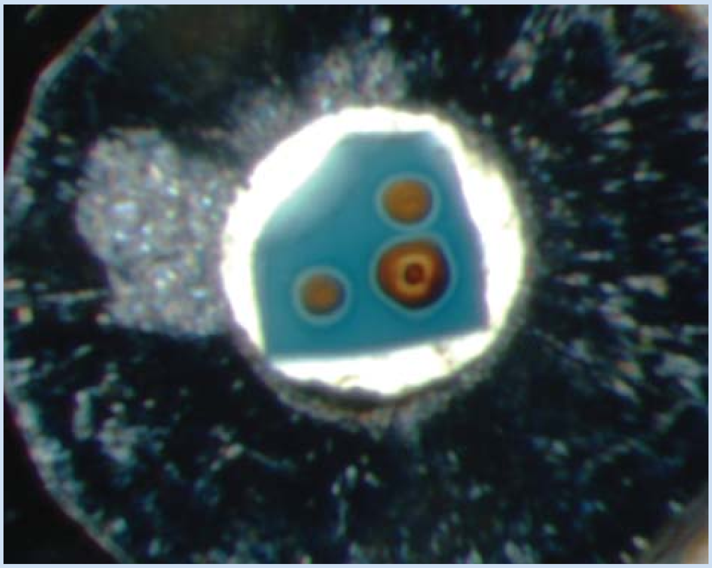
epicenters

News from the Department of Earth & Planetary Sciences at Northwestern University | Autumn 2008

Unraveling the Mystery of Plate Tectonics



Mineral physicist Steven Jacobsen uses high pressure-temperature experimental techniques to investigate the properties of mantle mineral phases such as ringwoodite, the blue crystal (left) pictured through the top of a diamond-anvil cell. Jacobsen's studies will help EPS seismologist Suzan van der Lee map the Earth's interior as they attempt to identify the driving forces behind plate tectonics. Read about their work beginning on page three.

Message from the Chair

Amidst the busy daily routine of a university department, it is sometimes difficult for faculty members to see "the long view" of their intellectual communities. As teachers and scholars, we live within the academic "trenches" from day to day, maintaining the focus necessary to guide our doctoral students, lead our classes, conceive and write grant proposals, and most of all, find the sacred moment of inspiration that drives our research. But every year, when the time arrives for my message to you, I have occasion to reflect on recent events within the Department of Earth and Planetary Sciences, assessing how those developments have shaped the current departmental mood and what they may mean for our future. Recognizing that the momentum we have established over the past few years continues to build, I am pleased to report that EPS is doing extremely well.

In this year's letter, I will refer to a few departmental highlights developed further herein, discuss some issues concerning our evolving position within the Northwestern community, and then offer a few personal notes. You will have noticed that our newsletter has assumed a new format. We sincerely hope that you enjoy it.

As detailed in the articles following my message, this year has been very exciting and successful for the department. Especially in regards to our junior faculty, we have enjoyed many occasions for celebration, including Suzan van der Lee's early promotion to associate professor, Steve Jacobsen's NSF CAREER grant and recently announced Packard Fellowship, and Andy Jacobsen's Clarke Medal from the Geochemical Society. The achievements of 2008 thus match the extraordinary accomplishments of the preceding year, during which, as you may recall, Suzan won an NSF CAREER grant, Andy received both an NSF-MRI grant and a Packard Fellowship, and Steve was named a distinguished lecturer by the Mineralogical Society of America. While trying to avoid seeming boastful, I am nevertheless extremely proud to say that this level of achievement would be astounding for many larger departments, let alone a small one such as ours, a fact that has been widely recognized across campus. To top off this good news, we recently had our best graduate student recruiting season

Inside

Business Administrator Hayes to Retire

Charlotte Hayes, the department's long-time business administrator, recently announced that she will retire in January of 2009. A fixture in the department for the past twelve years, Hayes has "guided the department's daily operations and financial affairs with unparalleled competence and professionalism", said EPS department chair Brad Sageman upon hearing the news of her impending departure. "She is equally cherished by students and faculty, and all of us are having a very difficult time imagining how we'll survive without her. She is the glue that has held the department together with a cheerful can-do attitude and an astounding level of wisdom and institutional knowledge."

For Hayes, the decision to retire was not an easy one because "the department is filled with such friendly and supportive people. The spirit of cooperation and common purpose shared by faculty and students has made my job a pleasure." While Hayes says she "will miss hearing about the diverse interests of the EPS community", she looks forward to having more time for "simple pleasures like visiting with friends and reading." An avid traveler whose exploits are legendary within the department, Hayes also plans "to take some very leisurely road trips to the Canadian Rockies and California."

While the EPS community will, as Sageman said, "miss Charlotte terribly…we also look forward to receiving her postcards from every corner of the planet following her extremely well-earned retirement." "Even though we are sad to see her go", Sageman added, "the depth of our appreciation for her service to the department cannot be adequately expressed. We owe her unbounded thanks for her warmth, her dedication and the incredible concern she has shown for everyone in EPS during her tenure. For all that and more, we wish Charlotte a very happy, healthy, and lengthy retirement."

in about a decade, successfully competing for the most promising applicants against many other respected graduate programs. If it is true that, as is often said, the most important decisions academic departments can make are those related to faculty hires and graduate student recruiting, then the future of EPS remains very bright indeed.

With the excitement of our recent successes—which have been accompanied by renovations of graduate student offices and the Sloss Room--the halls of Locy have been overtaken by an intangible but important sense of shared pride, camaraderie, and enthusiasm. It is this feeling that best captures the cumulative effect of the past year's many positive developments.

Following the lead of our young stars, the rest of the faculty has also been quite busy with a number of new projects. Although the newsletter's "faculty highlights" section briefly summarizes some activities of each faculty member not featured in a longer article, I want to mention a substantial undertaking spearheaded by our new colleague, Professor Neal Blair, who last year moved to Northwestern from North Carolina State University. Under Neal's guidance, EPS researchers partnered with faculty from Physics & Astronomy, Chemistry, Biology, and Engineering to draft a major proposal for a NASA-funded astrobiology center. Although our proposal was not ultimately chosen from an extremely competitive applicant pool, the process of assembling this plan succeeded in uniting scholars from many disparate fields. Because participating faculty members are strongly committed to the astrobiology project, this multidisciplinary collaboration will continue and may have a transformative effect on our department. After only a year at Northwestern, then, Neal has emerged as a significant force on our campus, and his efforts to forge new connections between EPS faculty and our colleagues in the physical sciences have been impressive.

