Message from the Chair

Greetings from Earth and Planetary Sciences. Many things have happened since the last Newsletter. Washington University has announced the fundraising Campaign for the Millennium, designed to accelerate the University toward excellence in its missions of research, teaching, and community service. We are in the last stages of approval for a new building for the Department that we expect to move into by the year 2003. The Biology Department will then occupy all of Wilson and McDonnell Halls. We have hired Jan Amend as an assistant professor. Jan is an outstanding young microbial geochemist who will enhance both the Department and the rapidly expanding Environmental Studies Program. I hope you enjoy reading the newsletter. Drop us a line and let us know what you are doing!

Phillips Named Director of McDonnell Center for Space Sciences

Professor Roger Phillips took over as the Director of the McDonnell Center for Space Sciences on July 1 of this year. Roger received a geological engineering degree from the Colorado School of Mines, and his Masters and Ph.D. from the University of California, Berkeley. Roger, a well-known planetary geodynamicist, succeeds Robert Walker, McDonnell Professor of Space Physics, as Director. There are currently 24 faculty members and 11 research associates who are Fellows of the McDonnell Center.

Roger spent 10 years at the Jet Propulsion Laboratory, then went on to be the Director of the Lunar and Planetary Institute in Houston, a professor at Southern Methodist University, and then professor of Earth and Planetary Sciences.

Podosek Named Editor of Geochemical/Meteoritical Journal

One of the most prestigious journals in geochemistry, Geochemica et Cosmochimica Acta, published by Elsevier, will now be under the editorship of Professor Frank Podosek. A specialist in mass spectroscopy, Frank spent many years as member and chair of the joint publication committee of the Geochemical and Meteoritical Societies, which sponsor Geochemica. Recently, the current editor of the publication, Karl Turck, decided not to remain beyond his current term, requiring the committee to select another editor. Frank resigned from the committee, volun teered his services as editor, and was selected to assume editorship in January 2000.

As editor, Frank will be responsible for the overall scientific evaluation of the articles printed, as well as ensuring that the journal is published in a tech-
Modern Mineralogy: From the Human Body to the Sea Floor

By Jill Pasteris

Professor Jill Pasteris and her research-group colleagues, Dr. Brigitte Wopenka and Dr. John Freeman, have been studying evidence of fluid-rock interactions and applying Raman spectroscopy to geological materials for many years. Some of their recent research projects have convinced them that the specific ways in which geologists view minerals have applicability in other fields, especially in medicine. The most important solid materials in the body, of course, are the bones and teeth, which are composed of material similar to the mineral apatite. However, humans also suffer from undesired mineralization, such as kidney and gall stones, calcification of joints, and calcification of arteries and heart tissue. These “calcifications” can be comprised of several different minerals, including calcite (calcium carbonate), aragonite (calcium carbonate), apatite (calcium phosphate), weddelite (calcium oxalate dihydrate), and whewellite (calcium oxalate monohydrate). Fortunately, the laser Raman microprobe technique employed by Jill’s group allows for the rapid, non-destructive identification of mineral grains (as well as many liquid and gaseous species) as small as 1 µm in diameter. It can be applied to thin-sections of human tissue as readily as to thin-sections of rock.

Currently, Jill and colleagues are studying bone material and synthetic phosphate phases that may be precursors to the final bone material in our bodies. For instance, they have begun to work with a professor at the School of Medicine who is interested in the effect of fluoride on bones. He is in vesti-
gating the mechanical properties of mouse bones before and after the bones are soaked in a fluoride solution. Because the Raman spectrum of a material is sensitive to the details of its structural state (which can be affected by recrystallization and changes in mineral chemistry), Dr. Freeman was able to monitor spectral differences between the bones soaked in the fluoride solution and the control samples. More work needs to be done with a variety of chemical and structural analytical techniques to determine exactly what changes have been induced in the bone. Jill’s group also has begun to work with another researcher from the medical school who wants to use Raman spectroscopy to monitor bone-producing cells. The goal is to identify and characterize the mineralized material grown during bone culture experiments. Research assistant Colleen Matts, a sophomore who began working with Jill’s group last fall, will do Raman spectroscopy on bone-related natural and synthetic materials this summer.

Raman microprobe analyses of biological materials are not limited to sections of human tissue. Jill gave a talk recently, on geological applications of Raman spectroscopy, at the Monterey Bay Aquarium Research Institute (MBARI) in Moss Landing, California. That talk led one of the microbiologists to ask whether Raman microprobe spectroscopy could be used to identify and characterize spherical bodies on the order of 1 to 2 µm in diameter in filamentous marine bacteria that oxidize hydrogen sulfide gas (in the seafloor sediments) to elemental sulfur. The tiny spherules had been inferred by others to consist either of a sulfur-rich compound or elemental liquid sulfur, which was stored in packets in the body for future use in bacterial metabolism. Jill’s group used the laser Raman microprobe to show not only that the spherules are a form of pure elemental sulfur, but that they are a crystalline form that consists of eight sulfur atoms in ring-like structures.

In addition to the joint work on sulfide-oxidizing bacteria, Jill’s group has an additional collaboration with the oceanographic researchers at MBARI. The two groups are working to select and purchase from an appropriate vendor a small, portable Raman probe that the MBARI engineering staff would outfit in a pressure housing so that it could be operated underwater. The Raman probe will use a fiber-optic sensor head to focus a laser beam onto the desired sample and to capture the Raman-scattered radiation that returns from the sample. The probe
will be deployed by MBARI’s remotely operated vehicle (ROV), which looks like a cross between a robot and a mini-sub, on the seafloor in Monterey Canyon at about three kilometers depth. The instrument will be controlled from the research ship to which the ROV is tethered. The ROV will position the instrument adjacent to rocks of interest, and the spectral information sent back to the ship will allow the minerals to be identified. One of the seafloor minerals of particular interest in this study is methane clathrate. Clathrate hydrates are cage-like minerals in which water forms an ice-like cage structure in which gas molecules, such as methane, reside. The fact that huge amounts of methane clathrate exist under the high pressures and cold temperatures of the seafloor make this an important mineral to consider as both a future source of natural gas (methane) and a major reservoir of carbon-bearing “greenhouse” gas that otherwise would be in our atmosphere. An in situ instrument, such as the proposed portable Raman probe, would be ideal for the study of the structure and composition of this important seafloor mineral.

