong entrepreneur in the life sciences, Barbier has founded, cofounded, or helped grow several biomedical companies, including Exelixis, Inc., a leading genomics-based drug discovery company; ArQule, a chemistry company; and EnzyMed, a chemistry company now owned by Albany Molecular Research, Inc. Barbier obtained his undergraduate degree from Oberlin College and an MBA from the University of Chicago.

Remi Barbier (above) was elected to the Carnegie board on December 7, 2006.

(Image courtesy Dan Singer.)

Dr. Maxine F. Singer

Maxine Singer Awarded 2007 NAS Public Welfare Medal

The National Academy of Sciences has awarded Carnegie president emerita Maxine F. Singer the Public Welfare Medal, the academy's most prestigious honor, for her inspired leadership in science and its application to education and public policy. Each year the academy awards the medal to recognize the use of science for the public good.

Recognizing Our Benefactors

In 1902, Andrew Carnegie pledged to support innovative researchers of exceptional ability in an environment free from the constraints found in most other research organizations. To this end, he created and endowed the Carnegie Institution. Carnegie scientists are financed largely by endowment income and other revenues; the balance comes from generous individuals and organizations who share the Carnegie vision.

Philanthropic support for the Carnegie Institution allows our scientists to pursue high-risk, high-reward research, which has put them at the forefront of their fields. Our primary benefactors play a key role in strengthening Carnegie's ability to fulfill its critical mission. Starting this year, individuals who donate $10,000 annually and those who have made significant cumulative donations will be recognized as members of Carnegie Philanthropic Societies. These societies recognize individuals who have given at different levels. The Barbara McClintock Society shows appreciation for individuals who contribute $10,000 or more in a fiscal year. The Carnegie Founders, Edwin Hubble, and Vannevar Bush societies honor individuals who have made lifetime contributions of $10 million, $1 million, and $100,000 respectively. Second Century Society members contribute to Carnegie through planned giving.

② Founder of the Carnegie Institution, **Andrew Carnegie**

③ Carnegie astronomer **Edwin Hubble**

① Carnegie scientist and Nobel laureate **Barbara McClintock**

④ Former Carnegie president and leader of American scientific research **Vannevar Bush**

① The Barbara McClintock Society

An icon of Carnegie science, **Barbara McClintock** was a Carnegie plant biologist from 1943 until her retirement. She was a giant in the field of maize genetics and received the 1983 Nobel Prize in Physiology or Medicine for her work on patterns of genetic inheritance. She was also the first woman to win an unshared Nobel Prize in that category. To sustain researchers like McClintock, annual contributions to the Carnegie Institution are essential. The McClintock Society thus recognizes generous individuals who contribute $10,000 or more in a fiscal year, making it possible to pursue the highly original research for which Carnegie is known.

② The Carnegie Founders Society

Andrew Carnegie, the founder of the Carnegie Institution, established it with a gift of $10 million. Although he ultimately gave a total of $22 million to the institution, his initial $10 million gift represents a special level of giving. In acknowledgment of the significance of this initial contribution, individuals who support Carnegie's scientific mission with lifetime contributions of $10 million or more are recognized as members of the Carnegie Founders Society.

③ The Edwin Hubble Society

The most famous astronomer of the 20th century, **Edwin Hubble**, joined the Carnegie Institution in 1919. His observations shattered our old concept of the universe. He proved that the universe is made of collections of galaxies and is not just limited to our own Milky Way; he also showed that the universe is expanding. This work redefined cosmology. Science typically requires years of work before major discoveries like these can be made. The Edwin Hubble Society honors those whose lifetime support has enabled the institution to continue fostering such long-term, paradigm-changing research by recognizing those who contribute between $1,000,000 and $9,999,999.

④ The Vannevar Bush Society

Vannevar Bush, the renowned leader of American scientific research of his time, served as Carnegie's president from 1939 to 1955. Bush believed in the power of private organizations and wrote in 1950, "It was Andrew Carnegie's conviction that an institution which sought out the unusual scientist, and rendered it possible for him to create to the utmost, would be worth while [sic] . . ." He further said that "the scientists of the institution . . . seek to extend the horizons of man's knowledge of his environment and of himself, in the conviction that it is good for man to know." The Vannevar Bush Society recognizes individuals who have made lifetime contributions of between $100,000 and $999,999.

Second Century Society

The Carnegie Institution is now in its second century of supporting scientific research and discovery. The **Second Century Society** recognizes individuals who have remembered, or intend to remember, the Carnegie Institution in their estate plans and those who have supported the institution through other forms of planned giving.

Frank Stanton, Former Carnegie Chairman, Dies at 98

◀ **Frank Stanton,** former chair of the Carnegie board of trustees and an icon of 20th century broadcast media, died on Sunday, December 24, 2006, at his home in Boston. He was 98.

Best known for his tenure as president of the CBS network from 1946 to 1971, Stanton served on the Carnegie board from 1963 to 1985. He was chairman of the board from 1977 to 1979 and sat on several committees, including the Executive Committee (member, 1968-1984; chair, 1974-1975) and the Audit Committee (chair, 1981-1984). After 22 years of active service, Stanton became a trustee emeritus in 1985.

Stanton assumed the presidency of CBS in 1946, when William S. Paley stepped down to become chairman of the board. Together, Stanton and Paley shaped the network into the most influential and reputable of the mid-20th century, largely by advocating for television as the medium of choice over radio. The network's trademark mix of arts, entertainment, and hard-hitting news earned it the nickname "the Tiffany Network" during Stanton's term.

Stanton was born March 20, 1908, in Muskegon, Michigan. He received a bachelor's degree from Ohio Wesleyan University in 1930, where he studied zoology and psychology. Graduate studies at Ohio State University earned him a master's degree in 1932 and a doctorate in 1935, both in psychology. Within months of receiving his doctorate, he began work in the research department at CBS.

In addition to his service to Carnegie, Stanton was chair of the American Red Cross (1973-1979) and the Rand Corporation (1961-1967), and the founding chairman of the Center for Advanced Study in the Behavioral Sciences in Stanford, California (1953-1971). He sat on the boards of many other organizations, including the Lincoln Center for the Performing Arts, the Educational Broadcasting Corporation, and the Rockefeller Foundation.

(Image courtesy Greg Asner.)

Introducing Carnegie's

Asner lab researcher Matt Jones guides the Carnegie Airborne Observatory (CAO) along its flight path. While the pilots, seated in front, actually steer the plane, Jones provides them with precise, real-time directions via a heads-up display to ensure that valuable flight time is not wasted.

The skies over Hawaii buzz with the propellers of small aircraft. Most of them ferry people among the islands, or give tourists a glimpse of inaccessible locales. But there is one among the swarm that is unlike anything else in the sky, distinguishable from the tourist planes only by a small opening underneath that bristles with lenses and sensors. This unassuming vessel will soon help researchers probe deeper into the structure and chemistry of ecosystems than ever before.

The Carnegie Airborne Observatory (CAO) wields some of the most powerful remote sensing instruments available today. Conceived, developed, and brought to life by Greg Asner and his team at the Department of Global Ecology, the CAO can efficiently image large swaths of forest in pinpoint three-dimensional detail. On a typical flight, the instruments gather gigabytes of data that can reveal patterns in native species diversity, foreign species invasion, forest growth rates, and overall ecosystem health. For the past several months, the Big Island of Hawaii—which contains examples of more than two-thirds of all ecosystem types on Earth—has served as the CAO's proving ground.

"It's as if the information is written in invisible ink, and all we have to do is figure out how to read it," Asner explains. "When we fly overhead, we see the tops of trees. But the CAO can see physical structures down below the canopy, and can pick up on biochemical information that is invisible to the naked eye."

A CAT Scan of the Forest

The heart of the CAO consists of two main instruments. One, a waveform light detection and ranging (LiDAR) system, maps the three-dimensional physical structure of the trees. LiDAR is a close cousin of radar, except that it bounces laser light off of its targets instead of radio waves. The second device is a hyperspectral imager, which gathers information about the biochemistry of the forest by measuring the wavelengths of light reflected by trees and other vegetation. The CAO integrates the LiDAR and hyperspectral data on the fly to construct a complete three-dimensional picture.

"Greg's team is using the CAO to gather and blend incredibly detailed physical and chemical data in a way that hasn't been done before," says Global Ecology department director Chris Field. "They've essentially devised a way to do a virtual 'CAT scan' of an ecosystem."

Strictly speaking, the plane itself is not part of the CAO; rather, the instruments are portable and designed to plug into just about any small aircraft. This will enable Asner's team to deploy the CAO anywhere in the world. It also allows razor-sharp scanning that other remote sensing equipment, much of which rides on satellites or in high-altitude aircraft, cannot equal. Depending on how low the plane flies, resolution can range from 1 meter per pixel to as fine as 20 centimeters per pixel—precise enough to make out the individual branches and leaves on trees.

Eye in the Sky

"It's as if the information is written in invisible ink, and all we have to do is figure out how to read it."

Diagnosis: Threatened Ecosystem

Much as a doctor can use a CAT scan to detect and diagnose myriad ailments in the human body, the CAO is designed to ferret out a variety of ecological threats. A crucial issue is the rampant thinning—and in some cases, disappearance—of native plant species.

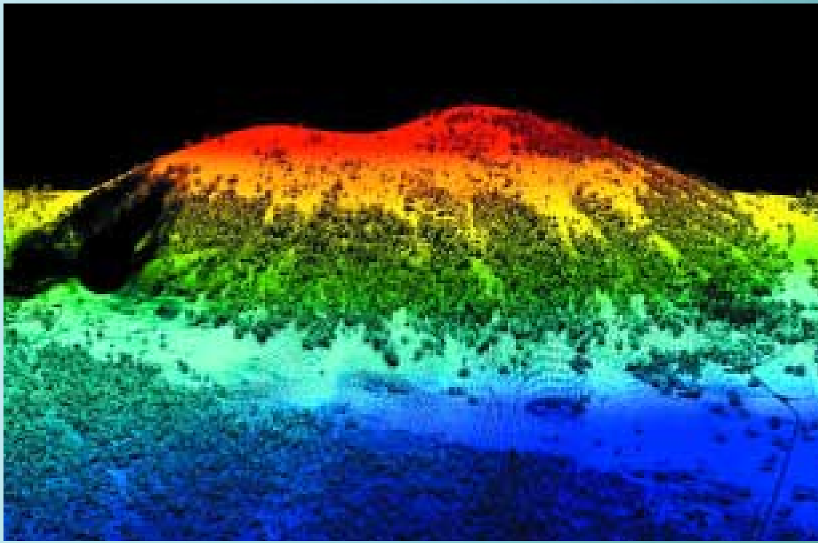
Asner plans to use the CAO to map the species diversity of rain forest ecosystems and discover which species are disappearing, and how quickly. Similarly, his team wants to know where they are surviving, and what factors are vital for their health. This information can aid conservation efforts in Hawaii, the Brazilian Amazon, northern Australia, and elsewhere by identifying the most threatened areas, as well as diversity "hot spots" where many species beat the odds and persevere.