> "With the excitement of our recent successes...the halls of Locy have been overtaken by an intangible but important sense of shared pride, camaraderie, and enthusiasm. It is this feeling that best captures the cumulative effect of the past year's many positive developments." --Brad Sageman, EPS Department Chair

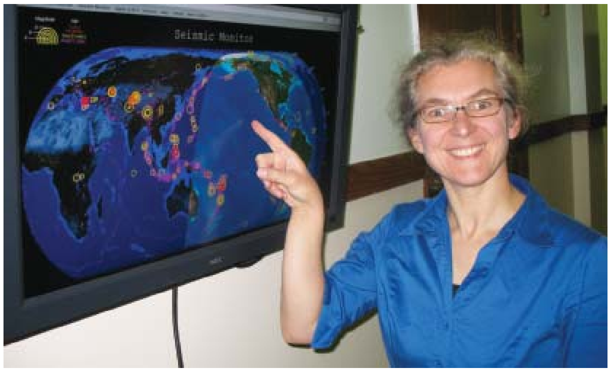
Another collaborative effort includes departmental participation in the NSF-funded Spatial Intelligence Learning Center, a multi-institutional project conducted by cognitive psychologists and faculty in the learning sciences. Probing the processes used to develop spatial thinking skills, these researchers have found that geology students constitute a perfect subject group. Because random studies of the college population have shown that students completing geology courses demonstrate greater aptitude for spatial reasoning than do non-geology students, the EPS population has been targeted for a battery of tests designed to help reveal when key spatial skills are acquired and what teaching methods most effectively develop them.

Graduate student Rich Barclay shows a Project EXCITE class how plant fossils can be used to determine the mean temperatures of past eras.

For the past two years, EPS has also played an active role in Project EXCITE, an elementary school enrichment program seeking to bridge the minority achievement gap in math and science. To date,

continued on back page

CAREER Recipient Van der Lee Promoted



Suzan van der Lee points to the web-based IRIS Seismic Monitor, which registers earthquakes in near real-time.

Since completing her doctoral degree at Princeton in 1996, EPS faculty member Suzan van der Lee has amassed a distinguished record of academic achievement. Widely recognized as one of the world's leading mid-career seismologists, Van der Lee has authored or co-authored forty-eight publications that have been cited more than 750 times, received a prestigious five-year CAREER award from the National Science Foundation, and ascended to the board of directors for the Incorporated Research Institutions for Seismology (IRIS). Given Van der Lee's admirable scholarly credentials and growing reputation in her field, her spring promotion to associate professor was enthusiastically welcomed by EPS. "We're thrilled that Professor van der Lee has joined the tenured faculty", said department chair Brad Sageman after the promotion was announced. "Ranking in the vanguard of mid-career seismologists today, Professor van der Lee has developed a research program that powerfully complements the work of our other geophysicists. Suzan also recently played a leading role in submitting an NSF-IF proposal for the department's acquisition of a powerful new computing cluster. She is a first-rate scholar and a major asset to the department".

Standing at the forefront of investigations into the Earth's structure, Van der Lee's research maps our planet's interior by employing many techniques, the most notable of which is an imaging procedure known as seismic tomography. Frequently compared to the process for generating CAT scans, which rely on multiple two-dimensional X-ray paths to compute three-dimensional images of the human body, seismic tomography uses seismic waves to remotely sense the Earth's interior. For Van der Lee, the seismic waves that spread from an earthquake beneath the Earth's surface are "rich messengers of its inner structure, relaying more information about it than any other type of physical data". These messengers do not, however, speak clearly and unequivocally, but communicate in "an intricate and multifaceted language" that requires the application of sophisticated analytical techniques for their messages to be understood. Because many properties of seismic waves—including their size, shape and velocity—are determined by the type of materials through which they pass, individual seismic waves provide clues about the thermal, physical and compositional state of the Earth's interior. By applying mathematical and computational inverse problem-solving techniques to vast quantities of seismograms, Van der Lee maps the distribution of seismic velocities--and thus material properties--within the Earth. In effect, she *translates* information supplied by seismograms into three-dimensional images of the mantle called tomograms.

By interpreting her tomograms in light of insights gleaned from the disciplines of tectonophysics and mineral physics, Van

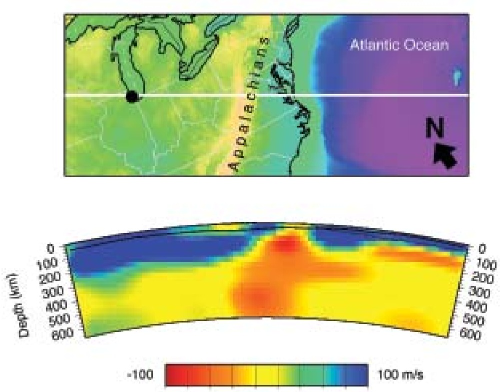
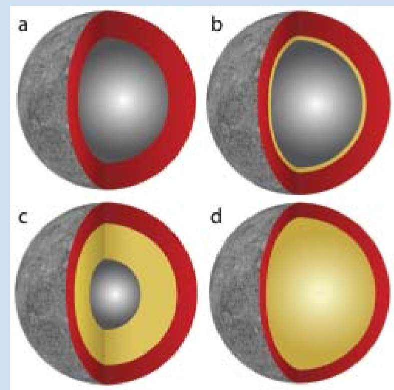


Figure: Part of a tomographic model for North America corresponding to the white horizontal line on the map above.The model shows deviations from a reference standard of seismic wave propagation velocities, a proxy for rigidity. The outer ~250 km are very rigid (blue shades) below Northern Illinois, but the area below the eastern continental margin appears weak (red shades) at all depths.