Water on the Red Planet?

By Becky Williams, graduate student

The high resolution topographic data from the Mars Orbital Laser Altimeter (MOLA) on the Mars Global Surveyor (MGS) mission are enhancing our understanding of the inventory and history of water on the red planet. While current atmospheric and temperature conditions on Mars are not suitable for liquid water to be stable, outflow channels (large, catastrophic flood systems) are the best evidence that large volumes of water once flowed on the surface. Professor Roger Phillips and graduate student Becky Williams are concentrating study on the largest outflow channel system, Kasei Valles. MOLA topographic profiles of Kasei Valles reveal new details of channel geometry. Kasei Valles has narrow inner channels not previously recognized in Viking images. Further, there are topographic benches on the channel walls, some of which they interpret to be fluvial terraces formed by changing energy conditions within the fluvial system. This revised channel geometry allows Becky and Roger to use first-order hydraulic formulas to estimate water discharge (flow per unit area) values involved in forming these channels. Their calculations indicate maximum discharge values ranging from $8 \times 10^4$ to $2 \times 10^7$ m$^3$ s$^{-1}$, at least two orders of magnitude less than estimated by previous studies. Superposition relationships, morphologic observations and hydraulic calculations in this study are consistent with a gradual formation history of the Kasei Valles system. They suggest that multiple flood events involving relatively modest flows operating over thousands of years are required to carve the outflow channels in this region.

Searching the History of Venus

Professor Bruce Fegley and third year graduate student Natasha Johnson are working together on an experimental project about the history of water on Venus. They are trying to determine whether the planet has always been as dry as it is now or whether it once had water. The Pioneer Venus Space Mission in 1979 found that Venus is enriched in heavy hydrogen (deuterium). In fact, the amount of deuterium on Venus is about 120 times higher than that on Earth, which suggests that Venus once had oceans that have evaporated, preferentially leaving the deuterium behind. In direct evidence of
Leaves of Lead

Julie Morris, Research Associate Professor, is currently involved in a research project that incorporates environmental geochemistry and biogeochemistry. Julie is working with Professor Everett Shock and Jay Turner, Environmental Engineering Associate Professor. Analytical, theoretical, and field work is being carried out with the help of graduate students Colin Enssle and Panjai Prapraipong, undergraduate Wendy Elmes, and Lara Douglas, an NSF Young Scholars Program participant from Ladue Horton High School. Lara's work led to a science fair project that qualified her for the International Science Fair. The project is the outgrowth of a Ph.D. project by Washington University alumnna Kate Crombie (1997) who examined the environmental consequences of lead smelting in southeast Missouri (the largest producer of lead in the world). Against a backdrop of declining lead in the environment due to successful EPA regulations (such as the regulation of leaded gas), the point sources of lead pollution now stand out strongly. Kate's thesis showed that lead washed off leaves from White Oak at different distances and directions from the smelter could be fingerprinted to determine the fallout pattern of lead emitted from the smelter.

The group has taken the study further with the use of the Department's new ICP-MS instrument (Inductively Coupled Plasma Mass Spectrometer) to measure lead isotopes on the leaves. These isotopes are a fingerprint: lead in the atmosphere has one fingerprint, while lead that comes from smelting has another. This way, researchers know how much lead on the leaves comes from which source and can track where smelted lead is falling. Kate's work also showed that there is lead inside the leaves, meaning it has been taken up from the soil. Since lead from smelters is in particulate form, Kate's work suggests that particulate Pb can become soluble in ground water in a form that is bioavailable and taken up into trees. To trace smelter lead through the environment, the group is using a variety of environmental and geochemical techniques. Colin is coring trees in the vicinity of a smelter, looking for smelter lead in the trees themselves, using trees from the Tyson Research Center as a control. Panjai is analyzing soil water for toxic trace metals as well as organic acids, investigating the possible role of organo-metallic complexes in Pb mobility. Wendy and Lara have been responsible for collecting and analyzing leaf samples. Their work has allowed them to trace the cycle of lead from the smelter into the atmosphere, then into the soil and from there, the trees. The group was joined this summer by a high school science teacher and student who spent six weeks doing field and lab research, and will develop a classroom science module.

past ocean on Venus might be found in the form of fossil hydrous minerals, which could be detected by a lander mission.

Bruce and Natasha's experiments involve the thermal decomposition and dehydration of tremolite, a common amphibole. What they have found is that if Venus was wet at one time and tremolite formed (e.g., via metamorphic reactions as on Earth), it would still be present on Venus today because at the current surface temperature and at higher temperatures, tremolite would have a very slow decomposition rate. Their hope is that their work will help to select experiments that will be carried out on a future lander mission to Venus.
A Raman Spectrometer for Mars

by Larry Haskin and the Planetary Materials Research Group

Two years ago, during the Mars Pathfinder mission, a chemical element analyzer on the Sojourner rover found rocks richer in silica than basalt, leading to the speculation that those rocks might be quartz-bearing andesites. The presence of andesites on Mars would have important implications for crustal recycling and crustal melting. The Mars Surveyor 2003 mission will have a more capable rover than Pathfinder’s Sojourner rover. On board that new rover will be a Washington University experiment for identifying minerals—a miniaturized Raman spectrometer proposed by our Planetary Surface Materials research group—as part of an instrument set known as the Athena instrument package.

Is there really andesite on Mars? Do the Martian rocks examined by the Sojourner instrument truly contain quartz? The thermal emission spectrometer on the Mars Global Surveyor currently orbiting the planet has not yet found evidence of quartz, not even in the ubiquitous dune fields. That instrument integrates its mineralogical signal over a fairly broad area and through an interfering atmosphere. An up-close, direct identification of the minerals present in individual rocks is needed. Only then will we know the rock types encountered on Mars and the conditions of their formation and alteration. Our Raman spectrometer will provide that necessary direct mineral identification.