In many areas, the biggest threat is from foreign, "invasive" species that outcompete the natives for space and resources. In the Hawaiian test sites, for example, two particular introduced tree species can get their nitrogen from the air rather than from the limited supplies in the ground, as the native species do. This has allowed the faster-growing invaders to push out the natives at an alarming rate. Using the CAO, Asner's group can map and track these species, gathering data that can be used to inform the effort to stem the invasion.

"The CAO has an unparalleled ability to measure and map the structure, composition, and physiology of ecosystems," says Flint Hughes, an invasive species ecologist and Asner's collaborator from the U.S. Forest Service's Institute of Pacific Islands Forestry. "The conservation and management potential is unique in Hawaii—and in the world, for that matter."

(Image courtesy Greg Asner.)

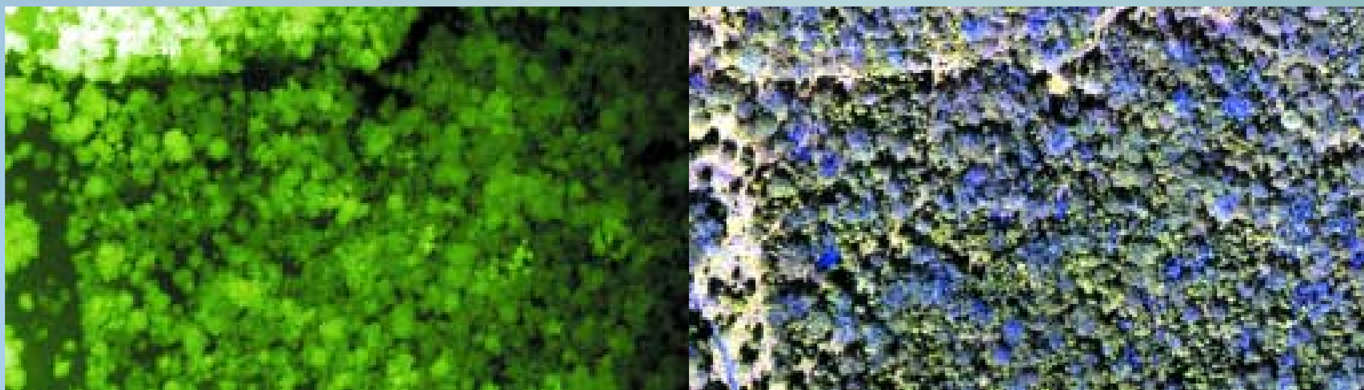
While this image might look like a screen capture from the popular computer game SimCity, it is actually a live image of a neighborhood in Hilo, Hawaii, taken by the CAO.



(Image courtesy Greg Asner.)

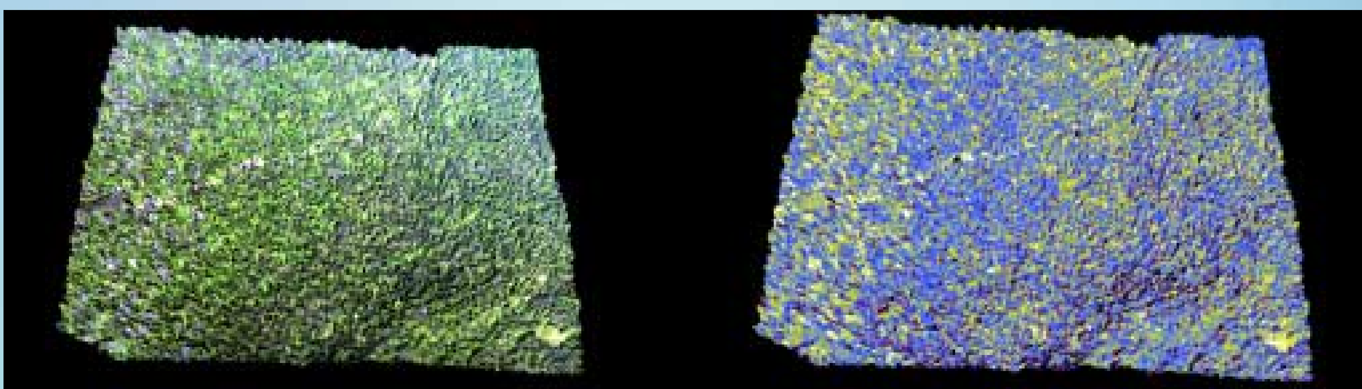
This three-dimensional CAO LiDAR image of the Pu'u Wa'awa'a cinder cone, a volcanic feature on the Big Island of Hawaii, holds detailed information about the structure of the vegetation on its slopes. The color coding indicates altitude.

(Images courtesy Greg Asner.)



The same square of forest looks very different to the two "eyes" of the CAO. On the left, the Light Detection and Ranging (LiDAR) system reveals the three-dimensional structure of the forest canopy; on the right, the hyperspectral imager highlights differences in chemical composition.

(Images courtesy Greg Asner.)



When hyperspectral and LiDAR data from the CAO are combined, stunning three-dimensional imagery like this is the result. Packed with hundreds of megabytes of data, a single image can reveal information about the health and diversity of an ecosystem with an unprecedented level of detail. At left, a natural color composite shows a dense rain forest area in Hawaii. At right, chemical detection in the same area reveals canopies with high nitrogen content (yellow-white) contrasting with low nitrogen content (blue-red).

Identification, Please

Asner's group will need a way to definitively identify plant species from the air in order to study species diversity and patterns of invasion. In theory, each species should have its own unique fingerprint based on the chemicals in its leaves and stems, which will reflect slightly different wavelengths of light.

To develop a key to these fingerprints, Asner's team is collecting leaf samples the old-fashioned way—on foot—and matching each species and their biochemistry with the spectra of light they reflect. With this information in hand, it is testing the CAO's ability to accurately detect plant fingerprints from the air. As it refines the system, the team hopes to eventually be able to identify all the tree species in a study area with just one pass.

While the CAO specializes in vegetation, it can also identify hidden geomorphologic features in the landscape. Asner's colleague and frequent collaborator, Stanford ecologist Peter Vitousek, recently looked at a CAO scan and could scarcely believe his eyes. There, in the middle of a study site he had traversed on foot literally hundreds of times, he saw that a series of depressions—water catchments and channels on the forest floor—was organized in a way that he had never seen as a whole. "The CAO has the advantage of aerial access and large-area coverage, but also provides levels of detail beyond what you can achieve on foot," Vitousek says. "It's going to prove incredibly useful in the study of fragile ecosystems, and learning more about how they respond to conservation efforts."

— Matthew Early Wright

The CAO hardware was funded by a grant from the W. M. Keck Foundation and a gift from William Hearst III.
Scientific studies currently under way in Hawaii are funded by NASA, the U.S. Forest Service, and the State of Hawaii.

Bling-Bling: Oldest Diamonds on Earth

Scientists have dated diamonds from the recently discovered diamond fields in Canada's Northwest Territories for the first time and have found that they are the oldest precisely dated diamonds on Earth. They formed 3.5 billion years ago in the Archean era, when the Earth was forming its first continents.

The researchers, Steven Shirey and Richard Carlson from Carnegie's Department of Terrestrial Magnetism, with colleagues, also report evidence indicating that the diamonds probably formed during subduction—a process in which one crustal plate sinks and slides under another hundreds of miles into Earth's mantle. The findings were published in the September 2006 issue of *Contributions to Mineralogy and Petrology.*

Department of Terrestrial Magnetism scientist Steve Shirey

(Image courtesy J.W. Harris.)

This photomicrograph is an example of a sulfide-inclusion-bearing rough diamond. It is from the Jwaneng Mine in Botswana. The hexagonal grain at center is iron sulfide (Fe-S) surrounded by an irregular black rim. Sulfide grains like these are removed for rhenium-osmium isotopic analysis to reveal the age of the diamond and the composition of the sulfide.

Diamonds in the Rough

Diamonds are dense forms of carbon and the hardest natural substance known. The largest diamonds come from cratons—ancient continental regions with deep roots providing a nucleus around which younger continental material gathered. Cratons contain the oldest rocks on the planet and hold much of the Earth's mineral wealth, including diamonds. The roots extend into the mantle more than 125 miles (200 km) deep where pressure is high enough, but temperature cold enough, for diamond formation. The mantle "keels" to cratons are as old as the overlying crust and date from 3.9 to 2.5 billion years ago. Diamonds come to the surface from rare volcanic eruptions of magmas that solidify into rocks called kimberlites.

