Washington University in St. Louis

Department of Earth and Planetary Sciences

Newsletter

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Department of Earth and Planetary Sciences
Washington University in St. Louis
St. Louis, MO 63130

Pluto's Geology is Spectacular! *Bill McKinnon*

NASA's New Horizons mission reached the Pluto system on July 14, 2015. This was the culmination of a 25-year effort to explore this remote world at the edge of our planetary system. I have taught in EPSc for over 30 years, and have been involved in the Pluto effort for much of that time, first spending 10 years creating a scientific case for the mission, and then 15 years to build and fly the spacecraft. It's a long way to Pluto!

But why Pluto, and why now? Pluto turns out to be the largest and most scientifically interesting (if not the most famous) world in what we now call the Kuiper belt, a vast reservoir of bodies orbiting beyond Neptune. There are perhaps 200,000 Kuiper belt objects (KBOs) greater than 100 km in diameter, making the Kuiper belt the Solar System's "third zone" (after the realms of the terrestrial planets and the gas giants). This realization, a product of astronomical discoveries in the 1990s, is what drove the National Research Council to call a reconnaissance mission to Pluto and the Kuiper belt its highest priority for a new NASA mission back around 2001.

New Horizons is a competed mission. It is the first of a new NASA program of medium-scale competed missions, called New Frontiers. The mission is led by Principal Investigator Alan Stern of the Southwest Research Institute in Boulder, CO, was built, and is managed out of the Applied Physics Laboratory in Laurel, MD. I am a Science Team member, with specific duties as a Deputy Lead for what we call the Geology, Geophysics & Imaging Theme Team. Other Theme Teams cover Pluto's atmosphere, its surface composition, and its interaction with the solar wind.

Figure 1. Enhanced color composite of Pluto (2375 km diameter) and Charon (1215 km diameter) as seen by NASA's New Horizons spacecraft during the July 14, 2015 encounter. Pluto exhibits a bewildering variety of geological terrains, some active, while Charon appears to be a more "normal" icy satellite, albeit one which underwent a major tectonic and cryovolcanic resurfacing event (note cratered canyons and plains) nearly 4 billion years ago. This image was created from blue, red, and near infrared images, with Charon's brightness boosted to enhance detail.

I am happy to report that we were able to build a compact, modern spacecraft in under four years, make our launch window in January 2006, which allowed us to get a gravity assist at Jupiter in February 2007 that shaved three years off our total trip time, and that the spacecraft performed nearly flawlessly during its 9.5 year flight to Pluto. The encounter last July itself was a fantastic success, and we continue to download images and other data from

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Overview *by Slava Solomatov*

Greetings. First, I must begin with some sad news. Professor Emeritus Ernst Zinner, a member of the Departments of Physics and Earth and Planetary Sciences, and a pioneer of stardust research, has passed away. He was at Washington University since the mid-1960's. Our condolences go to the Zinner family. Ernst will be dearly missed.

The New Horizons mission, after nine and a half years, finally reached Pluto. In this newsletter, Professor Bill McKinnon, a member of the New Horizons team, shares his excitement of their first discoveries. The coming years will be even more exciting for his team and the rest of the world as the majority of the data has yet to be transmitted to the Earth. The spacecraft will continue on its mission to explore further the remote region of the Solar System known as the Kuiper Belt.

The faculty search in Cosmochemistry resulted in two new hires. Assistant Professors Rita Parai and Kun Wang will join the department in summer 2016. They use high-precision laboratory measurements of isotopic compositions in terrestrial and extraterrestrial samples and have complementary expertise. Professors Parai and Wang will bring in powerful capabilities to study fundamental questions of the formation and differentiation of planetary bodies, the uniqueness of the Earth and ultimately the origin of life.

The Departments of Mathematics, Physics, and Earth and Planetary Sciences created a Joint Post-baccalaureate Program. The new program accepts those who already possess a bachelor's degree and prepares them for a graduate school. It is designed for individuals from groups traditionally underrepresented in math and sciences.

Continuing the tradition, we will have a joint reception with Northwestern University at the Fall AGU Meeting in San Francisco. All alumni and friends of Earth and Planetary Sciences are cordially invited.

Visit our Department Facebook page: www.facebook.com/WASHU.EPSci

Professor Ernst Zinner

It is with great sadness that we report the death of Professor Emeritus Ernst K. Zinner, an astrophysicist and cosmochemist in the departments of Physics and Earth and Planetary Sciences. Ernst died on July 30th of complications of the mantle cell lymphoma he had battled for more than 19 years. Ernst is survived by his wife, Brigitte Wopenka, a retired senior research scientist in our department, and his son, Max Zinner of New York City.

Ernst was born in Austria, about 100 miles west of Vienna, and obtained an undergraduate degree in physics from the Technical University in Vienna. He moved to the United States in the mid-1960's to attend Washington University where he earned his doctoral degree in 1972 in high-energy particle physics. That same year Bob Walker invited him to work for the new Laboratory for Space Sciences as a research associate. He was at Washington University for a total of 50 years. Zinner was a pioneer in the study of stardust. In 1987 he and his team were able to identify for the first time in the laboratory material that predated the formation of the solar system. This work used a secondary-ion mass spectrometer which detected minute amounts of stardust from primitive meteorites. Zinner became one of the leading authorities on the SIMS instrument, training scientists worldwide. In 1997, he received the J. Lawrence Smith Medal of the National Academy of Sciences, the top award in this field, and the Leonard Medal from the Meteoritical Society. He was a fellow of the Meteoritical Society, the American Physical Society and the American Association for the Advancement of Science.