The emphasis of the Mars Surveyor 2003 mission is the assessment of life on Mars, past or present. The Athena rover package will take small cores of rocks and soils to be sent to Earth (they should land on Earth in 2008). A mechanical arm on the rover will deploy our Raman spectrometer against the cores and against rock and soil surfaces. The spectrometer will assist in the choice of materials to be collected as well as characterize the mineralogy of rocks and soils generally along the rover path. Characterization of minerals produced under igneous, hydrothermal, sedimentary, or surface-weathering conditions will allow us to determine the nature of past environments on Mars. It will also allow us to study the early geological evolution of Mars.

The Mars Raman spectrometer came about through the exchange of ideas among three research groups with different interests within the Department of Earth and Planetary Sciences. Our group, mainly interested in lunar and terrestrial geochemistry, anticipated that future rover missions to the Moon would use infrared spectrometers to obtain mineralogical data. We wanted a better understanding of the nature of those data, so we “borrowed” spectroscopist Alian Wang from Jill Pasteris’ research group to teach us about infrared spectroscopy. Alian indicated, however, that Raman spectroscopy would be a better choice than infrared spectroscopy for on-surface planetary mineralogical characterization. She demonstrated her point by identifying major and trace minerals in some lunar samples using Jill’s Raman spectrometer. Alian also convinced us that a miniaturized but highly capable spectrometer suitable for rover deployment could be developed by taking advantage of recent technical developments in solid-state lasers, fiber optics, detectors, and high-performance optical elements. We obtained funds from NASA to build a prototype miniaturized Raman spectrometer, and Alian joined our research group to begin its development.

At this point, Ray Arvidson became aware of our project and the success with identifying minerals in lunar samples. As Deputy Principal Investigator for the Athena instrument package, Ray suggested to the Principal Investigator, Steve Squyres...
of Cornell University, that the Raman spectrometer would be a very useful addition to that package. An invitation was made, and our group joined the Squyres’ Athena proposal for the 2001 Mars Surveyor mission. The Athena proposal won the competition. That meant the prototype Raman spectrometer had to be reengineered to make it flight worthy. That task is being done by an excellent team of engineers at the Jet Propulsion Laboratory in California working with us. Also, a Raman group led by Tom Wdowiak of the University of Alabama-Birmingham joined our team. Tom’s interest in extraterrestrial life complements our own interest in planetary surface materials science. The 2001 mission has now been postponed to 2003 to allow more time for development of the rover.

The optical components (sans the electronics) of the current prototype of our instrument, built at JPL, are shown in Figure 1. This version is miniaturized from our original prototype that was ten times greater in size and mass. The spectrometer consists of two main parts: a probe that will be mounted at the end of the rover’s mechanical arm, and a source-spectrograph unit that will reside in the rover WEB (the temperature controlled “warm electronics box”). Light from a new type of laser will feed from the WEB to the probe via an optical fiber, and the Raman-scattered light collected by the probe will feed back to the spectrograph via another optical fiber. The light will then be analyzed by a transparent grating and sensed by a detector of the type used in digital cameras. A small microprocessor will operate the instrument and store the data for transmission to Earth.

Our Raman spectrometer mainly takes advantage of changes that we can induce in vibrational motions between atoms in minerals. We induce these changes by shining light from a red laser onto a spot some 20 mm in diameter on a mineral grain. A tiny fraction of the laser light is inelastically scattered (Raman-scattered) such that light of new wavelengths is emitted from the mineral grain. This scattered light is then analyzed to identify individual minerals by their characteristic Raman spectra.

Raman spectra of some common rock-forming minerals are shown in Figure 2. Notice that the peaks for the silicate minerals are narrow, far apart, and seldom overlap those of other minerals (unlike peaks obtained by infrared spectroscopy, which is also used to observe energy transitions in minerals). Raman spectral patterns (the number of peaks, their positions, and their relative intensities) are directly correlated with the type of oxy-anion groups of the minerals (e.g., silicates, carbonates, sulfates, phosphates) and the degree of polymerization in silicates (monomer, chain, layer, framework). Because Raman wavelengths are sensitive to cation chemistry, ratios such as Fe:Mg can be determined and calcite can be distinguished from dolomite. Waters of hydration and OH can be observed. Organic compounds and inorganic reduced carbon that might be present in the Martian rego-
parallel to the development of the flight instrument, we have undertaken a series of simulation experiments. Raman spectroscopy has been an important laboratory tool for determining mineral structures. Its use as a tool for determining general rock mineralogy is new, however, particularly in the field, and we must develop new techniques for its use. For example, we have introduced a technique for quantitative mineral analyses that is analogous to petrographic point counting. We acquire spectra for 100 tiny spots (~20 mm each) along a 1-cm traverse across a rock surface. The time to acquire each spectrum is short (from a few seconds to a minute). In this manner, we obtain the proportions of the minerals and information about their grain size and spatial distribution (Figure 3). Also, Alian Wang is developing a calibration procedure for obtaining Fe/Mg ratios of pyroxenes and olivines from their Raman peak positions. When perfected, this technique will provide key information about the crystallization histories of igneous rocks. Many analyses of rocks of various types and in various stages of weathering and alteration must be analyzed if Raman spectra taken on Mars are to be understood and correctly interpreted. Brad Jolliff is lead-

Figure 2. Typical Raman spectra are shown for three minerals and the waxy coating on a tiny lichen found on the surface of a sample of weathered basalt.
During the spring break, fifteen students, staff members, and faculty took a ten-day geologic tour of the southwestern U.S., camping at state and national parks along the way. This was not an ordinary trip, since it covered aspects of sedimentology, igneous petrology, stratigraphy, structural geology, petroleum geology, geomorphology, speleology, planetary science, and Mexican cooking. Covering 3,550 miles in vans (and a few miles on foot), the group discovered that there really is something between Missouri and New Mexico. The trip was arranged by Bob Dymek to complement a new undergraduate course, Development of the North American Landscape, an advanced version of the freshman-level Geology of National Parks, but was open to all Department members.