Time Capsules from Ancient Earth

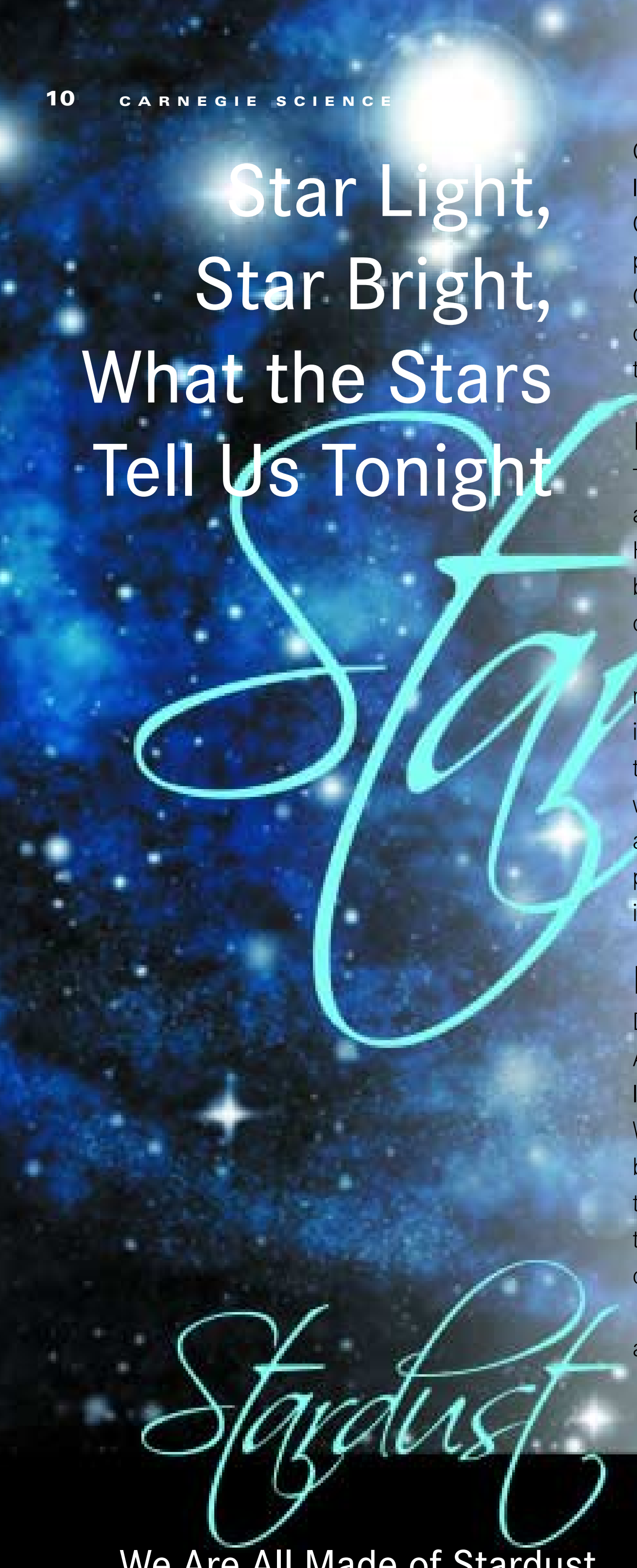
"Diamonds aren't just for spectacular jewelry," said Shirey. "They are scientific gems too. They act as tiny time capsules. Many diamonds encase tiny mineral grains—what jewelers call impurities but geoscientists call inclusions—that can tell us how old the diamond is and what geologic processes occurred in the deep Earth billions of years ago."

There are two major diamond varieties, eclogitic and peridotitic. For some time, scientists have believed that eclogitic diamonds form from the process of subduction. But this study contains the first evidence that peridotitic diamonds also may be formed from the water and other fluids released by subducting crustal plates at depth.

The researchers extracted sulfide inclusions from a sample of diamonds, each about 1 carat, from Canada's Slave Craton's Panda kimberlite. They determined their age with the rhenium-osmium (Re-Os) dating technique. Rhenium and osmium are natural radioactive isotopes that decay at a predictable rate and make good atomic clocks for determining absolute ages. Depending on the chemical composition of the sulfides, scientists can determine whether melt percolation, crustal recycling, or fluid addition contributed to sulfide formation. They can also determine the temperature history of the minerals by looking at how nitrogen is distributed within the lattice structure of the diamonds—nitrogen atoms tend to pair up, or aggregate, more with increasing temperatures.

"We found that the diamonds are 3.5 billion years old and that they resided at relatively low temperatures for billions of years," said Shirey. The isotopic signature also indicates that subduction may have been at work. "The evidence suggests that this is one of the oldest subduction events found and that subduction is a way to form the earliest continents."

Star Light, Star Bright, What the Stars Tell Us Tonight



Our galactic neighborhood is brutal. The Milky Way, home to our solar system, is on a collision course with the Andromeda galaxy; it is ripping apart the Large and Small Magellanic Clouds; and it is cannibalizing the dwarf galaxy Sagittarius. By analyzing the chemical compositions and orbital characteristics of individual stars, groups of stars, and star clusters, Carnegie astronomers in particular have made huge strides toward untangling some of this commotion. Their data allow them to determine stellar ages, the origins of stars, and ultimately the formation and evolution of galaxies—some of the hottest topics in astronomy today.

Long-standing Observatories Traditions

The Observatories has been preeminent in the history of studying the chemical compositions, ages, and origins of stars and stellar populations since its beginning in 1904. George Ellery Hale, the founder and first director of Carnegie's Mount Wilson Observatory and an early builder of the world's largest telescopes, was a pioneer in studying the chemical composition of the Sun and the stars.

Unlike biologists or geologists, who physically handle specimens, astronomers cannot control or manipulate their sources. They rely on starlight generated deep in stellar interiors. This light interacts uniquely with gases of different elements, including those in the stars' outer layers. Atoms consume or release photons, units of light energy, at specific wavelengths in characteristic ways. When a device such as a prism disperses the light into a rainbowlike spectrum, a signature pattern of absorption or emission lines is superimposed, like a fingerprint. From those "spectra" astronomers can derive the object's chemical composition.

Exploring the Stars

During the 1920s, early spectroscopic surveys by Mount Wilson director Walter Adams and Alfred Joy and spectra taken by Roscoe Sanford led to the eventual identification of old, or low-metallicity, halo stars of the Milky Way (see sidebar). In the 1940s, the celebrated Walter Baade took advantage of the unusually dark skies of Los Angeles caused by WWII blackouts and pointed the Mount Wilson telescopes to stars in other galaxies. By analyzing the colors and brightnesses of the stars in Andromeda and its neighbors and comparing them with observations of Milky Way stars, Baade discovered that all of the galaxies were comprised of stellar populations similar to those found in our galaxy.

The first unequivocal proof that elements were being created in stars came in 1952 at Mount Wilson with Paul Merrill's discovery of the short-lived radioactive element tech-

We Are All Made of Stardust

The essence of almost everything comes from stars. Of all the elements, only hydrogen and helium, plus a smattering of lithium, formed during the Big Bang 14 billion years ago. Everything heavier than beryllium was manufactured in stars in nuclear reactions.

Nuclear fusion (the phenomenon that occurs when two atomic nuclei react under intense conditions and form a heavier nucleus, releasing enormous energy in the process) is the engine behind the formation of many elements. A by-product of this energy generation is the step-by-step production of the elements of the periodic table. Our Sun shines by converting hydrogen to helium, a process first described by the famous physicist Hans Bethe at a 1938 symposium hosted by Carnegie's Department of Terrestrial Magnetism. Stars like the Sun can make elements up to oxygen. Beyond this point, however, further nucleosynthesis is not possible because of insufficient internal pressure. The star dies. The outer layers slough off, eventually mixing with the interstellar medium, out of which subsequent generations of stars will form. The core is all that remains, cooling for the rest of eternity.

In deriving energy from nucleosynthesis, stars that are more massive than the Sun can synthesize elements by fusion to those just heavier than iron. When its energy-generation capability is exhausted, along with its ability to support its own outer layers, the star collapses, resulting in an explosion known as a supernova. The colossal burst expels new elements into the interstellar medium, from which subsequent generations of stars will be born.

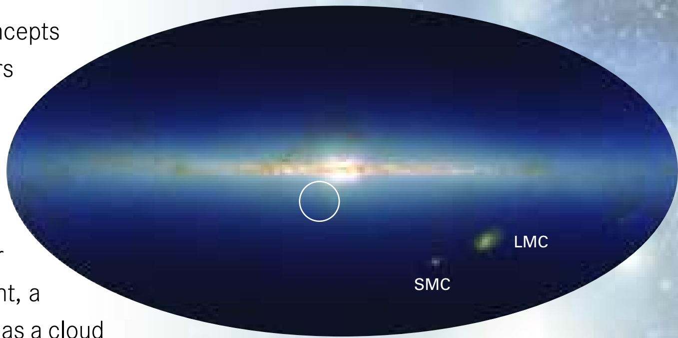
So what about elements heavier than iron? Most of these are made by a process called neutron-capture nucleosynthesis, in which netium in certain stars. In the following decades, by combining the basic concepts of stellar populations with ages and with chemical compositions, astronomers began developing an understanding of stellar evolution and nucleosynthesis—the formation of elements by nuclear reactions. In 1962 world-renowned Observatories astronomer Allan Sandage coauthored a landmark paper with Olin Eggen and Donald Lynden-Bell that revealed how the young galaxy, the protogalaxy, formed. They investigated the correlations between the stellar kinematics—the motions of stars as they orbit the galaxy—and their metal content, a signature of age (see sidebar), and derived a model of the early galaxy. Beginning as a cloud of gas, it contracted and collapsed to eventually form its signature flat, spiral disk, some 10 billion years ago.

In explaining the correlations, the model also made predictions about the chemical evolution of the galaxy. For instance, globular clusters—spherical collections of hundreds of thousands of very old stars—are particularly valuable tracers of galactic evolution. Because they are among the oldest subunits of our galaxy, they are thought to have formed about the same time as the rest of the Milky Way. If the Milky Way had formed by contraction and collapse, globular clusters that formed in the inner parts would have received a greater chemical enrichment (see sidebar) than those that formed in the outer regions.

Leonard Searle (Observatories director 1988-1996) was among those who recognized the importance of the globular cluster system in sleuthing out the history of the Milky Way. In the 1970s, he and Carnegie Fellow Robert Zinn surveyed the metal content of a number of globular clusters at a range of distances from the galactic center. They compared these and other observations against predictions they made based on simple models of chemical enrichment of stars and clusters in the Milky Way and concluded that the galaxy formed from smaller protogalactic fragments originating in different environments and over time, some falling into the Milky Way after its central regions collapsed.

Expanding the Horizons

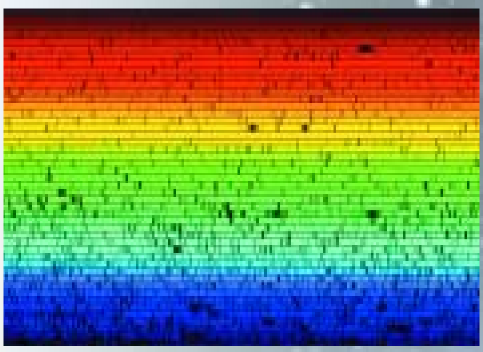
Concurrent with the globular cluster work done by Searle and Zinn, George Preston (Observatories director 1980-1986) and Steve Shectman decided to seek out the oldest and most metal-poor stars. Since then, they have discovered many of the oldest known stars identified to date, and have created a vast stellar populations' database. Today, along with staff astronomers Ian Thompson and Andy McWilliam, they continue to break new ground in this area. Preston puts it this way: "While our colleagues in the nebular



The Two Micron All Sky Survey (2MASS), a near-infrared survey, recently scanned about 70% of the sky to better understand the structure of our local universe. The central flat disk is our Milky Way, a spiral galaxy with a central bulge. The research revealed that although the Milky Way dominates the galactic neighborhood, the heart of the Sagittarius dwarf galaxy is intimately connected. In this image it is seen as a slight "extension" below the center of the Milky Way (circled area). Below right of the Milky Way disk are other neighbors, the Large and Small Magellanic Clouds (LMC and SMC).

(Atlas image courtesy Two Micron All Sky Survey (2MASS), a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology funded by NASA and NSF.)

