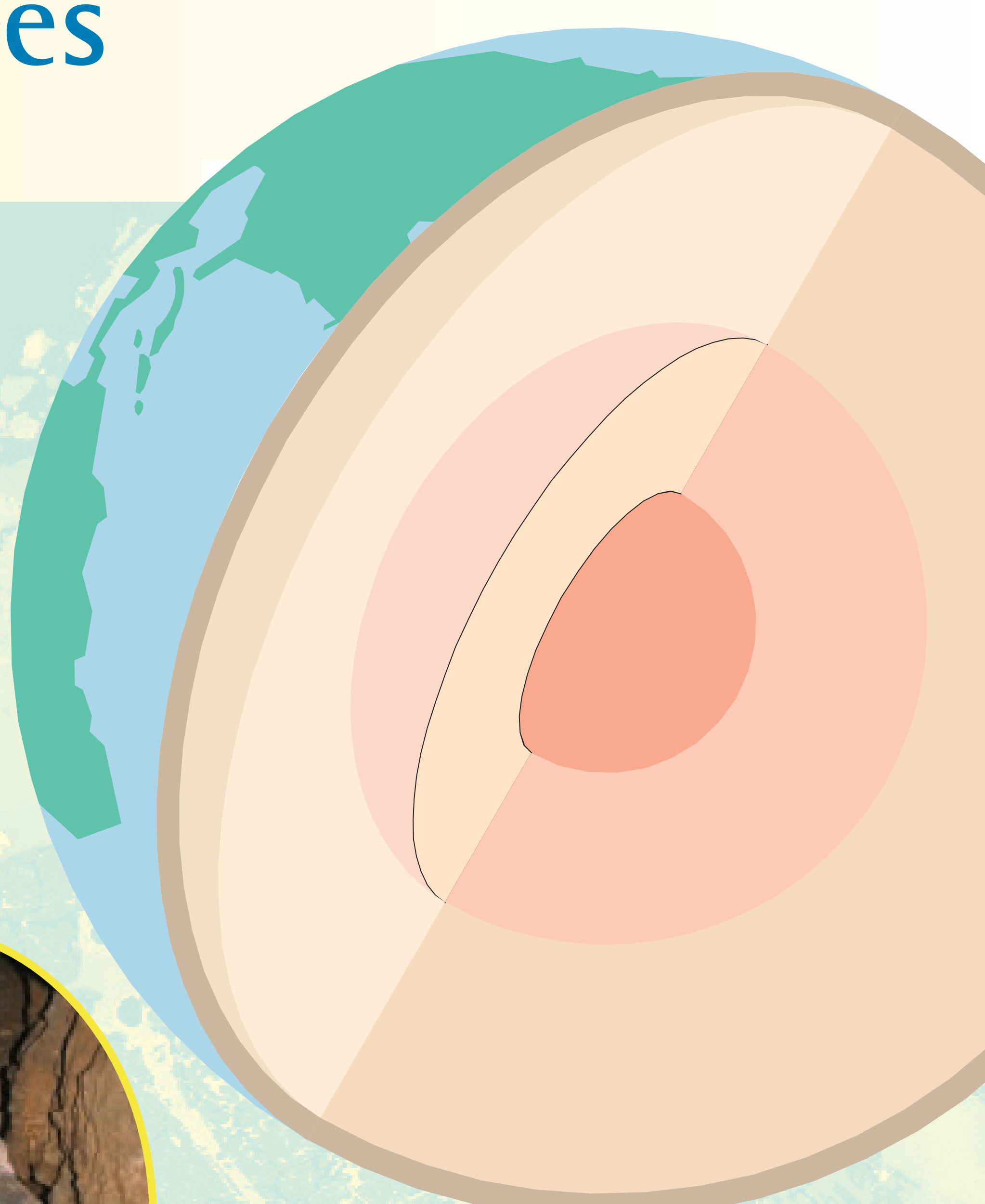
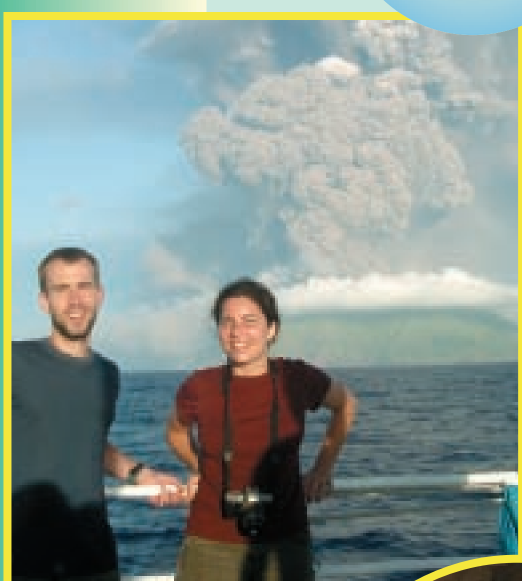
Graduate Studies in

Earth & Planetary Sciences





Washington University in St. Louis

Arts & Sciences

http://epsc.wustl.edu

Earth & Planetary Sciences

The Department of Earth & Planetary Sciences

at Washington University in St. Louis is one of the few departments in the country with an integrated program of instruction and research that treats Earth as a planet and makes direct use of knowledge gained by exploring the solar system. As a student you will have the opportunity to explore the many areas covered within the Department such as geology, geochemistry, geophysics, geobiology, and planetary sciences. You will participate in research that involves laboratory measurements, data analysis, theoretical approaches, and fieldwork at various locations around the world. The Department offers undergraduate and graduate programs leading to bachelor's, master's, and doctoral degrees. At the graduate level, we encourage students with undergraduate backgrounds in earth sciences, chemistry, physics, mathematics, and engineering to apply.