Not only was he an excellent physicist, he was also a terrific mentor to many grad students and post-docs. He was extremely generous in training and encouraging other scientists from all over the world and in his own laboratory. Besides researching particle physics, Ernst was an accomplished pianist and met weekly with his friends to play the harpsichord in a baroque music ensemble. Later in life he began playing the cello especially with his son, Max.

In recognition of the outstanding contributions of Professor Zinner to the McDonnell Center for the Space Sciences, the director of the center, Ramanath Cowsik, announced the "Ernst K. Zinner Fellowship in Cosmochemistry." This memorial fellowship will be offered to outstanding graduate students admitted to Washington University for carrying out research in this field.

Information for this article came from a "Newsroom" article by Diana Lutz

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New Horizons, and will do so until August of 2016. It's a long way to Pluto!

But the best part for me is that the geology of Pluto, and that of its big moon, Charon, turned out to be so varied and interesting. Figure 1 shows a montage of enhanced color views of the two. Pluto's radius is less than that of our Moon, so it qualifies as a "dwarf" or small planet. Charon is about half Pluto's size, so the two make a binary system (and are in turn orbited by four much smaller moons). Their densities are a bit less than 2 g/cm^3, and we think they both have big rock cores surrounded by thick ice mantles. Everything we see on their surfaces is in fact one kind of ice or another, except for the dark red stuff which is probably carbonaceous. On Pluto we have spectroscopic evidence from New Horizons for N_2, CO, CH_4, and H_2O ices, while on Charon we see both H_2O and NH_3-rich ice. The exotic and volatile ices in this list (as opposed to ordinary H_2O ice) are what allow bodies of this size and so far from the Sun to be or to have been geologically active.

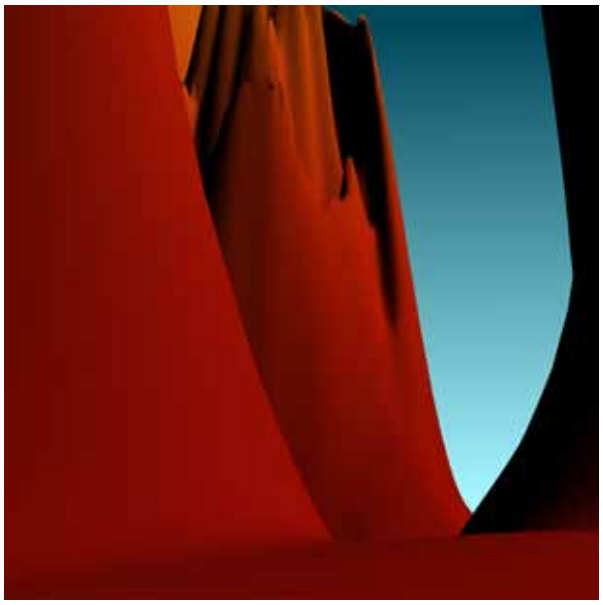
And Pluto is geologically active! Because both Pluto and Charon rotate slowly (every 6.4 Earth days) and because New Horizons was moving so quickly (13.8 km/sec), we have really high-resolution views of a single hemisphere of each body. Across the hemisphere of Pluto we got to see how the impact crater density varies from high (implying a great geological age, in excess of 4 billion years) to very low (implying geological youth). The particularly bright, yellowish region below center on Pluto is a vast basin we informally call Sputnik Planum (SP). Even in our highest resolution images we cannot detect a single impact crater (down to 2-km-diameter sizes); we estimate a crater retention age for SP of 10 million years or less.

Sputnik Planum is mainly made up of N_2 ice along with CO and CH_4 ices. These ices are volatile, and geologically soft even at Pluto conditions (Pluto's surface temperature is a balmy 37 K), softer than terrestrial glacier ice (Fig. 2). We think the SP ices are several kilometers thick or more. We have image and topographic evidence for convective overturn within portions of this ice sheet, as well as advection (lateral flow) of the ices in other portions. Pluto's N_2-CH_4 atmosphere is in fact supported in vapor-pressure equilibrium with these ices. We have evidence for "glacial" flow into the basin, as well as evidence for glacial erosion and mantling on Pluto's uplands. But on Pluto the glacial cycle is based on the sublimation and condensation of nitrogen ice, rather than the evaporation of water and snowfall as on Earth (the mind boggles).