(Image courtesy N. A. Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF.)

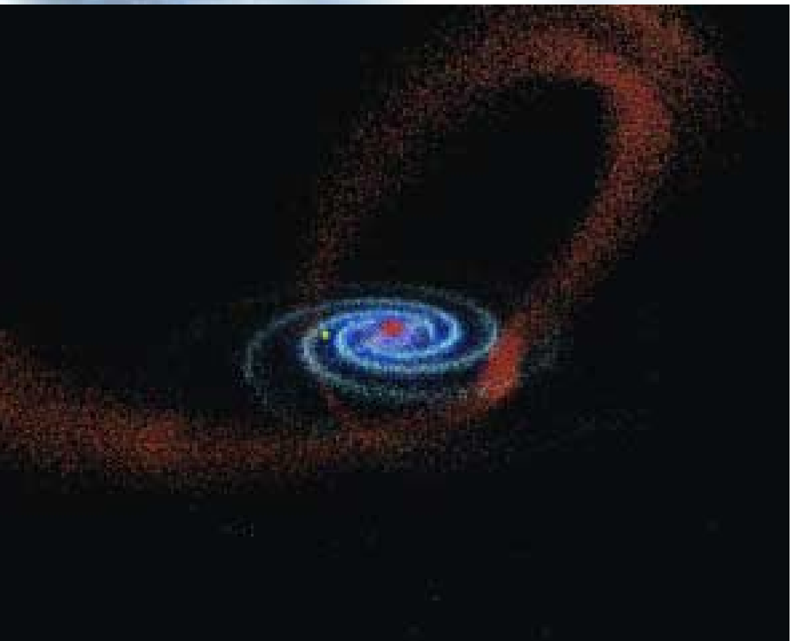


Different elements absorb or release photons—units of light energy—at specific wavelengths in characteristic ways. When the light is dispersed into a spectrum, a signature pattern of absorption or emission lines results, telling astronomers the object's chemical composition. This is a high-resolution spectrum of the cool giant star Arcturus.

free, energetic neutrons—uncharged atomic nuclear particles—are captured by atomic nuclei. The rapid neutron-capture process (r-process) is associated with explosive events in neutron-rich environments (e.g., supernovae), forming heavy elements including silver, gold, and platinum, and up through uranium. Neutron capture also occurs on slower timescales (the slow neutron-capture process, or s-process), tracing a different path along the route to building heavier isotopes and forming elements such as barium and lead. This process occurs in old, evolved stars of intermediate mass that are synthesizing intermediate-mass elements, freeing neutrons that are captured in the synthesis of heavier elements.

When a star dies it expels gas and dust, out of which new stars form. Each successive stellar generation comes from a richer mix of elements than the previous one. This cycle continues as the galaxy ages. By analyzing the spectra containing the chemical fingerprints from the stars' light, astronomers can discern ages and origins of individual stars, groups of stars, and stellar neighborhoods within galaxies.

Astronomers refer to elements heavier than hydrogen and helium as metals. Baade's Population I stars resemble those that inhabit the region near our Sun. They have relatively more heavy elements and are known as metal-rich. Population II stars, similar to those found in ancient globular clusters, inhabit the outer reaches of the Milky Way. They are older and are dubbed metal-poor because they have comparatively fewer heavy elements relative to the much more abundant hydrogen and helium. Despite the concentrated efforts of surveys such as those devised by Preston and Shectman, examples of the very first stars (Population III) have yet to be found. Their elusiveness has made them even more intriguing. As George Preston remarked, "Now everybody wants to get into the act."



(Image courtesy David Law/University of Virginia.)

Based on data from 2MASS, astronomer David Law modeled the distribution of stars (red areas) in the Sagittarius dwarf galaxy. That galaxy is currently being ripped apart by the gravitational attraction of the Milky Way, represented by the blue disk (not to scale). The Sun is shown as the yellow dot. The debris from Sagittarius extends from the dense "core" of the Sagittarius dwarf galaxy and surrounds the Milky Way.

department pursue the largest elements of the universe (galaxies), we chase the smallest ones (atoms). As the old song goes, they 'go together like a horse and carriage . . . you can't have one without the other.' "

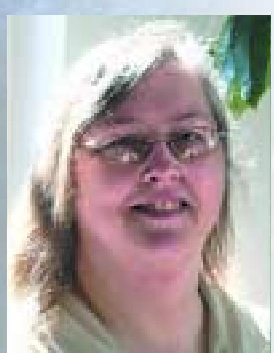
Andy McWilliam and collaborators have intensively studied the chemical compositions of other long-lived stellar populations: stars in both the Milky Way's galactic bulge and stars on the other side of the bulge, in the most densely populated regions of what was once the Sagittarius dwarf galaxy, currently merging with the Milky Way. The results indicate that the bulge formed faster than was previously believed and that Sagittarius has had an elemental processing, or nucleosynthetic, history very different from our own Milky Way's.

New Frontiers

With the latest discoveries of mergers in the Milky Way has come a new generation of astronomers. Carnegie-Princeton Fellow Inese Ivans is one such researcher. "I pictured myself as a scientist in kindergarten," reflected Ivans. "But it was as an undergraduate learning about stardust, stellar alchemy, and the search for the oldest stars in the universe, that ultimately captured my imagination, and still does."

Ivans explores our corner of the universe by studying the chemical compositions of stars belonging to various old stellar populations. By studying the nucleosynthesis of various isotopes, which are different forms of the same element, as well as nucleosynthetic origins—not just how, but where and when the elements formed—she is able to infer the origins and evolution of various stellar populations.

As a Carnegie-Princeton Fellow, Ivans has access to an impressive array of resources including the Magellan and du Pont telescopes at Carnegie's Las Campanas Observatory; the Sloan Digital Sky Survey (SDSS); and the echelle spectrograph at Apache Point Observatory. The data gained from these sources are helping to fill in the puzzle pieces toward understanding nucleosynthesis and how the Milky Way formed, evolved, and interacted with our nearby galactic neighbors.



(Image courtesy Scott Rubel.)

After completing her undergraduate work at the University of Toronto, Carnegie-Princeton Fellow Inese Ivans went to The University of Texas at Austin, where she received her Ph.D. in 2002. She was a Hubble Fellow at Caltech before coming to Carnegie in 2005.

The different facilities also expand the wavelength coverage, which increases the number of elements Ivans can study for a given object. One of the most interesting metal-poor objects studied to date, CS22892-052, for example, is a star that is extremely enriched in material formed via the rapid neutron-capture process (r-process; see sidebar). The star, discovered by Preston and Shectman and observed by McWilliam and Ivans with their collaborators, has been observed with numerous ground- and space-based observatories. This star is now second only to the Sun in the number of elements studied. It turns out that the chemical abundance pattern of this old star resembles, to an astounding degree, the predicted rapid process abundance pattern of the Sun, born hundreds and thousands of supernovae generations later.

In a more recent investigation, Ivans led a multiobservatory project that itemized the relative abundances of 51 elements in an old metal-poor, evolved star (HD 221170). The team discovered a previously undetected difference in the relative abundances of lighter versus heavier elements formed by the r-process (see sidebar) as compared with model predictions, providing new insights into the astrophysical conditions for r-process production. "Access to the telescope and instrument resources of Carnegie is crucial to my work," said Ivans. "However, an even greater advantage is the everyday access to the *human* resources. Folks here are not only keenly interested in the sorts of questions that interest me; they are also genuinely helpful and extremely generous with their expertise."

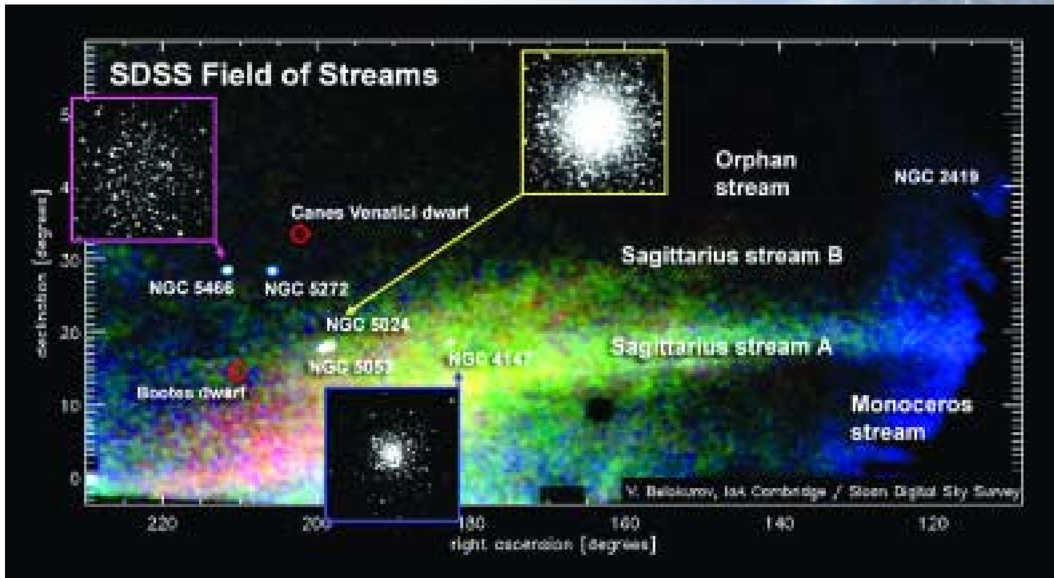
One of the interesting classes of stars identified by Preston and his colleagues is the class known as blue metal-poor stars. Since blue stars are typically young and metal-poor stars are old, the term seems to be unusual. In fact, the origins of these stars are a bit of a mystery and hold important clues not only to the evolution of the galaxy but to neutron-capture nucleoesynthesis as well.

Ivans and collaborators found that one such binary object (CS29497-030) contains material made by two distinctly different neutron-capture processes (see sidebar). The discovery spawned a new model of ancient binary star formation. The scientists believe that the formation of this pair of stars was triggered by a supernova that snowplowed and clumped a nearby molecular cloud, while highly enriching it in r-process material. The observed abundances are best matched by a model in which subsequent slow neutron-capture processing (s-process; see sidebar) relied on the unusual r-process enhancement. This model explains not only the abundances of this star but also of other objects that have also been observed to be enhanced in both r- and s-process elements. Previously, as many theories of the origins of these stars existed as the discoveries of the stars themselves.