Graduate students use a portable system to determine spectral reflectance of "unknown" rock samples as part of a graduate course in remote sensing.

On the cover (from left to right): students on a ship a safe distance away from the erupting Anatahan volcano in the Mariana Island Arc; former graduate student Jenny Lippmann spelunking in an overhang cave in western St. Louis County, Missouri, one of several caves developed near the contact between the Bushberg sandstone and the underlying Kimmswick limestone; graduate student Cynthia Fadem using a blowtorch to seal off a pyrex sample tube containing CO_2 gas (carbon from soil organic matter) for $\delta^{13}C$ analysis.

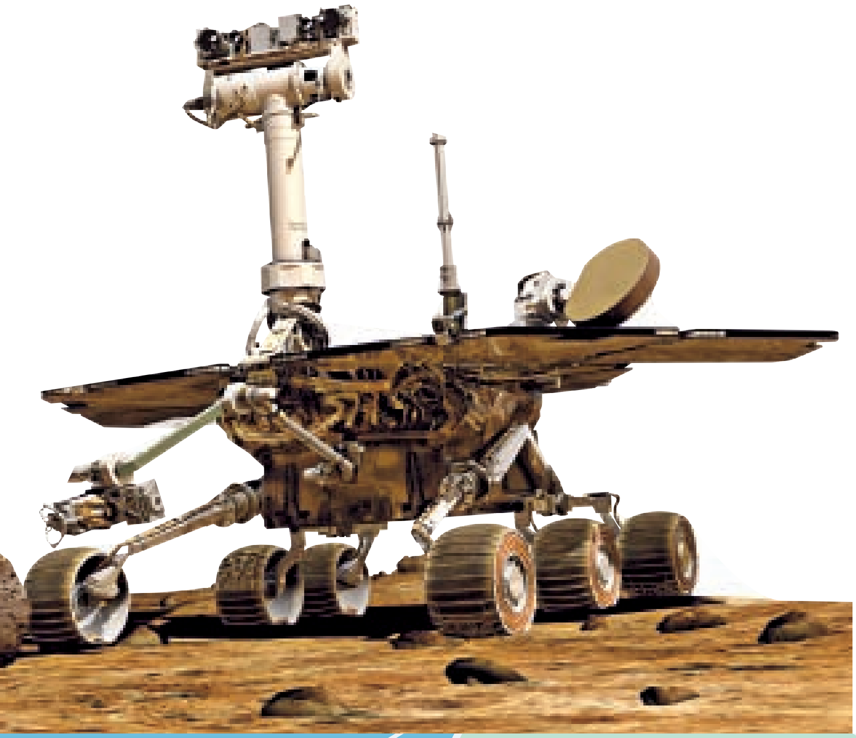
The Graduate Student Experience

Why Earth & Planetary Sciences?

It is an exciting time to do research in earth and planetary sciences. The need for top-notch undergraduates with backgrounds in earth sciences, chemistry, physics, biology, mathematics, and engineering to enter our field has never been greater. Our field is changing rapidly and becoming more interdisciplinary as links emerge among geology, geochemistry, geophysics, and geobiology. New opportunities are developing as research in natural hazards, energy sources, and the environment become more important to the global economy, and new space missions are developed to explore the solar system. Understanding our planet through research and discovery is vital to our survival and the development of sustainable ways of interacting with the Earth.

Why Washington University?

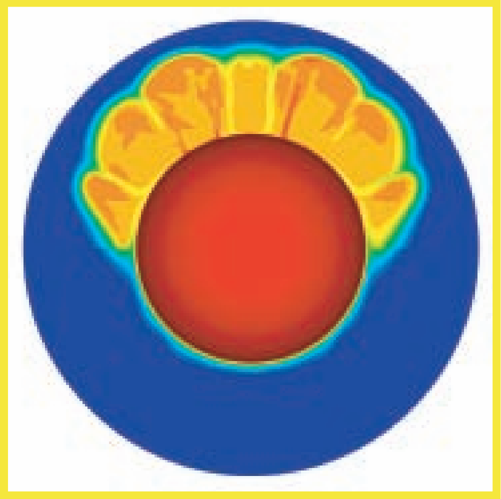
Washington University is a leading medium-sized research university located within the vibrant and historic city of St. Louis. The city has the major cultural attractions of a large metropolitan area, yet still retains the friendliness and low cost of smaller cities. The University is renowned for its excellence in the sciences, both at the undergraduate and graduate levels. Students come here from all around the country and the world to pursue their research and educational aspirations. The peers you will meet here at Washington University will join you in being the scientific leaders of the future.



Artist's conception of NASA's Mars Exploration Rover. The two rovers, *Spirit* and *Opportunity,* have traveled many kilometers across the red planet and found rocks that were produced in or modified in aqueous environments. These discoveries suggest that the planet was once habitable for the development of life.

What does our department have to offer?