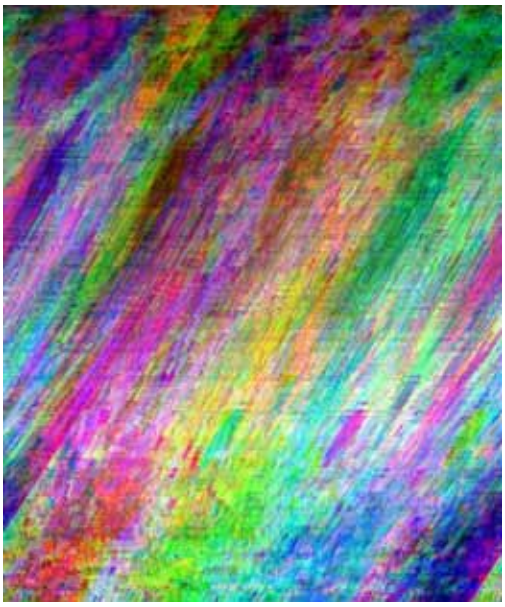
On Pluto we also have evidence for sublimation erosion, etching, and pitting, some quite spectacular. And then there are these broad (150-km-wide), multi-km high mounds with summit depressions that appear constructional. Could these be some new kind of icy volcano? We have much more data to download, and of course to analyze, so it will be some time before we can unscramble the full geological story of Pluto and its moons. But the New Horizons team believes this augurs well for exploration of the other dwarf planets in the Kuiper belt, someday. As for the spacecraft, it is now on course to rendezvous with an ancient, smaller KBO (2014 MU69) sometime around New Year's eve 2018. And for those interested, you can follow mission progress, get more details, and view amazing high-resolution images (make your own geological interpretations!) at the mission website pluto.jhuapl.edu.

Figure 2. Professor McKinnon near the first icefall on Athabasca Glacier, Alberta. Solid ice can flow downhill like a river, and the ice under the author's feet is creeping along at 20 cm/day. New Horizons has discovered a similar phenomenon on distant Pluto, but the glacier ice there is mostly solid nitrogen.

Research as Art Exhibit



Andrew Windisch

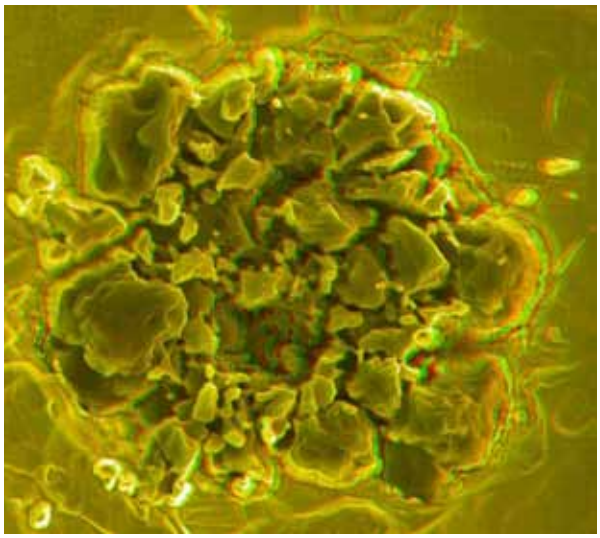


Kathryn Powell

On April 3rd the departments of Earth and Planetary Sciences, Physics, the McDonnell Center for Space Sciences and the Geographic Information System program held the first "Research as Art" exhibit in the Ginsburg Atrium of Rudolph Hall. The exhibit was produced and organized by Martin Pratt, a graduate student in EPS, and his committee of fellow grad students. The 42 entries were composed of whatever struck the researcher's eye as art and included scenes of research field trips, abstract art of mosaics, mathematical equations, spectra from an image of Mars data, electron micrographs and anaglyphs of a mote of space dust. By organizing the exhibit, Pratt hoped it would start a tradition and coax more researchers to think of their work as art in addition to science. Many of the pictures are now hanging in the stairwell of Rudolph Hall and have considerably livened up the blue walls.

Prizes were given out in three categories; best from department of Physics, best from Earth and Planetary Sciences and "The People's Choice Award." Andrew Windisch, a postdoctoral research associate in physics, won for his image of a double vortex in a superfluid. Kathryn Powell, an EPS grad student, won for an accidentally smeared image of data from an instrument aboard a satellite orbiting Mars. Frank Gyngard, a research scientist in physics, won the People's Choice for an anaglyph of a mote of dust propelled into space by a supernova.

For the first year the exhibit was opened only to the departments of Physics and EPS, but the organizers plan to invite more departments to join in next year's "Research as Art."



Frank Gyngard

For more information about the department and a listing of our faculty go to eps.wustl.edu

Credits

Editors

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Olivine crystallographic preferred orientation and flow in Earth's mantle

by Yuval Boneh

Plate tectonics, mantle convection and plastic deformation

Since the acceptance of the theory of Earth's plate tectonics, geophysicists have tried to understand the driving forces of plate motion. It is believed that circulation of material in the Earth's mantle drives the motion of the rigid upper plates. Under high temperature and pressure, like the conditions that prevail in the mantle, rocks behave like a viscous fluid. Deformation is achieved, in part, by intracrystalline plastic deformation. In order to assess the mantle's flow patterns, rheology and elastic properties, we have to understand the physical processes that underlie the plastic deformation at the grain-scale.

In the upper mantle, plastic deformation is enabled mainly by the movement of line defects, dislocations, in the crystal. When dislocations glide, they cause rotation in the crystal towards the dislocations' direction of movement. Depending on the specific conditions of deformation, dislocations may glide along a preferred crystallographic slip system. The crystals then rotate towards the flow direction and, as a result, the rock develops a Crystallographic Preferred Orientation (CPO). Rocks that contain a CPO are described as having "texture," in contrast to rocks with random crystallographic orientation.

Olivine, the most abundant mineral in the mantle, is elastically anisotropic. This means that seismic waves in olivine travel faster in one direction and slower in others. For olivine, the [100] axis is seismically the fastest axis. When the olivine crystals in a textured rock are highly aligned, the rock will be anisotropic for the propagation of seismic waves. The way geophysicists assess mantle flow in depths that are not physically accessible is by measuring the direction and magnitude of seismic anisotropy. Since olivine [100] crystallographic axis tends to align with deformation, the direction of fast seismic wave is interpreted as the direction in which the mantle flows.