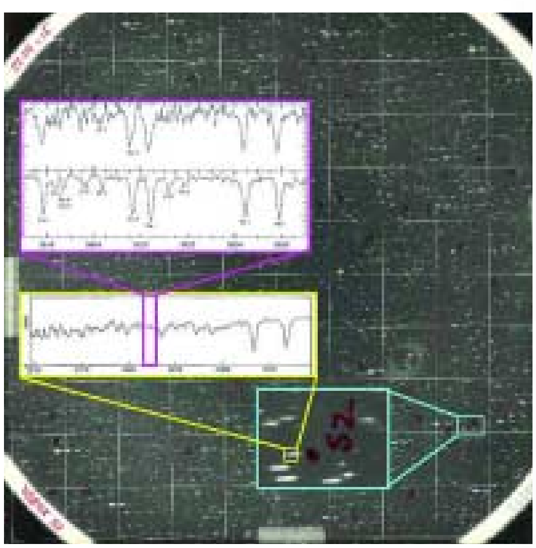
Many of Ivans's targets have also been selected by their kinematics. By mining the chemical-kinematic correlations, she can uncover stellar populations that originally formed together, but have since spread throughout the Milky Way. Studies like these are helping to identify and unravel the contributions of mergers such as those of the Sagittarius dwarf galaxy to the Milky Way. Some of this work is in collaboration with two other Carnegie post-doctoral scholars, Daisuke Kawata and Jeff Crane.

In the last few years, astronomers have found a number of satellite systems in the outer halo of the Milky Way. Taking advantage of these discoveries, Ivans is also looking at the chemical abundance differences among globular clusters within the Milky Way, between the Milky Way and the Magellanic Clouds, and in the newly discovered satellite systems. Some of her most recent observations include those of stars in a faint, newly discovered Milky Way satellite in the constellation of Boötes—a sparse system of unusual morphology, which may be a dwarf spheroidal galaxy, or a fossil remnant of one of the building blocks that grew into our Milky Way. The chemical compositions of its stars promise to tell an interesting story. In the coming years, Ivans will tease out additional clues to the origins of these and other celestial neighbors as she continues her quest to understand evolution on a galactic scale.

(Image courtesy Vasily Belokurov, SDSS-II Collaboration.)



This "Field of Streams" image, from the Sloan Digital Sky Survey, shows the Milky Way over about one-quarter of the sky. The colors indicate distance, so that groupings of stars, such as the streams from Sagittarius or the Monocerus ring, are more easily detected. Blue stars are closer than red ones. Among the various populations shown in this image, Ivans is analyzing data from stars in the Sagittarius and other streams, from some of the globular clusters, and from the newly discovered satellite in Boötes. The inset images, all from the Digitized Sky Survey, illustrate some of the variety of globular clusters. Some are sparse; some are rich; all tell us something about nucleosynthesis and galactic evolution.



CS22892-052 is one of the best-studied ancient stars from the Milky Way's halo. Astronomers from the Observatories and elsewhere have studied it for several decades, from the ground and from the Hubble Space Telescope. As technology has improved, Carnegie astronomers have been able to determine its chemical makeup in ever more detail, which is helping to piece together how our galaxy evolved. It is likely to be one of the early objects studied with the next-generation higher-resolution spectrograph—the Carnegie Planet Finder, currently under construction by Jeff Crane, Steve Shectman, and Paul Butler.

The underlying image is the photographic plate taken by Carnegie's Preston and Shectman in their 1970s survey for the most metal-poor stars. The lowermost plot, bordered in yellow, shows Shectman's "discovery spectrum" taken at moderate resolution in the 1980s, which confirmed the metal-poor nature of the star. The upper two plots illustrate higher-resolution spectra taken in the 1990s by McWilliam and collaborators at the du Pont and 4-meter telescopes for their initial studies of the neutron-capture elements of this star.

(Original plate, image courtesy George Preston; top plate, Astrophysical Journal 819, 821; bottom plate, Steve Shectman; manipulation, Inese Ivans.)

Bizarre Bacteria Discovered Two Miles Underground

Living things inhabit some fairly strange places. From pale, blind fish lurking in dark caves to giant worms clinging to the edges of deep-sea volcanic vents, the definition of "livable environment" just keeps expanding. But now researchers have discovered something that stretches the boundaries yet again: an isolated, self-sustaining bacterial community living nearly two miles below the surface in a South African gold mine.

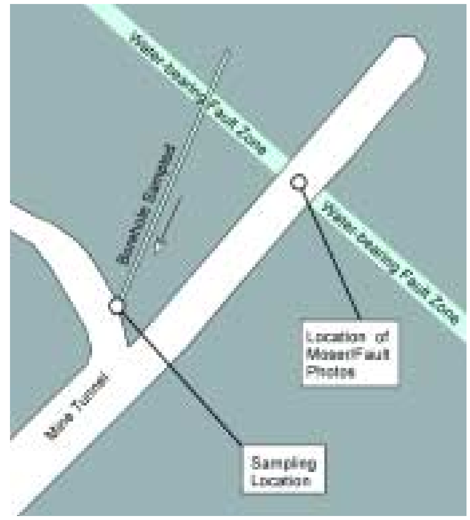
It is the first microbial community demonstrated to be exclusively dependent on geologically produced sulfur and hydrogen, and one of the few ecosystems on Earth that does not depend on energy from the Sun in any way. The discovery, reported in the October 20, 2006, issue of *Science*, raises the possibility that similar bacteria could live beneath the surface of other worlds, such as Mars or Jupiter's moon Europa.

"These bacteria are truly unique, in the purest sense of the word," said lead author Li-Hung Lin, now at National Taiwan University, who performed many of the analyses as a doctoral student at Princeton and as a postdoctoral researcher at the Carnegie Institution's Geophysical Laboratory. "We know how isolated the bacteria have been because our analyses show that the water they live in is very old and hasn't been diluted by surface water."

In addition, Lin explained, the hydrocarbon molecules found with the bacteria did not come from living organisms, as they usually do. Also, the hydrogen that the bacteria use for respiration does not come from air or the decomposition of organic matter but from the decomposition of water caused by the radioactive decay of uranium, thorium, and potassium.

Humans and most land-dwelling organisms ultimately get their energy from the Sun, with photosynthetic plants forming the base of the food web. But in dark places where sunlight doesn't reach, life has to depend on alternate energy sources. Other communities of chemoautotrophs—a word chained together from Greek roots meaning "chemical self-nourishment"—have been found in exotic places such as aquifers, petroleum reservoirs, and vents linked to deep-sea volcanoes.

Yet such communities all depend at least in part on nutrients that can be traced back to photosynthetic plants or bacteria. The strange bacteria in the study, however, get everything they need in the water-filled cracks of a rock fracture that intersects the Mponeng gold mine near Johannesburg, South Africa.



This diagram shows where the photograph was taken with respect to the discovery.

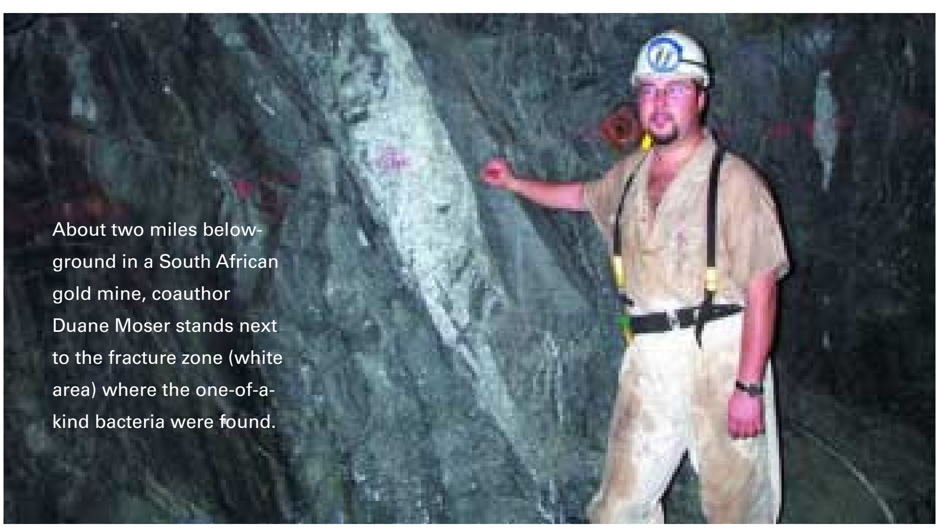
(Image courtesy Duane Moser.)

The international team was led by T. C. Onstott of Princeton University, and also included Carnegie staff scientist Douglas Rumble and former Carnegie postdoctoral researcher Pei-Ling Wang, also now at National Taiwan University.

Using genetic tools, the team discovered that there is very little species diversity in the rock fracture community. Compared with bacteria in the water used for mining, the fracture water is dominated by one type of bacteria related to *Desulfotomaculum*, which is known to get energy from the reduction of sulfur compounds.

"We also believe that the sulfate used by these creatures is left over from ancient groundwater mixed with ancient hydrothermal fluid. It is possible that communities like this can sustain themselves indefinitely, given enough input from geological processes," Rumble said. "Time will tell how many more we might find in Earth's crust, but it is especially exciting to ponder whether they exist elsewhere in the solar system." •

— Matthew Early Wright



About two miles below-ground in a South African gold mine, coauthor Duane Moser stands next to the fracture zone (white area) where the one-of-a-kind bacteria were found.

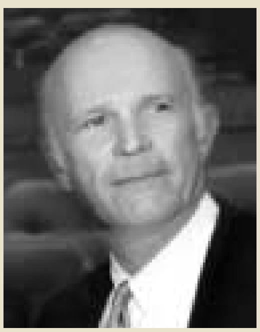
(Image courtesy Duane Moser.)

This work was supported by grants from the NSF, NASA, the U.S. Department of Energy, the National Science Council of Taiwan, the Natural Sciences and Engineering Research Council of Canada, Deutsche Forschungsgemeinschaft, and the Killam Fellowships Program. Granting divisions include the NASA/NSF Life in Extreme Environments (LExEN) Program, the NASA Astrobiology Institute's teams at Indiana-Princeton-Tennessee Astrobiology Institute (IPTAI) and the Carnegie Institution of Washington, the NASA Cosmochemistry Program, the NSF Division of Earth Sciences (EAR), and the DOE Genomics: GTL Program.

IN Brief

❶ U. Chicago honorary degree recipients, back row (left to right): Allan Spradling, Hazel Markus, Harm Pinkster, Sandra Faber. Front row (left to right): Alex Lubotzky, Robert Zimmer, Karen Strier, Michael Fried.

(Image courtesy Dan Dry.)



❷ Steven McKnight

❸ Carnegie president Richard A. Meserve (left) with Norwegian ambassador Knut Vollebaek at the "Arctic Meltdown—Global Effects" conference.

(Image courtesy Royal Norwegian Embassy.)