The Department of Earth & Planetary Sciences at Washington University is the smallest nationally ranked department in earth sciences, geophysics, and geochemistry *(U.S. News and World Report*, 2006*)*. The relatively small size engenders a friendly and personal place, offering a lot of personal interaction with faculty and researchers. Our graduate students have the opportunity to use cutting-edge laboratory equipment, high-speed parallel computers, and the latest planetary mission data in the course of their research. They travel to field sites around the world and publish research in the leading scientific journals. Our graduates go on to carry out research and teaching at major educational and research institutions and are leaders in earth and planetary sciences.



Numerical simulations of a giant hot upwelling ("superplume") on early Mars. This superplume is believed to be responsible for the formation of the Martian crustal dichotomy. The colors represent the temperature (red is hot, blue is cold).

Geology Program

Geological research within the Department of Earth & Planetary Sciences is broadly based and includes the study of planetary surfaces. Students examine the interactions of humans and their environments using a combination of geological and archaeological approaches, field-based and laboratory analyses of igneous and metamorphic rocks ranging in age from the earliest Precambrian to the Holocene, tectonic reconstructions based on field mapping and precision radiometric dating of key events, and detailed studies of mineralization processes of relevance to biological and environmental systems. This broad-based approach ensures that a range of disciplines is covered within the geological sciences while still providing a focus on field-based and laboratory-based analyses relevant to understanding the geological evolution of Earth and its neighbors, including the interaction of humans and the environment.

A group examines a terrace outcrop and searches for biosignatures during a field trip to the Rio Tinto fluvial system in Spain. The Rio Tinto is an acid-sulfate aqueous system, perhaps analogous to the surface of Mars, that produces evaporative sulfates that are converted to goethite and hematite as the deposits are uplifted to become part of the terrace record.

Geologic Research

Biomineralization and Environmental Mineralogy

Our Raman spectroscopy and applied mineralogy group explores the characteristics that define those minerals that are formed biologically, e.g., how is bone apatite chemically different from geological apatite and what are the biological advantages of those differences? Our collaborative research involves the synthesis and characterization of apatite with chemical and structural properties that mimic those of bone (thereby revealing the conditions necessary to stabilize this biomineral). This knowledge is applied to the use of nanocrystalline apatite for the remediation of heavy metals and to increase our understanding of how biominerals (and their chemical/isotopic signatures) are preserved through fossilization.

Paleoenvironmental Reconstruction

This branch of geology is strongly interdisciplinary and incorporates aspects of petrology, pedology, archaeology, sedimentology, geography, geophysics, and geochemistry. Paleoenvironmental reconstruction informs us of past climates and helps contextualize human occupation. For example, how could climatic processes have impacted human migration out of Africa or the origins of European agriculture? Recent field-based investigations in the United States, Egypt, Ethiopia, and Croatia have included archaeological surveying, geologic and topographic mapping, microstratigraphy, and soil description. Sediment and soil proxy records are examined in the laboratory using stable isotope analysis, bulk chemistry, granulometry, mineralogy, and trace and major elemental analyses.

Left: Fieldwork conducted in the Ka'u Desert, Hawaii, on a pahoehoe lava flow.

Right: A student uses a laser Raman microprobe to analyze a mineral in thin-section. The green laser light is focused by the same microscope objective used to view the sample.

Continental Evolution

The Continental Evolution Research Group focuses on Precambrian geology and crustal evolution to improve our understanding of the processes by which the continental crust has separated from the mantle, the processes that have affected the chemical maturation of the crust, and the processes by which the crust has aggregated to form continents. The current studies range from geological mapping of orogenic belts worldwide, predominantly in Africa, Canada, and the United States, to sophisticated state-of-the-art laboratory studies of minerals and rocks using X-ray diffraction, electron microprobe, and thermal ionization mass spectrometer instrumentation. A crucial part of all these studies is the integration of petrology, geochemistry, geochronology, and structural geology combined with field-based studies to constrain the cause, form, and timing of deformation, magmatism, and metamorphism of the areas of interest.

Geochemistry Program

The cosmos is made of the standard 92 chemical elements (plus a few more that, on Earth, are no longer around) that came to exist with basically no regard for their chemical properties. Yet most of what has happened to them since, in the parts of the universe we inhabit, has been dictated by chemistry. Geochemistry is the study of what natural materials are made of, how they got that way, and where they came from. There are many disciplines you may choose from within geochemistry. Important issues include when and how the solar system and its planets formed; how the Earth has differentiated into distinct reservoirs like its core, mantle, atmosphere, oceans, and the rocks beneath your feet; how the water you drink gets to you; and how vital resources like soils and ores formed. Geochemistry also includes the techniques for figuring out when natural events occurred and is a major aspect of understanding crucial environmental issues such as the effects of civilization on the Earth and global climate change.

Geochemical research involves sophisticated analytical instrumentation. As a graduate student working in geochemistry, you will have access to our extensive instrumental facilities as well as those in other departments and other institutions with which we collaborate. The research also involves studying the right samples, and students can work with materials from our own back yards (literally) as well as from around the world. And from off the world as well: the study of extraterrestrial materials—Apollo lunar samples and meteorites that sample asteroids, comets, the Moon, and Mars—is an important facet of our research.