The participants spent the first night at the Chickasaw National Recreation Area near Sulfur, Oklahoma, an area that originally was known as “Platt National Park.” The next morning they observed mineral spring (the main feature of the park), Permian red sandstones, and some fantastic conglomerates that are evidently stream deposits from now-eroded mountains. Patrick Shore then led the way across the Arbuckle Mountains, treating the group to spectacular overviews and three-dimensional close-ups of well-exposed folded sediments.

The next day the group visited the Odessa Meteor Crater, which is actually a group of several small, well-preserved craters, which have all the classical features of impact structures. The largest crater also has undisturbed sediments in the center, which are the remains of a Pleistocene lake. Thanks to extensive excavation during the 1950’s, it was easy to see the structure and stratigraphy of the craters in considerable detail. The group then explored the sand dunes of the Mona hans Sand Hills State Park.
Limestone, limestone, limestone, gypsum, gypsum, gypsum and salt, salt, salt

Pine Springs Campground in the Guadalupe Mountains National Park was home for the next three days, which was enough time for a regional overview of the Delaware Basin of West Texas and New Mexico. The Capitan Reef lies at the margin of the basin and is exposed magnificently by a vertical fault scarp. The group hiked the Permian Reef Trail in McKittrick Canyon, which gives an excellent cross-sectional view of the depositional and diagenetic features of the reef and cuts across sediments from the shelf crest to the toe of the slope. Everyone easily survived the seven-mile hike with 2,500 feet of vertical gain.

The next day, the group visited Carlsbad Caverns National Park, found in the very same Capitan Reef which here plunges underground. Bob Osburn, who we all know is an expert spelunker, provided us with a running commentary as we walked along the self-guided tour that ends in the “Big Roof” with its spectacular speleothems. Carlsbad Caverns were supposedly formed partly by sulfuric acid from nearby oil and gas fields. Some people were incredulous until they saw the vast amounts of gypsum cave stone.

Back above ground, the group looked at other sediments of the Delaware Basin, found stratigraphically below the reef. The group saw some enormous limestone blocks encased in sandstone, emplaced by a debris flow, and brought back samples of a very unusual deformed, layered, arenaceous gypsum evaporite from the Castille Formation.

The group then visited the Waste Isolation Pilot Plant (WIPP) near Carlsbad, NM, which is a permanent underground storage facility for nuclear waste. The facility was dug out of a thick layer of Permian salt, 2,150 feet below the surface. Shipments of waste have just begun to arrive at the site, and will eventually be encapsulated permanently as the tunnels gradually collapse. After a thorough safety lecture, the group was driven in electric cars through thousands of feet of tunnels, on an underground tour. Most people brought back halite samples containing large, easily visible, fluid inclusions.

At White Sands National Monument the group was given an expert tour of the dunes by Ranger John Manginelli of the National Park Service. We learned that, unlike most other dune complexes, White Sands are actually made of gypsum. Ranger Manginelli informed them about where all that gypsum comes from; where it goes; why the desert sand is often wet just below the surface; how plants stay out of the way of advancing dunes; and why dunes bark (don’t ask).

Craters, craters, craters

The group next visited the Portrillo volcanic field in southeastern New Mexico, following a spectacular drive across the Sacramento Mountains, one of several basin-and-range structures in this area. Many people brought back an assortment of volcanic bombs from Aden Cone, and samples of mantle peridotite and dunite from Kilbourne Hole. Aden Crater and the Valley of Fire Recreation Area provided splendid exam-
ples of basalt flows, in which surfaces are decorated with beautiful examples of pahoehoe. After a brief stop for alien burgers at Roswell, the trip concluded with...

More miles and miles of miles and miles

Underneath all those miles of West Texas lies some of the country's most beautiful scenery, found in and around the “Llano Estacado” where a tough caliche caprock protects the underlying Miocene Ogallala formation. Underneath these layers, just waiting to be exposed by a canyon, are red dish sand-mud- and silt-stone strata of Triassic age, which are reminiscent of the Mesozoic red-beds found on the Colorado Plateau. One of the most spectacular canyons cutting into the Llano Estacado is Palo Duro Canyon State Park, where the group spent its last night. A brisk hike a few miles long allowed us to pass around and climb on top of some spectacular mesas and to appreciate why Texans consider Palo Duro their own “grand canyon!”

All participants officially had a great time, and returned in tact, despite a few overcooked onions, seismic events in the van, and near brushes with skunks and the U.S. Border Patrol. And thanks to expert planning, the weather was perfect!

Wiens, Shore, and Graduate Student Study Antarctic Earthquakes

Professor Doug Wiens and Dr. Patrick Shore began the SEPA project (Seismic Experiment in Patagonia and Antarctica) by installing 10 seismographs in Patagonia and the Antarctic Peninsula during January 1997 aboard the Chilean Navy Ship ISAZA. In December 1997, Patrick and graduate student Stacey Robertson went down to Antarctica on the Able J, a 105-foot ship, crossing Drake Passage in order to service the seismic stations that had been installed in January. They found that the station that had been set up on Elephant Island had run for the whole year, through the winter, on solar and battery power with out any maintenance. This is the first time that a seismic station has run for an entire year unattended in Antarctica. Elephant Island is well known historically for being the place where a group, led by the English explorer Shackleton, was stranded for five months in 1916. The other seismic stations in the Antarctic peninsula area were also visited and most were operating well. Stacey has subsequently begun research for her Ph.D. thesis studying a large number of magnitude 2-4 earthquakes recorded by the sensors.

In December of 1998, Stacey and Doug went back on the Lawrence Gould, a new 240-foot U.S. Antarctic research ship. They had trouble getting off Elephant Island because their Zodiac was broken in the surf. They managed to get all the stations serviced and also deployed ocean bottom seismographs, in collaboration with a team from Scripps Institute of Oceanography, to stay...
on the ocean bottom for five months recording earthquakes.

The Antarctic mishaps did not discourage Patrick from returning in May and June, during the Antarctic winter, to pick up most of the land stations and all of the ocean bottom seismographs. He travelled aboard the Nathaniel Palmer, the largest U.S. Antarctic ship, and did his work in the five hours of light per day that is available during that part of the Antarctic winter.