Faculty Research Highlights

Craig Bina and collaborators recently published a *Journal of Geophysical Research* article detailing results of their multi-year effort to model Mercury's interior. Their project, preliminary results for which were earlier presented in Switzerland, Japan, and France, has proceeded with the goal of constraining that planet's composition and structure while demonstrating the importance of molten core materials. A figure (shown below) taken from this article

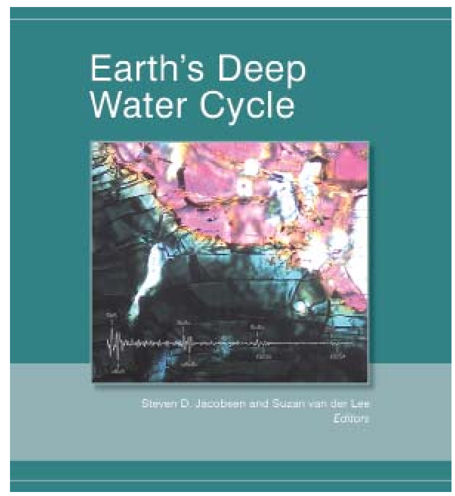


recently appeared as "image of the week" on the AGU website. It outlines four possibilities for Mercury's internal structure ranging from a solid iron inner core to an entirely molten core...**Neal Blair** has developed a new Carbon Biogeochemistry lab dedicated to analyzing the poorly understood behavior of nonextractable organic matter in surficial environments. The lab will allow Blair to track this material, which represents 90% of the Earth's organic carbon, as it moves across landscapes and the seafloor from upland sources to deepwater sinks. Active margin small river catchments and their associated marine dispersal systems have been targeted in general. Work is ongoing in the Waipaoa and Waiapu sedimentary systems on the North Island of New Zealand…**Matthew Hurtgen** and collaborators have conducted a geochemical study of Cambrian strata to identify the relationship between Earth-surface oxygen levels and life in the aftermath of Early Cambrian mass extinction. The emerging environmental picture of the Cambrian Earth system suggests that the delayed recovery of organisms with carbonate skeletons and animal reefs following late Early Cambrian extinction may have been due in part to fluctuating marine oxygen levels in the coupled ocean-atmosphere system…

Van der Lee--continued

der Lee explores one of the fundamental mysteries of plate tectonics, the question of the driving forces behind plate motion. As she explains, geoscientists "have long known *that* plate tectonics occurs--that mountains, volcanoes, and earthquakes are concentrated at the edges of about a dozen rigid plates that make up the Earth's outer shell. And we know that plates either move past each other, away from each other, or subduct beneath one another." But what remains unknown, she adds, "is *why* and *how* plate tectonics occurs, or what sustains this process over billions of years."

While Van der Lee's earlier research has already done much to advance knowledge about Earth structure and processes in an array of locations across the globe, her current work on estimating the amount, whereabouts and role of water in the upper mantle has recently attracted a great deal of attention. According to Van der Lee, water may be important to the dynamics of the Earth's interior because plate tectonics requires large spatial and temporal variations in the mantle's viscosity to operate. "By cycling between the deep upper mantle and the surface", she says, "water may help establish the necessary viscosity contrasts to initiate and sustain plate motion." Could the upwelling of water in the mantle, then, be one of the motors driving plate tectonics? Is water the agent that ultimately weakens plates to the point of rupture? And was this water first brought down to depth in the mantle by plate tectonics itself? These questions remain open partially because the subject of water within the Earth's interior is itself somewhat of a mystery.

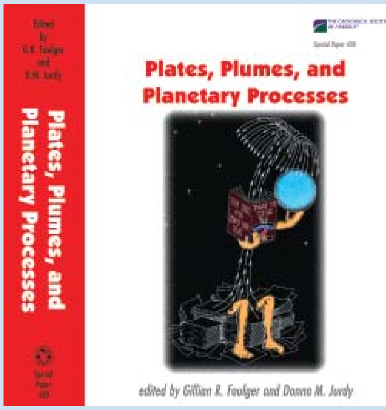


The attempt to seismically detect water hundreds of kilometers beneath Earth's surface--along with other compositional variations and thermal heterogeneity--thus constitutes much of Van der Lee's current research. Probing an area completely inaccessible to direct observation, Van der Lee faces special challenges due to the equivocal nature of the available data. For example, because mantle "hot" zones and "wet" zones share similar seismic properties, established analytical methods cannot distinguish between the effects of heat and water on the mantle and are thus of little use in the search for hydrated areas of the Earth's interior. Here Van der Lee confronts what scientists call a problem of "non-uniqueness", a situation in which available data can lead to multiple, contradictory interpretations that are nevertheless equally valid. To combat the uncertainty created by enigmatic data, Van der Lee has been developing new analytical methods to generate more accurate images of the North American mantle. Specifically, she is creating novel ways of combining many different kinds of data— teleseismic and regional body waves, surface waves, receiver functions, and gravity—to help differentiate between heat and water anomalies.

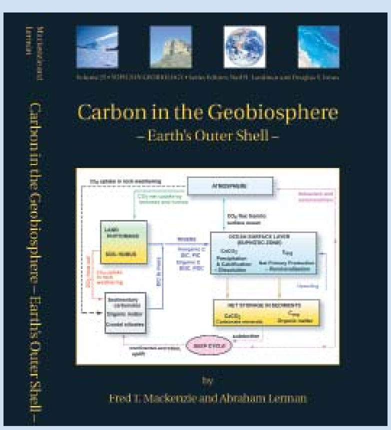
Describing her analytical perspective, Van der Lee likens herself to someone "putting together a jigsaw puzzle without knowing if you've got the right pieces—or the right puzzle". Because many tomographic problems have non-unique solutions, she says, "the uncertainties behind them are extremely large." But if the difficulty presented by complex and ambiguous data poses daunting challenges, it also presents enormous opportunities for discovery. "One of the reasons I find my work so exciting is its potential to help explain major phenomena, massive geological upheavals spread across vast gulfs of time and space", she says. Of course, sometimes the largest revelations, such as the identification of the sustaining forces behind plate motion, can be inextricably linked to seemingly insignificant details, like tiny amounts of water incorporated into minerals deep beneath the Earth's surface. If so, then Van der Lee may be helping to put the pieces of a very large jigsaw puzzle into place.

Faculty Research, continued

Donna Jurdy co-edited with Gillian Foulger *GSA Special Paper 430*: *Plates, Plumes, and Planetary Processes*, a compendium



of 45 chapters encompassing diverse aspects of the debate regarding the existence of mantle plumes. The book sprang from a 2005 Chapman conference in Scotland and revives the Royal Society Special Meetings monograph tradition of publishing discussions after the papers. Internet technology enabled the editors to widen the debate beyond conference participants to the worldwide scientific community... **Abraham Lerman**, co-editor of the recently published *Carbon in the Geobiosphere*, is part of a collaborative project studying the shallow coastal ocean, a regulating junction between the land, atmosphere, and open ocean. Using a model analysis of the coupled carbon-nitrogen-phosphorus biogeochemical cycles, Lerman's team identified the times of reversal in the air-sea CO_2 exchange of the shallow coastal and open



ocean, the limiting role of phosphorus in biological production on land, and the expected future hardships of the calcifying organisms in the coastal ocean due to atmospheric CO_2 increases.....