Geochemistry Research

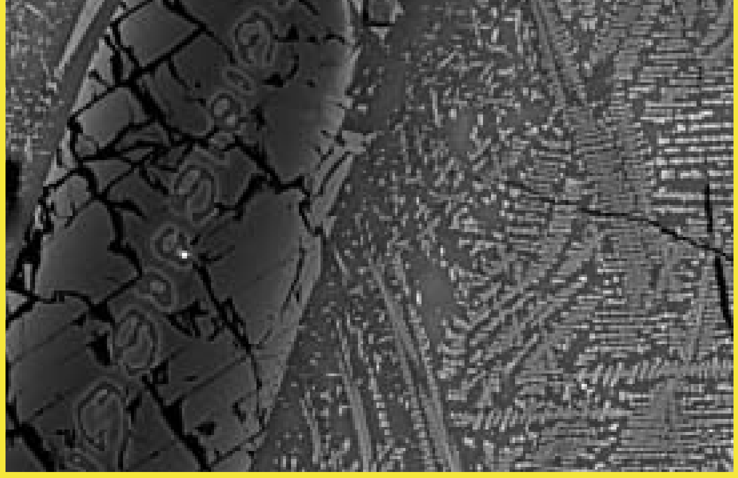
Geochronology

One of the key issues in understanding natural materials and processes is usually asking when something happened. Often the main approach to answering this question is geochemistry, the study of the proportions of different isotopes of elements like Pb, Sr, Nd, and a handful of others, which are affected by the radioactive decay of naturally occurring elements *through time*. This research generally involves careful laboratory processing of the samples and mass spectrometers to make the measurements. Topics pursued in our program prominently include the overall tectonic history of the Earth and the formation of planetary bodies.

The Early Solar System

Conditions in the early solar system were different from what they are now, and there were many one-time events and processes. Much of the study of star and planet formation is geochemistry, and is supported by examination of meteorites and lunar samples, including materials returned to Earth by spacecraft missions. Some of this work involves geochronology; some of it involves characterizing pre-

Aine Steiner extracts carbon dioxide from a cave air sample as Professor Bob Criss looks on.



Two generations of olivine crystals within a glass clast in feldspathic lunar meteorite Pecora Escarpment 02007.

served materials that formed in stellar atmospheres or interstellar space before there even was a solar system. Some of the most sophisticated analytical instrumentation in the world is used to illuminate the processes of star and planet formation.

Stable Isotopes

Variations in the relative proportions of the isotopes of various elements can arise in chemical as well as nuclear processes. Familiar everyday phenomena like rain, or the growth of biological tissue by extraction of carbon from the air, are among the most prominent sources of isotopic variation. In its isotopic proportions water records its history and where it came from, information that is crucial to understanding issues ranging from securing our water supplies to catastrophic floods. Stable isotope research is central in studying crucial issues from environmental pollution to potential climate change.

Planetary Chemistry

In fundamental ways, Earth, Venus, and Mars are very similar to each other. Why did they turn out so differently in ways that are so important to us? What might other planets, in our own solar system or around other stars, be like? Does it rain on Titan? These questions are part of planetary chemistry, which may be thought of as geochemistry with different boundary conditions. Research in planetary chemistry is partly theoretical but also involves a substantial amount of laboratory work to determine how planetary materials will behave under the different environmental conditions of other worlds, or even our own world at different times.

"I was drawn to the Department of Earth & Planetary Sciences at Washington University by the expertise of the faculty, the plentiful avenues for field experience, and the options for working in a variety of geochemistry laboratories.

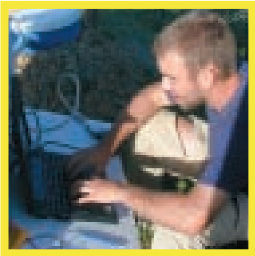
Both field and laboratory work are cornerstones in my career, and these facets of my work were developed via the opportunities I was given at Washington University. In addition to my education through course work and research projects in my first two years in the program, I was trained to develop and coordinate field expeditions to exciting hydrothermal systems, to work closely with undergraduate students in the lab, and to communicate with scientists not familiar with my academic field. These qualities of organization, communication, and mentorship are what have made me competitive in the job market, and have aided me in forging important collaborations with scientists in other disciplines. The E&PS department was a close-knit and supportive group, and interactions with faculty and other students helped to foster a sense of community that I very much appreciated."

D'Arcy Meyer-Dombard, BA 98, MA 00, PhD 04

Assistant Professor, University of Illinois at Chicago (Earth and Environmental Sciences)

Geophysics Program

How do planets work? *How do terrestrial planets form and evolve over time? Why do plate tectonics occur only on the Earth and nowhere else in the Solar System? How do Earth's plates move and interact? What happens to the subducted plates? What causes earthquakes and volcanoes? Are hotspots on earth and other planets caused by thermal plumes rising from the core-mantle boundary?* These are the kinds of questions you will encounter as a student doing research in our geophysics program. Much of the geophysical research we do addresses the structure, composition, and dynamics of the Earth, because this is where most of our data are. Other parts of our geophysics program probe the planetary dynamics of Mars, Venus, and other terrestrial bodies.



As a geophysics student, you will have access to a wide variety of opportunities in both data analysis and modeling. Students in seismology can travel to places such as Africa, Antarctica, South America, and the Pacific Islands to obtain new data for their research. For research in planetary science, you will have complete access to the most recent satellite data sets from all of NASA's space missions. Our geophysics program also has advanced computer software for analyzing geophysical data, as well as excellent computational facilities, including a multiprocessor BEOWULF cluster. Students in mineral physics utilize a state-of-the-art laboratory to probe heat flow in planets and planetary materials.