**Tucker and Team Search for Clues to Gondwana Formation**

While few people can locate Madagascar on a map, fewer still know anything about its geologic history. Professor Robert Tucker is working with other geologists to take the mystery out of Madagascar’s formation and how its geology relates to that of Africa and India. 545 million years ago saw the dawn of the Cambrian period in which animals began to secrete external skeletons. Scientists are now realizing that this time period also marks the time when Gondwanaland formed. Gondwanaland was the landmass made up of what eventually became the continents of South America, Africa, Asia, and Australia. Supporting evidence is provided in part by a major mountain range that formed in Gondwanaland, and now runs through a portion of East Africa, Madagascar, and Antarctica. The goal of Bob’s research is to better constrain the timing of the formation of the Cambrian supercontinent, and Madagascar is the little known keystone.

In July 1998, the research group, headed by Tucker, Professor Lew Ashwal of the Rand Afrikaans University in Johannesburg, and Chris Powell of the University of Western Australia in Perth, took a three-week rafting excursion on a river that traverses 300 km across central Madagascar. The Mania River begins south of Antsirabe and flows westward to Morondava. Using old but good quality maps, they set out to determine a crustal cross-section to discover the architecture of the rocks through central Madagascar—that which occurred with the formation of Gondwanaland. They also wanted to sample isotopic age dating and chemical composition of the rocks. Beyond the structural, aging, and chemical objectives, they were also interested in evaluating the mineral potential in this extremely impoverished country.

During their trip they were serviced by a very experienced guide, as well as 38 porters who were hired to transport food supplies and carry rock specimens. They covered an average of 10 to 15 km a day along a river infested by crocodiles and full of class 4 and 5 rapids. Although they had a couple of raft overturns, they experienced no major losses and made extensive collections that are now being investigated. The group continued their work this past summer, heading to northernmost Madagascar to do similar studies on two east-draining rivers.
The Unusual Conquers at LPSC

By Becky Williams, graduate student

A large contingency from the EPSC Department attended the Thirtieth Lunar and Planetary Science Conference in Houston, Texas, this past March. Twenty-two representatives, including nine graduate students, from several disciplines in the department attended the week-long conference.

The Planetary Surface Materials group was the most active, presenting five talks and three posters, and authoring six print-only abstracts focusing on in situ planetary Raman spectroscopy, lunar geology, and geochemistry. Larry Haskin, Randy Korotev, and Ailin Wang each gave oral presentations. Brad Jolliff and Jeff Gillis did double-duty by presenting both talks and posters this year.

The Remote Sensing Laboratory submitted four abstracts detailing work on future Mars missions and archiving data from the Mars Surveyor Program. Ray Arvidson presented on FIDO, a new rover which is a prototype for the Mars rovers that will fly in 2003 and 2005 Sample Return Missions and a separate paper about the Mars 2001 Landor Mission. Graduate student Kris Larsen presented a talk comparing soil and rocks at the Viking 1 and Pathfinder sites.

The Planetary Geodynamics and Tectonics group submitted four abstracts presenting results of studies on several terrestrial planets: coupled climate and interior evolution on Venus (Professor Roger Phillips); lunar mare volcanism and geochemistry (graduate student Mark Wieczorek); and outflow channel hydrology on Mars (graduate student Becky Williams). In addition, Roger contributed to the MESSENGER poster, a project proposing a future mission to Mercury. Venturing further out in the solar system, graduate student Andrew Dom-
New 'Companion' for Planetary Scientists

Dr. Katharina Lodders and Professor Bruce Fegley are the authors of a new handbook, The Planetary Scientist's Companion, published by Oxford University Press. Katharina got the idea for The Planetary Scientist's Companion when she realized how convenient it would be to have a single book that held all the numbers and equations that are commonly used by planetary scientists. Already among the top 50 best selling solar system books on Amazon.com, The Planetary Scientist's Companion is a compilation of frequently used constants, unit conversion factors, formulas, and properties of compounds and minerals. It also contains an overview of the solar system with descriptions of the Sun, each of the planets, and small bodies, as well as other information useful to those interested in planetary science and cosmochemistry.

Graduate Student Life from One Perspective

by Natasha Johnson, graduate student

I have been asked to write a little something about the grad students for this past academic year. Although I feel a bit daunted by this request I will do my best to heed the call so that you, the reader, might have a glimpse of the grad student side of the fence. Grad student life can be split into two main parts, academic and social. The ratio is dependent on the individual, and the values range the entire spectrum amongst the student body.

This past year we have had both good and bad tidings. On the up side, we have had two students graduate with a Masters and two more are in line to receive a Ph.D. in the very near future. EPSC also landed the first and second prizes in the Washington University Graduate Student Senate Symposium for poster presentations in the physical sciences. A few of us also went traveling to exotic locales for weeks at a time to further dissertation research.

This is the second full year in which a new academic graduate program in Earth and Planetary Sciences is in place and we are in the midst of going through orals, and so far so good. Prospective student weekend also went by with out a hitch. Unfortunately not all was rosy this year. There has been a high attrition rate amongst the first year students and two of the seven have departed.

Of course, grad school is not just about academics. There are hidden talents in the students ranging from superb homebrewing to musical or carpentry skills. Besides the usual debauchery brought upon by stress, fear of the real world, or sheer pleasure, there were enough brain cells remaining to organize several activities independent of the department. Some of these required advance planning, while others were spontaneous. There was a ski trip to Colorado that has become an annual tradition with lodge and hot tub included. Other events, but by no means all, included weekend canoeing, an intramural soccer team, paintball, roller hockey, the Kentucky Derby, poker nights and the latest, a foray into Star Wars fanaticism. As true 'die-hards', 14 of our number went to the first showing of Episode I at 12:05 AM on opening day. I think we all agreed that it was worth the wait.