Jacobsen Wins NSF CAREER Award

Steven Jacobsen at work in his mineral physics laboratory.

When asked what excites him most about his work, mineralogist and EPS assistant professor Steven Jacobsen barely pauses before answering, "I am a tinkerer, an experimentalist. I have always loved getting into the lab so I can design and build things to measure the unknown." Though he is in the early stages of his scholarly career, Jacobsen's passion and talent for invention have already carried him to significant heights in the field of mineral physics. In the past year, he was selected as a distinguished lecturer by the Mineralogical Society of America and named one of the most frequently cited authors published in the journal *Physics of the Earth and Planetary Interiors* from 2004-2007. Last winter, his ability as an experimentalist was again recognized when he won a five-year, $500,000 NSF CAREER award, the agency's most prestigious grant for early-career scientists. Jacobsen will use this funding to investigate the effects of hydration on the physical properties of mantle minerals from atomic to geophysical scales.

By simulating the extreme conditions of Earth's interior, Jacobsen's experiments seek to illuminate the origin and properties of the materials found within it. To reproduce the ultra-high pressure-temperature combinations under which distinct mineral phases develop, Jacobsen synthesizes samples inside large-volume multi-anvil presses, places them within a diamond-anvil cell, and then heats them with lasers. These techniques have allowed him to probe samples at temperatures as high as 5000 degrees Fahrenheit and pressures greater than 100 gigapascals (the equivalent of 1,000,000 atmospheres) so he can examine mineral properties such as density, compressibility, and electronic structure. Exploring entirely new pressure-temperature regimes, Jacobsen's investigations reveal many surprising aspects of what he calls "a physically and chemically unfamiliar world". In one of his most important experiments to date, Jacobsen and his collaborators cast light on this previously uncharted territory by providing evidence for the existence of the "spin transition zone" (STZ), a region in the lower mantle where the valence electrons of iron may change from an unpaired state of "high-spin" to a paired state of "low-spin, causing iron atoms to become smaller and denser. Announced in the journal *Science*, the identification of the STZ has important implications for understanding both how seismic waves travel through the Earth and how heat from the core is transferred through the mantle.

For his CAREER award, Jacobsen will conduct high pressure-temperature experiments to help resolve a significant impasse in the attempt to map the composition and mineralogy of Earth's interior. Investigating the possibility that several oceans worth of water may be stored in a deep, rocky layer of the mantle called the transition zone (250-400 miles beneath the surface), he poses the following question: "If the transition zone were full of water, what would it look like seismologically?" Jacobsen frames his inquiry in speculative terms because existing seismological tools have thus far been unable to identify the seismic fingerprint for "wet" mantle zones, unique characteristics that distinguish these areas from seismically similar mantle temperature anomalies. To address this problem, he will conduct experiments measuring the speed of elastic waves as they pass through hydrated samples of olivine, the mantle's most commonly occurring mineral, and its higher pressure phases, ringwoodite and

Faculty Research, continued

Emile Okal (at right, below) continues to study tsunami hazard from potential sources in the Indian Ocean and other basins. This work involves detailed studies of historical earthquakes, numerical simulation of tsunami propagation using hydrodynamic

codes, and field work (recently in Oman and Tanzania), to reconstruct quantitatively the field of inundation during ancient tsunamis. His most recent result is the reassessment of a large earthquake in 1929, which casts the poorly studied South Sandwich Islands region of the South Atlantic as a potential source of tsunami hazard for Brazil and South Africa...**Brad Sageman** (below) is pursuing four research projects. Collaborating with NU professors Hurtgen and Lerman, as well as former postdoctoral advisor Mike Arthur, he is exploring the role of Fe and P in the initiation and termination of exceptional episodes of organic carbon burial, such as Cretaceous and Devonian ocean anoxic events. Another project, led by graduate student Rich Barclay, involves the development of a paleobotanical record

of changes in pCO_2 before and during the Late Cenomanian OAE II. A third effort investigates the tectonic origins of the Western Interior basin. Lastly, Sageman continues to advance the cause of deep time chronology through continued orbital time scale work...

wadsleyite. By precisely measuring the degree to which hydration decreases seismic velocity, Jacobsen will be able to provide seismologists—including his collaborator and departmental colleague, Suzan van der Lee—with the data required to help accurately interpret tomographic images where water may be present. Once the amount and distribution of water in the mantle can be estimated, geophysicists will be able, according to Jacobsen, "to begin answering even larger questions about the role water may play in initiating and sustaining plate motion over geological time."

Jacobsen's ability to characterize the seismic properties of a potentially hydrous transition zone depends on a successful interfacing of the diamond-anvil cell with an instrument known as a gigahertz ultrasonic interferometer (GUI), which he and a German collaborator developed over a ten-year period. A device that generates "miniature earthquakes" under laboratory conditions, the GUI, says Jacobsen, "uses thin-film transducers to produce elastic strain waves at the ultra-high frequencies required to accommodate high-pressure samples only a few micrometers thick." Producing S (shear) waves through a novel P (compressional) to S conversion that mimics the reflection process responsible for creating S waves in the mantle, Jacobsen's invention is the only laboratory tool capable of introducing both P and S waves--the two main types of elastic waves--into the diamond-anvil cell. Since the high pressures characteristic of the mantle cannot be reached without the diamond-anvil cell, the GUI provides the only path to attaining a comprehensive seismic profile of the most common mantle mineral phases. And because Jacobsen's laboratory houses one of only two GUI's ever constructed, his research will play a pivotal role in the attempt to unravel the mystery surrounding the existence and significance of water deep beneath Earth's surface.

Students from Steven Jacobsen's freshman seminar, "The Future of Renewable Energy", display their hydrogen fuel cell experiment.

In addition to quantifying the extent to which hydration slows wave speeds, Jacobsen will also conduct a broad array of atomic-scale experiments designed to reveal why it transforms this and other physical properties so dramatically. To begin answering this question, he will visit several national laboratories to employ such techniques as X-ray diffraction, infrared spectroscopy, and neutron diffraction, cutting-edge analytical methods that will allow him to better understand how water inserts itself into and affects mineral structures. Early results indicate the apparently transformative power of hydration may actually be more strongly linked to defects in crystal structures than it is to any qualities inherent within hydrogen itself.