Geophysics Research

Earth Structure

Our seismology group uses seismic waves to make three-dimensional images of Earth's interior. These 3-D pictures of Earth's crust, mantle, and core provide constraints on the temperature, composition, and flow pattern of regions of the Earth that are too deep for us to examine any other way. One area of focus is the nature of subduction zones and volcanic arcs, where seafloor is consumed back into the mantle. Another area of focus is the unusual boundary between the solid rock of the mantle and the liquid iron of the outer core. We use several aspects of seismic waves, including P and S velocity, attenuation (energy absorption), and anisotropy (directional variation in velocity) to infer the properties of the earth's interior.

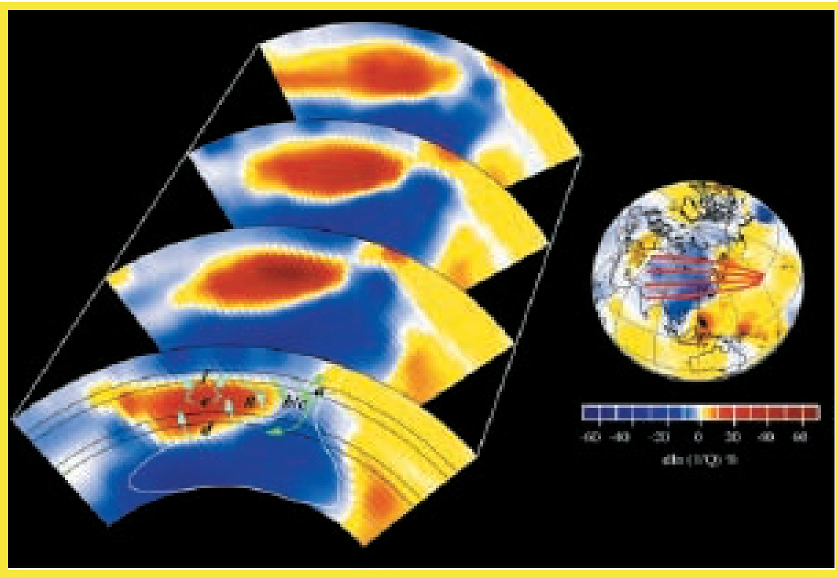
Planetary Dynamics

Our planetary modeling group uses theoretical methods as well as high-performance computing to investigate interior dynamics of the Earth and other planets. Examples include melting and planetary differentiation triggered by early giant impacts, planetary-scale superplumes that may have caused the Martian asymmetry, and global volcanic resurfacing of Venus about one billion years ago.

Planetary Gravity and Magnetism

Recent planetary probes to Mars and Venus provide essential gravity and magnetics data for understanding fundamental aspects of the formation and evolution of these planets. Our planetary geophysics group has been a leader in using potential field data as well as photographs and radar images in order to discover the surface age, resurfacing history, volcanic activity, tectonic evolution, and mass anomaly structure of Mars and Venus.

Four slices through the first whole-mantle 3-D seismic attenuation tomography model, done by former graduate student Jesse Fisher Lawrence. The blue regions correspond to the cold Pacific Ocean seafloor subducting beneath western Asia. The red regions are possibly water-enriched rock, in which the water was pumped into the lower mantle by subduction.



Washington University researcher Rigobert Tibi installs a broadband seismic station in Cameroon, West Africa, to study mantle dynamics associated with volcanism along the Cameroon Volcanic Line.

Mineral Physics

Both laboratory methods and theory are used to constrain the physical properties of earth and planetary materials. The mineral physics facility is unique and centered on measurements of thermal diffusivity. Light is used to probe microscopic behavior of solids held within diamond anvil cells at extreme pressures and temperatures, and to provide information on phenomena such as mantle phase transformations.

Seismic Sources—Earthquakes, Volcanoes, and Glaciers

Many different earth processes can be monitored and studied by sensing radiated seismic waves. The brittle behavior of rocks within Earth is examined through the detection and analysis of earthquakes, including the enigma of earthquakes that occur at great depth where pressure should prevent frictional sliding. Seismic events associated with volcanoes, glacier movement, and hydrothermal circulation provide important new insights into these processes.

"I was fortunate to have entered the Washington University Earth & Planetary Sciences department near the beginning of an exciting project, the Seismic Experiment in Patagonia and Antarctica. Not only did I have the opportunity to participate in three fascinating field seasons down south, but I was able to work with an entirely new data set that was full of new information. I used this data set for several very different projects, including waveform inversion, subduction zone seismicity, and a study of phase velocities. I really appreciated the breadth and variety of the research to which I was exposed, and I had many opportunities to collaborate with other scientists. After graduation I chose a career very different from earthquake seismology, but the regional geology experience and the skills I acquired in graduate school have played an important role in my current position; I have a unique perspective that has proven effective for addressing the scientific questions of the petroleum industry."

Stacey Robertson Maurice,
MA 99, PhD 03
Senior Petroleum Geologist
ExxonMobil Exploration Company

Planetary Studies

Exploration of the solar system is among the most exciting scientific enterprises of the past several decades. Earth's moon is now thought to have been formed by the reassembly of debris created during a massive impact event associated with accretion of the Earth. Mars is known to have had a complicated climatic history that involved both surface and subsurface water. Venus may preserve its surface for hundreds of millions of years before catastrophically turning over the lithosphere as interior heat builds up to the point of massive internal convection within the mantle. The icy moons in the outer solar system exhibit a fascinating array of processes, including active volcanism (Io), subsurface oceans (Europa), and surfaces with an abundance of organic compounds (Titan). Our faculty, staff, and students have been deeply involved in many of the key NASA missions and spacecraft that have explored our solar system, together with in-depth analyses of the data from these missions. We seek to understand the origin and evolution of the solar system and bodies within it from a systems perspective, using fundamental measurements of extraterrestrial materials, laboratory-based work, and theoretical calculations.