Although there are many activities outside the academic realm, do not doubt that this is a serious bunch of people who know how to work hard and play hard. May the force be with all of us for the upcoming year!
Asteroid Named For EPSC Professor

A large, inclined minor planet in the main belt of asteroids has been named in honor of Professor Ghislaine Crozaz. The asteroid, at magnitude 13.2, is about seven kilometers in diameter if it is a stony-iron and about twice as large if it is a carbonaceous chondrite. It was first discovered by Carolyn S. and Eugene M. Shoemaker at Palomar. A citation, prepared by M. Wadhwa at the request of the first discoverer, states that Ghislaine "began her productive career three decades ago, with studies of fission tracks in lunar samples and meteorites. Since then, she has contributed significantly to the understanding of the early history of the solar system and to the formation histories of various meteorite types through innovative studies of trace element microdistributions and extinct radionuclides in these objects. Through the Department and the McDonnell Center for the Space Sciences, Ghislaine actively participates in the training of the next generation of planetary scientists with her characteristic nurturing and enthusiastic spirit."

EPSC Alumnus Re-involved through LAPIS Student Mission

By Nathan Peck

I well remember my first taste of teaching while a graduate student in the EPSC Department some 17 years ago. Professor Rodey Batiza got stuck in the South Pacific and I ended up in charge of Oceanography 100 for a week. After the initial panic and shock wore off, I started to really enjoy myself. At some point while I was assisting Dr. Batiza, Dr. Larry Haskin, Dr. Ghislaine Crozaz, and Dr. Ray Arvidson, I became hooked on the idea of pursuing teaching as a career.

In fact, it was my experience as the teaching assistant for Ray's "The Solar System" elective that really helped me garner my first teaching position. I sat in on all of Ray's lectures, and I was fascinated by the information he delivered and impressed by his enthusiastic demeanor in class. After the course was over, I was asked by a local high school to be a guest lecturer in an introductory physical science class covering the formation and evolution of our solar system. Ray was generous enough to let me borrow some of his most impressive slides, and a week later, I was offered a job by the school to teach their advanced physics.

I've kept in touch with the Department sporadically over the 15 years since I started teaching, especially with Ray. Ray and I started our professional interaction about six years ago when I was named one of the chief editors of a video series being developed by the Missouri Department of Education featuring famous Missouri scientists and their research. Feel free to stop by your local Missouri public library and check out "Magellan: Mission to Venus," which features Ray.

Over the past two years, Ray has invited me and many of my students to get involved with some of the exciting projects he and the EPSC Department have been involved in. Last year, a group of 25 of my students helped to develop educational materials to augment an EPSC website devoted to charting the progress of Steve Fossett on his quest to circumnavigate the globe in a hot air balloon.

This year, Ray organized four high school teacher/student groups from around the country to become members of a team called LAPIS, the acronym representing the locations of the team members in Los Angeles, Phoenix, Ithaca, and St. Louis. This was a hugely successful project that actively involved participants in the testing phase of
Arvidson Installed as McDonnell Distinguished Professor

On November 30, 1998 Ray Arvidson was installed as the James S. McDonnell Distinguished University Professor, an event held at Ridgely Commons and attended by several hundred people, at which Ray spoke on the “Importance of Teaching at a Research University.” Afterward there was a dinner hosted by Chancellor Wrighton for the McDonnell family, Ray, and guests. This endowed chair is named after the founder of McDonnell Douglas and is one of three Distinguished University Professorships established by the McDonnell family to help ensure that Washington University continues challenging the frontiers of human understanding into the next century.

In addition to this honor, Ray also received the 1998 Missouri Governor’s Award for Excellence in Teaching, was named 1998 Academic Advisor of the Year by the Freshman Class and was voted 1999 Professor of the Year by the Student Union.

ALUMNI ALERTS

Crombie, Kate

Miller, Gretchen

Nielsen, Ernst (1946-50)

From page 1, Phillips Named Director of McDonnell Center for Space Sciences in 1992. He has been involved with a number of space missions, including Apollo, Pioneer Venus, Magellan, and Mars Global Surveyor (see article on MOLA in this newsletter). In addition to his new directorship, Phillips will continue to teach both undergraduate and graduate classes, including Earth Forces, Hydrology, Exploration and Environmental Geophysics, and Geodynamics.

From page 1, Podosek Named Editor of Geochemical/Meteoritical Journal technically correct and timely manner. He assigns submitted articles to associate editors who read the articles and reviews of articles, and provide him with recommendations. Frank will make decisions to accept or reject manuscripts. The journal publishes between 4500 and 5000 pages annually. Although his appointment does not officially begin until next year, Frank is already aware of the “substantial time commitment” the job will require. He has been accepting articles for review since October of last year. He will serve as editor for three years, with likelihood of reappointment at the end of his term.
Focus on Professor Harold Levin

By Margo Long

Professor Levin began his geological career in 1956 as a sedimentologist and micropaleontologist for Standard Oil of California. Prior to that employment, he obtained bachelor’s and master’s degrees in geology from the University of Missouri, served as company commander in the U.S. Army, and completed a Ph.D. in micropaleontology at Washington University. His work with Standard Oil included sedimentologic studies of directional properties of silicoclastics, porosity and permeability studies related to clay-matrix mineralogy, sedimentary petrography, correlation and provenance studies based on heavy mineral analyses, foraminiferal and palynologic biostratigraphy, and use of the microscopic fossils of coccolithophorids (calcareous green-brown algae) in the correlation of Tertiary subsurface sections in California and Oregon. He continued his studies of coccolithophorids when he made the transition to academia.

In 1962, Norman Hinchey, then chair of the Earth Science Department at Washington University, asked Hal if he would be interested in coming back to the university to assist James Brice in revamping the physical and historical geology courses. Always interested in teaching, Hal accepted the position (and revealed in the $7,600 annual salary). Earth Sciences at that time had eight faculty members. By 1967, the faculty had grown to eleven, including three geophysicists. Hal’s repertoire of courses included Stratigraphy and Sedimentation, Life of the Geologic Past, Invertebrate Paleontology, Advanced Historical Geology, Physical Geology, and Historical Geology. (In those days, Physical and Historical Geology enrolled over 400 students each, requiring six to seven Teaching Assistants, each teaching three to four labs.) In the early 1970’s, Hal replaced James Brice as chairperson. A faculty of only five professors worked hard in teaching sufficient courses to justify our graduate and undergraduate programs. By 1974, however, Ray Arvidson, Ghislaine Crozaz, and Frank Podosek had joined the faculty.