Trustees and Administration

❶ Trustee **Sandra Faber** was awarded an honorary doctorate from U. Chicago on Oct. 27 for her achievements on the nature of dark matter, the formation of galaxies and star populations, and early galactic evolution. "Her work has profoundly shaped the modern view of galaxy formation and has inspired a generation of astronomers," stated the citation. Embryology director Allan Spradling also received an honorary doctorate at the same ceremony.

—

❷ Carnegie trustee **Steven McKnight** was elected a fellow of the American Association for the Advancement of Science.

—

❸ Carnegie president **Richard Meserve** delivered opening remarks for "Arctic Meltdown—Global Effects," a conference sponsored by the Norwegian embassy and held at the administration building Oct. 2-4. On Oct. 24 he gave opening remarks for the conference "Stem Cells: Saving Lives or Crossing Lines/Avenues for Advancement," cosponsored by Carnegie and the James A. Baker Institute for Public Policy. He chaired the meeting of the IAEA's International Nuclear Safety Group in Vienna, Austria, on Nov. 6-8, and participated in a meeting on Nov. 21-22 in Canberra, Australia, to review a government task force report requested by the science advisor to the Australian prime minister. He also traveled to the Carnegie Observatories in Las Campanas, Chile, Jan. 15-19.

—

The accounting department welcomes **Patty Harrington**, who replaced **Heather Davis**. Several transitions occurred in the Office of Advancement: **Ellen Carpenter**, the advancement activities coordinator, left in Dec. and was replaced by **Ben Barbin** in Jan. **Mira Thompson** joined the office last summer.

Embryology

❶ U. Chicago awarded **Allan Spradling** an honorary Doctor of Science degree in Oct. Tony Mahowald, who presented the award to Allan, is a professor in the university's Department of Molecular Genetics and Cell Biology and was Allan's postdoctoral advisor from 1976 to 1979 at Indiana U. Spradling spoke in Nov. at a symposium held at the Academia Sinica's Institute of Molecular Biology in Taiwan to celebrate the institute's 20th anniversary and, also in Nov., at the Temesek Life Sciences Laboratories in Singapore.

—

Joe Gall received the Senior Award from Women in Cell Biology at the ASCB annual meeting in San Diego in Dec.

—

Doug Koshland spoke at the Academia Sinica's Institute of Molecular Biology in Taiwan in Nov.

—

Alex Schreiber received a grant from the Fulbright Senior Specialists Program for work in flatfish aquaculture and developmental biology with collaborators in Japan and Norway.

—

Staff associate **James Wilhelm** left the department in Dec. to become an assistant professor at UC-San Diego.

—

Carnegie Collaborative Fellow **Mary Goll** was awarded a three-year postdoctoral fellowship from the Damon Runyon Cancer Research Foundation.

—

The NIH awarded **Tina Tootle** a Ruth L. Kirschstein National Research Service Award, which will fund her work in the Spradling lab through 2009.

—

Mari Moren, a researcher at the National Institute of Nutrition and Seafood Research in Bergen, Norway, is visiting the Schreiber lab from Sept. to Mar.

—

Graduate student **Julio Castañeda** received a Johns Hopkins U. Dupont Teaching Award for General Biology.

—

Kyoto U. graduate student **Shun Adachi** visited the Koshland lab from Oct. to Dec.

—

Arrivals: Postdoctoral researcher **Don Fox** (Ph.D., UNC-Chapel Hill) came in Nov. to the Spradling lab. Postdoctoral researcher **James Walters** (Ph.D., U. Pennsylvania) arrived in Jan. while research technician **Amy Kowalski** and animal technician **Andrew Gurtler** came in Dec. and Jan. to the Farber lab. Research scientist **Chun Dong** arrived in Feb. and Johns Hopkins U. undergraduate **Shirley Shao** in Sept. to the Han lab. Johns Hopkins U. undergraduate **Ariela Friedman** joined the MacPherson lab in Dec. Research technician **Evan Siple** and animal technician **Sharon Dlubala** came to the Fan lab in July and Dec. Research technician **Keeyana Singleton** joined the Koshland lab in Aug. and research technician **Rong Chen** joined the Zheng lab in Jan.

—

Departures: Postdoctoral fellow **Catherine Huang** left the Koshland lab for a staff scientist position at BD Biosciences in Hunt Valley, MD. **Ming-Ying Tsai** left the Zheng lab in Jan. for an assistant professor position at U. Nebraska Medical Center, as did **Anna Hei Chan** in Feb. to complete her postdoctoral studies at U. Nebraska Medical Center.

—

Embryology business manager **Susan Kern** hosted a two-day meeting of the Standing Work Group in Sept.

—

Andrew Eifert joined the department as an assistant facility manager in Aug.

—

Earl Potts shifted his duties from general building maintenance to the mouse facility. Potts replaces **Warren Hall**, who left the department in Aug. to return to his native North Carolina.

—

Dolly Chin joined Embryology's administrative office in July.

Geophysical Laboratory

The American Astronautical Society awarded **Wesley Huntress** the William Randolph Lovelace II Award in Oct. for his contributions to space science and technology. *Brown Alumni Magazine* for Nov./Dec. had a short feature on him.

—

Claire Hardy, technical secretary at the Geophysical Laboratory since last summer, died on January 10. She had worked at the administration beginning in November 1998, and was the database and communications coordinator for the Office of Advancement before moving to GL. A memorial service was held on January 20 at the Good Shepherd Episcopal Church in Silver Spring, Maryland.

What's New With CDAC: The third Stewardship Science Academic Alliances (SSAA) Program symposium was held Feb. 5-7 at Carnegie headquarters in Washington, DC. The Broad Branch Road Campus hosted a workshop on pressure calibration at high temperatures Jan. 26-28. For details see the Scientific Highlights on the CDAC Web site at http://cdac.gl.ciw.edu.

Russell Hemley spoke at the Sixth International Conference on Cryocrystals and Quantum Crystals in Kharkov, Ukraine, in Sept. In Oct. he spoke at the Fall Joint Meeting of the Texas Sections of the American Physical Society, in Arlington, TX; at the 53rd Midwest Solid State Conference in Kansas City, MO; and at the U. Virginia chemistry department. In Nov. he cochaired a symposium at the MRS Fall Meeting in Boston and attended the Balzan Prize ceremony in Rome. In Dec. he spoke at the AGU Fall Meeting.

—

Ho-kwang (Dave) Mao gave the keynote lecture at the 3rd Asian Conference on High Pressure Research in Lijiang, China, in Oct. He spoke in Nov. at the Materials Research Society (MRS) Fall Meeting in Boston, and in Jan. at the Lawrence Livermore National Laboratory.

—

Robert Hazen gave the keynote lecture at the inauguration of Harvard U.'s Origin of Life Initiative in Nov. In Dec. he lectured at the National Academy of Sciences' Sackler Symposium on Evolution and Development. In Feb. he gave the Elsasser Lecture at Johns Hopkins U. and the Darwin Lecture at Northwestern U. He will give the Sokol Lecture at Montclair State U. in Montclair, NJ, in Mar.

—

George Cody lectured at U. Maryland in Oct. and at Penn State U. in Nov. In Dec. he spoke about the first science results from NASA's Stardust mission at Caltech and at the AGU Fall Meeting in San Francisco.

—

Bjørn Mysen spoke at the Institute for the Study of the Earth's Interior in Misasa, Japan, in Oct.

—

Alexander Goncharov cochaired a symposium at the MRS Fall Meeting in Boston in Nov.

—

Doug Rumble lectured at UC-Riverside and UCLA, and coauthored research presented at the AGU Fall Meeting in San Francisco in Dec.

—

Postdoctoral fellow **Jennifer Jackson** spoke at the Goldschmidt Conference in Melbourne, Australia, in Aug. She served as mineral physics representative on the program committee for the AGU Fall Meeting in San Francisco in Dec. She has recently accepted an assistant professor position at Caltech.

—

Postdoctoral associate **Jennifer Eigenbrode** has accepted a position at NASA's Goddard Space Flight Center and will become a visiting investigator in the Fogel lab.

—

Postdoctoral fellow **Elizabeth Stevenson** has accepted a position at the Smithsonian Institution and will become a visiting investigator in the Fei lab.

—

Guoyin Shen (HPCAT) spoke at the Diamond Light Source in Oxfordshire, UK, in Sept., and at the Advanced Photon Source in Dec.

—

Yue Meng (HPCAT) spoke at Ohio's Miami U. in Oct., at the Advanced Photon Source in Nov., and at SUNY in Dec.

—

Haozhe Liu (HPCAT) spoke at Florida International U. in Miami and at U. Nevada-Las Vegas, both in Nov. He also chaired a poster session at the AGU Fall Meeting in San Francisco in Dec.

—

Recent graduate **John Howard** (U. Nevada-Las Vegas) joined HPCAT as a lab assistant for UNLV.

—

As of Oct., all four of HPCAT's experimental stations are now operational and accessible to general users. For more information see http://www.hpcat.aps.anl.gov.

—

Arrivals: Postdoctoral fellow **Yufei Meng** (Sun Yat-Sen U., Guangzhou, China) joined the Hemley lab. Postdoctoral associate **Alexander Kolias** (UC-Berkeley) came to the Cohen lab. Senior research associate **Henderson James Cleaves** (UC-San Diego) arrived to the Hazen lab and interns **Christy Mancuso** and **Emily Snyder** (American U.) joined the Fogel lab.

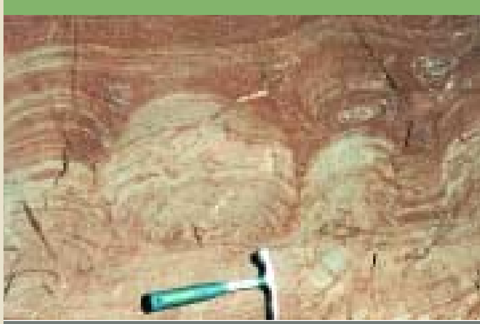
—

Departures: Postdoctoral associate **Qing Peng** completed her fellowship in the Cohen lab and returned to Johns Hopkins U. Predoctoral associate **Sandra Siljestroem** left the Steele lab and returned to Sweden, while postdoctoral fellow **Heather Watson** has taken a position at Caltech and predoctoral fellow **Yu Wang** has returned to Peking U. in Beijing.

—

DOUG RUMBLE'S STROMATOLITES

In Sept. Doug and Karen Rumble traveled to Western Australia to study stromatolites—layered, rocky structures made by algae and bacteria in shallow water. In the Pilbara Outback, fossil stromatolites—some of which are 3.4 billion years old—can be found in outcrops exposed to the surface. In Shark Bay, living microbes actively form new stromatolite reefs, with the exact same "upside-down bowling pin" shapes seen in the fossils.