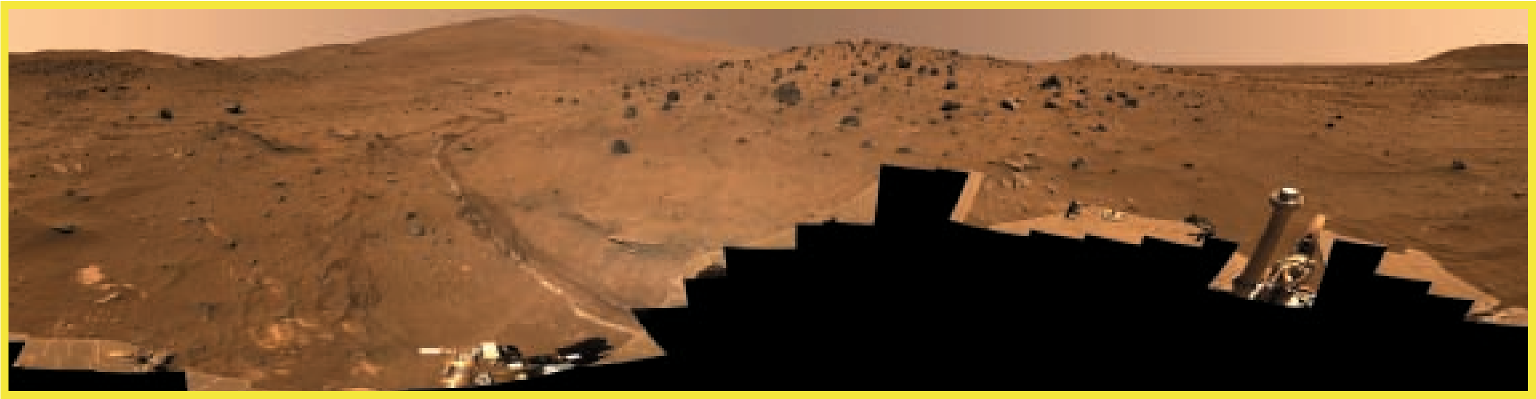
Understanding the internal structure and evolution of the solid planets and satellites is approached through analyses of gravity and magnetic fields, topographic measurements, and radar sounding in conjunction with powerful numerical techniques. Planetary surface studies integrate remote sensing from orbital and landed platforms with other data to understand the geological evolution of moons and planets and implications for habitability (e.g., Mars).

NASA/JPL

Moons of Jupiter: This montage shows, left to right, Io, Europa, Ganymede, and Callisto, as imaged by the New Horizons spacecraft in February 2007, during its flyby of Jupiter.

Cosmochemistry research focuses in part on lunar samples collected during the Apollo Missions, lunar meteorites, martian meteorites, meteorites with asteroidal sources, and stardust. These data, laboratory-based experiments, and theoretical calculations provide insight into earliest solar system history and dynamics, including the precursor materials (i.e., stardust) preserved during these events.

The Department is also home to the Geosciences Node of the Planetary Data System, an archive of data from planetary NASA and international missions (http://pds-geosciences.wustl.edu). Further, the international work with space partners from Europe, Japan, India, and China allows students a unique opportunity to collaborate with researchers from other countries.



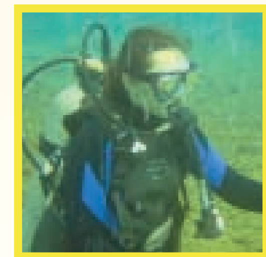
NASA/JPL/Cornell

The *Spirit* Mars Rover acquired this color panorama, called the McMurdo Pan, from its winter haven location.

Geobiology Studies

The vast diversity of life on Earth is the result of several billion years of co-evolution with geologic processes. For most of Earth history, the geochemical cycles that operate within the crust have been driven, in one way or another, by microorganisms. Changes in atmospheric composition, ocean chemistry, and continental weathering rates are only some of the most obvious signs of ubiquitous microbial activity. More recently, plants and animals, including humans, have also dramatically affected nearly every terrestrial environment. Geobiology at Washington University is a broadly crosscutting research program that includes investigations of hydrothermal ecosystems, the origin and early evolution of life, the subsurface biosphere, paleoenvironmental reconstruction, geoarchaeology, biomineralization, and astrobiology.

Associate Professor Jan Amend (right) with a student working on the arsenic-rich shallow-sea hydrothermal vents off Ambitle Island, Papua New Guinea



Much of our work relates to bacteria and archaea, which are geochemical agents of the first magnitude—they thrive in ice and thermal springs, in acid and base, in desert sands, in the deepest oceans, and several kilometers down in the subsurface; they harness sunlight or chemical energy to synthesize biomass or convert it to CO_2 and methane; they 'eat' rocks and metals; and they precipitate minerals. Students can study the relationship of bacteria and archaea to geological processes by combining organic and inorganic chemical analyses of waters and gases, thermodynamic modeling of reaction energetics, microbial culturing experiments, molecular probing for metabolic activity, and surveys of gene sequences.