From 1976 until 1993, Hal continued to teach in the Department. At the same time, however, he was appointed Associate Dean in the College of Arts and Sciences where he coordinated pre-professional programs for the university. As a way to keep abreast of new developments in geology, he tried his hand at textbook writing. The result has been six editions of The Earth Through Time; four editions of Contemporary Physical Geology, Essentials of Earth Science, and Life Through Time; co-authorship of Earth: Past and Present; and co-authorship (with Washington University graduate Michael S. Smith) of six editions of Laboratory Studies in Earth History. Hal’s latest textbook is entitled Invertebrate Fossils and their Living Relatives.

Hal clearly enjoys teaching, and each new semester provides the opportunity for refashioning explanations and improving presentation of course materials. He has received several awards from the Council of Students of Arts and Sciences and from the Alumni Federation for his efforts in the classroom.
Jan Amend  
Assistant Professor, University of California-Berkeley, 1995, Microbial geochemistry.

Raymond E. Arvidson  
James S. McDonnell Distinguished University Professor and Chairman, Brown University, 1974, Remote sensing, surficial geology.

Robert Criss  
Professor, California Institute of Technology, 1981, Stable isotope geochemistry, fluid-rock interactions, groundwater hydrology.

Ghislaine Crozaz  
Professor, University of Brussels, 1967, Trace elements in extraterrestrial and terrestrial rocks.

Robert F. Dynek  
Professor, California Institute of Technology, 1977, Igneous and metamorphic processes, Pre-Cambrian geology.

M. Bruce Fegley, Jr.  
Professor, Massachusetts Institute of Technology, 1977, Chemical processes on planetary surfaces, in planetary atmospheres, and in the early solar system.

Larry A. Haskin  
Ralph E. Morrow Distinguished University Professor, University of Kansas, 1960, Trace-element geochemistry, terrestrial and lunar materials.

Anne Hofmeister  
Research Professor, California Institute of Technology, 1984, Physical and thermodynamic properties of minerals, infrared spectroscopy.

Randy L. Kortep  
Research Associate Professor, University of Wisconsin-Madison, 1976, Lunar geochemistry.

Harold L. Levin  
Professor, Washington University, 1956, Invertebrate paleontology; micropaleontology, stratigraphy.

William B. McKinnon  
Professor, University of California-Berkeley, 1969, Isotopic compositions and elemental abundances in terrestrial, lunar, and meteoritic materials.

Evett Shock  
Professor, University of California-Berkeley, 1987, Geochemical processes involving fluids throughout the crust and upper mantle of the Earth, other planets and meteorites.

William Hayden Smith  
Professor, Princeton, 1966, The development and application of high-reliability instruments for space, airborne and ground-based environmental remote sensing.

Robert D. Tucker  
Associate Professor, Yale, 1985, High-precision U-Pb dating techniques and their application to the study of Pre-Cambrian and Phanerozoic orogeny.

Douglas A. Wiens  
Professor, Northwestern University, 1985, Earthquake source processes, structure of the mantle and crust, plate tectonic processes.

Michael E. Wyssession  
Research Professor, Northwestern University, 1991, Seismology and geophysics, structure of the Earth from the inner core, core-mantle boundary.

Ernst Zinner  
Research Professor, Washington University, 1972, Astrophysics, cosmochemistry, extraterrestrial materials.


Floss, C. Fe,Mg,Mn-bearing phosphates in the GRA 95209 meteorite occurrence and min eral chem is try. Am. Min eral., in press (1999).


Sadia Baqer • Postdoctoral Research Assistant

Sadia Baqer, a native of Baghdad, Iraq, where most of her family still lives, has lived in St. Louis since 1986 when her husband began his studies at St. Louis University. Sadia, with a B.Sc. and Masters in Geology from Baghdad University, began studying at St. Louis University a few years later, receiving her Ph.D. in Seismology in 1996. She began working for Professor Michael Wyssession in October 1997 on the visualization of seismic wave propagation. Sadia really enjoys cooking, and although she cooks mainly Middle Eastern foods, she also makes good pizza and enjoys cooking Chinese food. One of her other passions is travel, and she has traveled extensively in the western United States, including Hawaii. In her free time, Sadia enjoys spending time with her husband, two sons, and one daughter.

Judd Bowman • Systems Programmer

Judd Bowman is new to the Department only as a full-time employee. A 1998 graduate of Washington University with degrees in Physics and Electrical Engineering, he worked for Professor Ray Arvidson in the Remote Sensing Lab for two and a half years as an undergraduate. Staying on with the Department has allowed him to continue working with Mars rovers, which he started in 1996 with the field test rover, Rocky 7. Involved with the 2001 Mars mission and the prototype rover (FIDO) for the 2003 Mars Sample Return mission, Judd doesn’t spend all his time at the computer. At the end of April he spent two weeks in the Mojave Desert testing FIDO, allowing him to mix work with his love of travel. Judd also enjoys scuba diving, building things, and playing racquet ball.

Cassie Dunham • Mission Planner/Education Outreach Coordinator

Cassie Dunham started working for Professor Ray Arvidson in the Remote Sensing Lab in December of this year after graduating from Lawrence University in Appleton, Wisconsin in Spanish and Education and completing her student teaching in a south Chicago high school. This new job allows Cassie to combine her interests in educational programming with her desire for a job that is constantly challenging and changing. She enjoys opportunities to work directly with students and educators and to travel to new places such as Mauna Kea and the Mojave Desert. Whenever possible, Cassie likes to travel (anywhere), scuba dive, and cook for friends (or the lab).