This simple relation that fast seismic wave direction equals mantle flow direction, is the widely used paradigm for interpreting mantle kinematics. However, for this paradigm to be valid olivine [100] axis must always be aligned with direction of flow. In subduction zones and other plate boundary settings, mantle flow could be complex and involve local changes of flow direction, which can include either parallel or perpendicular flow to the trench, or flow around the slab (Fig. 1). Can we still assume crystallographic alignment with deformation where mantle changes its direction? In other words, do the crystals align instantaneously with change of flow, or rather is some finite strain required before an alignment is achieved? These are the questions Phil Skemer and I have addressed using both experimental and numerical model approaches.

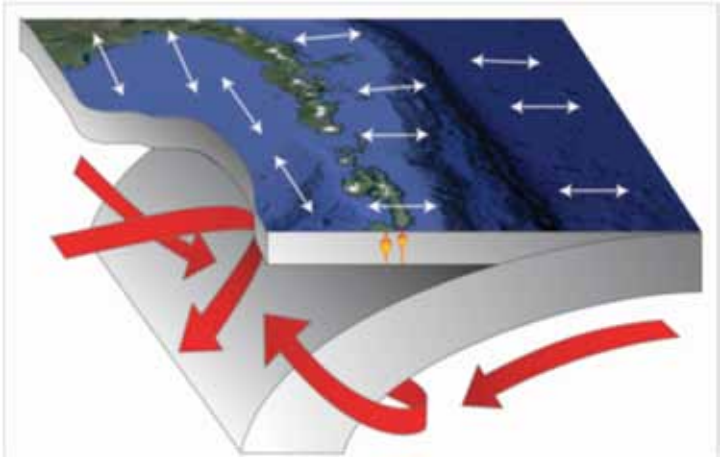

Fig. 1 – Illustration of a complex mantle flow under subduction zone. Red arrows show possible mantle kinematics and white arrows show the direction of fast seismic anisotropy.

Fig. 2 – Griggs apparatus (left), assembly parts (upper right), and a thin section of a deformed sample (right).

Squishing rocks in the lab

I performed experiments in the 'Experimental Study of Planetary Materials' (ESPM) lab with the 'Griggs' apparatus, also known as 'the rock squishing machine' (Fig. 2). The Griggs allows deformation in uniaxial compression under conditions of high temperatures (1200° C) and high pressures (1 GPa). Samples were deformed under very slow displacement-rates ~ 2 [μm/min] in order to induce plastic deformation, where rocks change their shape without breaking or fracturing.

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These types of experiments, which produce crystallographic rotation in olivine aggregates, have been conducted since the 1960s through the use of untextured synthetic samples. The rationale for our experiments differs in that we focus on CPO evolution with the effect of deformation history by using natural samples that contain a starting CPO prior to deformation. In order to evaluate how varying starting CPOs affect subsequent texture evolution, samples were cored in different orientations with respect to the existing rock foliation. For each orientation, a different amount of crystallographic rotation was expected (schematic illustration in Fig 3). After each experiment with a different strain, the CPO was measured and a projection of the three olivine axes, [100], [010], and [001], were plotted respectively on three pole figures (Fig. 3).

Previous studies on synthetic, untextured samples reached the expected textural steady-state after relatively low strain. However, our samples did not reach the textural steady-state also at the highest strain (Fig. 3). These observations suggest that crystallographic alignment is slower when the effect of deformation history is taken into account.

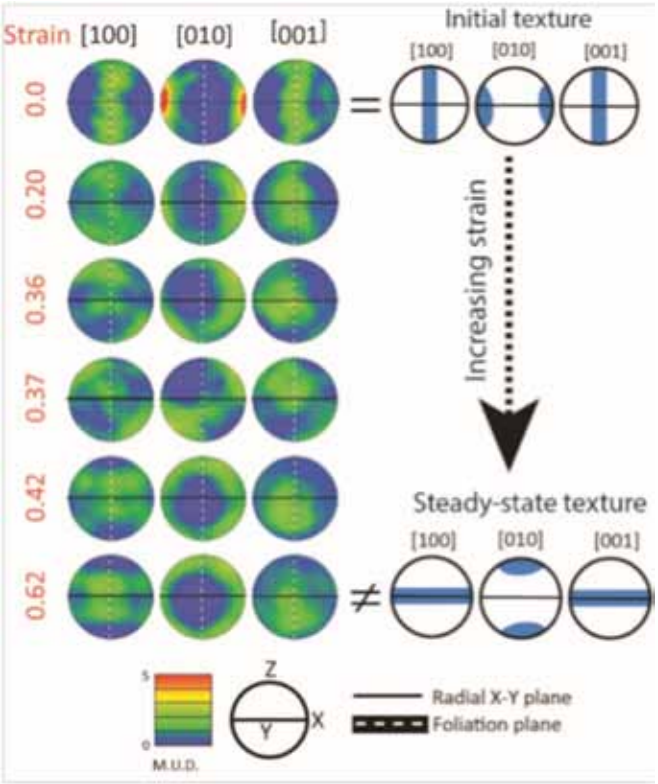

Fig. 3 – Pole figures showing the crystallographic preferred orientation (CPO) of each of the three olivine axes, [100], [010], and [001]. On the right is a schematic illustration of the starting CPO and the CPO expected when reaching steady-state. Our samples did not reach textural steady-state also at the highest strains.