Graduate students have the opportunity to work in one or more research groups, combining fieldwork (for example in the Aeolian Islands of Sicily, Egypt's Western Desert, Dalmatia in Croatia, or Yellowstone National Park), laboratory experiments, state-of-the-art analyses, geographic information systems, and computer modeling. Collaborations across departments and other institutions are commonplace and highly encouraged. Our geobiology faculty and students currently have joint projects with colleagues in Biology, Environmental Engineering, Anthropology, and the School of Medicine here at Washington University, as well as with leading labs at other institutions (e.g., MIT, Arizona State, Illinois, South Florida, Monterey Bay Aquarium, Woods Hole Oceanographic Institution, University of Bremen, INGV in Palermo).

Graduate student Johanna Kieniewicz measures a stratigraphic section through Pleistocene iron-rich spring sediments, Dakhleh Oasis, Western Desert, Egypt.

Research Opportunities

Graduate school is the entry point into the challenging and exciting world of scientific research. At Washington University, you will learn to carry out research under the mentorship of one or more top-notch scientists. Graduate students in our program initiate research projects during their first year and are heavily involved in research by their second year. The work typically results in peer-reviewed publications and ultimately leads to the PhD thesis.

Research topics are selected in consultation with a faculty advisor who will provide guidance, although the work you pursue will be done by you and will constitute new and independent research. Research opportunities in the past have included participation in planetary missions and data analysis; fieldwork in North America, Antarctica, Africa, Europe, and the Western Pacific; computations focused on the structure and dynamics of planetary interiors; and extensive use of our analytical instrumentation to explore the formation of the early solar system, the evolution of the Precambrian crust, paleoenvironmental reconstruction, and the thermodynamics of microbial communities.

An ocean bottom seismograph awaits deployment on the ship deck as the sun sets over the Mariana Islands in the Western Pacific. The instruments were recovered 11 months later and the resulting seismic data formed the basis for several PhD theses written by Washington University graduate students.

Graduate student Cynthia Fadem uses the mass spectrometer.

Propagation of seismic shear waves in Earth's mantle from a deep earthquake (red star at lower left). This image is part of a computer animation done with the summation of Earth's normal modes of oscillation.

Recent research sites around the globe...

Fiji

Antarctica

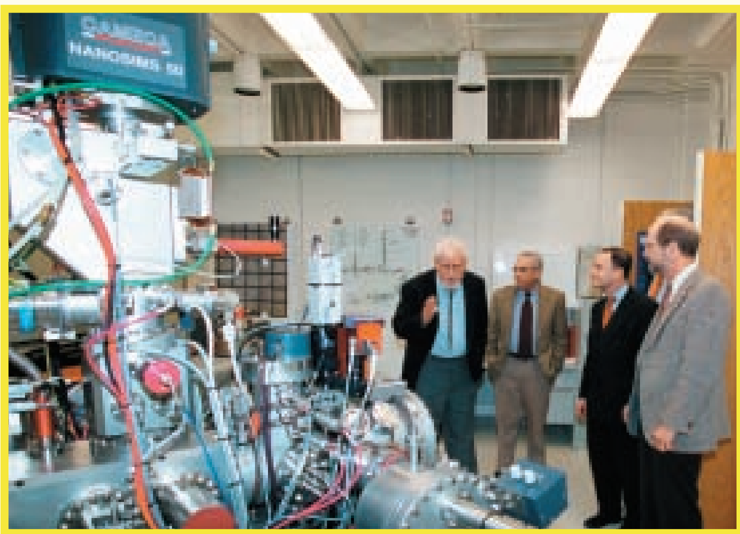
Mariana Islands

...and the Solar System

NASA/JPL

Related Departments and Programs

The Department's multidisciplinary approach includes strong connections to other departments in Arts & Sciences including: Anthropology (geoarchaeology); Biology (extremophiles); and Physics (extraterrestrial materials). We also have close ties with the Washington University School of Medicine (biomineralization and biomaterials), and the School of Engineering, in Electrical Engineering (signal processing and retrieval) and Energy, Environmental, and Chemical Engineering.



The NanoSIMS is an ion microprobe in the Laboratory for Space Sciences. The instrument is the first in the world built to analyze the isotopic and elemental composition of extremely small samples at a sub-micrometer scale. From left: the late Robert Walker, former director of the McDonnell Center for the Space Sciences, explains how the NanoSIMS operates to Edward Macias, dean of Arts & Sciences, Chancellor Mark Wrighton, and John F. McDonnell, former chair of the University's Board of Trustees.

The Department benefits greatly from the presence of the McDonnell Center for the Space Sciences (http://mcss.wustl.edu), an interdisciplinary center that facilitates collaborative research in the space sciences and ties together researchers in our department and the Department of Physics. The Center also facilitates short- and long-term visits from space scientists, provides funds for graduate fellowships, and awards seed funding for space science projects that need development before proposals for funding from outside agencies.

The Department is also involved in a University-wide environmental initiative to develop research and teaching programs at both the undergraduate and graduate levels. The undergraduate program is already well developed and run as the Environmental Studies Program with participating faculty from our department along with Biology, Anthropology, Political Science, and Economics (http://epsc.wustl.edu/enst). We expect to develop a similar program at the graduate level.