(continued on page 10)

Faculty Research, continued

Francesca Smith is currently leading a research team applying a multiple-proxy approach to reconstructing ecological impacts

of the warmest period of the Cenozoic, the Paleocene-Eocene Thermal Maximum. As part of an NSF-funded project, Smith and several colleagues conducted a successful field season in the Bighorn Basin, Wyoming (where she is pictured above), collecting fossil plants, fossil vertebrates, sediments and ancient soils. Their research has received considerable attention and will be the subject of a documentary by the American Museum of Natural History and articles in *National Geographic* and *High Country News*...**Seth Stein**, pictured below on a recent departmental field trip to Yellowstone National Park, has found that the dangers posed by a major earthquake in the Midwestern and Southern U.S. may be noticeably lower than commonly estimated. While many studies assume that the probability of a second earthquake is equal anytime after an initial major quake, Stein argues that the likelihood of a rapid succession of major quakes is extremely

rare, although the chances of recurrence increases over time. Stein concludes that seismic hazard maps should be adjusted to present much less dire predictions for these regions.

Jacobson Wins Packard Fellowship

Andrew Jacobsen displays his F.W. Clarke Medal, awarded to young scientists demonstrating the ability to become leaders in the field of geochemistry.

Assistant Professor Andrew Jacobson, a geochemist, likes to recount some advice he once received about how to succeed as a junior faculty member. “I was told to work like a duck, staying calm on the surface while paddling furiously beneath to keep afloat,” he says. “But I sometimes think that I spend most of my time with my head underwater and my feet flailing in the air!” While Jacobson’s anecdote reflects his typically self-deprecating manner, his recent accomplishments tell an entirely different story. In recent months, he has “paddled” his way to a string of remarkable successes that include a grant of $847,000 from the NSF Major Research Instrumentation program, the Geochemical Society’s coveted F.W. Clarke Medal, and, most notably, a five-year, $825,000 Packard Fellowship, one of the most prestigious financial awards given to early-career scientists. This unique “no strings attached” funding, which encourages innovative thinking among young scientists, will allow Jacobson to explore different aspects of the carbon cycle using the novel technique of calcium isotope geochemistry.

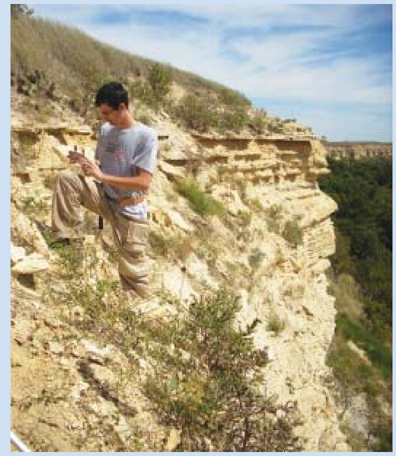
Jacobson’s research proceeds from the fundamental observation that the existence of life depends upon the cycling of carbon within and between various biogeochemical reservoirs that comprise the Earth. Seeking to understand “the co-evolution of Earth and life through time”, his work investigates all aspects of the carbon cycle at timescales ranging from the geological to the modern-day. He pursues these projects by analyzing isotope abundance variations, an approach that, he says, provides “extraordinary insight into the flow, transformation, and distribution of carbon under conditions of both natural and anthropogenic environmental change.”

Because the calcium and carbon cycles intersect across numerous spatial and temporal scales, Jacobson uses calcium isotopes as a proxy for carbon. Enhanced by recent advances in mass-spectrometry, the high-precision analysis of calcium isotope ratios ($^{44}Ca/^{40}Ca$) has emerged as a promising technique for revealing fundamental aspects of the carbon cycle. Jacobson, one of a few researchers worldwide pioneering application of Ca isotope geochemistry to problems at the cutting-edge of carbon cycle research, will use this method to shed new light on the origins of unicellular life, the factors shaping Earth’s habitability, and the relationship between global warming and the state of Arctic permafrost.

Fueled by the original thinking encouraged by the Packard competition, Jacobson’s first project will attempt to identify what he calls the “chemical fingerprint of life”. Conducting laboratory experiments that simulate rock weathering, Jacobson is probing the interface between inorganic and organic aspects of the carbon cycle. These simulations have already yielded an important discovery, one that reveals a crucial distinction between biotic and abiotic weathering. Jacobson’s experiments provide evidence that when bacteria use rocks as micronutrient sources, they accelerate chemical weathering and atmospheric CO_2 consumption rates while also fractionating Ca isotopes to build biomass. In contrast, no such Ca isotope fractionation occurs during abiotic weathering. Jacobson, then, has identified a unique chemical profile for biotic weathering, a breakthrough that may help resolve important questions con-

Graduate Student Highlights

Derek Adams, shown below collecting samples in Kansas, is advised by Matthew Hurtgen. He is using the sulfur isotope composition of seawater sulfate, as recorded in carbonate-associated sulfate,



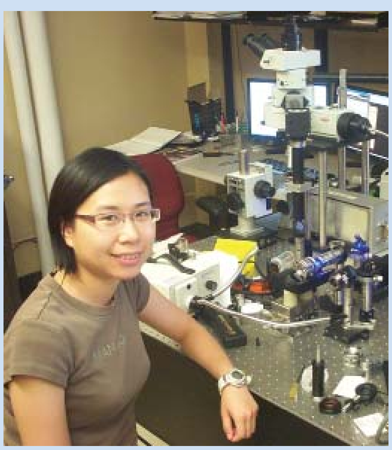
and the sulfur isotope compostion of pyrite to study the sulfur cycle. His work focuses on the coupling of the biogeochemical cycles of carbon and sulfur in the context of Oceanic Anoxic Events, specifically OAE II near the Cenomanian/Turonian stage boundary of the Late Cretaceous...Third-year student **Kim Adams**, below, points to the beam pipe carrying a brilliant infrared light to her experiment at the National Synchrotron Light Source. Advised by Professors Jacobsen and Jurdy, she is pursuing two projects. First, Kim is studying the distribution of small pits on Titan, one of Saturn’s satellites, and their relationship to tectonics and cryovolcanism. Second,

she is also investigating low-temperature visible to near-infrared reflectance of solid and liquid methane to interpret Cassini data and determine the composition of the Saturnian satellites...