Modeling texture

We used numerical models to simulate the same conditions as in the experiments. These models were previously benchmarked according to the old experiments. Using our experiments we set a new benchmark for the models' parameterization. We then used the models to simulate textures to high strains in simple shear deformation geometry which better represents deformation in the mantle. We ran these simulations to high strains and found that the [100] axis re-aligns toward the shear direction only after a strain higher than two. These results show that crystallographic re-alignment is not instantaneous and as a result seismic anisotropy depends on the deformation history. Therefore, whenever change in mantle flow direction is expected, a stage in which seismic anisotropy is not aligned with mantle flow has to be assumed.

In the next step we will use the newly developed, state-of-the-art Low Volume Torsion apparatus (LVT). The LVT can shear samples by a twist motion to almost unlimited strains of ~100. This will enable us to examine how much strain is needed to reach the textural steady-state (Fig. 4).

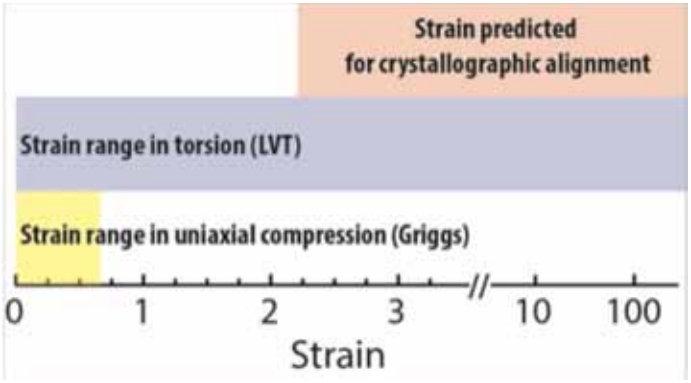

Fig. 4 – Strain range for experiments in uniaxial compression (yellow), torsion (blue) and numerical models prediction of strain needed for achieving crystallographic alignment (red). Experiments in the newly developed torsion apparatus will allow us to explore a large range of strains and to test the predictions for the kinetics of crystallographic alignment.

Catalano receives NASA grant

Associate Professor Jeff Catalano and Adjunct Professor Richard Morris have received a three-year grant from the NASA Mars Fundamental Research Program. The project seeks to determine how clay minerals formed on Mars and ways they have been altered since then. The research will help reconstruct environmental conditions on early Mars.

Fike and team receives DOE grant

The U. S. Department of Energy has awarded a grant to David Fike, Associate Professor of Earth and Planetary Sciences, and a team of three researchers to adapt the powerful chemical microscope called the 7F-GEO SIMS for biological samples. The SIMS was purchased with a grant from the NSF in 2013, and with this new DOE grant it will be enhanced to have the capacity to map the internal chemistry of biological cells. The modification of the SIMS will enable Fike and his co-investigators to make higher resolution images and collect large field of view images more quickly. Essentially it will make high-resolution maps of the elements and isotopes within many microbes simultaneously and give the researchers the ability to reconstruct the chemistry of a microbe's interior.

Arvidson leads PDS Geosciences Node

The NASA Planetary Data System (PDS) has approved the Cooperative Agreement Notice proposal submitted by Ray Arvidson, the John S. McDonnell Distinguished University Professor, to continue the PDS Geosciences Node at Washington University in St. Louis. The Geosciences Node will continue working with NASA missions to plan, ingest, validate and make available archives of use to the planetary science community. Currently the node supports 8 active or recently completed missions, 43 instruments, and 17 researchers who are restoring mission data sets or generating archives from Earth-based and laboratory observations. It is expected to have archived over 293 TB of data when this project is again reviewed for renewal in 2020.

Brad Jolliff recognized for mentoring

The 2014 Graduate Student Senate of Arts & Sciences announced the recipients of the 16th Annual Outstanding Faculty Mentor Awards. Of the one hundred submissions, eight were chosen for awards and another six recognized for their excellent efforts. Brad Jolliff, the Scott Rudolph Chair in Earth & Planetary Sciences, was chosen by the Graduate Student Senate for his commitment and excellence in graduate student training.

Lodders receives NSF grants

Dr. Katharina Lodders, Research Professor in Earth and Planetary Sciences, received two NSF grants for studying the abundances of the elements and their chemistry in stellar environments, and for the study of gas and cloud chemistry in the atmospheres of exoplanets, brown dwarfs, and low-mass stars.

Wiens named Distinguished Lecturer

Professor Doug Wiens was named the 2015 Distinguished Lecturer of the Seismological Society of America and the Incorporated Research Institutions in Seismology. Doug is giving public outreach lectures at various sites around the country, such as museums, with the title of "Fire and Ice: Volcanoes, Earth Structure, and the Evolution of the Antarctic Ice Sheet."

Students awarded TA Prizes

The undergraduate and graduate teaching assistant (TA) awards for outstanding service during the 2014-2015 academic year were named at the October 23rd colloquium. There were two recipients of the Tolman Award for graduate TAs, Sarah Valencia and Teresa Wong. Emeritus Professor Hal Levin was present to give Zoe Lefebvre and Amanda Staderman the Harold Levin Award for undergraduate TAs. Grad student Michael Bouchard and undergrad Haley Delk both were recipients of a Letter of Recognition for their excellent efforts. Thanks to all our TAs for their contributions to the education of our EPS students.