The Earth & Planetary Sciences Building

Equipment and Facilities

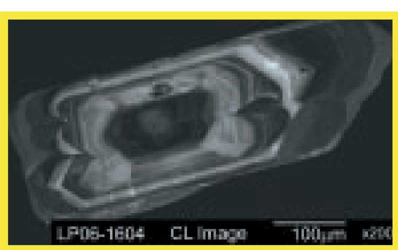
The Department of Earth & Planetary Sciences is housed in a new building containing excellent network and computing facilities. The building is LEED (Leadership in Energy and Environmental Design) certified by the U.S. Green Building Council. It contains the 3,200-square-foot Ronald Rettner Earth & Planetary Sciences Library with resources including 40,000 volumes, 175 print and electronic journals, a computer lab, and a map room, providing convenient access for all researchers and students.

The Department is equipped with a variety of the latest analytical and computational instrumentation. A list of the major equipment includes:

Graduate student Brian Dreyer loads a sample into the ICP-mass spectrometer for analysis.

Analytical Instrumentation

- Fully automated JEOL-8200 electron microprobe with five wavelength-dispersive spectrometers, an energy-dispersive spectrometer, and a cathodoluminescence detector
- Cameca IMS3f ion microprobe
- Cameca NanoSIMS 50 ion microprobe
- Two VG Sector 54 thermal ionization mass spectrometers
- Finnegan MAT "Element" high-resolution ICP-mass spectrometer
- MAT 252 stable isotope spectrometer
- Siemens SRS-200 and SRS-300 sequential X-ray fluorescence spectrometers for XRF analyses
- Rigaku vertical X-ray diffractometer
- SpectruMedix Aurora capillary electrophoresis DNA sequencer
- Two HoloLab 5000-532 Raman microprobes (Kaiser Optical System, Inc.)
- HoloLab 5000-633 Raman microprobe (Kaiser Optical System, Inc.)
- Bomem far-IR to visible Fourier transform spectrometer
- Nexus 670 FTIR spectrometer with attenuated total reflectance capability (Thermo Nicolet)
- Thirty microprocessor-controlled gas-mixing furnaces with electronic mass flow controllers and zirconia oxygen sensors
- Gas-source mass spectrometers for noble-gas isotopic analyses
- Diamond anvil cell laboratory
- Netszch laser-flash apparatus for thermal diffusivity



Cathodoluminescence (CL) image of the mineral zircon ($ZrSiO_4$) showing internal concentric growth zonation and a complex crystallization history.

- Canberra Genie-ESP gamma-ray spectrometry system with four detectors for neutron activation analysis

Geophysical and Remote Sensing Equipment

- Four Streckheisen broadband seismographs with Reftek dataloggers for seismic field deployments
- Two portable digital magnetometers
- Worden gravimeter
- 24-channel modular seismic exploration system
- Remote-sensing, mapping/imaging spectrometers for mineralogical and biogeochemical studies
- ASD portable field reflectance spectrometer (0.4 to 2.5 micrometers)
- Designs and Prototypes emission spectrometer (2 to 20 micrometers)

Computational Systems

- 90-node Beowulf parallel computer for geodynamical calculations
- Department computer laboratory (16 workstations used by classes and labs, graduate and undergraduate students, and library patrons)
- Planetary Data System (PDS) 16-processer data server
- Planetary Data System (PDS) 30 TB RAID data storage
- Steve Fossett Virtual Laboratory for Planetary Exploration, a CAVE-based simulation facility for stereo visualization of data sets
- Seismology 8-processor server with 6 TB RAID disk system
- Gigabit network connection into Department, and campus wireless throughout the building

Graduate Programs

The graduate program at Washington University is designed to give you the knowledge and experience needed to succeed in whatever future path you choose. Combining strong foundations with flexibility, the program prepares students for futures in academia, research, and industry.

Both the Master's and PhD programs emphasize course work during the first two years, combining breadth and depth requirements, both within and outside of the Department. The graduate programs also emphasize research and all students begin research during their first year, with an oral defense of their research work coming at the end of their second year. A successful research defense provides entry into the PhD program.

Tuition is typically waived for students accepted into the graduate programs, and monthly salaries are provided through a combination of research and teaching assistantships as well as fellowships. Teaching assistantships (TAs) are paid by the University for support in teaching courses. Research assistantships (RAs) are paid through the research grants of individual faculty members, and support research connected with funded projects. Salary support for several competitive fellowships is also available. Students are supported during summers through research grants and department funds.

The PhD is awarded upon completion of a thesis that is approved by a faculty committee after a formal presentation. The Department curriculum and research programs are designed to allow students to complete their PhD (including Master's degree work) within five years.

"Washington University was the right place and the right fit for me for graduate school. My nontraditional undergraduate major in aerospace engineering was treated as a strength when I came to the University's Department of Earth & Planetary Sciences, and my advisor and professors worked with me to build on that background for the future. Some of the most valuable aspects of my time in St. Louis were the pure strength of the training I received as well as the opportunities to explore the Earth and other planets in new ways and experience the excitement of planetary missions. Clearly, the camaraderie and common sense-of-place among the graduate students and the collegial relationships built with the faculty were important parts of making the process of achieving my academic goals and the graduate experience memorable. I can honestly say that the influences I had as well as the strength and breadth of experiences during my education at Washington University continue to open doors to new areas of research and make the process of doing science satisfying and enjoyable."

Steven A. Hauck, II, PhD 01
Assistant Professor, Case Western Reserve University

Left: A mural in the Earth & Planetary Sciences Building depicts the Moon, Mercury, and Venus over Antarctica.

For more information, or to schedule a visit, please contact us at:

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