Graduate Students, continued

Allie Baczynski, a first-year student advised by Francesca Smith, is interested in biogeochemistry...Supervised by Brad Sageman and Jennifer McElwain, **Richard Barclay**, pictured below in Utah, is studying

the terrestrial record of the Cenomanian-Turonian Oceanic Anoxic Event II. This event suggests a major perturbation in the global carbon cycle and climate. Rich will use the stomatal index method, developed by McElwain and colleagues, to test for changes in atmospheric CO_2 levels and trends in plant diversity and morphology across the event so he can reconstruct the climate history of his study area in Utah... **Yun-Yuan Chang** (below) is a first year



mineral physics student advised by Steven Jacobsen...With Professors Okal and van der Lee, **Carl Ebeling** is investigating tsunami earthquakes and the identification of robust early-warning discriminants. Carl was one of only fifteen Americans selected to participate in the Calabria (Italy) Summer School, which studies uplift and deformation in the Calabrian Arc...

cerning the emergence of life and its impact on the chemistry of the planet. Since "the genetic record shows that life processes occurring today were also important on the early Earth", he believes "the presence of isotopically fractionated Ca preserved in the rock record may ultimately reveal where and when life evolved."

While Jacobson's first project seeks to answer key questions about the emergence of life, his second study will help resolve fundamental mysteries surrounding Earth's habitability. In pursuing this topic, his work will help decipher the rapidly developing marine calcium isotope record, which details the Ca isotope composition of seawater for the past 500 million years. As Jacobson notes, this record is crucial to understanding the evolution of Earth's climate because it reveals "a history of continental rock weathering", the process that controls atmospheric CO_2 levels and regulates global temperatures via the greenhouse effect. By conducting a global-scale investigation of riverine calcium isotope geochemistry, Jacobson will work to understand factors that control chemical weathering, such as mountain building, temperature, precipitation and glaciation. Because each of these components shapes the calcium isotope composition of rivers, which are the primary conduits linking the terrestrial and marine realms, Jacobson can then use his analyses to interpret the marine calcium isotope record, thereby developing a better understanding of the climatic forces that have allowed the Earth to become and remain habitable.

Shifting from a geologic to a human timescale, Jacobson's final project—suported by an additional $650,000 of NSF funding--will develop a novel method for monitoring the melting of permafrost, which could play a key role in intensifying the effects of global warming. According to Jacobson, scientists are concerned that rising Arctic temperatures will cause vast quantities of CO_2 to be released into the atmosphere when permafrost, which contains approximately 700 gigatons of carbon, experiences increasingly lengthy melting periods. In this scenario, he says, "newly released CO_2 will act as a positive feedback to the greenhouse effect, causing temperatures to increase further, permafrost to melt at a greater rate, more CO_2 to be released, and so on." While obtaining accurate measurements of permafrost stability is thus essential for understanding the scope of Arctic climate change, the Arctic's inaccessible terrain and complex carbon cycle have hampered large-scale estimates of the problem. Circumventing these and others obstacles, Jacobson will not attempt to traverse the entire Arctic landscape, but will instead collect samples from several Arctic rivers, utilizing them as the landscape's "great chemical integrators", fluid messengers that retain the calcium isotope geochemistry of permafrost even as hydrologic discharge is transported great distances away from its point of origin. Jacobson's ability to use Arctic rivers in this way builds on the unique Ca isotope composition of permafrost. Specifically, he has discovered that permafrost's two main components—the "active" upper layer and the lower "inactive" one—have distinct calcium isotope ratios. By analyzing how each of these chemical signatures affects the calcium isotope geochemistry of Arctic rivers, Jacobson can determine which layer is melting, how this melting varies over time, and the extent to which new CO_2 is released into the atmosphere as a result of permafrost degradation.

Having begun to explore a broad array of topics through the support of his Packard Fellowship, Jacobson says the most exciting aspect of this work is the freedom it allows him. "Since the Packard Foundation doesn't require fellowship recipients to take their work in a particular direction, the award allows scientists to pursue questions entirely derived from their own intellectual curiosity. It's incredibly liberating to work under such circumstances, and it's also gratifying to know that people think my work is worthy of this unrestricted support", he says. Despite the vote of confidence provided by his recent successes, Jacobson can't resist wryly joking that "it's entirely possible that everything goes downhill from here." Clearly, though, this opinion is not widely held by his colleagues. Indeed, their high regard for his work suggests that Jacobson has yet to peak.

Recent PhDs Pursue Jobs in Oil Industry

Chevron geologist Joniell Borges (PhD, 2008)

EPS has long placed its PhDs in a variety of positions divided among academia, government, and industry. While academic jobs have generally offered the preferred career path for the department's doctoral students, a new placement trend has recently emerged. Of the department's six most recent PhDs, four have accepted positions in the petroleum industry while a fifth student is also currently considering an offer to work at an oil company. Moreover, while some EPS graduate students have been extended academic job offers before opting to enter the petroleum industry, others have focused exclusively on pursuing careers with oil companies, entirely foregoing the academic interview process. What, then, explains the sudden rise in popularity of oil industry jobs as a career choice for the department's new PhDs?

One reason for the surging interest in petroleum industry employment among EPS graduate students is the "current large demand and enormous opportunity" for geoscientists of all educational levels, says EPS alumnus Philip Richardson (PhD 1998), a geophysicist and recruiter for Chevron. According to Richardson, oil companies have begun aggressively hiring technical staff for the first time in almost two decades, a trend made possible in part by sharply rising oil prices. Richardson sees this hiring pattern continuing for at least the next ten years due to larger structural issues confronting the oil industry. As he points out, the "graying of the technical workforce…coupled with harder to find resources" has made the demand for new geologists acute.

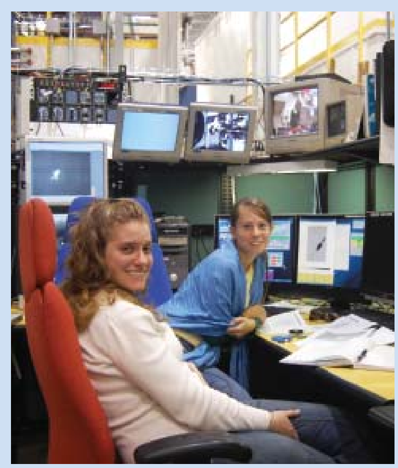
Even as the petroleum industry's need for qualified employees has recently risen, however, the domestic supply of students graduating with geology degrees has steadily declined over the past thirty years, with more dramatic decreases reported since 2000. "Fewer undergraduates majoring in geology also means fewer graduate students", says Richardson, adding that employing foreign nationals to compensate for this deficit has become more difficult "due to tightening Homeland Security restrictions", which can hinder the process of obtaining work credentials for foreign laborers.