These 1.9-billion-year-old fossil stromatolites are from the Duck Creek Formation and were photographed in Duck Creek Gorge, in the Pilbara Outback of Western Australia.

These living stromatolites in Shark Bay, on the Indian Ocean coast of Western Australia, have reached a height of about half a meter. They have the exact same shape as fossils found inland.

(Images courtesy Doug Rumble.)

LAB-ON-A-CHIP HEADS TO THE INTERNATIONAL SPACE STATION

An instrument that could revolutionize the way astronauts conduct chemical and biological research traveled to the International Space Station (ISS) aboard the space shuttle *Discovery* on Dec. 9. In the summer of 2007, the device will allow the first complete biochemical analysis of microorganisms, from sampling to data retrieval, by an astronaut in space.

GL's Jake Maule and Andrew Steele teamed with Norm Wainwright of Charles River Laboratories to develop the Lab-On-a-Chip Application Development Portable Test System (LOCAD-PTS) in collaboration with NASA's Marshall Space Flight Center. Space station crews will use the LOCAD-PTS to monitor microorganisms and potentially hazardous chemicals in the cabin environment. The lightweight and compact system is essentially a mobile laboratory, and uses interchangeable cartridges to perform a variety of tests within minutes.

The first generation of cartridges will detect two types of lipid-sugar molecules found in the cell walls of either bacteria or fungi. The second generation, scheduled for launch in Dec. 2007, will provide a more specific test for fungi, some of which are capable of causing significant structural damage to the ISS. The third generation will single out a major group of bacteria, some of which have already been found inside the ISS.

The LOCAD-PTS team tested the device here on Earth in several settings before it went into space: on the Arctic Mars Analogue Svalbard Expeditions (AMASE) to Spitsbergen, Norway; on the NASA Astrobiology Institute (NAI) expedition to Kamchatka, Russia; on the NASA Desert Research and Technology Study (D-RATS) expeditions in Arizona; and in parabolic flights of NASA's C-9 aircraft.

(Image courtesy NASA/MSFC.)

Li Zhang has transitioned from predoctoral associate to postdoctoral associate in the Fei lab.

—

Susana Mysen joined GL as technical secretary in Nov.

—

Lowell Miyagi, a CDAC graduate student at UC-Berkeley, received an Outstanding Student Paper award from the Rock and Mineral Physics section of the American Geophysical Union for his presentation "Deformation of the CaIrO3 Post-Perovskite Phase to 5 GPa and 1300 K in the Multi-Anvil Press," given at the 2006 AGU Fall Meeting.

—

Electronics specialist **David George** retired in Dec.

Global Ecology

Chris Field spoke at the Transatlantic Science Conference, held at Carnegie headquarters and jointly sponsored by the Norwegian embassy and Carnegie, in Sept., and organized a workshop on feedbacks between permafrost and climate change in Santa Barbara, CA, in Dec. Field also started a new project in collaboration with Roz Naylor of the Woods Institute at Stanford U. to study the capacity of world ecosystems to produce biofuels.

—

The *New York Times* published an opinion piece by **Ken Caldeira** in Jan. about the warming influence of forests in high latitudes. He spoke about this same topic on the PRI/BBC radio program *The World*, and about geoengineering on BBC Radio 4. Caldeira served on the selection committee for AGU's Sullivan Award, which annually recognizes excellent science feature stories written for a general audience. He eventually had to recuse himself because he was featured in one of the contending stories. Caldeira organized a workshop on geoengineering in association with NASA-Ames in Nov. and spoke at the Transatlantic Science Conference held at Carnegie headquarters, jointly sponsored by the Norwegian Embassy and Carnegie, in Sept. He has been appointed to the Inter-University Scholars Training Program, a new initiative to facilitate communication between university researchers and California policymakers working on climate change. Caldeira also spoke in London to a group that is developing rules for treating subseabed carbon stored under the OSPAR and London conventions.

—

Greg Asner, with team members **David Knapp**, **Matt Jones**, **Robin Martin**, **Ty Kennedy-Bowdoin**, and **Masahiro Negishi**, launched the Carnegie Airborne Observatory (CAO) program and began a second round of in-flight tests in Jan. (see feature on page 6). In addition, NASA has selected the Flora hyperspectral satellite mission, led by Asner and colleagues from JPL, for initial development study.

—

Erle Ellis (U. Maryland) will be on sabbatical at GL until June.

—

Postdoctoral researcher **Cho-ying Huang** (U. Arizona) joined the Asner lab in Dec. Huang and postdoctoral researcher **Maoyi Huang** both presented at the AGU Fall Meeting in San Francisco in Dec.

—

Postdoctoral researcher **Damon Matthews** left the Caldeira lab for a faculty position at Concordia U. in Montreal in Dec.

—

Graduate student **Adam Wolf** traveled to the Norwegian Institute for Air Research in Kjeller, Norway, and to the Laboratoire des Sciences du Climat et de l'Environment near Paris to work with international collaborators on atmospheric and climate modeling. Graduate students **Eben Broadbent** and **Angelica Almeyda** traveled to the trinational frontier of the Brazilian, Bolivian, and Peruvian Amazon, and conducted interviews with area residents from Dec. to Jan.

—

Ty Kennedy-Bowdoin joined the Carnegie Airborne Observatory's technical staff in Jan.

—

Technician **Mark Rogers** joined the Field lab in Nov.

—

Mary Smith is now Global Ecology and Plant Biology's special projects coordinator.

—

David Kroodsma's bike ride for climate has taken him more than 14,000 miles. In early Feb. he crossed the border from southern Chile back into Argentina. Check his progress at www.rideforclimate.com.

—

Global Ecology held its annual picnic for staff and their families in Oct., and a joint holiday party with Plant Biology in Dec.

More than 300 visitors attended the Carnegie Observatories' fifth annual open house on Oct. 22. They watched astronomers prepare for a night of observing on the Magellan telescopes through a live webcam feed from Las Campanas Observatory in Chile; learned about the progress of the Giant Magellan Telescope from a new 20-minute video; enjoyed an old-fashioned lantern slide show that featured recently discovered images from the Observatories' historic collection of astronomical photos; and much more.

A young visitor explores a hands-on display in the Observatories' instrument machine shop at the open house.

(Image courtesy Scott Rubel.)

❹ Chris Somerville (right) meets Italian president Giorgio Napolitano at the Balzan Prize awards ceremony.

(Image courtesy International Balzan Foundation.)

Observatories

Associate director and GMT project manager **Matt Johns**, with staff astronomers **Patrick McCarthy** and **Steve Shectman**, hosted two Giant Magellan Telescope instrumentation workshops: one at the Observatories in Oct. and another, cohosted by U. Arizona, at the Steward Observatory in Dec.

—

Staff astronomer **Alan Dressler** spoke at the Stars to Galaxies conference in Venice, Italy, in Oct. In Nov. he spoke at the Third Community Workshop on the Ground-based Optical/Infrared System in Scottsdale, AZ.

—

Staff astronomer **Luis Ho** co-organized the Central Engine of Active Galactic Nuclei conference in Xian, China, in Oct. He also spoke at Shanghai Astronomical Observatory, at Hong Kong U., and at the Institute of High-Energy Physics in Beijing.

—

Staff astronomer **Andrew McWilliam** attended the GMT instrumentation workshop in Pasadena in Oct., and cochaired a session of the Third Community Workshop on the Ground-based Optical/Infrared System in Scottsdale, AZ, in Nov.

—

Staff astronomer **Michael Rauch** spoke at the Applications of Gravitational Lensing conference at the Kavli Institute for Theoretical Physics in Santa Barbara, CA, in Oct. In Jan. he served on the Hubble Fellowship Committee at the Space Telescope Science Institute in Baltimore.

—

Senior research associate **Barry Madore** lectured at the Third Chilean Advanced School of Astrophysics at U. Chile in Concepción in Jan.

—

Carnegie-Princeton Fellow **Inese Ivans** answered visitors' questions at the Carnegie Open House and attended the GMT instrumentation workshop in Pasadena, both in Oct. She attended a Sloan Digital Sky Survey (SDSS-II) workshop at Case Western Reserve U., and spoke at UNC-Chapel Hill. Ivans also attended the NOAO Galactic Telescope Allocation Committee fall meeting.

—

Postdoctoral associate **George Becker** attended the conference "Radiation Backgrounds from the First Stars, Galaxies, and Black Holes" at U. Maryland in Oct.

Plant Biology

❹ **Chris Somerville** received the prestigious Balzan Prize in Nov.

—

Winslow Briggs spoke in Nov. at a symposium at the Academia Sinica's Institute of Molecular Biology in Taiwan to celebrate the institute's 20th anniversary, and at the Academia Sinica's Institute of Plant and Microbial Biology. Briggs also chaired one session of the Western Section of the American Society of Plant Biologists meeting at UC-Davis in Feb.

—

❺ **Shauna Somerville** was elected a fellow of the American Association for the Advancement of Science for her pioneering work on plant pathogen interrelations.

—

Wolf Frommer spoke at U. Cologne and the Max Planck Institute for Plant Breeding Research in Cologne, and at Merck in Darmstadt, Germany, in Sept. In Nov. he spoke at the American Society of Nephrology's Renal Week conference in San Diego, and in Dec. he spoke at the Academia Sinica in Taiwan and contributed to their advisory board. In Jan. he attended the HFSP Meeting at Stellenbosch U. in South Africa and gave a talk at the university.

—

Stephen Wenkel, Inseob Han, Tong-Seung Tseng, Srinivas S. Gampala and **Josh Gendron** presented their work at the Western Section of the American Society of Plant Biologists meeting at UC-Davis in Feb. Gampala and **Zhiyong Wang** spoke at the Plant Phosphorylation Workshop in Monterey, CA.

—

Postdoctoral researcher **Melisa Lim** (Shauna Somerville lab) spent three months at the Max Planck Institute for Plant Breeding Research in Cologne.

—

Arrivals: Postdoctoral research associate **Viktor Kirik** (Martin Luther U., Halle-Wittenberg, Germany) arrived in Sept. to the Ehrhardt lab. Visiting postdoctoral research associate **Miguel Carvalho** (Cornell U.) came in Sept. to the Shauna Somerville lab. His visit is funded by a fellowship from Fundação para a Ciência e a Tecnologia, Portugal. Postdoctoral research associates **Ying Gu** (UC-Riverside) and **Wensheng Qin** (Stanford U.) arrived in Sept. and **Shaolin Chen** in Dec. to the Chris Somervile lab. Assistant curator **Vanessa Swing** (UC-Davis), curator **Philippe Lamesch** (Harvard Medical School), and postdoctoral research associate **Jin Chen** (National U. Singapore) joined the Rhee lab. Joining the Frommer lab are postdoctoral research associate **Farzad Haerizadeh** (Australian Research Council Centre, Victoria) in Nov., predoctoral research associate **Thomas Echhard** (Groningen U., Netherlands) in Oct., and master's student **Iban Moeller-Hansen** and technicians **Kate Chabarek** and **Antoinette Sero**.