Joint Program launched

The Departments of Mathematics, Physics and Earth and Planetary Sciences created a Joint Post-baccalaureate Program (JPP). It is designed to prepare exceptional individuals who already have a bachelor's degree in any one of these or related fields to make the transition to graduate school. The JPP selects participants based on academic achievement, leadership, and commitment to diversity and encourages applications from individuals who come from groups traditionally underrepresented in Mathematics, Physics and Earth and Planetary Sciences — specifically African Americans, Hispanic Americans, Native Americans, Pacific Islanders, women and those with disabilities. For more information visit pages.wustl.edu/jointpostbac. Jennifer Gil Acevedo, from Puerto Rico, is the first post-baccalaureate student in Earth and Planetary Sciences.

Professor promoted

Michael Wysession was promoted to Full Professor effective July 2015. Michael is recognized as an accomplished researcher and educator who has done extraordinary service for the scientific community by leading a successful effort to improve geoscience education in this country. In spring 2016 he will be on sabbatical studying the seismic structure of the core-mantle boundary and planning for a seismic deployment in the Canary Islands.

New Professors to join EPS Department in 2016

Dr. Rita Parai, currently at Carnegie Institution for Science - Department of Terrestrial Magnetism, and Dr. Kun Wang, currently at Harvard University, will join our department as Assistant Professors in summer 2016.

Dr. Parai received her undergraduate and graduate degrees in Earth & Planetary Sciences at Harvard University. Her dissertation title was "Volatiles in the Earth and Moon: Constraints on Planetary Formation and Evolution." Her primary research interests are the origin of volatiles in terrestrial planes, early Earth environments, and the timing and mechanism of lunar formation. She has received many awards including the Carnegie Post-doctoral Fellowship, an NSF Graduate Research Fellowship and the Dwornik Planetary Geoscience Student Paper Award from GSA in 2013. Dr. Parai is a member of the American Geophysical Union and the Geochemical Society. When she arrives here she will build a noble gas mass spectrometry lab and will pursue new constraints on the formation and evolution of the Earth, Moon and planets.

Dr. Kun Wang is no stranger to our department as he received his doctoral degree here in Earth and Planetary Sciences in 2013. His dissertation topic was "Iron Isotope Cosmochemistry." Kun grew up in Tangshan, China. He received his undergraduate degree in Geology from China University of Geosciences and he worked as a research assistant from Purple Mountain Observatory at the Chinese Academy of Sciences. He came to the department in the fall of 2009 to begin his doctoral studies in geochemistry under Fred Moynier. When Kun was a teaching assistant at Wash U he was awarded the Carl Tolman Prize for Outstanding Graduate Teaching Assistant in 2011. He was a NASA Earth and Space Science Fellow during his last two years of graduate study. Currently Kun is the Origins of Life Initiative Postdoctoral Fellow at Harvard University. He is continuing his studies of meteorites and other extraterrestrial samples to understand the initial physical and chemical conditions during the formation and early evolution of Solar System and terrestrial planets. When Kun returns to Washington University in June 2016, he will direct the Isotope Cosmochemistry Laboratory and will focus on further understanding of the origin and evolution of the Solar System.

New Employees

Heng Chen Research Scientist

Heng Chen was born and raised in Yibin City, a medium–sized city along the Yangtze River in Sichuan Province. He attended the China University of Geosciences where he majored in geochemistry. He received his doctoral degree in geological sciences from Washington University in St. Louis. In January 2015 he started his research scientist job collaborating with Dr. Jeff Catalano working on isotopic behaviors of chromium and zinc during mineral dissolution/precipitation. Heng enjoys performing experiments especially when an experiment results in new or unexpected data. He also enjoys the collegial atmosphere in our department. His favorite things about St. Louis are Forest Park and Cardinal Baseball. In his off hours he spends time at the zoo, the Forest Park museums and eating St. Louis style barbeque or pizza. He frequently enjoys the running trails in the park and likes hiking in nearby state parks. Time at home is spent watching movies, baseball or NFL games.

Ryan (Clegg) Watkins Research Scientist

Ryan Watkins is the McDonnell Center for Space Sciences Postdoctoral Research Associate in Brad Jolliff's Planetary Materials Research Group. She was born and raised in Richmond, IN until age 11 and then her family moved to Inman, SC, where she stayed until college. Ryan attended Florida Institute of Technology (BS in physics and in space sciences) and earned her PhD in Earth & Planetary sciences here in May 2015. She particularly likes her colleagues because they are "smart and fun to be around." She loves her research and having access to great equipment, lunar samples, and experts in her field. Some of Ryan's favorite things about St. Louis include hav-

ing 4 seasons, many inexpensive or free things to do, and the availability of different cultural foods (but not a fan of provel cheese! Sorry Imos).

Nyssa Crompton Postdoctoral Research Associate

Nyssa Crompton is from Wilmington, Delaware. She received her undergraduate chemistry degree from Luther College in Iowa and her graduate degree in chemistry from Princeton University under Dr. Satish Myneni. Nyssa started working in Dr. Jeff Catalano's lab in September of 2015 and is currently researching the impact of trace metal limitations on methane flux in terrestrial systems. She is looking forward to tackling important scientific questions with the dedicated people in Jeff's lab. Nyssa is excited to live in St. Louis and already is taking advantage of walks in Forest Park and attending the free zoo. In her spare time she performs in both hand bell and vocal choirs.