Chevron geologist Rob Locklair (PhD, 2007)

Faced with a situation in which demand for geoscientists far exceeds the existing supply, oil companies have adopted the only measure available to them in the intensifying competition to attract and retain qualified workers. They have dramatically increased salaries for scientists of all experience levels. As recently reported in *The Explorer*, the newsletter of the American Association of Petroleum Geologists, an early 2008 survey of petroleum employers revealed that salaries for all industry geologists had "increased by an average of more than 35% over the past three years." For new PhDs, this upward wage trend translates into a starting annual salary averaging around $95,000, not including bonuses and other "perks"

Graduate Students, continued

First-year student **Maya Gomes** is studying geochemistry and planetary geology with Matt Hurtgen and Donna Jurdy...**Jeremy Gouldey,** another first-year student, has begun an isotope geochemistry project with Matt Hurtgen... Also in his first year, seismology student **Sutatcha Hongsresawat** is advised by Emile Okal...**Young Ji Joo**, a geochemistry student advised by Brad Sageman and Abraham Lerman, is working on a project investigating the biogeochemical cycles of phosphorus, nitrogen, and carbon... **Dan Li**, a first-year geochemistry student, is advised by Abraham Lerman...Advised by Suzan van der Lee, **Simon Lloyd** recently won an AGU outstanding student paper award and is using surface wave tomography and receiver function analysis to image the mantle structure and determine crustal thickness beneath South America... Also under Suzan van der Lee's direction, seismology student **Xiaoting Lou** uses teleseismic travel time tomography and receiver function analysis to investigate the three-dimensional velocity and discontinuity structure of the North American mantle...**Emily Martin,** a second-year planetary geology student shown below at Argonne's Advanced Photon Source with Kim Adams, is creating a digital database to facilitate spatial analysis of craters on



Iapetus, Saturn's third largest moon. The database will eventually also include morphological classifications and other data. She is advised by Donna Jurdy... **Laura Swafford**, a geophysics student advised by Seth Stein, is assessing the validity of seismic hazard maps by testing the methodology they use to determine earthquake probability in a given region.

Degrees and Awards

Doctoral Degrees

Heather Bedle
Thesis: *Studies on the S-Velocity Structure of the North American Upper Mantle*

Joniell Borges
Thesis: *Continental Weathering Products: Clay Mineral Surfaces as Sinks for Organic Carbon in Marine Environments; Chemistry and Petrography of Bed Sediments from Large Rivers--Provenance and Chemical Weathering*

Jason Flaum
Thesis: *Investigation of Phosphorus Cycle Dynamics Associated with Organic Carbon Burial in Modern and Ancient Marine Systems; Strengths and Limitations of Sequentially Extracted (SEDEX) Phosphorus Data*

Lingling Wu
Thesis: *Chemical Weathering: Theoretical Models, Field Study in the Yellow River Basin, and Laboratory Study of Microbially-Mediated Basalt and Granite Weathering*

Bachelors of Science

Colin Carney
Thesis: *Terrestrial Weathering and Nutrient Recycling: Bionutrient P Dynamics of the Late Devonian Appalachian Basin*

Ben Chartoff

Will Defliese
Thesis: *Oxidation of the early to mid Neoproterozoic Ocean*

Awards

Horace Scott Graduate Research Award: Laura Swafford

Marion Sloss Graduate Teaching Award: Heather Bedle

Sloss Research Awards: Derek Adams, Kim Adams, Richard Barclay, Heather Bedle, Carl Ebeling, Jason Flaum, Young Ji Joo, Simon Lloyd, Xiaoting Lou, Emily Martin

Phi Beta Kappa: Ryosuke Kita

Goldwater Scholarship: Rene Boiteau

Recent Grads--continued

Chevron geologist Heather Bedle (PhD, 2008)

that are becoming increasingly common in the current labor climate.

Although extraordinary financial opportunities offer graduate students a strong incentive to enter the petroleum industry, exploration jobs boast many other desirable qualities as well. For Jason Flaum (PhD, 2008), an ExxonMobil geologist, the decision to accept an oil company job was easy "simply because I've been in school for most of my life, going directly from my undergraduate degree to my Master's and then my doctorate. I felt like I needed a change, which is what the energy industry provides." The contrast to academic life offered by the petroleum industry also interested Joniell Borges (PhD, 2008), a Chevron deepwater stratigrapher who observes that "the chance to work on a variety of projects across the globe, a combination I wasn't likely to find as a professor, is very exciting and hard to resist." Concurring with Borges' observations, Chevron geophysicist Heather Bedle (PhD, 2008) also noted her enthusiasm for her company's work culture, "which stresses a team-oriented rather than an individual approach to solving problems."

While petroleum jobs appeal to students for a variety of reasons, "all career choices have pluses and minuses", says Richardson, adding that "it's impossible to know if working at an oil company is right for you without experiencing it first." It is for this reason that Richardson encourages graduate students interested in a possible career in the oil industry to pursue summer internships, an avenue several EPS graduate students have recently explored. And, with demand for petroleum geologists expected to continue rising over the coming years, it is an opportunity still many more students are likely to seek in the near future.

Jacobsen--continued

Though Jacobsen's research has been widely praised, he believes that teaching gives him the best chance to have a long--term social impact. Modestly suggesting that he "probably won't be remembered" for his experimental studies, Jacobsen says that he can nevertheless "help create a positive future by getting students to love science". Jacobsen's interest in teaching is evinced by his active participation in several educational initiatives. In addition to instructing NU students, he also makes regular science presentations at local preschools and leads modules for Project EXCITE, an elementary school program designed to improve science achievement among minority students. No matter what level he is teaching, however, Jacobsen adheres to a consistent "hands on" pedagogical approach. Because he "constantly builds new devices" in the laboratory, his students perform similar tasks in the classroom. When he introduces third graders and college freshman alike to the future of renewable energy, for instance, students learn about their subject matter first-hand, constructing hydrogen fuel cells and then testing them for their energy efficiency and economic viability. "There's no substitute for direct experience", says Jacobsen, whose strong faith in "active learning" is matched by the enthusiasm his students display for his classes. Still, even as Jacobsen has proven himself to be a skilled teacher to a variety of students from diverse backgrounds, he appears to have made a rare miscalculation in one regard: If his early career is any indication of what the future holds, he will likely be remembered both for his inspired teaching and his innovative research.