—

Departures: Postdoctoral research associate **Marcella Pott** left the Ehrhardt lab in Sept., for a position at U. Heidelberg. Postdoctoral fellow **Stefan Bauer** left the Chris Somerville lab in Sept. to work in his home country of Germany. Leaving the Frommer lab were postdoctoral research associate **Keren Bracha-Drori**; **Ida Lager** for Lund U., Sweden; **Loren Looger** for the Howard Hughes Medical Institute's Janelia Farm campus near Washington, DC; and visiting predoctoral student **Carlos Melo** to return to Portugal to continue his education. Senior curator **Marga Garcia Hernandez** relocated to Sacramento and curator **Katica Illic-Grubor** left in Oct. to work in the biotech sector from the Rhee group. Visiting investigator **Natasha Raikel** returned to UC-Riverside in Dec. after a brief sabbatical with Sue Rhee and the TAIR group. Graduate student **Hae Youn Cho** left the Briggs lab in Oct. for a position in her home country of South Korea.

—

Financial analyst **Evana Lee** and accounts payable specialist **Hulya Aksoy** joined the administrative staff in Oct.

—

Receptionist and accounts payable specialist **Lisa Simons** left the department in Oct. and accounts payable specialist **Renee Wang** left in Nov.

—

Weekend greenhouse assistant **John Jacobson** left in Oct. and was replaced by **Raymond Von Itter** in Nov.

❺ Shauna Somerville

Terrestrial Magnetism

Sean Solomon chaired the MESSENGER Participating Scientist Review Panel for NASA in Nov. In Dec. he delivered the commencement address at the U. Maryland's College of Computer, Mathematical and Physical Sciences. Solomon chaired a meeting of the MESSENGER Science Team hosted by Arizona State U. in Jan. The MESSENGER spacecraft completed the first of two flybys of Venus on Oct. 24.

—

Alan Boss commented on the Hubble Space Telescope's extrasolar planet discoveries at a NASA Science Update at NASA Headquarters in Washington, DC, attended the Kepler Mission Science Team meeting in Flagstaff, AZ, and chaired the NASA Origins of Solar Systems Review Panel in Colo. in Oct. In Nov. Boss gave an invited talk on planet formation at the Cool Stars XIV meeting in Pasadena and participated in a NASA review panel of the Keck Interferometer Nuller project at JPL. In Jan. Boss gave a colloquium about giant planet formation at U. Virginia's Dept. of Astronomy.

—

John Chambers spoke on terrestrial planet formation at the NAS Sackler Colloquium on Solar Systems in Irvine, CA, in Jan.

—

Larry Nittler presented a talk at the Stardust Science Results Workshop in Pasadena in Nov. He also gave a DTM seminar in Jan. on initial findings from the Stardust mission.

—

Vera Rubin delivered a colloquium on polar ring galaxies at the National Capitol Astronomers meeting in Sept. In Oct. she spoke at a dinner for the 80 female freshmen members of George Washington U.'s Women's Leadership Program in Washington, DC. Also in Oct., Rubin spoke at the Mensa Education and Research Foundation's "Revolution in Cosmology" colloquium weekend in Albany, NY. In Nov. Rubin visited U. Michigan's astronomy faculty and students. She also met with students enrolled in the university's "Gender, Women and Science" courses, and gave a lecture on women scientists in the U.S. from 1820 to 1960.

—

Sara Seager began an associate professor position at MIT's Earth, Atmospheric, and Planetary Sciences department in Jan.

—

Postdoctoral fellow **Alceste Bonanos** gave a colloquium at U. Toronto in Sept. and at the U.S. Naval Observatory in Nov. She gave a talk at the "Massive Stars: Fundamental Parameters and Circumstellar Interactions" conference in Carilo, Argentina, in Dec.

—

Postdoctoral fellow **Hannah Jang-Condell** presented a paper at the 209th meeting of the American Astronomical Society, held in Seattle in Jan.

—

Postdoctoral associate **Maureen Long** gave two invited talks at U. Southern California in Nov.

—

Postdoctoral fellow **Mercedes López-Morales** presented work at the Cool Stars XIV meeting in Pasadena in Nov. She gave a talk at Caltech's Michelson Science Center in Jan.

—

Hubble Fellow **Scott Sheppard** served as a member of the NASA Origins of Solar Systems Review Panel, which convened in Denver in Nov. He gave invited talks at SUNY-Stony Brook in Dec. and at Caltech in Feb.

—

Postdoctoral fellows **Henner Busemann**, **Taka'aki Taira, Margaret Turnbull,** and **Linda Warren** departed DTM this fall and winter. Busemann accepted a staff position at the Open U., UK, in Dec.; Taira began a fellowship at U. Utah in Jan.; Turnbull accepted a staff position at the Space Telescope Science Institute in Nov.; and Warren began a research associate position at U. Arizona in Dec.

—

Two visiting investigators returned to DTM during the fall and winter. **Stephen Richardson** of U. Cape Town spent Oct.-Dec. working with **Steve Shirey**, analyzing sulfide inclusions in diamonds from southern Africa. **Fenglin Niu** of Rice U. continued his collaboration with **Paul Silver** in Nov. to image time-dependent positions of seismic scatterers within major fault zones.

—

DTM welcomed postdoctoral associate **Maureen Long** and postdoctoral fellow **Julie O'Leary** in Oct. and Jan., respectively. Long earned her Ph.D. in geophysics at MIT in spring 2006. O'Leary earned her Ph.D. in geochemistry at Caltech in fall 2006.

—

The annual meeting of the Division for Planetary Sciences was held in Pasadena in Oct. Several from DTM presented papers, including **Sean Solomon**, **Alan Boss**, **John Chambers**, **Sara Seager**, postdoctoral fellows **Mercedes López-Morales** and **Isamu Matsuyama**, and visiting investigator **Jianghui Ji**.

—

Sean Solomon, **Rick Carlson**, **David James**, **Steve Shirey**, and **Paul Silver** gave presentations at the 2006 meeting of the Geological Society of America held in Philadelphia in Oct.

—

Several from DTM participated in the 2006 AGU Fall Meeting held in San Francisco in Dec., including **Sean Solomon**, **Rick Carlson**, **Alan Linde**, **Selwyn Sacks, Steve Shirey, Paul Silver**, and postdoctoral fellows **Catherine Cooper**, **Maureen Long**, **Taka'aki Taira**, **Lara Wagner**, **Linda Warren**, and **Dayanthie Weeraratne**.

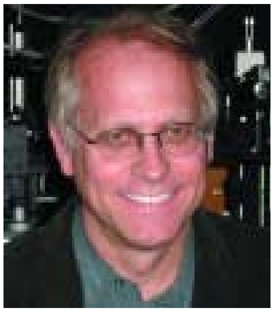
—

The scientific medals and awards of former DTM Director **George Wetherill** were donated to the department's archives by Wetherill's widow, Mary Bailey, and his daughters, Rachel Wetherill and Sarah Okumura.

GL/DTM

The first lecture of the new Carnegie Neighborhood Lecture Series was held at the BBR campus in Oct. and featured DTM's **Alan Boss** speaking on the possibility of planets like Earth around other stars. GL's **Robert Hazen** delivered the second lecture, on life's origin, in Nov.

Russell Hemley Appointed Director of Geophysical Laboratory



The Geophysical Laboratory's new director Russell J. Hemley

Longtime staff member Russell J. Hemley will become the Geophysical Laboratory's 10th director on July 1, 2007, succeeding Wesley T. Huntress, Jr., as he steps down from that position.

Hemley has been a staff scientist at Carnegie's Geophysical Laboratory since 1987. Born in Berkeley, California, he grew up in the Golden State and in Colorado and Utah. He studied chemistry and philosophy at Wesleyan University, where he obtained his B.A. in 1977. He went on to Harvard for graduate work in physical chemistry and was awarded his Ph.D. in 1983. He then joined the Geophysical Laboratory as a Carnegie Fellow, a position he held from 1984 to 1987, at which time he was appointed a staff scientist.

Hemley studies the behavior of Earth and planetary materials at high pressures and discovers new materials and new physical transformations along the way. He has also developed new high-pressure methods and analytical techniques such as micro-optical spectroscopy, synchrotron infrared spectroscopy, synchrotron X-ray diffraction and spectroscopy, laser heating, magnetic susceptibility, electrical conductivity, and high-pressure cryogenic methods.

Hemley has published over 480 scientific papers and has six patents awarded or pending. He was a visiting professor at École Normale Supérieure, Lyon, France, and at The Johns Hopkins University. He is the recipient of the 2005 Balzan Prize for Mineral Physics, the 2003 Hillebrand Medal of the American Chemical Society, and the 1990 Mineralogical Society of America Award. He is a member of the National Academy of Sciences and the American Academy of Arts and Sciences, and is a Fellow of the American Geophysical Union, the American Physical Society, and the Mineralogical Society of America.

Carnegie Gets Highest Fiscal Management Rating Sixth Year in a Row

Charity Navigator, America's largest charity evaluator, has awarded the Carnegie Institution four stars, its highest rating, for sound fiscal management for six years running. Only 12% of the more than 5,000 rated charities have received four stars in two consecutive years, and of this select group only 16 have received a four-star rating six years in a row.*

According to Charity Navigator, "[Carnegie's] rating is an exceptional feat, especially given the economic challenges many charities have had to face in the last year." Charity Navigator bases its analyses on public documents available through the IRS and institutional Web sites. During the last year, 83.1% of Carnegie expenses went toward scientific programs, while 16.8% was expended on administration and fundraising.

"Our founder would be pleased to learn of our careful stewardship of funds," said Carnegie president Richard Meserve. "Andrew Carnegie sought to ensure that administrative costs are kept low so that we may better finance the highly original scientific research for which the institution is known."

* Not all of the 5,046 charities that Charity Navigator evaluates have been evaluated for six or more years. For details on Charity Navigator's rating of Carnegie, see www.charitynavigator.org/index.cfm/bay/search.summary/orgid/3424.

Carnegie Institution of Washington
1530 P Street, NW
Washington, D.C. 20005-1910

Nonprofit Org.
U.S. POSTAGE
PAID
Washington, DC
PERMIT NO.1657