Rachel Folkerts Research Lab Assistant

Rachel Folkerts spent her childhood in Cedar Rapids Iowa. After completing her undergraduate studies in environmental Earth sciences at Washington University in 2012, Rachel spent two years working in West Africa on grassroots projects in the field of sustainable agriculture. Rachel started working for David Fike in June of 2015. As a research assistant and community outreach coordinator for the Environmental Studies Program, her work mixes community engagement, project coordination, and research. Her primary task is to guide WU's involvement in the Baden Pilot Project–a green space redevelopment effort in North City that is led by partners of the City's Urban Vitality and Ecology Initiative. She is thrilled to be back at WU to help with this project. Some of Rachel's favorite things about St. Louis include Forest Park, the Botanical Garden, and our large selection of tasty craft beers. When not working in Environmental Studies she enjoys outdoor activities such as gardening, biking, running, and hiking. She recently took up Jiu jitsu and is also a big reader of fiction.

Rachel Wells Postdoctoral Research Associate

Rachel Wells was born and raised in Carrollton, TX, a city outside of North Dallas. She completed her bachelor's in geology at the UT, Austin, and her masters and PhD in geology at Texas A & M in College Station. Rachel started her postdoc in April for Phil Skemer and Dan Giammar working under the DOE Geologic Carbon Sequestration project. She is excited to use new equipment and techniques not previously used in her graduate work. Rachel also enjoys working with the diverse group of people across a variety of fields. Since coming to St. Louis, she has really enjoyed the fall colors (in Texas trees just turn brown) and all the variety of outdoor festivals we have. In her spare time Rachel goes hiking or running with her 7 year old red heeler, Opal, or she tends her garden. When staying inside she works on stained glass projects.

Andrew Cross Postdoctoral Research Associate

Andrew Cross spent his childhood in Newark-on-Trent, England, located on the outskirts of Sherwood Forest. He graduated with a master's degree in geology and geophysics from the University of Liverpool, UK in 2011. In May of 2015, Andrew received his doctoral degree in rock mechanics from the University of Otago in New Zealand. He started working in Phil Skemer's rock deformation lab in February 2015. His favorite thing about working in the lab is using his hands a lot in designing and running experiments. His favorite things about St. Louis include our food (barbeque especially) and getting lost in the City Museum or attending baseball games. Andrew and his wife, Anna, were married earlier this year in Clayton. When he is not deforming rock samples he loves spending time outdoors either hiking, rock climbing or skiing.

Weisen Shen Postdoctoral Research Associate

Weisen Shen is from a small town called Meishan in the Sichuan Province, located in Southwest China near the High Tibetan Plateau. In 2008 he received his bachelor degree in geophysics from the University of Science and Technology of China in eastern China and his doctoral degree in geophysics from the University of Colorado, Boulder in 2014. Weisen started working in the seismology lab with Doug Wiens in October. When asked about his new job, he said, "I like going into the field and collecting the data I will be analyzing in the lab." Most of all he is looking forward to visiting Antarctica. Weisen and his wife, Jiayi Xie, who is a geophysics grad student at CU boulder, are hoping that eventually they will be working in the same city. Outside of work he enjoys watching animals at the zoo especially the hippos. He thinks St. Louis has the best US zoo he has ever seen. He also is a runner and likes to go to the gym or run in the parks. Weisen is a fan of rock and classical music.

Alumni News (or where they are now)

Neil Sturchio (PhD '83) is now the chair of the Department of Geological Sciences in the University of Delaware's College of Earth, Ocean, and Environment. Dr. Sturchio moved to UD in September 2014 from the Department of Earth and Environmental Sciences at the University of Illinois at Chicago. His research interests include: biogeochemistry; rock-water interactions; stable and radioactive isotope tracers in aquifers, geothermal systems, sediments, and soils; geochemical applications of synchrotron radiation.

Jeffery Seitz (AB '86 and AM '89), has been selected as the new Director of the Center for Student Research at California State University East Bay. Dr. Seitz, an Earth and Environmental Sciences Professor, has been the recipient of multiple major grant awards at CSU East Bay and was the George and Miriam Phillips Outstanding Professor in 2009-2010. He is very excited to be taking on the responsibility of mentoring the undergraduate and graduate students who are working with faculty on research projects. Jeff will also be working to prepare students to compete in the CSU Research Competition and to present posters during the CSU East Bay Week of Scholarship.

Margo Edwards (PhD '86) became the Executive Director of the Applied Research Laboratory at the University of Hawaii on April 1, 2015. The University of Hawaii ARL is one of five Navy University Affiliated Research Centers (UARCs). It was established in 2007. The other four UARCs, established near the end of WWII, are at Johns Hopkins University, Pennsylvania State University, Texas A&M University and the University of Washington. For more details check out their website: www.hawaii.edu/arl/.

Carla Koretsky (AB '92) currently Dean of the Lee Honors College at Western Michigan University, received the 2014 Geochemical Society Distinguished Service award. She is also continuing as one of the editors-in-chief for *Chemical Geology*.