Eryn Pratomo and daughter Madeleine

Gary Acton (PhD, 1991), recently completed a ten-week ice coring expedition in Antarctica...**Wendy Barrow** (M.S., 1997), who completed her PhD at UNLV in 2007, has moved to England and is preparing her research for publication... **Heather Bedle** (PhD, 2008) recently survived her first hurricane after relocating to New Orleans where she is a geologist for Chevron...**John DeLaughter** (PhD, 1998) is living in Houston where he is a geologist for Murphy Oil Co...**Paul Forward** (M.S., 1993) was recently named the top metals and mining equity analyst in the U.S. by *The Wall Street Journal*... **Dick House** (M.S., 1955) is involved with oil exploration and production in Louisiana. He recently traveled to Alaska for an AAPG field trip led by EPS alum **Robert Mitchum** (PhD, 1954)...**Richard Huszagh** (B.S., 1952), a retired Chicago lawyer, lives in Portland where he runs a commercial and industrial real estate business...**Alberto Lopez** (PhD, 2006) is the father of a ten-month old baby boy, Alfredo. Alberto recently completed a Mendenhall Postdoctoral Fellowship at the USGS and will be moving to Puerto Rico with his family...**Adabell Gandy Phillips** (M.S., 1950) lives in Vancouver, Washington with her husband. She looks back fondly on her NU days when she took classes with Professors Howland, Stark, Sloss and Krumbein...**Eryn Klosko Pratomo** (PhD, 2002) gave birth to a 7.5 pound baby girl, Madeleine, on July 17th. Eryn is currently chair of the Physical Sciences Department at Westchester Community College in New York and recently bought a home in the Bronx...**Brian Shiro** (B.S., 2000), who has a M.S. in geology from Washington University in St. Louis and a certificate from the International Space University, is currently a geophysicist at the NOAA Pacific Tsunami Warning Center in Hawaii and a doctoral student in the Department of Space Studies at the University of North Dakota. His wife, Holli, gave birth to their son, Henry, in November of 2007...**Paul Stoddard** (PhD, 1989) is an associate professor and president of the faculty senate at Northern Illinois University...**Lingling Wu** (PhD, 2007), a postdoctoral fellow at the University of Wisconsin-Madison, has given birth to a baby girl, Eva.

Alberto Lopez and son Alfredo

Lingling Wu and daughter Eva

2007-2008 Donor Honor Roll

Thank you alumni and friends for supporting our educational mission!

Gary Acton
Gerald Adams
Alfred Anderson
Carl Bowin
Marie Cahill
J. Allan Cain
Susan A. Carroll
Chih Shan Chen
Mary Sue Coates
Allen Cogbill
Neil W. Cook
Howard Cramer
Edward Dapples
Delos Flint
James Forgotson
Joseph Frizado
Craig Fulthorpe
Perry Glaister
Changrui Gong
Brian Hamilton
Charlotte Hayes
Mr. & Mrs. John Hebden
Elmer Herbaly
Kathleen Targos Hewell
Thomas A. Jones
James King
James Kistler
Ralph Kraetsch
Michael Laine
Robert Langan
Alfred Miesch
Robert Mitchum
Matthew Mulhall
Fritz Nagel
Emile Okal
Charles Petter
Adabell Phillips
Roberto Porto
Branch Russell
Robert T. Russell
Lawrence Sadlek
Jane Schoonmaker
Margaret D. Schutt
Marilyn Shay
Benjamin Sloan
John Snyder
Richard Stearns
Costas Synolakis
William Stuart
Vivian Bryan Taylor
John J. Thomas
David Toth
Mr. and Mrs. David Vanko
Harriet Wallace
Thomas Wolery
Elizabeth Zbinden

Recent EPS field course in Utah.

EPS faculty members and graduate students have led several modules for the same group of children, attempting to stimulate their interest in Earth science by immersing them in a variety of experiments and demonstrations. Because Project EXCITE employs a longitudinal approach to improving science achievement, students remain enrolled in it until reaching high school. At that point, it is hoped many program participants will register for honors and advanced placement science courses.

One final joint effort has witnessed EPS emerge as a leading force in a multidisciplinary attempt to bring Geographic Information System (GIS) expertise to Northwestern. Powerful tools for spatial analysis, GIS applications are widely used in a range of fields, including the social sciences, education, medicine and geology. It is surprising, then, that Northwestern does not currently employ a single GIS specialist among its tenure-line faculty. As an initial step towards addressing this problem, EPS will coordinate a video conference between many programs and departments to discuss how conference participants would mutually benefit from the addition of a faculty member with GIS credentials and how we can best advocate for the hiring of such an expert. Although this project is in its early stages, I believe it has great promise due to the broad interest in GIS at Northwestern.

In addition to the news about people and achievements, significant developments concerning bricks and mortar have also recently taken place. After many years of hearing rumors regarding our possible relocation to north campus, we have been presented with a concrete proposal for our exodus from Locy Hall. Targeting our new location for an infill between two wings of the Tech Institute, current architectural plans call for this addition to feature a sunlight-filled atrium that will be a focal point within our new space. To signify the department's presence in Tech and elevate our campus image, we would like to commission a sculpture of the Earth—large enough to make a statement and accurate enough to be used as a teaching tool—for placement in the atrium. Because we think it is unlikely that the sculpture will be built without external funding, we are seeking support for what will be a lasting symbol of department identity.

We are, of course, also awaiting the completion of our new analytical facility in Hogan Hall. Due to the complexity and scope of this project, it is running behind schedule. We now anticipate that it will be operational in early or mid-2010 and warmly thank all of our alumni donors who have supported this unique interdisciplinary laboratory for cutting edge research in stable and radiogenic isotope biogeochemistry and high pressure-temperature mineral physics.

As a final note, I must revisit some tragic news that has deeply affected the department. Many of you already know that Professor Seth Stein and his wife, Carol, suffered the death of their son, David, during the summer. After news of their loss reached our community, current and former department members acted in unison to offer sympathy and support during a very difficult time. Seth and Carol deeply appreciate this outpouring of concern. On behalf of the Stein family and EPS, I sincerely thank everyone who expressed their condolences and contributed to the David Stein memorial fund.--*Brad Sageman*

epicenters

Department of Earth & Planetary Sciences
Northwestern University
1850 Campus Drive
Evanston, IL 60208
www.earth.northwestern.edu

Epicenters is designed, written and edited by Will Kazmier. Email comments, suggestions and alumni news to him at will@earth.northwestern.edu.