Jeff Gillis • Postdoctoral Research Assistant

Jeff Gillis came to Washington University in October 1998 to work in the Planetary Surface Materials Research Group, headed by Larry Haskin. As a Postdoctoral Research Assistant, Jeff studies lunar volcanism in an attempt to unravel the geologic evolution of the Moon. His interest in planetary science was sparked by an undergraduate summer term internship at the Lunar and Planetary Institute (LPI) in Houston. He went on to receive a B.Sc. in Geology from the University of Massachusetts at Amherst, his home state where his family still resides. After graduation he returned to LPI and worked with Paul Spudis on the Clementine Moon mapping mission. Jeff supported the mission by selecting areas of geologic interest for the high resolution camera to image. His interest in lunar geology led him to graduate school at Rice University in Houston where he received his Ph.D. in Geology, studying volcanism on the Moon’s far side. In his free time, Jeff enjoys playing soccer, roller hockey, hiking, and spending a lot of time outdoors.
Karla Kuebler • Raman Spectroscopy and Neutron Activation Specialist

Karla Kuebler, a native of Overland Park, KS, started working for Professor Larry Haskin in June of last year. Her interest in geology developed during her undergraduate studies at the University of Kansas and her interest in planetary science evolved from her experiences as the president of the astronomy club at KU, in combination with her geology coursework. She cites the particular influence of Dr. Van Schmus.

So far, her work with Larry Haskin has focused on preparing for the upcoming Athena mission: characterizing the calibration standard for the Athena Raman spectrometer and Raman spectroscopic analysis of SNC meteorites and Martian analogs.

In her free time, Karla enjoys reading, camping, hiking, and astronomy.

Rachel Lindvall • Lab Technician

Rachel Lindvall is originally from Minneapolis, Minnesota, where her parents, brother, and sister still live. She graduated from Washington University with a major in Environmental Studies in December 1997. For two of her undergraduate years she worked with Professor Everett Shock in the GEOPIG Lab. Then she started working on the Ion Chromatograph as an assistant. She had planned to go into the Peace Corps or AmeriCorps after graduation, but on her last day at Washington University finishing up some research, Professor Shock suggested she apply for a lab technician opening in the ICP-Mass Spectrometry Lab. Rachel says she’s a “recycling fanatic” (which means she never throws anything away). In her spare time, she enjoys being outdoors hiking and biking, but her favorite outdoor activity is camping.

Rachel may consider graduate school in the future, but for now she really enjoys what she does.

Mike Malolepszy • Computer Specialist

Mike Malolepszy has a degree in Physics from the University of Missouri in St. Louis, and divides his time between department-wide system user support and systems and program work for Professor Roger Phillips in the Planetary Geodynamics and Tectonics Lab. Before coming to Washington University, Mike spent seven years at Monsanto as an Operations Consultant, and two years in Socorro, New Mexico, at the National Radio Astronomy Observatory as a Radio Telescope Interferometry Array and Correlator Operator at the VLA (Very Large Array). A native of St. Louis, Mike has worked part-time at the St. Louis Science Center’s planetarium almost continuously since 1981. In his spare time Mike likes to ride his bike, collect books, telescopes, fossils, and bicycles, and head out to the countryside to do deep sky observing.

Rose Osborne • Lab Assistant

Rose Osborne graduated from Washington University last spring with a degree in English. She began working for Professor Bruce Fegley during her freshman year simply because he was her advisor, and liked it well enough to work in the EPSC Department for all four years. Upon graduation she was offered a full-time position as a lab assistant, a job which includes working on a comet and asteroids project (mostly theoretical research) and as a teaching assistant. Although during her undergraduate years she did not take any classes in the EPSC Department, she has been able to gain necessary knowledge through reading and her work as a teaching assistant.

Rose is still thinking about graduate work in English some time in the future, perhaps leading her into teaching high school. In her free time, Rose enjoys plants and gardening, practicing ballet, and working on her bicycle.
Andrey Plyasunov • Postdoctoral Research Associate

Andrey Plyasunov has an international background in geochemistry. After receiving a degree in Geochemistry from Moscow State University, he studied at the Institute of Experimental Mineralogy in his hometown of Cheranogolovka, Russia, and received a Ph.D. in Geochemistry from the Vernadsky Institute of Geochemistry in Moscow. He then went to Sweden where he spent two years in Stockholm as a visiting scientist and then on to a postdoctoral position at the University of Delaware for one year. This past year he has lived in St. Louis with his wife and 3 1/2-year-old daughter, and worked for Professor Everett Shock on evaluation and prediction of thermodynamic properties of hydrocarbons in aqueous solutions. In his free time, Andrey likes to read and take a daily swim for a necessary break from his computer screen.

Gideon Smith • Research Scientist

Gideon Smith was hired in January 1998 as a research scientist for Professor Doug Wiens. His work centers around analyzing data from seismographs on the ocean bottom, from Patagonia, and from the Antarctic. He is from a small town near Edinburgh, Scotland and completed his undergraduate work at Royal College of Science in London. From there he went to the University of Leeds and did graduate work in seismology, earning his doctorate in 1994. He worked in the Department of Earth and Planetary Sciences at Harvard under the team of Göran Ekström and Adam Dziewonski. His love of more exciting work in Patagonia attracted him to Doug's research and, other than being dumped in the freezing waters of the Southern oceans, he really enjoys working at Washington University.

Thomas Presper • Postdoctoral Research Assistant

Thomas Presper found his career through his hobby—astronomy. He received a degree in mineralogy from Johannes Gutenberg University in Mainz. He did his Ph.D. thesis on micrometeorites from Greenland and Antarctica. These studies were done at MPI in Mainz and at the Museum of Natural History in Vienna. He joined a meteorite search team in Western Australia, and then returned to Mainz, where his large extended family lives, and worked with the MPI meteorite collection and on a project in the atmospheric sciences, which ultimately lead him to his job at Washington University. Before coming to the EPSC Department, however, Thomas spent time on the public outreach side of science as a member of the Science Gallery Design team at the Niedersächsisches Landesmuseum in Hannover, Germany. Thomas now works with Bruce Fegley on the ACE project (Acoustic Composition Experiment) which provides a different approach to chemical analysis of the outer planets, relying on in situ sound velocity and acoustic impedance measurements. In his free time, Thomas loves to study astronomy, listen to classical and electronic music, and ride his new bike.
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Phone number: _________________________ Email: ___________________________________________

Year graduated/degree: ___________________________________________________________________

Personal news to include in the next newsletter: ____________________________________________
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