Meenakshi Wadhwa (PhD '94) was recently awarded a Fulbright-Nehru Academic and Professional Excellence Award and will be spending four months during the spring semester of 2016 at the Physical Research Laboratory in Ahmedabad, India working on a collaborative research project with colleagues there. She is now the Director of the Center for Meteorite Studies and a professor in the School of Earth and Space Exploration, Arizona State University in Tempe.

Chris Frederickson (AM '98) got married to Julie Beck on December 13, 2014 by a waterfall in Kauai, Hawaii. They currently live in Northern Virginia where Chris is a GIS Analyst for Lockheed Martin on a contract with the Defense Health Agency in the Department of Defense.

Laurel Griggs Larson (AM '03) received two grants this year: An NSF CAREER award for work on sedimentation in the Wax Lake Delta, and a Moore Foundation Investigator in Data-Driven Discovery for work on emerging methods to reveal causal interactions and feedbacks in environmental systems. Laurel is an assistant professor in the department of Geography at UC Berkeley.

Bethany Ehlmann (AB '04) assistant professor at Caltech, will be the recipient of the James B. Macelwane Medal to be awarded at the 2015 Fall AGU Meeting. This medal is given annually to 3-5 honorees in recognition for significant contributions to the geophysical sciences by an outstanding early career scientist.

Ryan Zeigler (PhD '05) was on the Antarctic Meteorite Search team last year, and managed to travel to all 7 continents last year (trips to London, Morocco, Vietnam, Australia, New Zealand, Quito). All but one of those was for business travel, so Ryan is getting pretty good at flying in and out of Houston, TX.

Jessica Friedman (AB '07) is in her fourth year of medical school at Duke University in the Primary Care Leadership Track. Last year, Jess completed a Masters of Public Health at UNC Chapel Hill. She is also applying for residency in Family Medicine.

Paul Larsen (AB '07) finished his internal medicine residency at University of California, San Francisco, and has accepted a job as a hospitalist at UCSF. He is currently applying for a cardiology fellowship.

Yun Ke (PhD '09) joined Brock University in Niagara Falls, Ontario, Canada last year as an assistant professor of accounting. Previously he was at the University of British Columbia in Vancouver studying finance.

Alison Beehr (AM '10) left Fujifilm Electronic materials in June, 2015 and is now working as an analytical chemist for Heraeus Materials Technology in Phoenix, AZ.

Benjamin (Martin) Gross (AB '10) is now an employee at UNAVCO, the Boulder, CO-based consortium that facilitates geoscience research and education using geodesy.

Brittany Huhmann (AB '10) passed her qualifying exams and started her thesis research this year. She is studying how arsenic in irrigation water in Bangladesh affects rice agriculture. Brittany is an NSF Coupled Natural and Human Systems grantee, and works with a multidisciplinary team of natural and social scientists to explore ways to improve rice yields in arsenic-impacted areas. The team hopes to work with farmers to develop an intervention that they're actually interested in using, and then analyze the factors that affect which farmers decide to adopt it. Brittany often spends time in Bangladesh doing fieldwork, which has been both exciting and challenging!

Tara Seely (AB '12) started her M.S. program in Hydrology at U.C. Davis in Davis, CA. Tara's research will focus on stable isotopes and what they can tell us about water use in almond trees.

Steve Seddio (PhD '13) is currently a microanalysis application scientist at Thermo Fischer Scientific in the Madison, Wisconsin area.

Yang(AKA Steve) Liu (PhD '13) started a postdoc position at Southwest Research Institute in San Antonio, Texas in March of this year. He joined the Lunar Reconnaissance Orbiter's LAMP team and is studying the Moon using LRO datasets under Dr. Kurt Retherford and Dr. Randy Gladstone.

Abigail Fraeman (PhD '14) will be finishing her postdoc at Caltech with Bethany Ehlmann and will start a permanent position at the Jet Propulsion Lab as a research scientist. She is looking forward to the new opportunities at JPL and continuing to live in sunny southern California.

ALUMNI UPDATE!

Let us know what you are doing now.

Either send an email to mueller@wunder.wustl.edu or mail an update to: Washington University in St. Louis, Department of Earth & Planetary Sciences, Margo Mueller, Campus Box 1169, One Brookings Drive, St. Louis, MO 63130.

Join WUSTL Earth & Planetary Sciences Group Page on "Linked In"

ALUMNI, VISIT US THIS DECEMBER

Fall AGU Meeting
San Francisco
Department and Alumni Reception
Jillian's@Metreon

101 Fourth Street
San Francisco
Monday
Dec. 14, 2015 • 7:00–10:00 PM

PhDs Awarded 2014-15

Margaret Hinkle
Ion Interaction at the Mineral-Water Interface during Biogeochemical Iron and Manganese Cycling

Garrecht Metzger
The Late Ordovician Biogeochemical Carbon Cycle

Heng Chen
Zn and Cu Isotopic Fractionation during Planetary Processes and the Isotopic Composition of the Bulk Silicate Earth

Ryan Clegg
Physical and Compositional Properties of the Lunar Surface from the Photometric Studies of Lunar Reconnaissance Orbiter Narrow Angle Camera Images of Spacecraft Landing Sites and Soils of Extreme Compositions

Michael Zanetti
Investigating the Complexity of Impact Crater Ejecta Using Results from the Field, Laboratory, and Remote-Sensing

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